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Inventory and Habitat Preference of Pteridophytes in and around gold-mined areas in Gango, Libona, Bukidnon, Philippines

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ABSTRACT

Gold mining brings several benefits to developing countries like the Philippines. Although the industry results in economic gains and provides employment, it often destroys the environment through deforestation, vegetation removal, and biodiversity loss. This study considered the distribution, abundance, status, and uses of pteridophytes in and around the gold-mined areas of a village in Gango, Libona Bukidnon, Philippines. Collection and identification of pteridophytes were done in the fixed sampling points outside and inside the mining area. Results of the study revealed that the diversity of pteridophytes inside the mining area is higher than outside the mining area. Seventy-five percent of the pteridophytes in the area have economic importance; *Aglaomorpha heraclea* (Kze.) Copel, a vulnerable species, was recorded inside the mining environs. High pteridophyte diversity of 1.965 Shannon's index within the mining area implied that the underground-small-scale gold mining had little impact on pterydophytes in the study area.

Keywords: *Pteridophytes, Small-scale gold mining, Biodiversity, Ferns, artisanal gold mining*

1 Introduction

The Philippines is the 5th most mineral-rich country globally, with the third-largest reserves in terms of gold, the fourth largest for copper, and the fifth largest in nickel (Marasigan 2015). Mining and mineral processing can be significant sources of income and a driving force behind broader economic development (Eggert 2001).

However, the Philippines is considered both a biodiversity hotspot and a megadiverse country, placing it as one of the top priority countries for global conservation (Mukul et al. 2015). The country's floral diversity is estimated to be 10,000 to 14,000 species of plants, of which more than half are endemic. Altogether, the country is host to some 5 % of the world's species of flora and is ranked fifth worldwide in plant diversity (EMB 2009) State of Philippine Biodiversity (BMD-PAWB 2016). Pelser (2021) listed 1040 species of pterydophytes, almost 26% of which are endemic to the country. The pteridophytes are long known for their medicinal and therapeutic utility. These plants were prescribed herbal extracts to cure several diseases (Singh et al. 2010). Besides having various medicinal properties, they are also much valued as ornamentals and used for multiple commercial and environmental purposes. The majority of these plants are moisture and shade-loving and dependent upon the microclimatic conditions of the region for their successful survival. Factors like climate change, increasing urbanization, industrialization, encroachment of forest lands, unplanned developmental activities, over-exploitation of natural resources pose a significant threat to these groups of plants (Dixit 2000). Few fern species benefit from these disturbances, and most become less abundant or locally extinct (Mehltreter 2010).

Mining operations are inherently disruptive to the environment (Makweba and Ndonde 1996).

The country faces a significant challenge in utilizing the rich available mineral resources for economic growth and development without compromising its ecological integrity and species diversity. Gango is in the Municipality of Libona, Province of Bukidnon, with a total land area of 3,762.5534 hectares having elevations ranging from 201 to 397 masl. It is located in the northwestern part of the municipality of Libona, which is bounded on the north by Misamis Oriental province; on the south by Brgy. Kinawe; while the eastern side is bordered by Cugman River and the western side by Bobonawan River.

The gold mining activities in Gango started during the 1960s but became more active during the 1980s. In the 1980s, the government encouraged small-scale miners to apply for mining permits through the Small Scale Law of 1974 (PD 1899). However, mining operations continue nowadays despite the absence of a mining permit.

Strict implementation of the law to protect the environment may lead closure of mining sites and consequently the displacement of mine workers. Further, efforts to rehabilitate the mined areas will fail if enough knowledge of indigenous plants and their preferred environment is absent. In this study, the species richness, abundance, diversity, endemism, economic importance, conservation status, and survival envelope in and around the small-scale gold mining area of Brgy. Gango, Libona, Bukidnon, Philippines were assessed to determine artisanal underground gold mining impacts on pteridophyte diversity. The information generated can be used as the basis for a possible pteridophyte conservation strategy while pursuing economic development.

2 Materials and Methods

A. Description of the study site:

Barangay Gango (Figure 1) is in the Municipality of Libona, Province of Bukidnon, with 3,762.5534 ha. having elevations ranging from 201 to 397 masl. The human population as of 2012 is 5,190. The gold extraction methods employed are tunneling (Figure 2) and ball milling.

Early secondary growth forest patches are observed inside the mining area and the riparian habitat where *Narra Pterocarpus indicus, Molave Vitex parviflora*, and a few bamboo species are naturally growing. The surrounding area of the mine site is predominantly cultivated with mango and corn plantation.

B. Establishment of quadrats

Four 2-km. transect lines were established (2 transects within the mine area and two transects outside the mine area with at least 5 km distance). Each line was divided into nine sampling points placed every 250 m ensuring that the 2 km transects were parallel and 2 km apart. Five 1m x1m quadrats were established as the sampling area for every sampling point.

The collected pteridophytes were identified on-site by an expert and verified using taxonomic keys from the books and monographs of Zamora and Co (1986), Pelser et al. 2011, Amoroso et al. (1995). The conservation status of the floral species was assessed using the IUCN Red List and the Updated National List of Threatened Philippine Plants and their Categories as per DENR A.O. No. 2017-11. Economic importance was determined using the Guide to Philippine Flora and Fauna Vol .2 by Zamora, P, and L.Co (1986). Photographs were taken, and herbarium specimens were prepared for further verification by the experts.

Diversity indices including dominance, evenness, Simpson's index, and Shannon's index were performed using PAST Software v2.1 by Hammer et al. (2011).

Figure 1. Map of Gango, Libona, Bukidnon, Philippines, showing the established transects within and outside the mining area.

Figure 2. Entrance of the mine tunnel showing that tunneling is one method for gold extraction.

C. Measurement of Habitat Variables:

Habitat measurements were taken at every sampling point using the modified habitat assessment procedure of Heaney (1986). Habitat variables were measured, including the number of trees with diameter at breast height (dbh) 40-80 cm and 10-20 cm, elevation, slope, distance to the creek, and distance to mining activity. The trees selected were measured (tree height in meters, diameter at breast height, the height of the first branch) using 50-m diameter tape for tree size and clinometers for tree heights. The leaf litter thickness within a 5-m radius of each point was measured using a ruler. All the habitat variables except the tree counts were measured in each of the four quadrants per sampling point. The data from all quadrants per point were pooled, and mean values for each habitat variable were used for analysis. The elevation of each sampling point was determined using an altimeter. The geographic coordinates of each sampling point were recorded using an etrex Vista HCx Garmin G.P.S. The degree of slope at the sampling points was determined using a clinometer.

D. Analysis of Data:

Diversity indices and Canonical Correspondence Analysis (CCA) were performed using the PAST software version 2.14. The CCA scores obtained from the analysis were then used to construct a boxplot that contains information about the habitat preference and survival envelope or range of tolerance of each pteridophyte species.

3 Results and Discussion

The survey has identified eight pterydophyte families with 16 species (Table 1; Figure 3), where 75% were economically significant (Fig. 4). The species may be used as food, handicraft, medicinal and ornamental plants. From the species identified, *Sphaerostephanus unitus* occurs as an invasive weed. According to Pelser et al. (2011), this weed species generally grows on degraded habitats and can be used to indicate the area's ecological health. *Aglaomorpha heraclea* is the only species rated vulnerable based on the DAO-2017-11. Another

Table 1. Species profile of pteridophytes found inside and outside the mining area in Gango, Libona, Bukidnon, Philippines

FAMILY NAME	SCIENTIFIC NAME	DISTRIBUTION/ ECOLOGICAL STATUS/ ECONOMIC CATEGORY
1. ATHYRIACEAE	*Diplazium esculentum* (Retz.) Sw.	Widespread/Least Concerned/food
2. DRYOPTERIDACEAE	*Pleocnemia macrodonta* (Presl ex Fée) Holtt.	Widespread/Not assessed/food
3. LYGODIACEAE	*Lygodium circinnatum* (Burm. f.) Sw.	Asia-endemic/Not assessed/food; medicinal; handicraft
	Lygodium flexuosum (L.) Sw.	Widespread/Not assessed/food; medicinal;handicraft
	Lygodium japonicum (Thunb.) Sw.	Widespread/Not assessed/Food/handicraft
4. NEPHROLEPIDACEAE	*Nephrolepis biserrata* (Sw.) Schott	Widespread/Not assessed
	Nephrolepis cordifolia (L.) C. Presl	Widespread/Not assessed/Ornamental
	Nephrolepis hirsutula (G Forst.) C.Presl.	Widespread/Not assessed
5. POLYPODIACEAE	*Aglaomorpha heraclea* (Kze.) Copel	Widespread/Vulnerable; Ornamental; Food; handicraft
	Drynaria quercifolia (L.)J.Sm.	Widespread/Not assessed/ Medicinal;ornamental
	Microsorum punctatum (L.) Copel	Widespread/Not assessed
	Pyrrosia piloselloides (L.) M. Price	Widespread/Not assessed/medicinal
6. PTERIDACEAE	*Adiantum caudatum* L.	Widespread/Not assessed/medicinal
	Adiantum philippense L.	Widespread/Not assessed/medicinal
7. SELAGINELLACEAE	*Selaginella cupressina* (Willd.) Spring	The Philippines and Sulawesi/Not assessed
8. THELYPTERIDACEAE	*Sphaerostephanus unitus* (L.) Holttum	Widespread/Not assessed/weed

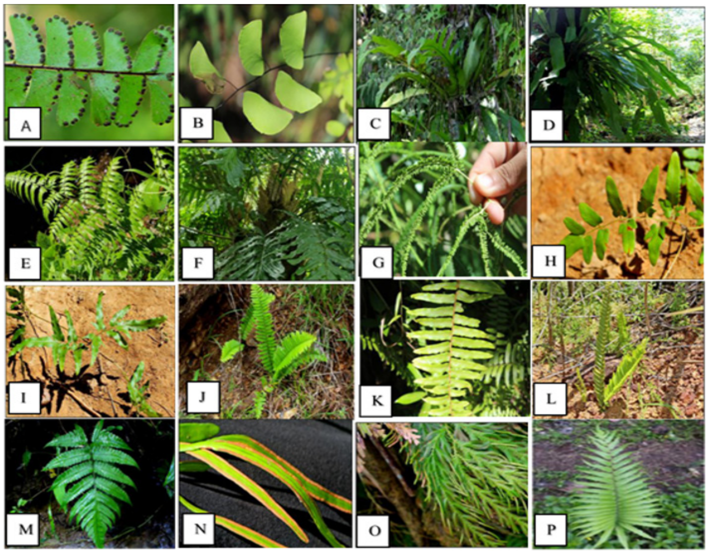

Figure 3. Ferns in Gango, Libona Bukidnon. A) *A. caudatum*, B) *A. Philippense,* C) *A. heraclea,* D) *M. punctatum*, E) *D. esculentum,* F) *D. quercifolia*, G) *L. circinnatum*, H) *L. flexousum,* I) *L. japonicum*, J) *N. hirsutula*, K) *N. biserrata*, L) *N. cordifollia*, M) *P. macrodonta*, N) *P. piloselloides*, O) *S. cupressina*, P) *S. unitus*

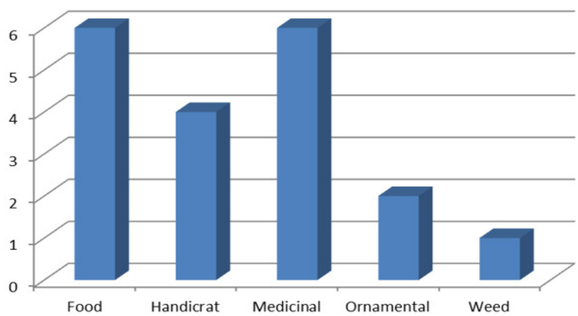

Figure 4. Number and categories of economic ferns in Gango, Libona Bukidnon.

Table 2. Diversity indices of pteridophytes in the area.

Parameters	Within Mining	Outside Mining
No. Species	13	12
Individuals	419	363
Dominance_D	0.1643	0.2252
Simpson_1-D	0.8357	0.7748
Shannon_H'	1.965	1.866
Evenness_e^H/S	0.5943	0.5385

species, *D. esculentum* appeared in the list of IUCN as a species of "least concern" while the rest of the pteridophytes were not assessed. It can be noted that all of the plants mentioned are observed to be distributed widely in the area. Being classified as "least concern" is favorable to the utilization of the plants as the community could harvest them for food purposes.

The diversity indices comparison in Table 2 show more species inside the mining area than outside the mining area. Further, there are more individuals inside than outside the mining area.

Computations of Shannon's index and Simpson's Diversity index revealed higher diversity values inside the mining area. The lower diversity values outside the mining area are attributed to its vast grassland, where fewer pteridophytes are present. Higher diversity is expected inside the mining area since people in the mining village live within the mining sites and have planted fruit trees which created a microhabitat favorable for the survival of the pteridophytes.

The underground mining method makes minor disturbances to the surface, leaving most vegetation untouched. This result is the opposite of the situation in the study of Ascaño et al. (2016), which inventoried pteridophytes in a hydraulicking mining area where most of the vegetation is eroded, decreasing the diversity indices in the mining area.

Figure 5 shows four species present inside the mining area but is absent outside. This result is consistent with the Canonical correspondent analysis in Figure 6, which shows *A. philippense, A. heraclea, A. caudatum,* and *M.punctatum* to survive in the areas associated with environmental variables such as distance from mining, canopy cover, bryophyte cover, leaf-litter, and 40-80 cm trees. This result conforms with Pelser et al. (2011), which mentioned *Adiantum* species to be present in fairly exposed areas at minor altitudes. The survival envelope of the pteridophytes is further characterized in Figure 7, which shows that these

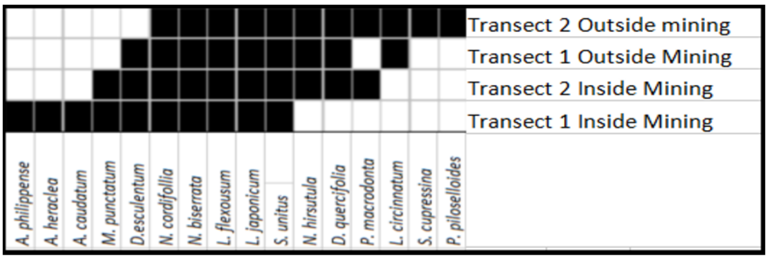

Figure 5. Presence and absence of pteridophytes in the areas as depicted by seriation method.

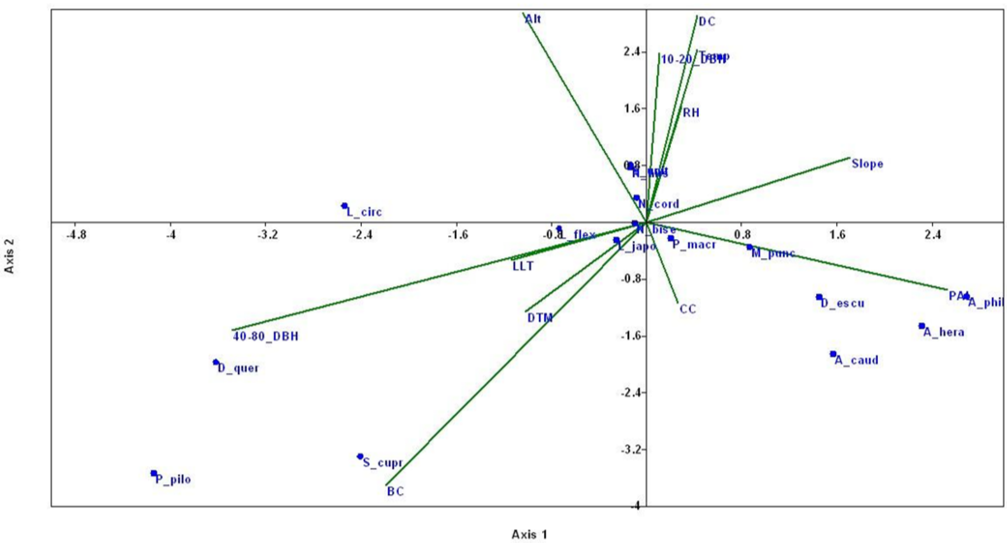

Figure 6. Canonical Correspondence Analysis (CCA) Biplot showing the Species-Habitat relationship of pteridophyte species found outside and inside the small scale gold mining area Gango, Libona, Bukidnon, Philippines. Legend: Alt-Altitude; DBH-Diameter at Breast Height; D.C.- to Creek; L.L.T.- leaf litter; DTM-distance to mining; PAL-palm; BC-bryophyte; Cover; Temp-Temperature; Distance CC-Canopy Cover; A_cauda-*A. caudatum*; A._phil- *A. Philippensi* ; A_hera-*A. heraclea*; M_punc-*M. punctatum*; D_escu-*D. esculentum*, D_quer-*D.quercifolia*; L_circ-*L. circinnatum*; L_flex-*L. flexousum*; L_japo - *L. japonicum*; N_hirs-*N. hirsutula*; N_bise-*N.biserrata*; N_cord-*N.cordifollia*; P_macro-*P.macrodonta*;P_pilo-*P.piloselloides*; S_cupr-*S. cupressina;* S_unit-*S. unitus*.

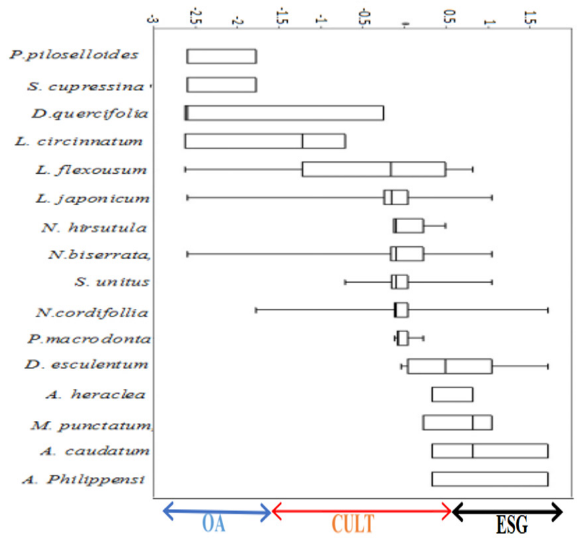

Figure 7. Box plot showing the Habitat Preference and Survival Envelop of Pteridophytes found Outside and Inside the Small Scale Gold Mining Area of Brgy. Gango, Libona Bukidnon Philippines (AO-open area; CULT-cultivated; ESG-early secondary growth).

species can very well survive in an area with early secondary growth forest, which is precisely the characteristic inside the mining area.

It should be noted that three unique species, namely, *L. circinatum, S. cupressina,* and *P. piloselloides* were identified outside the mining area. *Selaginella* and *Pyrrosia* species outside the mining area were associated with trees that could be remnants of a previous forest. The *Lygodium* species can also survive in the cultivated environment when viewed under the survival envelope. This finding is consistent with the data of Zamora and Co (1986), which described the habitat of this species to be in open places and woods at minor altitudes.

The species plotted in the survival envelop indicates that *N. cordifolia, N. biserrata, L. japonicum,* and *L. flexousum* can survive across the three habitat types. The ability of *N.cordifolia* to adapt well to various soil types, tolerance to full sun, and drought is the crucial factor of its widespread distribution(Riefner and Smith 2015). According to Pelser et al. (2011), *Lygodium* species can survive in a wide range of habitats, including open sites, thickets, and disturbed lowland forests. While most of the species are present in the cultivated area, it can be noted that 14 out of the 16 species can survive in more than one type of habitat. This means that most species are generalists and can be easily cultured to restore the degraded ecosystem and can be an alternative source of income by the villagers.

4 Conclusion and Recommendations

The study results show a negligible difference in the diversity of pteridophytes within and outside the mining area in Gango Libona Bukidnon. The slight increase in species within the mining area was due to habitat modification brought by trees planted by the villagers within the mining site. The underground mining method made minor disturbances to the surface, and the vegetation is not generally altered; hence, it favored the growth of the pteridophytes.

Due to the heavy usage of mercury to extract gold in the site, it is recommended that studies on mercury accumulation be made on food species of pteridophytes to safeguard the health of the villagers (consumers) who utilize the plants growing in the area. Propagation of economically potential ferns can be further studied to explore mass production.

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Statement of Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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