Pteridophyte Diversity along a Gradient of Disturbance within Mines in Thong Pha Phum District, Kanchanaburi Province

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Abstract: The diversity of pteridophyte in Thong Pha Phum District, Kanchanaburi Province was conducted along a gradient of disturbance within mines, from July 2002 to March 2003. Twelve plots of 5 x 20 meters have been established in each three study sites, i.e. abandoned mines, remnants of the forest in mine area and natural forests. Species richness, species diversity and species evenness indices were estimated using Menhinick's, Shannon-Weiner's and evenness indices, respectively. Species similarity was investigated using Jaccard's coefficient. Other physical environments related to pteridophyte diversity were examined, including light intensity and leaf temperature. It was found that species richness and species diversity of abandoned mines were lower than those of remnants of the forest in mine area and natural forests, while species evenness was the highest of all. Low Jaccard's coefficient was observed, indicating the difference of species composition between each sites. Light intensity and leaf temperature showed negative significant correlation with Menhinick's index, but was positively significantly correlated with evenness index. However, significant correlation between those physical factors and Shannon-Weiner's index was not found. One hundred and eighty-four specimens of pteridophytes were collected from the 36 sampling plots and were identified to 65 species, 1 subspecies, 5 varieties, in 40 genera, within 20 families. Among these 8 species, 2 genera, 2 families are fern allies. It was found that *Cheilanthes tenuifolia* (Burm. f.) Sw., *Sphenomeris chinensis* (L.) Maxon var. *divaricata* (H. Christ) K.U. Kramer and *Lycopodiella cernua* (L.) Pic. Serm. were found only in abandoned mines and tend to be indicator species for disturbed areas.

Key words: Kanchanaburi Province, pteridophyte, diversity, gradient, disturbance, mines

Introduction

Thong Pha Phum District in Kanchanaburi Province is located in south-western Thailand which is a part of the Thai western forest. Over the last six decades, this district was famous for its richness in mineral resources, such as tin and wolfram as well as a large stretch of fertile forest. There are many forest types in this area, i.e. tropical rain forest, dry evergreen forest, dry mixed deciduous forest and hill evergreen forest (Royal Forest Department, n.d.). By that time, there were some human activities, for example active logging and mining in the area, resulting in massive deforestation throughout. After the Second World War, there was a low demand for tin and wolfram, followed by a series of reductions in prices of these metals in the world market. Nowadays, Thong Pha Phum District has more than 20 abandoned mines left. From the aforementioned information, it is very interesting to investigate the impact of deforestation on plant diversity along a gradient of forest disturbance. This study aimed to investigate pteridophyte diversity along a gradient of forest disturbance, using pteridophytes as the representative plant group.

Thong Pha Phum District covers an area of 3,655.71 km.^{2} It is located on the north-west of Kanchanaburi Province and lies between latitudes 14° 15' - 15° 00' North and longitudes 98° 15' - 99° 00' East (Fig. 1). It is one of the important mineral resources of Thailand, especially of tin and wolfram. Nowadays, Thong Pha Phum District has more than 20 abandoned mines left, covering an area of more than 60 km^2.

The abandoned mines were originally formed by excavating to remove the land surface above the mineral layer. The physical structure of the soil became mixed, up slopes fell down, and humus and soil sludge were washed out by rainfall. The areas have only medium to large sized rocks, and almost no soil (N.S. Consultant, 1989). However, there were steep slopes or valleys or streams. These were not suitable for mining. At present some parts of the district have been declared as Thong Pha Phum National Park to encourage forest conservation and development. The national park covers an area of 1,120 km^2 (Royal Forest Department, n.d.), and includes all of the abandoned tin and wolfram mines of Thong Pha Phum District.

In general, the western part of Thong Pha Phum District comprises the mountainous areas of Ta Nao Sri Range. The park ranges in elevation from 100-1,249 m at the summit of Chang Puak Mountain. Several mountains of Ta Nao Sri Range are important water sources for the park. Streams originating from this mountain flow into waterfalls and downward streams which flow together into Vajiralongkorn Dam and Kwae Noi River (Royal Forest Department, n.d.).

The climate of Thong Pha Phum District is a tropical climate, with average high annual rainfall. Three distinct seasons are observed in this area, i.e., the summer season during February-April, the rainy season during May-October, and the winter season during November-January. The south-western Monsoon blows on to Ta Nao Sri Range and brings continuous heavy rain for 6 months. Temperature data of 2003, from Pilok mine Station (Fig. 2) show the average temperature of about 22.7°C. The highest temperature is 33°C in April and the lowest temperature is 14°C in December. Mean monthly rainfall from 1998-2003 at Pilok mine Station (Fig. 3) shows the average annual rainfall of 417 mm. The highest average monthly rainfall of approximately 1,251 mm is observed in August. The lowest monthly rainfall of about 12.68 mm is observed in December. The total annual rainfall is 5005 mm (Meteorological Department, 2003).

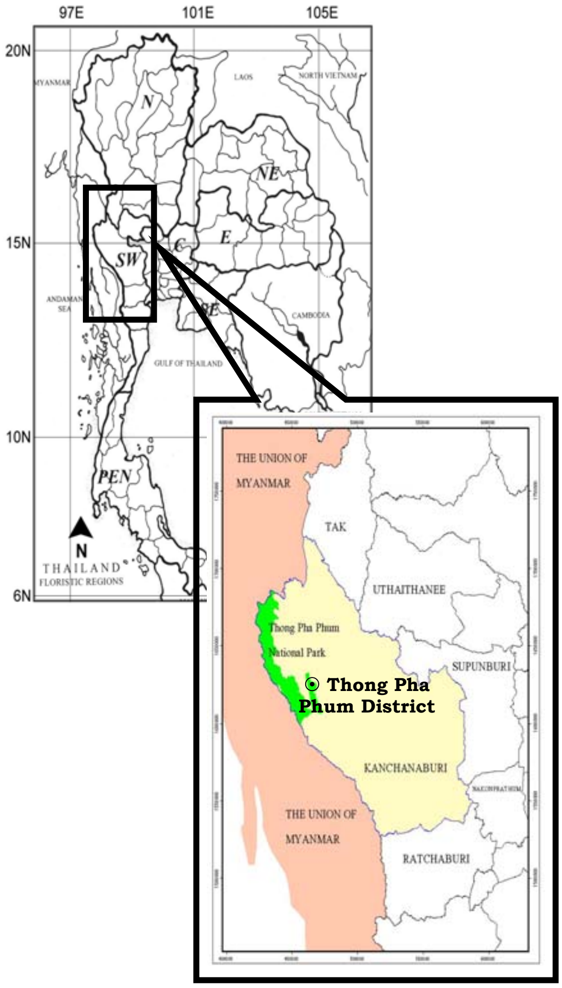


Figure 1. Locations of Thong Pha Phum District and Thong Pha Phum National Park.

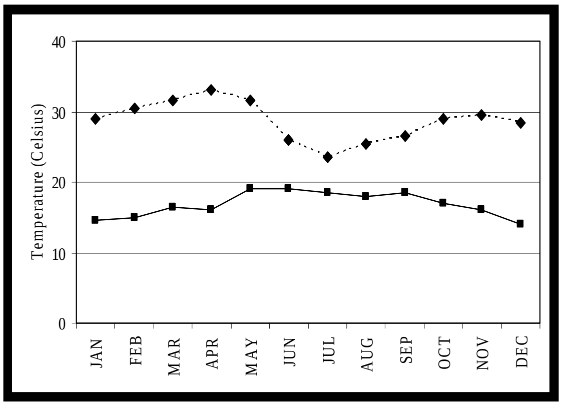


Figure 2. Temperature of 2003, from Pilok mine Station (Data from the Meteorological Department, Bangkok, Thailand).

Methodology

Field collection of pteridophytes was conducted every two months from July 2002 to July 2003 at Thong Pha Phum District, Kanchanaburi Province. A simple random sampling method (Krebs, 1998) was employed; twelve plots of 5 x 20 meters were established at each of three main study sites, i.e.,

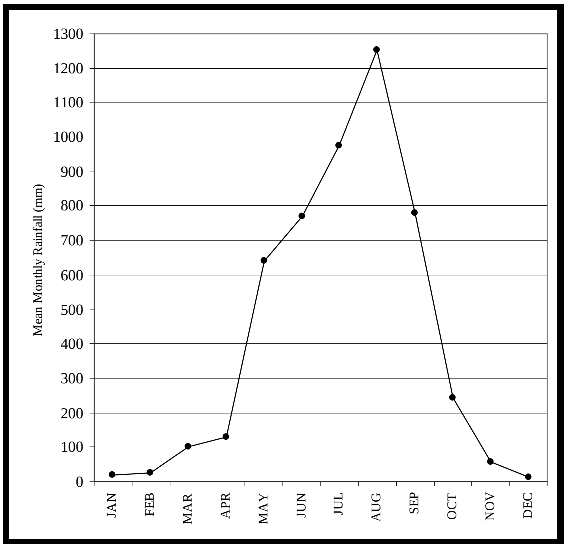


Figure 3. Mean monthly rainfall during the period, 1998-2003, from Pilok mine Station (Data from the Meteorological Department, Bangkok, Thailand).

abandoned mines, remnants of the forest in mine area and natural forests.

The number of species and individuals in each plot was counted and the physical environment factors related to pteridophyte diversity were measured including light intensity and leaf temperature. Measurements were made during 10.00-14.00 hours. Four measurements of photosynthetically active radiation (PAR) and air temperature in full sun 1 m above the plots were measured using a quantum photometer and thermocouple, respectively. Likewise, four measurements of PAR and leaf temperature at canopy of a dominant species within each plot were also measured. The mean values of these four data points were calculated, then an estimate of the percentage of full sunlight penetrating to the pteridophyte's canopy and the ratios of leaf temperature and air temperature at 1 m above each plot were obtained.

Species richness, species diversity and species evenness indices were estimated using Menhinick's, Shannon-Weiner's and evenness indices, respectively. Species similarity was investigated using Jaccard's coefficient (Ludwig and Reynolds, 1988).

One-way analysis of variance (ANOVA) was used to test for differences between study sites for species richness index, species diversity index, species evenness index, percentage of full sunlight penetrating to pteridophyte's canopy and the ratio of leaf temperature and air temperature. The Duncan Multiple Range Test (DMRT) was used to compare means where the F-test was significant.

Relationships between physical environmental factors and pteridophyte diversity were analysed using Pearson's Correlation available in SPSS for Windows Program, version 9.0.

Results

1. *Physical factors*

1.1 Light intensity

Light intensity at the canopy of pteridophytes among study sites was statistically significant different. The highest mean light intensity was observed in abandoned mines, while the lowest mean light intensity was found in the remnants of the forest in the mine area (Fig. 4A).

1.2 Leaf temperature

The mean values of the ratios of leaf temperature and air temperature among study sites were statistically significant different. The highest mean ratio of leaf temperature and air temperature was observed in abandoned mines, while the lowest mean ratio of leaf temperature and air temperature was found in the remnants of the forest in the mine area (Fig. 4B).

2. *Pteridophyte diversity*

2.1 Species richness

There was a statistically significant difference of species richness among study sites. The lowest mean value of species richness was observed in abandoned mines while the highest mean value of species richness was observed in remnants of the forest in the mine area. However, no statistically significant difference of species richness was found between remnants of the forest in the mine area and the natural forest (Fig. 4C).

2.2 Species diversity

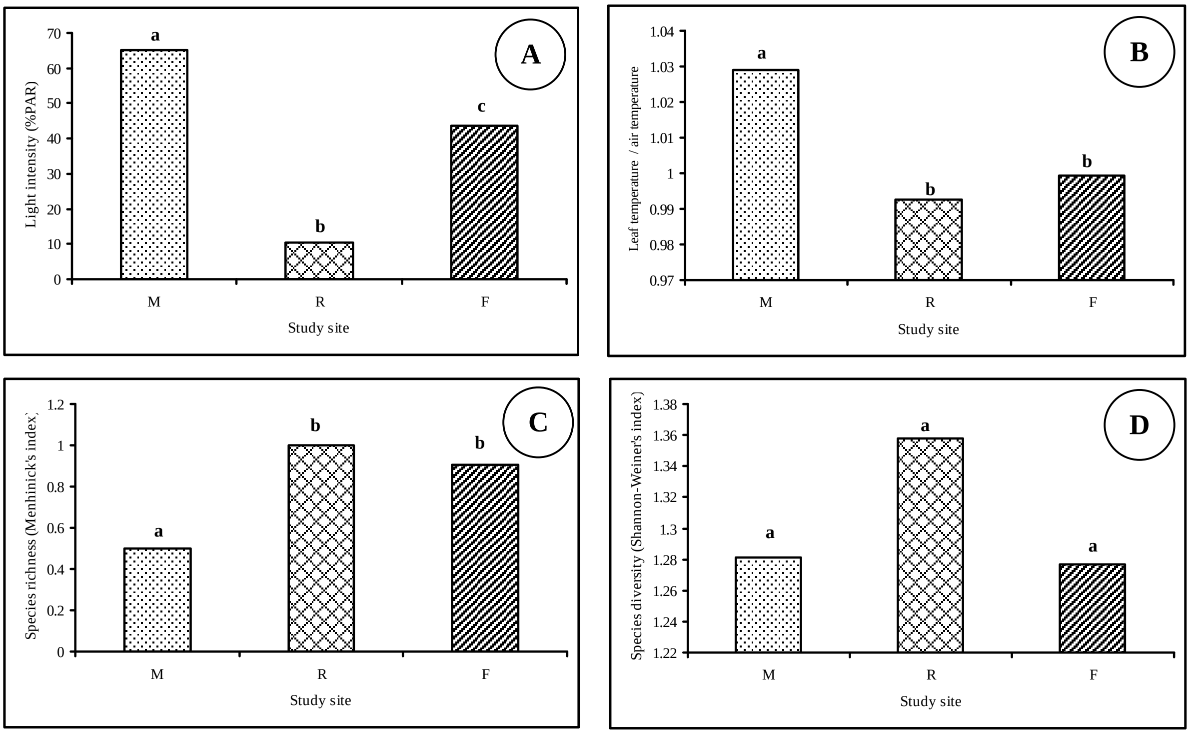
There was no statistically significant difference of species diversity among study sites. The highest value was observed in remnants of the forest in the mine area (Fig. 4D).

2.3 Species evenness

There was no statistically significant difference of species evenness between abandoned mines and remnants of the forest in the mine area. However, species evenness of these two sites were not statistically different from the natural forest (Fig. 4E).

3. *Similarity coefficient*

A list of ferns and fern allies that occurred at each study site is shown in Table 1.



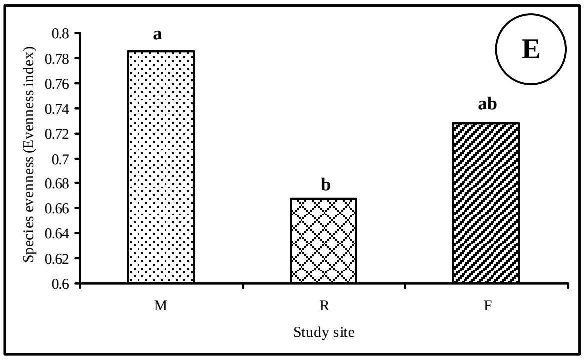


Figure 4. A. Means of light intensity
B. Mean ratios of leaf temperature and air temperature
C. Means of species richness
D. Means of species diversity
E. Means of species evenness

Significant differences among study sites are indicated by different letters.
M= Abandoned mines, R= Remnants of the forest in mine area, F= Natural forests.

It was found that the similarity coefficient between abandoned mines and remnants of the forest in the mine area was 0.21. The similarity coefficient between abandoned mines and natural forest was 0.05, while the similarity coefficient between remnants of the forest in the mine area and natural forest was 0.13.

4. Relationship between pteridophyte diversity and physical factors

Pearson’s correlation was used to explore the relationship between pteridophyte diversity and physical factors. It was found that species richness (Menhinick’s index) was negatively and significantly correlated with light intensity (%PAR) and ratio of leaf temperature and air temperature (Table 2, Fig. 5A and 5C). No statistically significant correlation was observed between species diversity (Shannon-Weiner’s index) and physical factors (Table 2). However, species evenness (Evenness index) was positively significantly correlated with light intensity (%PAR) and ratio of leaf temperature and air temperature (Table 2, Fig. 5B and 5D).

5. Taxonomic diversity of pteridophytes

One hundred and eighty-four specimens of pteridophytes were collected from three study sites, i.e., abandoned mines, remnants of the forest in the mine area, and natural forests nearby. These pteridophytes were classified into 20 families, 40 genera, 65 species, 1 subspecies and 5 varieties. Among these, 18 families, 38 genera, 57 species, 1 subspecies and 5 varieties are ferns, while 2 families, 2 genera, 8 species are fern allies. Only fifteen species were found in the abandoned mines, which was the lowest number, while, 41 species of pteridophytes were found in the remnants of the forest in mine areas. In addition, 26 species of pteridophytes were found in the natural forests.

Table 1. Check list of pteridophytes at each study site.

Taxa	Habitat	M	R	F
Fern Allies				
Lycopodiaceae				
-*Lycopodiella cernua* (L.) Pic. Serm	T	+	-	-
Selaginellaceae				
- *Selaginella biformis* A. Br. ex Kuhn	T	-	+	-
- *Selaginella helferi* Warb.	T	-	+	-
- *Selaginella inaequalifolia* (Hook. et Grev.) Spring	T	-	+	-
- *Selaginella lindhardii* Hieron.	T	+	-	-
- *Selaginella minutifolia* Spring	T	+	-	-
- *Selaginella siamensis* Hieron.	T	-	-	+
- *Selaginella tenuifolia* Spring	T	+	+	-
Ferns				
Adiantaceae				
- *Cheilanthes tenuifolia* (Burm. f.) Sw.	T	+	-	-
- *Pityrogramma calomelanos* (L.) Link.	T	+	+	-
Aspleniaceae				
- *Asplenium apogamus* Murakami et Hatanaka	T	-	+	+
- *Asplenium perakense* B. Mathew et H. Christ	E	-	-	+
- *Asplenium yoshinagae* Makino	E	-	+	+
Blechnaceae				
- *Blechnum orientale* L.	T	+	+	-
- *Brainea insignis* (Hook.) J. Sm.	T	-	-	+
Cyatheaceae				
- *Cyathea borneensis* Copel.	T	-	+	-
- *Cyathea gigantea* (Wall. ex Hook.) Holttum	T	+	+	-
Davalliaceae				
- *Araiostegia imbricata* Ching	E	-	-	+
- *Humata repens* (L. f.) J. Small ex Diels	E	-	-	+
Dennstaedtiaceae				
- *Histiopteris incisa* (Thunb.) J. Sm.	T	-	+	-
- *Hypolepis punctata* (Thunb.) Mett. ex Kuhn	T	-	+	-
- *Microlepia hookeriana* (Wall. ex Hook.) C. Presl	T	-	+	-
- *Microlepia speluncae* (L.) T. Moore	T	-	+	+
Dicksoniaceae				
- *Cibotium barometz* J. Sm.	T	-	+	-
Dryopteridaceae				
- *Dryopteris polita* Rosenst.	T	-	+	-
- *Heterogonium sagenioides* (Mett.) Holttum	T	-	+	-
- *Pteridrys australis* Ching	T	-	+	-
- *Pteridrys syrmatica* (Willd.) C. Chr. et Ching	T	-	+	-
- *Tectaria fuscipes* (Wall. ex Bedd.) C. Chr.	T	-	+	-
- *Tectaria impressa* (Fée) Holttum	T	-	-	+
- *Tectaria polymorpha* (Wall. ex Hook.) Copel.	T	-	+	+
- *Tectaria* sp.	T	-	+	-
Gleicheniaceae				
- *Dicranopteris linearis* (Burm. f.) Underw. var. *linearis*	T	+	+	-
Hymenophyllaceae				
- *Crepidomanes latealatum* (Bosch) Copel.	E	-	-	+
- *Hymenophyllum exsertum* Wall. ex Hook.	E	-	-	+
- *Hymenophyllum polyanthos* (Sw.) Sw.	E	-	-	+

Table 1. (continued)

Taxa	Habitat	M	R	F
Lindsaeaceae				
- *Lindsaea ensifolia* Sw.	T	+	+	+
- *Sphenomeris chinensis* (L.) Maxon var. *divaricata* (H. Christ) K.U. Kramer	T	+	-	-
- *Sphenomeris chinensis* (L.) Maxon var. *rheophila* K.U. Kramer	T	+	+	-
Lomariopsidaceae				
- *Bolbitis appendiculata* (Willd.) K. Iwats. subsp. *vivipara* (Hamilt. ex Hook.) Hennipman	L	-	+	+
- *Bolbitis heteroclita* (C. Presl) Ching	T	-	+	-
- *Bolbitis virens* (Wall. ex Hook. et Grev.) Schott var. *virens*	T	-	-	+
- *Elaphoglossum marginatum* (Wall. ex Fée) T. Moore	E	-	-	+
Marattiaceae				
- *Angiopteris evecta* (G. Forst.) Hoffm.	T	-	+	-
Polypodiaceae				
- *Aglaomorpha coronans* (Wall. ex Mett.) Copel.	E	-	+	+
- *Crypsinus oxylobus* (Wall. ex Kunze) Sledge	E	-	-	+
- *Crypsinus rhynchophyllus* (Hook.) Copel.	E	-	-	+
- *Goniophlebium subauriculatum* (Blume) C. Presl	E	-	-	+
- *Lepisorus scolopendrium* (Buch.-Ham. ex D. Don) Mehra & Bir	E	-	-	+
- *Leptochilus minor* Fée	L	-	+	-
- *Microsorum punctatum* (L.) Copel.	E	-	+	-
- *Pyrrosia albicans* (Blume) Ching	E	-	-	+
- *Pyrrosia lingua* (Thunb.) Farw. var. *heteractis* (Matt. ex Kuhn) Hovenkamp	E	-	-	+
Pteridaceae				
-*Pteris biaurita* L.	T	+	+	+
Schizaeaceae				
- *Lygodium microphyllum* (Cav.) R. Br.	T	+	+	-
- *Lygodium salicifolium* C. Presl	T	-	+	+
Thelypteridaceae				
- *Christella dentata* (Forssk.) Holttum	T	-	+	-
- *Christella parasitica* (L.) H. Lév.	T	+	+	-
- *Cyclosorus hirtisorus* (C. Chr.) Ching	T	-	-	+
- *Metathelypteris dayi* (Bedd.) Holttum	T	-	+	-
- *Metathelypteris singalanensis* (Baker) Ching var. *singalanensis*	T	-	+	-
- *Pronephrium nudatum* (Roxb.) Holttum	T	-	+	-
Woodsiaceae				
- *Diplazium donianum* (Mett.) Tardieu	T	-	+	-
- *Diplazium esculentum* (Retz.) Sw.	T	-	+	-
- *Diplazium simplicivenium* Holttum	T	-	+	-

Habitat: T= Terrestrial, E= Epiphyte, L= Lithophyte
Study sites: M= Abandoned mines, R= Remnants of the forest in mine area, F= Natural forests

Table 2. Correlation between pteridophyte diversity and physical factors.

Pteridophyte diversity	Light intensity (%PAR)	leaf temperature/ air temperature
Species richness (Menhinick's index)	-0.434**	-0.460**
Species diversity (Shannon-Weiner's index)	-0.014	0.068
Species evenness (Evenness index)	0.351*	0.397*

*, ** indicated significant correlation at 95% and 99% confidence levels, respectively

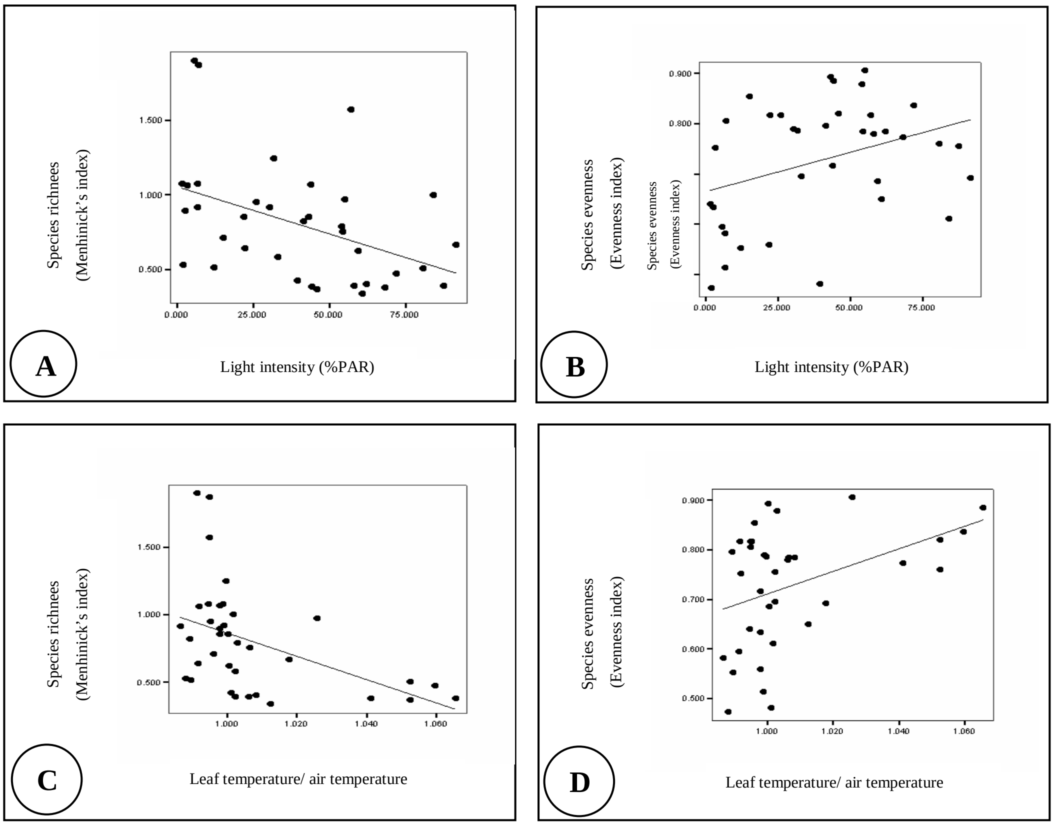


Figure 5. A. Relationship between light intensity and species richness
B. Relationship between light intensity and species evenness
C. Relationship between ratio of leaf temperature and air temperature and species richness
D. Relationship between ratio of leaf temperature and air temperature and species evenness

Discussion and Conclusion

1. *Physical factors*

1.1 Light intensity

Abandoned mine areas are fully exposed places because the vegetation was cleared since the beginning of mine working. This disturbance resulted in the highest light intensity over the area. However, there are some remnants of the forest in mine areas, especially in areas close to streams. There are plants of various habits in these undisturbed strips. So, ground covers are shaded by canopy of trees and shrubs. The lowest light intensity was observed in these areas. Natural forests in this study are hill evergreen forest; this evergreen forest has some tall trees scattered around. The tree canopy is not so close, so sunlight can reach the forest floor. Light intensity is different among these three habitats. Light has a profound effect on plant growth, especially pteridophytes (Holttum, 1954; Boonkerd, 1996). Vannasri (2002) working on the diversity of ferns and fern allies in natural forest and along the natural gas pipeline in Thong Pha Phum District, Kanchanaburi, also found that light intensity is an important factor to pteridophyte growth in each area.

1.2 Leaf temperature

In this study, the ratio of leaf temperature to air temperature was found to be significantly highest at abandoned mines. The high leaf temperature was a consequence of the high light intensity in abandoned mines where leaves of pteridophytes are fully exposed to sunlight.

2. *Pteridophyte diversity*

2.1 Species richness

The lowest mean value of species richness was observed in disturbed areas of mines while the highest mean value was observed in the remnants of the forest in mine area. However, no statistically significant difference of species richness was found between the remnants of the forest in mine areas and the natural forests (Fig. 4C). There were a few species of terrestrial sun-pteridophytes in abandoned mines, while most pteridophytes in the remnants of the forest in the mine area were terrestrial in shady places. Natural forests have both terrestrials and epiphytes. Likewise, disturbed woodland on the shore of lake Texoma, Oklahoma State in USA also has a lower number of plant species than undisturbed areas (Corbett et al., 2002).

2.2 Species diversity

In this study, the remnants of the forest in mine areas had the highest values of species diversity index. However, there was no statistically significant difference of species diversity between the three studied sites. Abandoned mines had a low number of species, but this site had high number of all individuals in each plot. In contrast, both remnants of the forest in mine areas and natural forests had a high number of species but a low number of all individuals in each plot. Therefore, no significant difference was observed among the three studied sites.

2.3 Species evenness

Since the calculated value of species diversity index alone does not show the degree to which each factor contributes to diversity (Elliott and Swank, 1994), this study calculated both species diversity and species evenness. The number of individuals of each pteridophyte species in abandoned mines was rather high and the common species were found in most plots. So, the highest value of species evenness index was observed in this studied site. The common species included *Lycopodiella cernua*, *Blechnum orientale* and *Dicranopteris linearis* var. *linearis*. They are the pioneer species of pteridophytes in disturbed areas (Holttum, 1954; Boonkerd, 1996), while, the remnants of the forest in the mine area had a lower number of individuals and the same species occurred only in one or two plots. Examples included *Asplenium apogamus*, *Microlepia hookeriana* and *Tectaria* sp.

In the past, Thong Pha Phum forests may have been rich in plant diversity, especially pteridophytes. However, after mine working, the forests were cleared except for the strip areas nearby streams. Only fragments of the forests can be found from place to place in the mine areas at present. Pteridophyte species in each fragment are rather different because they have a limited distribution. A possible additional explanation of the lowest species evenness in this habitat is that the distance from the natural forest and other fragments are too extensive for spores of the small terrestrial ferns to be dispersed by the wind.

In hill evergreen forest, the common pteridophytes usually occur in some plots. Therefore, this habitat had a medium value of species evenness index among the three sites.

3. Similarity coefficient

The result from this study indicated that each study site had a rather small number of species in common. This is probably due to the difference of physical environment between each study site which had different degrees of disturbance. Corresponding results were presented by Vannasri (2002), who found a low value of similarity coefficient of pteridophytes between natural forests and areas along the natural gas pipeline.

The highest value of the similarity coefficient between abandoned mines and the remnants of the forest in mine area indicated that there were some common species between these two sites. The common species included *Blechnum orientale* and *Dicranopteris linearis* var. *linearis*. They are species of pteridophytes, which naturally occur along forest edge as well as in exposed areas of disturbed forest.

The lowest value of species similarity coefficient was observed between abandoned mines and natural forests. Only two common species were found, i.e. *Lindsaea ensifolia* and *Pteris biaurita*. These two sites are different in most of the physical factors, for example, light intensity, temperature, moisture and substratum. Furthermore, most pteridophytes in natural forests are epiphytes, while abandoned mines had no trees, and all of the pteridophytes are terrestrial.

4. Relationship between pteridophyte diversity and physical factors

Light intensity and leaf temperature were the two physical factors investigated in this study. The two factors were negatively significantly correlated with species richness index (Fig. 5A and 5C). Similarly, Vannasri (2002) reported a negative correlation between light intensity and species richness index. In addition, Bhattarai and Vetaas (2003) who studied the variation of species richness of different life forms along a subtropical elevation gradient in the Himalayas, east Nepal, found that potential evapotranspiration has a negative relationship with species richness of pteridophytes.

Furthermore, light intensity and leaf temperature were positively significantly correlated with species evenness index (Fig. 5B and 5D). It is probable that the terrestrial sun-pteridophytes had their spores effectively dispersed by the wind. However, these two factors had no correlation with species diversity index.

5. *Taxonomic diversity of pteridophytes*

One hundred and eighty-four specimens were collected. A total of 65 species, 1 subspecies, and 5 varieties in 40 genera and 20 families were enumerated. Among these, 8 species in 2 genera in 2 families are fern allies. Polypodiaceae had the highest number of species, i.c., 9 species, whilst Dryopteridaceae and Selaginellaceae had 8 and 7 species, respectively. There were five families, viz. Pteridaceae, Marattiaceae, Lycopodiaceae, Gleicheniaceae and Dicksoniaceae, which included only 1 species. In all, there were 46 species of terrestrials, 16 species of epiphytes and 2 species of lithophytes.

5.1 Comparison of pteridophytes diversity among the studied sites

Abandoned mines were fully exposed areas, without trees. A few flowering plants including *Chromoleana odoratum* (L.) R.M. King et H. Rob., *Melastoma* spp., *Bambusa* spp. and *Thysanolaena* spp. were found throughout the mine area. Due to mine working in the past, most of the rocky hills were excavated and turned into little rocks. Hill slope was about 10°-40°. Most of these areas were covered with *Thysanolaena* spp. and *Dicranopteris linearis* var. *linearis*. There were 15 species of terrestrial pteridophyte in this area (Fig. 6).

The remnants of the forest in the mine area were found along or close to streams. It was a shady forest, with 10°-50° slope. Most plant species were shrubs, with a few small to medium sized trees. The ground consisted of humus rich soil and boulders. This area had rather high air humidity due to the streams nearby. Forty-two species of pteridophytes were found. They were 11 species of terrestrials, 2 species of epiphytes and 2 species of lithophytes (Fig. 6).

The greatest number of species among the three study sites occurred here probably due to suitable light intensity and humidity for pteridophyte growth. It is worth noting that some species are rather rare and found in only one sampling plot. These species include *Histiopteris incisa*, *Metathelypteris singalanensis* var. *singalanensis*, *Tectaria fuscipes*, *Leptochilus minor* and *Pteridrys syrmatica*. It is possible that each species can find a niche, such as the cracks and crevices of shattered rocks in a variety of habitats at each sampling plot. Furthermore, some large-sized ferns, *Angiopteris evecta*, *Cyathea borneensis*, *Cyathea gigantea* and *Cibotium barometz* were commonly found in this area. They usually thrive in moist grounds with partial sun-light at the edge of the forest. It is postulated that these tree ferns are indicators of undisturbed forest, especially in the Thong Pha Phum area.

Natural forests were hill evergreen forests including large to medium-sized trees mixed with bamboo. The common terrestrials were Fabaceae, *Calamus* spp., *Cinnamomum* spp., and *Rubus* spp. The forest floor comprised humus-rich soils. Air humidity in hill evergreen forest was rather high, especially where there were mossy tree trunks. There were 26 species of pteridophyte, consisting of 11 species of terrestrials, 14 species of epiphytes and 1 species of lithophyte (Fig. 6).

There were many species which were restricted to the hill evergreen forest, for example, *Brainea insignis*, *Humata repens*, *Elaphoglossum marginatum*, *Crypsinus oxylobus* and *Crypsinus rhynchophyllus*. Most

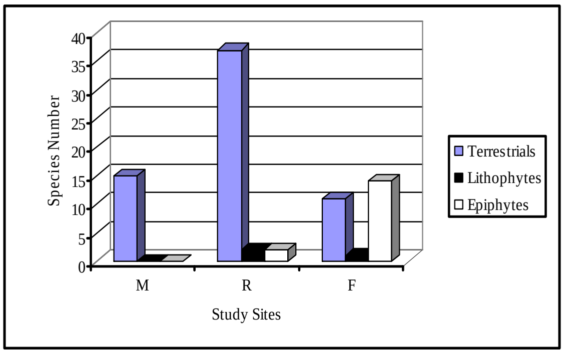


Figure 6. Habit of pteridophytes in each study site; M= Abandoned mines, R= Remnants of the forest in mine area, F= Natural forests.

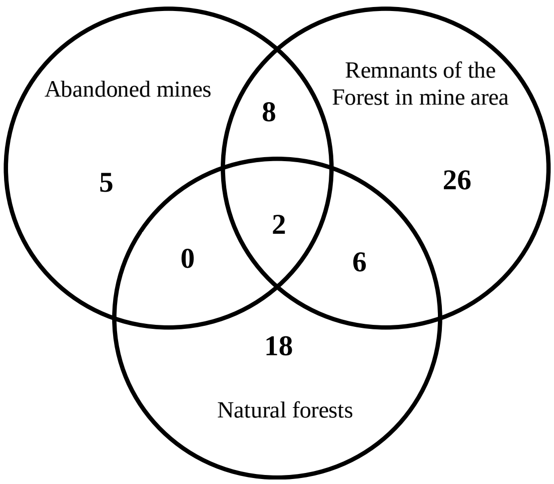


Figure 7. Number of pteridophytes in each study site.

pteridophytes in the natural forest were epiphytes. They grow on mossy tree trunks, which had rather high humidity. In contrast, there were no epiphytes in abandoned mines and only a few were found in the remnants of the forest in the mine area.

Among the 65 species, there were some species found in only one area, and some species were commonly found in two or three areas (Fig. 7). It was found that *Cheilanthes tenuifolia*, *Selaginella lindhardii*, *Selaginella minutifolia*, *Sphenomeris chinensis* var. *divaricata* and *Lycopodiella cernua* were found only in abandoned mines. However, the first three species grow in shady places usually under the shade of shrubs or in rock crevices, where there was some moisture underneath. *Dicranopteris linearis* var. *linearis*, *Pityrogramma calomelanos*, *Sphenomeris chinensis* var. *divaricata* and *Lycopodiella cernua* have characteristics of drought resistance, such as dissected and/or coriaceous fronds and were able to withstand the full sunlight of abandoned mines.

There were pteridophytes species commonly found in both abandoned mines and the remnants of the forest in the mine area, but they were different in their full sizes. It was found that pteridophytes growing in abandoned mines had a smaller frond size than those growing in remnants of the forest in the mine area.

Pteridophytes which occurred in both the natural forests and the remnants of the forest in mine areas had a rather wide distribution. They could grow in several forest types. These pteridophytes included *Aglaomorpha coronans*, *Lygodium salicifolium* and *Microlepia speluncae* (Tagawa and Iwatsuki, 1979, 1989).

It was found that two terrestrial ferns, namely *Lindsaea ensifolia* and *Pteris biaurita*, were commonly found in all study sites. *Lindsaea ensifolia* is fairly common and locally abundant throughout Thailand and the old world tropics. It is extremely variable in form and size of fronds, especially in different habitats (Tagawa and Iwatsuki, 1985). This species can be found on rather dry slopes or sandy ground, usually in open areas, but rarely on rocks. Likewise, *Pteris biaurita* is also a widely distributed fern, it was found in more than 3 forest types at Huaiyang Waterfall National Park (Yuyen and Boonkerd, 2002).

5.2 New records

It was found that *Sphenomeris chinensis* var. *rheophila* and *Metathelypteris dayi* are newly recorded species for Thailand.

Sphenomeris chinensis var. *rheophila* had been reported in Malesia. There are a number of this species in Thong Pha Phum District, especially in exposed areas. The var. *rheophila* is similar to var. *chinensis*; they differ in the pattern of venation.

Metathelypteris dayi has also been reported in Malesia. This species is very rare in Thong Pha Phum District.

5.3 Dubious species

In this study, there was one species of the genus *Tectaria*, which cannot be determined to species level, despite many attempts to use key determination from the Flora of Thailand as well as keys from neighboring countries. Herbarium specimens of related species were also studied from BCU and BKF, but it is still unidentified.

Tectaria sp. is a terrestrial pteridophyte, found on moist and humus-rich mountain slopes in the remnants of the forest in mine areas at about 900 m altitude. It is close to *Tectaria griffithii* (Baker) C. Chr. However, the details of their fronds and sori are different.

6. Recommendation

Permanent plots should be established in order to carry out a long term study of plant succession in these study sites. Further eco-physiological study of pteridophytes will enhance our understanding of ecological adaptation of this plant group.

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