Plant Communities in Running Streams of Peninsular Thailand

Milica Stankovic

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Ecology

Prince of Songkla University

2012

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I hereby certify that this work has not already been accepted in substance for any degree, and is not being concurrently submitted in candidature for any degree.

___________________ Signature

(Milica Stankovic)

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ชื่อวิทยานิพนธ์ สังคมพืชในบริเวณลำธารน้ำไหลในคาบสมุทรไทย

ผู้เขียน Miss Milica Stankovic

สาขาวิชา นิเวศวิทยา (นานาชาติ)

ปีการศึกษา 2555

บทคัดย่อ

ศึกษาองค์ประกอบพรรณไม้และสังคมพืชในบริเวณลำธารน้ำไหลที่อยู่บนชั้นหินแกรนิต และ หินปูน บางบริเวณที่กระจายอยู่ในคาบสมุทรไทย ตั้งแต่เดือนพฤศจิกายน 2553 ถึง พฤษภาคม 2555 พบพืชมีท่อลำเลียงทั้งสิ้นหนึ่งร้อยเก้าชนิด จัดอยู่ใน 75 สกุล และ 49 วงศ์ โดยพบ 59 ชนิดในบริเวณลำธารที่อยู่บนชั้นหินแกรนิต และอีก 60 ชนิดในลำธารที่อยู่บนชั้นหินปูน พืชทั้งหมดนี้แบ่งได้เป็น 2 กลุ่มคือ 1. พืชที่แสดงเอกลักษณ์ของการเป็นพืชที่ขึ้นในลำธารน้ำไหล โดยที่พืชกลุ่มนี้ได้รับผลกระทบโดยตรงจากสภาพน้ำไหล และ 2. พืชที่ขึ้นบริเวณอื่นได้แต่พบได้บ้างในลำธารน้ำไหลโดยที่พืชกลุ่มนี้ไม่ได้รับอิทธพลจากน้ำไหลโดยตรง ซึ่งได้จัดทำคำบรรยายลักษณะของพืชเฉพาะชนิดที่แสดงเอกลักษณ์ของการเป็นพืชที่ขึ้นในลำธารน้ำไหลพร้อมข้อสังเกตของการปรับตัวทางสัณฐานวิทยาบางประการของการขึ้นอาศัยในสภาพลำธารน้ำไหล สามารถจัดกลุ่มสังคมพืชออกตามลักษณะขององค์ประกอบพรรณไม้ที่พบได้เป็น 4 แบบโดยเป็นสังคมพืชที่พบบริเวณลำธารน้ำไหลบนชั้นกินแกรนิต 3 แบบ และหนึ่งแบบบนชั้นหินปูน ซึ่งจากการศึกษาปัจจัยแวดล้อมทางกายภาพที่พบสังคมพืช พบว่าค่าความเป็นกรด-ด่างของน้ำในลำธารมีผลต่อองค์ประกอบของสังคมพืชมากที่สุด ตามด้วย ความเข้มแสง และ ความกว้างของลำธาร ตามลำดับ

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ABSTRACT

Floristic and community study on the running streams of two different bedrock types in the Peninsular Thailand, were carried out from November 2010 until May 2012. One hundred and nine species of vascular plant belonging to 75 genera and 49 families were collected. Among those, 59 species were found on the granite bedrock streams and 60 on calcareous bedrock streams. The proposed groupings of the species included the characteristic stream species and associated stream species. The notes on the morphological adaptations of the characteristic species are given. Four types of the plant communities had been recognized, three communities on the granite bedrock streams: community A, B and C; and one community on the calcareous bedrock streams: community D. Their correlation of the environmental factors showed that the communities' composition is highly influenced by the water pH, following the light intensity and the width of the stream.

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CHAPTER 1

INTRODUCTION

Streams together with other flowing water systems are part of lotic ecosystems. These ecosystems are characterized with fast or slow flowing water; comparing to the lentic systems such as lakes, ponds, and marches, which are characterized with still and steady water body. Both types of ecosystems are part of aquatic ecology. Waters of lotic ecosystems can be very diverse, from slow flowing wide river to a few centimeters fast flowing stream (Hauer and Lamberti, 2006; Allan and Castillo, 2007.). Despite big differences, running waters are classified in lotic ecosystems because of some characteristics that they share: flow is unidirectional, there is a state of continuous change of physical parameters, there is a high degree of spatial and temporal heterogeneity (microhabitats), and biota is specialized to live in flowing conditions (Hynes, 1970).

A stream is defined as water body with a current, confined with a bed and banks (Hynes, 1970). The origin of the stream is a source and that upper part of the stream is called headwaters. From the source there is a continuous change of runs, riffles and pools (Naiman et al., 2005). Sometimes there is a sudden change in stream gradient, called knickpoint. On that place there is a drop in a stream bed and waterfall or cascade is formed. Streams can merge and at the end they discharge in a larger body of water, such as lake or river. From this point of view, stream ecosystems are very dynamic rather than static (Hauer and Lamberti, 2006). There is constantly shifting mosaics of interconnected habitats, which are created, modified, destroyed, and rebuilt (Hauer and Lamberti, 2006). This dynamic process in stream and river ecosystems, states the importance of habitat replacements and the biological communities' synchronization in a flowing water body (Vannote, 1980).

The habitat of the streams is exposed to two alternate environments. During summer period the water level is low, the species in the streams are exposed to the dry air and very high temperatures (van Steenis, 1981). On the other hand, during rainy season, water level rises and flash floods are occurring frequently, so the species are exposed to severe flooding periods. In such variable environment few plant species were able to adapt and to survive these harsh conditions. Their existence is highly associated with the morphological adaptations towards this environment. This group of species that was able to withstand these conditions was defined as rheophytes. The first definition of this specially adapted plants-rheophytes was first given by van Steenis (1981) as: “the plant species which are in nature confined to the beds of swift running streams and rivers and grow there up to the flood level, however not beyond the reach of regularly occurring flash floods”.

Stream ecosystems of the tropical region are one of the least explored areas of the world (Dudgeon, 2008). Most of the studies that have been done so far on plant communities in streams are in temperate region, so only temperate region streams are known in terms of environmental condition, construction and habitats/microhabitats and their influence on the stream biota. It is already known that tropical region streams differ from temperate in many ways (Dudgeon, 2008), but the data about tropical region streams is not focused on the flora. At present, the answer to basic questions such as what controls plant composition, abundance and community structure and how do they relate to a habitat where they occur, are still not answered.

The peninsular Thailand is a part of continental South-East Asia. It lies in the northern part of Malay Peninsula and many flowing systems runs towards east and west coast. These physiognomic features created unique places which are flooded at least once a year, especially during rainy season. The plant species that occupied these habitats developed unique characteristics as well, due to the fact that they must stand the flood period. Moreover, when the diversity of plant species is taken into account, it must be noted that the Peninsular Thailand is divided between two main biogeographical regions i.e. the Continental south-east Asian and the Malesian region, which are roughly separated by Kangar-Pattani line (Good, 1964; Takhtajan, 1986, Woodroff, 2003). Whithmore (1975) estimated around 7,900 species and 1,500 genera of seed plants in this area.

Throughout the peninsular Thailand, streams ecosystems have been disturbed as popular touristic areas, with few places left as remnant patches. These small undisturbed stream areas have rather high importance as they contain original stream vegetation. The present study was aiming not only to document these natural vegetation areas of the streams in the peninsular Thailand, but to explain the environmental forces that shape the communities along the streams. Moreover, the present study is the first recorded study on the stream vegetation and its relationship with the environmental factors in Thailand.

LITERATURE REVIEW

I. The concepts of communities in stream ecology

The interest in stream ecosystems, as the flowing waters, came many years after studies on lymnological ecosystems. By the end of 19th century the emphasis of research shifted to streams from rivers and many researchers gave their contribution in various scopes.

One of the first studies on the community level was done by Hynes (1961) with the main focus on the invertebrate communities due to the extensive research in that field and very few studies on plant groups. His studies covered the physical and chemical properties of running waters with reflect of specific types of habitats.

The most influenced study was done latter on by Vannote (1980) which gave results known as River Continuum Concept (RCC). This concept is based on dynamics of the flowing waters where flowing system is divided in orders, from 1 to 12 or more, and in between them there is a gradient of physical conditions. In the response of that continuous change of physical condition, there is a specific organization of biota. Biological communities are forming temporal continuum of synchronized species replacements in relation to the environment which they engage.

Minshall et al. (1985) added many factors in River Continnum Concept as very important ones that affect the stream biota. Important factors included in the study are climate and geology, turbidities, location-specific lithology and geomorphology; expanding River Continuum Concept to a broader geographic and historical model.

Even though the RCC is a broadly accepted theory, there are many limitations, such as riverine irregularities, dams, natural disasters. There had been many additions to the Concept due to lack of factors that shape the streams and communities and as a result several new concepts were made.

Ward and Stanford (1983) proposed the Serial Discontinuity Concept which addressed the impact of irregularities in the flow, such as dams or shore flooding.

Ward and Stanford (1993) proposed the second concept Hyporheic Corridor Concept which includes microhabitats between rocks and cobbles where water penetrate forming the interstitial space-hyporheic zone. This concept incorporated vertical dimension of the stream into already described lateral, longitudinal and time dimensions.

Up to current days many contemporary concepts arose and have been written down, filling up the gaps of the former ones with a lack of the plant groups as model organisms, mostly referring to the invertebrates.

II. Studies on the plant communities in streams on a global scale

Since the discovery of the Concepts the developments of the theories went into direction of invertebrate studies, with very few studies on plant groups. In the last decade the researches of aquatic plants and riparian vegetation have been recalled and many studies around the globe have been published.

Sagers and Lyon (1997) surveyed the vegetation along Buffalo National River, Arkansans, USA with purpose of identifying plant communities in different forest layers and their correlation to the environmental factors. They concluded that the main environmental factors that influence plant communities were pH and elevation, with the distinct differences of secondary factors between forest layers.

Baattrup-Pedersen and Riis (1999) did a study of macrophyte diversity and composition in relation to the substrate in regulated and unregulated Danish streams. Even though coverage was similar, species richness and diversity was higher in unregulated streams as the result of more heterogeneity of the streams, which indicated the heterogeneity importance in the plant composition, richness and diversity.

Riis et al. (2000) studied macrophytes composition of Denmark streams. They identified six plant communities and related them to the environmental factors. The plant communities were mainly related to water alkalinity as the most important factor, while the second most important factor was size of the stream in terms of depth and width. They concluded that influence of these two factors was not apparent because alkalinity was correlated with several other variables that characterize riparian zone.

Champion and Tanner (2000) did a study in the shallow streams of New Zealand. Their studies investigated seasonal variation of macrophyte abundance and its influence on flow and volume of the stream with the relation of the habitats in the stream.

Riis et al. (2001) did a study in the lowland streams of Denmark where they divided plants by their habitat into: terrestrial plants, amphibious and obligate submerged. Also, they examined them in relation to water depth, substrate and distance from the bank. Terrestrial and amphibious plants dominated in shallow waters near bank; while obligate submerged plants dominated at intermediate depths and at all distances from the bank. Their distribution reflected the ability of the species to disperse from the land to the water and only in the water. They reclassified plants in the streams, based on their habitats into: terrestrial, amphibious and obligate submerged, comparing to the previous classification which was based on the life forms-emergent, floating and submerged (Hauer and Lamberti, 2006). New classification based on habitats also included adaptations of the specific groups.

Riis and Sand-Jensen (2002) studied the abundance-range relationship between the plants in the streams, as well as the ecologically different groups in the streams of Denmark. The results showed that all the species had a positive relationship between local abundance and geographical range, tough the ecologically similar species had a significantly higher positive relationship. The importance of positive abundance-range relationship lies in the meta population dynamics and it was supported by the species with a multiple localities had a stronger positive relationship, on contrary the species from different stream systems with same habitat type showed the weaker positive relationship.

Riis and Biggs (2003) studied the factors that control macrophyte presence, abundance and composition in New Zealand streams. They concluded that the macrophyte presence and their development was primarily controlled by hydrologic regime and that spatial distribution of taxa was strongly influenced by local hydraulic conditions (depth/velocity/sediments) of a stream.

Daniel et al. (2006) conducted a study of relationships between physical features of rivers and distribution of macrophyte vegetation in western France. The main factor controlling growth was water flow except for several riparian plants, while the second factor was water depth. Also, the effective tool in vegetation analysis was ecomorphological types as each group was correlated with different sets of factors.

Riis et al. (2008) worked on hydrological variables and flow regime in relation to macrophyte cover, species richness, diversity and community composition in Danish low land streams. They concluded that macrophyte cover was the lowest in streams with high flow variability and highest in streams with long duration of low flow and low flow variability. Moreover, they did not find any relationship between community composition and hydrological regime, indicating that plant communities are developing independently of stream hydrology.

Makkay et al. (2008) tested the importance of physical versus chemical factors in explaining aquatic plant species diversity and community composition in lowland Canadian streams. They concluded that physical factors can predict species diversity but not species composition at a given site.

Grinberga (2010) conducted a study in a middle sized streams of Latvia, with the purpose of distinguishing how the stream constitution affects the macrophyte composition. The highest species richness was found in slow flowing streams with gravel as a substrate, while fast flowing streams with sandy substrate had very poor macrophyte composition.

III. Studies on the rheophytes worldwide

Rheophytes had been a topic for researchers at the end of 19th and beginning of 20th century (van Steenis, 1981).

One of the first noted rheophytes was done by Ridley (1893) in his account of the flora of the Tembeling and Tahan rivers in Malaya (from van Steenis, 1981).

The first morphological features of rheophytes were described by Beccari (1902, 1904) in his research of forests of Borneo. He placed them in a special ecological group characterized with leaf morphology–narrow leaf shape "stenophyllous plants" (from van Steenis, 1981).

Van Steenis started his expedition in 1932 in Malaya with purpose of recording stenophyllous plants. As he collected more data about morphological characteristics, habitats, ecology he changed the name of such plant group to the "rheophytic plants" since not all stenophyllous plants occurred in the streambed. His interest in rheophytes extended from Malaysian borders to the other tropical regions of the world and some other temperate zones. All his findings about rheophytes, their ecology, diversity, morphology, short descriptions of each species and paragraphs with hypothesized evolution of rheophytes were published in the Rheophytes of the world: an account of the flood–resistant flowing plants and ferns and the theory of autonomous evolution (van Steenis, 1981). In 1987 a supplement was published with more descriptions of fern species.

Since those publications, very few studies had been carried out, mainly by Japanese researchers in South East Asia and Japan.

Kato et al. (1991) surveyed the streams of Borneo with purpose of noting rheophytic fern species. They recorded 43 taxa of ferns which were grouped, based on habitats into the obligate, facultative and occasional rheophyte. They noted that 47% of the recorded taxa were endemic to Borneo and that Borneo was the richest island in the world in terms of the rheophytic species.

Kato and Imaichi (1992) did a study on the leaf anatomy of tropical fern rheophytes with implication of the evolution of rheophytes. They compared the anatomy of leaves between rheophytic fern and their closest dry land species. The results indicated that the stenophyllous leaves of rheophytes were produced by weaker cell expansion than in dry land species, and that a phylogenetic decrease in a cell expansion in leaves was involved in the origin of such broad leaves from dryland species to the stenophyllous leaves of rheophytes.

Imaichi and Kato (1992) studied a leaf development of the rheophytic *Osmunda lancea* Thunb. and phylogenetically related dryland species *Osmunda japonica* Thunb. The comparison of developmental patterns of pinnules between these two species indicated that differences in their leaf anatomy and morphology were due to the heterochrony, moreover progenesis in which descendant had an adult morphology that resembles juvenile stages of ancestor.

Uskura et al. (1994) did a research on leaf morphology of a facultative rheophyte *Farfugium japonicum* (L.) Kitam var. *luchense* (Masam.) Kitam. with the implication of evolution of narrow leaves in angiosperms. The results showed that in comparing to the ferns narrow leaves, the evolution of narrow leaves in angiosperm involved a decrease in numbers of leaf cells across the width of the leaf.

Nomura et al. (2006) studied the consequences of the stenophylly of the rheophytic leaves in *Farfugium japonicum* (L.) Kitam var. *luchense* (Masam.) Kitam. and its related non rheophyte *F. japonicum* (L.) Kitam. Their results indicated that the narrow shape of the leaves or rheophytes is the adaptation not for the light intensity but for the flood resistance, through an increased mechanical toughness.

Swaine et al. (2006) did a study of the plant communities along forest rivers in Ghana. They recorded only nine rheophytic species, which were major elements in the communities. They also correlated the communities with the environmental factors. The communities were mainly correlated by soil, geology and climate, which influenced through the medium of water chemistry.

IV. The studies on the plants along the streams in Thailand

One of the earliest recorded studies of the rheophytes was made by van Beusekom and Geesnik during 1971–1972 in Nam Phrom River (van Steenis, 1981). They collected quite a number of the rheophytes: Podostemaceae, *Antidesma*, *Distylium*, *Excoecaria*, *Homonoia*, *Mangifera*, *Phoebe*, *Photinia*, *Phyllanthus* and

Rotula aquatic Bor. Since then there were not many studies on the streams of Thailand.

Ramsri (1986) studies vascular plants at Gahrome waterfall, Khao Luang National Park Nakhon Si Thammarat province. His list included 81 families, 174 genera and 220 species. Most of the species were found on the forest ground or as epiphytes, but there were some habitats near the rivers or on the boulders in shaded areas that were influenced by the water level.

Panatkol et al. (1999) surveyed vascular plants along Mae Mon Stream at Chae Son National Park, Lampang Province. A total number of 128 species were collected, making it 45 families and 99 generas, with epilithic species along waterfall and outcrops along the stream. The most common family of the dicotyledons was Leguminosae (Papilionoideae) with 13 species, and the monocotyledon family with the most species was Zingiberaceae (15 species).

Muadsub (2009) studied the diversity of vascular plants along Bangwan and Tamnang streams in Kuraburi district, Phang Nga province. A total number of 159 species were recorded, grouped into 120 genera, 63 families. The most common families were Cyperaceae, with 15 species, Rubiaceae and Zingiberaceae with 14 and 11 species, respectively. Plant communities were divided into terrestrial and aquatic. Terrestrial plant communities included tree, shrub, herb and epiphyte species, while aquatic communities included submerged, emerged and floating plants.

Kongied et al. (2010) surveyed the Sok Canal in Surat Thani province with purpose of recording the diversity of vascular plants along the canal. They recorded total number of 221 species belonging to 141 genera and 57 families. The most common family was Euphorbiaceae with 34 speices, while the most common genus was *Ficus* L. with 14 species. The difference in plant composition along the canal was influences mainly by topography.

Puff and Chayamarit (2011) surveyed Mekong River with a purpose of recording rheophytes. They recorded and described total number of 25 taxa and they were grouped by the habitat types. Types of habitat included: rocky areas, sandy areas and other (loamy and sandy-loamy areas).

OBJECTIVES

1. To gain information about running streams in terms of habitats, environmental conditions and structure.

2. To document species composition and ecology of vascular plants in different types of bedrock streams.

3. To obtain the data about characteristic streams species in terms of their morphological adaptation and habitat preferences to the harsh stream environment.

4. To acquire information about structure and types of the communities on different bedrock streams as well as their correlation to the stream environment.

CHAPTER 2

MATERIALS AND METHODS

STUDY AREA

1. Location

The Peninsular Thailand is located in the northern part of the Peninsular Malaysia, covering an area around 70,713 km^2. To the north is bounded by the narrowest part of the Peninsula, Kra Isthmus, while the southern margin is Thai – Malaysian border. The study areas had been selected in order to study the structure and composition of the vegetation along the running streams on different types of rocks in the Peninsular Thailand.

The surveys for running streams were conducted on one from three mountain ranges of peninsular, Banthat or Nakhon Si Thammarat range which begins on Koh Samui, Koh Pha Ngan and Koh Tao in Gulf of Thailand, and ends with Koh Tarutao archipelago in Andaman Sea. This range is dividing the Peninsular to the west and east coast and selected streams are on the east as well as on the west side of the range.

Peninsular Thailand is comprised of 14 provinces, but the selected streams are in four provinces: Trang, and Satun province on the west coast; Songkhla and Phattalung province on the east coast. All the selected streams were part of the National Park or Protected areas e.g. Khao Ban Thad and Tong Nga Chang Wild Life Sanctuary, except the waterfall in Trang province.

Criterias that the selected streams fulfilled were: the streams were similar order; the streams had similar constitution within the groups; streams had different bedrock type; least human influence as possible; waterfalls with at least 5 m hight were not included.

2. Geology

The main rock formation of Banthat range is Triassic granite (Mineral Resources Department, 2012), with the different secondary rock formations on the east and west side. On the east side of the range granitic formations dominate, while on the west side secondary rock formations such as calcareous rock, sandstone, and shale are formed. (Mineral Resources Department, 2012).

Since the east side of the range dominates in granitic formations, representatives of granite bedrock streams were selected on that side of the range; while the representatives of calcareous bedrock streams were selected on the west side of the mountain range (Figure 2.1).

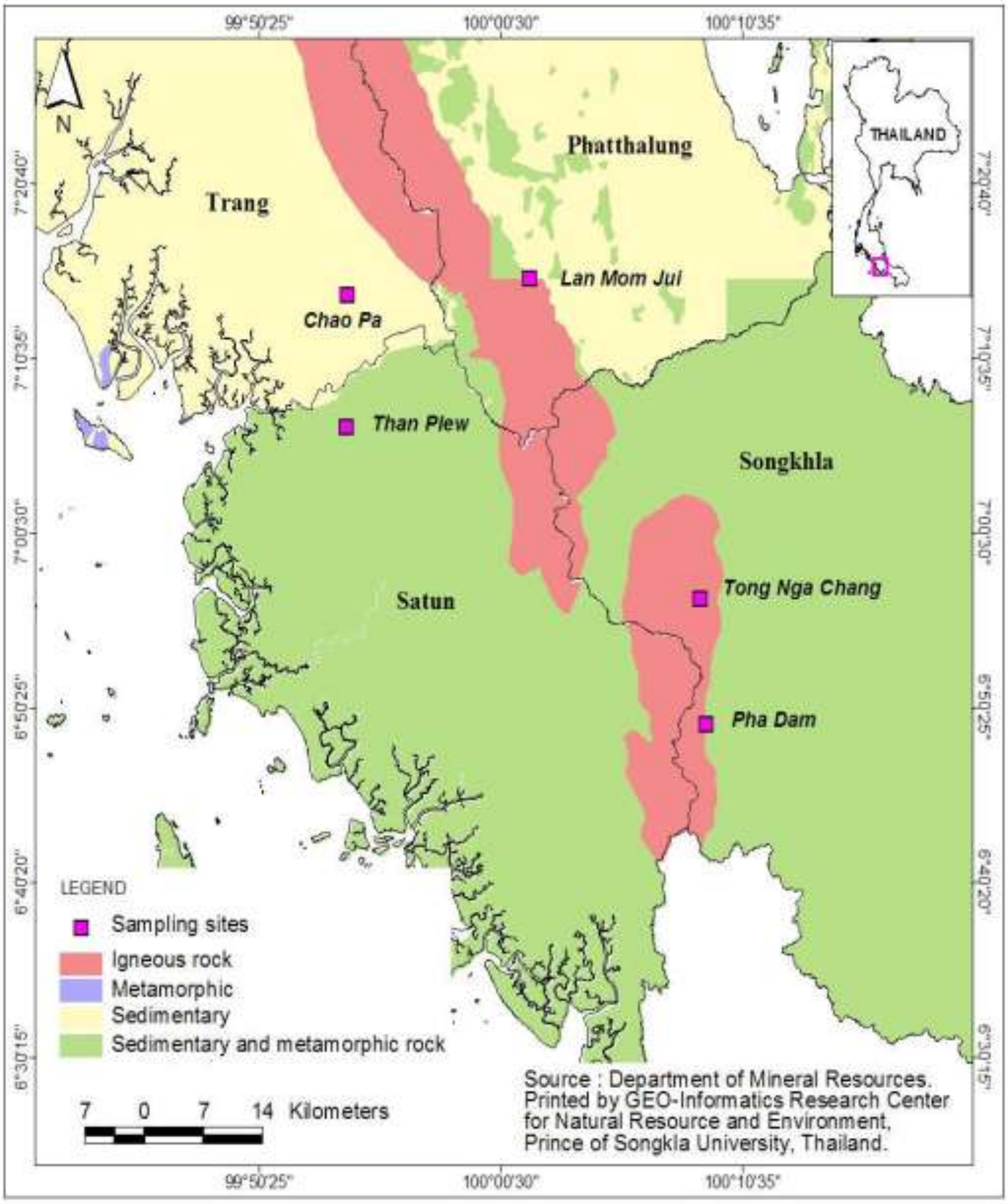


Figure 2.1. The types of the bedrock for selected streams in Peninsular Thailand

3. Climate

The climate of the area is tropical monsoon (Am) according to Köpen'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 periods of rainy season differs (Thai Meteorological Department, 2012b). The heaviest rainfall on the East coast is during October and November, with mean precipitation of 759.3 mm, while on the West coast is during August and September with mean rainfall of 1,895.7 mm (Thai Meteorological Department, 2012).

During the period of study from November 2010 to June 2012, the year 2011 was recorded as the wettest year in the last 60 years for Thailand (Thai Meteorological Department, 2012). In March 2011 on the east as well as the west coast, there was unusual increase of rainfall above normal, 505.6 mm and 353.7 mm. respectively. The average annual rainfall for the east coast was 2,317.5 mm and for the west coast was 2,964.1 mm, which was 36% and 8% above normal annual rainfall. The mean monthly precipitation during the period of study, in 2011 when most of the field work was done, was presented in Figure 2.1. Also, in the same month there was a decrease of mean monthly temperatures by 1.1 °C and 1.4 °C for the east and the west coast, respectively. (Thai Meteorological Department, 2012). The mean monthly values of air temperature on the east as well on the west coast are presented in Figure 2.2, in 2011 when most of the field work was done.

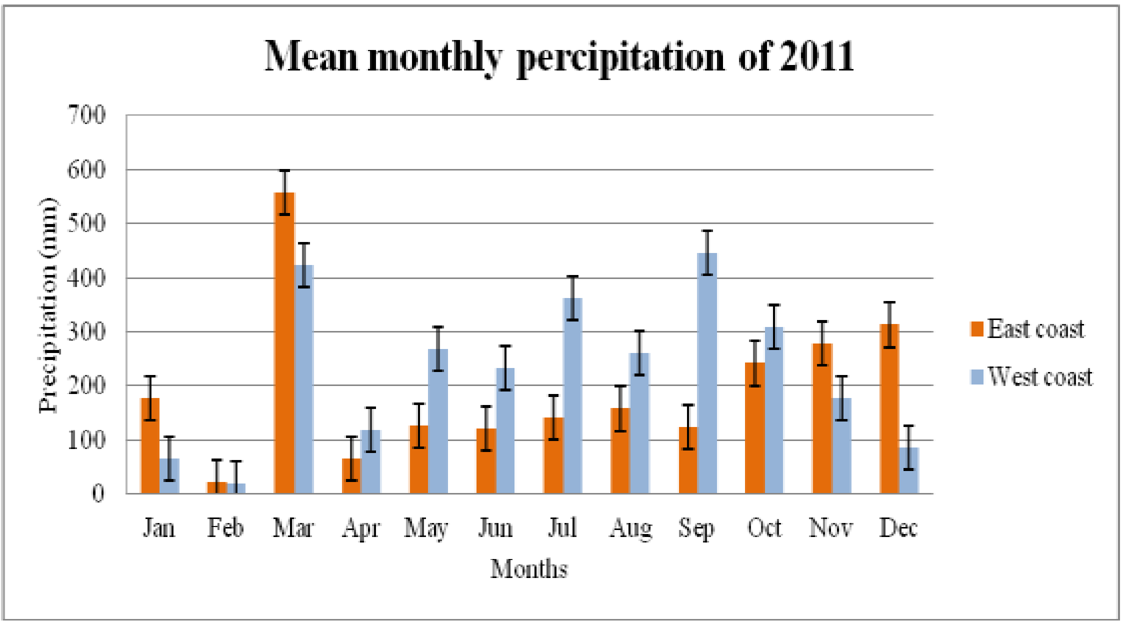


Figure 2.2. Mean monthly precipitation during the period of study (Thai Meteorological Department, 2012).

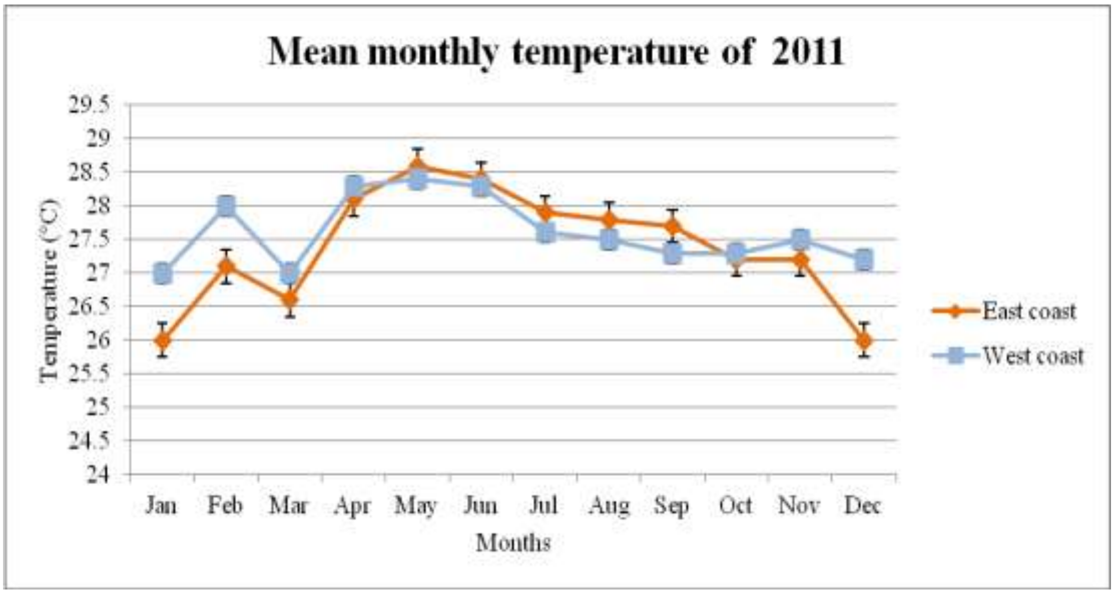


Figure 2.3. Mean monthly air temperatured during the period of study (Thai Meteorological Department, 2012).

4. Study sites and plots

The study was based on two different bedrock types and the selected streams were divided into two groups: 1) group representing granitic bedrock streams; 2) group representing calcareous bedrock streams. In the granitic group, there were three running streams viz. Ton Nga Chang waterfall, Pha Dam waterfall and Lan Mom Jui waterfall, located on the east side of the mountain range. While the calcareous group had 2 streams, Than Plew and Chao Pa waterall, with location on the west side of the mountain range. Each stream had a similar constitution and was surrounded by natural vegetation of tropical low land forest (Whitmore, 1985).

A total number of 14 plots were placed within the streams, with 3 plots in four streams and one stream with 2 plots. The site descriptions of plots are in Table 2.1.

Plots varied in shape, but the total area of the plot was kept in the range from 450 to 600 m^2. The limitation of the plot shape was width of the streambed during rainy season, so called “an upper flooding zone”. The distance between each plot was at least 100 m. Since there was lack of herbs and shrubs species, only one size of the plot was laid for the study. Rocky islands that were found inside the plots and flooded during certain period of time were included in the study. In each plot selected environmental factors were measured and features of the streams were described.

Table 2.1 List of study plots

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

FLORISTIC STUDY

1. Plant collection

1.1. Plant collection was carried out starting from November 2010 until July 2012 once or twice a month. During the rainy season, due to the heavy rain and inaccessibility to reach study sites, plant collection was postponed. Plants that were confined by the maximum stream bed during rainy season were collected as well as the ones that were found on the rocky islands that would be flooded during the rainy season. Also, plants that were on the rocky islands without soil layer that are not influenced by flood were collected. Species found along the streams but outside the plot area were also collected with a purpose of having a complete species list of plants that occupy in stream area beds.

1.2. Plant collections had been made with field notes of important morphological and ecological characters. Photographs of species and their characteristics were taken.

2. Laboratory study

2.1. Specimens were processed as directed in "The herbarium hand book" (Forman and Bridson, 1992).

2.2. The collected specimens were identified as far as possible with the available taxonomic literatures.

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

2.4. The voucher specimens have been deposited at the Prince of Songkla University Herbarium (PSU) and Forest Herbarium (BKF), Department of National Parks, Wildlife and Plant Conservation, Ministry of Natural Resources and Environment, Bangkok, Thailand.

2.5. Description of the plant group that inhabited streambed (characteristic species) was made in order to gain more information about this plant group.

2.5.1. Morphological adaptations such as root system, leaf, habit of species had been described and illustrated.

2.5.2. Leaf size had been measured. The length and the width of the lamina of a single leaf or leaflet in compound leaves per collected individual were measured.

2.5.3. Leaf index was calculated as the ratio of length and width.

3. Data analysis

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

COMMUNITY STUDY

1. Vegetation data collection

1.1. Species in each plot were recorded with information about their position in the plot, height and crown area in order to make vegetation profiles.

1.2. Abundance and percentage of coverage of species occurring in the plots were measured using nine grade ordinal transformed value scale (OTV), where c is cover percentage (van der Maarel, 1979, 2007).

Scale	Cover (%)
1	1–3 Individuals
2	Few Individuals < 0.5
3	0.5 < c < 1.5 %

4	1.5 < c < 3%
5	5 < c < 12.5
6	12.5 < c < 25
7	25 % < c < 50
8	50 % < c < 75
9	c > 75

2. Environmental data collection

2.1. The data loggers were placed in each study plot 1.5 m above ground level and in water about 0.5 m depth. They were placed every month from April to August.

2.2. Air temperature (°C) and relative humidity (%) were measured using data logger Hobo pro V2 RH/Temp; while water temperature (°C), light intensity (lux) were measured using Hobo pendant Temp/Light data logger. These data were recorded monthly by 15 minute intervals programmed and read by the software HOBOware Pro.

2.3. Factors such as water width (m), depth (m) were measured monthly by Bosch DLR 130K Digital Laser Distance Meter.

2.4. Water velocity (m/s) was measured monthly on 10 m distance by a floating method.

2.5. pH of water was measured few times on randomly chosen places inside the plot by Index ID 1000 pH meter.

2.6. Factors such as substrate class, stability of substrate and water flow were grouped as descriptive characteristics. Their description was noted monthly.

2.6.1. The substrate classes used for this study were followed an adapted Udden - Wentworth system:

Rocks - > 64 mm

Gravel - > 2–64 mm

Sand - > 0.0625–2 mm (abrasive to the hands)

Silt - < 0.0625 mm (have a soft texture)

2.6.2. Stability of substrate was described following 3 classes:

Solid–bedrock, rocks compacted

Sable–pebbles, rocks with little of silt and sand

Unstable–gravel, silt or sand dominate

2.6.3. Classes used to describe type of the water flow:

Free fall–waterfall

Chaotic–without any order

Chute–watercourse is forced into a narrow channel

Upwelling–water rises from the bottom to the surface, usually after rocks

Rippled–slight water waves over the surface

Smooth–surface of water is without any irregularities

3. Data analysis

3.1. 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.

3.2. The graphs of the environmental factors were done by computer program Graph Pad Prism, version 5 for Windows (GraphPad Software)

3.3. In order to distinguish plant communities, a cluster analysis Ward's method with Euclidean distance dissimilarity index was used by the computer program PC-ORD version 5.33 (McCune and Mefford, 2006). Plant species with frequencies < 5% across all sampling plots were excluded. In order to perform this analysis main matrix was created, that consisted of 99 columns which represented species, and 14 rows which represented study plots.

3.4. Correlation between plant communities and environmental factors was represented by CCA analysis by the computer program PC-ORD version 5.33 (McCune and Mefford, 2006). In order to perform this analysis second matrix was created with 14 rows, which represented study plots, and 11 columns which represented environmental data. Eight environmental data were described as qualitative, while other 3 were grouped as categorical variables. Qualitative variables included environmental factors such as air temperature, water temperature, humidity, light intensity, water velocity, stream depth, stream width and pH value of water. Categorical variables included factors such as substrate type, type of water flow and type of the stream floor.

CHAPTER 3

RESULTS

PART I: FLORISTIC STUDY

I. Plant species richness

A total number of 109 species was found comprising of all plant groups and life forms, belonging to 75 genera and 49 families (Figure 3.1). Among these, 5 species were Lycophytes, 28 species of Monilophytes, and 76 species of Angiosperm, 67 of Eudicots and 9 of Monocots (Table 3.1). The most abundant family of Eudicots were Rubiaceae (16 species), Moraceae (6 species) and Gesneriaceae (5 species); while the most common Monocots family was Zingiberaceae (4 species). On the other hand the most common families of Monilophytes are Hymenophyllaceae, Pteridaceae and Tectariaceae, each with 4 species. A species list was given in the Table 3.3.

The estimated number of overall species from the present study is 121 (Table 3.2.) The collected ones had performed 90% of the estimated existing plant species found in the study areas.

Table 3.1 Number of species in plant groups on all bedrock streams and on each type of the bedrock stream

Plant groups		Total	Granite bedrock streams	Calcareous bedrock streams
Lycophytes		5	3	2
Monilophytes		28	16	15
Angiosperm	Eudicots	67	34	5
	Monocots	9	6	38
Total number of species		109	59	60

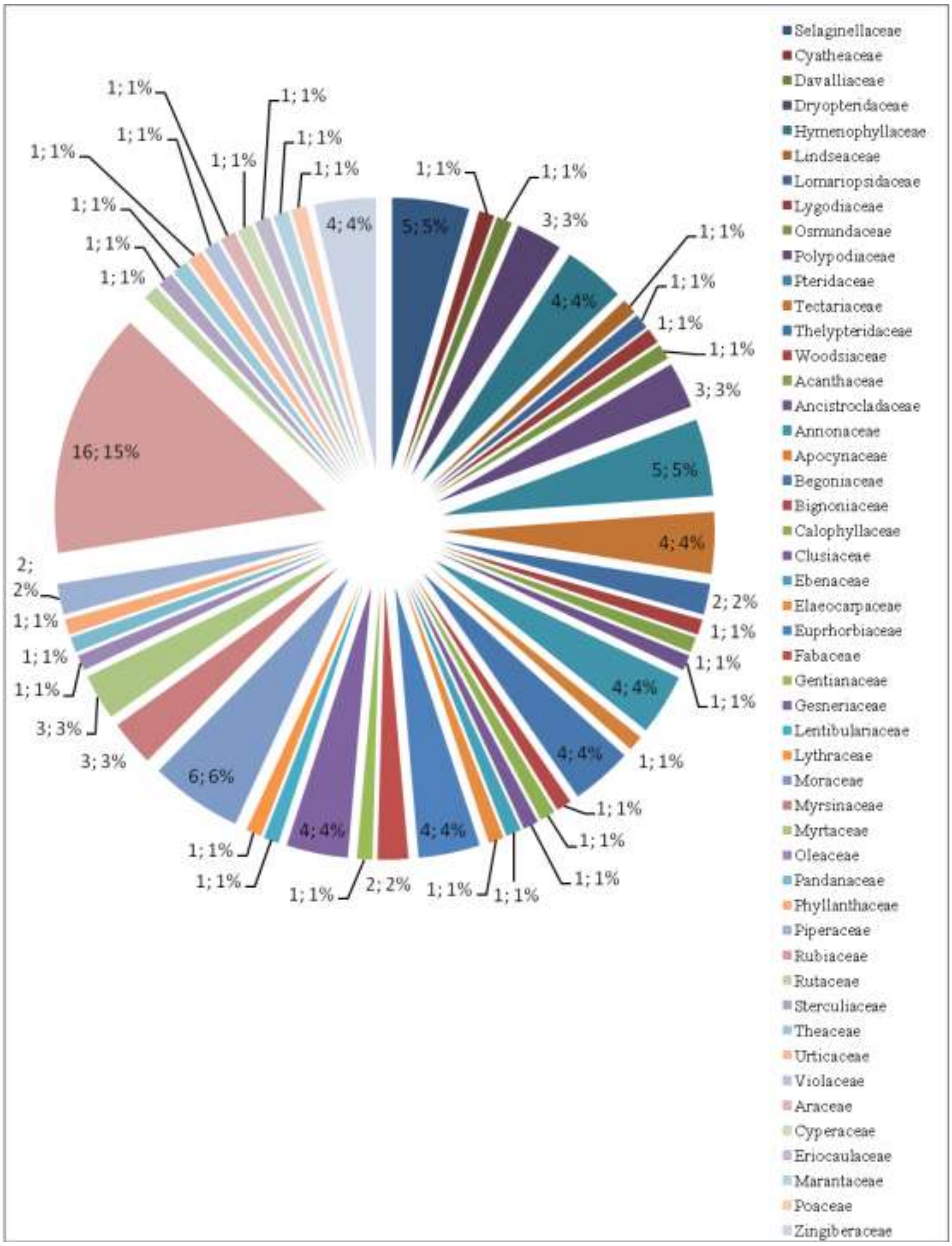


Figure 3.1. Pie chart of the number of species in families along all streams in peninsular Thailand

Table 3.2 Observed and estimated number of species as well as the completeness of the samples along granite and calcareous bedrock streams

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

II. A species richness on different bedrock types

A total number of 59 species was found on the granite bedrock stream. Among them 34 were Eudicots, 6 Monocots, 16 Monilophytes and 3 Lycophytes respectively (Table 3.1). The species that were common on granitic bedrock streams include: *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, *Osmunda javanica* Blume etc.

The estimated number of the species on the granitic bedrock streams was 65 (Table 3.2.), and the collected species number had performed 90.7 % of the estimated plant species number in this granitic bedrock habitat.

On the calcareous bedrock streams, total number of 60 species was recorded, with 38 Dicots, 5 Monocots, 15 Monilophytes and 2 Lycophytes (Table 3.1). Species that are commonly found on the calcareous bedrock streams are: *Begonia aliciae* C.E.C.Fisch., *Saraca indica* L., *Paraboia gracillima* Kiew, *Argostema neurocalyx* Miq., *Ixora bracteolata* Craib, *Nephrolepis undulata* (Afzel.) J.Sm., *Calciphilopteris ludens* (Wall. ex Hook.) Yesilyurt & H.Schneid., *Tectaria manilensis* (C.Presl) Holttum, *Globba leucanta* var. *bicolor* Holttum etc.

The estimated number of the species on the calcareous bedrock stream was 64 species (Table 3.2.). The collected species number had performed 93.7 % of the estimated plant species number in the calcareous bedrock habitat.

Even though the number of the species on the granitic and calcareous bedrock streams was almost similar the composition of the species, on the other hand, differed much from each other. There are only 10 common species in both types of bedrock 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.

III. 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. The rocky area; 2. The stream bank; 3. The stream floor; and 4. The shallow pool.

1. Rocky areas

These areas have the highest diversity of the plants, especially of streambed species. Further on, rocky areas could be divided various microhabitats such as small emergent rocks and sides of the boulders, rock crevices and boulders. Most of these areas are highly influenced by the fluctuations of the water level.

1.1 *Small emergent rocks and the sides of the boulders*

These microhabitats are regularly influenced by flood conditions and very high water velocities. They are usually located in the streambed and during rainy season the species that inhabit these microhabitats are totally or partially submerged.

Only six plant species occurred in these microhabitats since they can withstand these conditions e.g. *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*

This type of microhabitat is situated between two separated rocky areas where small soil and litter pockets were made and humidity is kept so the species can survive. This microhabitat is occasionally flooded during rainy season, while during the rest of the year it is under direct sun. Mostly it is inhabited by herb species *Globba pendula* Roxb., *Cyperus* sp. and *Pogonatherum paniceum* (Lam.) Hack. etc.

1.3 *Boulders*

These microhabitats are located near the stream banks and the water level does not ever reach the top of them. Only the sides of these boulders are under constant pressure from the high water velocity. During the dry period, the stream width narrows and sometimes they can be seen as a part of the nearby land. These microhabitats are usually in the deep shade and occupied by the species that are not directly influenced by the stream water e.g. *Argostemma* spp., *Begonia* spp., *Kaisupeea orthocarpa* B.L.Burtt etc (see also in the plants group categories discussion–“associated species” of the stream).

2. Stream banks

Stream banks based on substrate are further grouped into soil, sandy and rocky banks. Each substrate type is occupied by different sets of plant species.

2.1 *The soil banks*

These types of microhabitat occur mostly in the low velocity areas of the stream, i.e. pool areas. Mostly they are inhabited by tree and shrub species e.g. *Pseuduvaria reticulata* Miq., *Kopsia pauciflora* Hook.f., *Ficus tinctoria* G.Forst., *Ardisia* sp.. and *Ixora javanica* DC.

2.2 *The sandy banks*

This type of banks is rare along the streams. These areas occur usually after rocky areas and in the low velocity zone, as the water deposits all the particles to these areas. They are exposed to direct sun light and only few species are able to establish such as *Justicia genderussa* Bur.f.

2.3 *The rocky banks*

This type of microhabitat is the most common bank substrate along the fast flowing streams. They are established in the areas of the fast flowing conditions and they are inhabited by the species that are able to stand stress conditions (severe flooding during rainy season and high water velocities) e.g. *Cephalomanes javanicum* (Blume) C.Presl, *Osmunda javanica* Blume. In the upper part–upper flooding area, where flooding is occasional other set of species occur e.g. *Globba pendula* Roxb., *Argostemma condesum* Craib etc.

3. Stream floor

Stream floor is microhabitat that is always under water with different depths and velocities, which influences the species composition. This area in the granite bedrock streams is without plant species, while the calcareous bedrock stream floor is occupied with many trees in the pool areas or with few herbs on slope areas. In the pool area apart from tree species, shrub species such as *Ardisia oxyphylla* Wall. & A.DC. etc. are very common. On the slope areas where water velocity is very fast herb species e.g. *Homalomena repens* Ridl. and few tree species e.g. *Elaeocarpus grandiflorus* Sm., *Neonauclea* sp.1 and *Syzygium* sp.1 are frequent.

4. Shallow pools

Shallow pools are microhabitats which are during rainy season and excessive flooding filled with water. As the season changes to dry, they dried up our leaving shallow rocky dents. Species that occupied these areas are mostly grasses and sedges species e.g. *Cyperus* sp., *Eriocaulon* sp. etc.

Table 3.3. A complete list of species occurring in the streams of peninsular Thailand

Family	Species	Life form[1]	Micro habitat[2]	Bedrock type	
				Granitic	Calcareous
Lycophyte					
Selaginellaceae	*Selaginella inaequilifolia* (Hook. & Grev.) Spring	H	2	+	
	Selaginella roxburghii (Hook. & Grev.) Spring	H	4	+	
	Selaginella siamensis Hieron.	H	2		+
	Selaginella wallichii (Hook. & Grev.)	H	4	+	
	Selaginella sp.	H	4		+
Monilophyte					
Cyatheaceae	*Cyathea podophylla* (Hook.) Copel.	H	1, 7	+	
Davalliaceae	*Humata angustata* (Wall. ex Hook. & Grev.) J. Sm.	H	2	+	
Dryopteridaceae	*Bolbitis appendiculata* (Willd.) K.Iwats.	H	2	+	
	Bolbitis heteroclita (Presl) Ching ex.C.Chr	H	1	+	
	Bolbitis virens (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman	H	1	+	+
Hymenophyllaceae	*Abrodictyum idoneum* (C.V.Morton) Ebihara & K.Iwats	H	2		+

[1] H-Herb; S-Shrub; T-Tree; C-Climber; S/T-Shrubby tree.
[2] 1- Small emergent rocks and sides of boulders; 2 - Boulders; 3 - Rock crevices; 4 - Soil banks; 5 - Sandy banks; 6 - Rocky banks; 7 - Stream floor; 8 - Shallow pools.

Family	Species	Life form[1]	Micro habitat[2]	Bedrock type	
				Granitic	Calcareous
	Cephalomanes javanicum (Blume) C.Presl	H	1	+	
	Crepidomanes bipunctatum (Poir.) Copel.	H	4		+
	Hymenophyllum acanthoides (Bosch) Rosenst.	H	2	+	
Lindsaeaseae	*Lindsea orbiculata* (Lam.) Mett. ex Kuhn var. *orbiculata*	H	2	+	
Lygodiaceae	*Lygodium flexuosum* (L.) Sw.	H	2	+	
Lomariopsidaceae	*Nephrolepis undulata* (Afzel.) J.Sm.	H	2		+
Osmundaceae	*Osmunda javanica* Blume	H	1	+	
Polypodiaceae	*Loxogramme involuta* (D.Don) C.Presl	H	2		+
	Leptochilus pedunculatus (Hook. & Grev.) Fraser-Jenk.	H	2	+	
	Selliguea heterocarpa Blume	H	2	+	
Pteridaceae	*Adiantum erylliae* C.Chr. & Tardieu	H	2		+
	Adiantum soboliferum Wall. ex Hook.	H	2		+
	Antrophyum callifolium Blume	H	2	+	+
	Doryopteris ludens (Wall. ex Hook.) J.Sm	H	2		+
	Pteris vittata L.	H	2		+
Tectariaceae	*Heterogonium pinnatum* (Copel.) Holttum	H	1, 6		+
	Tectaria angulata (Willd.) C.Chr.	H	7	+	+

Family	Species	Life form[1]	Micro habitat[2]	Bedrock type	
				Granitic	Calcareous
	Tectaria manilensis (C.Presl) Holttum	H	2		+
	Tectaria semipinnata (Roxb.) C.V.Morton	H	7	+	
Thelypteridaceae	*Cyclosorus menisciicarpus* (Blume) Holttum	H	2		+
	Thelypteris sp.	H	2		+
Woodsiaceae	*Diplazium riparium* Holttum	H	2	+	
Eudicots					
Acanthaceae	*Justicia gendarussa* Burm. f.	H	5	+	
Annonaceae	*Orophea enterocarpa* Maingay ex Hook.f. & Thomson	T	4		+
	Pseuduvaria reticulata (Blume) Miq.	T	4		+
	Pheanthus sp.	T	4	+	
Apocynaceae	*Kopsia pauciflora* Hook.f.	T	4		+
Begoniaceae	*Begonia aliciae* C.E.C.Fisch.	H	2		+
	Begonia integrifolia Dalzell	H	2		+
	Begonia pteridiformis Phutthai	H	2		+
	Begonia saxifragifolia Craib	H	2		+
Bignoniaceae	*Radermachera glandulosa* (Blume) Miq.	T	6, 7		+
Calophyllaceae	*Calophyllum rupicola* Ridl.	S	6	+	

Family	Species	Life form[1]	Micro habitat[2]	Bedrock type	
				Granitic	Calcareous
Clusiaceae	*Garcinia* sp.	T	6	+	
Ebenaceae	*Diospyros* sp.	T	6	+	
Elaeocarpaceae	*Elaeocarpus grandiflorus* Sm.	T	4, 7	+	+
Euphorbiaceae	*Croton* sp.	T	6	+	
	Trigonostemon aurantiacus (Kurz ex Teijsm. & Binn.) Boerl.	S	4	+	
Fabaceae	*Bauhinia pottsii* G.Don	C	4	+	+
	Saraca indica L.	T	7		+
Gentianaceae	*Exacum* sp.	Sp	2		+
Gesneriaceae	*Chirita* sp.	H	2		+
	Cyrtandra pendula Blume	H	2		+
	Epithema sp.	H	2		+
	Kaisupeea orthocarpa B.L.Burtt	H	2		+
	Paraboea gracillima Kiew	H	2		+
Lentibulariaceae	*Utricularia* sp.	H	2	+	
Lythraceae	*Duabanga grandiflora* (Roxb. ex DC.) Walp.	T	7		+
Moraceae	*Ficus auriculata* Lour.	T	6, 7		+
	Ficus globosa Blume	T	6		+

Family	Species	Life form[1]	Micro habitat[2]	Bedrock type	
				Granitic	Calcareous
	Ficus ischnopoda Miq.	S	1, 3	+	
	Ficus tinctoria G.Forst. subsp. *gibbosa* (Blume) Corner	T	4	+	
	Ficus sp.1	T	4, 7	+	
	Ficus sp.2	S	2		+
	Ficus sp.3	T	6	+	
Myrsinaceae	*Ardisia oxyphylla* Wall. & A.DC.	S	4, 7		+
	Ardisia fulva King & Gamble	S	6	+	
Myrsinaceae	*Ardisia* sp.	S	4	+	
Myrtaceae	*Syzygium nervosum* DC.	T	6, 7	+	
	Syzygium sp.1	T	6, 7	+	+
	Syzygium sp.2	T	6	+	
Oleaceae	*Olea brachiata (*Lour.) Merr.	T	6	+	
Phyllantaceae	*Antidesma* sp.	T	6		+
	Bridelia tomentosa Blume	S	6	+	
	Phyllanthus gracilipes (Miq.) Müll. Arg	S	4	+	
Piperaceae	*Piper* sp.1	H/C	2		+
	Piper sp.2	H/C	2		+

Family	Species	Life form[1]	Micro habitat[2]	Bedrock type	
				Granitic	Calcareous
Rubiaceae	*Argostemma condensum* Craib	H	2	+	
	Argostemma lobulatum Craib var. *variabile* Sridith	H	2		+
	Argostemma neurocalyx Miq.	H	2		+
	Argostemma pictum Wall.	H	2	+	
	Argostemma ophirense Maingay ex Hook.f.	H	2		+
	Ixora bracteolata Craib	S	4,6		+
	Ixora javanica (Blume) DC.	S	4	+	+
	Neonauclea pallida (Reinw. ex Havil.) Bakh.f	T	6	+	
	Neonauclea sp.1	T	7		+
	Neonauclea sp.2	T	7		+
	Neonauclea sp.3	T	6, 7	+	
	Ophiorrhiza communis Ridl.	H	4	+	+
	Ophiorrhiza pallida Thwaites	H	4	+	
	Ophiorrhiza tomentosa Jack ex Roxb.	H	4	+	
	Ophiorrhiza sp.	H	2		+
	Tarenna sp.	T	4	+	
Rutaceae	*Citrus* sp.	T	6, 7		+

Family	Species	Life form[1]	Micro habitat[2]	Bedrock type	
				Granitic	Calcareous
Sterculiaceae	*Sterculia balanghas* L.	T	4	+	
Theaceae	*Eurya nitida* Korth.	T	6	+	
Urticaceae	*Elatostema* sp.	H	2		+
Violaceae	*Rinorea* sp.	T	4	+	
Monocots					
Araceae	*Homalomena repens* Ridl.	H	1, 7	+	+
Cyperaceae	*Cyperus* sp.	H	8	+	+
Eriocaulaceae	*Eriocaulon* sp.	H	8	+	
Marantaceae	*Donax canniformis* (G. Forst.) K. Schum.	H/S	4, 8	+	+
Pandanaceae	*Pandanus* sp.	S	6	+	
Poaceae	*Pogonatherum paniceum* (Lam.) Hack.	H	3	+	
Zingiberaceae	*Boensenbergia* sp.	H	2		+
	Caulokaempferia saksuwaniae K.Larsen	H	2		+
	Globba leucanta Miq.var. *bicolor* Holttum	H	3		+
	Globba pendula Roxb.	H	3	+	

IV. Species descriptions

In the present study, 109 species of vascular plants was found belonging to 75 genera and 49 families. A full description of species, ecological data as well as localities of the 36 species that inhabited streambed (characteristic species) is given. Due to the transportation damage 6 species are lacking full description. In addition 3 species are left in the genus level, due to lack of reproductive organs such as flowers and fruits, but they were included in the complete species list (Table 3.3).

Full description of the species follows:

MONILOPHYTES

CYATHEACEAE

1. ***Cyathea podophylla*** (Hook.) Copel., Philipp. J. Sci. 4: 33. 1909; Tagawa & K. Iwats. in Fl.Thailand 3(3): 104.1979.

Terrestrial fern. **Stem** erect, up to 0.5 m, bearing fronds at the apex. **Frond** monomorphic, 2-pinnate. **Stipe** 40–50 cm long, dark brown to black, scaly at base; scales linear, 10–17 by 2–2.2 mm, light brown, shining, edges ferrugineous. **Lamina** deltoid in outline, 1–1.3 by 0.9 m; rachis dark brown, smooth, with few scales; scales linear, 0.2–0.3 mm long; lower pinnae 25–30 by 10 cm, apex acuminate; pinnules up to 2 cm apart, in pairs, up to 25 pairs, lanceolate, 10–12 by 1.5–1.7 cm, apex acute, margin biserrate, base rounded; stalk 2–4 mm long; veins forking ones, returning before margin to form distinct loops. **Sori** round, dorsal on veinlets, close to midvein.

Ecology: On stream banks or rocky islands, close to the stream bed in deep shade.

Distribution: S China, Indochina, Taiwan and Ryukyus.

Thailand: NORTH-EASTERN: Loei; EASTERN: Ubon Ratchathani; CENTRAL: Nakhon Nayok; SOUTH-EASTERN: Chanthaburi, Trat; PENINSULAR: Surat Thani, Phannga, Nakhon Si Thammarat.

Specimen examined: *M. Stankovic* 174 (PSU)

DRYOPTERIDACEAE

2. ***Bolbitis appendiculata*** (Willd.) K. Iwats. Acta Phytotax. Geobot. 18: 48. 1959; Tagawa & K. Iwats. in Fl.Thailand 3(3): 316. 1979. ***Plate 2.A.***

Lithophytic fern. **Rhizome** creeping; scales light brown. **Frond** dimorphic. **Sterile frond** 1-pinnate, sparsely scaly; stipe up to 15 cm long; lamina lanceolate, 10–30 by 4–9 cm, apex acuminate; rachis scaly, winged at upper part; pinnae 15–25 pairs, lower ones shorter than next above, with middle ones largest, oblong, 1–3 by 0.5–1 cm, apex acute, margin shallowly lobed, base auricled; apical pinna variable in shape and size, mostly narrowly subtriangular; veins pinnate, free; lobes shallow, round, with a distinct tooth at each sinus. **Fertile frond** taller than sterile one, 1-pinnate; stipe up to 25 cm long; lamina linear-lanceolate, 15–20 by 2–4 cm; pinnae subsessile, narrowly oblong, 7–30 by 2–3 mm; rachis wingless. **Sori** acrostichoid, covering whole dorsal surface of pinna.

Ecology: On the rocks near the granite streambeds, in deep shade.

Distribution: S China, India to SE Asia generally, throughout Malesia, northwards to Taiwan and the Ryukyus.

Thailand: NORTHERN: Chiang Mai, Lampang; NORTH-EASTERN: Phetchabun, Loei, Sakhon Nakhon; EASTERN: Nakhon Ratchasima, Chaiyaphum; SOUTH-WESTERN: Kanchanaburi, Phetchaburi, Prachuap Khiri Khan; SOUTH-EASTERN: Chanthaburi, Trat; PENINSULAR: Chumphon, Ranong, Phangnga, Phuket, Nakhon Si Thammarat, Trang, Satun, Songkhla, Yala.

Specimen examined: *M. Stankovic* 153 (PSU)

3. ***Bolbitis virens*** (Wall. ex Hook. and Grev.) Schott var. ***compacta*** Hennipman, Blumea 18: 149. 1970; Tagawa & K. Iwats. in Fl.Thailand 3(3): 316. 1988. ***Plate 1.C.***

Terrestrial fern. **Rhizome** short creeping, thick, densely scaly; scales thin but firm, up to 8 by 1.5 mm, dark brown, clathrate. **Frond** dimorphic. **Sterile frond** 1-pinnate, sparsely scaly; stipe up to 40 cm long; scales irregular in shape, appressed, ferrugineous, light brown on the upper part; lamina oblong-ovate, up to 30 by 20 cm;

lateral pinnae 5–7 pairs, shortly stalked, oblong-lanceolate, 15–20 by 4–6 cm, green, glabrous, apex caudate, margin waved, base unequally rounded; apical pinna larger than lateral, up to 20 by 6 cm; stalk short, 1 cm long. **Fertile frond** as high as sterile one; stipe 20 cm; lamina narrow, 20 by 7 cm; pinnae 4–5 pairs, apex acuminate; stalk 7–14 mm long. **Sori** acrostichoid, dispersed on whole dorsal surface of pinna.

Ecology: On the rocky islands or on stream banks which are frequently flooded in granite bedrock streams.

Distribution: Peninsular Malaysia and S Vietnam.

Thailand: SOUTH-EASTERN: Chanthaburi; PENINSULAR: Phangnga, Trang.

Specimen examined: *M. Stankovic* 154 (PSU)

HYMENOPHYLLACEAE

4. *Cephalomanes javanicum* (Blume) C. Presl, Abh. Boehm. Ges. Wiss. V. 5. 334. 1848; Tagawa & K. Iwats. in Fl.Thailand 3(1): 96. 1979. ***Plate 1.A.***

Litophytic or terrestrial fern. **Rhizome** erect, bearing many wiry roots and tufted fronds. **Frond** monomorphic, 1-pinnate. **Stipe** 5 cm long or more, light green to dark brown, covered with dark brownish hairs; wingless. **Lamina** lanceolate in outline, gradually narrowing towards apex and base, 20 by 2.5–4 cm; pinnae many, oblong-lanceolate, 1 by 2.5 cm, apex rounded, margin serrate; pinnae bearing sori deeply cut on both sides of each sorus. **Sori** placed at apex of a lobe; involucres tubular, truncate at mouth, narrowly winged; receptacles very long extruded.

Ecology: On the rocky islands and on the rocky banks of the granite bedrock streams in deep shade.

Distribution: Throughout SE Asia.

Thailand: SOUTH-EASTERN: Chanthaburi, Trat; PENINSULAR: Ranong, Surat Thani, Phangnga, Phuket, Trang, Satun, Yala.

Specimens examined: *M. Stankovic* 45, 151 (PSU)

OSMUNDACEAE

5. ***Osmunda javanica*** (C. Presl) Blume, Enum. Pl. Javae 252. 1828; Holttum, Rev. Fl. Malaya, ed. 2, 2: 47. 1968. ***Plate 1.B.***

Terrestrial fern. **Rhizome** short, erect, bearing a tuft of fronds. **Frond** monomorphic, 1-pinnate. **Stipes** 40–50 cm long, stamineous, hairy in lower part; hairs 2–3 cm long, brownish. **Lamina** lanceolate, up to 120 by 35 cm, with numerous lateral and apical pinnae, apex acute; pinnae lanceolate, coriaceous, gradually narrowing towards apex, apex acuminate, margin entire, base cuneate; stalk 2–5 mm long; costa distinctly raised on the dorsal surface. **Fertile pinnae** in the lower part of frond, few sterile pinnae below, without lamina, shorter than sterile. **Sporangia** on short branches lobes along pinnae axis, shortly stalk; stalk 0.2–0.5 mm long; anulus consists of a single row of cells.

Ecology: Along streamside and on rocky islands in streams.

Distribution: S and SW China, Myanmar, Vietnam, Cambodia, Peninsular Malaysia and Java.

Thailand: NORTHERN: Mae Hong Son, Chiang Mai; NORTH-EASTERN: Loei; EASTERN: Surin; SOUTH-EASTERN: Trat; PENINSULAR: Trang, Satun, Songkhla, Yala, Narathiwat.

Specimen examined: *M. Stankovic* 49 (PSU)

POLYPODIACEAE

6. ***Leptochilus pedunculatus*** (Hook. and Grev.) Fraser-Jenk., Taxon. Revis. Indian Subcontinental Pteridophytes 62. 2008.— *Colysis pedunculata* (Hook. and Grev.) Ching, Bull. Fan Mem. Inst. Biol. 4: 321. 1933; Tagawa & K. Iwats. in Fl.Thailand 3(4): 538. 1989. ***Plate 6.D.***

Litophytic or epiphytic fern. **Rhizome** long creeping, 2–3 mm in diameter, bearing fronds 7–14 mm apart, scaly; scales pseudopeltate, narrowly subtriangular, 2.4–4 by 0.5–0.8 mm, dark brown, clathrate, apex acuminate, margin toothed. **Frond** dimorphic. **Sterile frond**: stipe 5–10 cm long, winged; lamina oblong–lanceolate, up to 14 by 5 cm, green, gradually narrowing towards apex, apex acuminate, margin entire, base rounded. **Fertile frond**: stipe 14–30 cm long, stramineous, wingless; lamina broadly oblong, 4–7 by 2–4 cm, gradually narrowing towards apex, apex acute, margin entire, base rounded. **Sori** elongated, 10–20 by 2–4 mm, covering almost whole dorsal surface of lamina except on main and secondary veins.

Ecology: On the moist rocks near streambeds in deep shade or epiphyte on the trees that are close to the streams.

Distribution: SE Himalayas, SW China, Vietnam, Malaysia, Sumatra and Java.

Thailand: NORTHERN: Chiang Mai; SOUTH-WESTERN: Phetchaburi; SOUTH-EASTERN: Chon Buri, Chanthaburi; PENINSULAR: Surat Thani, Krabi, Nakhon Si Thammarat, Trang, Satun.

Specimens examined: *M. Stankovic* 158a, 158b (PSU)

PTERIDACEAE

7. *Pteris vittata* L., Sp. Pl.: 1074. 1753; Tagawa & K. Iwats. in Fl.Thailand 3(2): 233. 1985. ***Plate 6.C.***

Terrestrial fern. **Rhizome** short creeping, then ascending, 3–6 cm long, bearing a tuft of fronds. **Frond** monomorphic, 1-pinnate. **Stipe** up to 30 cm long, scaly on the lower part; scales 2–3.4 by 1–2.1 mm, pale brown. **Lamina** oblanceolate, widest on the upper part, 15–30 by 6–13 cm; pinnae simple, lower ones gradually becoming smaller downwards to auricles, middle ones 4–15 by 0.4–0.9 cm, linear, apex acuminate, margin serrate, base cordate, terminal pinnae up to 20 by 1 cm; rachis grooved on verntal surface, minutely scaly; veins forked. **Sori** marginal, continuous along margin of pinnae; indusia thin, pale.

Ecology: On wet ground and rocks along the calcareous streams.

Distribution: Tropics and subtropics of the Old World and N to S Japan.

Thailand: NORTHERN: Mae Hong Son, Chiang Mai, Chiang Rai, Lamphun, Lampang, Tak; NORTH-EASTERN: Loei; SOUTH-WESTERN: Kanchanaburi; CENTRAL: Saraburi; SOUTH-EASTERN: Chanthaburi, Trat; PENINSULAR: Surat Thani, Phangnga, Krabi, Nakhon Si Thammarat, Phatthalung, Trang, Satun, Songkhla,Yala.

Specimen examined: *M. Stankovic* 188 (PSU)

TECTARIACEAE

8. *Heterogonium pinnatum* (Copel.) Holttum, Sarawak Mus. Journ. 5: 163. 1949; Tagawa and K. Iwats. in Fl.Thailand 3(3): 363, f. 33.8. 1988. ***Plate 2.B.***

Terrestrial fern. **Rhizome** short, erect, 5–8 cm long; scales lanceolate, 8 by 1 mm, dark brown. **Frond** dimorphic. **Sterile frond**: stipe 30–40 cm long, dark brown, pubescent, densely scaly at base; lamina oblong, deltoid, 27 by 30 cm, 2-pinnatifid; rachis densely pubescent; scales 6–8 by 0.7–1 mm, dark brown; lowest lateral pinnae: stalk 0.5 cm long; pinnae deeply lobed, 15 by 5 cm, entire; upper ones sessile, 1–3 pairs, 10 by 1–3 cm broad, shallowly lobed; apical pinna deltoid, lobes entire. **Fertile frond**: stipe longer than in sterile frond, 50 cm long; lamina 13 cm long, 2-pinnatifid, lobes 1–2 mm wide. **Sori** acrostichoid.

Ecology: By stream in shade.

Distribution: W Malesia and the Philippines.

Thailand: PENINSULAR: Surat Thani, Krabi, Nakhon Si Thammarat, Trang, Yala.

Specimens examined: *M. Stankovic* 94, 117, 215 (PSU)

THELYPTERIDACEAE

9. *Cyclosorus menisciicarpus* (Blume) Holttum, Dansk Bot. Ark. 25: 39. 1967.— *Thelypteris menisciicarpa* (Blume) K. Iwats., Acta Phytotax. Geobot. 21: 171. 1965; Tagawa and K. Iwats. in Fl.Thailand 3(3): 410. 1988.

Terrestrial fern. **Rhizome** short creeping, 4–7 cm long, with dense packed stipes; scales triangular, 3.5–5 by 1–1.5 mm, membranous, brown, hairy. **Frond** slightly anisomorphic, fertile frond taller than sterile one. **Sterile frond**: stipe 7–10 cm long, hairy throughout; lamina ovate, 20 by 10 cm; lateral pinnae sessile, 3–4 pairs, narrowly oblong, 5–6 by 2–3 cm, sometimes auricled, apex caudate, margin entire, base broadly cuneate; apical pinna longer than lateral pinnae, narrowly triangular, 15–20 by 5–7 cm. **Fertile frond**: stipe 25–37 cm long; lamina ovate, 30 by 12 cm; lateral pinnae sessile, 3–4 pairs, 2.6–7 by 1.2–2.8 cm, chartaceous, apex acuminate, base broadly cuneate. **Sori** round; indusia brown, persistent, hairy; sporangia setose.

Ecology: On the calcareous rocks close to the streams, flooded during heavy rains.

Distribution: Peninsular Malaysia, Sumatra, Java, Borneo, the Philippines and New Guinea.

Thailand: SOUTH-WESTERN: Prachuap Khiri Khan; PENINSULAR: Surat Thani, Trang, Satun, Yala.

Specimen examined: *M. Stankovic* 78 (PSU)

WOODSIACEAE

10. *Diplazium riparium* Holttum, Gard. Bull. Straits Settlem. 11: 97, f. 5. 1940; Tagawa and K. Iwats. in Fl.Thailand 3(3): 454. 1988.

Terrestrial fern. **Rhizome** short, 4–7 cm long, ascending to suberect; scales 11–15 by 1–1.3 mm, narrowing towards acuminate apex, margin entire, dark brown almost black. **Stipe** 35–50 cm long, stamineous, scaly. **Laminae** imparipinnate with less than four pairs lateral pinnae, 20 cm long and wide; rachis grooved on ventral surface; lateral pinnae oblong-lanceolate, more than 4–7 by 12–25 cm, subentire to crenate, apex rounded, base narrowly cuneate, ventral surface deep green, dorsal surface paler; costa grooved on upper surface, raised below; veins free, visible on both surfaces. **Sori** elongate along veins, 2 cm long; indusia usually on both sides of veins, attached by posterior side, pale brown.

Ecology: On the rocky islands or on the stream banks in deep shade of granite bedrock streams.

Distribution: Peninsular Malaysia, Borneo and the Philippines.

Thailand: PENINSULAR: Surat Thani, Satun, Yala.

Specimen examined: *M. Stankovic* 46 (PSU)

EUDICOTS

ACANTHACEAE

11. *Justicia gendarussa* Burm.f., Fl. Ind. (N. L. Burman) 10. 1768.— *Gendarussa vulgaris* Nees, Pl. Asiat. Rar. (Waillich). 3. 104. 1832; Ridl., Fl. Malay. Penin. 2: 593. 1923. ***Plate 6.A.***

Shrub, creeping, then erect, 0.7–1.5 m high, sometimes woody at base. **Leaves** opposite, narrowly lanceolate, 6–10 by 1–1.5 cm, glabrous, apex acute to shortly acuminate, margin subsinuate, base cuneate to attenuate; midvein purple, distinct, secondary veins 5–8 on each side of midvein ; petiole 0.5–0.7 cm long, glabrous. **Inflorescence** terminal or axillary, spike, 3–12 cm long, interrupted; peduncle 0.5–1.5 cm long; bract triangular, 2–6 by 1– 2.5 mm, basal ones longer than calyx, then gradually smaller with apical most ones shorter than calyx, apex acute, margin ciliate. **Flowers** bisexual, zygomophic, 5 mm in diameter; pedicels 0.2–0.3 mm long; bracteoles elliptic to linear-lanceolate, 3 by 1 mm, apex acute, margin ciliate. **Calyx** green, with purple dots, 5 mm in diameter, 5-lobed, pubescent; lobes linear-lanceolate, 3–4 by 0.4–0.6 mm, subequal, apex acuminate. **Corolla** creamy white, 1.2–1.5 cm long, strongly 2-lipped; tube basally cylindrical, greenish whitish, 2 by 8–9 mm; upper lip 2-lobed; each lobe trigular, violet blotched, 6–7 by 3–3.5 mm; lower lip 3-lobed, each lobe oblanceolate, 3–5 by 2.5 mm, violet with dots**.** **Stamens** yellow, 2, exerted; filaments 3–6 mm, glabrous; anthers oblong, 1.2 mm long, lower one spurred at base, upper one muticous. **Ovary** superior, glabrous, 1-locular, 2 ovules per locule, placentation axile; style pink, 1 mm long, glabrous; stigma capitate, shortly 2-lobed. **Fruit** not seen.

Ecology: Wide varieties of habitat from roadside and cultivated areas to primary forests.

Distribution: All over E and SE Asia.

Thailand: PENINSULAR: Songkhla.

Specimen examined: *M.Stankovic* 143 (PSU)

BIGNONIACEAE

12. ***Radmermachera glandulosa*** Miq., Ann. Mus. Bot. Lugduno-Batavi 3: 250. 1867; Santisuk in Fl.Thailand 5 (1): 39. 1987. ***Plate 2.D.***

Small tree, up to 10 m high, sometimes forming buttress root. **Leaves** decussate, 1-pinnate; petioles 4–6 cm long, glabrous; rachis 7–10 cm long, not kneeled on the ventral surface, glabrous; leaflets less than 7 pairs, opposite, elliptical to obovate, 20 –30 by 5–15 cm, apex acuminate, margin entire, base oblique with dark dense glandular patch on dorsal surface; petiolules up to 1 cm. **Inflorescence** terminal, gradually elongated thyrse, 15–20 cm long; peduncle 2–4 cm long, glabrous. **Flowers** many, zygomorphic, 1–1.5 cm in diameter; pedicel 0.7–1.2 cm long. **Calyx** purple spotted, 3–5 mm long, cup-shaped, irregularly lobed, truncate, with 6–8 glands. **Corolla** white with pinkish tip, 1.7 –2 cm in diameter, 5-lobed, glabrous; tube slightly curved, 1–1.7 cm long, widening towards the opening forming funnel shape; lobes rounded, subentire, 5–7 by 3–4 mm, margin ciliate. **Stamens** 4, didynamous, equal, exerted, hairy at insertion; filaments 7–10 mm long, glabrous; anthers 2-celled, 2–4 mm long. **Ovary** superior, rounded, 2-locular, ovules numerous in 2 rows in each locule, placentation axile; style included, 1.3–1.6 cm long; stigma 2-lobed, glabrous, ligulate. **Fruit** not seen.

Ecology: By the streams or in the streambed, usually lower trunk flooded.

Distribution: Assam, Myanmar, Laos, SE China, Malay Peninsula, Sumatra, Java.

Thailand: NORTHERN: Chiang Mai, Lampang; PENINSULAR: Chumpon, Ranong, Phannga, Krabi, Surat Thani, Trang, Satun, Songkhla, Pattani, Yala and Narathiwat.

Specimen examined: *M.Stankovic* 19 (PSU)

CALOPHYLLACEAE

13. ***Calophyllum rupicola*** Ridl., Trans. Linn. Soc. London, Bot. 3(9): 278. 1893. — *Calophyllum rupicolum* Ridl., Whitmore in Tr. Fl.Mal. 2: 169.1978.; Ridl. in Fl. Mal. Pen. 1: 182. 1967. ***Plate 2.C.***

Small tree, 5 m high, forming small buttresses. **Leaves** opposite, decussate, lanceolate to oblanceolate, 3–11 by 0.5–2.5 cm, coriaceous, apex obtuse to acute, base attenuate to cunete, margin entire; midvein raised on the lower surface, yellow, glabrous; secondary veins numerous, parallel, at right angles to the mid vein; petiole 0.5–1.4 cm long. **Inflorescence** axillary, paniculate, many flowered, 5–7 cm long; peduncle short, 3–6 mm long; rachis 3–5.5 cm long, glabrous. **Flowers** bisexual, actinomorphic, 3–6 mm in diameter; pedicels 0.3–0.7 cm long, glabrous. **Perianth** 4-merous; tepals 4, obovate-oblong, 3–5 by 1–2 mm, apex rounded, margin entire; outer tepals 2, greenish, decussate; inter 2, white, imbricate. **Stamens** numerous; filament slender, 0.5–0.7 mm long; anthers basifixed, oblong to oblique, erect, 2-celled, jointed at base into 4–8 bundles. **Ovary** superior, glabrous, 1-locular, 1 ovule, placentation basal; style slender, elongated; stigma peltate. **Fruit** not seen.

Ecology: Along the granite bedrock streams, frequently influenced by water velocity.

Distribution: NE Malaysia, Sumatra.

Thailand: PENINSULAR: Narathiwat.

Specimens examined: *M. Stankovic* 133 (PSU)

ELAEOCARPACEAE

14. ***Elaeocarpus grandiflorus*** Sm., Cycl. [A. Rees], (London ed.) 12: 5. 1809.; Phengklai in Fl.Thailand 2 (4): 427. 1981.; Ng, Tree Fl. Mal. 4: 88. 1989. ***Plate 2.E.***

Tree, 15 m high. **Leaves** spirally arranged, obovate to lanceolate, 12–15 by 4–6 cm, coriaceous, glabrous on the ventral surface, glabrescent on dorsal surface, apex acute, margin sinuate to serrate, base cuneate to acute; midvein distinct, raised on the upper surface, secondary veins 6–9 pairs, arched but not anastomosing; petiole up to 2 cm long, glabrous. **Inflorescence** in the axils of existing leaves, racemose; pedicel 3 cm long, glaborus. **Flowers** bisexual, actinomorphic, 1.5 cm in diameter **Calyx** purplish pink, 5–-merous; sepals free, lanceolate, 1.5 by 0.4 cm, glabrescent. **Corolla** white, free, sparsely hairy on both sides; petals 5, obovate, 1.5 by 1 cm, margin toothed; laciniae about 1/5 the length of petal. **Stamens** 30–40, glabrous; filaments free, borne on disk; anthers 9–10 mm long, opening by longitudinal slits. **Ovary** superior, densely covered with short hairs, ovoid, 2-locular, ovules 2–12 per locule; style 6–9 mm long, hairy; stigma acute; disc 10-lobed. **Fruit** a drupe, ellipsoid, pointed at both ends, 3 by 1 cm, endosperm hard. **Seeds** 1 per locule.

Ecology: Along the granite and limestone streams and on the slopes of the waterfalls.

Distribution: India, Myanmar, Laos, Vietnam, Cambodia, Malay Peninsula, Indonesia.

Thailand: Throughout the country.

Specimen examined: *M. Stankovic* 82 (PSU)

FABACEAE

15. ***Saraca indica*** L., Mant. Pl. 98. 1767; K. Larsen et al. in Fl.Thailand 4 (1): 97. 1984. ***Plate 3.A.***

Tree, up to 20 m high. **Leaves** alternate, paripinnate; stipules connate; rachis 10 to 46 cm long, glabrous; petiole 4 cm long; leaflets opposite, 1–5 pairs, elliptic ovate to lanceolate, 5–20 by 2–7 cm, apex acute to rounded, base cuneate, margin entire; secondary veins 15–20 pairs; petiolules 2–5 mm. **Inflorescence** terminal, corymbose, many flowered, 4–10 cm in diameter; peduncle 4–7 cm long, glabrous; rachis up to 10 cm long; bracts ovate to oval, 2–7 by 1.5–3 mm, spreading, persistent. **Flowers** bisexual, zygomorphic, 2 cm in diameter, apetalous; bracteoles orange color, 3–8 by 1.5–4 mm, spreading, persistent; pedicel 10–25 mm long; receptacle tubular 7–16 mm long.; sepals 4, orange, ovate-oblong, 5–12 by 2–7 mm, apex rounded. **Stamens** 6–8, exerted; filaments fee, up to 20 mm long, glabrous, opening by longitudinal slits. **Ovary** superior, stipitate, pubescent along the margin, 1-locular, ovules 6–8; style 4–6 mm long, filiform, curved; stigma terminal, minute. **Fruit** a pod, flattened, oblong-lanceolate, 2–25 by 2–6 cm, coriaceous, breaked at apex, rounded at base; stipe 4–6 cm long. **Seeds** 1–8, ellipsoid, flattened.

Ecology: Along or in the limestone bedrock streams.

Distribution: Laos, S Vietnam, Malay Peninsula, Sumatra, Java.

Thailand: NORTHERN: Chiang Mai; EASTERN: Nakhon Ratchasima; CENTRAL: Saraburi, Ohra Nakhon (Bangkok); SOUTH-EASTERN: Trat (Koh Chang); SOUTH-WESTERN: Kanchanaburi; PENINSULAR: Surat Thani, Nakhon Si Thammarat, Yala, Narathiwat, Pattani, Krabi, Trang, Satun.

Specimens examined: *M. Stankovic* 17, 93, 130, 186 (PSU)

LYTHRACEAE

16. *Duabanga grandiflora* Walp., Repert. Bot. Syst. (Walpers) 2: 114.1843; Santisuk in Fl.Thailand 5(4): 435. 1992. ***Plate 3.B.***

Tree, up to 40 m high. **Leaves** opposite, oblong to oblong-ovate, 15–25 by 6–9 cm, leathery, glabrous, dark green on the upper surface, light green on the lower surface, apex acuminate, margin sinuate, base broadly rounded to cordate; midvein distinct, raised on the lower surface, secondary veins 12–25 pairs, raised, curving towards the margin; petiole short, 5–8 mm long. **Inflorescence** terminal, solitary cyme, 1–3 flowered, hanging; peduncle 5–7 cm long. **Flowers** bisexual, actinomophic, 4–6 cm in diameter; pedicel 3 cm long, glabrous. **Calyx** green, broadly cup-shaped, 1.7–3 cm in diameter, 6–lobed, glabrous; lobes triangular to ovate, 1.2–2 by 0.8–1.7 cm, apex acute, margin entire. **Corolla** white, showy; petals 6, obovate, 4 by 3 cm, apex rounded, margin sinuate, claw 3 mm long. **Stamens** 50 or more, biseriate, exerted; filaments white, 1–1.5 cm long; anthers yellow, curved, versatile. **Ovary** superior, glabrous, partially fused to the calyx tube, 4–8-locular, ovules numerous, placentation axile; style yellow, 1 cm long; stigma green, thick, 2-lobed. **Fruit** a capsule, green turning brown, ovoid, 2.5–3 by 3.6–4 cm, with persistent calyx lobes. **Seeds** numerous, linear, tailed.

Ecology: Along and in the streambed of limestone streams.

Distribution: India, Myanmar, S.China, Indo–China, W. Malaysia.

Thailand: NORTHERN: Chiang Rai, Chiang Mai, Phrae; NORTH-EASTERN: Nong Khai; EASTERN: Nakhon Rachasima, Ubon Ratchathani; SOUTH-EASTERN: Chon Buri; SOUTH-WESTERN: Kanchanaburi; CENTRAL: Saraburi; PENINSULAR: Chumpon, Satun, Yala.

Specimens examined: *M. Stankovic* 21, 127, 129 (PSU)

MORACEAE

17. ***Ficus auriculata*** Lour., Fl.Cochinch. 2: 660. 1790.; C.C.Berg *et al.* in Fl.Thailand 10 (4): 559. 2011. ***Plate 3.C.***

Tree, 10–15 m high, forming buttress roots in growing mature plants, dioecious. **Leaves** spirally arranged, ovate, oblong or elliptical, 10–30 by 6–15 cm, symmetrical, chartaceous to subcoriaceous, glabrous, apex acute or shot acuminate, margin denticulate-crenulate, base broadly rounded; cystoliths on both surfaces; midvein distinct, puberulous, secondary veins 3–5 pairs; waxy glands in the axils of the secondary veins bases; petiole 5–15 cm long, brownish hairs on lower part; stipules 1.5 cm long, brownish, sparsely covered with hairs. **Synconium** axillary, urn-shape, in clusters on leafless branches; the leafless branch 15 cm long on the trunk and also the main branches; peduncle 1 cm long; bracts 3, 2–5 mm long, verticilate; receptacle reddish to dark red or purple at maturity, discoid, 1.5–2 cm in diameter when dry, sparsely puberulous, numerous longitudinal ridges; ostiole 2–12 mm in diameter; internal hairs minute, white. **Staminate** and **gall flowers** not seen. **Pistilate flowers** 2–5 mm long; perianth reddish purple, tubular to 3-partite, 0.5–4 mm long, tepals lanceolate, 0.7–1 by 0.3–0.5 mm, apex acute; ovary sessile, 0.7 mm in diameter, style lateral, 0.9–2.1 mm long, sparsely hairy. **Fruit** not seen.

Ecology: In the streambed and along the limestone streams.

Distribution: Pakistan, N India, Nepal, Sikkim, Bhutan, Myanmar, S China, Laos, Vietnam, Cambodia, Peninsular Malaysia.

Thailand: NORTHERN: Mae Hong Son, Chiang Mai, Chiang Rai, Phayao, Nan, Phrae, Tak; EASTERN: Nakhon Ratchasima; SOUTH WESTERN: Kanchanaburi, Phetchaburi; CENTRAL: Nakhon Nayok; SOUTH-EASTERN: Chon Buri, Trat: PENINSULAR: Phattalung, Nakhon Si Thammarat, Satun, Pattani, Yala, Narathiwat.

Specimen examined: *M. Stankovic* 184 (PSU)

Note: This species is very variable, especially in the shape of lamina and position of the figs on the tree.

18. ***Ficus ischnopoda*** Miq., Ann. Mus. Bot. Lugduno-Batavi 3: 229. 1867. C. C. Berg *et al*. in Fl.Thailand 10 (4): 522. 2011. ***Plate 1.D.***

Shrub, 3–6 m high, with shot shoots bearing leaves at branch ends, dioecious. **Leaves** spirally arranged, linear-oblanceolate, 3–21 by 0.5–4 cm, chartaceous to coriaceous, symmetrical, glabrous, apex acuminate to sub-acute, margin entire to revolute, base cuneate to rounded; cystoliths only on the lower surface; midvein distinct on the lower surface, brownish to whitish, puberulous, secondary veins 7–20 pairs, unbranched; waxy glands in the axils of the secondary veins bases; petiole 0.7–2.3 cm long, brownish, puberulous; stipules 0.5–1 by 0.2–0.4 cm, lateral, brownish to whitish, puberulous. **Synconium** axillary, solitary or paired, conic to spindle-shaped with longitudinal ridges, 1–2 by 0.5–0.8 cm; peduncle 0.3– 2 cm long; bracts 3, 1–2 by 0.7–1 cm, sparsely puberulous; receptacle ellipsoid, sub-pyriform, 1.5–2.3 cm in diameter when dry, glabrous, dark red to purple when mature, apex protracted; ostiole 2–3 mm in diameter, slightly sunken. **Staminate flowers** near the ostiole; pedicel 0.7–1.2 cm long; tepals 4 lanceolate 0.8–1.1 by 0.3–0.4 mm; stamens 2, glabrous; filaments short 0.3–0.5 mm long; anthers basifixed, ellipsoid, 0.6–0.8 by 0.3–0.5 mm. **Gall flowers** sub-sessile; tepals 4, oblanceolate 0.5–0.9 by 0.3–0.5 mm; gall ovary globose, 0.9–1.1 by 0.7–0.9 mm; stile lateral; stigma shallowly 2-lobed. **Pistilate flowers** pedicel 2–6 mm long; tepals 4, oblanceolate, 0.7–1 by 0.3–0.5 mm, reddish purple, apex short acuminate; ovary sessile, oblique, 1–1.3 by 0.9–1.1 mm; style lateral, 0.7–1.3 mm long, persistent. **Fruit** not seen.

Ecology: On the rocks in and along the streams.

Distribution: NE India, Bhutan, Bangladesh, Myanmar, S China, Laos, Vietnam, Cambodia, Peninsular Malaysia.

Thailand: NORTHERN: Mae Hong, Son, Chiang Mai, Lamphun, Tak, Phitsanulok; NORTH-EASTERN: Phetchabun, Loei, Nong Khai, Sakon Nakhon, Nakhon Phanom, Kalasin, Khon Kaen; EASTERN: Chaiyaphum, Nakhon Rathcisima; SOUTH-WESTERN: Kanchanaburi; CENTRAL: Nakhon Nayok; SOUTH-EASTERN: Prachin Buri, Chon Buri, Rayong, Chanthaburi, Trat; PENINSULAR: Ranong, Surat Thani, Phangnga, Nakhon Si Thammarat, Phattalung, Songkhla, Yala, Narathiwat.

Specimens examined: *M. Stankovic* 47, 202, 203 (PSU)

19. ***Ficus tinctoria*** G. Frost. subsp. ***gibbosa*** (Blume) Corner, Gard. Bull. Singapore 17:476.1960.; C. C. Berg *et al.* in Fl.Thailand 10 (4): 554. 2011. ***Plate 3.D.***

Tree, 15–20 m high, dioecious, branches brownish to yellow. **Leaves** distichous, oblong elliptic to lanceolate, (3–)5–20(–30) by (1–)3–8(–13) cm chartaceous, glabrous, shiny and smooth on the upper surface, scabridulous on the lower surface, apex acuminate to subacute, margin entire to revolute, base cuneate to slightly decurrent on one side; cystoliths on both surfaces; midvein slightly prominent on the upper surface, sparsely hispidulous, secondary veins 5–9 pairs, basal veins running close to margin, to 1/8–1/3 the length of lamina, unbranched, tertiary venation reticulate; waxy glands in the axils of either secondary veins bases; petiole 0.4–1.5 cm long, sparsely minutely hispidulous; stipules 0.5–1 cm long, sparsely minutely puberulous, amplexicaul. **Synconium** axillary or just below the leaves, solitary or in pairs; peduncle 1–1.3 mm long; bracts 3, triangular-ovate, 1–1.5 by 0.5–0.8 mm, in whorl; receptacle globose to ellipsoid, 0.4–1 cm in diameter when dry, sparsely minutely hispidulous, scabridulous, without lateral bracts, yellow to orange when mature; ostiole 1 mm in diameter, surrounded by a prominent rim; internal hairs minute, abundant. **Staminate flowers** near the ostiole, tepals 4-6, white, linear, 1.7–2 by 0.3–0.5 mm; stamen 1, glabrous; filament 1.3–1.5 mm long; anthers cordate, dorsifixed; rudimentary ovary present. **Gall flowers**: pedicel 1–2.3 mm long, tepals 4–6, linear, 1.7–2 by 0.3–0.5 mm; gall ovary ovoid, 1–2 by 0.7–0.9 mm; style lateral, short, 0.7–1.1 mm long. **Pistilate flowers**: pedicel 1–3.5 mm long; tepals 4, transparent, glabrous, linear 0.8–2 by 0.6–1.4 mm; ovary sessile, oblique, 0.7–2.1 by 0.3–0.5 mm; style lateral, 0.3–2.6 mm long, glabrous; stigma enlarged . **Fruit** not seen.

Ecology: Along the granite bedrock streams.

Distribution: Sri Lanka, India, Nepal, Sikkim, Bhutan, Bangladesh, Myanmar, S China, Vietnam, Laos, Cambodia, Malaysia, Brunei, Sumatra, Java, Kalimantan Lesser Sunda Islands: Bali, the Philippines.

Thailand: NORTHERN: Chiang Mai, Lamphun, Lamphang, Phear, Tak, Phitsanulok; NORTH-EASTERN: Phetchabun, Sakon Nakhon, Khon Kaen; Nokhon Nayok; SOUTH-EASTERN: Chon Buri, Chanthaburi; EASTERN: Nakhon Ratchisima; SOUTH-WESTERN: Ratchaburi, Phetchaburi; CENTRAL: Saraburi; PENINSULAR: Chumpon, Surat Thani, Krabi, Nakhon Si Thammarat, Phattalung, Trang, Satun, Pattani, Narathiwat.

Specimen examined: *M. Stankovic* 156 (PSU)

20. *Ficus* sp.1 *Plate 3.E.*

Tree, 10–17 m high, dioecious. **Leaves** spirally arranged, equally oblong to elliptic, 6–20 by 4.5–8 cm, coriaceous, scabrous, apex long acuminate, margin entire, base slightly oblique, cuneate; midvein raised on the lower surface, puberulous, secondary veins 6–8 pairs, basal veins running close to the margin, unbranched; waxy glands in the axils of the veins bases; petiole 1–1.5 cm long, sparsely puberulous; stipules 0.3–0.7 cm long, amplexicaul, minutely puberulous. **Synconium** axillary, in clusters on short leafless branches; leafless branches woody, 4–5.5 cm long, on main branches; peduncle 1.5–2 cm, sparsely puberulous; bracts 3, lanceolate, 0.8–1.1 by

0.3–0.7 mm; receptacle 1.5–2 mm in diameter when dry, sparsely puberulous, yellow to reddish when mature; ostiole 0.4–0.6 mm in diameter, surrounded by rim; internal hairs abundant. **Staminate** and **gall flowers** not seen. **Pistilate flowers**: pedicel 1–4 mm; tepals 4, linear to lanceolate, 0.5–1.2 by 0.2–0.9 mm, whitish, glabrous; ovary sessile, oblique, 0.6–1.9 by 0.3–1.2 mm; style lateral, 1–1.9 mm long, glabrous. **Fruit** not seen.

Ecology: Along and in the streambed of the granite bedrock streams, often on the pebbly islands.

Distribution: PENINSULAR: Songkhla.

Specimen examined: *M.Stankovic* 146 (PSU)

Note: The plant materials of this species did not fit any description of all *Ficus* species of the subgenus Sycidium recorded in the Flora of Thailand. C.C.Berg *et al*. (2011) noted that this subgenus have 115 species recorded in Thailand, while the key represented 15 indigenous species.

MYRSINACEAE

21. ***Ardisia fulva*** King & Gamble, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74(1): 124. 1906.; K. Larsen and C.M.Hu in Fl.Thailand 6 (2): 119. 1996. ***Plate 4.B.***

Shrub, 1–4 m high, young branches terate, densely villous with ferruginous short capitates hairs. **Leaves** alternate, lanceolate to elliptic, 6–18 by 1–5 cm, chartaceous, lower surface glabrous, upper surface tawny-villous, apex acuminate, margin subentire, base cuneate to acute, petiole 5–12 cm, hairy; glands many, black, distinct on both surfaces; midvein raised on the lower surface, densely villous, secondary veins 14–22 pairs. **Inflorescence** in the axils of the reduced leaves in upper part of branches, sub-umbellate raceme, two to many-flowered; peduncle 1–3 cm, hairy. **Flowers** bisexual, actinomorphic, 5-merous, 0.7–1 cm in diameter; pedicel 5–

15 mm. **Calyx** green, 3 mm in diameter, deeply lobed; lobes not overlapping at base, at anthesis, distinctly imbricate, ovate, 1.5–2.3 by 1–1.4 mm, puberulous outside, dotted with black glands, apex obtuse, margin ciliate. **Corolla** pink, 5 mm in diameter, deeply lobed; convolute in bud, lobe elliptic to obovate-elliptic 2.3–3 by 0.4–0.8 mm, glabrous, with scattered dark purple or black dots and lines, apex obtuse**.** **Stamens** 5, inserted on the base of the corolla; filaments 0.5–0.9 mm long; anthers ovate 1.3–1.8 mm long, apiculate, punctuate, opening by means of longitudinal slits. **Ovary** superior, glabrous, ovoid, 1-locular, ovules many in 2–3 series, placentation basal; style 3.5 mm long, slender; stigma punctiform. **Fruit** a drupe, globose, slightly depressed, 6–7 mm in diameter, longitudinally striate, minute glandular dots, purple and black when mature. **Seeds** not seen.

Ecology: Along and on the pebbly islands of granite bedrock streams, in shade and open area.

Distribution: W Malaysia, Myanmar.

Thailand: CENTRAL: Saraburi; SOUTH-WESTERN: Prachuap Khiri Khan; PENINSULAR: Chumpon, Ranong, Surat Thani, Krabi, Trang, Satun, Yala, Narathiwat, Pattani.

Specimen examined: *M. Stankovic* 199 (PSU)

22. ***Ardisia oxyphylla*** Wall. & A.DC., Trans. Linn. Soc. London 17(1): 119. 1834.; K.Larsen & C.M.Hu in Fl.Thailand 6(2): 129.1996. ***Plate 4.A.***

Shrub, up to 3m high, branches brownish, stout, terate, glabrous, with leaf scars. **Leaves** alternate, elliptic to oblong-oblanceolate, 8–20 by 3.5–6 cm, chartaceous, glabrous, apex acute to shortly acuminate, margin entire, base cuneate; glandular dots many, black, abundant along the margin; petiole 1–2 cm; secondary veins more than 20 pairs, 4–6 mm apart, almost parallel. **Inflorescence** axillary, racemose, 3–5-flowered; peduncle 3–5 cm. **Flowers** bisexual, actinomophic, 3 mm in diameter, 5-merous, buds rounded. **Calyx** greenish, split nearly to base; lobes orbicular, 2–2.5 mm diameter, with distinct black-dotted glands, apex acute, margin ciliate, distinctly overlapping to the right. **Corolla** pinkish-purple, campanulate, 6–7 mm in diameter, overlapping to the right, deeply lobed; tube less than 1 mm; lobes broadly ovate, 3.5–4 by 8–9 mm, apex acute, densely dotted with glands, jointed at base. **Stamens** 5, attached at base of the tube; filaments 0.7–1 mm long; anthers 4 mm long, apiculate, punctulate on back. **Ovary** superior, glabrous, ovoid, 1-locular; ovules many, in 2 rows on placenta; style 4 mm long; stigma minute, apiculate. **Fruit** a drupe, 7 mm in diameter, with numerous black glandular dots, dark purple to blue. **Seed** only 1.

Ecology: Along and in the stream bed, in the shallow and deeper areas of limestone streams.

Distribution: Myanmar, West Malaysia

Thailand: SOUTH-WESTERN: Kanchanaburi; PENINSULAR: Ranong, Surat Thani, Phannga, Phuket, Nakhon Si Thammarat, Trang

Specimen examined: *M. Stankovic* 132 (PSU)

MYRTACEAE

23. *Syzygium nervosum* DC., Prodr. [A. P. de Candolle] 3: 260. 1828.; — *Cleistocalyx nervosum* (DC.) Kosterm var. *nervosum*, J.Parn. & Chantar. in Fl.Thailand 7 (4): 786. 2002. ***Plate 4.C.***

Tree, up to 25 m high, bark dark grayish to brown. **Leaves** opposite, elliptic obovate to lanceolate, 18.2–27.6 by 4.7–10 cm, coriaceous, apex acute to acuminate, margin entire, base broadly cuneate; midvein impressed on the upper surface, secondary veins 10–12 pairs, intramarginal vein 1, faint; petiole 11–23 mm long, glabrous. **Inflorescence** in the axils of the fallen leaves, on the leafless branches, paniculate, 6–14 cm long; peduncle up to 5 cm long; rachis terate; bracts triangular, 1.3 by 1.2 mm. **Flowers** bisexual, actinomorphic, 5 mm in diameter, sessile; bracteoles triangular, 0.4 by 0.3 mm long. **Hypanthium** greenish, funnel shaped, 2.8–4.2 by 2–3 mm; with or without pseudostipe, if present ca 1 mm long. **Calyx** 2.4–5.5 in diameter, calyptrate, undivided, apex muconate. **Corolla** white, 4-merous; petals ovate, 1.8–4.2 mm, sometimes claw at base, cohering, attached to the inside of the calyx, 34–50 glandular dots per petal. **Stamens** free, numerous, outer stamens 4.5–6.8 mm; anthers oblong to ovate, 0.2–0.3 mm long. **Ovary** inferior, 2–5-locular, 11–23 ovules per locule, placentation axile; style single, 4.9–8.4 mm long, filiform, not exceeding the stamens; stigma minute. **Fruit** a berry, 1 cm in diameter, globose, to oblong, glabrous, violet to black when mature. **Seeds** not seen.

Ecology: Along and on pebbly islands in the granite bedrock streams.

Distribution: India, Sri Lanka, Myanmar, Vietnam, China. Indo-China, Malaysia, Australasia.

Thailand: NORTHERN: Chiang Mai, Kamphaeng Phet; SOUTH-WESTERN: Uthai Thani, Kanchanaburi; CENTRAL: Nakhon Nayok; SOUTH – EASTERN: Prachin Buri, Chanthanaburi; PENINSULAR; Chumphon, Ranong, Surat Thani, Phangnga, Nakhon Si Thammarat, Phattalung, Trang, Satun, Songkha, Yala.

Specimens examined: *M. Stankovic* 204 *(*PSU*)*

24. ***Syzygium* sp.1** ***Plate 4.D.***

Tree, up to 25 m high, bark striate, flaky, reddish brown color. **Leaves** opposite, oblong to lanceolate, 4.5–10 by 3–5 cm entire, apex acute to acuminte, margin entire, base cuneate to acute; midvein impressed on the ventral surface, secondary veins 17–25 pairs, 1 intramarginal vein; petiole short, up to 5 mm long. **Inflorescence** terminal or axillary, paniculate, 8–10 cm long; peduncles up to 10 mm. **Flowers** not seen. **Hypeanthium** green yellowish, funnel-shaped, 3.5–5 by 3 mm; pseudostipe 2 mm. **Fruit** a berry, 8–9 mm, globose, glaborus, green yellowish color, with shallow rim; rim purple-colored. **Seeds** solitary.

Ecology: Along or in the stream bed of the limestone bedrock streams.

Distribution:

Thailand: PENINSULAR: Trang, Satun

Specimen examined: *M. Stankovic* 182 (PSU)

Note: Flowers of this species were not found during the data collection and that enabled the identification to the species level.

PHYLLANTACEAE

25. ***Phyllanthus gracilepes*** (Miq.) Müll. Arg., Linnaea 32: 47. 1863.; Welzen and Chayam. in Fl.Thailand 8 (2): 490. 2007. ***Plate 5.F.***

Shrub, up to 3 m high, branches shortly puberulous, glabrescent. **Leaves** alternate, distichous, oblong to lanceolate, 4–7.3 by 2–2.5 cm, membranous to papery thin, glabrous to minutely pilose on the lower surface, apex acute to apiculate, margin revolute, base unequal; secondary veins 9–11 pairs; petiole short, 2–3 mm long, puberous; stipules triangular, 1–3 by 0.7–1.6 mm. **Flowers** axillary, unisexual, actinomorphic, in fascicles. **Staminate flowers** 2–7 flowers in bundle; pedicel 4–7 mm long, pinkish; sepals 4, red purplish, triangular to ovate, 2–3 by 1.5–2 mm, puberulous, apex acuminate, margin fimbriate; petals absent; disc glands 4, orbicular; stamens 4, staminal column 4 mm long, filament 0.2 mm long, glabrous, anthers basifixed, extrose, 0.2 mm long. **Pistillate flowers** not seen. **Fruit** a dry capsule, 5 mm in diameter, 3-lobed, densely rufo-lanate; stalk 3–6 cm long. **Seeds** not seen.

Ecology: In evergreen forests and along the granite bedrock streams.

Distribution: Laos, Vietnam, Malaysia, Sumatra, Java, Borneo.

Thailand: EASTERN: Nakhon Ratchasima, Ubon Ratchathani; CENTRAL: Nakhon Nayok; SOUTH – EASTERN: Chanthaburi, Trat; PENINSULAR: Songkhla, Pattani, Narathiwat.

Specimen examined: *M. Stankovic* 141 (PSU)

RUBIACEAE

26. ***Neonauclea pallida*** (Reinw. ex Havil.) Bakh.f., Blumea 12: 63.1963. ***Plate 5.C.***

Small tree, 7–10 m high, bark grey brown to dark brown, smooth. **Leaves** opposite, elliptic to oblong, 8–20 by 5–8 cm, in young individuals lanceolate, 15–28 by 2–6 cm, chartaceous to subcoriaceous, glabrous, apex acute to acuminate, margin entire, base cuneate; secondary veins 6–10 pairs; petioles 10–25 mm long; stipules ovate, 13–25 by 6–10 cm, pubescent at base, caduceous.**Inflorescence** terminal, 1 to 2 heads together; heads 1.5–2 cm in diameter; young heads surrounded by a pair of enlarged bracts, light green, ovate, 1–1.8 by 0.6–0.8 cm; peduncle stout, 10–12 cm long. **Flowers** bisexual, actinomorphic, 5-merous, subsessile, **Calyx** dark brown, persistent, slightly hairy; tube 4–5 mm long; lobes ovate, 0.4–0.6 by 0.2–0.3 mm. **Corolla** tubular, white, yellowish to greenish, glabrous; tube 9–11 mm long; lobes ovate, 1 mm long. **Stamens** 4, exerted, inserted on the upper part of the corolla tube; filaments short, 1 mm long; anthers basifixed, 1–2 mm long. **Ovary** inferior, 1 mm in diameter, sparsely hairy, 2-locular, ovules numerous, not fused together with close flowers, placentation axile; style 1, subglobose, long exerted, 10–12 mm long. **Fruiting head** (aggregated) 20–30 mm in diameter, woody, brown. **Individual fruit** obovoid, 8–10 mm long, glabrous, crowned by the persistent calyx, splitting into 4 from the base to apex. **Seeds** elliptic, numerous, flattened.

Ecology: Along and in the streambed of limestone and granite bedrock streams.

Distribution: Myanmar, Thailand, Malaysia, Sumatra, Java, Borneo.

Thailand:SOUTH-EASTERN: Chanthaburi; PENINSULAR: SuratThani, Phuket, Nakhon Si Tammarat, Phattalung, Trang, Satun, Songkhla, Pattani.

Specimen examined: *M. Stankovic* 89 (PSU)

27. *Neonaculea* sp. 1 *Plate 5.D.*

Small tree, 7 m high, developing buttress roots, bark dark brown. **Leaves** opposite, elliptic oblong to lanceolate, 7–25 by 5–8 cm in adult-individuals, 4–20 by 3–6 cm in young treelets, glabrous, chartaceous to coraceous, apex acute to acuminate, margin entire, base cuneate; veins raised, glabrous, distinct on the lower surface, secondary veins 7–9 pairs; petiole 1–2.3 cm long; stipules ovate, 1.5–2.5 by 1–1.5 cm, caduceus, adpressed in the terminal bud, apex rounded. **Inflorescence** terminal, 1–3 flowering heads; heads 2–3 cm in diameter, young heads surrounded by a pair of enlarged bracts green, ovate, 1.1–2 by 0.5–0.7 cm; peduncle 11–14 cm, stout, woody, swollen, with distinct scars. **Flowers** bisexual, actinomorphic, 5-merous, subssesile, in condense heads. **Calyx** persistent, glabrous; lobes ovate, 0.6–0.8 by 0.3–0.4 mm when dry, slightly hairy; tube 3–4 mm long. **Corolla** tubular glabrous; tube 10 mm long when dry; lobes ovate, 1 mm long when dry. **Stamens** not seen. **Ovary** inferior, 0.3 mm in diameter when dry, glabrous, 2-locular, ovules numerous in each locule, placentation axile; style long exerted; stigma globose. **Fruiting head** 20–25 mm in diameter, globose, woody, dark brown. **Individual fruits** obovoid, 7–9 mm long, free from one another, glabrous, with persistent calyx, splitting into 4 from base to apex. **Seeds** elliptic, numerous, slightly flattened, shortly winged.

Ecology: Along and in the streambed of limestone bedrock streams.

Distribution:.

Thailand: PENINSULAR: Satun, Trang

Specimens examined: *M. Stankovic* 83, 112 (PSU)

Note: Fresh flowers of this species were not seen, only dry flowering heads with few flowers left. The identification to the species level was difficult without proper flowering material.

28. *Ixora javanica* (Blume) DC., Podr. (DC.) 4: 487. 1830.; K.M. Wong, Tree Fl.Mal 4: 360. 1989.; M.R. Hend., Malay.Wild Fls.Dicots.: 218. 1950. ***Plate 6.B.***

Shurb, 1–3 m high, branchlets brownish, glabrous. **Leaves** opposite, elliptic-obovate, 10–21 by 2–6 cm, glabrous, the upper surface dark green, lower surface greenish, apex acute to acuminate, margin entire, base cuneate; secondary veins 8–12 pairs; petiole 4–7 mm long; stipules interpetiolar, basally united into sheath, small, 1.5–2 by 0.7–0.9 mm, glabrous, with few long hairs, apex attenuated forming needle 2–3 mm long. **Inflorescence** terminal, erect, inn loose compound cyme; peduncle 1.5–3 cm long, hairy; bracts narrowly triangular, 4–7 by 2–3 mm, glabrous. **Flowers** bisexual, actinomorphic, orange to pale orange; pedicels 0.5–1.5 cm long, central shorter than lateral ones; bracteoles connate, opposite, narrowly triangular, apex acute. **Calyx** cup-shaped, glabrous; tube 1.2–1.4 cm long; lobes 4, 0.1–0.3 mm long, apex rounded. **Corolla** salverform, 2–2.3 cm in diameter, glabrous; tube 3–4.2 cm long; lobes 4, 9–10 by 5.5–6.5 mm, valvate in bud, apex acute to obtuse, margin entire. **Stamens** 4; filaments 1.5 mm long; anthers linear, 3.5–3.8 by 0.7–0.8 mm, pale orange; disc annular. **Ovary** inferior, 5-locular, numerous ovules in each locule; style 4–4.4 mm long, glabrous; stigma 2-lobed, exerted from corolla. **Fruit** a fleshy drupe, green turning black, globose, 4–7 mm in diameter, glabrous.

Ecology: In lowland forest in shade.

Distribution: India, China, Peninsular Malaysia, Java

Thailand: NORTHERN: Lampang, Tak; NORTH-EASTERN: Ubon Thani, Nong Khai, Sakon Nakhon, Nakhon Phanom, Maha Sarakham; EASTERN: Nakhon Ratchisima, Surin, Yasothon, Si Sa Ket, Ubon Ratchathani; SOUTH-WESTERN: Phachuap Khiri Khan; CENTRAL: Nakhon Nayok; SOUTH-EASTERN: Sa Kaeo, Prachin Buri, Chon Buri, Rayong, Chanthaburi, Trat; PENINSULAR: Chumpon, Ranong, Surat Thani, Phangnga, Puket, Krabi, Nakhon Si Thammarat, Phattalung, Trang, Satun, Songkhla , Narathiwat.

Specimens examined: *M. Stankovic* 51, 205 (PSU)

THEACEAE

29. ***Eurya nitida*** Korth., Verb. Nat. Gesch. Bot. 115. t. 7.1840; –– *Eurya japonica* Thunb. var. *nitida* (Korth.) Dyer in Hook.f., Fl. Br. Ind. 1: 284. 1874. ***Plate 5.E.***

Shrub to small tree, 2.5–10 m high, dioecios. **Leaves** alternate, distichous, obovate to ovate-oblong, 4–6.5 by 1.2–2.5 cm, chartaceous, glabrous, upper surface dark green and shiny, lower surface pale green to yellow, apex acute to broadly acuminate, margin in lower part entire, in upper part serrulate, base cuneate; midvein raised on the lower surface, impressed on the upper surface, secondary veins 9–12 pairs; petiole 1.5–4 cm long, glabrous; exstipulate. **Flowers** axillary, solitary or in groups of 4, unisexual, actinomorphic, 0.5 mm in diameter, 5-merous; bracts 2, persistent; pedicel 2–3 mm, slender, glabrous. **Staminate flowers**: sepals ovate, 1.5–2 by 0.2–0.3 mm, imbricate, glabrous, sub-membranous, apex round; petals ovate, 3.5–4 by 0.5–0.7 mm, connate at base; stamens 12–15, in whorls; anthers basifixed, glabrous. **Pistilate flowers**: sepals as in staminate ones; petals oblong, 2–2.5 by 0.3–0.4 mm; ovary superior, globose, glabrous, ovoid, 3–5-locular, several ovules in each locule, placentation axile; style free, 1.5–3 mm long, 2–3 branched. **Fruit** a berry, blue brackish when mature, globose, broadly elliptic, 3–4 mm in diameter **Seeds** not seen.

Ecology: On rocks in or along the granite bedrock streams at the edge of forest.

Distribution: India, Indochina, Sumatra, Java, Borneo, the Philippines, S and SW China, Hainan, Caroline and Marianna Islands.

Thailand: NORTHERN: Mae Hong Son, Chiang Mai; SOUTH-EASTERN: Chantaburi, Trat; PENINSULAR: Chumphon, Krabi, Ranong, Satun, Songkhla.

Specimen examined: *M. Stankovic* 207 (PSU)

MONOCOTS

ARACEAE

30. *Homalomena repens* Ridl., Fl. Malay Penins. 5: 106. 1925. ***Plate 1.E.***

Aquatic herb. **Rhizome** long creeping, up to 13 cm long, tip ascending. **Leaves** elliptic to ovate, 6–8 by 3–4 cm, thin, apex short acuminate, margin entire, base cuneate; midvein distinct on the lower surface, light yellow, secondary veins 3–4 pairs, palmately arranged; petiole up to 10 cm long, much longer than the lamina. **Inflorescence** spadix in 3.5–4 cm long; peduncle 2 cm long; spathe thick, 1.5 cm long, persistent; spadix elongate, included; pistilate flowers associated with staminode; staminate zone is longer and separated from female by a ring of staminodes. **Flowers** apetalae, unisexual. **Stamens** 2–6, in hexagonal groups; anthers oblong, opening by slits. **Ovary** superior, ovoid, incompletely 2–4-locular, ovules numerous in two rows; stigma sessile, minute, lobed. **Fruit** not seen.

Ecology: On the rocky islands, and banks in granite and limestone bedrock streams, where is frequently flooded.

Distribution: Peninsular Malaysia.

Thailand: PENINSULAR: Pangnga, Krabi, Satun, Trang, Songkhla,

Specimens examined: *M. Stankovic* 21, 127, 129 (PSU)

PART II: COMMUNITY STUDY

I. Environmental data of the streams

Environmental data gathered from fourteen plots were divided classified into environmental and physiographic data. Each of the data characteristic to the plots is represented in Table 3.4 and Table 3.5.

Ton Nga Chang waterfall

Plot TC1 is the first plot, which is characterized by the open space over the stream bed, which reflected higher values of the light intensity, mean 1333.2 lux (Table 3.5). This plot is characterized with the mean value of 24.86 °C of air temperature, 89.86 % humidity, which is the lowest recoded in all the plots and 23.32 °C of water temperature which is around minimum (Table 3.4). Daily fluctuations of the environmental factors such as air temperature, humidity, water temperature and physiographic factor light intensity are represented in Figure 3.2. During 24 h the air temperature increased, while the humidity decreased, reaching minimum point when air temperature is at its maximum. By end of the day air temperature decreased and humidity increased. The daily fluctuations of the water temperature decreased and increased by steps. Light intensity highly increased in the early morning with the peak before mid day, latterly showing smaller increases of the sunlight as the Sun moved on the sky. Substrate of this plot was solid, composed of rocks and gravel, which produces chaotic and chute water flow and increased water velocity (Table 3.5).

Plot TC2 is the second plot, where direct sunlight over the stream is also present but in the less intensity than previous plot. It is characterised by the mean air temperature of 24.69 °C, 91.34 % humidity and 23.39 °C of water temperature (Table 3.4). The daily fluctuations of the environmental data showed fewer variations than the previous plot, with slight increase in air temperature and slight decrease of humidity (Figure 3.3.A). Since the plot was exposed to the direct sunlight, the light intensity was high, max 27, 900.2 lux (Table 3.5) which is the highest recorded value in the plots. The maximum of light intensity is around mid day, which is also represented by the highest peak in the graph (Figure 3.7.B). The streambed was stable, mainly composed of rocks, which resulted in chaotic and chute water flow with 0.7 m/s water velocity (Table 3.5), the highest velocity recorded in the plots.

TC3 is the third plot that is also characterized by slightly smaller open space and more areas of partly broken shade. It is characterized by the mean air temperature of 24. 72 °C, 99.23 % of humidity and the 23.10 °C of water temperature which is the lowest recoded mean water temperature in all of the plots (Table 3.4). Daily fluctuations of the environmental factors showed increase in the air temperature as the day is passing and decrease in humidity (Figure 3.4.A). Water temperature also showed the decrease from midnight until 6 AM, and then increase as the day passed, with the stepped variations (Figure 3.4.C). Light intensity was slightly lower with the mean value of 904.3 lux, and the maximum of 15, 327.9 lux (Table 3.5) which peaked around mid day (Figure 3.4.B). The substrate was stable, mainly composed of rocks and sand between them, which produced chaotic and upwelling flow type, with high water velocitied 0.7 m/s (Table 3.5).

Pha Dam waterfall

PD1 is the plot that is characterized with the deep shade from the tree species in the streambed and on the banks. The air temperature varied from 21.86 to 32.27 °C, with the mean air temperature of 25.21 °C, mean value of the humidty were 94.95%, and mean value of the water temepature was 24.28 °C (Table 3.4). The fluctuations of the air temperature increased with the peak after mid day, with the decrease of the humidty, and latter on during day there was decrease and increase in air temperature and humidty, respectively (Figure 3.5.A). Daily fluctuations of the water temperature were also stepped, with the peak after mid day (Figure 3.5.C). Since the plot was in shaddy area, the light intensity was low 528.8 lux (Table 3.5), with the few peaks in the daily flucutations (Figure 3.5.B). Streambed was unstable, mainly composed of small pebbles and sand, with many areas of smooth rippled water flow and few places with upwelling flow that increased water velocity up to 0.9 m/s (Table 3.5).

PD2 is the plot that is also characterized with the deep shady throughtout the plot. The air temperatre varied from 22.08 to 32.45 °C, with the mean walue of 25.33 °C (Table 3.4), and during day it peaked after mid day (Figure 3.6.A). The humidity varied significantly from 68.41 to 100 %, with its lowest value after mid day (Figure 3.6.A). Water temperature varied from 23 to 25.52 °C (Table 3.4), while its daily fluctuations showed the highest peak around mid day (Figure 3.6.C). The light intensisity was low, 571.5 lux with the many peaks throughout the day (Figure 3.6.B). The streambed was unstable mainly comprised of pebbles and sadn wich produced mainly chaotic water flow, with few areas of rippled (Table 3.5)

PD3 is the plot that is characterized with the deep shady areas. The air temperature varied from 22.2 to 32.58 °C, with the mean value of 25.41 °C (Table 3.4). The daily fluctuations of the air temrature showd the peak of increase of the temperature is around mid day (Figure 3.7.A), with the decrease latter on during the day. The himidity in this plot varied from 63.09 to 99.98 % (Table 3.4), while the daily fluctuations of the high decrease around the mid day (Figure 3.7.A). The water temperature variated from 23 to 26.68 °C (Table 3.4), while the daily fluctuations showed the peak around the mid day (Figure 3.7.C). Since the plot was not exposed to the direct sunlight, the light intensity was rather low 510.1 lux (Table 3.4), while the daily fluctuations also showed few small increases of the light intensity throughtout the day (Figure 3.7.B). The substrate was stable, mainly composed of soild rocks and sand, which produced chaotic and chute water flow with water velocity of 1.4 m/s (Table 3.5).

Lan Mom Jui waterfall

LJ1 is the plot that is characterized with the open area along the streambed, and partially shaddy areas along the banks. The air temperature varied from 23.55 to 28.92 °C (Table 3.4), while the daily fluctuations showed the increase of the temperature after mid day (Figure 3.8.A). Humidity in this plot varied from 83.16 to 100 %, with the decrease after miday around afternoon (Figure 3.8.A). Water temperature was rather high, from 24.16 to 26.78 °C (Table 3.4) with the decrease at the beginning of the day and the increase of the water deperature in the afternoon (Figure 3.8.C). As the plot was exposed to the direct sunlight the maximum light intensity recoded was 13,777.9 lux (Table 3.5), while the daily fluctuations showed several peaks during the day (Figure 3.8.B). The stream bed was stable, mainly composed of rock and gravels with chaotic and smooth areas, where water velocity was up 1 m/s (Table 3.5).

LJ2 is characterized by the open areas along the streambead where direct sunlight is present and partially shaddy areas along the banks. The air temperature varied from 23.4 to 30.39 °C with the low daily fluctuations of the temperature (Figure 3.9.A). The humidity varied from 87.42 to 100 % (Table 3.4) with the low decrease in the daily fluctuations after mid day (Figure 3.9.A). The water temperature varied from 24.06 to 26.68 °C (Table 3.5), with the daily fluctuations of the decrease in the first part of the day and increase in the afternoon (Figure 3.9.C). This plot is exposed to the direct sunlight so the light intensity was high 510.1 lux (Table 3.5), and during the daily fluctuations only one peak was recorded (Figure 3.9.B). The streambed was stable composed of rocks and silt in between, with chute and rippled water flow, which gave fast water velocitu of 0.9 m/s (Table 3.5).

Than Plew waterfall

TP1 is the plot which is characterized by the partially shaddy areas, and few places where direct sun is present. The air temperature varied from 22.31 to 28.68 °C (Table 3.4), and the daily variations showed low fluctuatation of this variable with the peak around mid day (Figure 3.10.A). The humidity varied from 82.90 to 97.48 % (Table 3.4), the daily variations showed the slight decrease of the humidty around the mid day (Figure 3.10.A). Water temperature varied from 24.06 to 25.13 °C (Table 3.4), while the daily variations showed very little fluctuations, almost constant temperature throughtout the day (Figure 3.10.C). The light intensity was rather low 404.9 lux (Table 3.5), with the low fluctuations and one peak throughout the day (Figure 3.10.B). The streambed was solid, mainly composed of rocks, which produced chaotic fater flow with the waterfall. The water velocity was highest recorded in all of the plots 0.7 m/s (Table 3.5).

TP2 is the plot that is characterized with the deep shaddy areas without direct sunlight. The air temperature varied from 22.32 to 25.92 °C (Table 3.4), with the low daily fluctuations of the increase around the mid day (Figure 3.11.A). The humidity varied from 79.1 to 99.83 % (Table 3.4). Daily fluctuations of the humidity showed almost stagnant variable throughout the day, with the slight decrease around mid day (Figure 3.11.A). Water temperature varied from 24.45 to 25.27 °C (Table 3.4), while the daily flucutations showed almost constant water temperature throughtout the day (Figure 3.11.C). The light intensity in this plot is low 422.1 lux (Table 3.5), while daily fluctuations of this variable showed few peaks throughout the day (Figure 3.11.B). The substrate is stable with rocks and silt in between. Water flow is chaotic and chute, which produced high water velocity of 1.1 m/s (Table 3.6).

TP3 is the plot that is characterized with the deep shade throughout the plot. The air temperature varied from 22.11 to 27.18, with the lowest mean value recoderded in all plots of 24.33 °C (Table 3.4). The daily fluctuations of the air temperature showed increase around mid day and stepped decrease by end of the day (Figure 3.12.A). The humidity varied from 82.26 to 100 %, with the highest mean value recorded in all of the plots of 98.65 % (Table 3.4). The daily fluctuations of the humidity showed that there is a decrease of the variable around the mid day and the increase by the end of the day (Figure 3.12.A). The light intensity was the lowest recorded in all of the plots, 263.2 lux (Table 3.5), with very high daily fluctuations of the variable (Figure 3.12.B). The streambed was solid, composed of rocks and silt in between with chute and smooth water flow in pool areas, producing lower water velocity of 1.7 m/s (Table 3.5).

Chao Pa waterfall

CP1 is characterized with the partially to deep shaddy areas. The air temperature varied from 21.80 to 31.28 °C though the season (Table 3.4), while the daily fluctuations showed gradual increase of the variable, with its peak after the mid day and gradual decrease (Figure 3.13.A). The humidity varied from 79.8 to 100 % throughout the season (Table 3.4), while daily variations showed the constant fluctuations with the decrease after mid day (Figure 3.13.A). Water temperature varied from 24.16 to 31.68 °C (Table 3.4), whith the low daily fluctuations of the variable (Figure 3.13.C). Light intensity is low 634.5 lux (Table 3.5), with the gradual increase up to mid day and gradual decrease (Figure 3.13.B). The substrate is stable, composed of rocks and gravel, which produced chute water flow and waterfall. The water velocity is rather low because of the pool areas, 2.6 m/s (Figure 3.5).

CP2 is the plot which is characterized by deep shaddy areas. The air temperature varied from 22.06 to 31.08 °C (Table 3.4). The daily fluctuations showed the gradual increase of the temperature up to the mid day and then decrease of the variable (Figure 3.14.A). The humidity varied from 53.34 to 98.12 % (Table 3.4), which represented high differences of the variable. This was also showed by the daily fluctuations of the humidity, where around mid day there is a sudden high decrease, followed with smaller increases and decreased of the variable (Figure 3.14.A). Water temperature varied from 24.75 to 26.88 °C (Table 3.4), while daily fluctuations were almost constant thorughtout the day (Figure 3.14.C). The light intensity was rather low 518.5 lux (Table 3.5), with the small daily variations (Figure 3.14.B). The bedrock was stable, mainly composed of rock and silt in between, chute water flow in shallow rocky areas, and rippled in pool areas, which produced the lowers water velocity oof 3.2 m/s (Table 3.5).

CP3 is characterized with the shaddy areas and few plaes with direct sun. The air temperature varied from 21.74 to 31.28 °C though the season (Table 3.4). The daily fluctuations showed slight increase and decrease of the air temperatre (Figure 3.15.A). The humidity varied from 84.75 to 100 % (Table 3.4), with almost constant daily fluctuations of the humidty (Figure 3.15.A). Water temperature varied from 24.16 to 31.78 °C through the season (Table 3.4), while daily fluctuations showed slight stepped increase around mid day and decrease afterwards (Figure 3.15.C). Light intensity was low 574.4 lux (Table 3.5), with the daily fluctuations of the gradual increase until mid day and sudden decrease by end of the day (Figure 3.15.B).

Table 3.4. Values of the microclimatic data along the study plots during one season

Study plots	Air temperature (°C)			Humidity (%)			Water temperature (°C)		
	min	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**
TC1	19.93	31.85	24.86	65.65	99.07	89.86	22.14	28.33	23.31
TC2	20.11	31.47	24.69	67.37	99.33	91.34	22.28	27.82	23.39
TC3	20.48	31.92	24.72	66.37	99.23	91.36	22.14	27.83	23.19
PD1	21.86	32.27	25.21	63.62	99.80	94.95	21.10	25.51	24.28
PD2	22.08	32.45	25.33	68.41	100.00	94.04	23.00	25.42	24.24
PD3	22.20	32.58	25.41	63.09	99.98	94.28	23.00	26.68	24.20
LJ1	23.55	28.92	25.37	83.16	100.00	98.00	24.16	26.78	25.25
LJ2	23.40	30.93	25.23	87.42	100.00	98.55	24.06	26.68	25.13
TP1	22.31	28.68	24.49	82.05	99.89	97.48	24.06	25.13	24.75
TP2	22.32	25.91	24.50	79.10	99.83	97.75	24.45	25.27	24.85
TP3	22.11	27.18	24.33	82.26	100.00	98.68	24.35	25.18	24.74
CP1	21.80	31.28	24.78	79.80	100.00	98.60	24.16	31.68	25.13
CP2	22.06	31.08	24.78	53.34	98.12	93.57	24.74	26.88	25.30
CP3	21.74	31.28	24.66	84.75	100.00	97.42	24.16	31.78	25.18

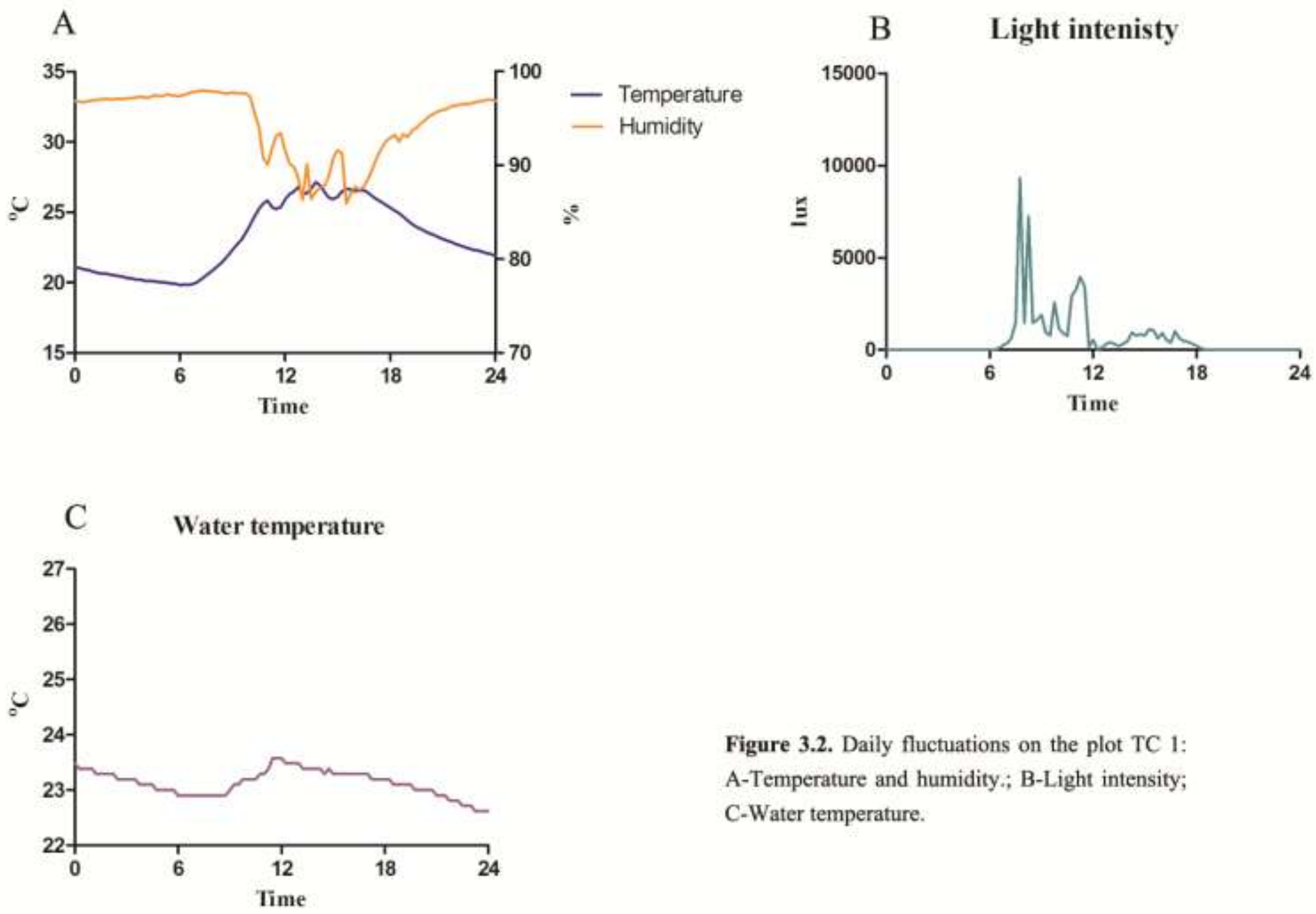
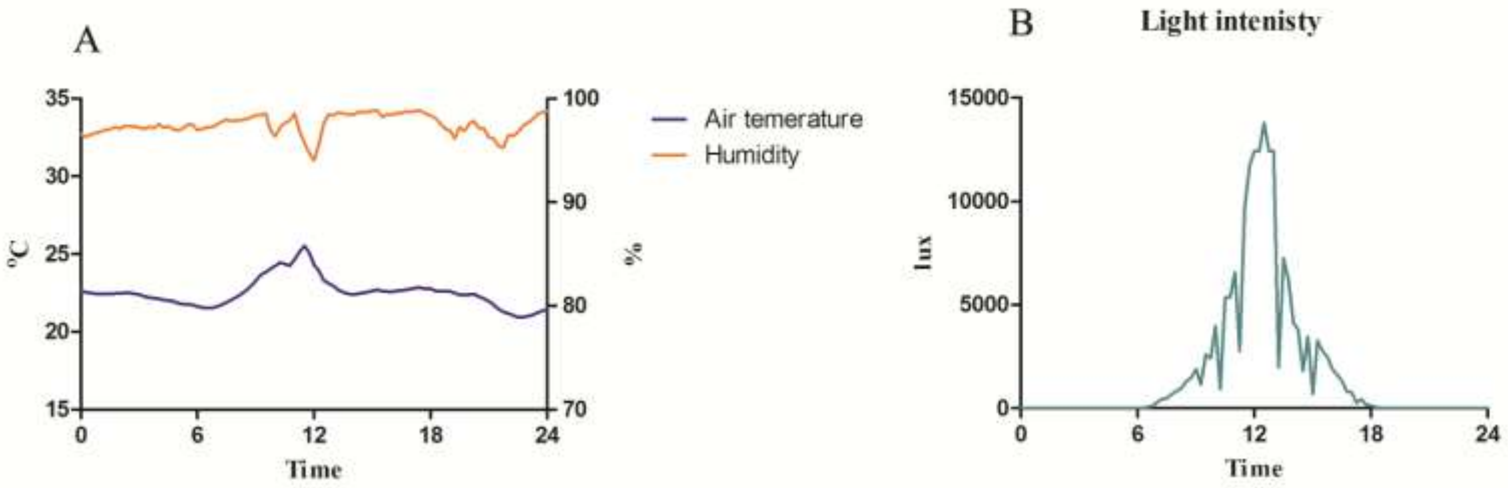


Figure 3.2. Daily fluctuations on the plot TC 1: A-Temperature and humidity.; B-Light intensity; C-Water temperature.



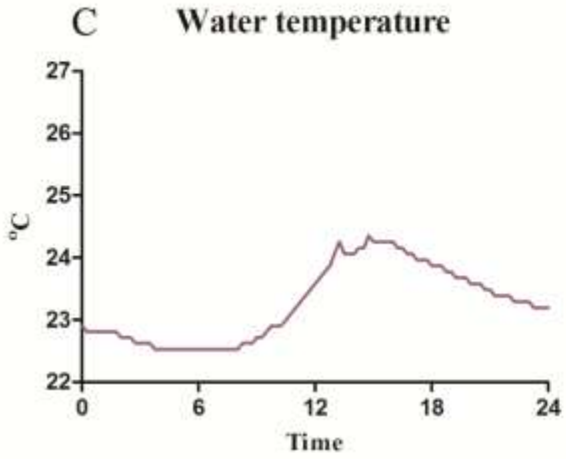
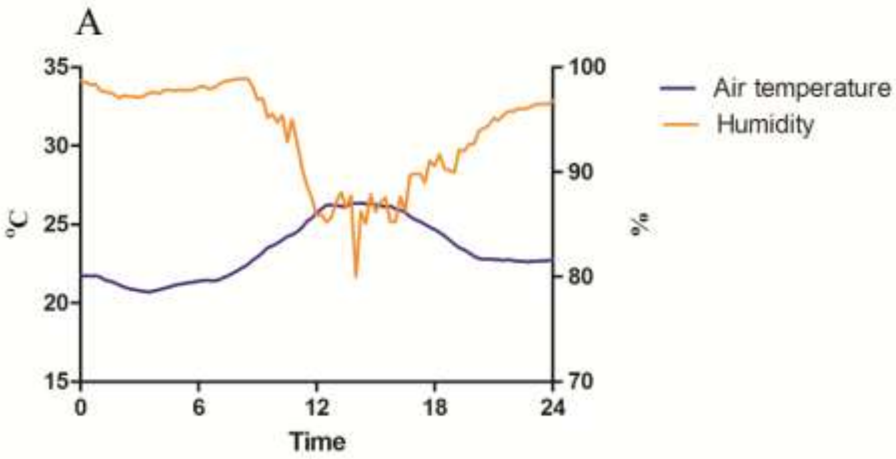
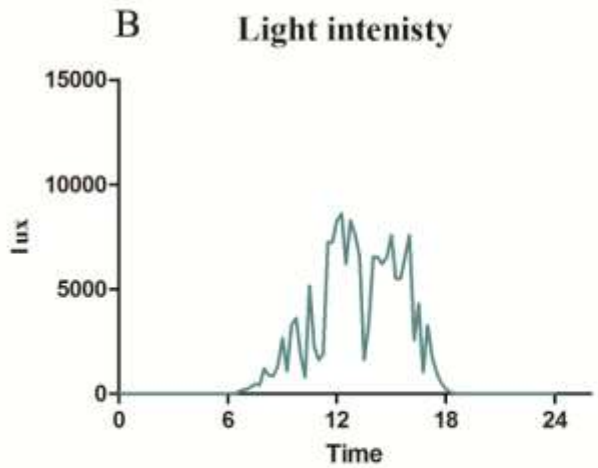


Figure 3.3. Daily fluctuations on the plot TC 2: A-Temperature and humidity.; B-Light intensity; C-Water temperature.





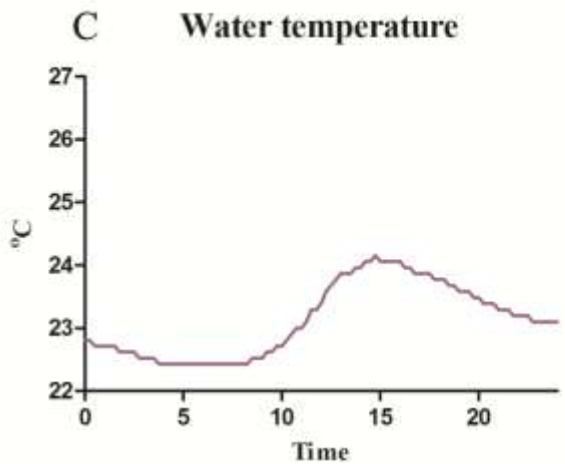


Figure 3.4. Daily fluctuations on the plot TC 3: A-Temperature and humidity.; B-Light intensity; C-Water temperature.

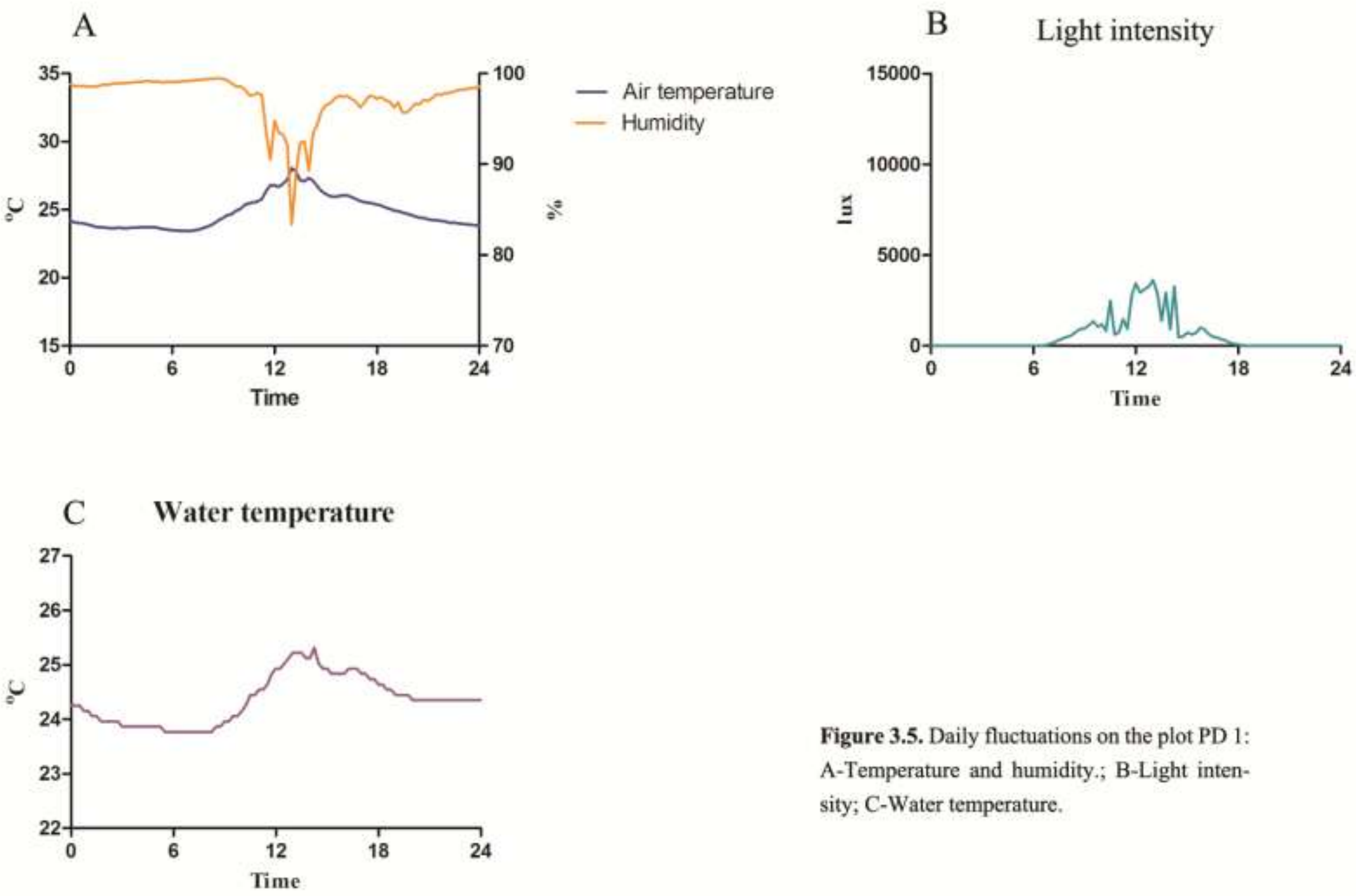


Figure 3.5. Daily fluctuations on the plot PD 1: A-Temperature and humidity.; B-Light intensity; C-Water temperature.

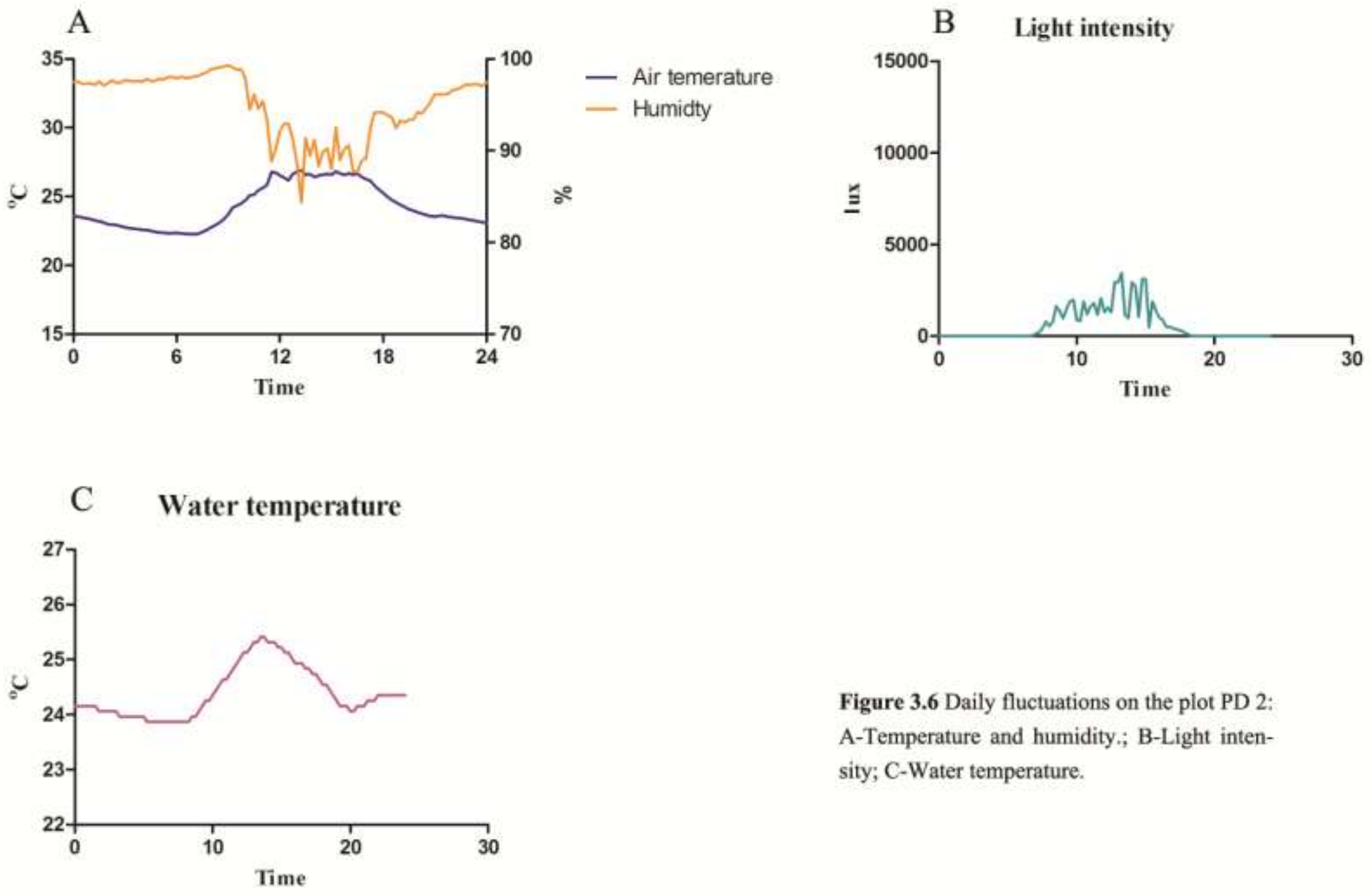


Figure 3.6 Daily fluctuations on the plot PD 2: A-Temperature and humidity.; B-Light intensity; C-Water temperature.

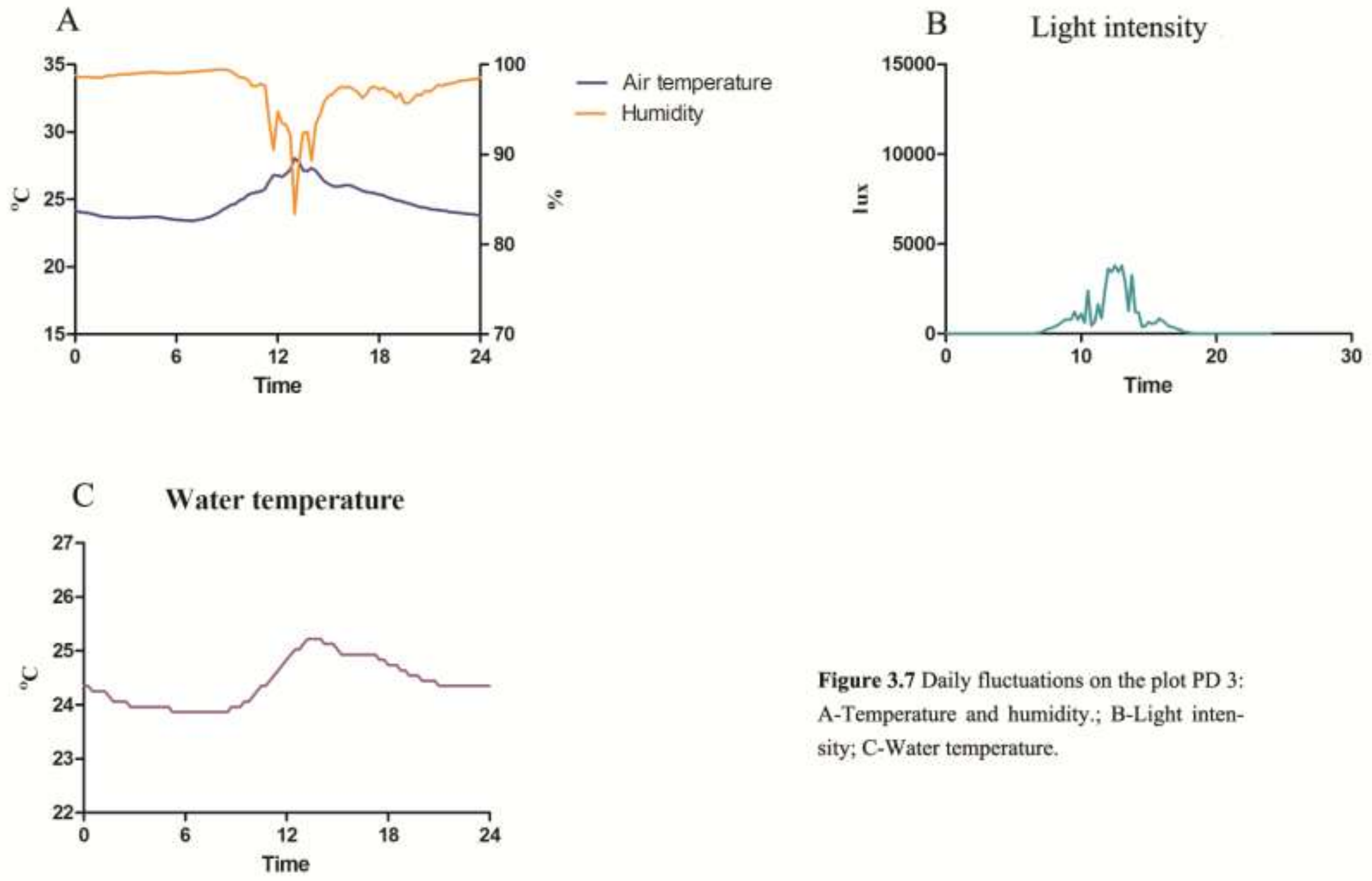
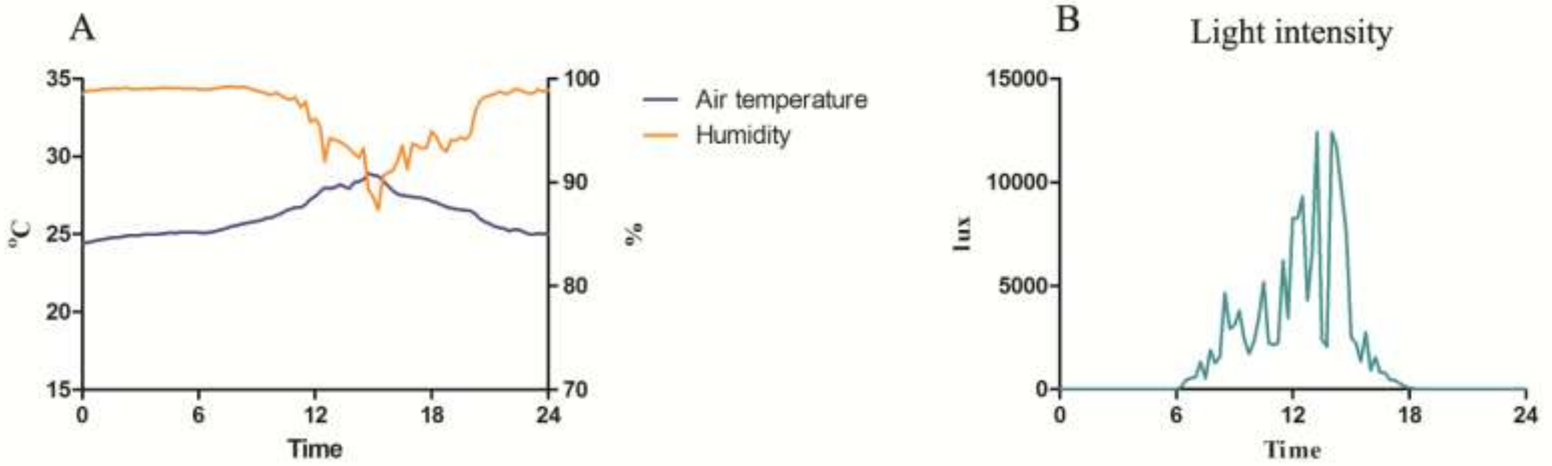


Figure 3.7 Daily fluctuations on the plot PD 3: A-Temperature and humidity.; B-Light intensity; C-Water temperature.



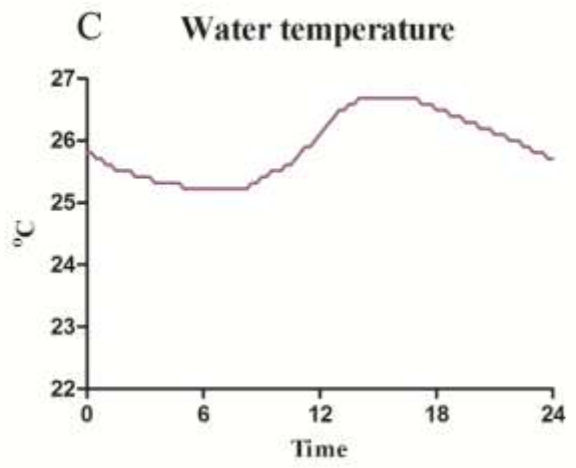


Figure 3.8. Daily fluctuations on the plot LJ 1: A-Temperature and humidity.; B-Light intensity; C-Water temperature.

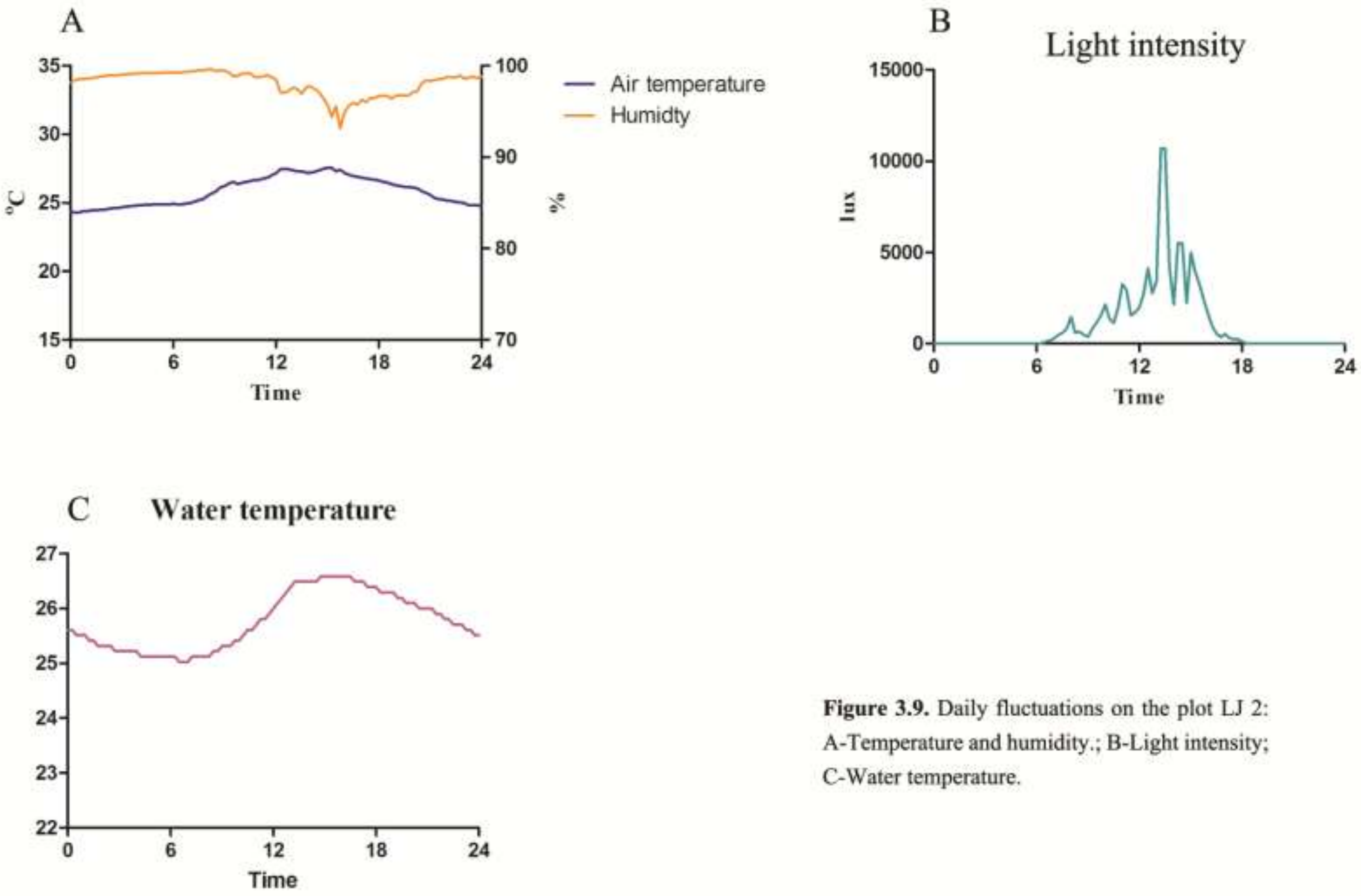


Figure 3.9. Daily fluctuations on the plot LJ 2: A-Temperature and humidity.; B-Light intensity; C-Water temperature.

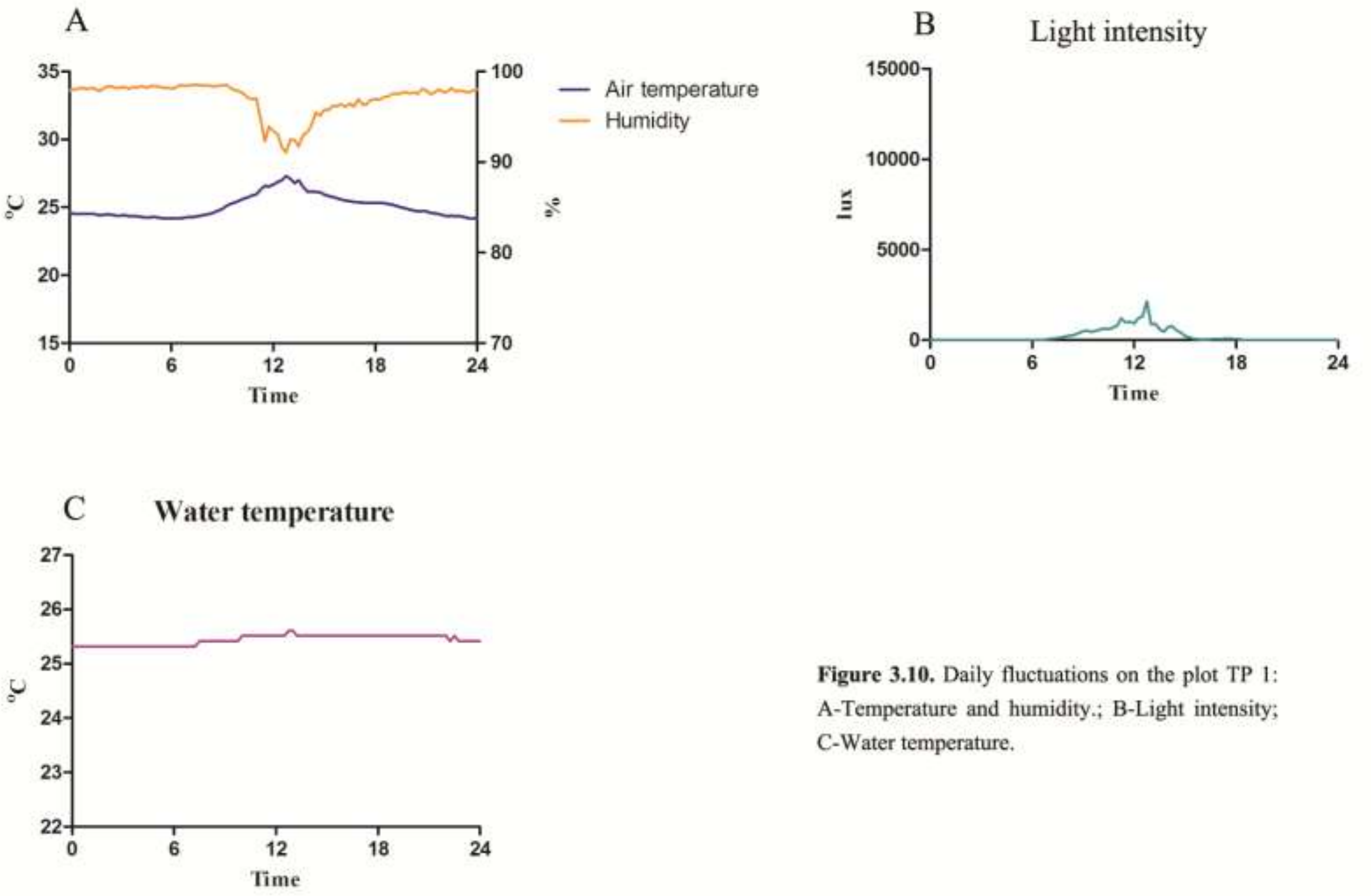
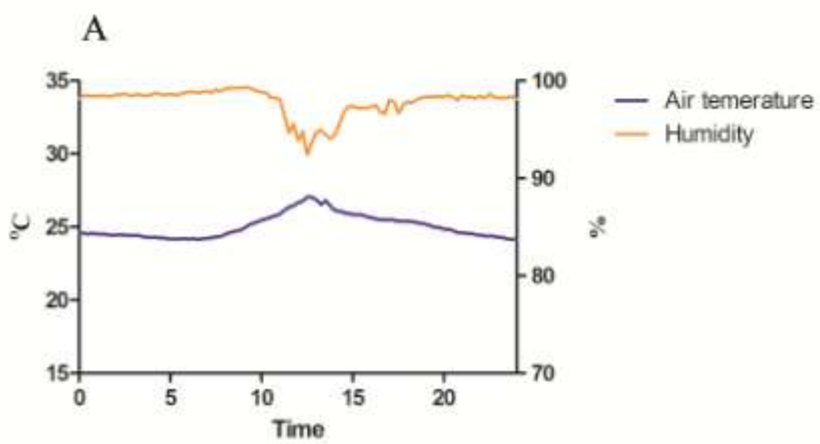
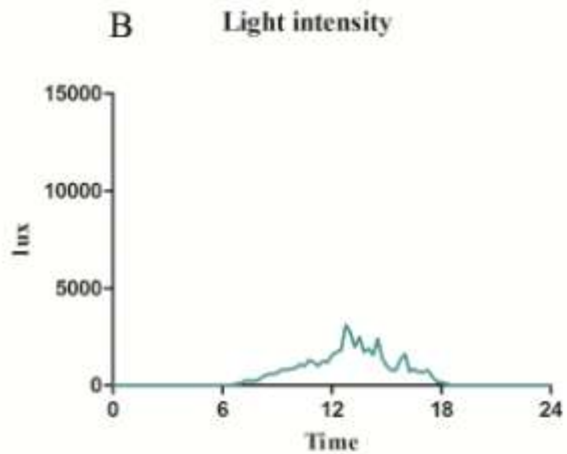


Figure 3.10. Daily fluctuations on the plot TP 1: A-Temperature and humidity.; B-Light intensity; C-Water temperature.





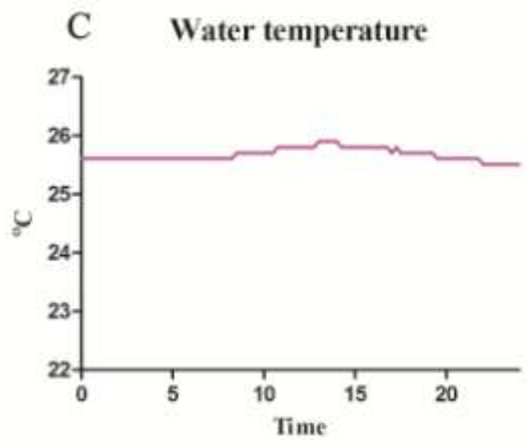
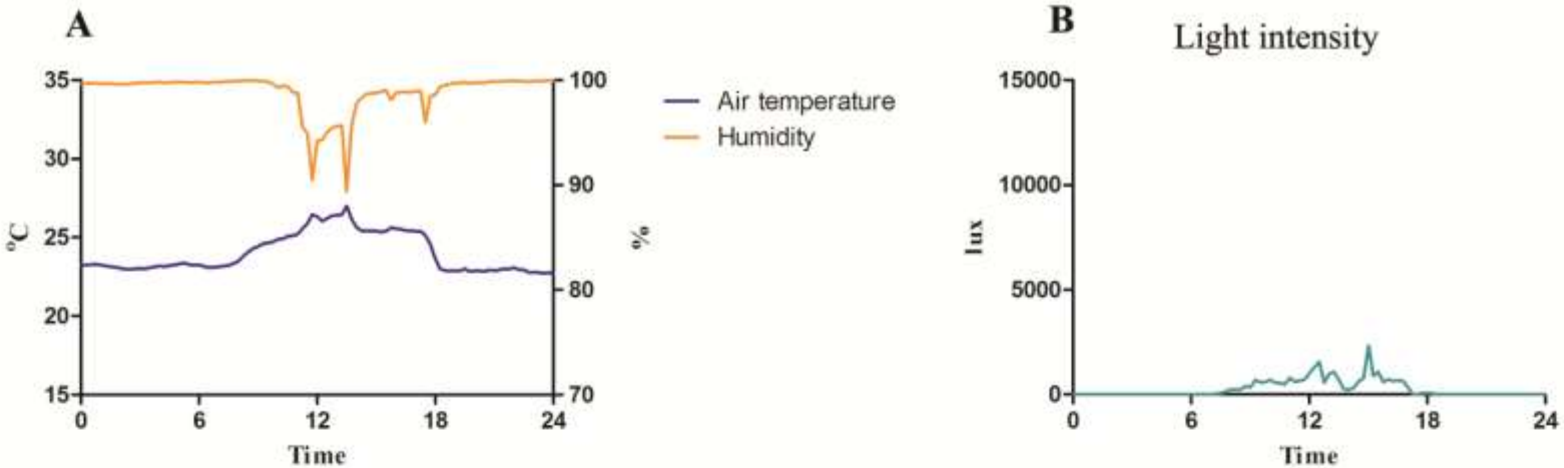


Figure 3.11. Daily fluctuations on the plot TP 2: A-Temperature and humidity.; B-Light intensity; C-Water temperature.



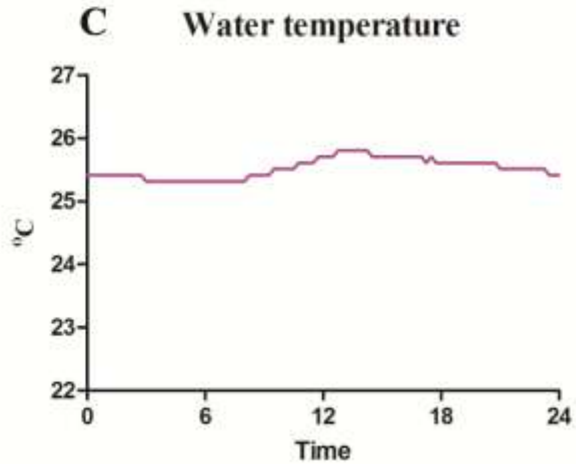


Figure 3.12. Daily fluctuations on the plot TP 3: A-Temperature and humidity.; B-Light intensity; C-Water temperature.

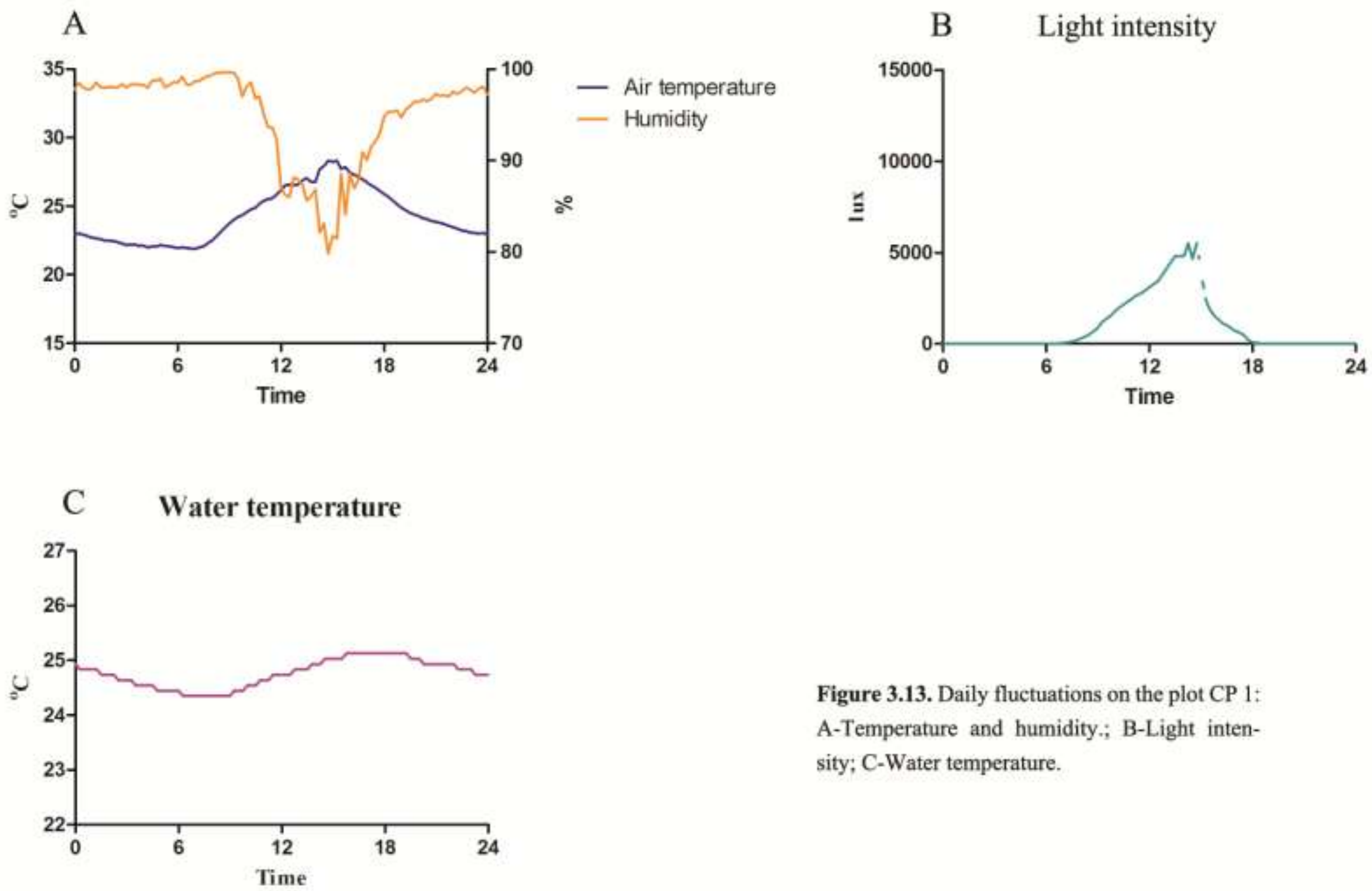


Figure 3.13. Daily fluctuations on the plot CP 1: A-Temperature and humidity.; B-Light intensity; C-Water temperature.

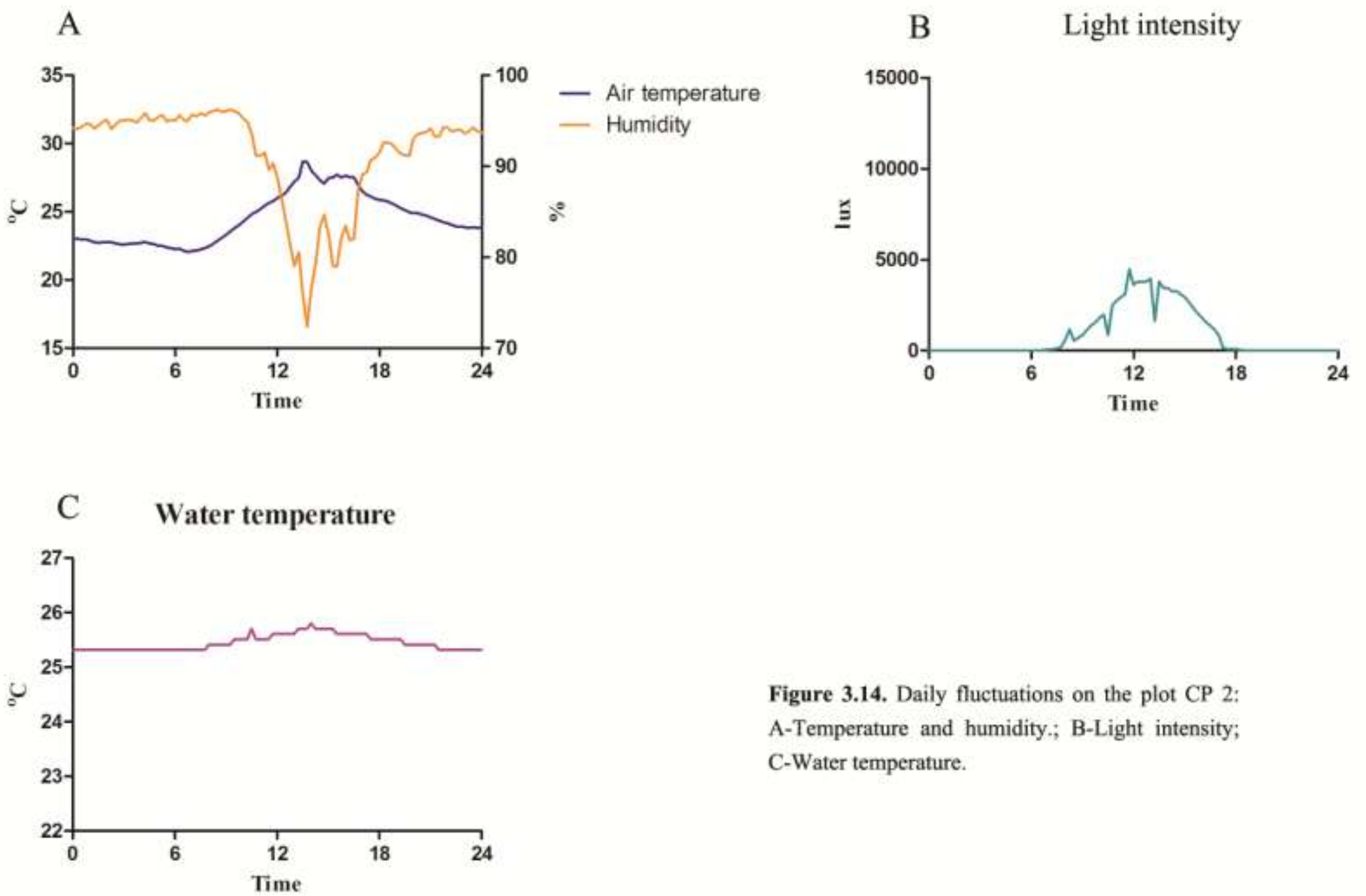
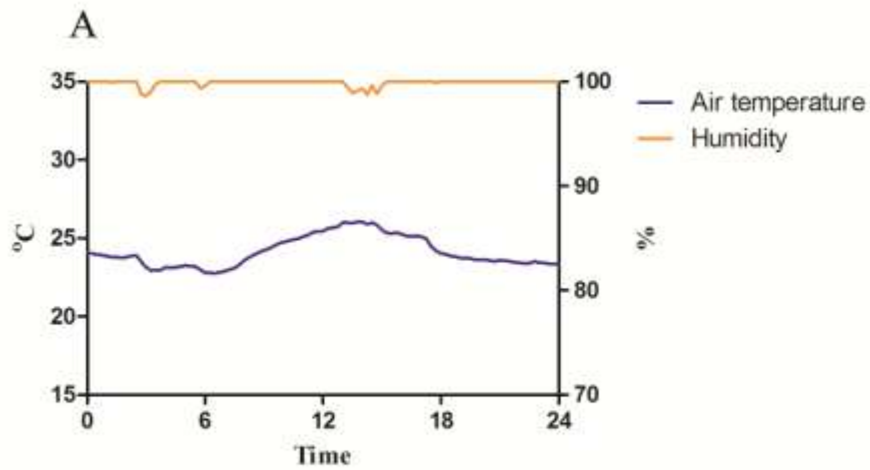
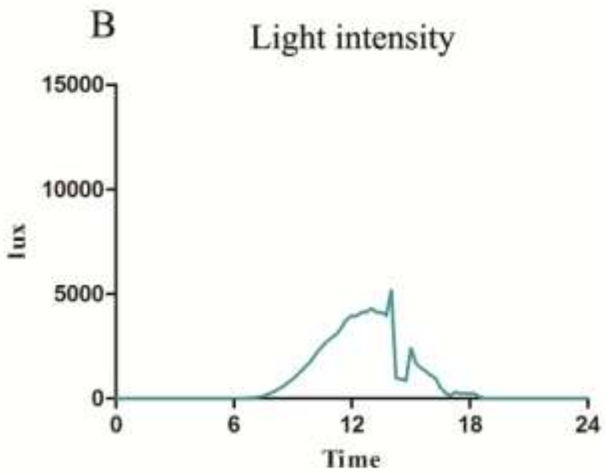


Figure 3.14. Daily fluctuations on the plot CP 2: A-Temperature and humidity.; B-Light intensity; C-Water temperature.





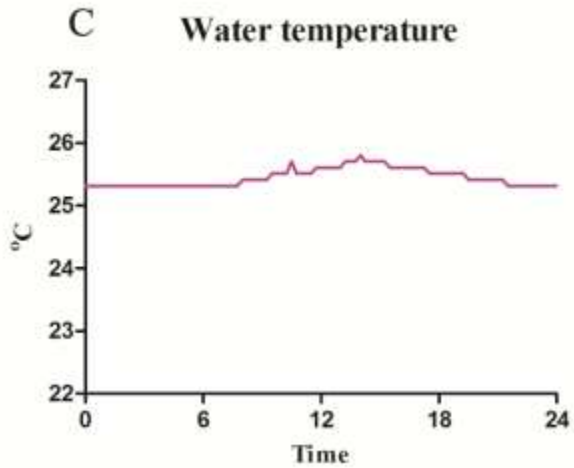


Figure 3.15 Daily fluctuations on the plot CP 3: A-Temperature and humidity.; B-Light intensity; C-Water temperature.

Table 3.5. Values and the description of the physiographic factors along the plots in granite and calcareous bedrock streams during one season

Study plots	Light intensity (lux)		pH of water	Water velocity (m/s)			Water width (m)			Substrate	Stability of substrate	Flow type
	max	mean		min	max	mean	min	max	mean			
TC1	74801.0	1333.2	6.5	1.0	0.7	0.8	2	12	5.3	rocks and gravel	solid	chaotic and chute
TC2	27900.2	887.3	6.5	0.8	0.3	0.7	1.2	7.8	4.5	rocks	stable	chaotic and chute
TC3	15327.9	904.3	6.5	0.6	0.8	0.7	4.2	7.9	6.1	rocks with sand	stable	chaotic and upwelling
PD1	4994.5	528.8	6.5	0.9	1.8	0.9	1.5	12.7	7.1	pebbles with sand	unstable	upwelling and rippled
PD2	4650.0	571.5	6.6	1.9	0.7	1.3	1.4	8.2	4.8	pebbles with sand	unstable	chaotic and rippled
PD3	4994.5	510.1	6.5	2.0	0.8	1.4	0.8	10.3	5.6	rocks with sand	stable	chaotic and chute
LJ1	13777.9	1213.5	6.6	1.9	0.1	1.0	5.6	11	8.3	rocks with gravel	stable	chaotic and smooth
LJ2	12050.8	984.5	6.6	1.3	0.5	0.9	8	13.8	10.9	rocks and silt	stable	chute and rippled
TP1	4764.8	404.9	8.2	0.5	0.9	0.7	10	26	18.0	rocks	solid	free fall and chaotic
TP2	16992.7	422.1	8.2	0.8	1.3	1.1	10.6	19.8	15.2	rocks and silt	stable	chaotic and chute
TP3	3379.9	263.2	8.3	1.1	2.3	1.7	20.7	24.3	22.5	rocks and silt	stable	chute and smooth
CP1	7233.4	634.5	8.1	1.7	3.5	2.6	10.5	24.3	17.4	rocks and gravel	stable	free fall and chute
CP2	4477.8	518.5	8.2	2.6	3.7	3.2	14.2	17.5	15.9	rocks and silt	stable	chute and rippled
CP3	5338.9	574.4	8.3	1.6	2.8	2.2	12.3	24.8	18.6	rocks	solid	free fall and chute

II. Species number and similarity

The species number in study plots varied from 17–41 (Table 3.7). The highest number of the species per plot was found in TP2 with 41 species, followed by TP3 with 37 species. The lowest number of species per plot was found in two plots TC3 and LJ1 with 17 species, followed by LJ2 with 19 species.

On the granitic bedrock streams the species number varied from 17–27, while on the calcareous bedrock streams varied from 23–41 species.

The most frequently recorded species was *Homalomena repens* Ridl. which was found in all 14 plots, followed by *Ophiorrhiza communis* Ridl. found in 12 plots (Table 3.7). Among the all recorded species there were 17 the least frequent species found in only 1 plot e.g. *Antidesma* sp., *Diospyros* sp., *Cyrtandra pendula* Blume, *Humata angustata* (Wall. ex Hook. & Grev.) J. Sm., *Kopsia pauciflora* Hook.f., *Olea brachiata* (Lour.) Merr., *Paraboea gracillima* Kiew and *Pseuduvaria reticulata* (Blume) Miq. On the other hand, there were 26 species found in 2 plots e.g. *Ardisia fulva* King & Gamble, *Argostemma pictum* Wall., *Begonia saxifragifolia* Craib, *Bridelia tomentosa* Blume, *Crepidomanes bipunctatum* (Poir.) Copel., *Diplazium riparium* Holttum, *Eriocaulon* sp., *Eurya nitida* Korth., *Ficus auriculata* Lour., *Justicia gendarussa* Burm. f., *Kaisupeea orthocarpa* B.L.Burtt, *Leptochilus pedunculatus* (Hook. & Grev.) Fraser-Jenk., *Pteris vittata* L., *Rinorea* sp. *Selaginella inaequilifolia* (Hook. & Grev.) Spring, *Sterculia balanghas* L. and *Syzygium nervosum* DC.

The number of shared species between the plots varied from 1 to 33 species (Table 3.7). The higest number of 33 in common species was between the plots TP2 and TP3, while the lowest number of shared species was between TC1 and TP1 and between CP1 and TC1, with only 1 shared species. On the granitic bedrock streams the number of shared species varied from 3 to 23 species. The highest number of shared species on the granite bedrock streams was between PD2 and PD3 with 23 shared species. The lowest number of shared species was between plots TC3 and PD1 with 3 shared species. Between the calcareous bedrock streams number of shared species varied from 11 to 33 species. The lowest number of shared species between calcareous bedrock streams was between the plots TP1 and CP with 11 shared species. The highest number of shared species was between the plots TP3 and TP2 with 33 species.

The similarity Bray-Curtis index varied from 0.05 to 0.85 (Table 3.7). The lowest similarity index of 0.05 was between the plots TC2 and CP1, followed by 0.06 similarity between the plots TC1 and TP2. The highest similarity index of 0.85 was between the plots PD1 and PD3, PD2 and PD3. Between granitic bedrock streams the similarity index varied from 0.15 to 0.85. The lowest value of similarity index between granitic bedrock streams of 0.15 was between plots PD3 and TC1, followed by 0.16 similarity between the plots PD1 and TC1, PD2 and TC1. The highest value of Bray-Curtis index was between the plots PD1 and PD3 and between PD2 and PD3 with the value of 0.85. On the calcareous bedrock streams the similarity index varied from 0.41 to 0.83. The lowest similarity index of 0.41 was between plots CP1 and TP1, while the highest value of index of 0.83 was between plots CP2 and CP3.

Table 3.6. The abundance and the frequency of the species in the study plots.

Taxa	Study plots														Frequency
	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

Taxa	Study plots														Frequency
	TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ2	TP1	TP2	TP3	CP1	CP2	CP3	
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

Taxa	Study plots														Frequency
	TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ2	TP1	TP2	TP3	CP1	CP2	CP3	
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
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

Taxa	Study plots														Frequency
	TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ2	TP1	TP2	TP3	CP1	CP2	CP3	
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. and 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

Taxa	Study plots														Frequency
	TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ2	TP1	TP2	TP3	CP1	CP2	CP3	
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
Euphorbiaceae															
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

Taxa	Study plots														Frequency
	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

Taxa	Study plots														Frequency
	TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ2	TP1	TP2	TP3	CP1	CP2	CP3	
Myrsinaceae															
67. *Ardisia oxyphylla* Wall. & A.DC.												5	5	5	3
68. *Ardisia fulva* King & Gamble							6	6							2
69. *Ardisia* sp.				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

Taxa	Study plots														Frequency
	TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ2	TP1	TP2	TP3	CP1	CP2	CP3	
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
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. *Tarenna* sp.				5		5									2
Rutaceae															
95. *Citrus* sp.												6	7	7	3

Taxa	Study plots														Frequency
	TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ2	TP1	TP2	TP3	CP1	CP2	CP3	
Sterculiaceae															
96. *Sterculia balanghas* L.					6	7									2
Theaceae															
97. *Eurya nitida* Korth.							7	7							2
Urticaceae															
98. *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

Taxa	Study plots														Frequency
	TC1	TC2	TC3	PD1	PD2	PD3	LJ1	LJ2	TP1	TP2	TP3	CP1	CP2	CP3	
Poaceae															
105. *Pogonatherum paniceum* (Lam.) Hack.	3	1					2	2							4
Zingiberaceae															
106. *Boensenbergia* 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**	

Table 3.7. Similarities between the plots using Bray-Curtis similarity index and the shared number 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							

III. Community classification

Fourteen study plots along the streams of Peninsular Thailand were used in order to classify the plant communities. The abundance data of the species in the fourteen study plots is represented on Table 3.6. Based on the abundance data of the species in Table 3.6 and the Bray-Cutirts similarity index (Table 3.7) communities were distinguished using cluster analysis. From the cluster analysis at 62.5% similarity, four community groups are recognized, A to D (Figure 3.16).

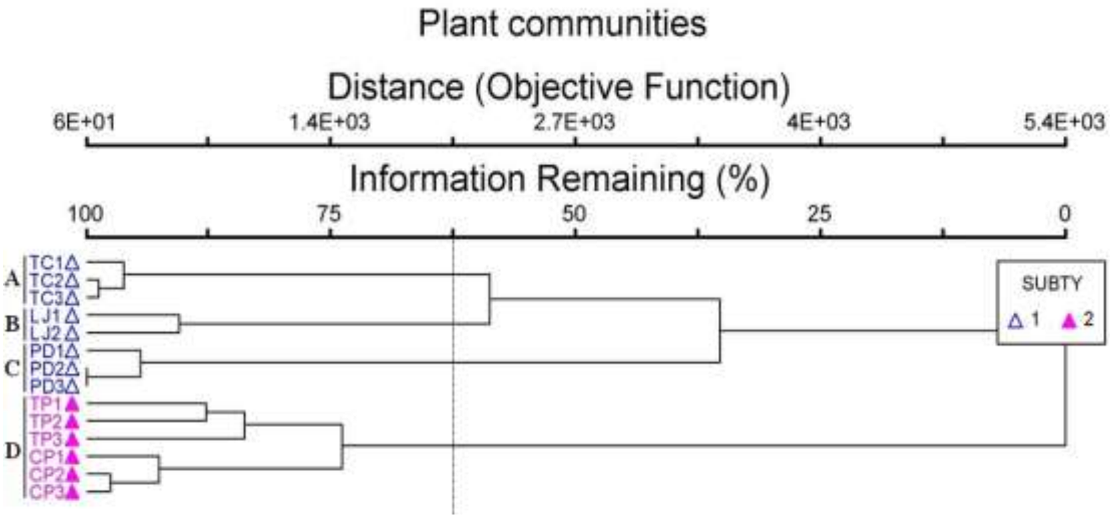


Figure 3.16. Cluster analysis dendrogram based on similarity of the plant species composition and their abundances among the study sites. SUBTY 1 – Granite bedrock; SUBTY 2 – Calcareous bedrock

1. Community A (TC1, TC2, TC3) ***Plate 13.***

This type of community is characterized by the granitic bedrock and the structure of the stream is represented by the Profile A (Figure 3.17)

The structure of the streams in this community includes the open areas, where direct sunlight over the stream is present. The streambed is mostly occupied with the boulders and the small emergent rocks. During dry season boulders are seen as part of the nearby land, where rock crevices and shallow pools are formed. Dominant substrate of the stream banks is rock, with few places with sand. Tree species that occupied rocky banks lean diagonally towards the stream creating partly shady areas on the banks. Stream floor is mainly composed of compacted rock and gravel. Water depth varies from very shallow to the deep pool areas, where the sand and gravel is accumulated. Water flow varies from fast turbulent chaotic to the rippled and smooth in pool areas. Similarity between the plots within this community is shown in Table 3.7.

The vegetation is 2-layerd. The upper layer is tree leayer, up to 20 m high, while the lower layer is dominated by herb and few shrub species. Few tree and shrub species occupy the stream banks e.g. *Bridelia tomentosa* Blume, *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f. Ground floor is characterized by the presence of streambed species e.g. *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman, *Cephalomanes javanicum* (Blume) C.Presl., *Ficus ischnopoda* Miq, *Homalomena repens* Ridl., *Osmunda javanica* Blume. which are the main components of this community. Minor components of this community are 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.

2. Community B (PD1, PD2, PD3) ***Plate 14.***

This community is represented on the granitic bedrock and the physiognomy of the stream is represented by the Profile B (Figure 3.18).

The structure of the streams in this community is in deep shaded areas, and there is no direct sunlight over the stream water. Streambed is mostly occupied by small emergent rocks. Stream banks are mostly soily, with few places with rock. The stream floor is composed of pebbles, gravel and sand that during dry season can emerge as islands. This profile is distinguished by the absence of the boulders and deep pool areas. Water level is low, barely covering emergent rocks during rainy season. Water flow is mostly chaotic and chute throughout, with few places close to the banks that have ripped and smooth flow. Similarity between the plots within the community is shown in Table 3.7.

The vegetation is dominated by the tree species that occur on the stream banks as well as in the streambed. The community is 3-layered. The upper canopy layer is 15–30 m high and it is composed of the dominate tree species e.g.

Ficus tinctoria G.Forst. and *Ficus* sp.1, and minor components e.g. *Bauhinia pottsii* G.Don, *Pheanthus* sp., *Rinorea* sp. and *Sterculia balanghas* L. The lower layer 5–10 m high is mainly composed of the shrub species such as *Ardisia* sp., *Donax canniformis* (G. Forst.) K. Schum. and *Trigonostemon aurantiacus* (Kurz ex Teijsm. and Binn.) Boerl. The ground floor is 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 characteristic streambed species are not common in this community and occur sporadically on the emergent rocks e.g. *Bolbitis heteroclita* (Presl) Ching ex. C.Chr, *Cephalomanes javanicum* (Blume) C.Presl. and *Homalomena repens* Ridl.

3. **Community C** (LJ1, LJ2) ***Plate 15.***

This type of the community is found along the granitic bedrock streams and its structure is represented by the profile C (Figure 3.19).

This type of the community is characterized by the open space in along the streambed and shaddy areas along the banks. The streambed is mostly occupied with big boulders and few emergent rocks, which are not completely flooded even during rainy season. Dominant substrate of the streambanks is soil, with few places with rocks. Tree species that occupied stream banks lean diagonally towards the stream creating partly shaddy areas. Stream floor is mainly composed rocks with gravel and silt between them. Water depth varies from shallow rocky areas to deep pools where water is smooth. Water flow in shallow rocky areas is chaotic and chute. Similarity between the plots is shown on Table 3.7.

The vegetation is composed of 3-layers. The upper layer is dominated by the tree species from the banks e.g. *Diospyros* sp., *Garcinia* sp. and *Syzygium nervosum* DC. The middle layer is dominated by the shrub species e.g. *Eurya nitida* Korth., *Ficus ischnopoda* Miq. and *Ardisia fulva* King and Gamble, while the ground floor is composed of manu heb species e.g. *Globba pendula* Roxb., *Homalomena repens* Ridl., *Ophiorrhiza communis* Ridl. and *Selliguea heterocarpa* Blume.

4. Community D (TP1, TP2, TP3, CP1, CP2, CP3) ***Plate 16.***

This type of community is restricted to the calcareous bedrock streams and its structure is represented by Profile D (Figure 3.20).

This type of stream structure is characterized with deep shade throughout the profile with several places of broken shade and direct sunlight. The tree canopy is dense keeping the daily fluctuations of the humidity small. The most common microhabitat is boulders, which are placed in deep shady areas. Stream banks are soily with several rocky areas. Stream floor is mostly solid, composed of the compacted bedrock and with gravel and silt in pool areas. Water depth varies from shallow places of chaotic water flow to the deep pool areas with rippled and smooth flow. Similarities between the plots in this community are shown in Table 3.7.

The vegetation of this community is dominated by the tree species that mostly occupy streambed. The community is 3-layered. The upper canopy layer is 20–30 m high and it is composed of the species that occur sporadically throughout the plots e.g. *Bauhinia pottsii* G.Don, *Duabanga grandiflora* Walp and *Radermachera glandulosa* Miq. The lower canopy layer is 10–20 m high and it is composed of the dominant tree species e.g. *Saraca indica* L., which is forming more or less pure stands, and minor components e.g. *Elaeocarpus grandiflorus* Sm., *Kopsia pauciflora* Hook.f, *Neonauclea* sp.1, *Pseuduvaria reticulata* Miq. and *Syzygium* sp.1. The crowns of these species are winded between each other producing a continuous layer of the canopy. The ground floor is dominated by the herb species, especially the associated group, which occur on the boulders in the deep 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. These species expressed the seasonal dynamic in vegetation. During dry period the vegetation is dominated 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 shred their leaves and disappear and the other set of species dominates e.g. *Begonia integrifolia* Dalzell, *Cyrtandra pendula*

Blume, *Kaisupeea orthocarpa* B.L.Burtt, *Nephrolepis undulata* (Afzel.) J.Sm, *Piper* sp.1 etc.

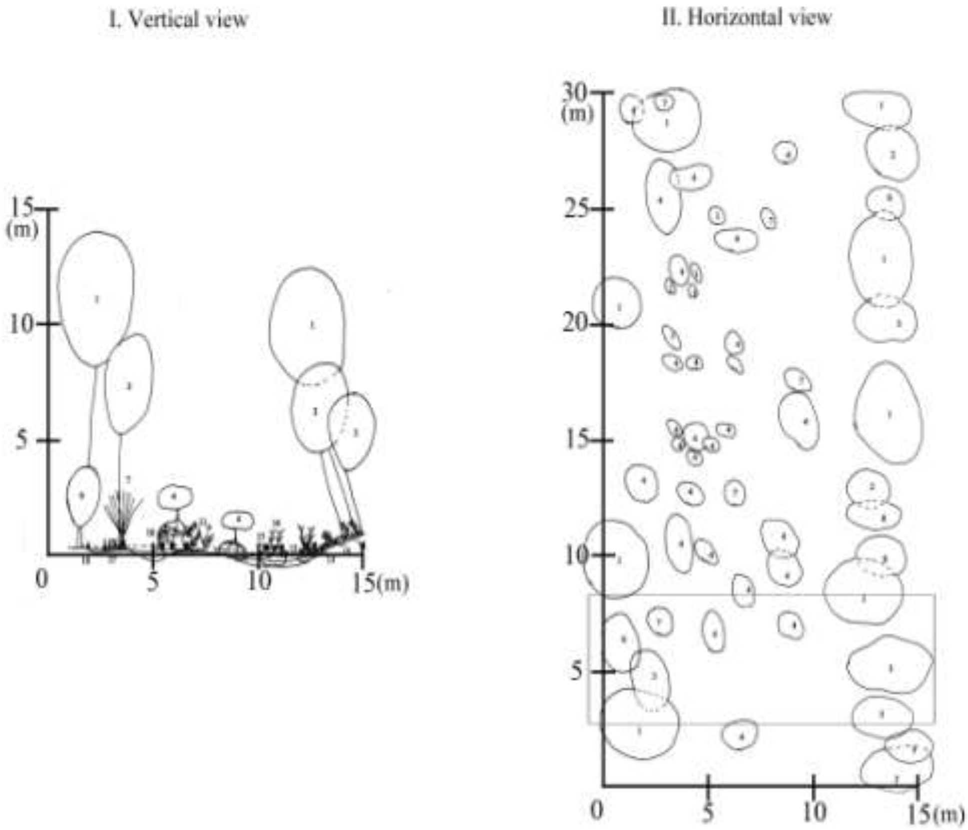


Figure 3.17. The vegetation profile for the community A. I.Vertical view of the profile; II.Horizontal view of the profile.

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.

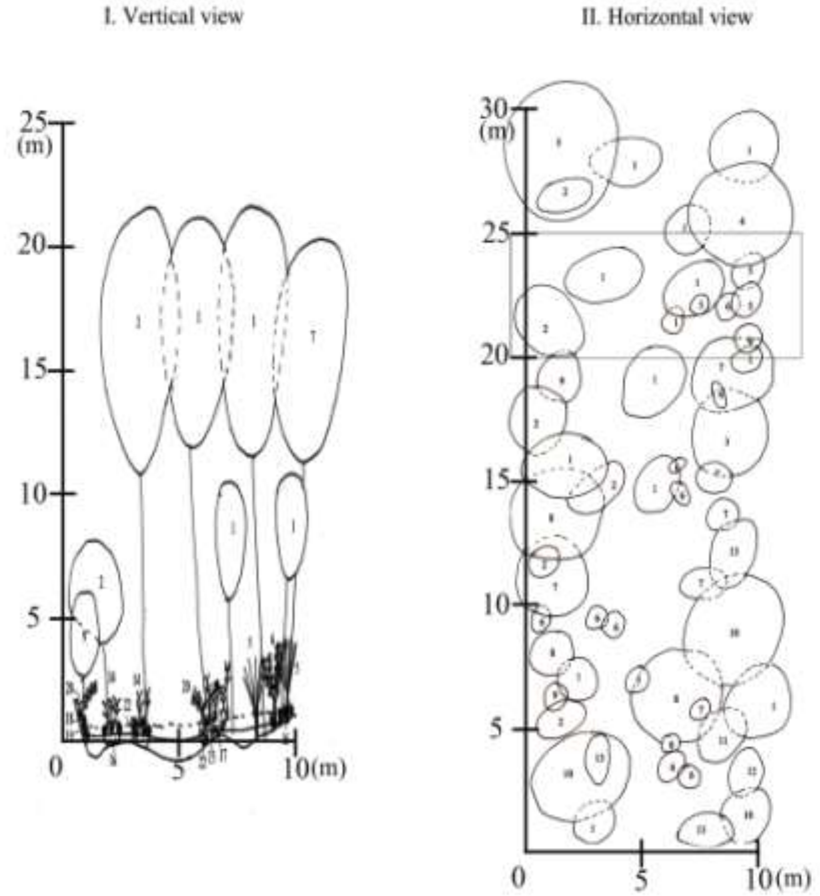


Figure 3.18. The vegetation profile for the community B. I.-Vertical view of the profile; II. Hotizontal view of the profile.

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-T*rigonostemon 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.

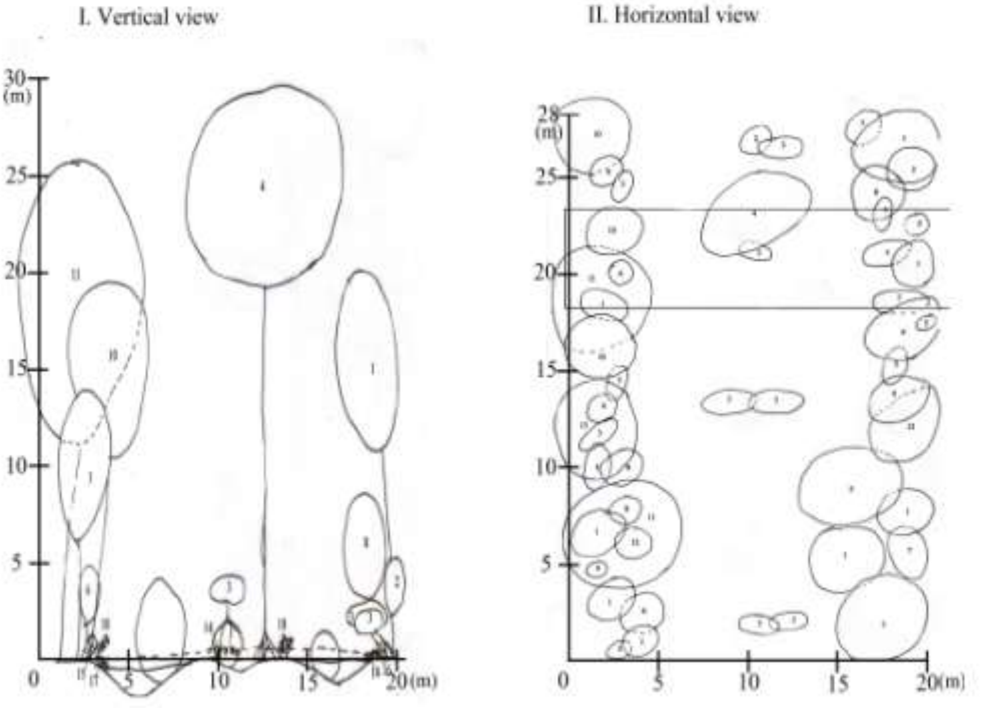


Figure 3.19. The vegetation profile of the C community on the granitic bedrock streams. I.Vertical view of the profile; II.Horizontal view of the profile.

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.

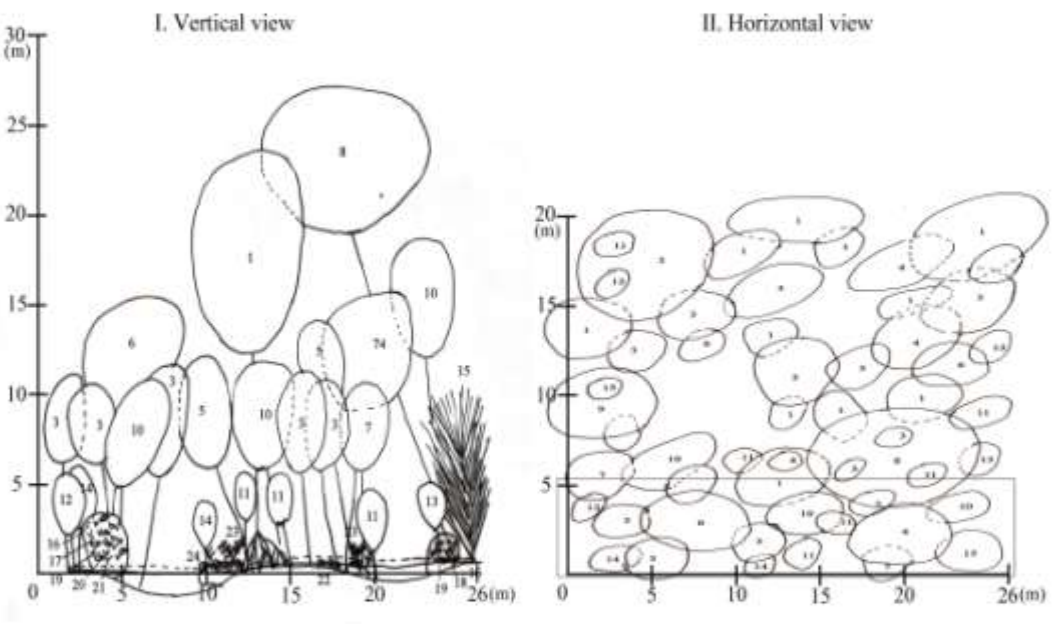


Figure 3.20. The vegetation profile of the D community on the calcareous bedrock streams. I.Vertical view of the profile; II.Horizontal view of the profile.

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-R*adermachera glandulosa* Miq.; 9-*Antidesma* sp.; 10-*Neonauclea* sp.2; 11-*Ardisia oxyphylla* Wall. & A.DC.; 12-*Cytrus* sp.; 13-*Ixora javanica* DC.;14-*Ixora bracteolata* 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.

IV. Community correlation with environment

CCA analysis was conducted on the 14 plots, consisting of 99 species, providing two axes, Axes 1 and Axes 2, with eighenvalues of 0.794 and 0.623 respectively. Correlation was calculated for the axis, which indicated that Axis 1 was negatively correlated with pH value of the water as well as stream width and the positively correlated with light intensity (Table 3.8). The highest correlation with the Axis 1 had pH value of water, the distribution along the Axis 1 reflected different values of pH of water: from the left to right it went from high pH values of water to the low values. Along the second ordination Axis 2, correlation with any of the environmental factors is not clearly represented.

Table 3.8. Correlation calculated between the axes and the CCA ordination and the values of quantitative environmental variables

Variable	Correlations			Biplot Scores		
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
Air temperature	-0.058	0.213	-0.326	-0.055	0.191	-0.272
Humidity	-0.380	0.415	-0.474	-0.358	0.371	-0.396
Light intensity	0.826	0.455	0.150	0.778	0.407	0.126
Water temperature	-0.580	0.185	-0.694	-0.546	0.166	-0.580
Water velocity	-0.444	-0.402	-0.134	-0.419	-0.359	-0.112
Stream depth	-0.508	0.491	-0.532	-0.479	0.439	-0.444
Stream width	-0.789	0.408	-0.236	-0.743	0.365	-0.197
pH of water	-0.991	0.090	-0.006	-0.933	0.080	-0.005

1. Ordination of the samples

The ordination of the plots in correspondence with environmental factors is presented on Figure 3.21. Samples were distributed along the different substrate type, as well as the climatic data. Samples from the calcareous bedrock streams are clustered on the left side of the ordination, with the higher pH value of the water, lower light intensity and wider streams; while samples towards the right side of the ordination are from the granite bedrock streams with lower pH values of water and narrower streams. Samples on the right side are grouped into upper and lower group. Upper group prefers higher light intensities, while lower prefers lower intensities.

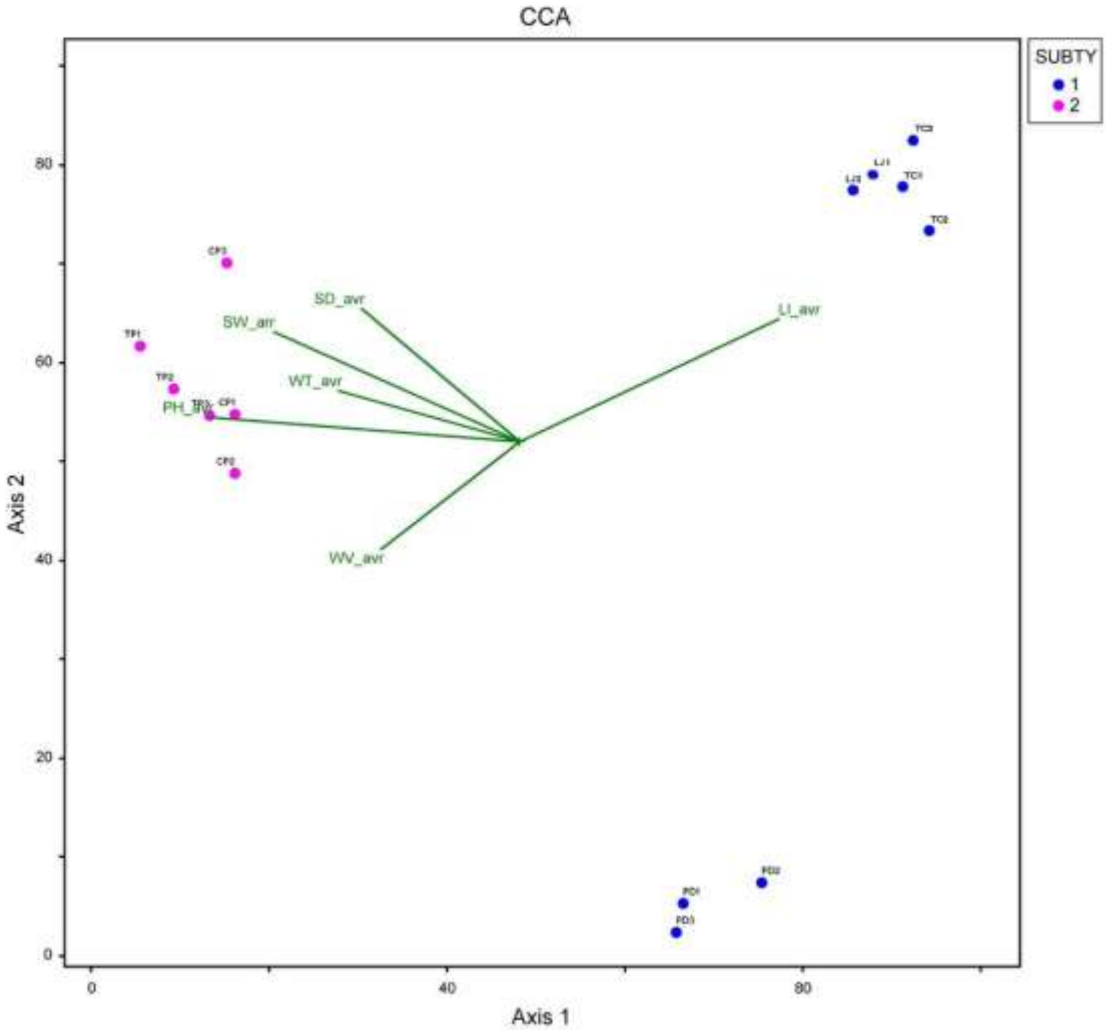


Figure 3.21. CCA ordination of the samples of vegetation of the running streams on granite and calcareous bedrock for 14 plots. The first axis goes from high pH values of water to the low pH values of the water.

CHAPTER 4

DISCUSSION

PART I: FLORISTIC STUDY

I. Floristic richness

In the present study total number of 109 species was recorded, belonging to 75 genera and 49 families. The observed number of the species might be underestimated due to sampling of non frequent species along the streams. The estimated number of the species in overall study sites was 121, which is relatively high for the species restricted to the streambed and low if the terrestrial habitats are included.

In comparison to the similar work in the rivers and streams of Thailand the numbers of total recorded species fluctuate from low to high number. For example, Puff and Chayamarit (2001) recorded 25 species of plants that are confined to the Mekong river bed, while Maxwell (2009) recorded 402 species of emerald pool area (Sra Moragote), Krabi province. On the other hand Muadsub et al. (2009) recorded 159 species in the Bangwan and Tamnang streams of Phangnga province, while Panatkoll et al. (1999) recorded 128 species along Mae Mon stream in Chae Son National Park, Lampang Province. The variation of the number of the species along the streams is affected by many factors, such as sampling methods, forest structure, elevation, climate, stream size etc. as well as the degree of tough stream environment.

Considering plant species composition of studied the streams of Peninsular Thailand, the most abundant families were Rubiaceae, Moraceae and Gesneriacea for Eudicots, Zingiberaceae for Monocots and Hymenophyllaceae, Pteridaceae and Tectariaceae for Monilophytes. It is not surprising that these families of Eudicots are the most common as they are one of major families in Thai flora. In

Thailand there are about 600 and 1,070–1,100 species of Rubiaceae and Moraceae, respecitely (Berg et al., 2011; Puff et al., 2005). This is due to the fact that these families occupy diverse habitats and have many types of life forms, especially Rubiaceae family. Concerning the number of species of fern and fern allies, species from family Hymenophyllaceae are very abundant in the moist, humid, shaded areas, such as streams.

The total number of the species that are commonly found along the stream and they were in fully described in results, is 36. However, it is interesting that few species that are very common and abundant along the streams and rivers of Thailand were not found, such as *Homonoia riparia* Lour., species from families Hydrostachiaceae and Podostemaceae, which are restricted to the fast flowing streams. The absence of the species *Homonoia riparia* Lour. might be due to the size of selected streams; while the absence of the species from Podostemaceae and Hydrostachiaceae can be explained by the preference of the bedrock as the major reason and the size of the granite bedrock streams.

II. Species richness on different bedrock types

The study was conducted on two different bedrock types, granite and calcareous, which resulted in the total number of species 59 and 60, respectively. The observed number of species on both type of the bedrock might be underestimated as the estimated number for each type of bedrock is 65 and 64, respectively. The similar total number of the species recorded on both type of the bedrock was unexpected, as the calcareous streams can support more species comparing to granite. For example Maxwell (2009) recorded 402 species of emerald pool area (Sra Moragote), Krabi province, where the main bedrock type is calcareous. On contrary Ramsri (1986) recorded 200 species of Gahrome waterfall in Khao Luang National Park, Nakhon Si Thammarat province, with the granitic bedrock as the main type of rock. The similar number of recorded species in the granite and calcareous bedrock is probably due to the difference of the number of selected streams as well as the types and number of microhabitats on each type of bedrock streams.

Species diversity on two different bedrock type differs greatly, that only 10 species were found on both type of the streams. This is indicating that the bedrock type have impact in determining a community composition.

III. The microhabitats along the streams on different bedrock type

Types of microhabitat were divided based on topographical characteristics of both types of bedrock streams. The frequencies of microhabitats differed greatly on both types of bedrock streams.

Granitic bedrock streams supported more types of microhabitats comparing to the calcareous bedrock streams. On granite bedrock streams the most common microhabitat is emergent rocky islands, which are inhabited by the streambed species. The second most frequent microhabitat is rocky banks, which dominates the stream banks of granitic bedrock streams. Few microhabitats occur only along the granitic bedrock streams e.g. rock crevices, shallow pools and sandy banks. These microhabitats are occupied by the specific set of plant species, and they are not found in the calcareous bedrock streams. The existence of these microhabitats along the granite bedrock streams increased the diversity of the species along the granite bedrock streams. Species diversity is predicated to increase with heterogeneity in streams (Townsend, 1989). Moreover, this result corresponds to the result of the increased macrophyte diversity in unregulated Danish streams (Battrup-Pedersend and Riis, 1999). The similar pattern of the increase of that habitat types and the plant diversity were found in the river Deben, England (Kemp et al., 1999). The greater number of habitats that is available for the plant colonization, the higher is the species diversity.

On the calcareous bedrock streams the most common microhabitat is stream floor as well as the boulders. Stream floor is inhabited mostly by the tree species that would usually occupy stream banks. This type of microhabitat is unique to the calcareous bedrock streams, and it is without any species along granite bedrock streams. The existence of this microhabitat along the calcareous bedrock streams did not increase the diversity of the species, but it increased the number of individuals of specific species that occupied it.

Further studies about correlation of the microhabitats and the diversity of the species are necessary in order to make more precise conclusions.

IV. The proposed categories of the plant species found along the fast-flowing streams

Plant species in this study are roughly grouped into two major categories based on microhabitat that the species occupy, their frequency in the study plots and whether or not they develop morphological adaptations towards the stream: characteristic and associated species.

1. Characteristic species

A total number of 36 species was grouped as characteristic species (Figure 4.1). They belong to 23 genera and 21 families. The most abundant families are Rubiaceae (5 species), Moraceae (4 species) and Dryopteridaceae (3 species).

This plant group was abundant on both types of bedrock streams. There were 25 species on granitic bedrock streams and 17 on calcareous bedrock streams. Among the species on the granitic bedrocks streams there were 10 trees, 5 shrubs and 10 herbs, while among calcareous bedrock there were 11 trees, 2 shrubs and 4 herbs.

Even thou the number and composition of the characteristic species differs greatly between two types of the bedrock streams, there were 6 species that are found on both places. They include one species of fern *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman; two species of trees *Elaeocarpus grandiflorus* Sm., and *Syzygium* sp.; one species of climber *Bauhinia pottsii* G.Don; one species of shrub *Ixora javanica* DC.; and one species of herb *Homalomena repens* Ridl.

Characteristic species are further divided into:

1.1 *Species of the streambed* ***Plate 1.***

Species grouped as streambed species occupy various microhabitats in the stream bed i.e. small emergent rocks, stream floor and sides of boulders where they grow under constant pressure from high water velocities and regular flooding periods. During rainy season, when flooding is excessive they are partially or completely submerged.

A total number of 7 species were classified as this group, with 7 that can be found on granitic and 2 on calcareous bedrock streams (Figure 4.1). Most of the species in this group are fern species such as *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman, *Bolbitis heteroclita* (Presl) Ching ex. C.Chr; *Cephalomanes javanicum* (Blume) C.Presl, *Osmunda javanica* Blume, one shrub *Ficus ischnopoda* Miq., and one herb species *Homalomena repens* Ridl.

1.2 *Terrestrial plants along the stream* ***Plate 2–5.***

Species grouped as terrestrial plants are frequent along the streams, where are influenced by occasional flooding. Mostly they inhabit stream banks on both type of bedrock, however on calcareous streams they occur in the streambed.

Total number of 25 species was classified as terrestrial plants, with 15 granitic and 13 on calcareous bedrock streams and 3 shared species (Figure 4.1). Most of these species are tree species (14 species) e.g. *Duabanga grandiflora* Walp. *Ficus auriculata* Lour., *Syzigium nervosum* DC., *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f etc., one climber *Bauhinia pottsii* G.Don, few species of ferns e.g. *Bolbitis appendiculata* (Willd.) K.Iwats., *Heterogonium pinnatum* (Copel.) Holttum, *Cyclosorus menisciicarpus* (Blume) Holttum, *Diplazium riparium* Holttum, and *Cyathea podophylla* (Hook.) Copel.; and few shrub species *Pandanus* sp., *Ardisia oxyphylla* Wall. & A.DC., *Ardisia* sp., and *Ardisia fulva* King & Gamble.

1.3 *Flexible stream species* ***Plate 6.***

Species classified as flexible stream species occupy different types of habitats e.g. forest floor, epiphytic on tree etc., but on some occasions they occur along the streams.

Total number of 4 species was classified as flexible stream species, with 3 species on granitic bedrock streams, and 2 species on calcareous bedrock streams (Figure 4.1). Two of them are shrub species such as *Justicia gendarussa* Burm. and *Ixora* *javanica* DC.; while there were two species of ferns *Leptochilus pedunculatus* (Hook. & Grev.) Fraser-Jenk and *Pteris vittata* L.

2. Associated species ***Plate 7–12.***

This group of species includes the species that do not have direct impact from the stream water and do not develop any permanent adaptations towards the stream environment. They occupy the areas where water from nearby stream hardly reaches i.e. top of the boulders or on banks beyond upper flooding zone.

A total number of 73 species were classified as associated belonging to 54 genera and 35 families. The most common families are Rubiaceae (11 species), Gesneriaceae and Selaginellaceae with 5 species per family.

This group of species is distributed on both types of bedrock streams, granite and calcareous. On granitic bedrock streams total number of 34 species was recorded (Figure 4.1). Among them there were 9 trees, 4 shrubs and 21 herbs. On the other hand, on calcareous bedrock streams 43 species were recorded, 5 trees, 2 shrubs and 36 herbs.

There were 4 species of associates that were found on both types of the streams, 2 fern species *Antrophyum callifolium* Blume and *Tectaria angulata* (Willd.) C.Chr.; one herb *Ophiorrhiza communis* Ridl.; one shrub *Donax canniformis* (G. Forst.) K. Schum.

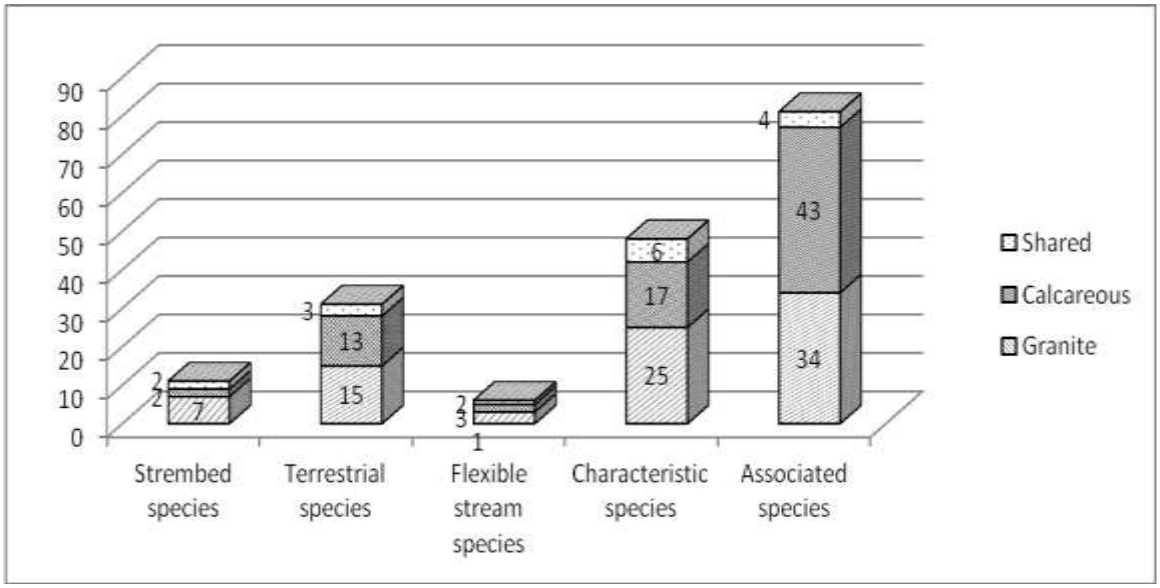


Figure 4.1. The number of species of plant groups on granite and calcareous bedrock

V. Proposed plant categories on different bedrock type

As already discussed bedrock has high influence on the species composition in the stream ecosystem. Granitic bedrock stream accommodated almost as same number of species as calcareous bedrock streams. However the number of species of the proposed groups differed greatly between two types of bedrock.

The number of the characteristic species commonly found along the stream differed greatly between granitic and calcareous bedrock streams. Granitic bedrock streams accommodated more species than the calcareous bedrock streams. It can be explained by the properties of each rock type as the calcareous is softer and less firm, comparing to granite, and it is more difficult for the species in the streambed to establish themselves. This is in accordance with the van Steenis (1981) as the rheophytic species are not able to anchor firmly in the calcareous bedrock due to the breaking down into pieces.

VI. Note on the proposed groups of plant species in the running streams

Two major groups of the species along the streams were divided based on the microhabitat that the species inhabited and whether they developed morphological adaptations or not. A similar classification on the temperate streams was suggested by Riis et al. (2001), where the low land stream species were grouped into: terrestrial, amphibious and obligate submerged plants. This classification was also based on habitat of the species and the development of morphological adaptations.

Species grouped as characteristic species of the running streams could be referred as rheophytes (van Steenis, 1981), since they inhabited similar habitats as rheophytes. Due to the fact that not enough ecological data was collected, these species were not referred as rheophytes. Further studies of these species about morphology, ecology and anatomy are needed to make such conclusions.

On the other hand some of species grouped as associated species resemble the characteristics and habitat types of the group of plants of moist areas and humid areas – hygrophytes. Their composition corresponded to the seasonal change from dry to rainy season. In the study they were not ascribed as hygrophytes as more gathered ecological data of this plant group is necessary. Further analysis on their phenology, morphology and similar ecological studies is needed to make more certain conclusions.

PART II: MORPHOLOGICAL STUDY

Plant species grouped as characteristic species of the running streams had specialized morphological adaptation for the harsh stream environment. The most obvious morphological adaptations include: habit, branching of the root system and shape and size of leaves.

I. Habit

The habit of these species is very diverse. Roughly it can be divided into following groups:

1. *Distorted*

This type of habit occurs in species that always occur in the running waters. Growth form of these species is distorted along the water current, so one part which is up stream, is under constant pressure from the water velocities. The twigs and buds of these species usually develop on the downstream side, while the upstream side is damaged with broken branches and twigs. On the first appearance, these species look like that shoots develop only on the downstream side of the plant axis. Very few species were found to have this type of habit *e.g*. *Ficus ischnopoda* Miq., *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman and *Osmunda javanica* Blume etc.

2. *Leaning*

This type of habit of the species occurs mostly in land plants, where branches and the trunk are bended diagonally over the stream. The root system of these species is anchored on the bank of the stream very close to the water e.g. *Ficus globosa* Blume, *Olea brachiata* Merr., *Antidesma* sp. and *Phyllanthus gracilipes* (Miq.) Müll. Arg etc. Also, the species that occupy waterfalls and slopes where water velocity is very high, have this type of habit e.g. *Ficus auriculata* Lour. and *Calophyllum rupicola* Ridl. etc.

3. *Horizontal*

This habit of species is expressed with the straight trunk and regular shoots branching. This type of habit occurs mostly in the species of the calcareous bedrock streams e.g. *Radermachera glandulosa* (Blume) Miq., *Saraca indica* L., *Neonauclea* sp.1., *Daubanga grandiflora* (Roxb. ex DC) Walp. etc. On granitic bedrock streams this type of habit is common among the young trees of the species *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f. and *Ficus tinctoria* G. Forst., *Pheanthus* sp. etc.

4. *Hanging*

This habit is expressed with the straight shoot and drooping branches. This type of habit is more common for the temperate *Salix* species, while very few plant species along the streams have similar habit e.g, *Ardisia oxyphylla* Wall. & A.DC., *Ardisia fulva* King & Gamble etc.

II. Root system

The structure of the root system varies from species to species, but some kind of regularities of the root system can be seen, especially in accordance to the microhabitat and habit. Five different root structures and branching are recognized:

1. *Horizontal expanded*

This root system is the most common root adaptations of the species along the streams. It is expressed as a large root system that expanded horizontally over soil or rock to cover as much of the surface as it is possible (Figure 4.2.A). Their large netted root system is supporting the species, especially in the places where the substrate is not really stable and there is a constant stress from water velocity e.g. *Neonauclea* sp.1 and *Saraca indica* L etc.

However, the streambed species *Ficus ischnopoda* Miq. develops similar type of the root system, where the roots expands over the rocks, embrace them giving firm support for the plant (Figure 4.2.B).

2. *Buttress*

This type of root is the second most common adaptation of the root system (Figure 4.2.C). It is expressed in the large and firm flat buttresses that form a firm foothold for the species. Sometimes buttresses are formed on one side of the tree, the one that is closer to the stream against steep rocky banks e.g. *Daubanga grandiflora* (Roxb. ex. DC.) Walp., *Elaeocarpus grandiflorus* Sm, *Ficus auriculata* Lour. and *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f. etc.

3. *Stilt*

This root system is only seen in *Syzygium* spp. (Figure 4.2.D) which is expressed by numerous adventitious roots growing from the main trunk in order to support the species.

4. *Herbaceous rhizomatous*

This type of root system is developed in herbs, especially in the species that grow in the crevices and along the side of the rocky islands (Figure 4.2.E). Their long thick creeping rhizome with stiff roots keeps those species stable even they are exposed to flooding and high water velocities e.g. *Homalomena repens* Ridl. On the other hand, species that occupy rocky islands in the stream bed are exposed to the similar influences, and their rhizomes extend so they occupy the whole rock e.g. *Bolbitis heteroclita* (C.Presl) Ching ex C.Chr; *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman and *Leptochilus pedunculatus* (Hook. & Grev.) Fraser-Jenk.

5. *Trunk like root formation*

This type of root system is developed in fern species (Figure 4.2.F) such as *Cephalomanes javanicum* (Blume) C.Presl, *Cyathea podophylla* (Hook.) Copel and *Osmunda javanica* Blume. They have erect rhizomes with long stiff roots which are tufted, and forming a trunk like formation from root, which is very firm as a foothold.

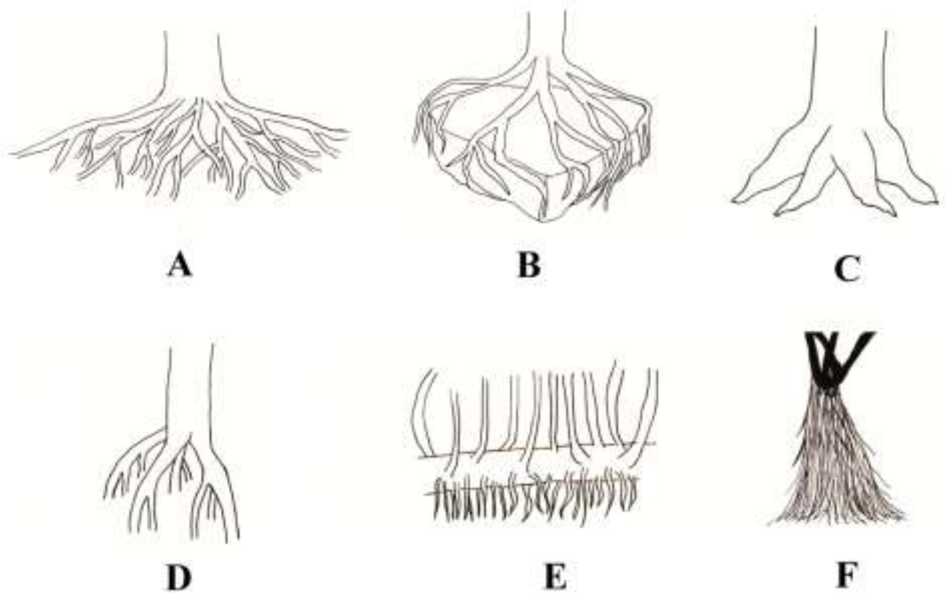


Figure 4.2. Different types of adaptation of the root system of characteristic species. A–Horizontally expanded root; B–Expanded root that embraces the rock; C–Butress root; D–Stilt root; E–Thick herbaceous rhizome; F–Trunk like root formation.

III. Leaf morphology

Leaf shape and size is one of the most important adaptation of species along the streams. The shape of the leaf varies from very narrow almost linear, oblong – lanceolate or oblanceolate (Figure 4.3).

The shape and size of the leaves or leaflets of the compound leaves is different for each group of stream species and can be divided into 3 groups according to the stream species:

1. *Leaf (leaflet) of streambed species*

Leaf (leaflet) of these species is very narrow, almost linear to lanceolate (Figure 4.3.1–7). The value of leaf index in such species is always higher than 4 (Table 4.1) e.g. *Bolbitis heteroclit*a (C.Presl) Ching ex C.Chr; *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman; *Ficus ischnopoda* Miq.; *Homalomena repens* Ridl.; *Osmunda javanica* Blume etc.

2. *Leaf (leaflet) of terrestrial plants*

Leaf (leaflet) of these species is more oblong, oblanceolate or obovate (Figure 4.3.8–16). The leaves (leaflets) of these species are wider than previous group. The value of leaf index is 4 or lower (Table 4.1) e.g. *Bolbitis appendiculata* (Wild.) K.Iwats, *Elaeocarpus grandiflorus* Sm, *Ficus tinctoria* G.Forst. and *Neonauclea pallida* (Reinw. ex Havil.) Bakh. f.

Unusual leaf adaptation for this group is seen in young treelets of some species e.g. *Ficus auriculata* Lour. and *Neonauclea pallida* (Reinw. ex Havil.) Bakh. f. The shape of treelet leaves is linear lanceolate with high value of leaf index, while leaves of adult individuals is oblong or oblanceolate with low value of leaf index. In *Neonauclea pallida* (Reinw. ex Havil.) Bakh. f. the adult size of leaf is oblong shape (Figure 4.4.A.left), 7–25 by 5–8 cm, with the value of leaf index 2 (Table 4.1). On contrary, leaves of treelets have very narrow lanceolate leaves (Figure 4.4.right), 7–19 by 2–4 cm, with value of leaf index 4. The same pattern is seen in adult and young leaves of *Ficus auriculata* Lour. Adult leaves of this species are ovate, oblong (Figure 4.4.B.right), 10–30 by 9–15 cm, with the value of leaf index 2 (Table 4.1); while yong treelet leaves are more elliptic (Figure 4.4.B.left), 7–15 by 3– 6 cm, with the value of leaf index 4 (Table 4.1)

3. *Leaves (leaflets) of flexible stream species*

These species have variable shape and sizes of leaves (leaflets) (Figure 4.3.17–18). The value of the leaf index for this grouped varied from high values of 6 to low values of 3 (Table 4.1). Fern species *Leptochilus pedunculatus* (Hook. & Grev.) Fraser-Jenk. in the stream microhabitat has lanceolate leaves (Figure 4.4.C.left), 9.7–15.5 by 1.6–2.4 cm, with the value of leaf index 6; while the species in epiphytic habitats have broadly lanceolate leaves (Figure 4.4.C.right), but in different size 9.8–15.6 by 3.7–4 cm, with the value of leaf index 3 (Table 4.1).

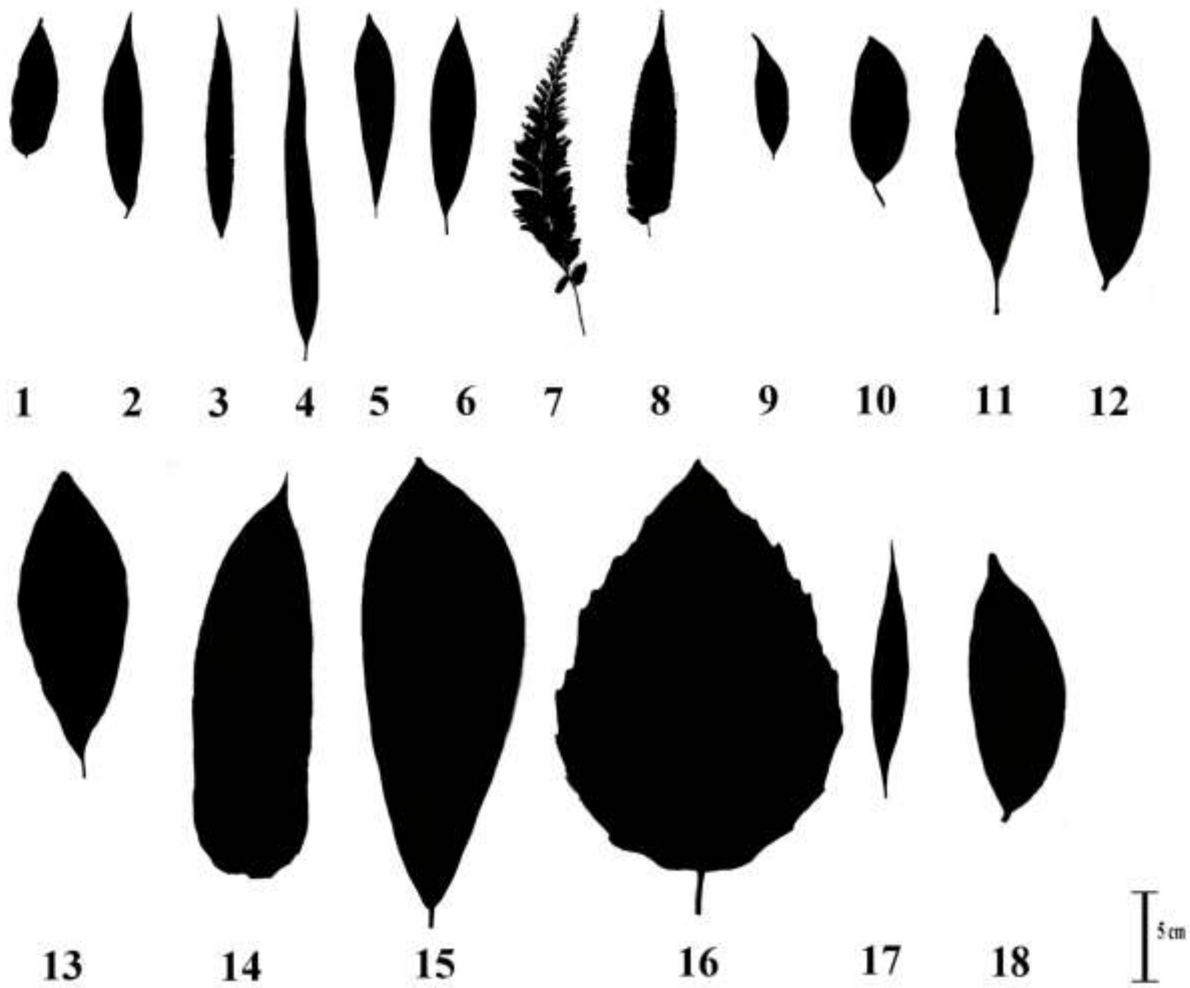


Figure 4.3. Leaf (leaflet) shape and size of groups of characteristic species. 1–7. Stream bed species: 1. *Bolbitis heteroclita* (C.Presl) Ching ex C.Chr; 2. *Bolbitis virens* (Wall. ex Hook. and Grev.) Schott var. *compacta* Hennipman; 3. *Diplazium riparium* Holttum ; 4. *Osmunda javanica* Blume; 5. *Ficus ischnopoda* Miq.; 6. *Homalomena repens* Ridl.; 7. *Cephalomanes javanicum* (Blume) C.Presl.; 8–16. Terrestrial species along the streams: 8.*Cyclosorus menisciicarpus* (Blume) Holttum; 9. *Syzygium* sp.1; 10. *Calophyllum rupicolum* Ridl.; 11. *Elaeocarpus grandiflorus* Sm.; 12 *Saraca indica* L.; 13. *Neonauclea pallida* (Reinw. ex Havil.) Bakh. f.; 14. *Radermachera glandulosa* (Blume) Miq.; 15. *Ficus* sp.1.; 16. *Ficus auriculata* Lour.; 17–18. Flexible stream species: 17. *Leptochilus pedunculatus* (Hook. and Grev.) Fraser-Jenk.; 18. *Ixora javanica* DC.

Table 4.1: Leaf (leaflet) measurements of selected characteristic species along streams. StrB-stream bed species; TrSp-Terrestrial species; Flx-Flexible stream species.

Species	Species group	Leaf length in cm ± SD	Leaf width in cm ± SD	Leaf index
Osmunda javanica Blume	StrB	10 ± 1	1.2 ± 0.3	9
Ficus ischnopoda Miq.	StrB	8.2 ± 2.7	1.1 ± 0.2	7
Homalomena repens Ridl.	StrB	11.55 ± 2.5	2 ± 0.6	6
Bolbitis heteroclita (C.Presl) Ching ex C.Chr	StrB	15.6 ± 8.4	2.9 ± 1.4	5
Bolbitis virens (Wall. ex Hook. & Grev.) var. *compacta* Hennipman	StrB	10.4 ± 3.7	2.3 ± 0.6	5
Cephalomanes javanicum (Blume) C.Presl	StrB	18.5 ± 3.5	4.1 ± 0.6	5
Bolbitis appendiculata (Wild.) K.Iwats	TerPl	2.8 ± 0.8	0.8 ± 0.1	4
Diplazium riparium Holttum	TerPl	14.5 ± 2.5	3.5 ± 0.7	4
Calophyllum rupicolum Ridl.	TerPl	7.3 ± 2.1	3 ± 0.4	4
Elaeocarpus grandiflorus Sm.	TerPl	11.4 ± 1.9	4.4 ± 0.2	3
Saraca indica L.	TerPl	14.8 ± 5.5	4.9 ± 0.7	3
Neonauclea pallida (Reinw. ex Havil.) Bakh. f. adult	TerPl	16 ± 4	6.5 ± 1.5	2
Neonauclea pallida (Reinw. ex Havil.) Bakh. f. young treelet	TerPl	13 ± 3	3 ± 1	4
Ficus tinctoria G.Forst.	TerPl	11.2 ± 6.3	5.5 ± 0.6	2
Ficus auriculata Lour.	TerPl	20 ± 4.8	11.5 ± 2.5	2
Ficus auriculata Lour.young treelet	TerPl	16 ± 5	4.5 ± 1.5	4
Leptochilus pedunculatus (Hook. & Grev.) Fraser-Jenk. streambed	Flx	12.6 ± 2.9	2 ± 0.4	6
Leptochilus pedunculatus (Hook. & Grev.) Fraser-Jenk. epiphytic habitat		12.7 ± 2.9	3.9 ± 0.2	3
Justicia gendarussa Burm. f.	Flx	12 ± 2.9	2 ± 0.4	6
Ixora javanica (Blume) DC.	Flx	13.15 ± 1.9	4 ± 0.2	3

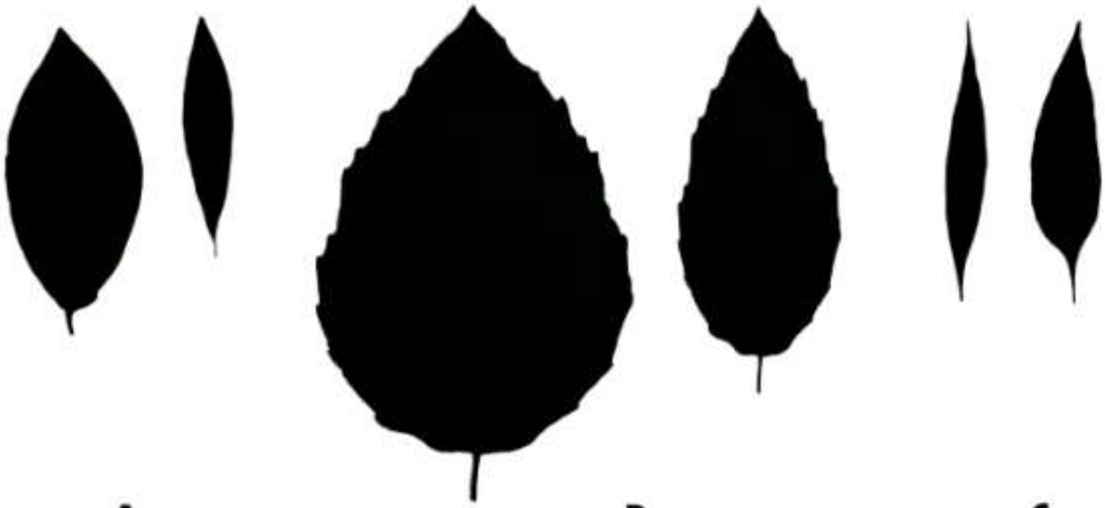


Figure 4.4. Comparison of the leaf shapes and sizes of the: A–B. Different growth stages, adult leaves (right) and treelet (left) in species. A. *Neonauclea pallida* (Reinw. ex Havil.) Bakh. f.; B. *Ficus auriculata* Lour.; C. Different environments shady epiphyte (right) and streambed (left) of *Leptochilus pedunculatus* (Hook. and Grev.) Fraser-Jenk.

IV. The morphological adaptations along the streams on different bedrock type

Type of the morphological adaptations of the root systems and the type of the habit corresponded to the type of the bedrock of the streams.

In granitic bedrock streams water velocity is higher and the distorted and leaning type of habit is more common in the streambed, than on calcareous bedrock streams. Also, buttress root system of the species along the banks is more frequent on the granitic bedrock streams.

On the other hand, on the calcareous bedrock streams straight habit of the trees with the horizontally expanded root system is more common. Moreover, this type of the root system occurs only in the species in the calcareous bedrock streams.

The different occurrence of the root systems and the habits of the species on different bedrock streams can be explained by the properties of the bedrock and physiographic characteristics of the streams. The calcareous bedrock is less solid and easily brakes into pieces, so the large cover of surface of the root system is necessary to anchor firmly tree species. The floor of the granitic bedrock streams is covered with the compacted rock with high water velocities and the developments of buttresses is essential for the tree species to anchor themselves in these conditions. Further studies on morphological adaptations on different bedrock streams are needed in order to conclude the correlations between each other.

V. Morphological adaptations in different microhabitats

Type and the frequency of the morphological adaptations in the species are also in accordance with the type of microhabitat.

The microhabitats with high water velocity and frequent flooding such as small emergent rocks, sides of the boulders and some areas of the streambed, supported specific set of morphological adaptations is present. Species that occupy these types of habitat have distorted (herbs, shrubs) or leaning (trees) habit. They have buttress root system (trees), expanded root that embraces the rock (shrubs), thick rhizomatous root (herbs) or trunk like root formation (ferns) in order to persist these conditions. The most obvious characteristic for these species in all life forms is that their leaves or leaflets of compound leaves are very narrow, linear to lanceolate, with the high values of leaf index. This adaptation is the most important since this type of the leaf shape is giving the least resistance when the water rushes over the species. As the running water goes over the species, the leaves (leaflets) make serpentine movements in order to resist the water current. The least resistance to the high force of the water current is made by narrow lanceolate leaves (leaflets). Similar features of the leaves (leaflets) in the similar microhabitats are noticeable in the rheophytes (van Seenis, 1981).

Microhabitats with occasional flooding such as stream banks are occupied with the species that mostly develop straight habit with stilt or horizontally expanded root system. Their leaves (leaflets) are more oblong, since they are not constantly under pressure from high water velocities. Some of the species in the young stages of growth have different leaf shape and size and they occupy different microhabitats e.g. small emergent rocks. A peculiarity of the seedling of these species that leave are very narrow and differ strongly from the leaves of the mature trees which are not exposed to the immersion (van Seenis, 1981). Van Steenis (1981) separated these species into subgroup of the rheophytes and called them paedorheophytes.

Microhabitats that were described as smooth water areas with low water velocities are occupied by the species that develop hanging and straight habit with oblong leaves (leaflets). These species are never influenced by the fast running waters, so they developed straight trunks with drooping branches.

More studies about leaf morphology and the physiology of the species in different types of microhabitats as well as their stages of the growth in the fast flowing streams are necessary in order to make exact conclusions about the correlations of the morphological adaptations and the microhabitats of the species in the fast flowing streams.

VI. Note on narrow leaves and leaf index of streambed species

The narrow leaves (leaflets) are not unique for this group of species, rather it is occurs more often within this group than in other groups. Similar morphological changes of the narrow stenophyllous leaves were found in arid and sunny environments, especially in desert and alpine habitats. Plant species in such habitats are exposed to strong irradiance and desiccation, and as the result they developed small narrow leaves (Groom and Lamont, 1997; Bragg and Westoby, 2002). In these environments the leaves with lower surface were better able to withstand and recover photosynthesis after high temperature stress (Knight and Ackerly, 2003). Moderate changes of the leaf areas, but not the leaf shape (resulting with the same value of leaf index) were noted as the light adaptation under sun and in shady areas (Rozendaal et al, 2006; Nomura et al., 2006). In comparison with the sun exposed and shady leaves, the leaves of the streambed species had a significant change in shape and size towards the narrower (Nomura et al., 2006). The change of the shape and size in the streambed species resulted in the increase of the leaf toughness, which made these species more flexible to the strong water flow (Nomura et al., 2006). This change in the shape and size and the increased toughness of the leaves of the streambed species offered the least resistance to the water rush over the plant and the leaves are harder to tear.

In this study the leaf shape, size and leaf index of the fern species *Leptochilus pedunculatus* (Hook. & Grev.) Fraser-Jenk. was compared between two types of the habitats, streambed and shady area. The leaf shape in both cases was lanceolate, with a decrease of the leaf width in the streambed species, which resulted in the significantly higher value of leaf index. The reduction of the leaf width and the increase of the value of the leaf index agree with the results of the Nomura et al. (2006), which is indicating that the narrow leaves of the these species is correlated with the streambed habitat.

PART III: COMMUNITY STUDY

I. Microclimate of the streams

The variations of other environmental factors were significantly different on both types of the bedrock streams. The small variations of the environmental factors characterized the calcareous bedrock stream, while there were higher variations on the granitic bedrock streams. The biggest difference of the daily fluctuation between these two bedrock types was in the humidity, following by water temperature and light intensity.

The daily fluctuations of the environmental factors on different bedrock streams showed similar patterns in each study site. During the day, in the morning there was an increase of the measured component followed by a decrease in the late afternoon by end of the day. The unusual fluctuation was recorded for water temperature, as on granite bedrock streams there is a distinct pattern of increase and decrease (Figure 3.2–3.9); while on calcareous bedrock streams it is less obvious. On the calcareous bedrock streams where was very small increase and decrease of the water temperature during 24 hours, which presented on the graph as almost constant temperature (Figure 3.10–3.15).

The light intensity fluctuations were very high on granitic bedrock streams with the highest values on the TC2 and LJ2. The differences in the light intensity in these two types of the bedrock were the result of the different community structure. On the granitic bedrock streams mostly there was open space with direct sunlight during the day, while on calcareous bedrock streams there are many trees, which produced dense 2-layer of canopy, which is blocking direct sun exposure.

The environment of two types of the bedrock streams is clearly different, which is specific influence on the species composition in the streams. The environment of the calcareous streams is clearly less variable in terms of water temperature, air temperature, humidity and light intensity. These small variations of the environmental factors influenced on the species composition, and it is noticeable that this type of streams is more occupied with the associated stream species, which are influenced by the stream environment. On the granitic bedrock streams the fluctuations of the environmental factors are higher and the specific species adapted to those conditions, and the streams are abundant with characteristic stream species.

II. Plant communities

Plant community composition on different bedrock type differed greatly in the species composition, with few species found on both type of the bedrock streams. The similarity analysis between the plots showed that there is a high dissimilarity between the plots on granitic and calcareous bedrock streams. This can indicate that the complex environmental factors are important in determining the species composition of the communities. The results of the CCA analysis (Figure 3.21) confirmed that the plots of the communities are highly influenced by environmental factors. Moreover, the result of this analysis suggested that some environmental factors such as water pH, clearly define plant communities. This is indicating that the niche differentiation is major factor in determination the community composition.

In comparison with the other communities in the flowing ecosystems, these communities have a low number of species. The composition of the species in these communities corresponds to the aquatic and partial terrestrial zone of the Bangwan and Tamnang streams in Pangnga province (Muadsub et al, 2009). The species that corresponded to these zones of two streams were: *Ardisia oxyphylla* Wall. ex A. DC, *Argostemma neorocalyx* Miq., *Argostemma ophiense* Maingay ex Hook.f., *Anthrophyum callifolium* Blume, *Cephalomanes javanicum* (Blume) C. Presl, *Donax cannaeformis* Rolfe, *Homalomena repens* Ridl., *Kopsia pauciflora* Hook.f. and *Saraca indica* L. Several of these species were part of aquatic zone e.g. *Homalomena repens* Ridl. and *Cephalomanes javanicum* (Blume) C. Presl while the rest of the species were grouped into terrestrial zone (Muadsub et al, 2009). In this study few species that corresponded to the aquatic zone were one of the major components of the communities on the granitic bedrock streams, while many the species of the terrestrial zones were found only along calcareous bedrock streams. It is very interesting that the species of the terrestrial zone with the granitic bedrock (Muadsub et al, 2009) in this study were found only on calcareous bedrock stream and were clearly separated by the cluster analysis into community C. The low similarity with the species of Bangwan and Tamnang streams in Pangnga province is mainly to the streams structure and their physiognomic features, as these two streams are wide with low water velocity.

Comparing to the wider flowing systems, the community composition had very little similarities with the floodplain vegetation of Trang River (Pattarakulpisutti, 2011). The only species that were in common in the streams and in the flood plain were grasses and sedges, *Eriocaulon* sp. and *Cyperus* sp. Even though the species composition was very different, similar patterns were noticed in this study and in the study of the floodplain of Trang river. In the Trang floodplain one wood land community was recognized (Pattarakulpisutti, 2011), with its structure and 2-layered tree canopy, which corresponds to the structure of the community B on granitic bedrock streams and community D on calcareous bedrock streams. On the other hand, the vegetation dominated by perennial herb in the floodplain of Trang River expressed the spatial variation (Pattarakulpisutti, 2011), while most of the species in this study grouped as the associated species represented the similar pattern. The small similarity with the floodplain of Trang River can mainly be explained by the different features of the river, as it is much wider than the streams, its position in the low land area and higher influence of the humans.

The composition of the species in community D on calcareous bedrock had low similarity of the species with the species in the emerald pool, Sra Moragote in Krabi province (Maxwell, 2009) where the limestone is the basic bedrock type e.g. *Donax cannaeformis* Rolfe, *Eurya nittida* Korth., *Ficus tinctoria* G.Forst. subsp. *gibbosa* (Blume) Corner, *Ixora javanica* DC., *Lygodium flexuosum* (L.) Sw., *Pteris vittata* L and *Saraca indica* L. All of the mentioned species, except *Ficus tinctoria* G.Forst. subsp. *gibbosa* (Blume) Corner and *Saraca indica* L., are minor components of the communities in this study. Moreover, these species were mainly found in the open areas of the streams where direct or partially direct sunlight is present. The similarity of these species in the emerald pool, Sra Moragote in Krabi province with this particular species in this study is due to the different variations of the environmental factors and the physiognomy of the emerald pool. Area in Sra Moragote in Krabi province is mostly open, especially over the stream, and few tree species are leaning towards the streambed. The species in the emerald pool are exposed to the very high values of the light intensity, such as in community A in this study, which has granitic bedrock as the main base. The low similarity between emerald pool and the study sites in this study is due to the different stream structure in comparison to the calcareous bedrock streams in this study.

III. Plant communities and the importance of environmental variables

Along the streams of peninsular Thailand four types of the plant communities were recognized by cluster analysis and similarity index: community A, B, C and D, with each community having specific set of the species. At 25% of the similarity in the Cluster analysis (Figure 3.16) these four plant communities could be separated based on the type of the stream bedrock into:

1. Plant community on the granitic bedrock streams
2. Plant community on the calcareous bedrock streams.

This clear division into two communities based on the bedrock type is supported by the CCA analysis, where the plots on the calcareous bedrock streams were clustered in the left hand side, and plots on the granite bedrock streams were spread along right hand side. This pattern indicates the existence of underlying environmental gradient between plant communities (Riis et al, 1999). The separation of the plots on the right and left hand side was mainly based on the value of pH of water (Figure 3.21), where the water pH level is result of the type of the bedrock. In the calcareous bedrock streams, calcium carbonate ($CaCO_3$) is the main component which in contact with water produces alkaline components such as bicarbonate ions (HCO_3^-). These components increase the alkalinity of water resulting in the higher values of the pH.

In this study the most important measured environmental variable was value of pH of water that distinguished the communities. Previous studies about plant communities in the low land temperate streams also indicated that alkalinity was the most important factor in the distribution of the macrophytes in the streams (Riis et al., 1999). On the other hand, in the riparian vegetation alkalinity was also important variable in distinguishing plant communities (Sagers and Lyon, 1997). On contrary, in the tropical African streams and rivers the most important variables that distinguished the communities were conductivity of water, calcium, silicon and ammonium (Swaine et al., 2006). The water chemistry has a significant impact for the aquatic plants, while for the riparian species did not have any significant impact (Sagers and Lyon, 1997).

Other factors that highly influenced the division of the plant communities were light intensity, stream deph and width, water velocty and water temperature.

The light intensity resulted as an important variable in distingusihing plant communities; they can be divided into groups with higher amount of ligth intensity and the ones with lower amount. This division was clearly shown on the granitic bedrock streams in CCA analysis (Figure 3.21), where the upper group with prefer high light intensitities and the lower with low intensities. This is reflected into the plant community as the communities defined by these plots have very low number of shared species. Similar pattern of the availability of the light intensity was noted for the Buffalo River in Arkansas, USA, where the light intensity was important variable that defined plant communities in different forests layers (Sagers and Lyon, 1997). In this study light intensity had a highest infleunce on the herbaceous community, while it had very low infleunce on the tree communities.

Stream width and stream depth also showed infleunce in determinating plant communities. As these two factors are not correlated to any other factors it is possible to state that the plant communities are influenced by the stream size, where communities on calcareous bedrock stream are in deep wider streams, and granitic A and C community rather have similar consitition of the streams, while granitic B community prefers shallow narrow streams. The clear division of the granitic communities into upper and lower group is not only influenced by the ligh intensity but the stream size. Similar patterns of community preferance of the wider or narrower streams is noted in the Danish lowland streams, where *Potamogeton* communities were mainly represented in wider and deeper streams, while *Callitriche* communities were found in shallow narrower streams (Riis et al., 2000). Even though the aquatic communities in the Danish low land streams are clearly differentiated the communities in this study, they are noticeably influenced by the similar environmental factors.

Water velocity was also one of the important environmental factors that based on the CCA analysis results (Figure 3.21) had infleunce in determinating plant communities. The number of the species in the plots of the calcareous bedrock streams was very high comparing to the plots on granitic bedrock streams. The increase of the abundance of the species in the lower velocity areas is most likely caused by an increase in plant growth: as the water velocity increases, nutrients can diffuse more easily into the plant cells (Riis and Biggs, 2003). The water velocity of the macrophyte were infleunced by the velocity of the Danish streams, where the optimum velocity was 0.4 m/s, and plant species did not develop lower than this velocity (Riis and Biggs, 2003). It is also noted by van Steenis that rheophytic species could sustain themselves in fast flowing streams, such as 0.1–0.4 m/s (van Steenis, 1981). In this study some of the species, described as characteristic stream species, showed the preferance towards the faster flowing streams. As mentioned in the part I of this chapter these species are more abundant and higher in number on the granitic streams than on the calcareous bedrock streams. Further investigations about these species and infleunce of the water velocity on them are necessary to make more exact conclusions.

The results of the CCA analysis showed that the water temperature also influenced the plant communities. This result was unexpected and peculiar, since the water temperature of the tropical region does not show high fluctuations during the seasons as the waters in temperate regions. In the temperate regions, during the cold periods water plants stop growing and go to the dormancy period. In the tropical region there are small fluctuations of the water temperature during the season and the plants are able to grow all year round. Because of the high mean water temperature, the oxygen reserves at saturation are substantially lower for tropical waters than for temperate waters (Lewis, in Dudgeon, 2007). The main significance of the temperature of the flowing waters is through its effect on metabolisma and the capacity of the water to hold dissolved oxygen (Lewis, in Dudgeon, 2007). For the low land tropical waters, the range of the aquatic metabolism is between 70 and 93, while the oxygen concentration is in the range 7.6–8.1 mg L^{-1}, which is smallest range for the tropical waters (Lewis, in Dudgeon, 2007). This small range of the oxygen concentration provides much smaller oxygen reserves to respiratory losses at night or under other conditions when respiration exceeds photosnthesis.

IV. Variations within the community in the calcareous bedrock streams

Variation between the plots of the D plant community in the calcareous bedrock streams was very low. Based on the Bray-Curtis similarity index between these plots the similarity was always 20s resulting in low variation within the plots (Table 3.7). The tree species found in almost all the plots include species as *Duabanga grandiflora* Walp., *Elaeocarpus grandiflorus* Sm., *Neonauclea* sp.1, *Radermachera glandulosa* Miq., *Saraca indica* L. and *Syzygium* sp.1. The composition of the ground floor did not varied a lot between the plots and the species composition in all of the plots was almost the same e.g. *Begonia aliciae* C.E.C.Fisch., *Begonia integrifolia* Dalzell, *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman, *Cyclosorus menisciicarpus* (Blume) Holttum, *Epithema* sp., *Heterogonium pinnatum* (Copel.) Holttum, *Homalomena repens* Ridl, *Nephrolepis undulata* (Afzel.) J.Sm. etc.

This was confirmed by the CCA analysis with plot ordination (Figure 3.21), where most of the plots were clustered on the left hand side. The clumping of the species in the plots on the left hand side of the CCA analysis can be explained by their preference of the low fluctuations of the environmental factors such as deep shady areas with the low light intensity and almost constant water temperature; or their specific adaptation and restriction on the calcareous bedrock.

V. Variations within communities in the granitic bedrock streams

The variation within granitic bedrock community was clearly divided into three separate plant communities, A, B and C. The similarity between the plots between these three communities based on Bray-Curtis similarity index was very low, 0.17 (Table 3.7), with few in common species e.g. *Cephalomanes javanicum* (Blume) C.Presl, *Cyathea podophylla* (Hook.) Copel., *Globba pendula* Roxb., *Ixora javanica* DC., *Homalomena repens* Ridl., *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f and *Ophiorrhiza communis* Ridl. On the other hand the similarity between the plots within A community was from 0.30 to 0.80 (Table 3.7), and between plots within B community was 0.80, with 15 to 17 shared species (Table 3.7). The species that were very abundant in the community A throughout the plots e.g. *Ficus ischnopoda* Miq., *Globba pendula* Roxb., *Homalomena repens* Ridl., *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f, *Pandanus* sp., *Pogonatherum paniceum* (Lam.) Hack. and *Selliguea heterocarpa* Blume. The species such as *Ficus ischnopoda* Miq., *Neonauclea pallida* (Reinw. ex Havil.) Bakh.f, and *Homalomena repens* Ridl. were dominant species of this community, while the rest of the species were minor components. The species that were common throughout the community B include *Antrophyum callifolium* Blume, *Bolbitis appendiculata* (Willd.) K.Iwats., *Bolbitis heteroclita* (Presl) Ching ex.C.Chr, *Cephalomanes javanicum* (Blume) C.Presl, *Donax canniformis* (G. Forst.) K. Schum., *Ficus* sp.1, *Ficus tinctoria* G.Forst. subsp. *gibbosa* (Blume) Corner, *Homalomena repens* Ridl., *Tectaria semipinnata* (Roxb.) C.V.Morton and *Trigonostemon aurantiacus* (Kurz ex Teijsm. & Binn.) Boerl. The tree species such as *Ficus* sp.1 and *Ficus tinctoria* G.Forst. subsp. *gibbosa* (Blume) Corner were dominant components of the community, while the rest of the species are minor components.

The C community was separated from the A community as their similarity index was not above 0.3, with 6 to 9 shared species (Table 3.7). Even though the plots had similar variables of environmental factors and were together separated in the CCA analysis (Figure 3.21), the similarity of the species composition was not high enough for clumping them into one community. The differences between community C and B was very clear, as the plots in CCA analysis (Figure 3.21) were separated into upper and lower part and their number of shared species varied from 4–5 (Table 3.7).

Three communities in the granitic bedrock streams were confirmed with the CCA analysis where two types of the communities preferred different set of environmental factors that resulted in the plots separation to the upper and lower part. The species on the right hand side of the ordination were more spread along the axis, which can be interpreted by two possible explanations: species do not have any specific preference towards the fluctuations of the environmental factors, they can tolerate high variation and fluctuations of the selected factors or they are not bedrock specific. The second explanation for the species distribution along the right hand side of the ordination is more likely, since some of these species are not restricted to the granitic bedrock and could be found on the other types of the bedrock.

On the other hand, the third explanation for the spread distribution of the species along the ordination of the Axis 2 is that, other factors that were not included in the study had high influence on the species composition and the distribution. The factors that were not included in the study, but might have influence on the species composition are geological history of the mountain range, phytogeographical affinities of the species towards different phytogeographical zones, physiographic factors and similar geomorphological factors. The separation of the granitc community into three communities A, B and C can be interpreted as the influence of these factors.

CHAPTER 5

CONCLUSION AND FURTHER STUDIES

This study gave an overview of the floristic, morphological and community study along the streams on different bedrock type in Peninsular Thailand. The observations showed the pattern of the species richness on granitic and calcareous bedrock streams, as well as the diversity and the structure of the plant communities. Also, the morphological adaptations of the characteristic species of the streams were described and illustrated in order to get better understanding of these species. On the other hand, environmental factors that shape the microclimate of the streams as well as the physiognomic factors of the streams were collected, so the correlation of the plant communities and these factors has been drawn. The results showed that stream communities are highly correlated with the type of the bedrock as well as the environment of the each stream. In order to have better understanding of these communities, further studies and analysis of their structure and the composition as well as their correlations with other factors is necessary.

This study raised many questions about the plants in the streams, such as their morphological adaptations, their relationship with the microhabitats of the species, and the differences between adaptations within proposed plant groups. Also, further studies on morphological and anatomical adaptations of these species are needed in order to explain how these species are able to withstand harsh stream environment. On the other hand, the further studies of the relationship between the species and between the proposed species are necessary, hence the better understanding and the groupings of these species.

Conservation aspects

The vegetation along the streams is very unique not only in the terms of the plant diversity and genetic resources, but also these species adapted to a very peculiar environment. The plant species in the stream ecosystem provide microhabitats with slower water velocity and accumulation of the sand and silt, so the aquatic fauna can survive in these flowing systems.

Most of the selected study sites were included in the protected areas or national parks, or well hidden deep in the forest, but many other streams and the waterfalls are very well known touristic places. During this study, several areas of the streams had been destroyed due to the human activities as the picnic areas or for swimming. These flowing systems are very unique and the better conservation and protection of such areas is necessary.

COLOR PLATES

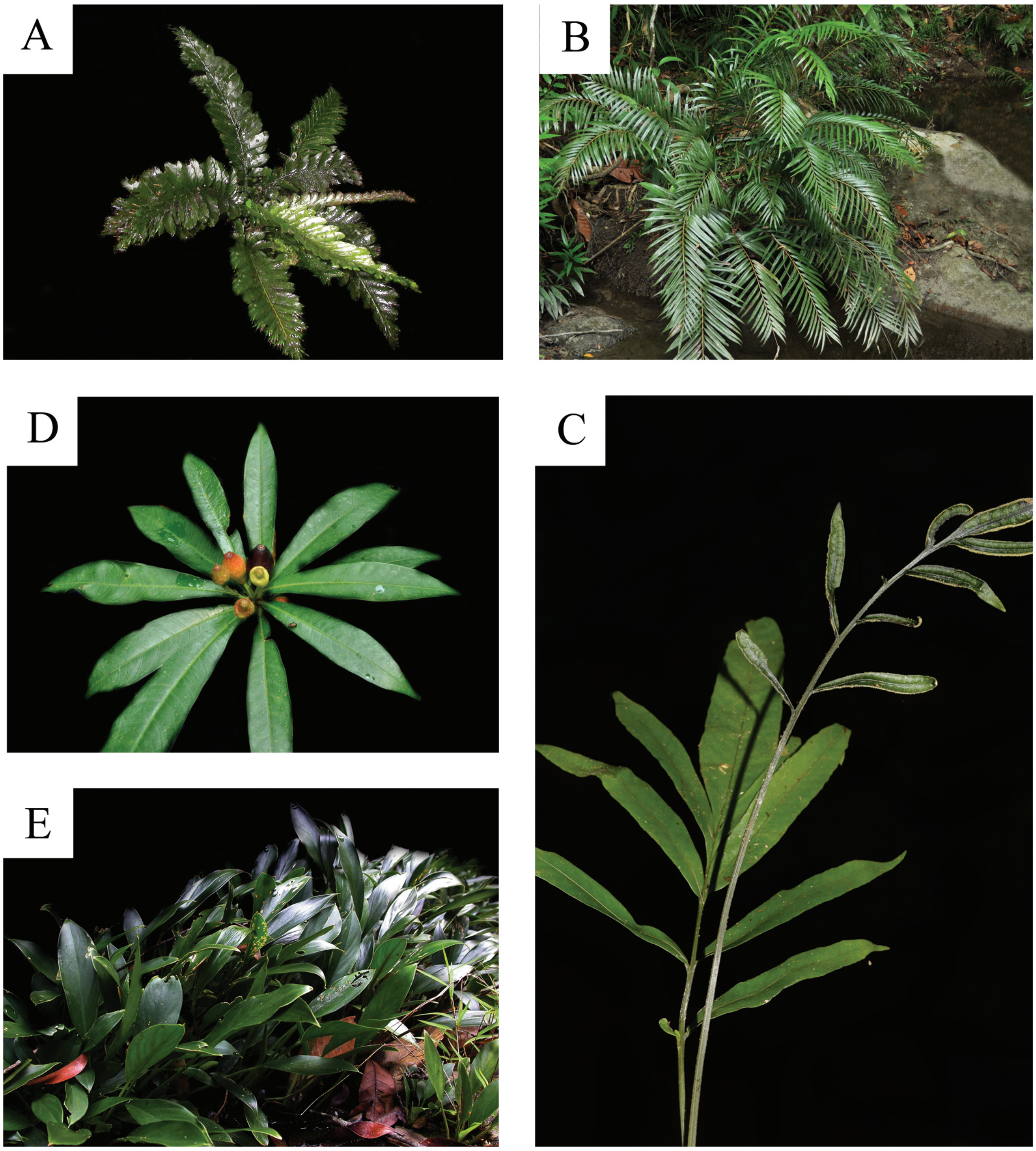


Plate 1. Streambed species: A. *Cephalomanes javanicum* (Blume) C.Presl; B. *Osmunda javanica* Blume; C. *Bolbitis virens* (Wall. ex Hook. & Grev.) Schott var. *compacta* Hennipman; D. *Ficus ischnopoda* Miq.; E. *Homalomena repens* Ridl.

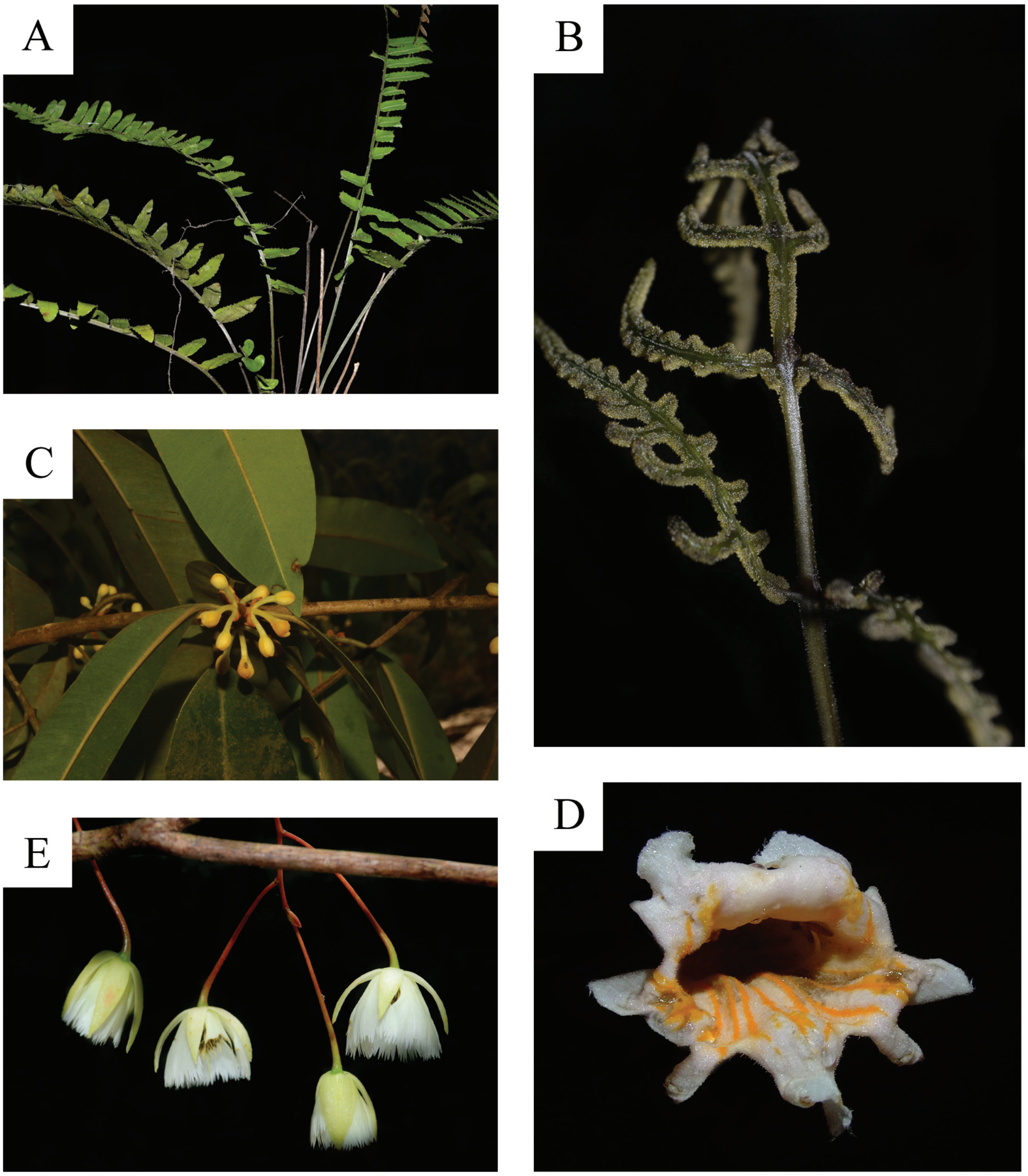


Plate 2. Terrestrial stream species: A. *Bolbitis appencidulata* (Wild.) K.Iwats.; B. *Heterogonium pinnatum* (Copel.) Holttum.; C. *Calophyllum ripicola* Ridl.; D. *Radermachera glandulosa* (Blume); E. *Elaeocarpus grandiflorus* Sm.

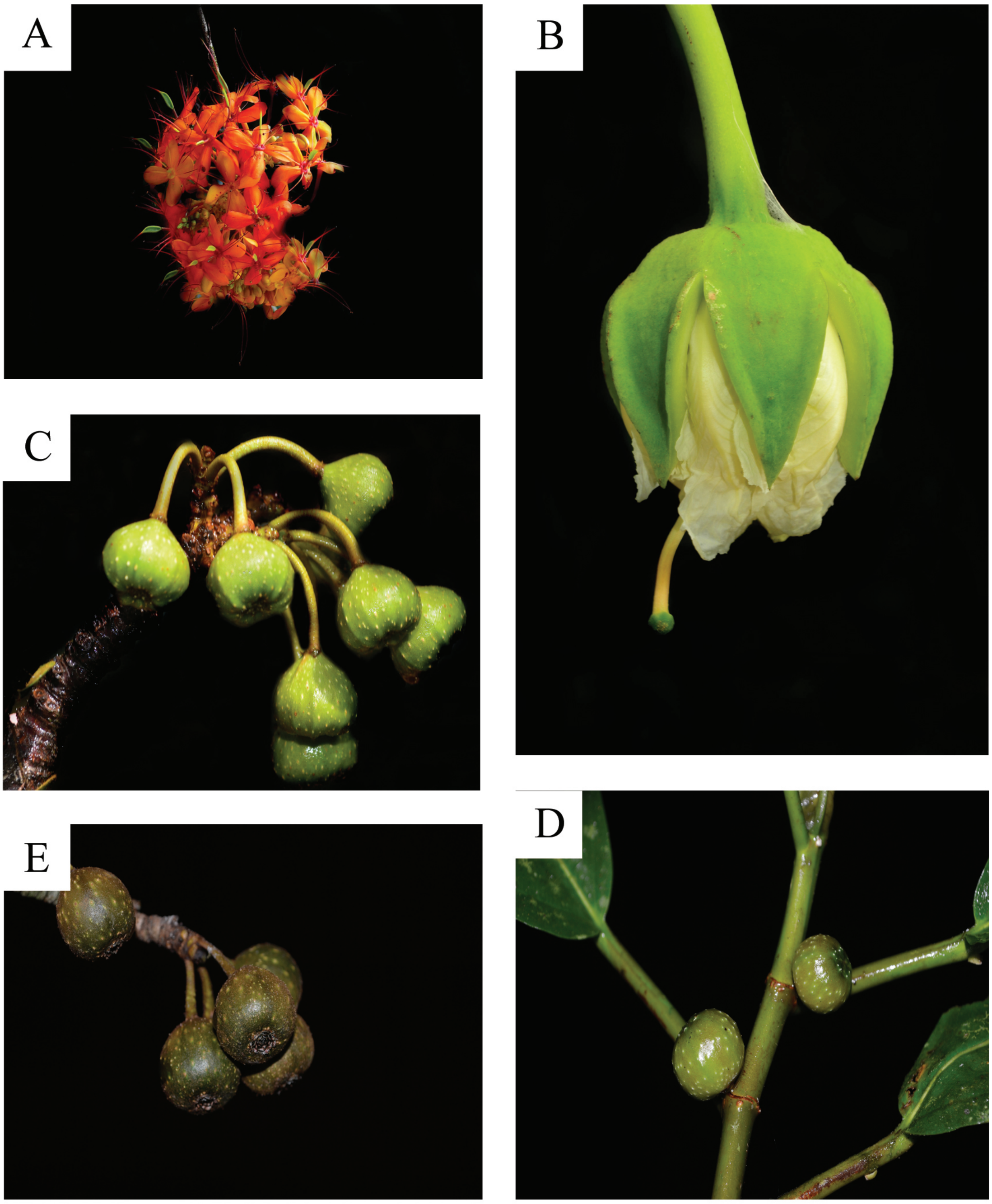


Plate 3. Terrestrial stream species: A. *Saraca indica* L.; B. *Daubanga grandiflora* (Roxb. ex DC.) Walp.; C. *Ficus auriculata* Lour.; D. *Ficus tinctoria* G.Forst. subsp. *gibbosa* (Blume) Corner.; E. *Ficus* sp.1.

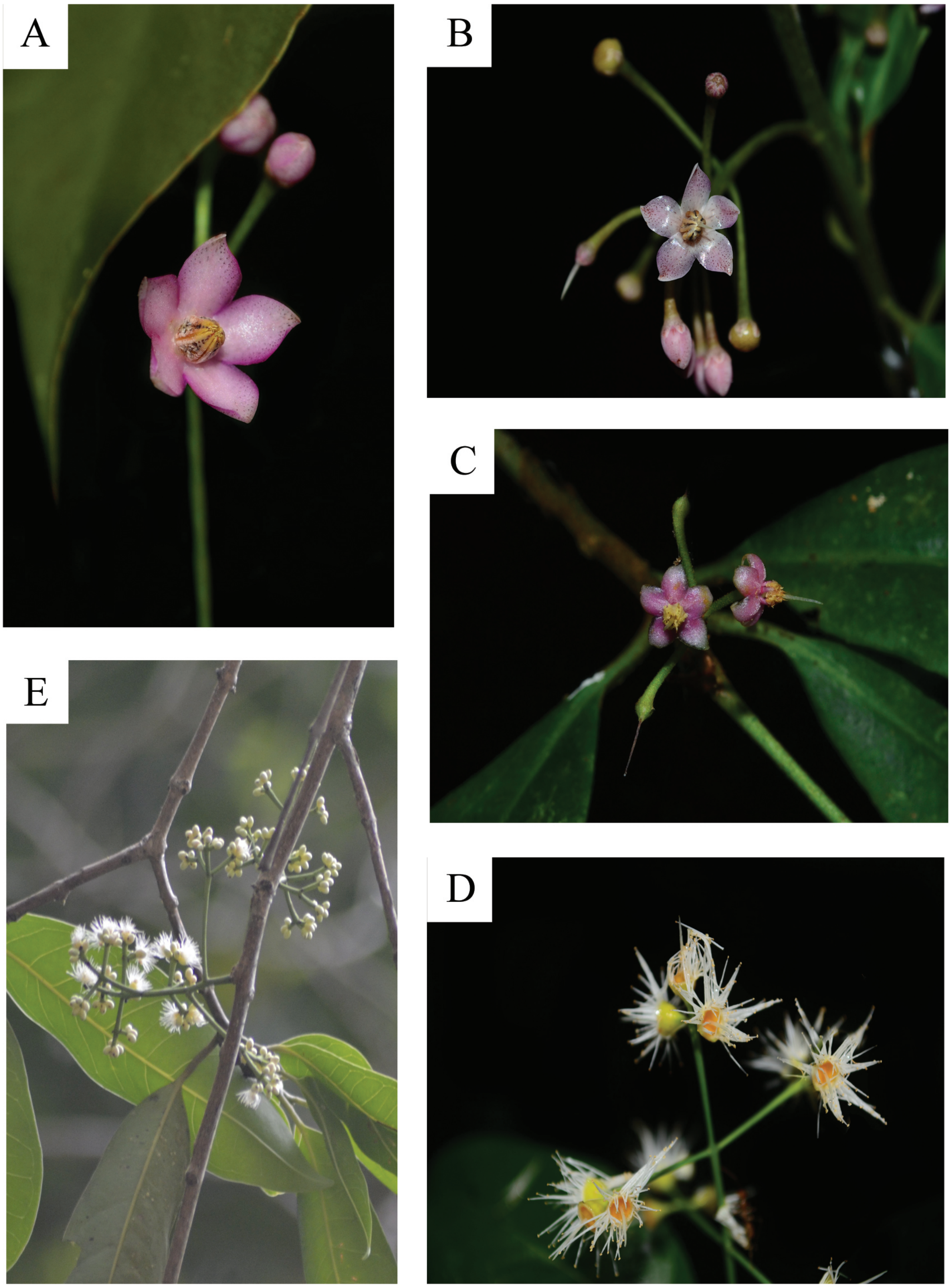


Plate 4. Terrestrial stream species: A. *Ardisia oxyphylla* Wall. & A.DC; B. *Ardisia fulva* King & Gamble; C. *Syzygium nervosum* DC.; D. *Syzygium* sp.1.

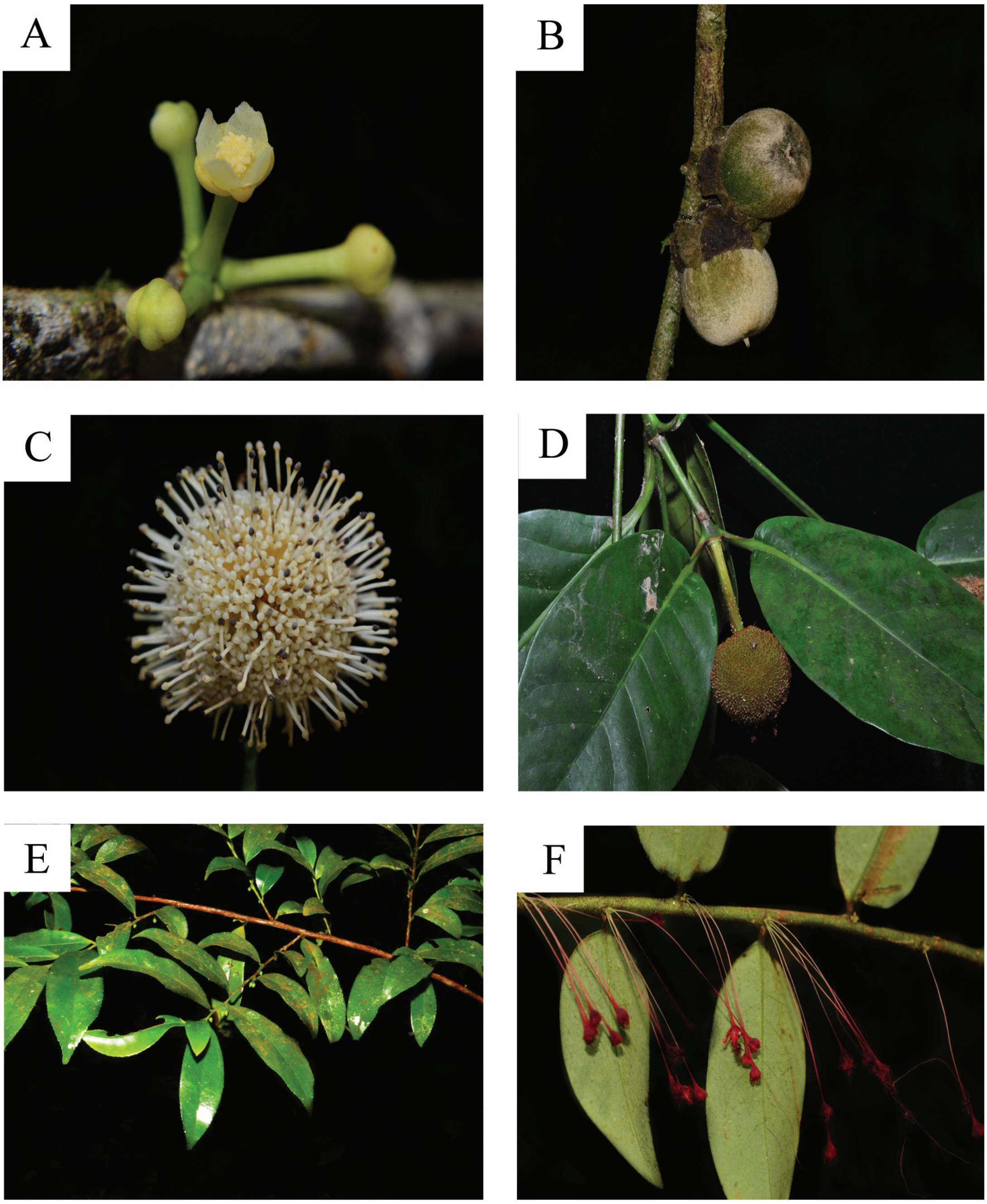


Plate 5. Terrestrial stream species: A. *Garcinia* sp.; B. *Diospyros* sp.; C. *Neonaucle pallida* (Reinw. ex Havil.) Bakh.f; D. *Neonauclea* sp.1.; E. *Eurya nitida* Korth; F. *Phyllanthus gracilipes* (Miq.) Müll. Arg.

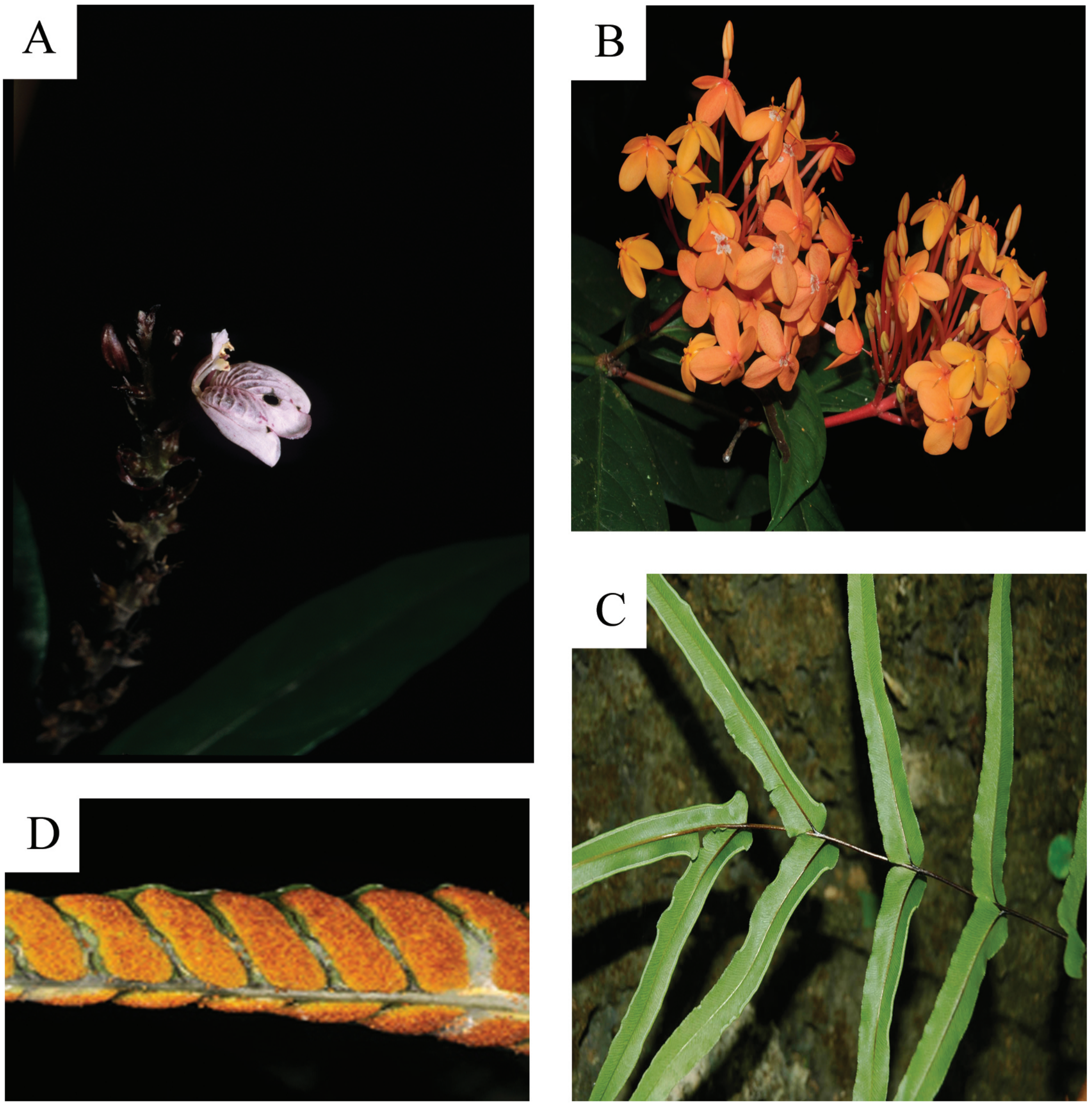


Plate 6. Flexible stream species: A. *Justicia gendarussa* Burm.f.; B. *Ixora javanica* (Blume) DC.; C. *Pteris vittata* L.; D. *Leptochilus pedunculatus* (Hook. & Grev.) Fraser-Jenk.

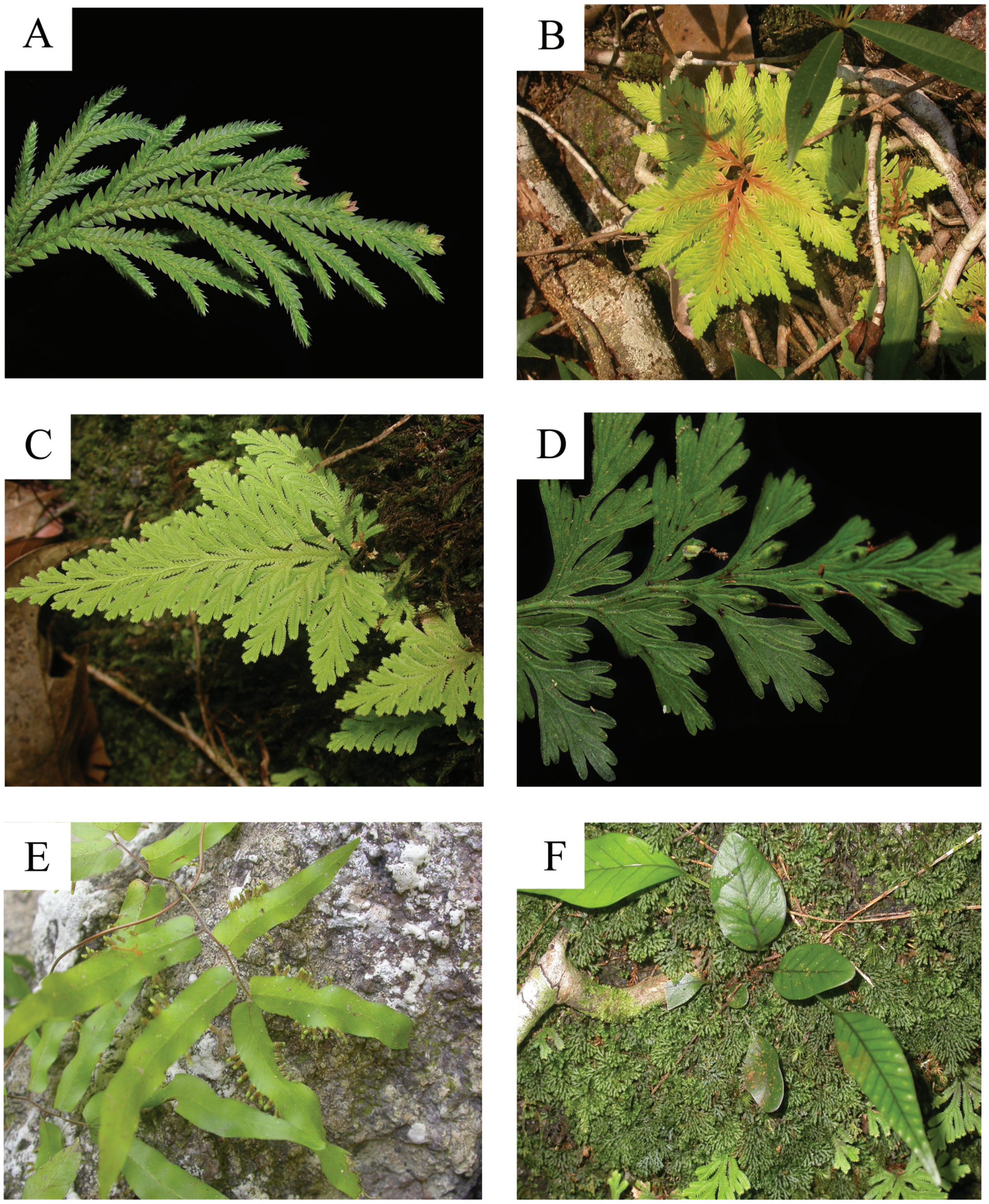


Plate 7. Associated stream species: A. *Selagnella siamensis* Hieron; B. *Selaginella roxburghii* (Hook. Grev.) Spring; C. *Sellaginella inaequilifolia* (Hook. Grev.) Spring; D. *Abrodictyum idoneum* (C.V.Morton) Ebihara K.Iwats; E. *Lygodium flexuosum* (L.) Sw.; F. *Selliguea heterocarpa* Blume.

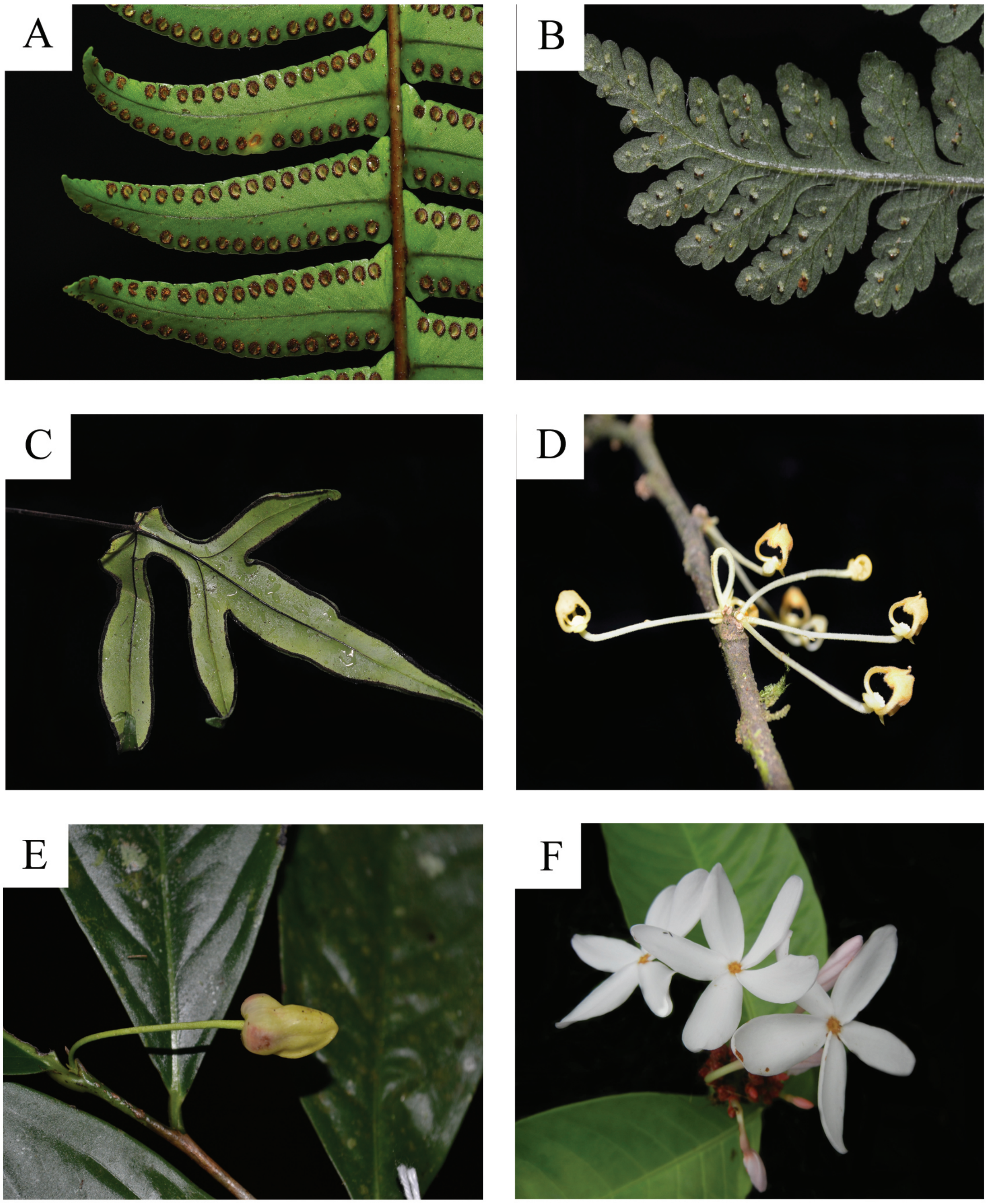


Plate 8. Associated stream species: A. *Nephrolepis undata* (Afzel.) J.Sm.; B. *Tectaria manilensis* (C.Presl) Holttum.; C. *Doryopteris ludens* (Wall.ex Hook.) J.Sm.; D. *Pseuduvaria reticulata* (Blume) Miq.; E. *Phaenthus* sp.; F. *Kopsia pauciflora* Hook.f.

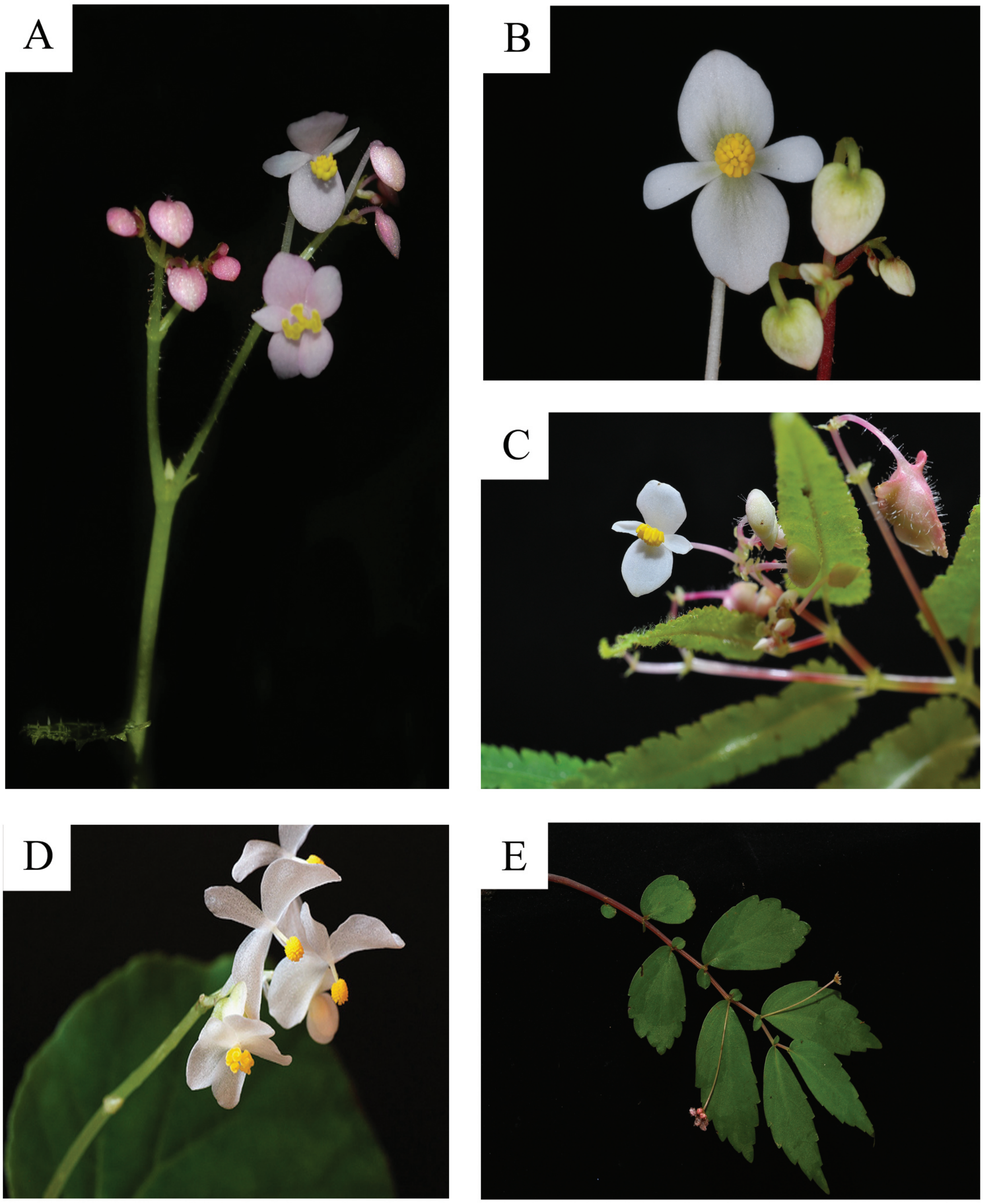


Plate 9. Associated stream species: A. *Begonia aliciae* C.F.C.Fisch.; B. *Begonia saxifragifolia* Craib; C. *Begonia pteridiformis* Phutthai; D. *Begonia integrifolia* Dalzell; E. *Elatostema* sp.

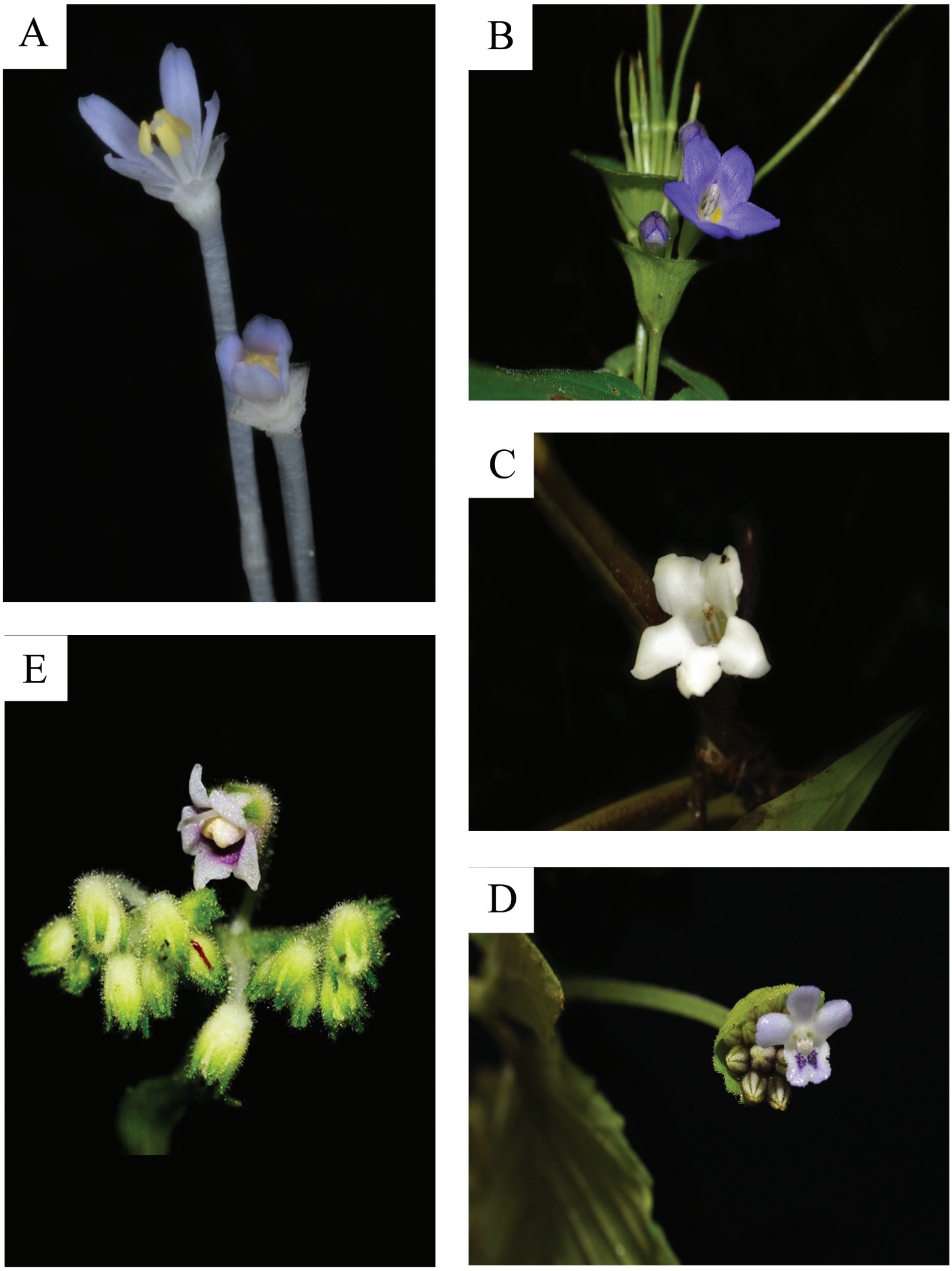


Plate 10. Associated stream species: A. *Exacum* sp.; B. *Chirita* sp.; C. *Cyrtandra pendula* Blume; D. *Epithema* sp.; E. *Kaisupeea orthocarpa* B.L.Burtt.

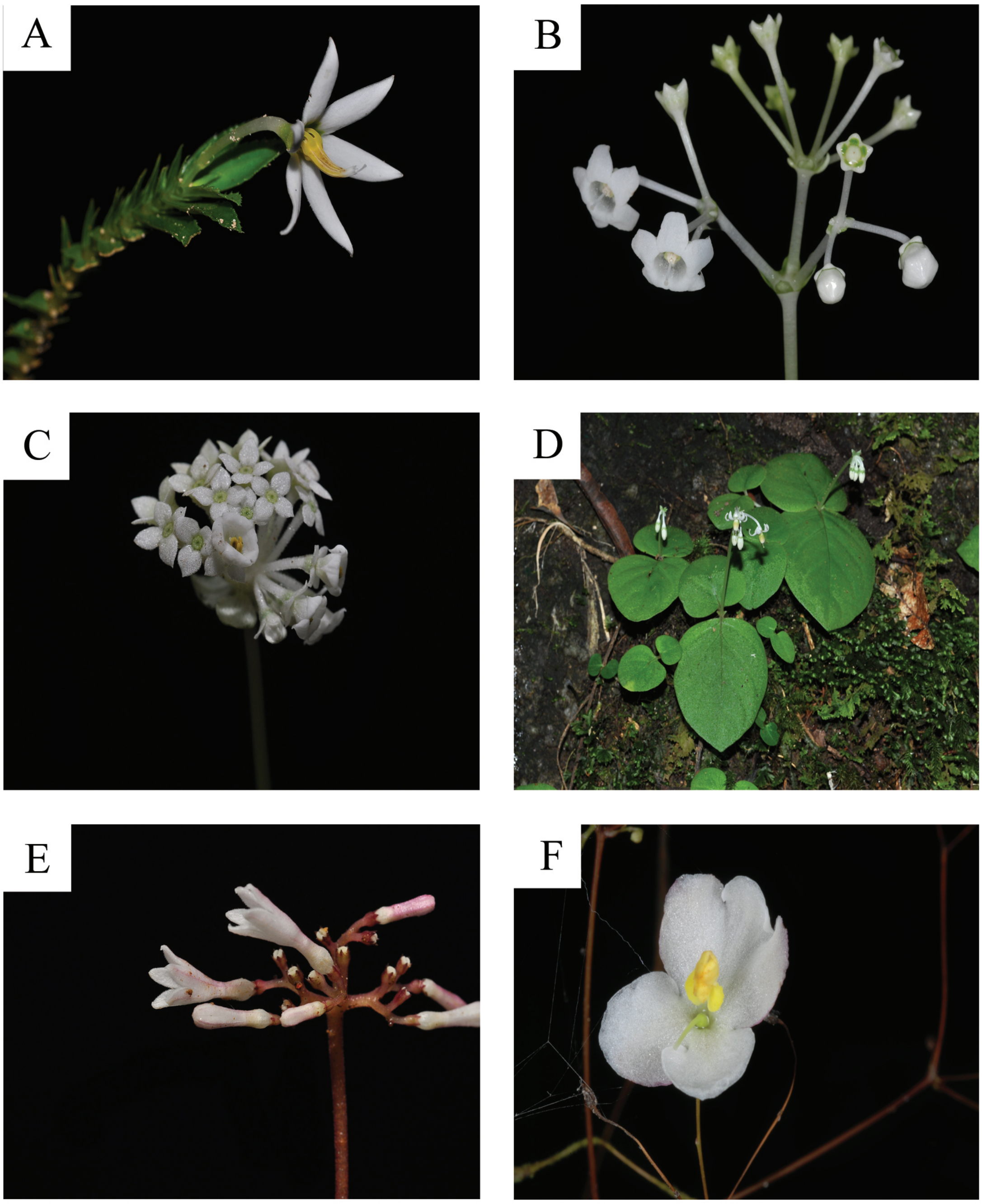


Plate 11. Associated stream species: A. *Argostemma condensum* Craib; B. *Argostemma lobulatum* Craib var. *variabile* Sridith; C. *Argostemma neurocalyx* Miq.; D. *Argostemma pictum* Wall.; E. *Ophiorrhiza communis* Ridl.; F. *Paraboea gracillima* Kiew.

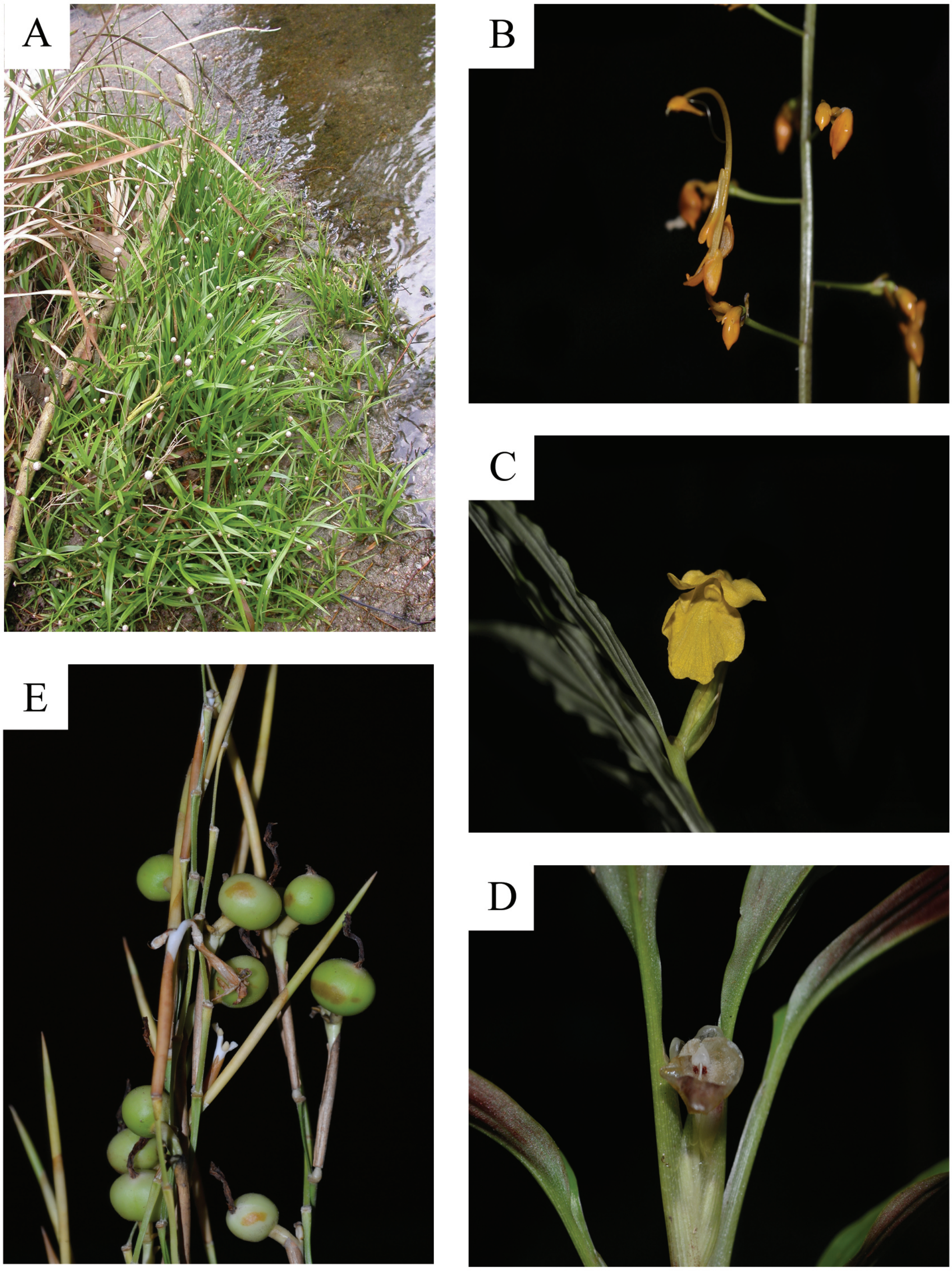


Plate 12. Associated stream species: A. *Eriocaulon* sp.; B. *Globba pendula* Roxb.; C. *Caulokaempferia saksuwaniae* K.Larsen; . B*oesenbergia* sp.; E. *Donax canniformis* (G. Forst.) K. Schum.

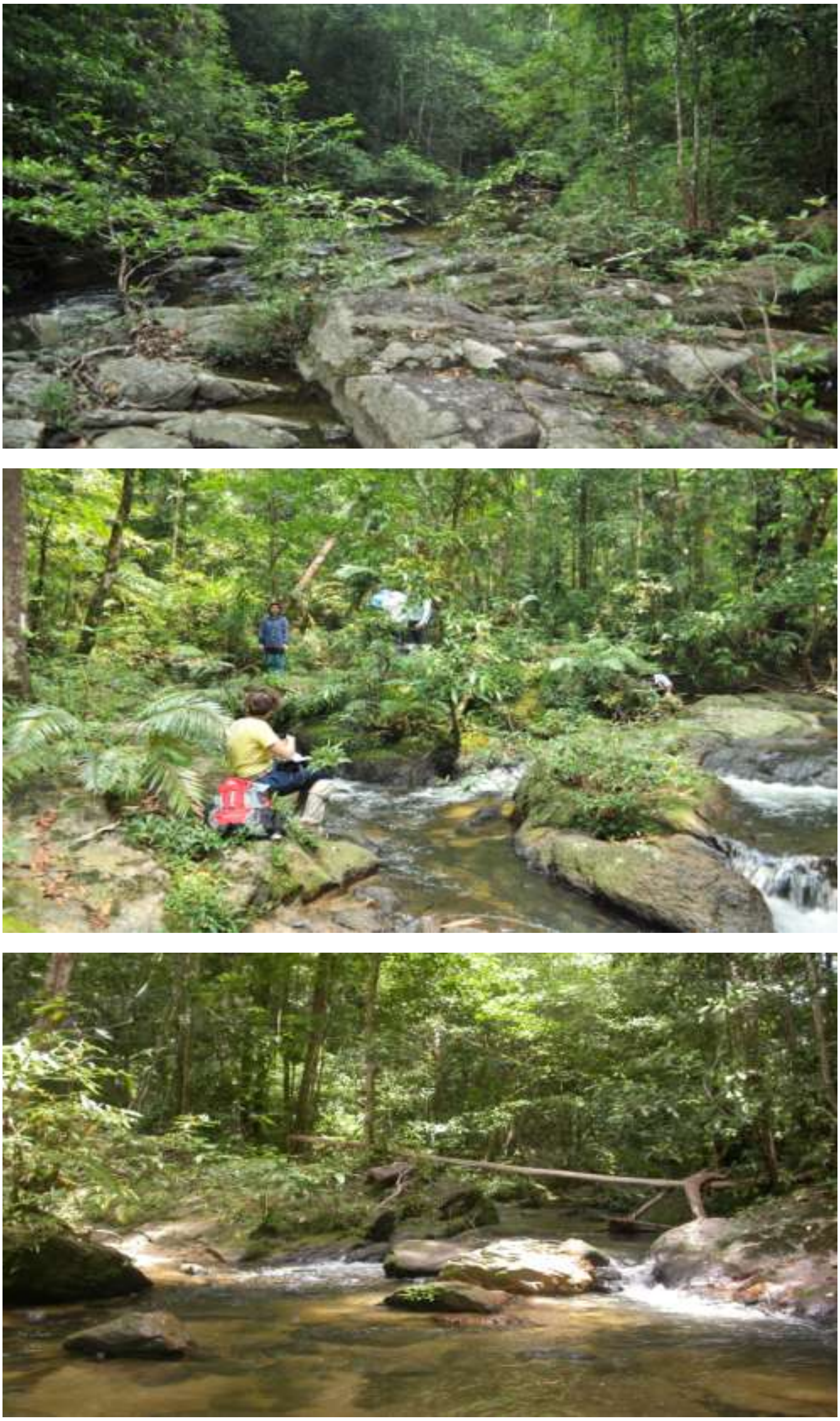


Plate 13. Structure of the streams in the community A.

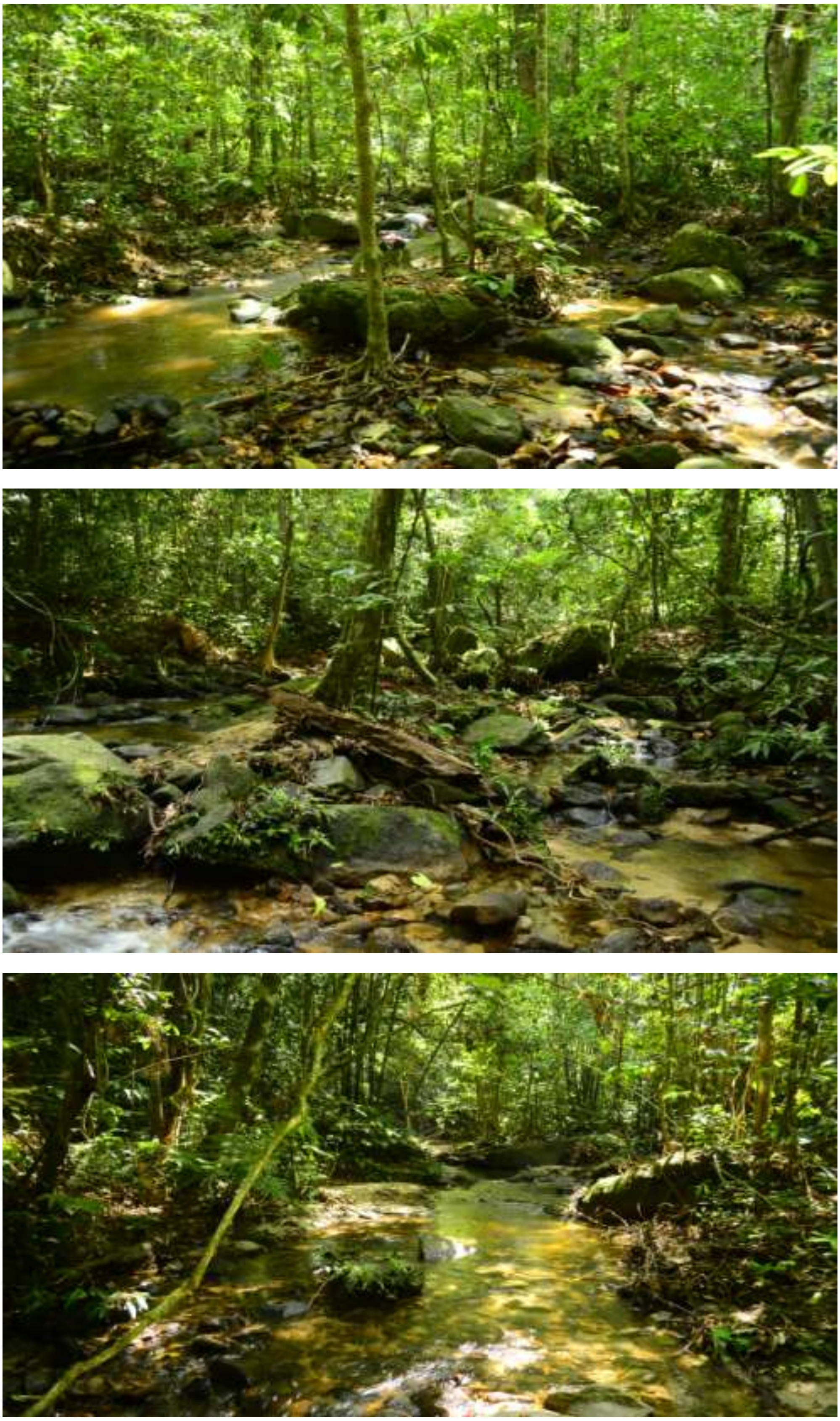


Plate 14. Structure of the streams in the community B.

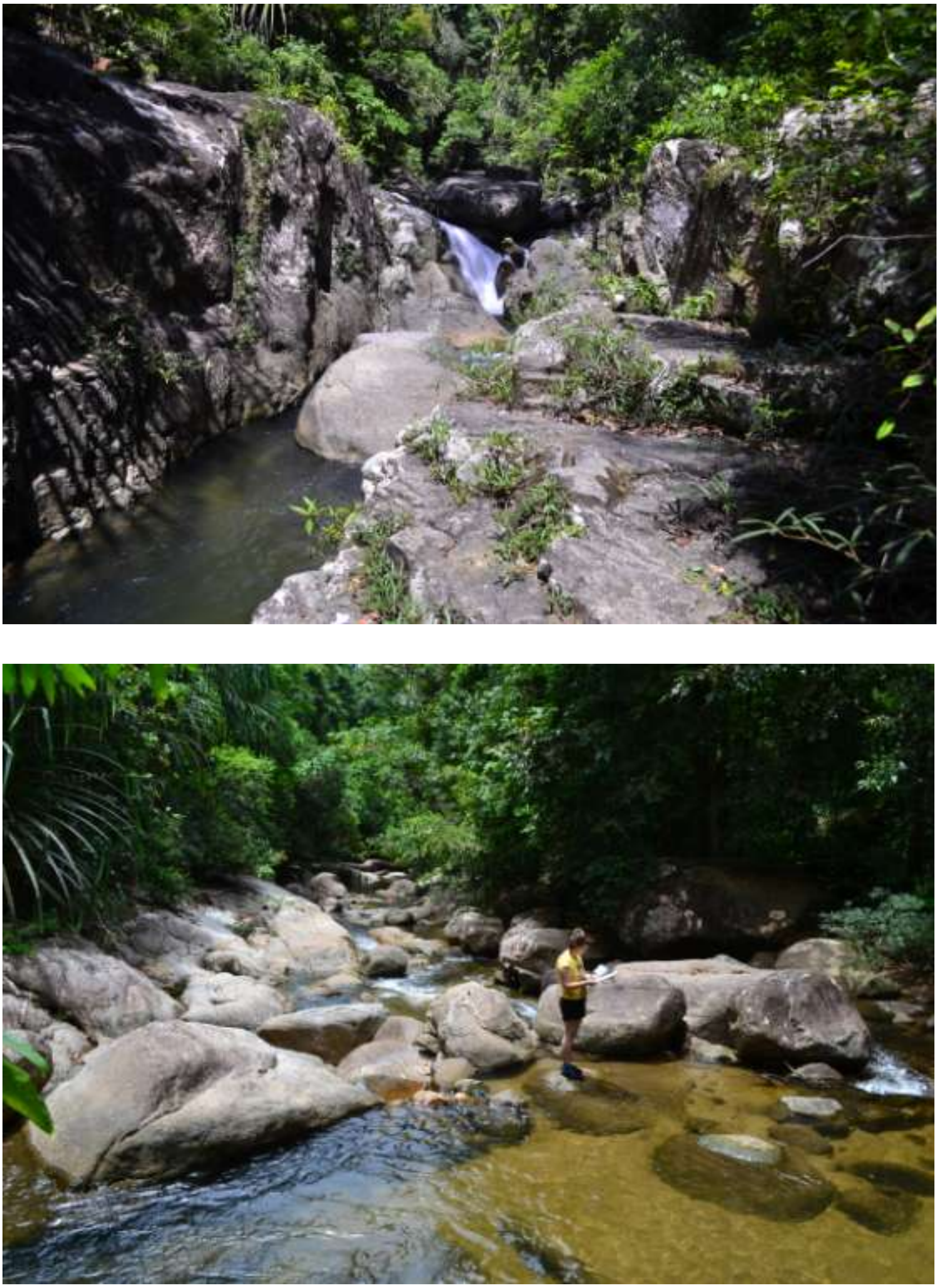


Plate 15. Structure of the streams in the community C.

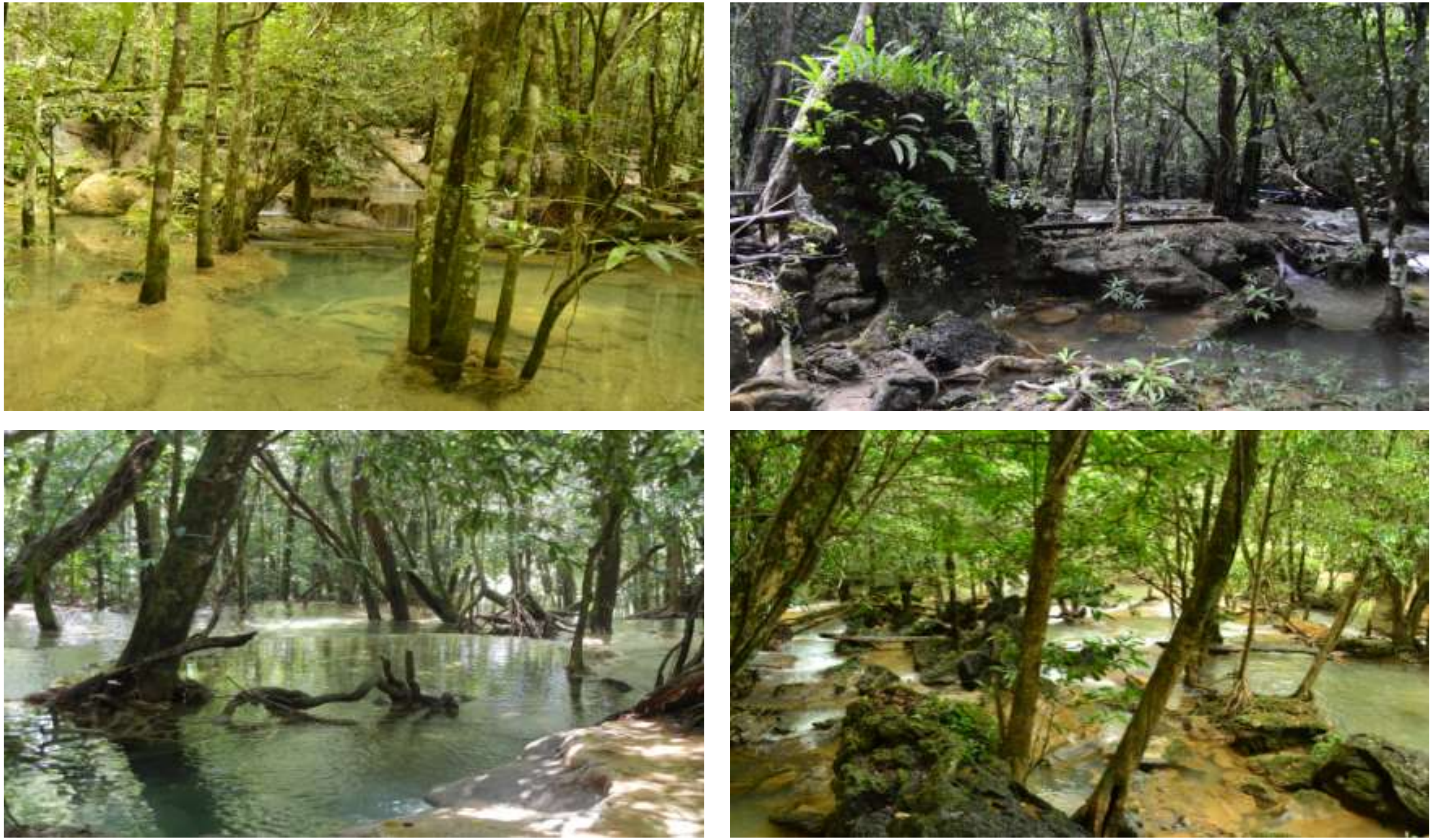


Plate 16. Structure of the streams in the community D.

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