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RESEARCH ARTICLE

Notes on the Vegetation of the Fast-flowing Streams in Peninsular Thailand, the Tropical Mainland of South East Asia

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ABSTRACT: The species composition and structure of the plant communities along and in the fast-flowing streams on different bedrock types of the tropical mainland South-East Asia were investigated. The study was carried out in Peninsular Thailand, on the Nakhon Si Thammarat mountain range. A total number of 14 plots were placed within the five selected streams where vascular plants species had been collected, starting from November 2010 until July 2012. The estimation of the species was calculated by computer program EstimateS, and in order to distinguish plant communities, a cluster analysis was performed. A total number of 109 species of vascular plants has been recorded, with 59 species in the granite and 60 in the calcareous bedrock streams. There were four types of plant communities that had were categorized; of which three types occurred in the granitic bedrock streams and the other could be seen exclusively in the calcareous bedrock. It is convinced that the types of the bedrock as well as the topographic features of the streams might have major impact on the characterization of the plant communities.

KEY WORDS: Plant community, stream, tropic.

INTRODUCTION

The stream ecosystems are part of such lotic systems, which refers to the flowing waters. The definition identifies a stream as the body of water with a current, confined with a bed and banks (Hauer and Lamberti, 2006). These lotic systems could be described as very dynamic since there is a constantly shifting mosaics of interconnected habitats, which would be created, modified, destroyed, and rebuilt (Hauer and Lamberti, 2006). This dynamic process stated the importance of habitat replacements and the biological communities' synchronization in a flowing water body (Vannote, 1980).

Stream ecosystems of the tropical regions are one of the least explored areas of the world (Dudgeon, 2008). The habitats of the tropical streams are exposed not only to horizontal dynamics, but to the alternate environments. During summer period the water level is low, the plant species in the streams are exposed to the dry air and very high temperatures. On the other hand, during rainy season water level rises and flash floods are more frequent, so the plant species are exposed to severe flooding periods. In such variable environment few plant species are able to adapt, therefore, survive in these harsh conditions. Knowledge and studies about these species have been noted in tropical regions around the world, but unfortunately, none of the ecological studies have been done in tropical Asia (which mostly fall into the South-East Asia region), precisely in Peninsular Thailand. Few collections of the species along the streams were made in the northern part of Thailand (van Beusekom and Geesnik 1971–1972, from van Steenis, 1981) and taxonomic studies on the family Podostemaceae were done (Kato, 2004, 2006). The more recent ecological study was done on Mekong River (Puff, 2011). When diversity is taken into account, it is important to note that Peninsular Thailand is on the boundary between two phyto-geographical regions i.e. the Continental south-east Asian and the Malesian regions (Takhtajan, 1986, 1988; Woodroff, 2003).

This study is among the first vegetation studies on the streams on the tropical mainland South-East Asia. The descriptions of the plant communities along and in the streams as well as the floristic composition in the two most common types of bedrock types i.e. granite vs. calcareous in Peninsular Thailand were provided. In additions, the descriptions of each microhabitat type together with plant diversity have been noted. Moreover, due to the fact that the streams of the Peninsular Thailand are popular touristic and picnic areas, their destruction is, therefore, imminent. It is expected that the present study would, then, provide a first overview of the plant communities of the fast-flowing streams in the tropical mainland South-East Asia which could be available for further investigations in the future.

MATERIAL AND METHODS

Study areas

Study areas had been located on the mountain range of Nakhon Si Thammarat/Banthat range, which is running North-South dividing the Peninsula to the East and West coasts. The climate of the area is tropical monsoon (Am) according to Knpen's classification (Kottek et al., 2006) with slight climate differences in the western and eastern coasts. The average temperature (based on the data between years 1971–2000) between eastern and western coasts is approximately same, 27.3°C and 27.5°C respectively, while the amount of the precipitation and the beginning of rainy season differs (Thai Meteorological Department, 2012b). The heaviest rainfall on the East coast is from November to January of the following year, with a mean rainfall of 759.3 mm, while on the West coast is during August and September with a mean of 1895.7 mm (Thai Meteorological Department, 2012a).

All of study areas are surrounded by natural vegetation and have similar stream constitutions (repetitions of riffles, runs and pools). Study sites were divided based on the bedrock types into: granitic and calcareous streams respectively. The granitic bedrock streams are located on the East coast in Songkhla (Ton Nga Chang and Pha Dam waterfall in the Ton Nga Chag Wild Life Sanctuary), Pattalung provinces (Lan Mom Jui waterfall in the Khao Ban Tad Wild Life Sanctuary), while the calcareous bedrock streams are located on the West coast, in Trang (Chao Pa waterfall, Palaen district) and Satun provinces (Than Plew waterfall, Thung Wa district) (Fig. 1).

A total number of 14 plots were placed within the streams, with 3 plots each in four streams and one stream with 2 plots each. The full descriptions of plots are presented in Table 1. The streams width varied from 10 m to 26 m, so placed plots were different in quadrangular shape but the areas that they covered were kept constant in the range of 450 to 600 m^2 representing the minimal area.

Data collection

All vascular plants had been collected once a month starting in November 2010 until July 2012, in order to cover all flowering seasons. All those species confined within the stream beds, on the rocky islands or on the stream banks which were regularly flooded were included in the study.

Scientific names, author names and abbreviation followed the International Plant Names Index (IPNI) (The Plant Names Project, 1999). Flowering plant family classification followed the Angiosperm Phylogeny Group (APG III, 2009). Fern classification followed the Flora of Thailand (Tagawa and Iwatsuki, 1979, 1985, 1988, 1989) and Smith et al. (2006, 2008).

Plants collected were identified as far as possible with available taxonomic literature. Voucher specimens were deposited at the Herbarium, Department of Biology, Faculty of Science, Prince of Songkhla University (PSU), Songkhla, Peninsular Thailand as well as the Forest Herbarium (BKF), Department of National Parks Wildlife and Plant Conservation, Ministry of Natural Resources, Bangkok, Thailand.

The abundance and percentage of coverage of species occurring in the plots were measured and transformed into nine-grade ordinal scales (OTV), where "c" refers to the percentage covering (van der Maarel, 1979, 2007).

Data analysis

The estimation of the species richness for each type of the bedrock streams as well as the total number of species on all fast-flowing streams were calculated by the computer program EstimateS (version 8.2.0, Colwell, 2009). The estimated number of species was calculated by the first order Jackknife, in order to see if the observed number of species was adequately represented. The Jackknife1 was calculated from the formula $S_{est}=S_{obs}+R(m-1/m)$; where S_{es} refers to the total number of estimated species; S_{obs} refers to the total number of observed species; R is a number of species that occurs only in one sample (singletons) and m is a number of the study sites.

The Bray-Curtis similarity index was calculated for the similarities between the plots. The index was calculated by the formula $S_{bc} = 2w/(m+n)$; where m is the total abundance of the species for the first sample; n is the total abundance of the species for the second sample; w is the minimum abundance amount for the shared species.

In order to distinguish plant communities, a cluster analysis according to Flexible beta linkage with β= -0.25 and Sørensen (Bray-Curtis) distance were used by the computer program PC-ORD (version 5.33, McCune and Mefford, 2006).

RESULTS

Plant species richness

A total number of 109 species was found, belonging to 75 genera and 49 families. Among them, 5 species were Lycophytes, 28 species Monilophytes, and 76 species of Angiosperm (67 Eudicots and 9 Monocots). The most abundant famililies of Eudicots were Rubiaceae (16 species), Moraceae (6 species) and Gesneriaceae (5 species); while the most common Monocot family was Zingiberaceae (4 species). On the other hand, the most common families of Monilophytes were Hymenophyllaceae, Pteridaceae and Tectariaceae, each with 4 species. The estimated number of overall species from the present study was 121 (Table 2.). All

Table 1. List and description of the plots within the selected study sites

Study plot	Code	Map reference	Altitude (m)	Width (m)	Length (m)	Depth (m)	Bedrock type
Ton Nga Chang 1	TC1	N 06˚ 56.703' E 100˚13.271'	485	15	30	0.5–1.2	granite
Ton Nga Chang 2	TC2	N 06˚ 56.709' E 100˚ 13.159'	489	14–18	25	0.35–1.5	granite
Ton Nga Chang 3	TC3	N 06˚ 56.700' E 100˚ 13.095'	495	12	45	0.35–0.7	granite
Pha Dam 1	PD1	N 06˚49.501' E 100˚ 13.574'	162	15	33	0.01–2.3	granite
Pha Dam 2	PD2	N 06˚49.479' E 100˚ 13.531'	175	10	40	0.15–1.7	granite
Pha Dam 3	PD3	N 06˚49.494' E 100˚ 13.472'	190	15	37	0.05–0.7	granite
Lan Mom Jui 1	LJ1	N 07˚ 15.294' E 100˚ 02.287'	140	15	32	0.1–2.3	granite
Lan Mom Jui 2	LJ2	N 07˚ 15.365' E 100˚ 02.349'	90	20	30	0.15–1.7	granite
Than Plew 1	TP1	N 07˚ 06.664' E 099˚ 50.656'	156	10–20	35	0.07–0.6	calcareous
Than Plew 2	TP2	N 07˚ 06.652' E 099˚ 50.644'	120	15–20	30	0.08–1.2	calcareous
Than Plew 3	TP3	N 07˚ 06.659' E 099˚ 50.597'	117	20–25	26	0.03–1.4	calcareous
Chao Pa 1	CP1	N 07˚ 14,284' E 099˚ 50.684'	92	20–22	20	0.3–3.3	calcareous
Chao Pa 2	CP2	N 07˚ 14.286' E 099˚ 50.725'	120	22–26	25	0.5–1.35	calcareous
Chao Pa 3	CP3	N 07˚ 14.303' E 099˚ 50.769'	133	20	30	0.3–1.2	calcareous

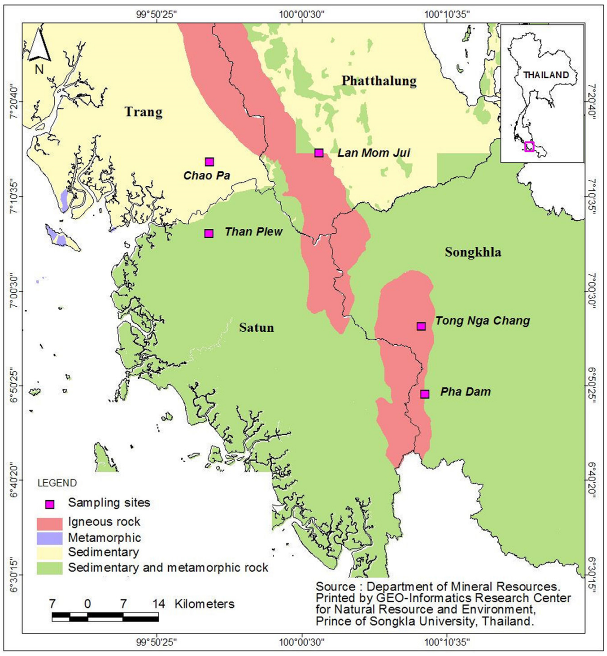

Fig. 1. Bedrock types and the vegetation sampling sites for the selected streams in Peninsular Thailand.

species recorded were accounted for 90% of the estimated existing plant species found in the study areas.

The total numbers of the species in the streams of two different bedrock types were not that different. In the granitic bedrock streams, 59 species of plants were recorded (65 estimated), while in the calcareous bedrock streams, there were 60 species (64 estimated) (Table 2.). Among the species in the granitic bedrock streams, 34 were Eudicots, 6 Monocots, 16 Monilophytes and 3 Lycophytes, with the most common species, i.e. *Ficus ischnopoda* Miq., *Eurya nittida* Korth., *Argostemma condensum* Craib, *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f., *Bolbitis heteroclita* (Presl) Ching ex. C.Chr, *Cephalomanes javanicum* (Blume) C.Presl and *Osmunda javanica* Blume. Within 60 recorded species in the calcareous bedrock streams 38 were Dicots, 5 Monocots, 15 Monilophytes and 2 Lycophytes, with the most common species, i.e. *Begonia aliciae* C.E.C.Fisch., *Saraca indica* L., *Paraboia gracillima* Kiew, *Argostema neurocalyx* Miq., *Ixora bracteolata*

Table 2. Observed and estimated number of species as well as the sampling completeness along granitic and calcareous bedrock streams

Type of bedrock stream	Observed species number	Estimated species number	Sampling completeness
Granitic bedrock streams	59	65	90.70%
Calcareous bedrock streams	60	64	93.70%
Total	109	121	90.00%

Craib, *Nephrolepis undulata* (Afzel.) J.Sm., *Calciphilopteris ludens* (Wall. ex Hook.) Yesilyurt & H.Schneid., *Tectaria manilensis* (C.Presl) Holttum and *Globba leucanta* var. *bicolor* Holttum. The numbers of the species along these two types of the bedrock streams were similar, while the diversity on each bedrock type was specific, with only 10 species collected from both types of bedrock streams (i.e. *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman, *Antrophyum callifolium* Blume, *Tectaria angulata* (Willd.) C.Chr., *Elaeocarpus grandiflorus* Sm., *Bauhinia pottsii* G.Don, *Syzygium* sp.1, *Ophiorrhiza communis* Ridl., *Ixora javanica* DC., *Homalomena repens* Ridl. and *Donax canniformis* (G. Forst.) K. Schum.).

The microhabitat types and the species composition

Based on the topographic characters of the streams in both types of bedrock, four microhabitat types that had been inhabited by the plants of the streams could be recognized i.e.:

1. **Rocky areas:** There is highest diversity of plants in these habitat areas comparing to others, especially the species that are confined to the streambeds. Moreover, such microhabitat type was further divided into various ones. Almost all of these areas have been highly influenced by the fluctuation of the water levels at intervals.

   The microhabitat types in rocky areas can be categorized as follows:

   1.1. *Small emergent rocks and the sides of the boulders.* Such microhabitat types have been regularly influenced by interval flooding conditions with high water velocities. They were usually located in the streambeds, and during the rainy season the plant species would have been either totally or partially submerged. Only six plant species have been found in these microhabitats since they could be able to withstand such conditions, i.e. *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman, *Cephalomanes javanicum* (Blume) C.Presl, *Osmunda javanica* Blume, *Bolbitis heteroclita* (Presl) Ching ex. C.Chr, *Ficus ischnopoda* Miq. and *Homalomena repen*s Ridl.

   1.2. *The rock crevices.* The rock crevices are narrow spaces between two separated rocky areas where there have been accumulations of litter pockets/soil, hence, keeping the humid condition that favored many herbaceous species of both annual and perennial ones. This mentioned microhabitat was occasionally flooded during rainy season. However, it has been exposed to the direct sunlight throughout the year. Some common herbaceous species in such places are: *Globba pendula* Roxb., *Cyperus* sp. and *Pogonatherum paniceum* (Lam.) Hack. etc.

   1.3. *The boulders*. These microhabitats are located along both sides of the stream banks. They have never been flooded by the accessing water level in the rainy season. However, their upstream sides are always under constant pressure from the high water velocity. In the dry period, the streams become less narrow as the water level decreases, then these boulders connect to the rocks/islands in streams. Such microhabitats occurred in the deep shade under canopy of big trees and were occupied by the plant species that would not directly be influenced by the streams. Most species which could be seen here are among the herbaceous species e.g. *Argostemma* spp., *Begonia* spp., *Kaisupeea orthocarpa* B.L.Burtt., etc.

2. **Stream banks**. These microhabitats had been categorized according to their parent material substrate that had formed as the bank shape, i.e. soil, sand and rock banks:

   2.1. *The soil banks.* Such microhabitats could be seen on the bank where the stream performed rather low velocity, and provided sedimentation chances of the silt as to form a soil bank, such as in the pool areas of the stream. The soil banks are able to accommodate many woody trees and shrubs e.g. *Pseuduvaria reticulata* Miq., *Kopsia pauciflora* Hook.f., *Ficus tinctoria* G.Forst., *Ardisia* sp. and *Ixora javanica* DC.

   2.2. *The sandy banks/beaches.* Along the given areas of stream banks in the place where stream performed a low velocity, especially, around the rocky areas in the stream, these conditions could slow down the stream. In such places, the sedimentations of coarse sand occurred and formed a sandy bank/beach. In contrast to the former ones, these microhabitats are always in the sun light of open areas along streams. Few species of herbs were recorded which were more tolerant of the access heat and light. The most common one is *Justicia genderussa* Bur.f.

   2.3. *The rocky banks*. This is the most common type of banks along any fast-flowing stream. These habitats are able to accommodate only the plants species which can stand the stress from high

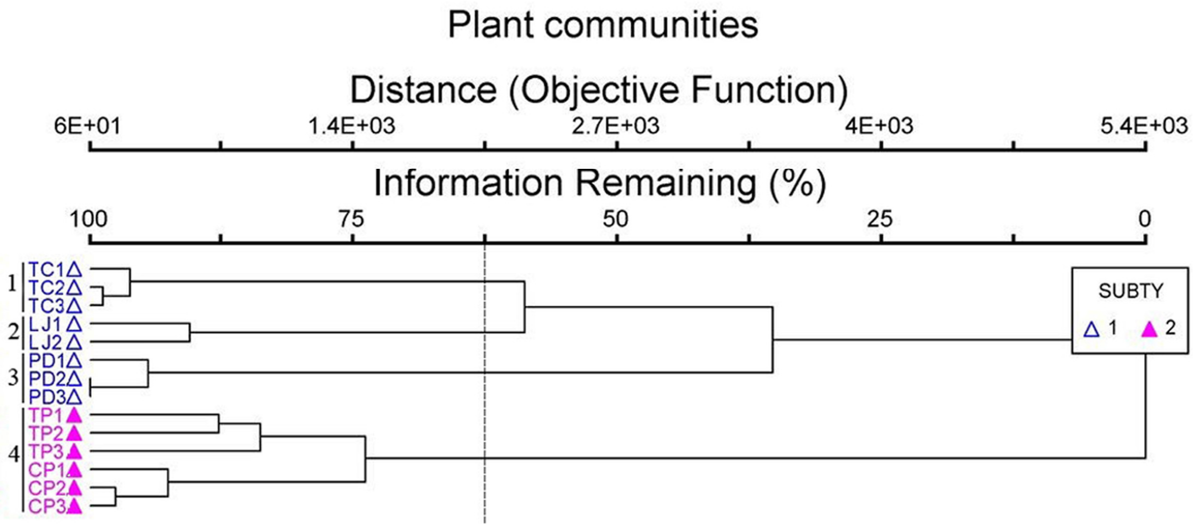

Fig. 2. Cluster analysis dendrogram based on similarities of the plant species composition and their abundances among the study sites. The numbers on the side represent communities. SUBTY 1 – Grainite bedrock; SUBTY 2 – Calcareous bedrock.

velocity of stream, especially in the rainy season, e.g. *Cephalomanes javanicum* (Blume) C.Presl and *Osmunda javanica* Blume.

3. **Stream floor**. The floor of the stream is a permanent under-water microhabitat. The various stream depths as well as velocities have impacts on the plant species composition which grow directly in the streams, so does the types of the bedrock that formed the stream bases. In the case of granite bedrock, none of the vascular plant species were noted growing in such extreme condition. On the other hand, in the calcareous stream few woody plant species had occupied the pool areas of the stream floor, e.g. *Ardisia oxyphylla* Wall. & A.DC., etc. where the stream velocity is not so high. Along the slope areas in calcareous streams, where water run quickly many tree species, e.g. *Elaeocarpus grandiflorus* Sm., *Neonauclea* sp. and *Syzygium* sp. are rather common as well as some herbaceous species such as *Homalomena repens* Ridl. etc.

4. **Shallow pools**. The shallow pools are those microhabitats on the rocks that during the rainy season and excessive flooding filled with water. On the other hand, in the dry period, they remained as shallow rocky pits/dents. Plant species that occupied these areas are mostly grasses and sedges species, e.g. *Cyperus* sp., *Eriocaulon* sp., etc.

Plant communities

The total number of 14 plots along the streams of Peninsular Thailand had been sampled in order to classify the plant communities. The species number in each study plot varied from 17–41 (Table 3.), with the highest number in the plot TP2 (42 species) and lowest in the plot TC3 and the plot LJ1 (17 species). Only one species *Homalomena repens* Ridl., a common stream herb, occurred in all 14 plots, followed by *Ophiorrhiza communis* Ridl. which had been recorded in 12 plots, while there were 17 species found exclusively in only a single plot (Table 4.).

Based on the Cluster analysis and the Bray Curtis similarity index, four types of the plant communities had been distinguished. The Cluster analysis clearly separated the communities on the granitic bedrock streams (blue color in Fig. 2.) from the ones on the calcareous bedrock streams (pink color in Fig. 2.). As the representation of the plant communities within granitic bedrock streams was not apparent, Bray-Curtis similarity index had been used in the present study to confirm the similarities vs. the differences between each proposed community. The Bray-Curtis similarity index had confirmed the two types of the communities (Community 1 and 3) on the granitic bedrock streams adding the third type (Community 2), which showed very low similarities as well as the low number of shared species with previous communities (Table 3).

The proposed plant community types along the fast-flowing streams of the two bedrock types in Peninsular Thailand are as follows:

Plant communities of the granite bedrock stream:

Community 1*: Croton – Callophyllum rupicola* scrub
(plots: TC1, TC2, TC3) Fig. 3

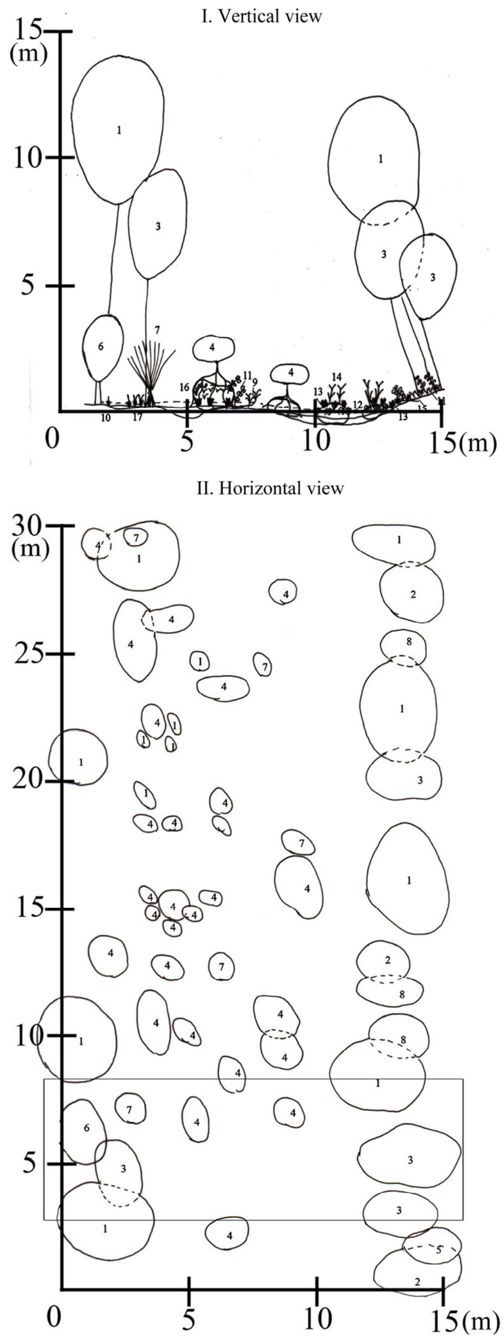

Fig. 3. The vegetation profile for the community Croton-Callophyllum rupicola scrub. I: Vertical view of the profile. II: Horizontal view of the profile. 1: *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f. 2: Unidentified bamboo; 3: *Calophyllum rupicola* Ridl. 4: *Ficus ischnopoda* Miq. 5: *Croton* sp. 6: *Ixora javanica* DC. 7: *Osmunda javanica* Blume. 8: *Phyllanthus gracilipes* (Miq.) Arg. 9: *Justicia gendarussa* Burm. f. 10: *Eriocaulon* sp. 11: *Globba pendula* Roxb. 12: *Homalomena repens* Ridl. 13: *Cephalomanes javanicum* (Blume) C.Presl. 14: *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman. 15: *Argostemma condensum* Craib. 16: *Humata angustata* (Wall. ex Hook. & Grev.) J. Sm. 17: *Cyperus* sp.

The plant community was situated in the open areas under full sunlight. The streambed was mostly occupied by boulders and small emergent rocks. During dry season when the water level decreased, boulders were seen as a part of the bank where rock crevices and shallow pools were formed. The stream banks were composed of rock with more/less small sand beach. Tree species that occupied rocky banks often lean diagonally towards the stream, hence created partly shady areas on the banks. Stream floor was mainly composed of compacted rock and pebbles/gravel. Water level would vary from very shallow at the bank sides to deep pool areas where the sand and gravel would be accumulated. The water flow has varied from a fast turbulence to a ripple one and would be rather stagnant in such pool areas.

The vegetation was 2-layered. The upper tree layer was up to 20 m high, while the lower layer was dominated by herb and few shrub species. Few tree species were dominant along stream banks, e.g. *Croton* sp., *Callophyllum rupicola* Ridl. and *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f. The ground floor was characterized by the species that were confined to the streambed, e.g. *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman, *Cephalomanes javanicum* (Blume) C.Presl., *Ficus ischnopoda* Miq, *Homalomena repens* Ridl., and *Osmunda javanica* Blume. These species often occurred along the streams, in spite of that they were not characteristic species of the mentioned community as they could be often found also in other community types as well. The minor components of this community were the herb species of specific microhabitats, e.g. *Globba pendula* Roxb in the rocky crevices; *Pogonatherum paniceum* (Lam.) Hack. and *Eriocaulon* sp. in shallow pool areas; *Argostemma condensum* Craib and *Selaginella inaequilifolia* (Hook.Grev.) Spring on the boulders.

Community 2: *Ficus tinctoria* woodland (plots: PD1, PD2, PD3) Fig. 4.

The *Ficus tinctoria* woodland was situated along the streams in shaded areas without the direct sunlight. The streambed had been mostly occupied by small emergent rocks. The stream banks were composed of either degraded litter/silt/soil or rocks in some given areas. The stream floor was composed of pebbles, gravel and sand that during the dry season, when water level decreased, some of the stream floor areas come up above the water as islands. There were no boulders and deep pool area at all in such community. However, in the rainy season, water level increased and covered such emergent rocks, presenting chaotic and chute flow throughout. Just along few nearby bank lines that the stream was not chaotic and chute, but rather rippled.

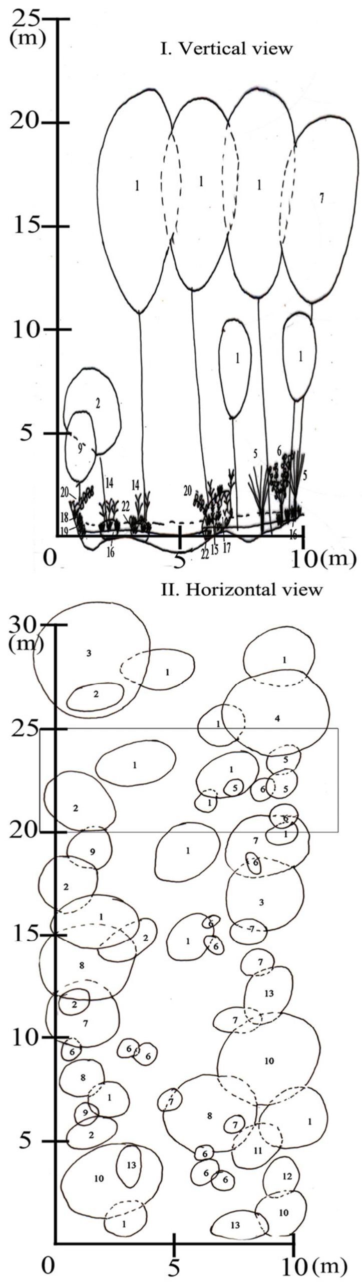

Fig. 4. The vegetation profile for the community Ficus tinctoria-woodland. I: Vertical view of the profile. II: Horizontal view of the profile. 1: *Ficus* sp.1. 2: *Donax canniformis* (G. Forst.) K. Schum. 3: *Bauhinia pottsii* G.Don. 4: *Sterculia balanghas* L. 5: *Cyathea podophylla* (Hook.) Copel. 6: *Tectaria angulata* (Willd.) C.Chr. 7: *Neonauclea* sp.3. 8: *Rinorea* sp. 9: *Trigonostemon aurantiacus* (Kurz ex Teijsm. & Binn.) Boerl. 10: *Ficus tinctoria* G.Forst. subsp. *gibbosa* (Blume) Corner. 11: *Pheanthus* sp. 12: *Ixora javanica* DC. 13: *Ardisia* sp.1. 14: *Bolbitis heteroclita* (Presl) Ching ex.C.Chr. 15: *Bolbitis appendiculata* (Willd.) K.Iwats. 16: *Cephalomanes javanicum* (Blume)C.Presl. 17: *Leptochilus pedunculatus* (Hook. & Grev.) Fraser-Jenk. 18: *Sellaginella wallichii* (Hook.&Grev.) 19: *Argostemma pictum* Wall. 20: *Globba pendula* Roxb. 21: Unidentified bamboo. 22: *Homalomena repens* Ridl.

The vegetation had been dominated by the tree species that occurred in the stream banks as well as in the streambed. The community was 3-layered. The upper canopy layer was 15–30 m high and dominated by tree species, i.e. *Ficus tinctoria* G.Forst. and some other *Ficus* sp. Some minor components in such vegetation were *Bauhinia pottsii* G.Don, *Pheanthus* sp., *Rinorea* sp. and *Sterculia balanghas* L. occured sporadically. The lower layer was 5–10 m high and mainly composed of the shrub species, e.g. *Ardisia* sp., *Donax canniformis* (G. Forst.) K. Schum. and *Trigonostemon aurantiacus* (Kurz ex Teijsm. and Binn.) Boerl. The ground floor was mainly occupied by the fern species, e.g. *Bolbitis appendiculata* (Willd), *Bolbitis heteroclita* (Presl) Ching ex.C.Chr, *Cyathea podophylla* (Hook.) Copel., *Leptochilus pedunculatus* (Hook. & Grev.) Fraser-Jenk. and *Tectaria semipinnata* (Roxb.) C.V.Morton. The species confined to the streambed were not frequent in this community and occurred sporadically on the emergent rocks, e.g. *Cephalomanes javanicum* (Blume) C.Presl. and *Homalomena repens* Ridl.

Community 3: *Syzygium nervosum – Eurya nitida* scrub (LJ1, LJ2) Fig. 5

Syzygium nervosum-Eurya nitida scrub was situated along the streambed in the areas with more open space. The streambed was mostly occupied by big boulders and few emergent rocks, which had not been completely flooded, even during the rainy season when the water level was increased. The stream banks where the vegetation was present, was mainly formed by soil in general, but there were few places where rocky banks were situated. The tree species that occupied the stream banks leaned diagonally towards the stream, therefore, created some shady areas. Concerning the stream floor, it was mainly composed of rocks with gravel and silt. The water depths varied from shallow rocky areas to deep pools where the stream has run slowly. In contrast, the stream running in the shallow rocky areas was chaotic and chute.

This community was composed of 3-layers. The upper layer had been dominated by the tree species, i.e. *Syzygium nervosum* DC., while *Diospyros* sp. and *Garcinia* sp. were distributed sporadically throughout the community. The middle layer had been dominated by the shrub species, i.e. *Eurya nitida* Korth., *Ficus ischnopoda* Miq. and *Ardisia fulva* King & Gamble. The ground floor had been composed of many herb species, e.g. *Globba pendula* Roxb., *Homalomena repens* Ridl., *Ophiorrhiza communis* Ridl. and *Selliguea heterocarpa* Blume etc. which were minor components of the community.

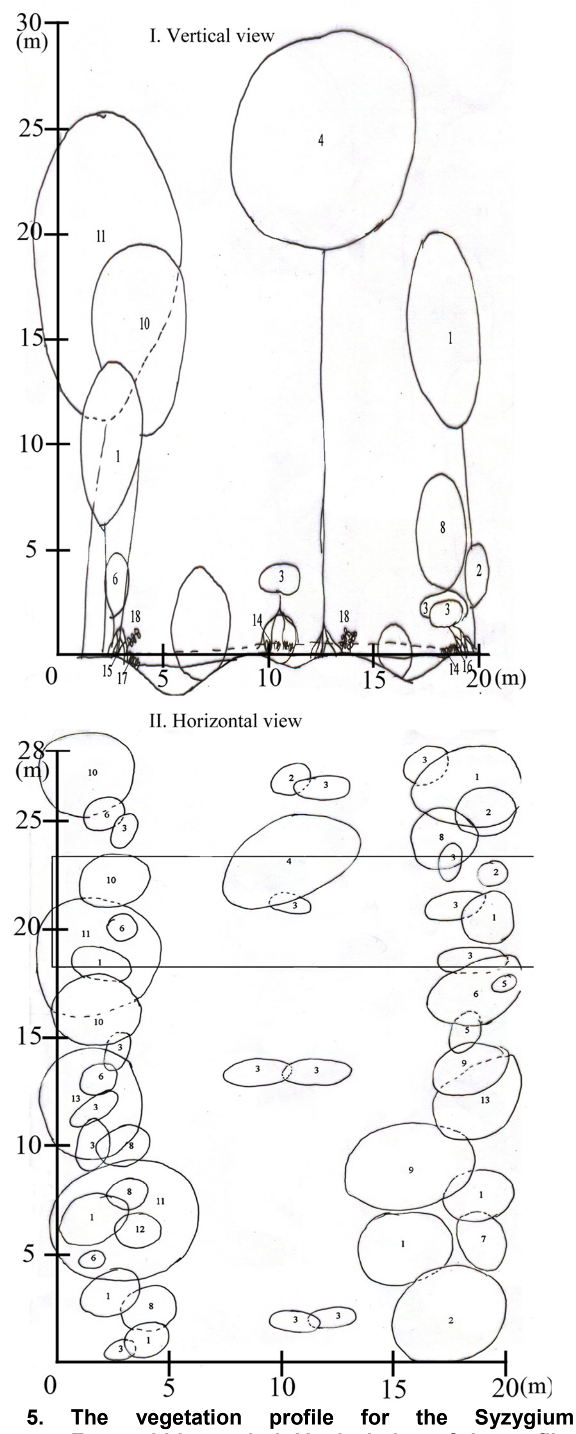

Fig. 5. The vegetation profile for the Syzygium nervosum-Eurya nitida scrub. I: Vertical view of the profile. II: Horizontal view of the profile. 1: *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f. 2: *Bridelia tomentosa* Blume. 3: *Ficus ischnopoda* Miq. 4: *Syzygium nervosum* DC. 5: *Ixora javanica* (Blume) DC. 6: *Ardisia fulva* King & Gamble. 7: *Ficus* sp.3. 8: *Eurya nitida* Korth. 9: *Pandanus* sp. 10: *Syzygium* sp.1. 11: *Diospyros* sp. 12: *Syzygium* sp.2. 13: *Garcinia* sp. 14: *Homalomena repens* Ridl. 15: *Selliguea heterocarpa* Blume. 16: *Ophiorrhiza communis* Ridl. 17: *Pogonatherum paniceum* (Lam.) Hack. 18: *Globba pendula* Roxb.

Plant communities of the calcareous bedrock streams:

Community 4: *Saraca indica* woodland (TP1, TP2, TP3, CP1, CP2, CP3) Fig. 6

The most common microhabitat which belonged to this type of plant community was boulders placed in shady areas. Stream banks were composed of litter/silt/soil mixed up with limestone platforms. The stream floor was mostly solid, composed of the limestone accumulations, with gravel and silt in the pool areas. The water depths varied from shallow places of chaotic water flow (fast-flowing) to the deep pool areas with a ripple as well as rather stagnant (low-flowing) areas.

The vegetation of this community had been dominated by the tree species that mostly occupy streambed. The community was 3-layered. The upper canopy layer was 20–30 m high and was composed of the species that occurred sporadically throughout the plots, e.g. *Bauhinia pottsii* G.Don, *Duabanga grandiflora* Walp and *Radermachera glandulosa* Miq. etc. The lower canopy layer was 10–20 m high and composed of *Saraca indica* L., which formed more/less pure stands plus minor components, e.g. *Elaeocarpus grandiflorus* Sm., *Kopsia pauciflora* Hook.f, *Neonauclea* sp., *Pseuduvaria reticulata* Miq. and *Syzygium* sp. etc. The crowns of those trees overlapped each other and produced continual patches of the canopies. The ground floor was dominated by the herb species, which occurred on the boulders in the shady areas, e.g. *Argostema neurocalyx* Miq, *Begonia aliciae* C.E.C.Fisch, *Begonia integrifolia* Dalzell, *Cyclosorus menisciicarpus* (Blume) Holttum, *Epithema* sp., *Kaisupeea orthocarpa* B.L.Burtt, *Tectaria manilensis* (C.Presl) Holttum, etc. They had performed a seasonal dynamic in vegetation. During dry period the vegetation was dominated by one set of species, e.g. *Argostemma neurocalyx* Miq., *Begonia aliciae* C.E.C.Fisch., *Begonia pteridiformis* Phutthai, *Caulokaempferia saksuwaniae* K.Larsen, *Epithema* sp., etc. During rainy season, these species shed their leaves and disappeared and the other set of species dominated e.g. *Begonia integrifolia* Dalzell, *Cyrtandra pendula* Blume, *Kaisupeea orthocarpa* B.L.Burtt, *Nephrolepis undulata* (Afzel.) J.Sm., etc.

DISCUSSION

Floristic richness

In the present study, total number of the recorded species 109, reflecting the diversity of the streams and the flooded banks. The observed number of species was comparable with the similar works done in Thailand on rivers and streams (Puff and Chayamarit, 2011; Maxwell

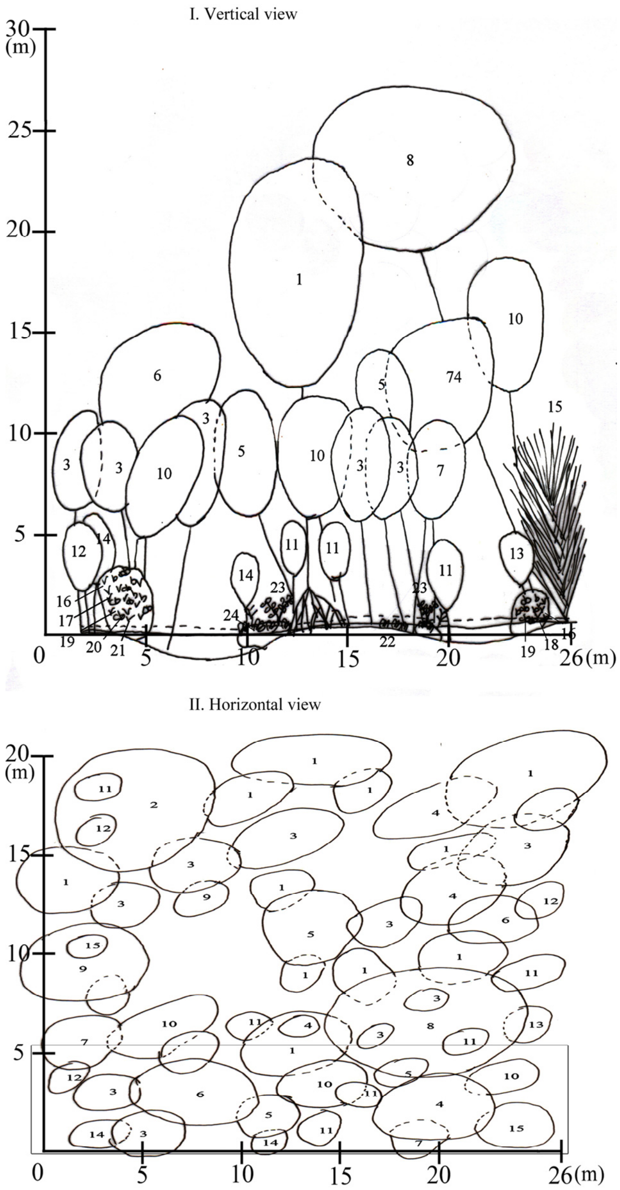

Fig. 6. The vegetation profile of the Saraca indica woodland. I: Vertical view of the profile. II: Horizontal view of the profile. 1: *Syzygium* sp.1. 2: *Duabanga grandiflora* Walp. 3: *Saraca indica* L. 4: *Neonauclea* sp.1. 5: *Ficus auriculata* Lour. 6: *Elaeocarpus grandiflorus* Sm. 7: *Orophea enterocarpa* Maingay ex Hook.f. 8: *Radermachera glandulosa* Miq. 9: Antidesma sp. 10: *Neonauclea* sp.2. 11: *Ardisia oxyphylla* Wall. & A.DC. 12: *Cytrus* sp. 13: *Ixora javanica* DC. 14: *Ixora bracteolate* Craib. 15: Unindetified palms. 16: *Epithema* sp. 17: *Begonia pteridiformis* Phutthai. 18: *Begonia integrifolia* Dalzell. 19: *Argostemma neurocalyx* Miq. 20: *Tectaria manilensis* (C.Presl) Holttum. 21: *Ophiorrhiza communis* Ridl. 22: *Homalomena repens* Ridl. 23: *Tectaria angulata* (Willd.) C.Chr. 24: *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman.

, 2009; Muadsub et al., 2009). Concerning the floristic composition, the most abundant families in this study were Rubiaceae, Moraceae and Gesneriaceae, which are major families in Thai flora. In Thailand there are about 600 and 1,070–1,100 species of Rubiaceae and Moraceae, respectively (Berg et al., 2011; Puff et al., 2005). The diversity of fern and fern allies showed that Hymenophyllaceae is the most abundant family, which was expected as the species of this family prefer humid, moist and shaded areas, such as streams (Smith et al., 2006). It was interesting to note that several species that are very common and restricted to the fast-flowing streams had not been found in the present study (e.g. *Homonoia riparia* Lour., species from the genus *Microsorium* and from families Hydrostachiaceae and Podostemaceae). The absence of these species was probably due to size of the streams or bedrock preference of these species.

Microhabitats along the streams on different bedrock type

Types of the microhabitats were divided based on topographical characteristics of bedrock streams and their frequencies were clearly different along these two types of bedrock streams. Granitic bedrock streams supported more types of microhabitats comparing to the calcareous bedrock streams, and there were few microhabitats that occurred only along granitic bedrock streams. The existence of these microhabitats increased the species number along granitic bedrock streams, as species diversity is predicted to increase with the increase of heterogeneity (Townsend, 1989). The similar pattern of increase of the diversity with the increase of heterogeity was recorded in river Deben, England (Kemp et al., 1999) and in unregulated Danish streams (Battrup-Pedersen and Riis, 1999). Along calcareous bedrock streams the species that usually occurred along the stream banks, inhabited stream floor. In this case, the number of the species did not increase, but the number of individuals of specific species. The peculiarity of two different patterns of the plant distribution along granitic and calcareous bedrock streams was not yet recorded and further investigations and studies are necessary in order to make more precise conclusions.

Plant communities

The results of this study recognized four types of plant communities on two different bedrock types, three occurred on the granite bedrock streams and the other on the calcareous ones. The plant communities in granite and calcareous bedrock streams were different not only in composition, but in a structure as well. This suggested that the bedrock types might have some impacts on the plant species composition. These results correspond to the results of Baattrup-Pedersen and Riis (1999) and Sagers and Lyion (1997). However, it is far to conclude at this stage how the bedrock types play role in plant

Table 3. Similarities between the plots using Bray-Curtis similarity index and the shared numbers of species.

Study Plots	TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ1	TP1	TP2	TP3	CP1	CP2	CP3
												Number of shared species		
TC1		17	13	4	4	4	6	7	1	2	2	2	3	3
TC2	**0.72**		15	5	6	6	8	9	2	4	4	1	2	2
TC3	**0.70**	**0.73**		3	5	5	6	7	2	4	4	2	3	2
PD1	0.16	0.21	0.21		18	21	4	4	3	5	5	4	4	4
PD2	0.16	0.23	0.22	**0.78**		23	5	5	3	4	5	3	3	2
PD3	0.15	0.20	0.21	**0.85**	**0.85**		5	5	4	5	6	5	6	5
LJ1	0.25	0.28	0.25	0.18	0.20	0.20		16	3	4	4	4	4	4
LJ1	0.29	0.29	0.30	0.17	0.18	0.19	**0.82**		3	4	4	3	3	3
TP1	0.04	0.05	0.06	0.11	0.07	0.12	0.12	0.11		22	19	11	15	16
TP2	0.06	0.09	0.11	0.15	0.12	0.16	0.13	0.12	**0.65**		33	15	20	20
TP3	0.07	0.09	0.11	0.17	0.13	0.17	0.14	0.13	**0.55**	**0.76**		15	20	20
CP1	0.07	0.05	0.07	0.14	0.12	0.15	0.18	0.15	0.41	0.48	0.55		22	22
CP2	0.14	0.13	0.14	0.22	0.15	0.21	0.13	0.12	0.44	0.52	0.58	**0.80**		28
CP3	0.13	0.12	0.13	0.22	0.17	0.21	0.17	0.14	0.51	0.55	0.56	**0.77**	**0.83**	
Bray-Curtis similarity index														

species composition determining and it would need more investigations on many other aspects, e.g. habitats preferences and role of some selected biological factors in such habitats as well as the on-place physical environment and plant responses of each bedrock types.

The composition of the plant communities, along both types of the bedrock streams, revealed some species that were present and dominant in most of the communities. These species, e.g. *Ficus ischnopoda* Miq., *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f. and *Homalomena repens* Ridl. etc. were not characteristic species of those communities, however their frequency and distribution suggested that they are common species in and along the streams. On the other hand, the structure of the *Saraca indica* community on calcareous bedrock stream suggests a high relationship with the environment, as the seasonal change of the species was noted.

The plant communities occurred in and along the fast-flowing streams in the tropical areas, are rather fragile, as the results of the present study had suggested that the plant species composition of different bedrocks types and microhabitats are much different. Therefore, any change to the microhabitats in each bedrock types of the fast-flowing stream might change the plant species composition occurring there as well. The further studies, focusing on the physical environment and plant response in each habitat type, might give rise to the more understanding of how such bedrock types play role in species composition determining of the fast-flowing streams, such extreme and dynamic environment for plants, in the tropics.

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Table 4. Complete list of the species with their abundance and the frequency in the study plots

Taxa		Study plots														Freq
		TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ2	TP1	TP2	TP3	CP1	CP2	CP3	
Lycophytes																
Selaginellaceae	1. *Selaginella inaequilifolia* (Hook. & Grev.) Spring	2	2													2
	2. *Selaginella roxburghii* (Hook. & Grev.) Spring		2													1
	3. *Selaginella siamensis* Hieron.									2	2	3				3
	4. *Selaginella wallichii* (Hook. & Grev.)										2	2		2	3	4
	5. *Selaginella* sp.				1	3	2									3
Monilophytes																
Cyatheaceae	6. *Cyathea podophylla* (Hook.) Copel.	2	3		5	6	5									5
Davalliaceae	7. *Humata angustata* (Wall. ex Hook. & Grev.) J. Sm.		3													1
Dryopteridaceae	8. *Bolbitis appendiculata* (Willd.) K.Iwats.				2	3	3									3
	9. *Bolbitis heteroclita* (Presl) Ching ex.C.Chr				4	4	4									3
	10. *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman	3	4	4							4	3		3	2	7
Hymenophyllaceae	11. *Abrodictyum idoneum* (C.V.Morton) Ebihara & K.Iwats									2	3	2		2	2	5
	12. *Cephalomanes javanicum* (Blume) C.Presl	2	4	4	4	4	4									6
	13. *Crepidomanes bipunctatum* (Poir.) Copel.										3	3				2
	14. *Hymenophyllum acanthoides* (Bosch) Rosenst.		3													1
Lindsaeaseae	15. *Lindsea orbiculata* (Lam.) Mett. ex Kuhn var. *orbiculata*	1	2													2
Lygodiaceae	16. *Lygodium flexuosum* (L.) Sw.	1														1
Lomariopsidaceae	17. *Nephrolepis undulata* (Afzel.) J.Sm.										3	4	2	2	3	5
Osmundaceae	18. *Osmunda javanica* Blume	3	4	4												3
Polypodiaceae	19. *Loxogramme involuta* (D.Don) C.Presl									2	3	2				3
	20. *Leptochilus pedunculatus* (Hook. & Grev.) Fraser-Jenk.					3	2									2
	21. *Selliguea heterocarpa* Blume		3					3	2							3
Pteridaceae	22. *Adiantum erylliae* C.Chr. & Tardieu											2				1
	23. *Adiantum soboliferum* Wall. ex Hook.											3				1
	24. *Antrophyum callifolium* Blume				3	2	3			2	2	2				6
	25. *Doryopteris ludens* (Wall. ex Hook.) J.Sm									3	2	9				3
	26. *Pteris vittata* L.													3	1	2

Table 4. Complete list of the species with their abundance and the frequency in the study plots (continued)

Taxa		Study plots														Freq
		TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ2	TP1	TP2	TP3	CP1	CP2	CP3	
Tectariaceae	27. *Heterogonium pinnatum* (Copel.) Holttum										3	3	3	2	2	5
	28. *Tectaria angulata* (Willd.) C.Chr.				5		5						4	4	3	5
	29. *Tectaria manilensis* (C.Presl) Holttum									2	4	2		2	3	5
	30. *Tectaria semipinnata* (Roxb.) C.V.Morton				2	3	3									3
Thelypteridaceae	31. *Cyclosorus menisciicarpus* (Blume) Holttum									2	2	2	3	2	3	6
	32. *Thelypteris* sp.										2	2				2
Woodsiaceae	33. *Diplazium riparium* Holttum		2	4												2
Eudicots																
Acanthaceae	34. *Justicia gendarussa* Burm. f.	5		5												2
Annonaceae	35. *Orophea enterocarpa* Maingay ex Hook.f. & Thomson												7	6	7	3
	36. *Pseuduvaria reticulata* (Blume) Miq.											6				1
	37. *Pheanthus* sp.				7	7	6									3
Apocynaceae	38. *Kopsia pauciflora* Hook.f.										6					1
Begoniaceae	39. *Begonia aliciae* C.E.C.Fisch.									2	4	4	4	3	2	6
	40. *Begonia integrifolia* Dalzell									3	3	3	2	2	1	6
	41. *Begonia pteridiformis* Phutthai										4	4		3		3
	42. *Begonia saxifragifolia* Craib									4	2					2
Bignoniaceae	43. *Radermachera glandulosa* (Blume) Miq.									8	7					2
Calophyllaceae	44. *Calophyllum rupicola* Ridl.	6	7	7												3
Clusiaceae	45. *Garcinia* sp.							8								1
Ebenaceae	46. *Diospyros* sp.								7							1
Elaeocarpaceae	47. *Elaeocarpus grandiflorus* Sm.				7		6			6	7	7		6	6	7
Euprhorbiaceae	48. *Croton* sp.	7	7	8												3
	49. *Trigonostemon aurantiacus* (Kurz ex Teijsm. & Binn.) Boerl.				5	5	5									3
Fabaceae	50. *Bauhinia pottsii* G.Don				6	6	6				4	5	8	8	7	8
	51. *Saraca indica* L.									7	9	9	9	9	7	6
Gentianaceae	52. *Exacum* sp.										2					1

Table 4. Complete list of the species with their abundance and the frequency in the study plots (continued)

Taxa		Study plots														Freq
		TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ2	TP1	TP2	TP3	CP1	CP2	CP3	
Gesneriaceae	53. *Chirita* sp.									3			2	2	1	4
	54. *Cyrtandra pendula* Blume									3						1
	55. *Epithema* sp.									3	4	3	3	4	3	6
	56. *Kaisupeea orthocarpa* B.L.Burtt										3	2				2
	57. *Paraboea gracillima* Kiew										3					1
Lentibulariaceae	58. *Utricularia* sp.			2												1
Lythraceae	59. *Duabanga grandiflora* (Roxb. ec DC.) Walp.									7	8				7	3
Moraceae	60. *Ficus auriculata* Lour.									7	6					2
	61. *Ficus globosa* Blume											6				1
	62. *Ficus ischnopoda* Miq.	6	6	5				7	8							5
	63. *Ficus tinctoria* G.Forst. subsp. *gibbosa* (Blume) Corner				6	6	5									3
	64. *Ficus* sp.1				8	8	7									3
	65. *Ficus* sp.2										5					1
	66. *Ficus* sp.3								6							1
Myrsinaceae	67. *Ardisia oxyphylla* Wall. & A.DC.												5	5	5	3
	68. *Ardisia fulva* King & Gamble							6	6							2
	69. *Ardisia* sp.1				5	6	5									3
Myrtaceae	70. *Syzygium nervosum* DC.							7	8							2
	71. *Syzygium* sp.1							8	8	6	6	6	7	7	9	8
	72. *Syzygium* sp.2							6	7							2
Oleaceae	73. *Olea brachiata (*Lour.) Merr.	6														1
Phyllantaceae	74. *Antidesma* sp.													6		1
	75. *Bridelia tomentosa* Blume							6	7							2
	76. *Phyllanthus gracilipes* (Miq.) Müll. Arg	2	3	5												3
Piperaceae	77. *Piper* sp.1									3						1
	78. *Piper* sp.2													2		1
Rubiaceae	79. *Argostemma condensum* Craib	1	2	3												3
	80. *Argostemma lobulatum* Craib var. *variabile* Sridith										3	2				2
	81. *Argostemma neurocalyx* Miq.									1	3	2	3	3	2	6
	82. *Argostemma pictum* Wall.		3			2										2
	83. *Argostemma ophirense* Maingay ex Hook.f.												4	3	2	3
	84. *Ixora bracteolata* Craib										4	5	5	5	4	5
	85. *Ixora javanica* (Blume) DC.		2	6	5	5	6	5	6		3	2				9
	86. *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f	7	7	8				6	6							5
	87. *Neonauclea* sp.1									9	6	6	6	5	7	6

Table 4. Complete list of the species with their abundance and the frequency in the study plots (continued)

Taxa		Study plots														Freq
		TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ2	TP1	TP2	TP3	CP1	CP2	CP3	
	88. *Neonauclea* sp.2									8	7	7	6	6	7	6
	89. *Neonauclea* sp.3				8	7	7	7	8							5
	90. *Ophiorrhiza communis* Ridl.		1	2		3	3	4	3	2	3	3	4	2	4	12
	91. *Ophiorrhiza pallida* Thwaites						2									1
	92. *Ophiorrhiza tomentosa* Jack ex Roxb.													2	3	2
	93. *Ophiorrhiza* sp.					2	3									2
	94. *Tarena* sp.				5		5									2
Rutaceae	95. *Cytrus* sp.												6	7	7	3
Sterculiaceae	96. *Sterculia balanghas* L.					6	7									2
Theaceae	97. *Eurya nitida* Korth.							7	7							2
Urticaceae	99. *Elatostema* sp.									3						1
Violaceae	99. *Rinorea* sp.					6	5									2
Monocots																
Araceae	100. *Homalomena repens* Ridl.	4	4	4	4	4	4	4	4	4	4	4	4	4	4	14
Cyperaceae	101. *Cyperus* sp.	2						3	2				3	2	3	6
Eriocaulaceae	102. *Eriocaulon* sp.	1	1													2
Marantaceae	103. *Donax canniformis* (G. Forst.) K. Schum.				6	5	5						5	5		5
Pandanaceae	104. *Pandanus* sp.	6	5	6					8							4
Poaceae	105. *Pogonatherum paniceum* (Lam.) Hack.	3	1					2	2							4
Zingiberaceae	106. *Boenserbergia* sp.										1	1				2
	107. *Caulokaempferia saksuwaniae* K.Larsen										1	2				2
	108. *Globba leucanta* Miq.var. *bicolor* Holttum									3	3	3				3
	109. *Globba pendula* Roxb.	2	3	1	2	2	5	3	3							8
Total number		21	25	17	21	24	27	17	19	27	41	37	23	32	30	

泰國半島內高流速河域之植被紀要

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摘要：本文研究了東南亞不同岩床類型的高速溪河流域內，其植物物種的組成與結構。研究地點為泰國洛坤府山區，並在5個溪流流域內設置了14個樣區，研究期間為2010年11月至2012年7月。本文使用軟體EstimateS來估算物種數量，植物群落的識別則使用群集分析。本文共記錄109種維管束植物，有50種生長於花崗岩岩床、69種生長於石灰岩岩床；共有4種植物群落被識別出來，其中3種生長於花崗岩床流域內、1種生長於石灰岩床流域。本研究之結果說明了河流流域之岩床類型，具有其地形學上的影響力來影響生長其上的植物群落組成。

關鍵詞：植物群落、熱帶、溪流。