Journal of Tropical Biology and Conservation 21: 96–110, 2024 *ISSN 1823-3902*
E-ISSN 2550-1909

Research Article

Diversity of Pteridophytes in Different Vegetation Types of Mount Musuan, Bukidnon, Philippines

Fulgent P. CORITICO[1,2]*, Pamela Joy F. ORIAS[2], Ivy C. ADLAON[1], Joevina C. NOBLEZA[1,2], and Victor B. AMOROSO[1,2]

[1]Plant Biology Division, Institute of Biological Sciences, College of Arts and Sciences, Central Mindanao University, University Town, Musuan, Maramag, 8714 Bukidnon, Philippines.
[2]Center for Biodiversity Research and Extension in Mindanao (CEBREM), Central Mindanao University, University Town, Musuan, Maramag, 8714 Bukidnon, Philippines.

*Corresponding author email address: cfulgent@gmail.com

Received 20 February 2024| Accepted 15 October 2024| Published 11 December 2024
DOI: https://doi.org/10.51200/jtbc.v21i.5674

ABSTRACT

Mount Musuan is one of the Long-Term Ecological Research (LTER) sites in the Philippines. As part of continuous monitoring of pteridophyte distribution and ecological sensitivity, this paper investigated pteridophyte diversity on the established vegetation types of Mount Musuan as basis for conservation management. Two 20 m × 20 m plots were established per vegetation type—Natural Forest, Mixed/Biro, Thailand Shower, and Teak which recorded 38 pteridophyte species, from 28 genera, and 18 families. Highest diversity index was recorded in Mixed/Biro vegetation (H'=1.18), followed by Teak vegetation (H'=1.006), Thailand Shower (H'=0.886), and Natural Forest (H'=0.85). Pteridaceae had the highest number of species (6), Thelypteridaceae (4), Nephrolepidaceae (3) and Lygodiaceae (3). *Sphaeropteris glauca* is an endangered species and a new record for Mount Musuan, and *Angiopteris evecta* as other threatened species. The presence of these species highlights the importance of botanical exploration in Mount Musuan as well as the need for conservation management to protect its remaining biodiversity.

Keywords: diversity; LTER; vegetation type; species richness; pteridophytes.

INTRODUCTION

The Philippines has diverse floral species with a high endemism level, and recent classification shows that the Philippine flora have an estimated number of 1,100 species of ferns and lycophytes, widely distributed among 154 genera and 34 families. Ferns and lycophytes, collectively referred to as pteridophytes, are a group of vascular plants that do not produce seeds and reproduce through spores (Myers et al., 2000; Smith et al., 2006; Pelser et al., 2024; Singh, 2024).

Mount Musuan is one of the Long-Term Ecological Research (LTER) sites in the Philippines, located in Bukidnon, Northern Mindanao (Kim et al., 2018) and is in a decade-long monitoring, targeted by research programs by Amoroso et al., 2013 and 2015b. It is known for its rich biological resources, allowing the growth of pteridophytes and gymnosperms along with different plant species.

Copyright: ©Coritico et al.
This is an open access article distributed under terms of the Creative Commons Attribution-Noncommercial 4.0 International License (Attribution-Noncommercial 4.0 International – CC BY-NC 4.0).

Mount Musuan also has the highest litter turnover among the three LTER sites in Mindanao, viz., Mount Apo, Mount Hamiguitan and Mount Musuan, correlating forest litter as an important aspect of healthy ecosystems (Acma et al., 2018). It is also a dormant volcano, and it is known that volcanoes greatly affect landscape evolution which can generate predictable biodiversity processes and usually possess outstanding levels of richness and endemism (Sanin et al., 2024). Pteridophytes located in Mount Musuan are significant due to their high number of species (Amoroso, 2007). However, habitat destruction such as forest fires, environmental pollution as neighbouring places undergo heavy infrastructure development, presence of invasive species, and over-exploitation for recreational activities and ornamental purposes have been observed in Mount Musuan, posing major threats to its biodiversity (Dadang et al., 2020; Khapugin et al., 2020; Paquit et al. 2023). Many pteridophyte species have been investigated extensively, and it was discovered that a substantial number of these are becoming rare and endangered, particularly in Mindanao, Philippines (Coritico & Amoroso, 2020).

This study builds on the preliminary pteridophyte data from the earlier studies (Amoroso et al., 2013; 2015b) and aims to continually assess species diversity, composition, distribution, species importance value, and assessment of dominant species in the established vegetation types of Mount Musuan based on the classification of Paquit et al. (2023) for future pteridophyte flora conservation management plan.

MATERIALS AND METHODS

Entry protocol

A gratuitous permit was obtained from the Department of Environment and Natural Resources with the GP number R10 2023-140, allowing researchers to collect pteridophyte flora from Mount Musuan, LTER Site, Bukidnon, Philippines.

Study site

The duration of the study was from February-March 2023, at Mount Musuan situated at 7° 52' 37.62639" N, 125° 4' 11.0422" E, with the highest altitude of 600 m asl. This site is one of the target research sites for the third LTER program following previous studies conducted in 2013 and 2015 (Amoroso et al. 2013; 2015b), hereafter referred to as 'LTER 1' and 'LTER 2', respectively. The sampling sites were according to the vegetation types recognised by Paquit et al. (2023). The four vegetation types are classified as, (1) Natural Forest (7°52'57" N 125°03'56" E, 372-383 m asl); (2) Mixed/Biro (7°5242 N 125°04'04" E, 491–499 m asl); (3) Thailand Shower (7°52'46" N 125°04'05" E, 471–474 m asl); and (4) Teak (7°52'38" N 125°04'06 E, 528-535 m asl). Natural Forest vegetation type is classified as a forest composed of indigenous trees, with a tree canopy cover of more than 10 percent (CBD, 2023). Mixed/Biro, on the other hand, is characterised by a combination of different trees as well as the Biro tree (*Rhus* sp.), as the dominant species which can be observed in the area. Thailand Shower vegetation type comprises the Thailand Shower tree (*Cassia siamea* Lam.) dominant in the area. Lastly, Teak (*Tectona grandis* L.) vegetation type is characterised by the presence of the towering Teak trees planted in the area (Figure 1).

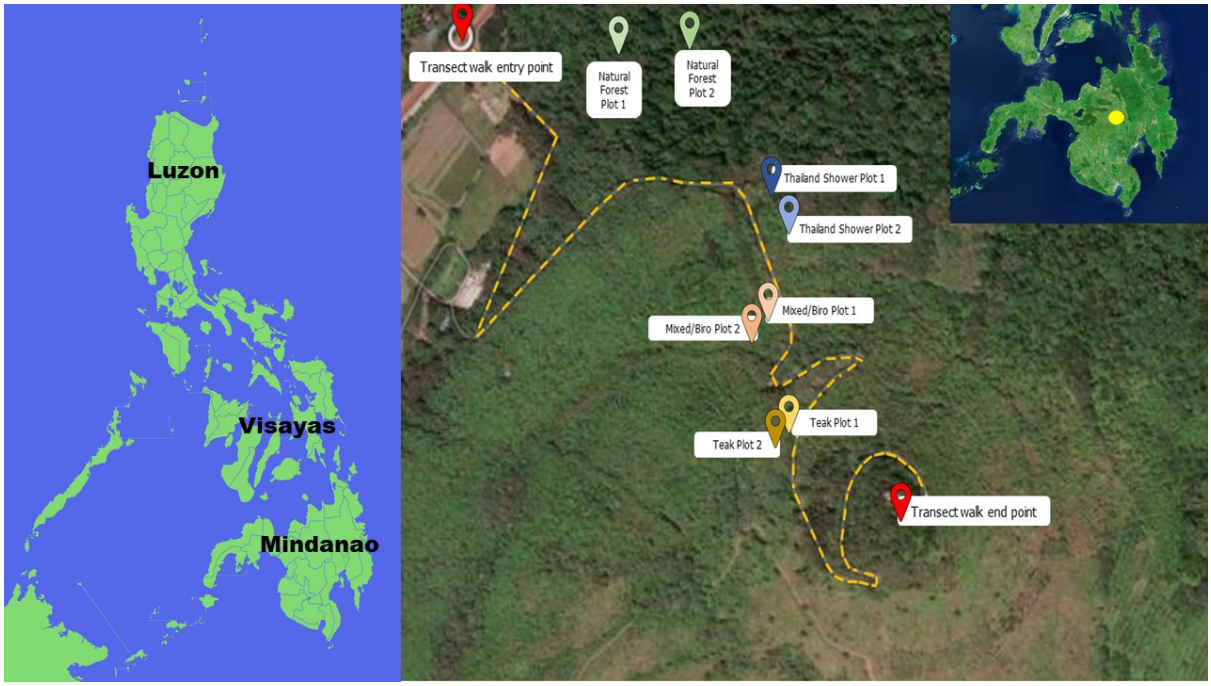

Figure 1: Repeated transect walk map for different vegetation types in Mount Musuan LTER Site, Bukidnon, Philippines.

Sampling procedure and data gathering

Two 20 m × 20 m sampling plots were established at a 50 m interval in elevation and 20 m width on both sides of the trail were marked and established in each of the four vegetation types for the computation of diversity indices. The sampling plots were established objectively based on the spatial distribution of pteridophyte species across different vegetation types. Repeated transect walks and opportunistic sampling was also employed in the study to document the pteridophyte species found outside the established plots for a more comprehensive list of Mount Musuan pteridophytes. All pteridophyte species were recorded, including epiphytic species.

Specimen collection, herbarium voucher processing and identification

Shear and trimming cutter were used in the collection of at least 4 fertile fronds of each pteridophyte flora for the voucher specimens. Specimens were processed in the field using the wet method (Hodge, 1947). All voucher specimens were deposited at the Central Mindanao University Herbarium (CMUH). The specimens were identified and examined by the experts in this study, Co's Digital flora, and Copeland's Fern flora of the Philippines (1958–1961). Initial identification was done by the authors.

The conservation status of the species recorded were listed following the national list of threatened Philippine plants and their categories (DAO, 2017), which in turn largely follows the criteria of the International Union for Conservation of Nature (2023). An additional category established by the national list is 'Other Threatened Species', which refers to 'a species, subspecies, varieties, or other infraspecific categories that is not critically endangered, endangered nor vulnerable but is under threat from adverse factors, such as overcollection throughout its range and is likely to move to the vulnerable category in the near future' (DAO, 2017). The information from the national list serves as a basis for governmental agencies that set environmental policy (Protected Area Management Board [PAMB], Department of

Environment and Natural Resources [DENR] and Local Government Units [LGUs]) for monitoring and protecting threatened species, both within the sanctuary and beyond.

Computation of diversity indices

The computation of the species importance value for the plots established in each vegetation types was done by utilising the formula of Brower et al. (1997) in Microsoft Excel, and the diversity of the pteridophyte flora was calculated using the Shannon-Weiner Index of Diversity, in BioDiversity pro software (McAleece et al., 1997). The species importance value of Importance Value Index (IVI) in each vegetation types was estimated as IVI = RA+RD+ RF, where RA is relative abundance calculated as the number of individuals per species, RD is relative dominance defined as the basal area per species and RF is relative frequency (Curtis, 1959; Mishra, 1968). To statistically test whether there are significant differences in species diversity and the altitudinal differences in each vegetation types, ANOVA (Analysis of Variance) was used. Hence, giving confidence to the quantitative results on the diversity.

Species similarity

BioDiversity pro software (McAleece et al., 1997) was used to determine the similarity of the species composition of the different sampling sites using the Bray-Curtis cluster analysis.

Occurrence of species in different vegetation types

Published literature (Amoroso, 2007; Pielser et al., 2011; Coritico & Amoroso, 2020), data from research projects conducted between 2013 and 2015, i.e. LTER 1 and LTER 2 (Amoroso et al., 2013; 2015b), and fieldwork conducted during the present study, i.e., 'LTER 3' using Garmin Global Positioning System (GPS) were used to record the occurrence of species in different vegetation types.

RESULTS

Diversity

Results revealed that among the four established sampling sites, Mixed/Biro has the highest diversity index of H'=1.18. Followed by Teak, H'=1.006, Thailand shower, H'=0.886, and the vegetation type with the lowest diversity is the Natural Forest with H'=0.85 index of diversity (Table 1).

Table 1: Shannon-Weiner Diversity Index of Mount Musuan per vegetation type.

Index	Natural Forest	Mixed Biro	Thailand Shower	Teak
Shannon H' Log Base 10.	0.85	1.18	0.886	1.006
Shannon Hmax Log Base 10.	0.954	1.301	0.954	1.079
Shannon J'	0.891	0.907	0.929	0.933

The ANOVA indicated that there was no significant difference among the diversity of pteridophytes in different vegetation types (Table 2).

Table 2: Analysis of variance (ANOVA) of species diversity and the altitudinal differences in each vegetation type for pteridophytes of Mount Musuan.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.097676	3	0.032559	2.605189	0.124026	4.066181
Within Groups	0.099981	8	0.012498			
Total	**0.197658**	**11**				

Species composition

A total of 35 species of ferns and 3 species of lycophytes belonging to 18 families and 28 genera (Fig. 2, Table 3) were recorded in Mount Musuan, Bukidnon, Philippines. Pteridaceae recorded the highest number of species (6), followed by Thelypteridaceae (4), Nephrolepidaceae and Lygodiaceae (3), Dennstaedttiaceae, Polypodiaceae, Tectariaceae, Dryopteridaceae and Selaginellaceae (2), and families Marattiaceae, Lomariopsidacae, Gleicheniaceae, Hymenophyllaceae, Cyatheaceae, Lycopodiaceae, Ophioglossaceae, Lindsaeaceae and Pteridryaceae with one species each (Fig. 2, Table 3).

Table 3: Checklist of pteridophytes in Mount Musuan, Bukidnon, Philippines from 2013 to 2023.

FAMILY/SPECIES	Amoroso et al. 2013	Amoroso et al. 2015b	Present 2023
I. CYATHEACEAE			
1. *Sphaeropteris glauca* (Blume) R.M. Tryon			/
II. DENNSTAEDTIACEAE			
2. *Microlepia* sp.			/
3. *Hypolepis tenuifolia* (G.Forst.) Bernh.			/
III. DRYOPTERIDACEAE			
4. *Bolbitis heteroclita (*C.Presl) Ching	/	/	/
5. *Bolbitis rhizophylla* (Kaulf.) Hennipman	/	/	/
IV. GLEICHENIACEAE			
6.*Dicranopteris linearis (*Burm.f.) Underw.			/
V. HYMENOPHYLLACEAE			
7. *Hymenophyllum javanicum* Spreng.			/
VI. LINDSAEACEAE			
8. *Odontosoria chinensis* (L.) J.Sm.			
VII. LOMARIOPSIDACEAE			
9. *Cyclopeltis crenata* (Fée) C.Chr.			/
VIII. LYCOPODIACEAE			
10. *Palhinhaea cernua* (L.) Vasc. & Franco			
IX. LYGODIACEAE			
11. *Lygodium circinnatum* (Burm.f.) Sw.	/	/	/
12. *Lygodium flexuosum* (L.) Sw.			/
13. *Lygodium japonicum (*Thunb.) Sw.			
X. MARATTIACEAE			
14. *Angiopteris evecta* (G.Forst.) Hoffm.	/	/	/
XI. NEPHROLIPEDACEAE			
15. *Nephrolepis biserrata* (Sw.) Schott			/
16. *Nephrolepis cordifolia* (L.) C.Presl			/
17. *Nephrolepis hirsutula* (G.Forst.) C.Presl.	/	/	/
XII. OPHIOGLOSSACEAE			
18. *Ophioglossum reticulatum* L.			/
XIII. POLYPODIACEAE			
19. *Selliguea* sp.			
20. *Phymatosorus scolopendria* (Burm.f.) Pic.Serm.			/
21. *Aglaomorpha quercifolia* L.			

22. Microsorum punctatum (L.) Copel.			
23. *Pyrrosia longifolia* (Burm.f.) C. V. Morton	/		/
XIV. PTERIDACEAE			
24. *Adiantum philippense* L.			/
25. *Hypolepis tenuifolia* (G. Forst) Bernh.			/
26. *Pityrogramma calomelanos (*L.) Link			/
27. *Pteris ensiformis* Burm.f.	/	/	/
28. *Pteris tripartita* Sw.	/	/	/
29. *Pteris cretica* L.			
XV. PTERIDYACEAE			
30. *Pteridrys microthecia (Fée)* C.Chr. & Ching			/
XVI. SELAGINELLACEAE			
31. *Selaginella* sp. 2	/		
32. *Selaginella usterii* Hieron.	/		/
33. *Selaginella gastrophylla* Warb.			/
XVII. THYLEPTERIDACEAE			
34. *Christella dentata* (Forssk.) Brownsey & Jermy	/		/
35. *Macrothelypteris torresiana* (Gaud.) Ching			/
36. *Pronephrium xiphioides* (Christ) Holtt.			/
37. *Sphaerostephanos unitus* (L.) Holttum			/
XVIII. TECTARIACEAE			
38. *Tectaria polymorpha* (Wall. ex. Hook.) Copel.			/

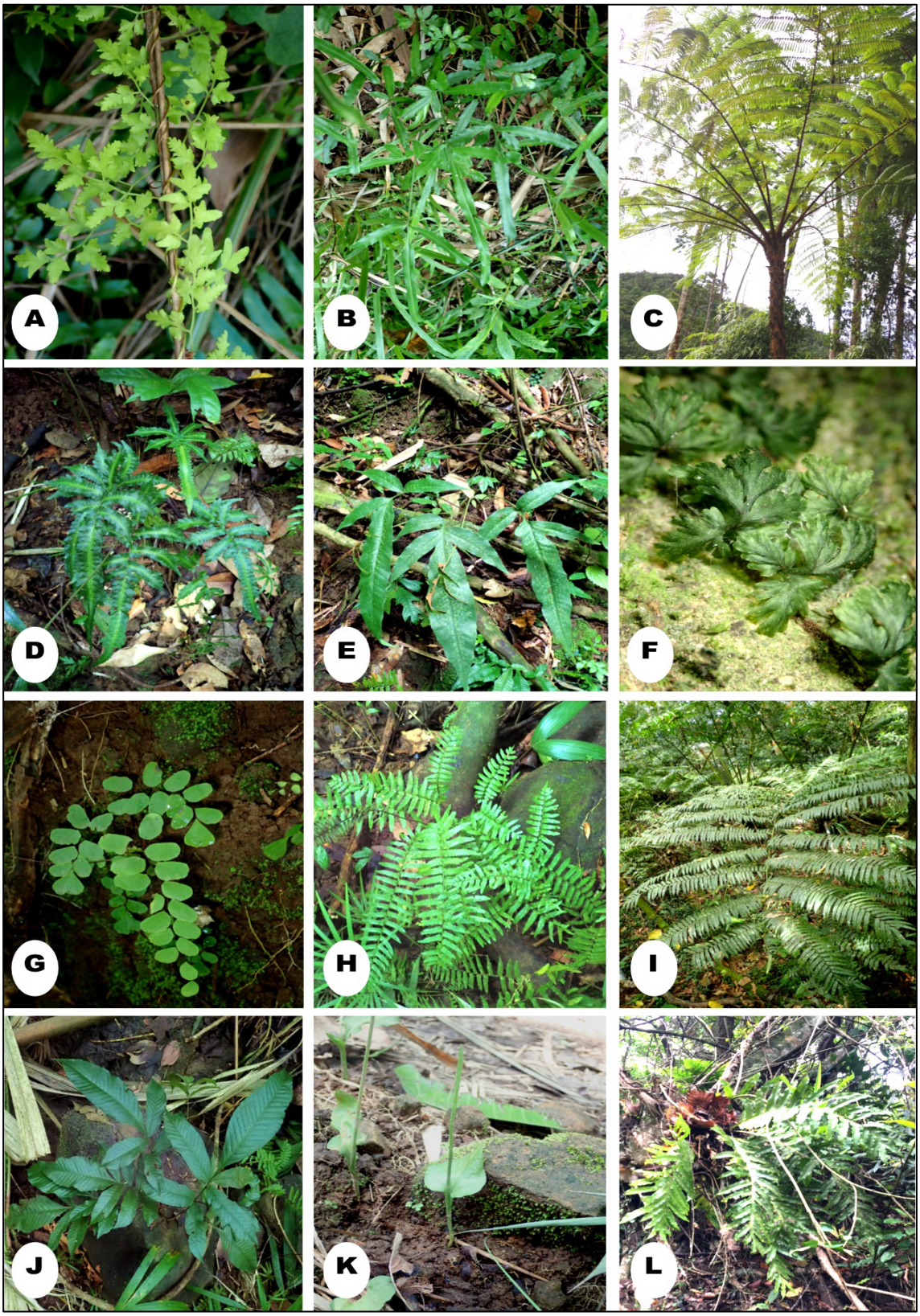

Figure 2: Habit. **A.** *Lygodium japonicum* (Thunb.) Sw.*;* **B.** *Pteris ensiformis* M.G. Price*;* **C.** *Sphaeropteris glauca* (Blume) R.M. Tryon*;* **D.** *Pronephrium xiphoides* (Christ) Holttum*;* **E.** *Tectaria polymorpha* (Wall. ex Hook) Copel.*;* **F.** *Hymenophyllum javanicum* Spreng.*;* **G.** *Adiantum philippense* L.*;* **H.** *Cyclopeltis crenata* (Fee) C.Chr.; **I.** *Angiopteris evecta* (G.Forst) Hoffm.*;* **J.** *Bolbitis heteroclita* (C.Presl) Ching*;* **K.** *Ophioglossum reticulatum* Hook.*;* **L**. *Aglaomorpha quercifolia.*(L.) J.Sm.

Species distribution and similarity across vegetation types

Of all the four vegetation types, Mixed/Biro (491–499 m asl) recorded the highest distributed number of species recorded with 20; this is followed by Teak vegetation (528–535 m asl) with 14, Thailand Shower (471–474 m asl) with 11, and Natural Forest (372–383 m asl) with 10 species of ferns and lycophytes.

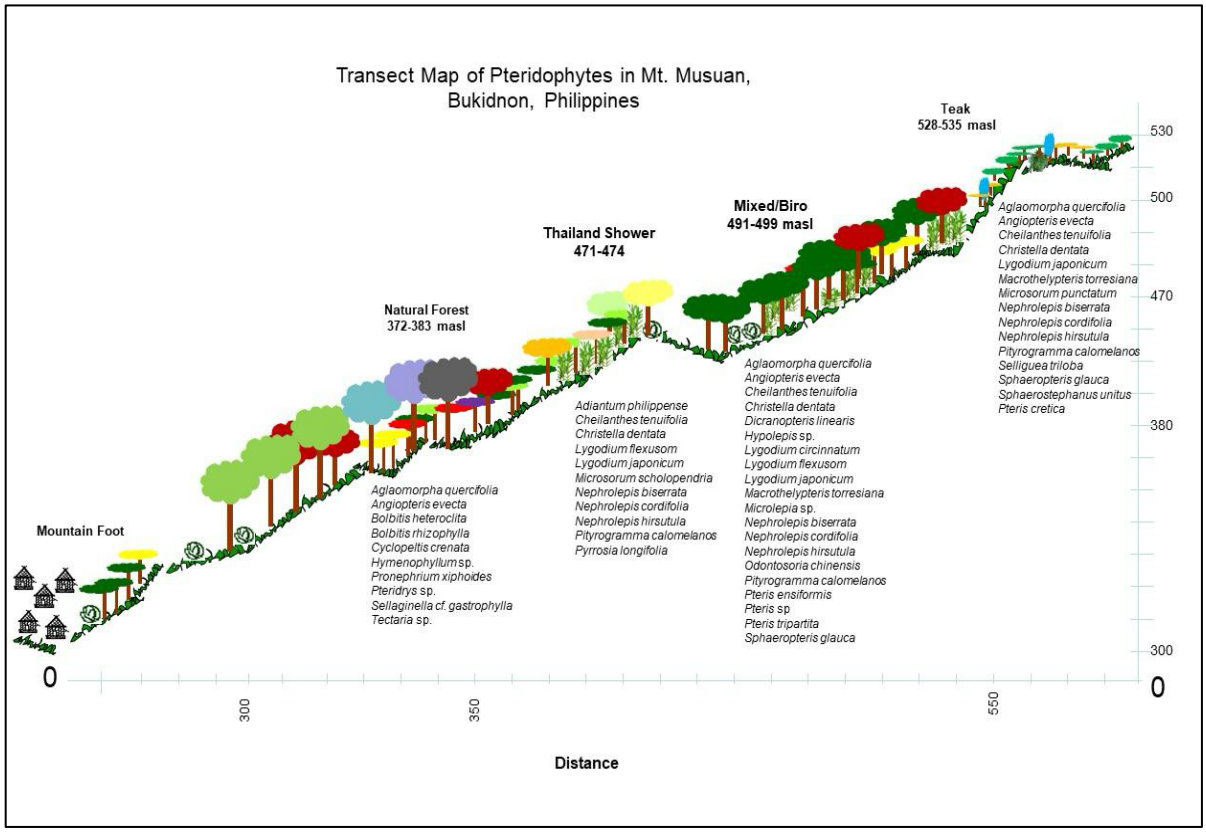

Figure 3: Pteridophyte species occurrence across four vegetation types in Mount Musuan, Bukidnon, Philippines.

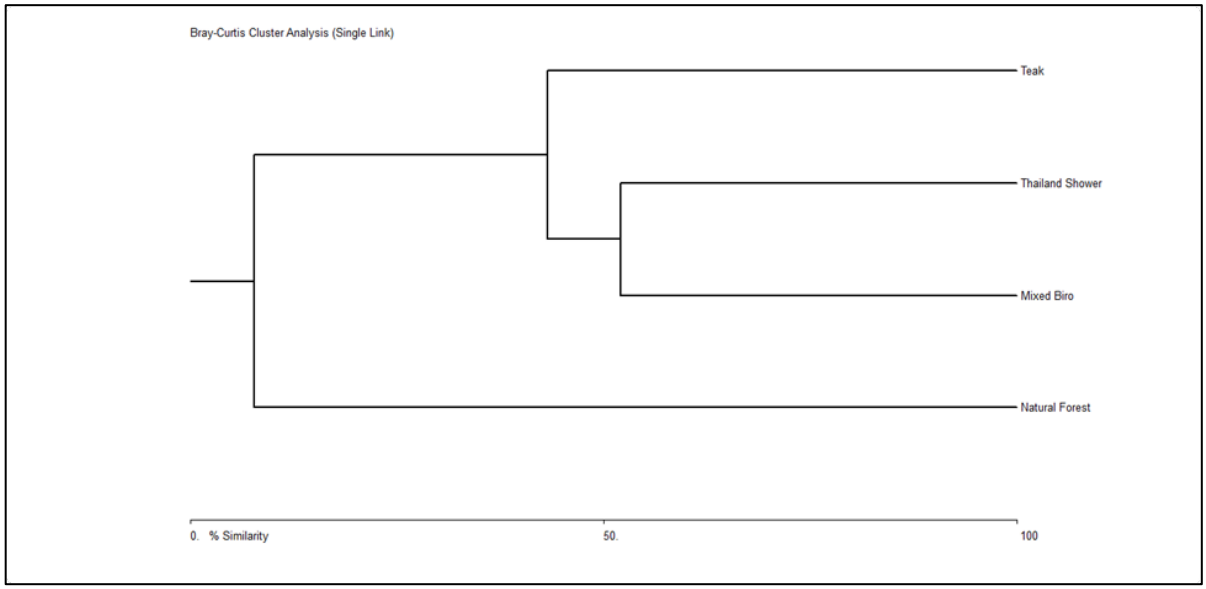

Figure 4: Bray-Curtis species similarity index of pteridophyte species across four vegetation types in Mount Musuan.

Similar species clustered in the vegetations Mixed/Biro, Thailand Shower, and Teak vegetation types (Fig. 4). Some species belonging on these vegetation types include *Adiantum philippense* (Thailand Shower), *Dicranopteris linearis* (Mixed/Biro), *Hypolepis tenuifolia* (Mixed/Biro), *Microlepia* sp. (Mixed/Biro), *Microsorum scolopendria* (Thailand Shower), *Odontosoria chinensis* (Mixed/Biro), *Selliguea triloba* (Teak), and *Pteris cretica* (Teak).

Species importance value

In determining the dominant species in an area, whilst providing an overall estimate of the influence of the species in the community, it is important to compute for the species importance value (SIV). The species listed for the importance value were gathered from the plots established in each sampling sites for each vegetation type (Table 3). Species with high species importance value in Mount Musuan-Natural Forest vegetation includes *Bolbitis rhizophylla* (73.44%), followed by *Bolbitis heteroclita* (66.34%), *Pteridrys microthecia* (42.25%), *Selaginella usterii* (30.03%) and *Aglaomorpha quercifolia* with 29.62% SIV. Mixed/Biro vegetation type recorded high Species importance value of *Nephrolepis biserrata* (51.58%), *Christella dentata* (36.04%), *Nephrolepis cordifolia* (27.90%), *Nephrolepis hirsutula* (20.66%), and *Lygodium circinnatum* (19.05%). The Thailand Shower vegetation type also recorded *Nephrolepis cordifolia* (68.82%), *Nephrolepis biserrata* (52.84%), *Christella dentata* (43.53%), *Nephrolepis hirsutula* (29.87%), and *Microsorum scolopendria* (28.19%). Lastly, Teak vegetation recorded species with high importance value, i.e., *Hypolepis tenuifolia* (63.99%), *Sphaerostephanus hirsutus* (45.60%), *Pityrogramma calomelanos* (30.70%), *Sphaeropteris glauca* (28.55%), and *Nephrolepis biserrata* (22.70%).

Table 4: Species Importance Values (SIV) of pteridophytes at Mount Musuan, Bukidnon, Philippines.

Vegetation Types	Species	SIV	Rank
Natural Forest	*Bolbitis rhizophylla*	73.44	1st
	Bolbitis heteroclita	66.34	2nd
	Pteridrys microthecia	42.26	3rd
	Selaginella wildernovi	30.03	4th
	Aglaomorpha quercifolia	29.62	5th
Mixed/Biro	*Nephrolepis biserrata*	51.8	1st
	Christella dentata	36.41	2nd
	Nephrolepis cordifolia	27.89	3rd
	Nephrolepis hirsutula	20.66	4th
	Lygodium circinnatum	19.05	5th
Thailand Shower	*Nephrolepis cordifolia*	68.82	1st
	Nephrolepis biserrata	52.84	2nd
	Christella dentata	43.54	3rd
	Nephrolepis hirsutula	29.87	4th
	Microsorum scolopendria	28.19	5th
Teak	*Hypolepis tenuifolia*	64.00	1st
	Sphaerostephanos hirtus	54.61	2nd
	Pityrogramma calomelanos	30.7	3rd
	Sphaeropteris glauca	28.56	4th
	Nephrolepis biserrata	22.70	5th

Trend of pteridophyte richness from 2013, 2015 and 2023

The diagram highlights the pteridophyte species richness between the monitoring of Amoroso et al. in 2013 (LTER 1), 2015b (LTER 2), and 2023 (LTER 3), respectively (Figure 5). Results show that the same nine (9) pteridophyte species are recorded for LTER 1, 2, and 3, namely, *Angiopteris evecta, Bolbitis heteroclita, Bolbitis rhizophylla, Lygodium circinnatum,*

Nephrolepis hirsutula, Pteris ensiformis, Pteris tripartita, Pyrrossia longifolia and *Selaginella usterii.* Additionally, from 2015 (LTER 2) to 2023 (LTER 3), more pteridophytes (9) are recorded, namely, *Aglaomorpha quercifolia, Cyclopeltis crenata, Hymenophyllum* sp.*, Hypolepis tenuifolia, Microlepia* sp.*, Nephrolepis cordifolia, Pronephrium xiphoides,* and *Pteris cretica.* Notably, two identified species are recorded exclusively in 2015, namely, *Asplenium nidus* and *Huperzia serrata,* and recent assessment (LTER 3) shows no record for these species in Mount Musuan. Furthermore, an additional of 19 species are recorded for LTER 3, namely, *Adiantum philipppense, Hypolepis tenuifolia, Dicranopteris linearis, Lygodium flexusom, Lygodium japonicum, Macrothelypteris torresiana, Microsorum scolopendria, Microsorum punctatum, Odontosoria chinensis*, *Ophiglossum reticulatum, Palhinhaea cernua, Pityrogramma calomelanos, Pteridrys microthecia, Pteris cretica, Selaginella* cf. *gastrophhylla, Selliguea triloba, Sphaeropteris glauca Sphaerostephanus hirsutus,* and *Tectaria polymorpha*. As observed in this study, the increase of species composition from 2013 to 2023 can be explained by the increase in sampling area and the identification of the different vegetation types covering Mount Musuan.

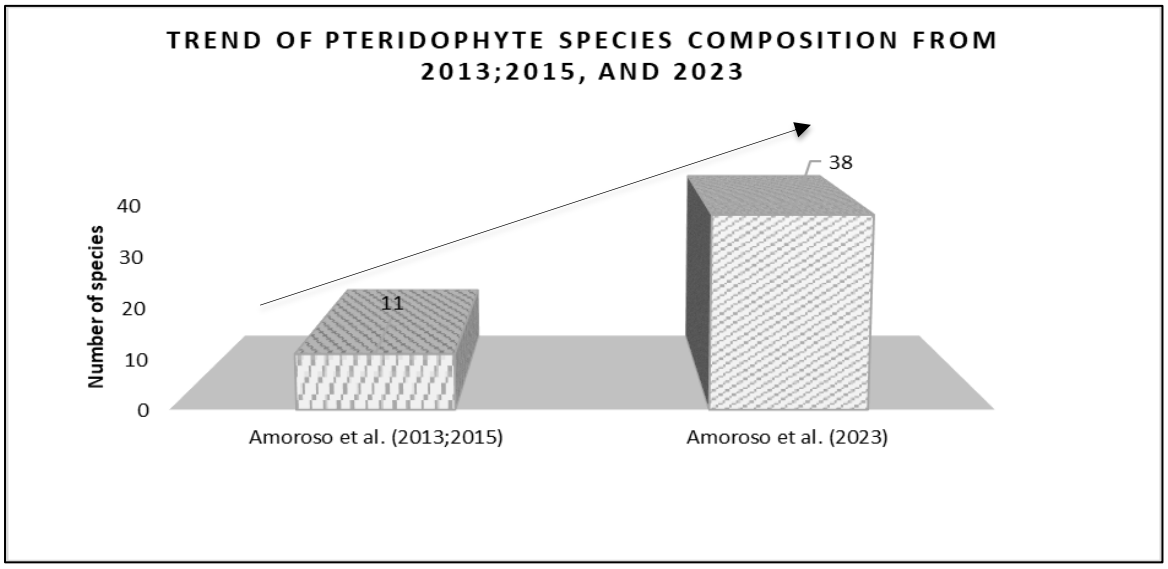

Figure 5: Graph showing increasing trend of species richness from 2013, 2015 and 2023.

Conservation status based on DENR-DAO (2017) and IUCN (2023)

To monitor the conservation status of pteridophyte flora across the three LTER projects, a table was generated based on DENR-DAO (2017) and IUCN (2023) (Table 4). *Asplenium nidus* is categorised as a vulnerable species and was documented in LTER 2 but is no records for LTER 1 and 3. *Angiopteris evecta*, categorised as other threatened species, was recorded for all LTER programs. Notably, the endangered fern species, *Sphaeropteris glauca*, is a new record for Mount Musuan in LTER 3 (2023), implying no records for LTER 1 and 2 for this endangered species.

Table 4: Conservation status of pteridophyte species in Mount Musuan based on DENR-DAO (2017) and IUCN list (2023).

LTER PROJECTS	CONSERVATION STATUS		
	VULNERABLE	OTHER THREATENED SPECIES	Endangered
LTER 1 (2013)	-	*Angiopteris evecta* (Forst.) Hoffm.	-
LTER 2 (2015)	*Asplenium nidus* L.	*Angiopteris evecta* (Forst.) Hoffm.	-
LTER 3 (2023)	-	*Angiopteris evecta* (Forst.) Hoffm	*Sphaeropteris glauca* (Blume) R.M.Tryon

DISCUSSION

The diversity of pteridophytes in Mount Musuan has already been in a decade-long monitoring from 2013 to 2023 by Amoroso et al. (2013; 2015b). Recent results show that Mount Musuan has a low index of pteridophyte diversity as Fernando et al. (2008) defined sampling sites with <1.99 index of diversity is classified as low species diversity. However, occurrence of the unique fern *Ophioglossum reticulatum* L. in Mount Musuan, only observed during the wet season, and newly recorded endangered species *Sphaeropteris glauca,* indicate the importance of Mount Musuan as a suitable environment for these significant ferns to thrive.

Mount Musuan has four types of vegetation (Paquit et al., 2023), among these, Mixed/Biro has the highest diversity index with the most unique soil type observed by the presence of rocks, which provide an appropriate substrate for epiphytic ferns to attach (Delos Angeles et al., 2020). Meanwhile, the Natural Forest vegetation type was recorded to have the lowest diversity index due to the presence of the invasive understory plant *Donax canniformis* (G.Forst) K. Schum. which dominates the natural forest, disabling proper sunlight absorption for pteridophyte species. This species cohabitation where competition occurs is one of the factors, along with microclimate, area sampled, and elevation gradient that influence pteridophyte diversity (Kessler, 2010).

Human activities in Mount Musuan can also affect species composition, where activities that can be observed include, but are not limited to, tourism, deforestation, and conversion of forests for various specific purposes.

Implications of distribution

The highest number (20) of pteridophytes in Mixed/Biro vegetation type can be explained by the presence of tall trees enclosed in large canopies, this canopy layer composition hosts a wide variety of understory plants, which represents the largest component of biodiversity in most forest ecosystems and plays a key role in forest functioning (Mestre et al., 2017). The Mixed/Biro vegetation is also considered to be the least disturbed of all the plots, located near a steep cliff with the presence of rocks—where lithophytic pteridophytes thrive. Ecological study shows that epiphytic and lithophytic ferns survive in different ecology types and pteridophytes in general, can tolerate dry soil environments and direct sunlight (Suksathan, 1998; Perida et al., 2023). Furthermore, species distribution of the aforementioned species is consistent with their ecology in that they occupy a variety of habitats—these pteridophytes thrive in moist environment that can still be penetrated by sunlight, intolerant of shade, opportunists of open, disturbed areas (Hennipman et al., 1990; Khwaiphan & Boonkerd, 2008; Brownsey and Perrie, 2018; Russell et al. 1998; McGlone et al., 2005).

The Natural Forest vegetation type, on the other hand, has the lowest number of distributed species with 10. Although this vegetation type is ideal for some pteridophytes, the low number

of species distribution can be explained by the dominating presence of the understory plant—specifically *Donax canniformis* (G. Forst.) K. Schum., a native understory plant that is common in low and medium elevation secondary forests, especially along streams (Pelser et al., 2011). Notably, hygrophilous ferns in this study such as *Hymenophyllum javanicum* Spreng., *Bolbitis rhizophylla* (Kaulf.) Hennipman*, Bolbitis heteroclita* (C. Presl) Ching*, Pronephrium xiphoides* (Christ) Holtt*, Cyclopeltis crenata* Fée*,* and *Tectaria polymorpha,* (Wall ex. Hook) Copel are found in the Natural Forest vegetation type where the presence of a small stream and large canopy cover are observed. This suitable habitat is where most moist-loving pteridophytes thrive and greatly affect the species richness of pteridophytes in Mount Musuan (Amoroso et al., 2015a; 2016).

Aglaomorpha quercifolia is the most widely distributed species across the four vegetation types. Ecological information of this species shows that *A. quercifolia* thrives on dry rocks on hillsides in light shade or at the edge of forests, and are fairly common at low altitudes (Chayamarit and Balslev, 2019)—which is consistent with most of the vegetation type characteristics in this study.

CONCLUSION

This study revealed that Mount Musuan has a low index of pteridophyte diversity (38 species, 28 genera, 18 families). Diversity in different vegetation types showed that Mixed/Biro vegetation recorded the highest index of diversity with H'=1.18, Teak vegetation with H'=1.006, Thailand Shower with H'=0.886, and Natural Forest with H'=0.85. *Bolbitis rhizophylla, Bolbitis heteroclita, Pteridrys microthecia, Selaginella usterii,* and *Aglaomorpha quercifolia* are recorded to have the highest species importance value, thus, identified as the dominant species in the different vegetation types. *Sphaeropteris glauca,* a new record in Mount Musuan, is categorised as Endangered species, meanwhile, *Angiopteris evecta* as Other Threatened Species; *Aglaomorpha quercifolia* is also classified as an Economically Important Species. The findings of this study provide necessary information for the potential drafting of scientific-based policies for the protection and conservation of pteridophyte species in Mount Musuan.

ACKNOWLEDGMENTS

This study received funding from the Commission on Higher Education (CHED) as part of the research project titled "Biodiversity Conservation and Utilization for Product and Development (BioConUP) in Long-Term Ecological Research (LTER) Sites in Southern Philippines" with Gratuitous Permit no. R10 2023-140. We express our gratitude to Central Mindanao University (CMU) and the Center for Biodiversity Research and Extension in Mindanao (CEBREM) for providing logistical support and other resources.

REFERENCES

Acma FM, Quimpang VT, Amoroso VB, Mendez NP (2018) Litterfall production and turnover in the long-term ecological research sites in southern Philippines. CMU Journal of Science, 22(2): 23–25.

Addo-Fordjour P, Yeboah-Gyan K, Lawson B, Akanwariwiak W (2007) Diversity and distribution of ferns on the campus of the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. Journal of Science and Technology (Ghana), 27(1): 35–44. https://doi.org/10.4314/just.v27i1.33022.

Amoroso VB (2007) Pteridophyte and gymnosperm diversity in Musuan, Bukidnon. Philippine Journal of Systematic Biology, 1(1): 1–11.

Amoroso VB, Laraga SH, Calzada BV (2011) Diversity and assessment of plants in Mount Kitanglad Range Natural Park, Bukidnon, Southern Philippines. Gardens' Bulletin Singapore, 63 (1 & 2): 219–236.

Amoroso VB, Amoroso CB, Coritico, FP (2012) Diversity and status of plants in three mountain ecosystems in southern Mindanao, Philippines. Asian Journal of Biodiversity, 3: 50–73. https://doi.org/10.7828/ajob.v3i1.83.

Amoroso VB, Acma FM, Mohagan AB, Opiso EM, Quimpang VT, Ballentes MG, Opiso, JG (2013) Biodiversity Inventory, Assessment, Monitoring and Conservation in Mindanao Long Term Ecological Research (LTER) Sites. Central Mindanao University, Unpublished report submitted to Commission on Higher Education (CHED), Terminal Report. 281 pp.

Amoroso VB, Acma FM, Dela Cruz RY, Coritico FP, Nietes AD, Hamo GB, Lumista HP (2015a) Diversity of herbaceous pteridophytes in four Long Term Ecological Research sites in Mindanao, Philippines. Asia Life Sciences, 24 (1) 69–85.

Amoroso VB, Acma FM, Mohagan AB, Bojo PB, Ledres LB, Laureto AS, Opiso EM, Marin RA, Lumista HP, Dela Cruz RY, Quimpang VT, Nuneza OM, Ballentes MG, Daquiado NP, Arnado JM, Simborio LT, Villar RG, Leano EP, Galan GL, Magbunua FS (2015b) Biodiversity, Re-assessment, Monitoring and Conservation in Mindanao Long Term Ecological Research (LTER) sites. Central Mindanao University, Unpublished report submitted to Commission on Higher Education (CHED), Terminal Report. 221 pp.

Amoroso VB, Coritico F, Fritsch PW (2016) Species richness and conservation status of ferns and lycophytes in Mount Hamiguitan Range Wildlife Sanctuary, Davao Oriental, Philippines. Philippine Journal Science, 145(2): 127–137.

Aribal LG, Buot IE Jr (2009) The threatened plants species in various regions in Mindanao Island, Philippines. Journal of Natural Studies, 8(2): 23–33.

Barbour MT, Gerritsen J, Snyder BD, Stribling JB (1999) Rapid Bioassessment Protocols for use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, And Fish, Second Edition. EPA 841-B-99-002. U. S. Environmental Protection Agency, Office of Water; Washington, D. C. 337 pp.

Brower SE, Zarr JH, Ende, CN (1997) Field and Laboratory Methods for General Ecology. 4th ed. Boston: McGraw Hill. 28 pp.

Brownsey PJ, Perrie LR (2018) Flora of New Zealand: Ferns and Lycophytes. Fascicle 19, Dennstaedtiaceae. Lincoln, N.Z.: Manaaki Whenua Press, 34 pp. http://dx.doi.org/10.7931/B11G9K.

Catibog-Sinha C, Heaney L (2006) Philippine biodiversity: principles and practice. Quezon City: Haribon Foundation for the Conservation of Natural Resources Inc. 495 pp.

Chayamarit K, Balslev H (2019) Flora of Thailand. The Forest Herbarium, National Park, Wildlife and Plant Conservation Department, Bangkok, vol 14. 175pp.

Comvol (1981) Catalogue of Philippine volcanoes and solfataric areas. Philippine Commission on Volcanology, Pp. 87.

Coritico FP, Amoroso VB (2017) A rapid assessment of vascular plants in Mount Kiamo, Mindanao, Philippines. Asian Journal of Biodiversity, 8(1): 62–78. https://doi.org/10.7828/ajob.v8i1.998.

Coritico FP, Amoroso, VB (2020) Threatened lycophytes and ferns in four protected areas of Mindanao, Philippines. Nature Conservation Research, 5(4):78–88. https://doi.org/10.24189/ncr.2020.061.

Copeland EB (1961) Fern flora of the Philippines. Manila: Bureau of Printing, (6): v.1; (6) v. 2–3.

Dadang RJ, Casinillo NGB, Coritico FP, Simborio LT, Amoroso VB (2020) Living with endangered species: collection of tree ferns in the forest-reserve of Marilog district, southern Philippines. Trees, Forests and People, vol 2, 100041. https://doi.org/10.1016/j.tfp.2020.100041.

Del Moral R, Grishin, SY (1999) Volcanic disturbances and ecosystem recovery. Ecosystems of Disturbed Ground, 5: 137–160.

Delos Angeles MD, Alcala AA, Buot IE Jr (2020) Ecological diversity of pteridophytes across land use types in Mount Makiling Forest Reserve, Luzon Island, Philippines. Journal of Marine and Island Cultures, 9(2): 105–123. https://doi.org/10.21463/jmic.2020.09.2.08.

DENR Administrative Order No. 2007-01. "Establishing the national list of threatened Philippine plants and their categories, and the list of other wildlife species" (Approved January 22, 2007).

Fernando ES, Co LL, Lagunzad DA, Gruezo WS, Barcelona JF, Madulid DA, Lapis AB, Texon GI, Manila AC, Zamora PM (2008) Dynamic tree aggregation patterns in a species-poor-temperate woodland distributed by fire. Philippine Threatened Plants. 1–47pp.

Hennipman E, Veldhoen P, Kramer KU (1990) Polypodiaceae. In: Kramer KU., Green PS. (eds) Pteridophytes and Gymnosperms. The Families and Genera of Vascular Plants, vol 1. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-02604-5_41. 397pp.

Hodge WH (1947) The use of alcohol in plant collecting. Rhodora, 49: 207–210.

IUCN (2023) The IUCN Red List of Threatened Species. Version 2023. Accessed from: http://www.iucnredlist.org.

Kessler M (2010) Biogeography of ferns. In Mehltreter K, Walker L, Sharpe J editors. Fern Ecology. Cambridge: Cambridge University Press. Pp22–60.

Khapugin AA, Kuzmin IV, Silaeva TB (2020) Anthropogenic drivers leading to regional extinction of threatened plants: insights from regional Red Data Books of Russia. Biodiveristy and Conservation, 29(8): 2765–2777. https://doi.org/10.1007/s10531-020-02000-x.

Khwaiphan W, Boonkerd T (2008) The pteridophyte flora of Khao Khiao, Khao Yai National Park, Thailand. Tropical Natural History 8(2): 69–82.

Krebs JR (1994) Introduction to Plant Biology. Dubuque, Iowa: C. Brown Company Publishers.493 pp.

McAleece N, Gage JDG, Lambshead PJD, Paterson, GLJ (1997) BioDiversity Professional statistics analysis software.

McGlone MS, Wilmshurst JM, Leach HM (2005) An ecological and historical review of bracken (*Pteridium esculentum*) in New Zealand, and its cultural significance. New Zealand Journal of Ecology, 29: 165–184.

Mestre L, Toro-Manriquez M, Soler R, Huertas-Herrera A, Martinez-Pastur G, Lencinas MV (2017) The influence of canopy-layer composition on understory plant diversity in

southern temperate forests. Forest Ecosystems. https://doi.org/10.1186/S40663-017-0093-z. 13 pp.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GA, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature, 403: 853–858. https://doi.org/10.1038/35002501.

Oseguera-Olalde TK, Bonilla-Valencia L, Fonseca RM, Martínez-Orea Y, Lorea-Hernández F, Castillo-Argüero S (2022) Fern diversity in altitude and anthropogenic gradients in a temperate forest in Mexico City, Mexico. Trees, Forests and People, vol 10: 100345, ISSN 2666-7193. https://doi.org/10.1016/j.tfp.2022.100345.

Paquit JC, Amoroso VB, Polinar, KD (2023) Carbon storage of vegetation in the different land uses of Mount Musuan in Bukidnon, Philippines. Philippine Journal of Science 152(3): 1085–1093. https://doi.org/10.56899/152.03.27.

Pelser PB, Barcelona JF, Nickrent DL (2011 onwards) Co's Digital Flora of the Philippines. www.philippineplants.org. (Accessed date: October 18, 2023)

Perida HA, Peñaverde HA, De Villa KR, Barrera, WB Jr (2023) Fern species diversity along selected roadside vegetation of Macalelon and Infanta, Quezon, Province, Philippines. Philippine Journal of Science. 152 (2): 621–633. https://doi.org/10.56899/152.02.08.

Russell AE, Raich JW, Vitousek PM (1998) The ecology of the climbing fern Dicranopteris linearis on windwards Mauna Loa, Hawaii. Journal of Ecology, 86: 765–779.

Sanin MJ, Cardona A, Cespedes-Arias LN, Gonzalez-Arango C, Pardo N, Cadena, CD (2024) Volcanoes, evolving landscapes, and biodiversity in Neotropical mountains. Frontiers of Biogeography, vol 16.1, e61882. https://doi.org/10.21425/F5FBG61882.

Singh V, Babita (2024) A green approach: living nanofactories. In: Garg VK, Yadav A, Mohan C, Yadav S, Kumari N (eds). Green Chemistry Approaches to Environmental sustainability. Status, Challenges and Prospective. Elsevier. Pp. 239–259. https://doi.org/10.1016/B978-0-443-18959-3.00016-1.

Suksathan P (1998) Taxonomy and ecology of epiphytic and lithophytic pteridophytes at Doi Chiang Dao, Chiang Mai. AGRIS. (https://agris.fao.org/search/en/providers/122623/records/647237ed53aa8c8963029c3a)

Weins JJ, Ackerly DD, Allen AP, Anacker BL, Buckley LB, Cornell EID, Davies TJ, Grytnes JA, Harrison SP, Holt RD, Mccain CM, Stephens, PR (2010) Niche conservatism as an emerging principle in ecology and conservation biology. Ecology Letters, 13: 1310–1324. https://doi.org/10.1111/j.1461-0248.2010.01515.x.

World Bank Climate Change Knowledge Portal (1991–2020) Climatology Climate Change Knowledge Portal. (https://climateknowledgeportal.worldbank.org/country/philippines/climate-data-historical).