DISCUSSION

Extensive Qualitative Survey

Pteridophyte biodiversity was higher in the extensive qualitative survey (Appendix A) than in the intensive quantitative survey, since the former covered the whole study area. Figure 14 shows that the EGF had the highest Pteridophyte diversity which is probably due to having more suitable conditions for the growth of many Pteridophytes which require shade and moisture. The two lower deciduous forests had lower Pteridophyte diversity which indicates that these habitats are less suitable for Pteridophytes. The reason behind this is directly related with the sexual reproduction of Pteridophytes. Sexual reproduction in this group of plants is quite different from that in flowering plants since the prothallus with the male gametes (n) and female gametes (n) must be in a moist environment because the male gametes need to swim to the female gametes to effect fertilization (2n). The sporophyte develops on the prothallus, eventually maturing into the conspicuous plants that we often observe with sori on them. Thus, moisture is very important for this critical period, hence reproduction is more successful in wetter and moister areas such as the EGF and is less successful in seasonally dry areas such as the DOF and BB/DF which is the main factor for the higher species richness in the EGF and RR areas than in the DOF and BB/DF areas. Also, fewer ferns are able to tolerate drier conditions and those that can are deciduous. Reproduction in EGF, in some places, occurs throughout the year.

Thelypteridaceae had the highest number of species both in the EGF and RR areas (Figure 15) implying that this family thrives in shaded, upland areas. Likewise, this family has more genera and species than most other Pteridophyte families thus, its distribution is likely to be wide (Tagawa and Iwatsuki, 1985). Similarly, Holttum (1968) found that most *Thelypteris* species are confined to high mountain forests. Parkeriaceae and Selaginellaceae were more abundant in lowland DOF and BB/DF deciduous forests. This is confirmed by Tagawa and Iwatsuki (1985), who reported that species in Parkeriaceae grow mostly in open areas and some are even xerophytic. This trend is also present in northern Thailand deciduous forests where *Adiantum philippense* L. and *A. zollingeri* Mett. ex Kuhn (Parkeriaceae) are very common.

Intensive Quantitative Survey

The results of the analyses of the different indices (species richness, diversity, and evenness) revealed that Parkeriaceae had the highest number of species in the deciduous forests (Figure 18) implying that the representatives of this family in my study area thrive in open and seasonally dry conditions. Likewise, it was found that the EGF site still had, significantly, the highest Pteridophyte diversity, followed by the RR area and the least in the DOF site (Figure 17 and Table 1) for the intensive quantitative survey. However, species richness in DOF and BB/DF were not significantly different from each other. These results are attributed to several factors such as similarities in the canopy cover, light intensity, soil moisture content, soil temperature, elevation, and the overall degree of disturbance of the areas which in turn affects the general conditions of habitats sampled. The canopy cover in the EGF was significantly higher than in the other sites (Table 12). Due to greater canopy cover, light intensity was lower, soil moisture higher, and soil temperature lower--all of which are favorable conditions for the growth of Pteridophytes; hence, high species diversity. Such conditions still prevail, even in the established tea plantations in the area. In Thailand, it is a common practice for tea growers to thin the forests up to approximately 50% or sometimes even higher than this figure for the maintenance of the tea plantations and optimum yield of tea leaves.

Above the established tea plantation was an area in which the canopy cover was higher because it had not been cultivated and was relatively undisturbed. The place was more shaded and had higher amounts of leaf litter, however, it was disturbed since the villagers in Mae Kampong still cut some trees in this area for fuelwood and for construction. Because of these conditions, a wide range of niches in the EGF area were available for Pteridophytes, such as sun-loving species, e.g. *Dicranopteris linearis* (Burm. f.) Underw. var. *linearis* (Gleicheniaceae), *Blechnum orientale* L. (Blechnaceae), and *Pteridium aquilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try. (Dennstaedtiaceae) thrived in open, disturbed areas, while shade-loving species, e.g. *Brainea insignis* (Hk.) J. Smith (Blechnaceae), *Thelypteris hirtisora* (C. Chr.) K. Iwats. (Thelypteridaceae), and *Bolbitis virens* (Wall. ex Hk. & Grev.) Schott var. *virens* (Lomariopsidaceae) thrived in shaded, moister parts of the EGF.

The Pteridophyte communities in both deciduous forests, had fewer species due to the very disturbed and more arid conditions of these places. As shown in Table 12, the canopy cover in these forests was significantly lower than in the EGF area. Indiscriminate cutting of trees and seasonal fires were frequent as evidenced by ashes, tree stumps, and charred logs. As a result, only those perennial, deciduous Pteridophyte species which are tolerant to high light intensity and low soil moisture can grow in these lowland forests, e.g. *Selaginella ostenfeldii* Hieron., *S. repanda* (Desv.) Spring (Selaginellaceae), and *Cheilanthes tenuifolia* (Burm. f.) Sw. (Parkeriaceae) which are all deciduous. In contrast, all the EGF species were evergreen implying that there is enough soil and atmospheric moisture to sustain these Pteridophytes throughout the year, thus, higher species diversity.

Species abundance in the BB/DF site was more or less shared by all species as indicated by the higher N1 value relative to species richness, thus the Pteridophyte community in this area was the most even. This was also confirmed by having the highest evenness value which was 0.90 (Table 1). This result simply means that there is no single dominant species in this site and also indicates that all the species there are equally suitable to this habitat due to the uniform, very degraded conditions there. The DOF site had the same diversity results as in the BB/DF site. For the EGF and RR sites, the situation was completely different from the other sites because, as mentioned earlier, a wider range of habitats is present in these areas. Thus, Pteridophytes in these places were more abundant than in the two deciduous forests. Also, some species in these areas were more abundant than others as shown by their N1 values and which was also confirmed by their lower evenness values (Table 1).

Owing to the great differences in environmental conditions between the four sampling areas, the Pteridophyte communities were very different as indicated by the lower values of the SI of similarity and higher values of CRD of difference (Table 6). Specifically, Pteridophyte communities between the RR areas and that of the two deciduous forests were completely different as reflected by the 0 SI value of similarity and 1.41 CRD value of difference. This difference is due to the moisture content of the soil where soil moisture in the RR was significantly higher than in the DOF and BB/DF areas (Table 11 and Appendix Ea-d). Thus, species which are very dependent on a high moisture habitat are restricted to the RR areas, while the dry-tolerant and the deciduous ones thrive in the drier conditions present in the DOF and BB/DF. The two deciduous forests had the most similar Pteridophyte communities, highest SI value (0.43), and the lowest CRD value of difference (1.06) due to the similar conditions in the two areas. Upon looking at the information in the CMU Herbarium Database, it was confirmed that the species found in these deciduous forests were also found in the same type of forests in other areas. Likewise, these two forests were close to each other, so there is a high chance of spores exchange between them. Since some Pteridophytes have already become successful in this kind of environment, they have some characteristics that enable them to tolerate and survive in this kind of seasonally dry and relatively arid habitat. One of their most obvious survival characteristics is their being deciduous and perennial. During the dry season, these Pteridophytes shed their fronds to conserve moisture and regrow when the rain comes, hence all species here are relatively small with little biomass. However, the SI value of similarity was not high implying that the two forests are still different in their Pteridophyte compositions. The differences are probably influenced by the contrasting microhabitats present in the areas. For instance, in the DOF, species belonging to Dipterocarpaceae were the dominant trees while in the BB/DF, bamboo was the dominant vegetation. By looking at this very conspicuous difference, conclusions can be made that their soil conditions and other ecosystem components must be different. Unfortunately, results of the soil analysis were dubious and can not be used to support the discussion covering soil versus forest type, hence were deleted to avoid any misleading interpretations or confusion. However, even without the soil data, the results imply that some Pteridophyte species are really specific to certain forests and the exact reasons for this hypothesis can only be found by doing a more detailed study of the different components in the area, such as the soil type and soil conditions, as well as laboratory tests for the microhabitat and nutrient requirements of Pteridophytes.

The results of comparisons of Pteridophyte communities in the same habitat, but with different degrees of disturbance, showed that there is no significant difference in species richness between the different subsites in the two deciduous forests (Tables 2 and 3). Similarly, species abundance was more or less shared by all species as shown by the higher N1 values relative to the total number of species and by higher evenness values. This fact implies that there is no significant difference in the general conditions of the three established subsites, hence the similarity in results. In addition, the results of the SI of similarity and CRD of difference showed that Pteridophyte species composition between the subsites in the two deciduous forests were more or less similar as shown by the higher SI and lower CRD values (Tables 7 and 8) reinforcing the conclusion that there was no significant difference in the overall conditions between the subsites of the two areas. Finally, observation of forest structure, vegetation, and abuse of these areas confirms this similarity. Although the subsites were established based on different degrees of disturbance, site selection was very subjective because quantification of tree density was not done due to time limitations.

However, in the EGF area, species richness in the EGFL was significantly lower than in the EGFX and EGFM while the latter were not significantly different from each other (Table 4). Difference in canopy cover is the main reason for the difference in their species composition and species abundance. However, it should be noted that even if there was a difference in tree density and canopy cover in EGFM and EGFL, the soil conditions of these subsites have not been greatly changed, because in tea plantations the soil is not disturbed since there is no digging or fire, thus soil properties more or less remain the same. In fact, Maxwell (personal communication, 1997) stated that tea plantations are the most ecologically successful agro-forestry activity in Thailand because they do not require pesticides or synthetic fertilizers, never have fire, and tea plants are native to northern Thailand. As a result, the soil remains intact since it has been protected from the direct impact of rain and wind by the remaining trees and dense ground flora. Thus, it is suspected that differences in canopy cover between the EGFM and EGFL was the main factor for differences in their species richness and species composition. In contrast, soil conditions in the EGFX were different from the former subsites because it was located in an eroded, marginal portion of a tea plantation with a dirt road that cut through the area. As mentioned earlier, there is a wide range of habitats in the EGFX and EGFM due to the established tea plantations in these areas, hence, higher species richness. In the EGFL, although it was also disturbed, the canopy cover was higher since there was no tea plantation. As a consequence, only those shade-loving species (mentioned earlier) grow in this area.

The Pteridophyte community in the EGFX was dominated by a few species e.g. *Dicranopteris linearis* var. *linearis*, *Blechnum orientale* and *Pteridium aquilinum* ssp. *aquilinum* var. *wightianum* which was reflected by the higher N1 value (Table 4) and lower evenness. The dominance of some species in the EGFX was due to its very disturbed condition. As mentioned earlier, there were frequent landslides in this area and the canopy cover was sparse due to the dirt road that cut through the area. As a consequence, *Dicranopteris linearis* var. *linearis, D. splendida, Blechnum orientale* and *Pteridium aquilinum* ssp. *aquilinum* var. *wightianum* dominated this place (Table 13). As reported by Holttum (1968), the above mentioned Pteridophytes are sun-loving species. Similarly, Maheswaran and Gunatilleke (1988) reported that *Dicranopteris linearis* readily dominates in many deforested lands in Sri Lanka. Likewise, Gliessman (1978) reported that *Pteridium aquilinum* is a dominant and vigorous weed throughout the world, due to its rapid and vigorous growth, its strong allelopathic capabilities, lack of predators, and resistance to fire. It should be emphasized that even if *Pteridium aquilinum* is a successful invader, it does not grow in DOF and BB/DF areas probably due to the seasonally dry and arid lowland conditions (vide CMU Database). As expected, species composition between the three subsites were very different as shown by the SI and CRD indices (Table 9) due to the difference in their niche or habitat conditions.

Lastly, species richness in the RR/WF was significantly higher than in the RR/BDF and RR/VL while the latter were not significantly different from each other (Table 5). The differences in elevation as well as the degrees of disturbance are the main contributing factors for these results. Moreover, there was no dominant species in the RR/BDF and RR/WF as reflected by the higher evenness value, while the RR/VL was dominated by one species which is attributed to disturbance. As I observed during my fieldwork, *Diplazium esculentum* (Retz.) Sw. (Athyriaceae) was dominant in RR/VL even though it was damaged by cattle and villagers who eat the young fronds. In fact, Zamora and Co (1988) reported that *Diplazium esculentum* is valuable in the Philippines since its young fronds are made into a delicious and nutritious green salad. In contrast, species composition was very different between the three subsites as indicated by the lower SI values of similarity and higher CRD values of difference (Table 10). As mentioned earlier, differences in elevation and the degree of disturbance were the causal factors for this result.

Pteridophytes As Habitat Indicators

Since species richness of Pteridophytes was not a good indicator of prevailing habitat conditions in my study area, a special species or a certain group of Pteridophytes which reflect the overall conditions of the area were used. Selection of these important indicator species was given great care and was based on their abundance and uniqueness to a particular habitat. For the strongest factual support, the CMU Herbarium Database at the Department of Biology was consulted for verification of the different habitats and abundance of the indicator species selected .

DOF and BB/DF Areas

As noted above, there was no significant difference species richness, diversity, and composition between the three established subsites in the two deciduous forests. The DOF and BB/DF forests were both very disturbed, degraded, and suffer continuous destruction by man and his feral animals while fire, grazing, and logging are still going on. Likewise, the results of several studies revealed that DOF and BB/DF in Thailand are really disturbed areas. In fact, Maxwell *et al.* (1995) stated that DOF in Thailand has lost much of its soil and as a consequence an open, often scrubby, fire climax, relatively short kind of forest with many Dipterocarpaceae and Fagaceae has developed. The BB/DF is no exception because, as stated by Maxwell (1994), this forest was originally a deciduous hardwood (teak) forest.

The characteristic Pteridophyte species in the DOF area were *Selaginella repanda, S. ostenfeldii* and *Cheilanthes tenuifolia* (Table 13). These three species were the most abundant in this site, indicating that they are the only ones which thrive under very degraded and seasonally arid conditions. Similarly, the CMU Herbarium Database has the same information that these species are only found in very degraded habitats such as DOF. Likewise, Tagawa and Iwatsuki (1979, 1985) reported that these species are found in seasonally dry, lowland forests. Therefore, if these three species are seen together in an area, they are considered as indicator species of a disturbed, degraded, deciduous dipterocarp-oak forest. If one happened to see these three species in a particular area without knowing the type of surrounding forest, one can tell right away that it is a DOF. With this particular finding, it is proposed that a DOF, as far as the Pteridophyte flora is concerned, can be referred to as **SROC.**[1]

The characteristic Pteridophytes in the BB/DF area were *Selaginella repanda, Dryopteris cochleata*, and *Anisocampium cumingianum* (Table 13). As expected, Maxwell *et al.* (1995) found these species dominant in disturbed, degraded BB/DF at Doi Khuntan National Park. Also, the CMU Herbarium Database has the same information. Even though *Selaginella repanda* was also dominant and considered as one of the indicator species in DOF, it was also dominant in the BB/DF area and considering the earlier findings that the conditions in the DOF and BB/DF were more or less similar, i.e. very degraded, seasonally dry and arid soil, deciduous vegetation, and are contiguous, it can also be considered as one of the indicator species in the BB/DF, provided that the above three species are found together in the same type of habitat. Therefore, the Pteridophyte flora in BB/DF in consideration of the three dominant representatives can be referred to as **SEDA.**[2]

[1] S = *Selaginella*, R = *repanda*, O = *ostenfeldii*, C = *Cheilanthes*

[2] SE = *Selaginella*, D = *Dryopteris*, A = *Anisocampium*

EGF Area

Although tea plantations are common in the EGF area, the soil was not very disturbed for it has never been severely degraded since the forest canopy has only been partially destroyed because the leaf quality of tea plants is best with about 50% shade (Maxwell, 1997, personal communication).

However, earlier findings revealed that disturbed subsites in the EGF were generally different from the less disturbed ones and this was attributed to the presence of Mae Kampong Village which has been established in this area for over a century, thus, there is a history of forest destruction. A good example is the dirt road that cut through the forests resulting in constant landslides as well as to the cutting of many trees adjacent to the road. As a consequence, a large gap was created which was occupied by a variety of sun-loving Pteridophytes. The dominating species in these open areas were *Dicranopteris linearis* var. *linearis*, *Blechnum orientale,* and *Pteridium aquilinum* ssp. *aquilinum* var. *wightianum* (Table 13). These three species were good indicators of the degraded conditions in this area. Walker and Boneta (1995) observed that *Dicranopteris pectina* and *Gleichenia bifida* (both Gleicheniaceae), are always associated with heavily eroded areas in Puerto Rico, suggesting that they have roles in the establishment and succession of vegetation on landslides. Since these species are always associated with heavily disturbed, upland areas, they are good indicators of this kind of habitat. Thus, if these three species are observed in another area, one could immediately tell that the place is a degraded upland. Therefore, an open, very disturbed, evergreen forest in reference to Pteridophytes, could alternatively be called DIBP.[3]

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[3] DI = *Dicranopteris*, B = *Blechnum*, P = *Pteridium*

The EGFL area was not as disturbed as the EGFX because it was situated on the uppermost part of a ridge where there were no agricultural activities. The most abundant Pteridophytes in this area were: *Brainea insignis*, *Thelypteris hirtisora*, and *Bolbitis virens* var. *virens* (Table 13) which are characteristic species of a seasonal, shaded, upland forest. The CMU Herbarium Database confirmed this finding that these three species are always found in shaded EGF areas. From these findings, it is proposed that the Pteridophyte component in this kind of area be referred to as **BITB.**[4]

RR Areas

The Pteridophytes in the riverine areas of this study were completely different from those in the forest areas due to differences in habitat. However, species composition between the lower and upper parts of the stream was different. In the lower part of the stream, the most abundant species were *Equisetum debile* Roxb. ex Vauch. (Equisetaceae) and *Thelypteris nudata* (Roxb.) Morton (Thelypteridaceae) (Table 13). Although these species were abundant in this area, it is improper to use them as bioindicators of lower stream conditions because they are also found in streams at higher elevations in other places (CMU Herbarium Database). In the upland part of

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[4] BI = *Brainea*, T = *Thelypteris*, B = *Bolbitis*

the stream, the most abundant Pteridophyte species were *Colysis pothifolia* (D. Don) Presl, *Leptochillus decurrens* Bl. (both Polypodiaceae), and *Thelypteris ciliata* (Wall. ex Benth.) Ching (Thelypteridaceae). As reported by Tagawa and Iwatsuki (1988, 1989) and the CMU Herbarium Database, these species are always associated in streams at higher elevations. Consequently, they are bioindicators of a permanent stream at higher elevations and can be called CLT[5] as far as the Pteridophyte flora is concerned.

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[5] C = *Colysis*, L = *Leptochillus*, T = *Thelypteris*