Molecular Phylogenetic Analysis of the Recently Discovered Species of Mosses (2014-2015) in Mindanao Island, Philippines and its Taxonomic Distribution, Physical Attributes, and Biogeography

Ariel Luis Daga, Kristine Tamaray, Andrea Denisse Verendia, Enrico Garcia
Bachelor of Science in Biology

ABSTRACT

Documentation of the rich flora diversity of the Mindanao Island was not given much attention. In 2014, a group of bryologists conducted two joint botanical expeditions between the Center for Biodiversity Research and Extension in Mindanao (CEBREM) of Central Mindanao University (CMUH) and the California Academy of Sciences (CAS). They have reported over 73 new species of mosses found in Mindanao Island and 17 of these species are new to the Philippines. Thus, the researchers aimed to construct a molecular phylogenetic tree of these recently discovered species using MEGA software and build a table of its taxonomic distribution based on several published studies in order to provide a detailed overview of the new moss species in the Mindanao Island. Based on the geographical distribution of the moss species, there is a strong floristic connection of Mindanao Island with neighboring islands such as Borneo, Java, Malaysia, New Guinea, and Australasia. The moss species were mainly found on tree trunks, branches, soil, and decaying woods. Moreover, evolutionary history is inferred using phylogenetic trees amongst mosses in Mindanao Island. Chloroplast DNA sequences with rbcL as its end product were used to infer phylogenetic trees using Maximum Likelihood and Maximum Parsimony with adjusted bootstrap intended for 100 replicates. Species from genus Acroporium are considered to be the oldest organisms for both trees: A. aciphyllum & A. joanis-walkeri in Maximum Likelihood while A. rufum & A. Rigens in Maximum Parsimony. The most advanced moss flora in Maximum Likelihood inferred phylogenetic tree is the species of genus Taxiphyllum: T. taxirameum and T. arcuatum. Opposingly, P. subtortile is the latest species of moss in the inferred phylogenetic tree using Maximum Parsimony.

Keywords: *Mindanao mosses, molecular phylogenetic analysis, taxonomic distribution*

INTRODUCTION

Significant researches about Philippine mosses are lacking and only a few researchers seem to be interested in conducting studies related to this. For this reason, it led the researchers to come up with a bibliographic approach to study Mindanao mosses in particular. This research paper focuses on designing a phylogenetic tree based on the DNA nucleotide sequence using FASTA file from GenBank, a collection of sequences of species, of newly discovered mosses in Mindanao Island of the Philippines from 2014-2015 that is anchored from the reports of a joint expedition of researchers from Center for Biodiversity Research and Extension in Mindanao (CEBREM) of Central Mindanao University (CMUH) and the California Academy of Sciences (CAS).

Bryophyta is considered as an informal group comprising of approximately 40,000 species that are known to be autotrophs: energy and food-producing organisms through mainly the use of sunlight, water, and nutrients thus garnering its name ‘producers’. In reference to its taxonomy, this group is divided into four classes: Anthocerotopsida (hornworts), Marchantiopsida and Jungermanniopsida ‘(liverworts), and Bryopsida (mosses). Hornworts, liverworts, and mosses are land plants that undergo haploid (gametophyte) and diploid (sporophyte) stages but are matured dominantly from the former stage.

These organisms' biomass production is essential in ecosystems of the subarctic and mountainous tropical rainforests and is an important ecological factor in several habitats including water springs and soil as well. They are natural monitors and indicators not just in aquatic but in terrestrial habitats as well. In the 1960s, two Swedish ecologists utilized mosses, specifically, as indicators of the pollution of heavy metals, radionuclides, and toxic organic compounds. In line with this, this class of Bryophyta possesses many features to be recognized as a bio-indicator and a biological marker.

Review of Literature

Mindanao Island and Malesia Region

Mindanao is considered as the second largest island next to Luzon Island in the Philippines. It is located at the southern end of the country, close to Borneo, Sulawesi, and the Moluccas island groups. Mindanao Island has a rich flora diversity, however, is it not well collected and studied. It is for this very reason why expeditions are currently being conducted or planned (B. Tan, Shevock, & Coritico, 2015). The 6th report of the two joint botanical expeditions between the Center for Biodiversity Research and Extension in Mindanao (CEBREM) of Central Mindanao University (CMUH) and the California Academy of Sciences (CAS) conducted in 2014 and 2015, produced a total of more than 600 packets of moss specimens (B. Tan et al., 2015; Benito C. Tan, Ochyra, Ho, & Bednarek-Ochyra, 2019; Benito C. Tan, Shevock, Azuelo, & Lubos, 2017; Benito C Tan & Shevock, 2014). Many of these are the widespread species across the archipelago and represent the common Malesian mosses.

Mindanao has a fewer documented number of mosses compared to Luzon Island to the North despite both islands sharing many similarities, such as size, peaks that exceed 2,000 m, protected landscapes, and forest environments. Hence, this situation is just an example of the under-collection of bryophytes in Mindanao. Some areas in Mindanao are unsafe for interested researchers due to civil unrest (Linis, 2009; B. Tan et al., 2015).

Malesian region consists of New Guinea, Philippines, Java, and the Malay Peninsula. It is known to be home of the oldest forests on earth which is attributed to the region's high biodiversity in which these forests have survived through the Pleistocene Ice Ages because of its fortunate location straddling the equator. The climate within the region is consistently hot and humid with a high rate of rainfall ("Malesia Region", n.d.).

The distribution of Malesian mosses has become more urgent today due to the intimate increase rate of forest destruction across the entire region. The distribution of Malesian mosses is strongly connected to the rain forest habitat. These patterns can be explained by relating them to local plate tectonic movements than by a long-distance dispersal hypothesis (B C Tan, 1998).

Bryophytes

Bryophytes are considered as the second largest group of land plants to angiosperms and there are approximately 40, 000 species. There are three distinct lineages of bryophytes: mosses, liverworts, and hornworts. They mostly thrive in moist environments and habitats such as tree trunks, on soil, bare rocks, in caves, along streams, and on roofs (Derviş, 2013). Bryophytes lack vascular tissue and they also do not have true roots, stems, or leaves. They are spore-bearing and have free-living, haploid gametophytes, diploid sporophytes that remain attached to the maternal gametophyte throughout their lifespan. They are anchored by root-like hairs called rhizoids and often they are only one cell layer thick (Azuelo & Puno, 2018; Shevock, Lambio, & Tan, 2014).

Mosses are important for nutrient cycling, they use the limited precipitation and airborne minerals that are then become not available for seed plant vegetation. The moss mat's rapid evaporation is critical to some vegetation types by preventing moisture penetration to the root systems of seed plants, thus, it indirectly controls the vegetational composition of some forests. Bryophytes are also essential to the development of wetland habitats (Schofield, 2019).

Moreover, mosses are part of the low-level plant groups. They can act as air pollution bio-indicator agents due to their wide range of sensitivity. Bryophytes are considered as an ideal organism for pollution studies base on its habitat diversity, structural simplicity, totipotency, and high metal accumulation capacity (Khujjah & Ekowati, 2018). One of the most important functions of the mosses is that they absorb the pollutants from the air which mostly piles up in their tissue. The pile-up of air pollution is helped by the high surface to the volume ratio of moss tissue. Mosses help in monitoring heavy metals and nitrogen pollution. For air pollutants, mosses are one of the most appropriate organisms to monitor spatial patterns and other atmospheric concentrations (Harmens et al., 2013).

Moreover, mosses give a lot of large components of aboveground productivity and produce recalcitrant biomass that decomposes more slowly than a variety of vascular tissues. Mosses help in insulating the soil which can help in lessening directional climate change (Turetsky et al., 2010).

Objectives of the Study

This study aims to construct a phylogenetic tree based on genomic sequences of the recently discovered species of mosses in Mindanao Island, Philippines. Moreover, it aims to create a table of taxonomic distribution, biogeography of where the species were found, and the physical description of moss species.

METHODOLOGY

A quantitative research design was used for determining the association between this study's subjects, the new species of mosses, using the molecular data that were provided by GenBank. The available protein sequences were then inputted on MEGA software to construct a phylogenetic tree. On the other hand, a bibliographic approach was done to gather data about the recently discovered moss species. Most of the information came from several published studies headed by Benito C. Tan and James R. Shevock with other fellow researchers. They were the ones involved during the joint expedition of collecting new species of mosses in Mindanao Island in which they have provided the description of mosses, where they were collected, and their geographical distribution. In their research studies, they have also indicated to have used other references for the identification of the new species of mosses (Shevock, Lambio, & Tan, 2014; B. C. Tan, Ochyra, Ho, & Bednarek-Ochyra, 2019; B. C. Tan, Shevock, Azuelo, & Lubos, 2017; B. C. Tan & Shevock, 2014; B. Tan, Shevock, & Coritico, 2015).

Nucleotide and protein sequences from different studies obtained from GenBank, a collection of publicly known organisms. The organisms' genomes, accession codes, and gene features are presented below in a tabular form. Moreover, molecular data were also acquired from another web page that provides protein sequences solely, UniProt.

To further the visual output of these tabular data, sequences were aligned by MEGA sequence alignment editor (Tamura et al. 2007) which were subjected to the creation of a Phylogenetic Tree using Maximum Likelihood and Maximum Parsimony as its analyses. Adjusted bootstrap was set to 100 replication.

The software FigTree v.1.4.1 was used to create a cladogram based on the 9 available genomic sequences in GenBank. This was done to determine the evolutionary distances between the moss species.

RESULTS AND DISCUSSIONS

Table 1 shows the variation of gene sets such as gene, protein-coding genes, ribosomal RNA and transfer RNA that were extracted from the organisms completes genomes that were obtained from GenBank. The majority of the gene sets were obtained from the cpDNA (chloroplast DNA), mtDNA (mitochondrial DNA) and ribosomal RNA gene of each moss. On the other hand, these genes were then coded as rcbL (ribulose bisphosphate carboxylase large chain), rps4 (ribosomal protein S4), tRNA (transfer RNA), SSU rRNA (Small subunit ribosomal ribonucleic acid), LSU rRNA (large subunit ribosomal ribonucleic acid), and ITS (internal transcribed spacer). To infer phylogenetic trees at diverse levels of taxonomy, cpDNA or chloroplast DNA is widely used. Sequencing direct polymerase chain reactions (PCR) products are oftentimes used to enlarge the scope of plant's evolutionary history. Conclusively, its featured gene products of cpDNAs have resulted in the majority of rbcL genes that encode a large subunit of ribulose-1,5-biphosphate carboxylase/oxygenase (RuBisCo) that is used to infer data sequences for plant taxa and plant systematics (Gielly & Taberlet, 1994).

Table 1. Molecular data summary of the Philippine moss flora

Accession Codes (*data unavailable)	List of Mosses (*new to Philippines)	Genome	Length (bp)	Feature
AAQ84590	*Acroporium aciphyllum*	cpDNA	475 bp	rbcL
ABU96267	*Acroporium convolutum*	cpDNA	299 bp	rbcL
AAQ84592	*Acroporium joannis-winkelri*	cpDNA	475 bp	rbcL
AAQ8459	*Acroporium rigens**	cpDNA	475 bp	rbcL
*	*Acroporium rufum*	cpDNA	475 bp	rcbL
*	*Acroporium sigmatodontium*			
*	*Aerobryidium crispifolium*			
BAD98302	*Bryoxiphium japonicum*	cpDNA	475 bp	rbcL
	*Callicostella armata**			
ABD72286	*Calomnion complanatum**	cpDNA	434 bp	rbcL
	Calymperes fasciculatum			
*	*Chaetomitrium ciliatum**			
*	*Chaetomitrium elmeri*			
*	*Chaetomitrium everettii*			
*	*Chaetomitrium lanceolatum*			
AVZ43473	*Clastobryopsis robusta*	cpDNA	452 bp	rbcL
AAR05097	*Clastobryum cuculligerum*	cpDNA	475 bp	rbcL
*	*Clastobryum indicum*			
*	*Clastobryum leucophyllum*			
BAG65786	*Ctenidium malacobolum*	cpDNA	448 bp	rbcL
*	*Dendrocyathophorum paradoxum*			
*	*Distichophyllum shevockii**			
*	*Distichophyllum subcarinatum**			
ADR72796	*Distichophyllum subcuspidatum*	cpDNA	195 bp	rps4
*	*Distichophyllum undulatum*			
*	*Ditrichum difficile*			
*	*Ectropothecium penzigianum**			

BAG65757	*Ectropothecium ptychofolium*	cpDNA	475 bp	rbcL
AG65807	*Ectropothecium zollingeri*	cpDNA	475 bp	rbcL
BAG65743	*Elmeriobryum philippinense*	cpDNA	442 bp	rbcL
AER08595	*Ephemeropsis tjibodensis*	mtDNA	194 bp	rps4
*	*Erpodium luzonense*			
ABB53765	*Euptychium setigerum**	mtDNA	202 bp	rsp4
BBB21998	*Fissidens anomalus*	cpDNA	475 bp	rbcL
BBB22005	*Fissidens coacervatus**	cpDNA	475 bp	rbcL
*	*Fissidens ganguleei**			
BBB22023	*Fissidens hyalinus*	cpDNA	475 bp	rbcL
BBB22032	*Fissidens oblongifolius*	cpDNA	475 bp	rbcL
BBB22035	*Fissidens pallidinervis*	cpDNA	475 bp	rbcL
BBB22038	*Fissidens pellucidus*	cpDNA	475 bp	rbcL
*	*Fissidens polypodioides*			
BBB22049	*Fissidens taxifolius*	cpDNA	475 bp	rbcL
*	*Garovaglia bauerlenii*			
ABB80418	*Garovaglia powellii**	cpDNA	383 bp	rbcL
*	*Garovaglia punctidens*			
AAY34834	*Groutiella tomentosa*	cpDNA	191 bp	rps4
AAQ84596	*Hampeella pallens*	cpDNA	418 bp	rbcL
AAN09776	*Holomitrium cylindraceum*	mtDNA	191 bp	rps4
ABV69076	*Homalothecium laevisetum**	cpDNA	67 bp	psbN
*	*Hookeriopsis wishurae*			
*	*Leiomela javanica*			
AAQ84600	*Macrohymenium muelleri**	cpDNA	475 bp	rbcL
MH730522	*Macromitrium cuspidatum*	ribosomal RNA gene	494 bp	rRNA
*	*Macrothamnium javense*			
*	*Meiothecium tenellum*			
JQ943518	*Metadistichophyllum rhizophorum**	cpDNA	407 bp	tRNA
AAY62919	*Meteoriopsis reclinata*	mtDNA	199 bp	rps4
AAY34820	*Mniomalia semilimbata*	cpDNA	198 bp	rps4
CCG47551	*Oedicladium rufescens*	mtDNA	183 bp	rps4
AYN06853	*Pelekium velatum*	cpDNA	198 bp	rps4
AYN06833	*Pelekium versicolor*	mtDNA	198 bp	rps4
AY396493	*Pogonatum subtortile*	cpDNA	466 bp	tRNA
*	*Pohlia elongate*			
AY306815	*Pseudospiridentopsis horrida*	cpDNA	446 bp	tRNA
*	*Pseudotaxiphyllum arquifolium*			
*	*Pterobryopsis crassicaulis*			
*	*Radulinala laevihamata**			
*	*Rhacocarpus alpinus*			
*	*Rhaphidostichum piliferum*			
*	*Rhapidostichum luzonense*			
*	*Rhodobryum aubertii*			
*	*Rhynchostegiella menadensis*			
AXF74220	*Rosulabryum billarderi*	cpDNA	7 bp	rbcL
*	*Sinskea flammea*			
*	*Symphyodon copelandii*			

*	*Symphyodon perrottetii*			
AAY33153	*Symphysodon longicuspis*	mtDNA	194 bp	rps4
APW79628	*Syrrhopodon gardneri*	mtDNA	202 bp	rps4
*	*Syrrhopodon japonicas*			
MN080857	*Taxiphyllum arcuatum*	ribosomal RNA gene	805 bp	SSU RNA, ITS 1 & 2, 5.8s rRNA, and LSU rRNA)
MN075318	*Taxiphyllum taxirameum*	ribosomal RNA gene	758 bp	SSU RNA, ITS 1 & 2, 5.8s rRNA, and LSU rRNA)
QBA17766	*Trachypodopsis serrulata*	cpDNA	193 bp	rbcL
*	*Trachypus longifolius*			
*	*Trismegistia complanatula**			
AAQ84608	*Warburgiella leptocarpa**	cpDNA	475 bp	rbcL

Note: Data gathered from NCBI GenBank and UniProt: (a) accession codes, (b) organism name, (c) genome, (d) length of base pairs, and (e) features present

The species Acroporium genus garnered the highest likelihood of reoccurring again in the same drawn tree. It is observed that the five species were forked initially as compared to the other remaining organisms. On another note, other species including W. leptocarpa, M. muelleri, T. serrulata, E. zollingeri, E. ptychofolium, E. philippinense, C. malacobolu, and B. japonicum speciated from the same node the initial species of genus Acroporium were formed. However, genus Fissidens was split into two forkings: species F. taxifolius, F. anomalus, and F. oblongifolius evolved earlier than F. pellucidus, F. pallidinervis, and F. hyalinus.Forkings from different species of mosses are also observed but the sole species of genus Fissidens, F. coacervatus evolved directly from the node without having apomorphies and synapomorphies. In this evolutionary history, the species of genus Taxiphyllum derived lastly from the node which in conclusion, the most advanced species of all the mosses found in Mindanao Island.

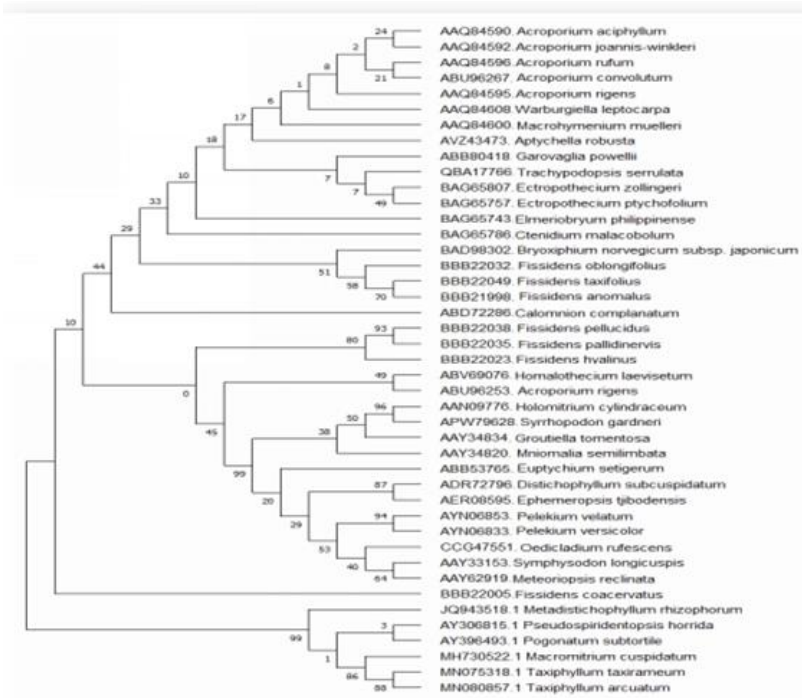

Figure 1. Evolutionary Analysis using MEGA X: Phylogenetic Tree using Maximum Likelihood Method

Inference of evolutionary history was gathered utilizing JTT matrix-based and Maximum Likelihood Method. The tree that attained the highest log likelihood garnering -9842.47 is displayed. Tree percentages on where associated taxa are clustered together were exhibited secondly from the branches. Initial trees for heuristic search were obtained automatically by applying Neighbor-Join and BioNJ algorithms to a matrix of pairwise distances estimated using a JTT model, and then selecting the topology with superior log likelihood value. Initial trees were obtained automatically through Neighbor-Join and BioNJ algorithms application in relation to JTT model estimation to pair-wise distances, and choosing the superior log likelihood topology. This analysis involves fourty-three (43) amino acid sequences. Overall total of 932 positions were located at the final set of data.

In this tree, a similar sense applied with the maximum likelihood inferred phylogenetic tree. Both trees were backed with a hundred bootstrap replications to infer reliability. In this case, if numbers 70 above were found on nodes, a validation for branch scoring will be applied. F. pallidinervis is placed on the right positioning in the tree. This means that on 100 replications of this phylogenetic tree, 93% of the time, the aforementioned species will still appear at the same exact positioning. It is observed that on the lower side of the phylogenetic tree, the numbering of nodes differs from lower 20's to higher '90s which could possibly mean that at some point, the species will not be appearing on the same position on the tree anymore. In this maximum parsimony inferred tree, the most advance species among moss flora is *P. subtortile.*

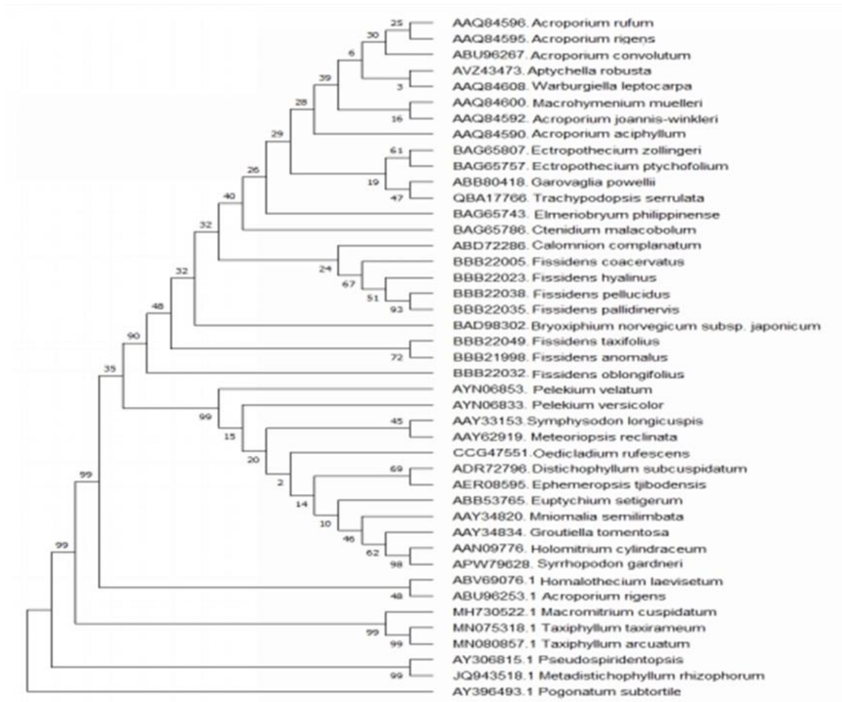

Figure 2. Inference of evolutionary history was obtained through Maximum Parsimony method *The tree that attained the most parsimony length=1371. Consistency index is (0.903049), retention index is (0.963562), and composite index is 0.876412 (0.870144) for all sites and parsimony-informative sites. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (100 replicates) is shown next to the branches. The MP tree was obtained using the Subtree-Pruning-Regrafting (SPR) algorithm with search level 1 in which the initial trees were obtained by the random addition of sequences (10 replicates). This analysis involved 43 amino acid sequences. There were a total of 932 positions in the final dataset. Evolutionary analyses were conducted in MEGA X.*

Out of the 17 newly discovered moss species in the Philippines, only 9 species have available genomic sequences in the GenBank. The cladogram was created in FigTree v1.4.4 with a scale root of 1.0. It has an optimal tree with the sum of branch length = 1.57258705. The evolutionary distances were computed using the Maximum Composite Likelihood method. Fissidens coacervatus has a scale root of 1.0 which means it is the most common ancestor of the new mosses in the Philippines found in the Mindanao. while Metadistichophyllum rhizophorum is the latest daughter species among the new kinds of mosses. The cladogram provides the making on the set of mosses. However, cladograms do not point directly on the ancestor-descendent relationship of the mosses instead all of the mosses appear on the terminal branches which are linked to other nodes. This entitled those bifurcation points that presume ancestors have separated into the daughter species (Pellis, Pellis, & Himmler, 2014).

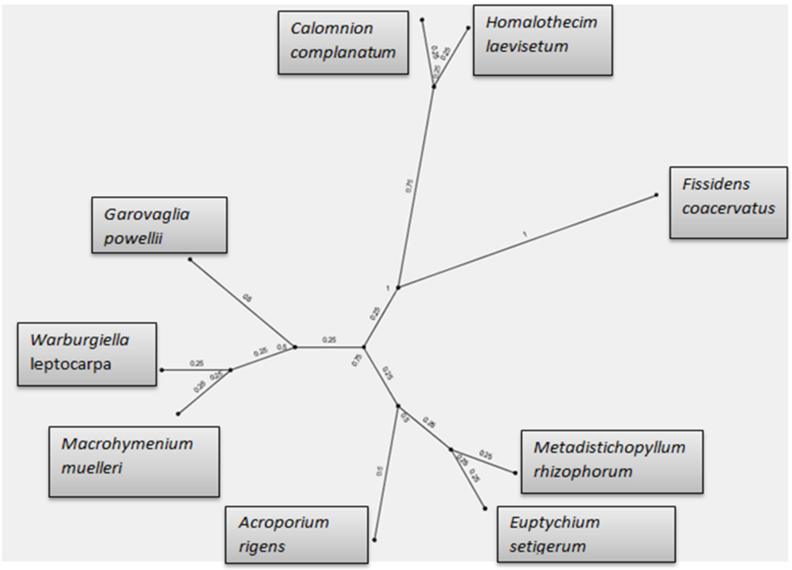

Figure 3. Cladogram of newly discovered moss species in the Philippines found in Mindanao Island

Table 2 shows the list of re-discovered and discovered species of mosses in the Philippines, specifically in Mindanao Island, during the joint expedition (2014-2015) conducted by botanists of Central Mindanao University (CMUH) in the Philippines and the California Academy of Sciences (CAS) in the United States. The taxonomic distribution shows where the specimen was discovered, morphological description, habitat, and geographic distribution of each species. All information was provided by several reports done by (B. Tan et al., 2015; Benito C. Tan et al., 2019, 2017; Benito C Tan & Shevock, 2014). Based on the geographical distribution of the moss species, there is a strong floristic connection of Mindanao Island with neighboring islands such as Borneo, Java, Malaysia, New Guinea, and Australasia (Linis, 2009; B. Tan et al., 2015). Out of the 73 discovered new species in Mindanao Island, only 17 of them are new to the Philippines. 53 were already known from Luzon and Visayas island groups. The Mindanao moss flora has the highest resemblance to Luzon. Their findings in Mindanao Island have extended their local ranges inside the country.

In addition, it also resembles the mass flora of the Malesia region, this includes the Philippines, Malay Peninsula, Malay Archipelago, New Guinea, Bismarck Archipelago, Java, and Borneo. The region is known to be home to the oldest forests on earth which is attributed to the region's high biodiversity. Around 27% of the higher plant genera found in the Malesia region are mainly Asian origin and 4% are of Australian origin. Nearly 14% of the genera are endemic while 27% have primarily distributed across Malesia. The high number of endemic plants in the area can be explained by a large number of islands in the region. This leads to isolation, many plants become isolated from their parent stock and evolve into new forms ("Malesia Region", n.d.).

The distribution of Malesian mosses is strongly connected to the rain forest habitat. These patterns can be explained by relating them to local plate tectonic movements than by a long-distance dispersal hypothesis (B C Tan, 1998). Two continental collisions resulted in the movement of vegetation into and out of the Malesian region, hence, the origins and evolution of the perhumid rainforest. Plate tectonics combined with climate constraints have shaped the distribution and diversification of plant lineages in Malesia throughout time (Kooyman et al., 2019).

Table 2. Mindanao island moss flora tabular distribution

Species	Location of studied specimen	Description	Habitat	Geographical distribution
Acroporium aciphyllum [Sematophyllaceae]	North Cotabato Province, Mt. Apo National Park (1735m)	Aciphyllous leaf apex	On tree trunks in evergreen forest	Malaysia & Philippines
Acroporium convolutum [Sematophyllaceae]	Bukidnon Province, Mt. Kiamo (1580m) and North Cotabato Province, Mt. Apo (2230m)	Ovate-oblong and involute leaves with a long acuminate apex	On branches	Borneo, Java, Malay Peninsula, Sumatra, & Philippines
Acroporium johannis-winkleri [Sematophyllaceae]	North Cotabato Province, Mt. Apo (1800 m) and Bukidnon Province, Mt. Kiamo (1300 m and 1500 m)	Leaves are triangular-lanceolate, broad at the base; dense, often acicular	On branches and on decayed logs	Borneo, Malaysia, & Philippines
Acroporium rigens [Sematophyllaceae]*	Bukidnon Province, Mt. Kiamo (1680m)	Leaves are erect, setaceous	On tree trunks	Malesia region
Acroporium rufum [Sematophyllaceae]	Bukidnon Province, Mt. Kiamo (1520m)	Falcate, oblong-lanceolate leaves and acuminate leaf apices	On tree in mossy forest	Malaysia, Indonesia, Celebes, Borneo, & Philippines
Acroporium sigmatodontium [Sematophyllaceae]	Davao Oriental Province, Hamiguitan Range Wildlife Sanctuary (920 m)	Synoicous; leaves lancolate, acuminate; stems irregularly branched with cuspidate at tips	Widespread pantropical moss on branches	Malesia region
Aerobryidium crispifolium [Meteoriaceae]	Bukidnon Province, Mt. Kitanglad range natural park toward Mt. Dulang-dulang (2000 m)	Crispate undulate and rugose leaf apices	On twigs and barks	China, Philippines, Malay Peninsula, & Borneo
Bryoxiphium japonicum [Bryoxiphiaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (2875 m)	Distichous foliation; complanate and conduplicate	On vertical volcanic rock wall	Across Asia
Callicostella armata [Pilotrichaceae]*	Camiguin Island Province, Mt. Hibok-Hibok (885 m)	Long, acuminate apex and strongly papillose	On volcanic boulder and shaded root stump	Malesian region
Calomnion complanatum [Calomniaceae]*	North Cotabato Province, Mt. Apo (2000 m)	Caducous, lateral and median leaves; denuded stem base	On tree trunks	Australia, New Zealand, Philippines, & Indonesia
Calymperes fasciculatum [Calymperaceae]	North Cotabato Province, Mt. Apo (2000 m)	Leaves are falcate and narrowly lanceolate-linear. Lacks teniolae	On tree trunks, bases, and rock in forests	Across Asia
Chaetomitrium ciliatum [Symphyodontaceae]*	Bukidnon Province, Mt. Kiamo (1580m)	Long creeping stem, lateral branches, undulate leaves with long dorsal spines	On podocarp shrub branches	Indonesia & Philippines
Chaetomitrium elmeri [Symphyodontaceae]	Davao Oriental Province, Hamiguitan Range Wildlife Sanctuary, Mt. Hamiguitan (675 m)	Lingulate leaves with numerous prominent tubercles	On tree trunks	Philippines & Borneo
Chaetomitrium everettii [Symphyodontaceae]	Camiguin Island Province, Mt. Timpoong (1250 m)	Leaf margins undulate; throat-like apex	On trunks of tree fern	Philippines

Chaetomitrium lanceolatum [Symphyodontaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (1775m)	Ovate-lanceolate and concave leaves; toothed leaf apex	On shrug branches	Indonesia, Philippines & Borneo
Clastobryopsis robusta [Sematophyllaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park	Broad, decurrent leaf bases; upper leaf margins recurved	On twigs, branches, or tree trunks	China, Japan & Malesia region
Clastobryum cuculligerum [Sematophyllaceae]	North Cotabato Province, Mt. Apo (2000 m), Bukidnon Province, Mt. Kiamo (1300 m and 1500 m) and Mt. Dulang-Dulang, Kitanglad Range Natural Park (2200 m)	Terminal elongate leaves and pointed leafy shoot	On branches and logs	Malesia region & Australia
Clastobryum indicum [Sematophyllaceae]	Camiguin Island Province, Mt. Hibok- (1100 m)	Leaves are ranked into one plane, narrowly ovate- lanceolate with long acuminate apex	Below the rim of the caldera	China & Philippines
Clastobryum leucophyllum [Sematophyllaceae]	North Cotabato Province, Mt. Apo (1500 m), Bukidnon Province, Mt. Kitanglad Range Natural Park (2200 m) and Mt. Kiamo (1680 m)	Oblong-lanceolte leaves with long acuminate and recurved apex; serrulate	On branches	Borneo, Malay Peninsula & Philippines
Ctenidium malacobolum [Hylocomiaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (1,900 m)	Broad base of stem leaf; branches are pinnately regular and serrulate leaf margins	On soil or tree bases	Across Asia
Dendrocyathophorum paradoxum [Sematophyllaceae]	Misamis Oriental Province, Mt. Balatukan	The complanate and dendroid plant with irregular branches and leaves arranged in three rows	On thin soil over rocks and tree trunks	China, Japan, India, Thailand, Vietnam, the Philippines, and New Guinea.
*Distichophyllum shevockii**	Mt. Limbawon from campsite about 1.5 km below summit and about 7.5 km above Kibalabag Village	Piliferous leaves with very long, smooth, straight, or flexuose, capillaceous acumen	On hardwood and podocarp cloud forests	Philippines
Distichophyllum subcarinatum [Daltoniaceae]*	Bukidnon Province, Mt. Kitanglad Range Natural Park (2945m)	Carinate leaves that end with a short cuspidate apices	On trunk of tree fern	Borneo, Philippines, Malaysia, & Sabah
Distichophyllum subcuspidatum [Daltoniaceae]	Bukidnon Province, Mt. Limbawon (1820 m and 1675 m)	Laterally compressed leaves with dorsiventral stems	On soil and rocks	Borneo, Malaysia, Philippines, Sabah
Distichophyllum undulatum [Daltoniaceae]	Bukidnon Province. Mt. Limbawon (1800 m)	Irregularly denticulate upper leaf border	On soil and fallen branches	Philippines
Ditrichum difficile [Ditrichaceae]	North Cotabato Province, Mt. Apo (1800 m)	Overlapping sheathing leaf bases. Leaf narrows and become grass-like	On soil and wet boulder	Widely distributed in the world
Ectropothecium penzigianum [Hypnaceae]*	Bukidnon Province, Mt. Limbawon (1750 m)	Bicostate, smooth, and concave leaves	On tree trunks, rotten woods and soil	China, Indonesia, & Philippines
Ectropothecium ptychofolium [Hypnaceae]	Bukidnon Province, Mt. Kiamo (1400 m)	Strongly plicate leaves	On forest floor	Borneo, Malaysia, & Philippines

Elmeriobryum philippinense [Sematophyllaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park	Weakly plicate stem leaves	On tree trunks and rocks	China & Philippines
Ephemeropsis tjibodensis [Ephemeropsidaceae]	Bukidnon Province, Mt. Kiamo (1300 m)	Brown, erect, and long protonemal setae	On leaves of several shrubs	Philippines & Thailand
Erpodium luzonense [Erpodiaceae]	Bukidnon Province, Central Mindanao State University	Operculum has a conic tip with plenty of capsules	On tree trunk	Philippines
Euptychium setigerum [Garovagliaceae]*	Davao Oriental Province, Mt. Hamiguitan Range Wildlife Sanctuary (950 to 1200 m)	Perichaetial leaves covers sessile capsule; long setaceous leaf apices	On tree trunks and small branches	Borneo & Philippines
Ectropothecium zollingeri [Hypnaceae]	North Cotabato Province, Mt. Apo Natural Park (1350 m)	Asymmetric ovate-lanceolate leaves; acute apices; stems prostrate	On base or trunk of trees, rotten wood, or rocks and soil in forests	Across Asia & Oceania
Fissidens anomalus [Fissidentaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (2200 m)	Densely gregarious tufts; leafy stems simple or branched	On rocks, rarely on trees or on soil	Across Asia
Fissidens coacervatus [Fissidentaceae]*	Bukidnon Province, Mt. Kiamo (1350 m)	Dark green color; leaf acosta; stout limbidia and a consistent excurrent	On wet shaded stream bed	Madeira & Philippines
Fissidens ganguleei [Fissidentaceae]*	North Cotabato Province, Mt. Apo (2200 m)	Bent leaf costa	On tree bases in evergreen forests and soil bank	China, Japan, Nepal, India, & Philippines
Fissidens hyalinus [Fissidentaceae]	North Cotabato Province, Mt. Apo (2000 m)	No leaf costa	On moist rocks and on deepy shaded bank	China, Japan, India, Philippines, North, and South America
Fissidens oblongifolius [Fissidentaceae]	North Cotabato Province, Mt. Apo (1800 m)	Paired leaves (15-30), mid-stem overlaps	Mostly on soil, rarely on rocks and on wet cliff	Across Asia, Australia, New Zealand, Mexico, & Central America
Fissidens pallidinervis	Bukidnon Province, Mt. Kitanglad Range Natural Park	Obtuse-round leaf apice; restricted-vaginant laminae	On soil and rocks	Madagascar, Brazil, America & Philippines
Fissidens pellucidus [Fissidentaceae]	North Cotabato Province, Mt. Apo Natural Park (1350 m)	Broad percurrent costa leaves; lower leaves are densely arranged lanceolate	On soil	Across Asia and South America
Fissidens polypodioides [Fissidentaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (2495 m)	Mucronate-broadly acute and coarsely serrate leaf apex	On soil, boulders, or cliffs	Across Asia and America
Fissidens taxifolius [Fissidentaceae]	North Cotabato Province, Mt. Apo Natural Park (2020 m)	Leafy stems simple; usually rounded base of dorsal laminae	On soil, rarely on rocks	Widely distributed in the world
Garovaglia bauerlenii [Garovagliaceae]	Bukidnon Province, Mt. Limbawo (1300 m)	Leaves are appressed and strongly rugose, undulate and plicate	On tree trunks	Malesia region
Garovaglia powellii [Garovagliaceae]*	South Cotabato Province, Mt. Matutum (700–900 m)	Broad ovate and plicate leaves with acute apices	On tree trunk	Malesian region, Australia,

				Vietnam, & Thailand
Garovaglia punctidens [Garovagliaceae]	Bukidnon Province, Mt. Limbawon (1480 m)	Compared with *G. plicata* because they have both distinct characteristics (foliation, serration, and plant habit) but it is not considered as a subspecies of it.	On tree ferns and on trunk	Philippines
Groutiella tomentosa [Orthotrichaceae]	Bukidnon Province, Mt. Kiamo (1210 m)	Well differentiated basal leaf border; oblong-smooth capsule	On tree trunks, branches, rotting logs, and rocks	Widespread in SE region, America, Malesia region, Philippines
Hampeella pallens [Ptychomniaceae]	North Cotabato Province, Mt. Apo National Park (1875 m)	Curved leaves; complanate plant habit	Lower slopes	New Zealand, Philippines, Taiwan
Holomitrium cylindraceum [Sematophyllaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park	Large perichaetial round-oval leaves, numerous quadrate leaf alar	On rotten wood, bases of trees, or rocks	China, Philippines, & Africa
Homalathecium laevisetum [Brachytheciaeae]*	Bukidnon Province, Mt. Kiamo (1195 m)	Plicate leaves; terete branches	On hardwoord branch, tree trunks, and thin soil over rocks	Across Asia & Russia
Hookeriopsis wishurae [Pilotrichaceae]	Bukidnon Province, Mt. Limbawon (1820 m and 1690 m)	Long and acuminate leaf apices	On soil and rocks	Philippines
Leiomela javanica [Sematophyllaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park	Leaves long and setaceous	On trunk of tree fern	Malesia region
Macromitrium cuspidatum [Orthotrichaceae]	Bukidnon Province, Mt. Kiamo (1775 m)	Long excurrent costa; rectangular upper laminal cells and linear-smooth basal laminal cells	Summit ridge	Philippines
Macrothamnium javense [Hylocomiaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (2190 m)	Strongly serrated leaf margins; decurrent leaf base	On tree trunks and on rocks seasonally submerged	China, Sri Lanka & Malesia region
Macrohymenium muelleri [Sematophyllaceae]*	Bukidnon Province, Mt. Kiamo (1680 m) and North Cotabato Province, Mt. Apo (2455 m)	Large, erect-appressed leaves with long acuminate apex	On tree trunks	Madagascar & Philippines
Meiothecium tenellum [Sematophyllaceae]	Bukidnon Province, Campus of Central Mindanao University (320 m)	Leaves concave, ovate to ovate-oblong; often with 2 central plicae	Forest openings or in areas with landscaped trees	Malesia region
Metadistichophyllum rhizophorum [Daltoniaceae]*	Bukidnon Province, Mt. Kitanglad Range Natural Park (2945 m)	Long and stiff rhizoidal filaments; gemmae at the tip	On tree fern trunk	Java, Borneo, & Philippines
Meteoriopsis reclinata [Meteoriaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (1350 m)	Long creeping stem with distinctive rows of squarrose leaves on branches	On tree trunks and calcareous rocks	Across Asia

Mniomalia semilimbata [Sematophyllaceae]	Agusan del Sur Province, Philsaga Mining Corporation, Brgy. Bayu-gan, Rosario	Leaf asymmetrical with one-sidedly located midrib	On moist rock	Philippines
Oedicladium rufescens [Myuriaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (2250 m)	Long, strongly concave ovate-lanceolate leaves; margins are involute	On rocks, cliff walls, and tree trunks	China, Sri Lanka, Malaysia, Philippines, New Caledonia, & Australia
Pelekium velatum [Thuidiaceae]	Davao Oriental Province, Hamiguitan Range Wildlife Sanctuary (550 m)	Stem leaf apex long apiculate; seta strongly hispid	Mostly on shady and moist rocks	Across Asia and Africa
Pelekium versicolor [Thuidiaceae]	Bukidnon Province, Mt. Kiamo (1210 m)	Muticous stem leaves; smooth setae	On soil and rocks	Philippines & Africa
Pogonatum subtortile [Polytrichaceae]	North Cotabato Province, Mt. Apo (2000 m)	Low lamellae occupies the leaf acosta with adjacent laminal area	On soil and semi-shaded boulder	Borneo & Philippines
Pohlia elongate [Mniaceae]	North Cotabato Province, Mt. Apo (2200 m)	Broad spearhead lower leaves; narrow upper leaves	On soil	Across Asia, Europe, & North America
Pseudotaxiphyllum arquifolium [Hypnaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (2240 m)	Arcuate leaves; complanate plant habit; acute-acuminate leaf apices	On clayey volcanic soil	Philippines
Pseudospiridentopsis horrida [Meteoriaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (2200 m)	Squarrose leaves, lower half of leaf abruptly reflexed	On tree trunks, shrub branches, and rock surfaces	China, Nepal, India, Japan, & Philippines
Pterobryopsis crassicaulis [Pterobryaceae]	Bukidnon Province, Mt. Kiamo (1680 m)	Coupled main stem with many erect and small branched secondary stems	On tree trunks and fallen logs	Across Asia
Radulina laevihamata [Sematophyllaceae]*	Bukidnon Province, Mt. Kiamo (1500 m)	Falcate and narrowly lanceolate leaf	Tropical hardwood rainforest on log	Papua New Guinea & Philippines
Rhacocarpus alpinus [Sematophyllaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park, on summit ridge of Mt. Dulang-Dulang	Dull yellowish-brown appressed, think, and leathery leaves	On tree trunks and soil	Malesia region
Rhapidostichum luzonense [Sematophyllaceae]	Davao Oriental Province, Hamiguitan Range Wildlife Sanctuary (960 m)	Oblong-ovate leaves, long acuminate apex; margins denticulate near apex	On soil and rarely on rocks	Papa New Guinea & Philippines
Rhaphidostichum piliferum [Sematophyllaceae]	Bukidnon Province, Mt. Kiamo (1500 m)	Loosely arranged leaves oblong-ovate; elongated main stems; spirally arranged branches	On tree trunks	China & Philippines
Rhodobryum aubertii [Bryaceae]	Bukidnon Province, Mt. Limbawon (1365 m)	Teeth of leaf margins single	On rotten logs and soil	Brazil & Philippines
Rhynchostegiella menadensis [Brachytheciaceae]	Camiguin Island Province, Mt. Hibok-Hibok (790 m)	Stem leaves are appressed, narrowly-lanceolate to lanceolate-triangular	Below caldera	Philippines

Rosulabryum billarderii [Bryaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (2495 m) and North Cotabato Province, Mt. Apo Natural Park (2020 m)	Leaves uniformly distributed, spreading when moist; dioicous	On soil	Brazil & Philippines
Sinskea flammea [Meteoriaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (2615 m)	Pendulous mats; orange-reddish cast	On tree trunks or branches	China, Nepal, India, and Thailand, & Philippines
Symphyodon copelandii [Symphyodontaceae]	Bukidnon Province, Mt. Kalatungan (2000 m)	Acute-acuminate leaf apices	On tree trunks	Borneo & Philippines
Symphysodon longicuspis [Sematophyllaceae]	Bukidnon Province, Mt. Kiamo	Concave, unicostate leaves with acuminate leaf apices	On tree trunk by a deeply shaded stream	Papa New Guinea & Philippines
Symphyodon perrottetii [Sematophyllaceae]	Bukidnon Province, Mt. Kitanglad Range Natural Park (2200 m)	A bit complanate-undulate leaves; upper half of the blade have irregular toothed margins	On branches or saplings	Across Asia
Syrrhopodon gardneri [Calymperaceae]	North Cotabato Province, Mt. Apo (1300 m)	Demarcated cancellinae on the leaf; reddish rhizoids	On tree trunks and bases, branches, decaying logs, and rocks	Pantropical regions
Syrrhopodon japonicas [Calymperaceae]	North Cotabato Province, Mt. Apo (2200 m) and margin of Lake Jordan (2300 m)	Lacks demarcated cancellinae on the leaf; thick leaf margin with double short teeth	On tree trunks and bases, decaying logs, rock, and soil in forests	China, Korea, Japan, India, Malaysia, Philippines & Western Oceania
Taxiphyllum arcuatum [Hypnaceae],	North Cotabato Province, Mt. Apo (2000 m)	Distichous, strongly appressed branch leaves that overlap; leaf margins crenulate-apiculate apex	On soil or tree trunks in forests	China, Japan, Indonesia, Thailand & Philippines
Taxiphyllum taxirameum [Hypnaceae],	North Cotabato Province, Mt. Apo (1800 m)	Glossy, complanate-foliate plants; stiff, distant leaves	On soil, rocks, on tree trunks or rotten wood	Across Asia, America, & Australia
Trachypodopsis serrulata [Sematophyllaceae]	Bukindon Province, Mt. Kitanglad Range Natural Park (2620 m and 2875 m)	Longitudinally plicate leaves, unipapillose, unicostate with long acuminate leaf apices	On forest ground and rock surfaces	China, India, Nepal, Vietnam, Philippines, & Africa
Trachypus longifolius [Sematophyllaceae]	Bukidnon Province, Mt.Kalatungan (2000 m)	Oblong-lanceolate leaf blade with narrow and acuminate acumen	On tree trunks and shaded rocks	China & Philippines
Trismegistia complanatula [Pylaisiadelphaceae]*	Camiguin Island Province, Mt. Timpoon (1380 m) and Davao Oriental Province, Mt. Hamiguitan (1040 m)	Stem leaves have ovate base; narrows leaf apex	On root stump in forest with filtered light and on tree trunk	Papua New Guinea, New Caledonia, & Philippines
Warburgiella leptocarpa [Sematophyllaceae]*	Bukidnon Province, Mt. Kitanglad Range Natural Park (2200 m)	Broad expanded leaf base; narrow, strong toothed leaf acumen	On soil and branches	Philippines

Almost all of the moss species were discovered along summit ridges or slopes of mountains. These ecosystems found within mountains are known as montane ecosystems. The distribution of moss diversity is highly like to occur in montane forests (Azuelo & Puno, 2018). Their habitats are mostly on tree trunks, on soil, on branches, on moist rocks, along streams, or decaying woods. Mosses like damp shaded habitats or environments where they can be protected from the sun’s heat and drying effects, hence, it is not a surprise to find them at these habitats. Moreover, climate and substrate chemistry are factors that affect the distribution of mosses. Mosses grow abundantly in subtropical climates. They form deep and soft forest floors and over rock surfaces, branches of trees and shrubs. Once mosses start to grow on rock surfaces, soil formation starts. This leads to the production of substratum attractive to seed plant colonists that invade mossy sites. These are important for nutrient cycling of forest vegetation. On the other hand, mosses that are seen along margins of streams can tolerate drier habitats compared to other species (Schofield, 2019; Lepp, 2008).

CONCLUSIONS

Heuristic searches intended for scientific inquiries in connection to evolutionary history are of great importance.

In this study, data from previous expeditions spearheaded by Tan and other researchers across the globe are combined. The evolutionary history of Philippines mosses is inferred using phylogenetic trees amongst mosses species found in Mindanao Island. For the purpose of easier classification of moss flora, taxonomic key (in tabular form) was created by the researchers and its significant inclusions is the location of where specimens were gathered, description, habitat, and geographical distribution. Aside from a taxonomic key, sequences that hold crucial information about species played a pivotal role in identifying evolutionary history: phylogenetic tree. Alignment of protein sequences from cpDNA, mtDNA, and rRNA allowed the investigators to infer history trees using Maximum Likelihood and Maximum Parsimony analyses. Despite adjusted bootstraps, results still vary because of several reasons that may include differences in gene features and unavailability of data of newer species, however; taxonomic key and phylogenetic trees indeed provided a newer way of identifying the new species and its evolutionary history through the use of a bibliographical approach. The increasing trends of MDR K. pneumoniae isolate every year is alarming as categorized antimicrobial agents seem to have little to no efficacy against these pathogens. People are oblivious as to how this health crisis would affect the future of medicine and the magnitude of it can bring the pre-antibiotic era back.

In conclusion, the researchers suggests an in-depth study inclusive of complete data from the main reference (i.e.: concentrations of the antibiotics used to examine resistance per region) and the morbidity and mortality reports of patients that suffered illnesses due to K. pneumoniae infection since the plotted trends only supplement superficial information regarding the seriousness of resistant K. pneumoniae isolates. Moreover, health awareness programs tackling antimicrobial resistance and its future undesirable outcomes must also be considered and implemented.

For further studies, the researchers suggest obtaining additional information through books articles, and publications regarding Philippines mosses for the succeeding years after 2015, which was already conducted by the former. On a similar note, tracing evolutionary history based on gross morphology moss, moss histology, and taxonomic classification could be done. For genetic analysis, moss extractions are of great significance for these may also provide supplemental information for new sets of researchers and even bryologists themselves.

REFERENCES

Azuelo, A. G., & Puno, G. R. (2018). Moss and lichen diversity in Mt. Kalatungan Range Natural Park, Bukidnon, Philippines. International Journal of Biosciences (IJB), 12(3), 248–258. https://doi.org/10.12692/ijb/12.3.248-258

Derviş, B. (2013). Moss. Journal of Chemical Information and Modeling, 53(9), 1689–1699. https://doi.org/10.1017/CBO9781107415324.004

Felsenstein J. (1985). Confidence limits on phylogenies: An approach using the bootstrap. Evolution 39:783-791.

Gielly, L. & Taberlet, P.

Harmens, H., Foan, L., Simon, V., & Mills, G. (2013). Terrestrial mosses as biomonitors of atmospheric POPs pollution: A review. Environmental Pollution, 173, 245–254. https://doi.org/10.1016/j.envpol.2012.10.005

Jones D.T., Taylor W.R., and Thornton J.M. (1992). The rapid generation of mutation data matrices from protein sequences. Computer Applications in the Biosciences 8: 275-282.

Khujjah, M., & Ekowati, G. (2018). Epiphyte mosses (bryophytes) on plants in parking areas along the main line of Brawijaya University. AIP Conference Proceedings, 2019(October 2018). https://doi.org/10.1063/1.5061844

Kooyman, R. M., Morley, R. J., Crayn, D. M., Joyce, E. M., Rossetto, M., Slik, J. W. F., … Wilf, P. (2019). Origins and Assembly of Malesian Rainforests. Annual Review of Ecology, Evolution, and Systematics, 50(1), 119–143. https://doi.org/10.1146/annurev-ecolsys-110218-024737

Kumar S., Stecher G., Li M., Knyaz C., and Tamura K. (2018). MEGA X: Molecular Evolutionary Genetics Analysis across computing platforms. Molecular Biology and Evolution 35:1547-1549.

Lepp, H. (2008, February 28). Habitats. Retrieved from https://www.anbg.gov.au/bryophyte/ecology-habitats.html

Linis, V. C. (2009). Biogeography of Mindoro mosses. Blumea: Journal of Plant Taxonomy and Plant Geography, 54(1–3), 290–296. https://doi.org/10.3767/000651909X476319

Malesian Region. (n.d.). Retrieved from https://www.malesiana.com/index.php?option=com_content&view=article&id=78&Itemid=210

Nei M. and Kumar S. (2000). Molecular Evolution and Phylogenetics. Oxford University Press, New York.

Pellis, S. M., Pellis, V. C., & Himmler, B. T. (2014). How Play Makes for a More Adaptable Brain: A Comparative and Neural Perspective. American Journal of Play, 7(1), 73–98.

Schofield, W. (2019, March 6). Ecology and habitats. Retrieved from https://www.britannica.com/plant/bryophyte/Form-and-function

Shevock, J. R., Lambio, I. A. F., & Tan, B. C. (2014). Collection and Preparation Techniques of Bryophyte Specimens in Biodiversity Inventories. The Coral Triangle: The 2011 Harst Philippine Biodiversity Expedition, 395–405.

Shevock, J. R., Lambio, I. A. F., & Tan, B. C. (2014). Collection and Preparation Techniques of Bryophyte Specimens in Biodiversity Inventories. The Coral Triangle: The 2011 Harst Philippine Biodiversity Expedition, 395–405.

Tan, B. C., Ochyra, R., Ho, B.-C., & Bednarek-Ochyra, H. (2019). Distichophyllum shevockii (Daltoniaceae), a New Moss Species from the Philippines. Annales Botanici Fennici, 56(4–6), 361. https://doi.org/10.5735/085.056.0422

Tan, B. C., & Shevock, J. R. (2014). Noteworthy mosses and a new variety collected from the 2014 joint expedition of CAS and CMUH new to Mindanao Island of the

Philippines. Bryophyte Diversity and Evolution, 36(1), 22. https://doi.org/10.11646/bde.36.1.2

Tan, B. C., Shevock, J. R., Azuelo, A. G., & Lubos, L. (2017). Additions to the moss floras of Mindanao and the Philippines with a focus on the rediscovery of Euptychium setigerum. Natural History Bulletin of the Siam Society, 62(1), 15–20.

Tan, B., Shevock, J., & Coritico, F. (2015). Mosses new for Mindanao Island, the Philippines(3). Bulletin of the National Museum of Nature and Science. Series B, Botany, 41(3), 91–97.