ความหลากหลายและความชุกชุมของผีเสื้อกลางวันบริเวณน้ำตก ของพื้นที่มรดกโลก ดงพญาเย็น-เขาใหญ่

นางสาวสุกัญญา ลาภกระโทก

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาชีววิทยาสิ่งแวดล้อม
มหาวิทยาลัยเทคโนโลยีสุรนารี
ปีการศึกษา 2558

BUTTERFLY DIVERSITY AND ABUNDANCE IN WATERFALL AREAS OF DONG PHAYAYEN-KHAO YAI FOREST COMPLEX WORLD HERITAGE

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Environmental Biology

Suranaree University of Technology

Academic Year 2015

สุกัญญา ลาภกระโทก : ความหลากหลายและความชุกชุมของผีเสื้อกลางวันบริเวณน้ำตกของพื้นที่มรดกโลกดงพญาเย็น-เขาใหญ่ (BUTTERFLY DIVERSITY AND ABUNDANCE IN WATERFALL AREAS OF DONG PHAYAYEN-KHAO YAI FOREST COMPLEX WORLD HERITAGE) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.พงศ์เทพ สุวรรณวารี, 131 หน้า.

ความหลากหลายของผีเสื้อสามารถใช้เป็นดัชนีวัดคุณภาพของระบบนิเวศบกได้อย่างดี การศึกษานี้มีวัตถุประสงค์เพื่อเปรียบเทียบความหลากหลายของผีเสื้อกลางวันบริเวณน้ำตก 6 แห่ง ในผืนป่ามรดกโลก ดงพญาเย็น-เขาใหญ่ โดยการเดินสำรวจตามเส้นทางศึกษาธรรมชาติความยาว 1 กิโลเมตร ของแต่ละน้ำตก 2 ครั้ง ในตอนเช้าและตอนบ่าย เป็นเวลาทั้งหมด 6 ชั่วโมง ร่วมกับการใช้กับดัก เดือนละ 1 ครั้ง ตั้งแต่เดือนมิถุนายน พ.ศ. 2552 ถึงเดือนธันวาคม พ.ศ. 2553 พบผีเสื้อกลางวันทั้งหมด 306 ชนิด (37,584 ตัว) ความหลากหลายของผีเสื้อกลางวันมีความแตกต่างอย่างมีนัยสำคัญทางสถิติ ($p<0.01$) ในแต่ละน้ำตก น้ำตกที่พบผีเสื้อกลางวันมากที่สุด คือ น้ำตกปางสีดา (244 ชนิด) รองลงมา คือ น้ำตกเหวสุวัต (201 ชนิด) เหวนรก (195 ชนิด) สาริกา (193 ชนิด) ห้วยใหญ่ (169 ชนิด) และวังม่วง (139 ชนิด) โดยผีเสื้อกลางวันที่พบมากที่สุด คือ ผีเสื้อเฉรยอดไม้ (1,374 ตัว) ผีเสื้อเฉรธรรมดา (1,207 ตัว) ผีเสื้อตาลพุ่มสามจุดเรียง (1,172 ตัว) ผีเสื้อหนอนพุทราธรรมดา (1,156 ตัว) และผีเสื้อตาลพุ่มสี่จุดเรียง (1,107 ตัว) เวลาในการสำรวจมีผลต่อความหลากหลายของผีเสื้อกลางวัน โดยจำนวนชนิดและจำนวนตัวของผีเสื้อกลางวันในช่วงเช้ามีค่ามากกว่าช่วงบ่ายอย่างมีนัยสำคัญทางสถิติ ($p<0.01$) ในทำนองเดียวกันจำนวนชนิดผีเสื้อกลางวันมีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p<0.01$) ในแต่ละเดือนที่สำรวจ โดยเดือนที่พบชนิดและปริมาณผีเสื้อมากที่สุดคือ เดือนพฤษภาคม พ.ศ. 2553 แต่พบน้อยที่สุดในเดือนสิงหาคม พ.ศ. 2553 เมื่อศึกษาความสัมพันธ์ของปัจจัยทางกายภาพกับผีเสื้อกลางวัน พบว่า อุณหภูมิ ความชื้นสัมพัทธ์ และความสูงจากระดับน้ำทะเล มีความสัมพันธ์กับจำนวนชนิดและจำนวนตัวของผีเสื้ออย่างมีนัยสำคัญทางสถิติ ($p<0.01$) โดยอุณหภูมิมีความสัมพันธ์ทางลบ ในขณะที่ความชื้นสัมพัทธ์และความสูงจากระดับน้ำทะเลมีความสัมพันธ์ในทางบวก

ส่วนการทดสอบอาหารที่ใช้สำหรับดึงดูดผีเสื้อกลางวันในช่วงเดือนพฤษภาคมถึงเดือนตุลาคม พ.ศ. 2553 ที่น้ำตกปางสีดา พบผีเสื้อกลางวันทั้งหมด 79 ชนิด (3,038 ตัว) โดยสับปะรดผสมปลาร้าเป็นอาหารที่ผีเสื้อชอบมากที่สุด (69 ชนิด) รองลงมา คือ น้ำปลา (49 ชนิด) ปลาร้า

(46 ชนิด) สับปะรด (35 ชนิด) กล้วย (26 ชนิด) มะละกอ (17 ชนิด) แตงโม (11 ชนิด) และเบียร์ (8 ชนิด) ตามลำดับ

สาขาวิชาชีววิทยา ลายมือชื่อนักศึกษา_____

ปีการศึกษา 2558 ลายมือชื่ออาจารย์ที่ปรึกษา_____

SUKANYA LAPKRATOK : BUTTERFLY DIVERSITY AND ABUNDANCE IN WATERFALL AREAS OF DONG PHAYAYEN-KHAO YAI FOREST COMPLEX WORLD HERITAGE. THESIS ADVISOR : ASST. PROF. PONGTHEP SUWANWAREE, Ph.D. 131 PP.

DIVERSITY/BUTTERFLY /DONG PHAYAYEN-KHAO YAI/WATERFALL/ LEPIDOPTERA

Butterfly diversity is a good indicator for terrestrial ecosystems. The objective of this study was to compare diversity of butterflies among 6 waterfalls in Dong Phayayen-Kkao Yai Forest Complex World Heritage. Butterflies were recorded by transect walk and bait trap methods. The 1-km sections of natural trails of each waterfall were walked twice, in the morning and the afternoon, for a total of six hours, once a month from June 2009 to December 2010. A total of 306 butterfly species (37,584 individuals) were found in this study. Butterfly species and individual significantly differed among waterfalls ($p<0.01$). Pang Sida waterfall had the highest butterfly diversity (244 species), followed by Haew Suwat (201 species), Haew Narok (195 species), Sarika (193 species), Huai Yai (169 species) and Wang Muang (139 species) waterfalls, respectively. The most abundant butterflies were *Gandaca harina* (1,374 individuals), followed by *Eurema hecabe* (1,207 individuals), *Mycalesis perseus* (1,172 individuals), *Castalius rosimon* (1,156 individuals), and *Mycalesis mineus* (1,107 individuals), respectively. Additionally, the observation times affected butterfly diversity greatly. Morning observation had significantly more numbers of

butterfly species and individual than those in the afternoon ($p<0.01$). Also, butterfly species significantly varied by month ($p<0.01$). May 2010 was the richest month in term of species diversity, while September 2010 was the lowest. For the relationships between physical factors and butterfly diversity, the number of butterfly species and individual were significantly negative correlated with temperature but positive correlated with relative humidity and elevation ($p<0.01$).

For food preference experiment, after 6 months of sampling from May to October 2010 at Pang Sida waterfall, a total of 79 butterfly species (3,038 individuals) were bait trapped. Fermented fish mixed with fermented pineapple was the most attractive food for butterflies (69 species), followed by fish sauce (49 species), fermented fish (46 species), pineapple (35 species), banana (26 species), papaya (17 species), watermelon (11 species) and beer (8 species), respectively.

School of Biology Student's Signature_____

Academic Year 2015 Advisor's Signature_____

ACKNOWLEDGEMENTS

I am very grateful to Asst. Prof. Dr. Pongthep Suwanwaree, my thesis advisor who actively help me throughout the period of my study. I thank Assoc. Prof. Dr. Nooduan Muangsan, Assoc. Prof. Dr. Nantasak Pinkaew, Dr. Rut Morakote, and Mr. Taksin Artchawakom, my thesis committee who advised me how to complete this thesis.

I also would like to thank all of park rangers at Khao Yai National Park, Pang Sida National Park and Tap Lan National Park for kind support. Also, my indebtedness goes to the SUT friends in the School of Biology, especially Ms. Glinsukol Suwannarat and Ms. Arunpark Pitakpong for their assistance with field sampling and help solving some critical issues when I was away for fieldwork. I am particularly indebted to Suranaree University of Technology for providing scholarship and grant for my study and research.

Special gratitude is expressed to my parents for their encouragement and understanding throughout my academic study.

Sukanya Lapkratok

CONTENTS

Page

CONTENTS (Continued)

Page

CONTENTS (Continued)

Page

CONTENTS (Continued)

Page

LIST OF TABLES

LIST OF TABLES (Continued)

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF FIGURES (Continued)

Figure **Page**

LIST OF FIGURES (Continued)

Figure **Page**

CHAPTER I

INTRODUCTION

1.1 Background and Problems

Global diversity is currently to be about 10 million species; however, insects comprise more than half of earth's diversity of species (Groombridge, 1992). Healthy biological communities depend on insects as pollinators, seed dispersers, herbivores, predators and prey. Within the ecological communities, insects comprise a large proportion of the biomass and are critical conduits of energy through the ecosystem (Battist, 1988). Butterflies are certainly the most popular and probably the most familiar insects in order Lepidoptera which is divided into two major groups, butterflies and moths.

New (1991) described some unique characteristics of the butterflies differ from the moths. First, most butterflies are diurnal whereas the moths are nocturnal; however, there are some exceptions. Second, the antennae of butterflies are club-shaped. Third, butterflies are brightly colored. And the last one, when at rest, most butterflies have their wings closed vertically above their bodies.

Butterflies play an increasingly important role in conservation biology. They act as "flagships" for the identification and preservation of critical habitats under threat, for the conservation of biodiversity, and as convenient "indicators" for monitoring climate change or pollution. The world contains roughly 18,000–20,000 species of butterflies and there is a clear latitudinal gradient in butterfly species diversity, with

numbers highest in the tropics (Larsen, 2005). Pelham (2008) listed 800 species throughout the United States and Canada and Lamas (2004) estimated 7,784 species in the neotropics. Similarly, Tolman and Lewington (2008) listed 440 species for Europe and Britain, compared to the roughly 4,000 species found in the afrotropics (Larsen, 2005)

Many butterflies are declining in numbers and becoming regionally and nationally rare or extinct (Asher et al., 2001). This can be due to a variety of factors, especially due to changes in land-use and increased habitat fragmentation. Species with more specialized habitat preferences and restricted range of larval food-plants have declined more severely than habitat generalists. This reduction in butterfly numbers is particularly worrying as they are the best known of the invertebrate fauna (Bourn and Thomas, 2002; Thomas, 2005) and reflect changes in the rest of the insect community (Bourn and Thomas, 2002; Thomas et al., 2004).

Butterfly declines may become more severe in future years. This is due not only to continuing unfavorable land management, but also to the preponderance of small and highly fragmented areas of habitat (Warren, 1993). Many existing populations of rare species may be unsustainable in the longer term and become extinct due to local fluctuations in their population that are not redressed by immigration (Bulman et al., 2007). Moreover, climate change may also be worsened, which is predicted to increase the frequency of extreme weather events (King, 2005) and force butterflies on small reserves out of their habitats or their food-plant's preferred environmental conditions (Dennis and Shreeve, 1991). Earlier emergence in the spring is being recorded in many butterflies (Roy and Sparks, 2000) which may contribute to declines, as butterfly emergence and host-plant growth become mismatched (Roy et

al., 2001). As a result, it is essential to develop long term resource management policies for butterfly conservation, based on an understanding of the ecological processes to maintain balance between the sustained yield of agricultural and forest products for human benefits and abundant reservoirs of natural habitat for butterfly and wildlife (Boonvanno et al., 2000).

Dong Phayayen-Khao Yai forest complex world heritage site of Thailand is very critical for conserving forest and wildlife. It covers four national parks and one wildlife sanctuary (G. O. Asia Co. LTD., 1996). They are Khao Yai National Park, Tap Lan National Park, Pang Sida National Park, Ta Phraya National Park and Dong Yai Wildlife Sanctuary. This world heritage standard endows the area with continuity in ecosystems and makes the conservation of natural resources imperative. Butterfly research will provide updated information which is essential to establish a monitoring program as an early alert system for changes in butterfly diversity as well as environment in this area.

This study aimed to investigate butterfly diversity and its relationship with environmental factors especially humidity, temperature, light, and precipitation. The results can be used as a butterfly checklist for tourists and as database for a proper butterfly conservation and management in the future.

1.2 Research Objectives

1.2.1 To study butterfly abundance and diversity of six waterfalls in Dong Phayayen-Khao Yai forest complex world heritage.

1.2.2 To compare the changes of butterflies abundance and diversity in each season.

1.2.3 To examine the association between environmental factors and butterfly diversity.

1.2.4 To study food preference of butterflies in bait traps.

1.3 Research Hypothesis

1.3.1 Abundance and diversity of butterflies are different in each site.

1.3.2 Environmental and seasonal factors have an effect on butterfly diversity and abundance.

1.3.3 Abundance and diversity of butterflies are different in each food.

1.4 Scope and Limitations of the Study

1.4.1 Six waterfalls, in Dong Phayayen Khao Yai complex world heritage, including Salika, Haew Narok, Haew Suwat, Wang Muang, Pang Sida, and Huai Yai waterfalls were selected as studied sites.

1.4.2 All butterfly surveys were conducted once a month at each site from June 2009 to December 2010, except Wang Muang waterfalls (January - December 2010).

1.4.3 The environmental factor data including temperature, humidity, light, and monthly rainfall were collected from the survey and the nearest meteorological stations.

1.4.4 Eight bait types, including fermented fish, fermented pineapple, fermented banana, fermented papaya, fermented watermelon, fish sauce, beer and fermented fish mixed with fermented pineapple, were tested for butterfly attraction effectiveness.

CHAPTER II

LITERATURE REVIEW

2.1 Diversity of Butterfly

2.1.1 Butterfly Diversity of the World

Bobbin and Opler (1997) estimated a total 17,500 species of world butterflies. Schappert (2000) then increased it to 19,445 species. The numbers of butterfly species in each world major biogeographical realm are shown in Figure 1. Butterfly diversity is greater in tropical than temperate areas. Of the two northern temperate regions, Palearctic region has bigger area and more species than Neartic. However, these temperate regions have fewer species than the Tropical, Neotropic, Oriental-Australian and Ethiopian regions. Among all regions, the Neotropic has the most diverse butterfly, approximately 7,500 species (Robbins and Opler, 1997).

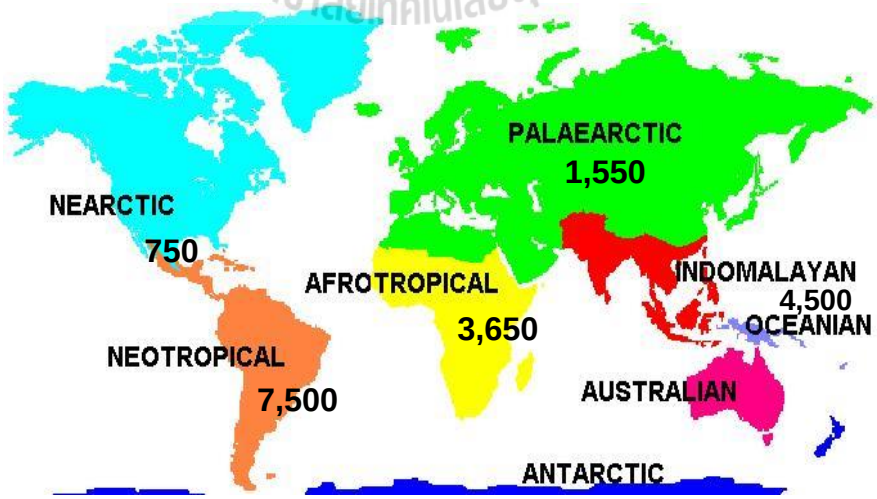


Figure 2.1 Number of butterfly species by biogeographical regions (Robbin and Opler, 1997).

The numbers of butterfly species in some countries are shown in Table 2.1, with India having the greatest butterfly diversity (1,400), followed by Thailand (1,393) and Costa Rica (1,044), respectively. Oman has the lowest diversity (72).

Table 2.1 Butterfly diversity in some countries.

Countries	Number of Species	References
India	1,400	Sikkiminfo (2008)
Thailand	1,393	Ek –Amnuay (2006)
Costa Rica	1,044	De Vries (2001)
Myanmar	1,039	Sikkiminfo (2008)
Philippines	1,030	Mohagan and Treadway (2010)
Papua New Guinea	959	Parsons (1999)
Malaysia	909	Sikkiminfo (2008)
Bhutan	800	Oneworld (2008)
Kenya	720	De Vries (2001)
Australia	383	Parsons (1999)
Taiwan	364	Parsons (1999)
Madagascar	262	De Vries (2001)
Sri Lunka	242	Sikkiminfo (2008)
Japan	237	Matsuka (2008)
Spain	220	Stefanescu et al. (2004)
Singapore	207	Khoon (2008)
Lebanon	139	Nagypal (2008)
Norway	100	Nagypal (2008)
Jordan	81	Nagypal (2008)
Oman	72	Nagypal (2008)

2.2 Biology of Butterflies

2.2.1 External Morphology

Butterflies are in the order Lepidoptera, and suborder Frenatae, whose whole body is covered with minute hair and scales. The body consists of three main regions, head, thorax and abdomen as shown in Figure 2.2 (Smart, 1981; Novak, 1998).

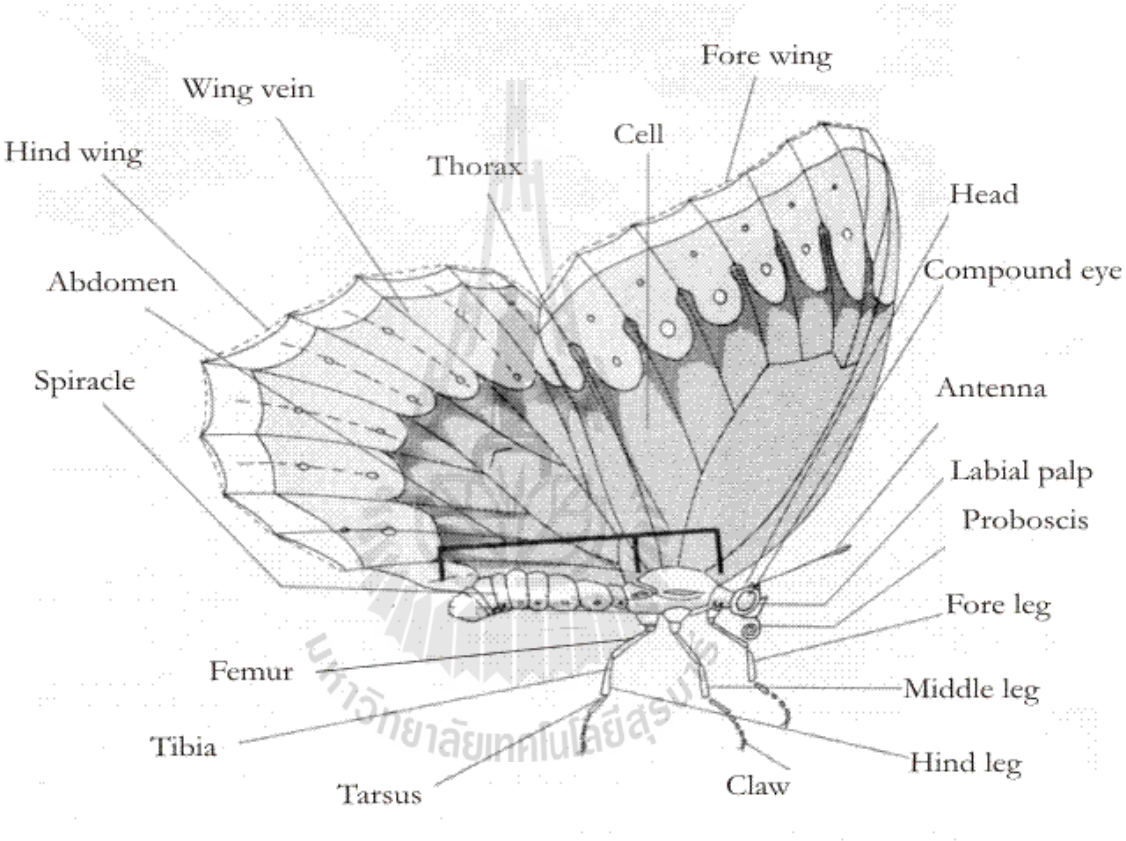


Figure 2.2 Morphology of a butterfly (Wikimedia, 2006).

Butterfly head is a small spherical capsule, which joined to the thorax by a short neck. The head bears a pair of large compound eyes and two club-shaped antennae. Butterflies usually have sucking mouthparts (siphoning type called “proboscis”) that evolve from the galea; it is a double organ-two grooved halves joined by a seam to

slender tube. The proboscis will fully extend only when butterflies are sucking nectar. But when not in use, proboscis is coiled up in a spiral (Novak, 1998).

Butterfly thorax comprises three parts: prothorax, mesothorax and metathorax. The three pairs of leg are attached to each thoracic segment. The legs are usually well developed. The wings, attached to the thorax by means of complex system of tiny sclerites. Wings are densely clothed with tiny, usually colored scales, orientated in one direction and overlapping each other like tiles on a roof. The whole colorful splendor of the butterflies lies in these small scales which either contain pigments, or produce colors physically by the differentiation or refraction of light. The individual colored scales are arranged like a mosaic to form the elaborate wing patterns. The profusion of different patterns typical of butterflies is dependent on this basic scheme. (Novak, 1998).

Butterfly abdomen is cylindrical and consists of ten segments. The first 7-8 segments are similar in shape and internal structure. The terminal segments have been transformed into copulatory organs. The external sexual organs formed the sclerites of the terminal abdominal segment and function as mechanical organ for copulation. (Novak, 1998).

2.2.2 Butterfly Life Cycle

Butterflies undergo complete metamorphosis: egg, larva, pupa, and adult (Figure 2.3). The first stage is the egg. Depending on the species, an adult female butterfly may lay up to 400 or more eggs in her lifetime on selected food plants. The butterfly eggs are commonly green in color although they may darken just before hatching. The shape of the egg varies in different species. The egg usually hatches

within 5 to 15 days and gives rise to the first larval stage (Sand Ridge Nature Center, 2008).

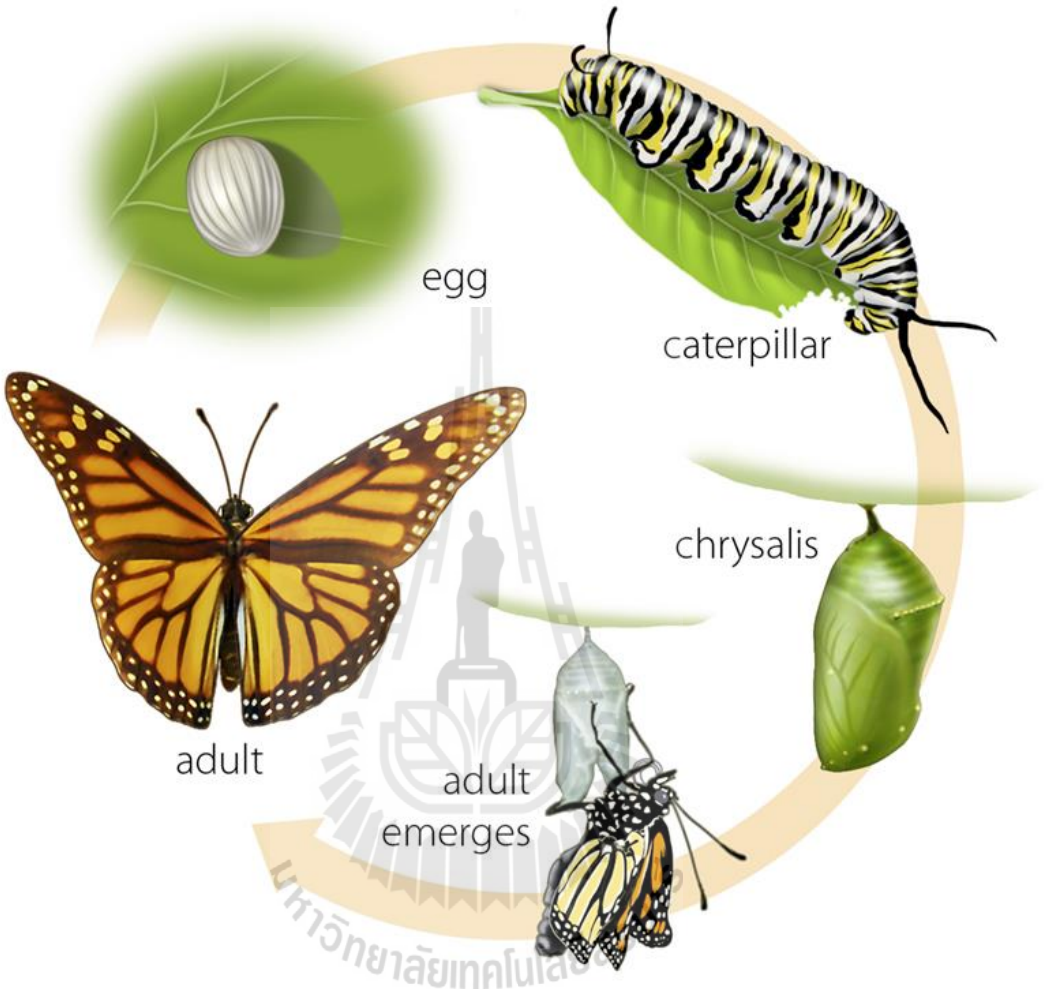


Figure 2.3 Life cycle of butterfly **(**Sand Ridge Nature Center, 2008).

A butterfly larva is called caterpillar. Its external morphology is different from adult. The larva has a prominent head followed by 13 trunk segments of which the first three are regarded as the thorax and the remainder are the abdomen. The larval skin is soft and flexible. The caterpillar has chewing mouthparts and usually feeds on vegetative materials such as leaves, buds, and fruits. Compound eyes are lacking but the main visual organs are lateral ocelli. These are arranged in two groups on each

side of the head. The three segments of the thorax each have a pair of short legs which end in a single claw. The abdomen has ten segments; five of these bear a pair of prolegs. As it grows larger, the caterpillar has a need to shed its skin. There are usually five molts before the caterpillar is fully mature and then it molts into the pupal stages (Sand Ridge Nature Center, 2008).

Butterfly pupa is almost immobile. In most pupae, the internal cellular matter is rearranging itself to produce the essential body part of the adult, i.e. wings, legs and head. Depending on climate conditions, the time period spent as a pupa is usually about 10 - 80 days. The skin of the pupa splits behind the head and the adult butterfly emerges (Sand Ridge Nature Center, 2008).

2.3. Effects of Environmental Factors on Butterfly

2.3.1 Temperature

Temperature is the main factor controlling the life of butterflies. Most butterflies are not active in dull weather, usually because it is too cold to fly. Butterflies have the developmental threshold, usually between 5 and 10 ^{o}C (Ratiwiriyapong, 2004). When the temperature is below 5 ^{o}C, caterpillars will stop developing and there will be no reproduction for adult butterfly (Öckinger et al., 2006). The temperature threshold varies among species. Temperate butterflies are most active at temperature between 20 and 25 ^{o}C (Ratiwiriyapong, 2004). Boonvanno et al. (2000) found that high temperature increased the development of caterpillars to pupae. Finally, temperature also affects the development of plants which provide food and shelter for butterfly.

2.3.2 Humidity

Many butterflies require suitable humidity environments. All butterfly developmental stages are well adapted for the prevention of water loss. Boonvanno et al. (2000) found that increased humidity between 80-85 % had a negative effect on the caterpillar diapause. Thus adult population decreased.

2.3.3 Sunlight and Photoperiod

Sunlight and photoperiod are also important to butterfly with respect to signaling and orientation. Butterflies can detect wavelength beyond those included in the spectrum of visible light and near ultraviolet. They see quite different colors from human. Butterflies are sensitive to light changing during the day so that the activity of most butterflies is concentrated in the morning and afternoon. Boonvanno et al. (2000) found that sunlight was the main factor on egg laying of butterflies.

2.3.4 Food and Enemies

Caterpillars live on leaves, flowers, or fruits whereas adults suck nectar from flowers and sweet juice from fruits. Caterpillars are rarely predators; they feed on other insect larvae (Omura and Honda, 2003).

In all developmental stages of butterflies have many natural enemies both as parasites (Moss, 1933) and predators (Richards, 1940). Predators prey on both larva and adult butterflies such as beetles, spiders, mantis (Feeny et al., 1985) and birds (Stamps and Gon, 1983).

2.3.5 Behavior of Butterflies

Most butterflies live solitarily. Occasionally, individuals assemble and form organized communities. The most common causes are migration, hibernation or concentration at source of food or water. The aggregation of butterflies around food

can most easily be obtained by smearing some sweet, fermenting juice in dry and warm weather. Sometimes the aggregation of butterflies could be found on damp sand, muddy ground or on patches of dung or urine (Chamratloetlak, 2004).

2.4 The Ecological Roles of Butterfly

Because butterflies have complete metamorphosis and they feed on different foods between their developing stages, they play many roles in the ecosystems.

2.4.1 As Primary Consumers

The larval stage is herbivore. Some species are monophagous they feed on only a few plant species (Thomas, 1990; Thompson, 1998). For example, the larva of common milkweed butterflies feeds on milkweed plants (Asclepiadaceae) only (Ralph, 1977). Some species are polyphagous they feed on many species of plants (Nylin et al., 2000; Ting et al., 2002). For example, *Delias nigrina* feed on *Amyema*, *Dendrophthoe* and *Muellerina* (Braby and Lyonns, 2003).

2.4.2 As Prey

All developmental stages of butterflies serve as food for other animals (Novak, 1998). The animals that consume butterflies are small arthropods (such as spiders, harvestman, mantids and ants) and vertebrates including birds, frogs and lizards.

2.4.3 As Predators

In rare case, butterflies are reported to be predators. The butterflies in the family Lycaenidae feed on homoptera or ant larvae (Gilbert and Singer, 1975).

2.4.4 As Pollinators

Adult butterflies are known to feed on floral nectar. Many species of butterflies are common visitors to the flowers of a diverse array of species with brightly corolla (Bawa, 1990). The foraging selectivity of adult butterflies is influenced by their proboscis lengths (May, 1992), so that the butterflies which have long proboscis prefer long-corolla flowers, while short-proboscis prefer open flowers.

2.5 Butterfly Diversity Studies in Different Ecosystems

Nowadays, many researchers studied the diversity of butterfly communities in various types of world ecosystem (Table 2.2). For example, deciduous forest, Lewis (2001) found 49 butterfly species in investigated the effect of experimental selective logging regime on the fruit feeding butterflies in Belize (Caribbean coast of Central America). The species abundance distributions for logged and unlogged forests do not differ significantly. In contrast, in the northern part of Ibaraki, central Japan, butterfly species considerably decreased in the cutover land site (Inoue, 2003).

In tropical rain forest, Cleary and Genner (2004) studied changes in rain forest butterfly diversity following major ENSO-induced fires in Borneo (Balikpapan-Samarinda region of East Kalimantan). During the study, 22,333 individuals belonging to 362 butterfly species were sampled. The fires dramatically altered the butterfly community and resulted in a major decline in observed species richness within landscape surveyed. In 2006, Cleary et al. found 133 species in studied of butterfly diversity and composition in fire-affected in Southern Oscillation burn event in East Kalimantan. Rarefied species richness and Shannon's H′ were higher in unburned forest than burned forest.

In grassland, Vessby et al. (2002) studied the number of species of butterflies in 31 Swedish seminatural grasslands in south-central Sweden. They found 30 butterfly species. In addition, Collinge et al. (2003) studied effects of local habitat characteristics and landscape context on grassland butterfly diversity near the city of Boulder, Colorado. They found 7,246 individuals of 58 species. Tallgrass plots supported significantly higher butterfly species richness than shortgrass plots.

Table 2.2 Butterfly diversity in different ecosystems.

Ecosystems	Country	Diversity (species)	References
Deciduous	Belize, Central America	49	Lewis (2001)
forest	The northern part of Ibaraki, Japan	86	Inoue (2003)
Tundra	Solovetskie Island, Northwestern Russia	29	Bolotov (2006)
Temperate	Chatienshan Nature Reserve, Taiwan	77	Hsu (2002)
Glassland	Colorado (Boulder) USA	58	Collinge et al. (2003)
	South-central Sweden, Sweden	30	Vessby et al. (2002)
Rainforest	Central Kalimantan (Borneo), Indonesia	89	Walpole and Sheldon (1999)
	East Kalimantan, Indonesia	362	Cleary and Genner (2004)
	East Kalimantan, Indonesia	133	Cleary et al. (2006)
	Sabah (Danum Valley Field Centre), Indonesia	54	Hill et al. (2001)
Countryside	Costa Rica, Coto Brus	196	Devine et al. (2003)
Urban	Adelaide, South Australian	21	Collier et al. (2006)
	Catalonia, North east Iberian Peninsula	131	Stefanescu et al. (2004)
Roadside	Imatra – Lappeenranta region, South east Finland	53	Saarinen et al. (2005)
Filter strip	Krakow, Southern Poland	29	Reeder et al. (2005)
Coast	Kenya	63	Rogo and Odulaja (2001)

In urban area, Stefanescu et al. (2004) studied butterfly species richness in the north-west Mediterranean Basin, the role of natural and human- induced factor in Catalonia (north-east Iberian Peninsula). A total of 131 species were detected in the monitoring transects. They also found that a significant decrease in species number was associated with an increase in human pressure.

Roadside, Saarinen et al. (2005) studied the communities of butterflies and day-active moths in 51 sites along the verges of the three road types, i.e., highways, urban roads and rural roads. The species richness and total abundance of butterflies (53 species, 5,964 individuals) and diurnal moths (46 species, 4,626 individuals) were also rather similar in each road type. Butterfly diversity increased (but not significantly) from the verges of narrow rural roads to wider highways. The highest numbers of meadow species were recorded along highways and the total abundance, especially of diurnal moths, decreased in accordance with the road size.

At Kenya coast, Rogo and Odulaja (2001) studied butterfly populations in two forest fragments. They found 63 species from each forest remnant. Species accumulation curves for both forests did not reach an asymptote. The number of species was less than half that recorded from the large forest reserve of Arabuko-Sokoke, located in the same geographical area (134 species).

In filter strip area, Reeder et al. (2005) studied factors affecting butterfly use of filter strip in Midwestern USA. The number of butterfly surveys were 1,789 individuals of 29 species. Butterfly diversity (H′) and abundance of habitat-sensitive butterflies were positively correlated with filter strips width. Butterfly abundance related the coverage of forbs and the number of ramets in bloom in the strips and indicated positive relationships between forbs and the butterfly community.

Abundances of large, habitat-sensitive butterflies depended on the height and vertical density of vegetation.

2.6 Butterfly Diversity Studies in Thailand

The first investigation of Lepidoptera in Thailand was conducted by Fabricius in 1787, followed by Druce in 1874 and then Fruhstorfer described new endemic subspecies of butterfly in 1900-1901 (Lekagul et al., 1977).

The first publication describing butterflies in Thailand is The *Butterflies of Siam* by Godfrey in 1916, recording 371 species. In 1930, the numbers increased to 692 species, and was not until 1977 that the first known guidebook entitled The *Field Guide to Butterflies of Thailand* by Lekagul and colleagues was published. This guide has nearly 700 illustrated species and has been widely used for field identification of Thai butterflies. Pinratana (1981, 1983, 1985, 1988) and Pinratana and Eliot (1992, 1996) published six volumes of The *Butterflies in Thailand* which described 900 species. Recently, Ek-Amnuay (2006) published The *Butterflies of Thailand* describing 1,393 species.

There are only a few empirical butterfly diversity studies in Thailand so far (Table 2.3). Watanasit (1984) made many butterfly survey trips in Tarutao National Park, Songklanakarin province. Over the period of seven months, he found 105 species. Choldumrongkul and Chumnarnkid (1998) found total 323 butterfly species from five habitats in Chern watershed area, Namnao National Park, Petchabun province, from October 1996 to September 1997. The highest diversity of butterflies was found in the evergreen forest while grassland had the lowest. The highest peaks

of butterflies were observed in October 1996 and May 1997, while the lowest was found in January 1997.

Table 2.3 Butterfly diversity studies in Thailand**.**

	Sites	Species	References
National park	Tarutao, Songklanakarin province	105	Watanasit (1984)
	Namnao, Petchabun province	323	Choldumrongkul and Chumnarnkid (1998)
	Khao Yai, Nakhon Ratchasima province	138	Ratiwiriyapong (2004)
	Chaloem Rattanakosin, Kanchanaburi province	222	Chamratloetlak (2004)
	Pang Sida Sa Kaeo province	250	Jansaka (2006)
	Doi Inthanon	296	Tasen et al. (2008)
	Kaeng Krachan, Phetchaburi province	300	National Park, Wildlife and Plant Conservation Department (2008 a)
Wildlife Sanctuary	Ton Nga-Chang, Songkhla province	147	Boonvanno et al. (2000)
	Huay Kha Khaeng, Uthai Thani province	53	Ghazoul (2002)
Community Forest	Thung Soong Village, Krabi province	154	Khunwiset (2003)
	Hala – Bala	219	Wangthaveesup (2008)
Natural Butterflies Garden	Khaokheow Open Zoo, Chon Buri province	47	Phinetsathian (2008)
Biosphere reserve	Sakaerat Environmental Research Station, Nakhon Ratchasima province	304	Suwanwaree and Lapkratok (2010)

Boonvanno et al. (2000) found 147 butterfly species in Ton Nga-Chang Wildlife Sanctuary, Songkhla province, from June 1997 to May 1998. The highest butterfly diversity was in February 1998 and the lowest in September 1997. They reported no statistically significant relationship between physical factors and butterfly diversity.

Ghazoul (2002) studied the impact of logging on butterflies in a tropical dry forest in western Thailand (Uthai Thani). He found that the abundance of butterflies and diversity of the butterfly community decreased with increased logging disturbance.

Khunwiset (2003) studied butterfly diversity in Community Forest at Thung Soong Village, Krabi province, from July 2001 to June 2002. She found 154 species from three habitats which were the oil palm plantation, secondary forest and natural forest. The highest diversity measured by Shanon-Wiener's index was found in secondary forest with $H' = 3.89$. Family Nymphalidae was the most abundant in all three habitats.

Ratiwiriyapong (2004) surveyed butterfly diversity bimonthly along the Pha Kluai Mai and Haew Suwat Waterfall natural trail in Khao Yai National Park from March 2002 to February 2003 and found 138 species of butterfly. The highest number of species (69 species) was in December 2002, while the lowest (47 species) was in July 2002. In the morning and afternoon observation, butterfly species had no significant correlation with environment factors.

Chamratloetlak (2004) studied the diversity and feeding behavior of butterflies in Chaloem Rattanakosin National Park, Kanchanaburi province, resulted in 222 species of 11 families. The experiments on the influence of five fermented fruits

(pineapples, guavas, bananas, watermelons, and papayas) and five solutions (sugar, fish sauce, beer, urine, and water), showed that the number of the butterflies on each fermented fruits and solutions were different significantly. Urine was the most favorite solution, having more efficiency than fish sauce, pineapple, banana, papaya, watermelon, guava and beer respectively while sugar solution and water did not absolutely attract butterflies' appetite.

Suwanwaree and Lapkratok (2010) compared the species diversity of butterflies between dry dipterocarp forest and dry evergreen forest at Sakaerat Environmental Research Station, a UNESCO biosphere reserve, in Nakhon Ratchasima province**.** They found 304 butterfly species (19,277 individuals) in both forests, while dry evergreen forest had more butterfly diversity (238 species, 12,500 individuals) than dry dipterocarp forest (210 species, 6,777 individuals). One hundred and fourty four species were found in both forests whereas 66 species found only in dry dipterocarp forest and 94 species found only in dry evergreen forest. May had the highest butterfly species and number.

Tasen et al. (2008) studied butterfly diversity at Doi Inthanon National Park, Chiang Mai province. The results indicated that there were 296 species, belonging to 5 families. The most abundance of butterflies was in mixed deciduous forest (173 species) and followed by dry dipterocarp forest (170 species) in rainy season. On the other hand, hill evergreen forest and grass land in high altitude habitat had more abundance in summer.

Phinetsathian (2008) found 47 species during the surveys in the Natural Butterflies Garden in the Khaokheow Open Zoo, Chon Buri province, from February 2005 to January 2006.

Finally, Wangthaveesup (2008) studies of butterflies at Hala – Bala Forest at Amphoe Betong, Yala Province. They observed into 21 subfamily, 108 genera and 219 species and forms from all 5 families: Hesperiidae, Lycaenidae, Nymphalidae, Papilionaidae and Pieridae. The relative abundance was 45.79 individuals/km. Venn diagram showed that the species composition in different areas are also different.

2.7 Food Preference Research

Adult butterflies feed from a variety of food such as flower nectar, fruits, honey-dew, tree sap, mud, carrion and dung. Many adult butterflies are flower visitors and nectarious. Nectar composition is an important criterion in butterfly flower selection (Omura et al., 2000). Nymphalid adults frequently feed on sap exuded from broad-leaves tree, such as oaks, elms, walnuts and willows, and on wounded and rotting plums, peaches, figs and persimmon (Dierks and Fischer, 2008). A diversity of microbes, including wild yeasts, utilize sugars and amino acids in exuded tree sap and wounded fruit and produce various consequent metabolites as food for butterflies (Beck et al., 1999).

To attract butterflies, many studies used fermented banana (Bossart et al., 2006; Bossart, and Opuni-Frinpong, 2009; De Vries et al., 1997; De Vries et al., 2012; Hill et al., 2001; Nyafwonoa et al., 2014) and fermented banana mixed with sugar cane juice (Marini-Filho and Martins, 2010; Ribeiro et al., 2010; Sant'Anna et al., 2014) as baits to capture fruit-feeding and mud-pudding butterflies. Although they are cheap and easily available in tropical countries, they attract only some group of butterflies.

Fermented fish, a common food in Thailand and Lao, mixed with fermented pineapple was successfully used to attract butterflies in Ton Nga Chang Wildlife

Sanctuary, Songkhla Province, in Southern Thailand (Boonvanno et al., 2000). Therefore, various local foods and fruits could be used as butterfly baits.

2.8 Dong Phayayen-Khao Yai Forest Complex World Heritage

This world heritage consists of four national parks (Khao Yai, Thap Lan, Pang Sida, and Ta Phraya) and one wildlife sanctuary (Dong Yai; Figure 2.4). The complex covers an area of 6,152 km^2 in Saraburi, Nakhon Nayok, Nakhon Ratchasima, Prachin Buri, Sakeao, and Buri Rum provinces. The topography, which are rugged mountain is covered by thick forest with 1,000 - 3,000 mm. annual rainfall and 23 ºC annual temperature. All of these outstanding features prove the value of Dong Phayayen Khao Yai forest complex and justify the consensus of the UNESCO World Heritage committee in approving it as a Natural World Heritage site on 14th July, 2005 (Geo Asia, 1996).

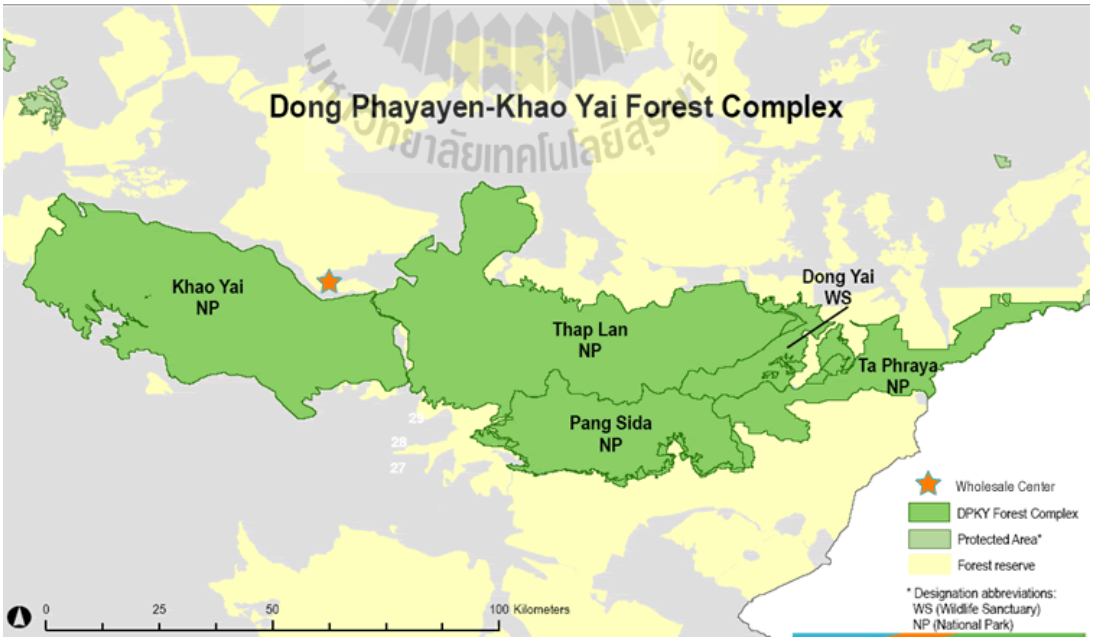


Figure 2.4 Dong Phayayen-Khao Yai Forest Complex World Heritage.

2.8.1 Khao Yai National Park

The park, which covered an area of 2,168 km^2 and situated approximately at 14°15'N 101°50'E in the Phanom Dong Rak mountain range, stretches over four provinces including Nakhon Ratchasima, Nakhon Nayok, Saraburi, and Prachin Buri. Khao Yai became Thailand first national park on 18th September 1962 and is also originally recognized as the National Park Heritage of Asian Group Countries. The park is comprised of mixed forests and rainforests with some wide plains and grasslands interspersed with verdant forests. There are many valuable plants, including commercial plants, scented plants and herbs. In addition, there are several mountains with peaks ranging from 800 to 3,000 m above sea level making Khao Yai a cool climate area, even in summer. Mean annual rainfall is 1,352 mm, mean annual temperature is 28.5 °C and mean annual relative humidity is 73.4 % (GeoAsia, 1996).

2.8.2 Pang Sida National Park

Pang Sida National Park, situated approximately at 14°12'N 101°55'E, has been declared as a national park on February 22, 1982. Covering the area in Amphoe Muang, Amphoe Wattana Nakhon, Amphoe Ta Phraya of Sa Kaeo and Amphoe Na Di of Prachin Buri, this park occupies an area of 844 km^2. The topography of the area consists of complex highlands with various and diversified forests, and an abundant of wild and rare animals. The area is the origin of many creeks which form the Bang Pakong River. Mean annual rainfall is 119.7 mm, mean annual temperature is 28 °C and mean annual relative humidity is 74.7 % (GeoAsia, 1996).

2.8.3 Thap Lan National Park

Thap Lan National Park covers Amphoe Pak Thongchai, Khornburi and Soeng Sang of Nakorn Rachasima province, and Amphoe Na Dee of Prachinburi province. It

is situated approximately at 14°33'N 101°50'E. The forests are fertile and consist of the rare fan palm forests found only in such territory. It is the source of many streams and has natural uniqueness such as the cliffs and waterfalls. Tab Lan National Park is the second biggest national park of the country with its area of 2,040 km^2. It was declared as national park on 23 December, 1981 to be the 39^{th} national park of Thailand. Mean annual rainfall is 62.3 mm, mean annual temperature is 27.3 °C and mean annual relative humidity is 70.5 % (GeoAsia, 1996).

2.8.4 Tapraya National Park

Tapraya National Park is close to Pang Sida National Park and is a part of Phanom Dong Rak Mountain Range located in the eastern side laying towards the west. It covers two provinces that is Sa Kaew and Burirum. The park occupies an area of 625 km^2. It is situated approximately at 14°22'N 103°14'E. In this region, there are fertile forests, most of which are mixed deciduous, dry evergreen and dipterocarp forest. It was declared as a national park on 22^{nd} November, 1996 to be the 82^{nd} national park of Thailand. Mean annual rainfall is 111.2 mm, mean annual temperature is 28.2 °C and mean annual relative humidity is 73.6 % (GeoAsia, 1996).

2.8.5 Dong Yai Wildlife Sanctuary

Dong Yai Wildlife Sanctuary is close to Tapraya National Park. It is in Burirum provinces. The wildlife sanctuary occupies an area of 122 km^2. It is situated approximately at 14°22'N 102°35'E. In this region, there are fertile forests, most of which are dry evergreen and dipterocarp forest. It was declared as a wildlife sanctuary on 22^{nd} November, 1996. Mean annual rainfall is 1,110 mm, mean annual temperature is 28 °C and mean annual relative humidity is 75.6 % (National Park, Wildlife and Plant Conservation Department, 2008 b).

2.9 Forest types in Dong Phayayen-Khao Yai Forest Complex World Heritage

Moist evergreen forest accounts for 66.36 % of the area. This forest contains high humidity so perennial trees grow densely. Not much sunlight reaches the ground below. Most of the trees are Yang Klong (*Dipterocarpus dyeri*), and Krabak (*Anisoptera costata*), Lumphu Pa (*Duabanga grandiflora*), Po I Keng (*Pterocymbium javanicum*), and many species of Ko (Fagaceae family). The ground level vegetation consists of ferns, many species of Kut (Parkeriaceae family), and bamboo. There are also many kinds of orchids (GeoAsia, 1996).

Dry evergreen forest accounts for 17.43 % of the area. Trees found in this type of forest are Yang Na (*Dipterocarpus alatus*), Yang Daeng (*Dipterocarpus turbinatus*), Takhian or Iron wood (*Hopea odorata*), Somphong (*Tetrameles nudiflora*), Makha Mong (*Afzelia xylocarpa*), and Po I Keng (*Pterocymbium javanicum*). The ground level vegetation consists of wild bananas, Krachiao in the Zingiberaceae family, and Toei in the Pandanaceae family (GeoAsia, 1996).

Mixed deciduous forest accounts for 9.57 % of the area. This forest is at the altitude of 400-600 m above sea level. Perennial trees with high tops are deciduous trees like Makha Mong (*Afzeladia xylocarpa*), Pradu (*Pterocarpus macrocarpus*), Tabaek Yai in the Lythraceae family, and Takhian Nu (*Anogeissus acuminata*). Secondary plants consist of bamboo and many species of grass (GeoAsia, 1996).

Grassland and secondary forest accounts for 7.65 % of this area. This vegetation type is result of past deforestation is *Imperata cylindrical* Beauv. (GeoAsia, 1996).

Hill evergreen forest accounts for 0.77 % of this area. Most of the trees are softwood species. This type of trees are Phaya Mai (*Podocarnus neriifoluis*), Khun Mai (*Negeia wallchianus*), Makham Pom Dong (*Cephalotaxus griffithii*), and Sam Phan Pi (*Dacrydium elatum*) (GeoAsia, 1996).

CHAPTER III

MATERAILS AND METHODS

3.1 Study Sites

Butterflies diversity studies were conducted at 6 waterfalls in Dong Phayayen-Khao Yai Forest Complex during June 2009 and December 2010 (Figure 3.1). In 2009, we investigated 5 waterfalls including Sarika, Haew Narok, Heaw Suwat, Pang Sida, and Huai Yai waterfalls. But in 2010, we added Wang Muang waterfall. All study sites were in Dong Phayayen-Khao Yai Forest Complex World Heritage. The site descriptions are as follows.

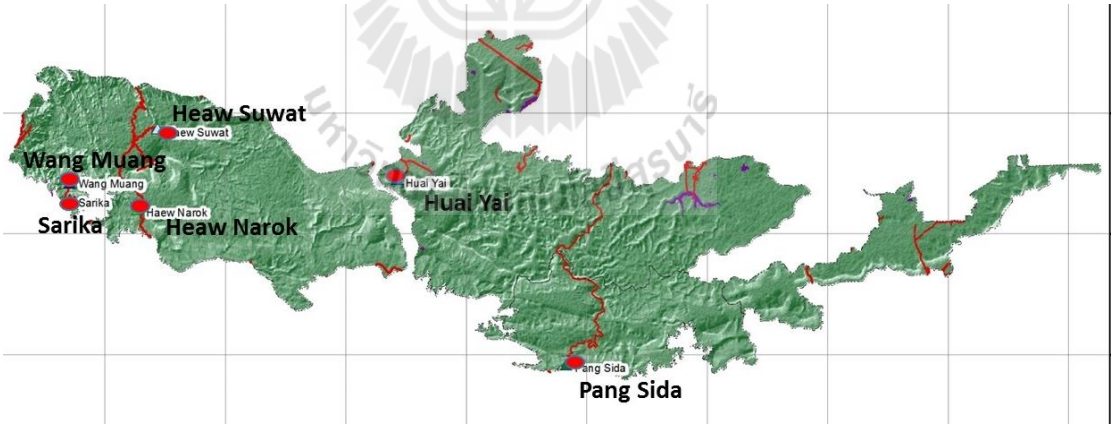


Figure 3.1 Study sites of waterfall in Dong Phayayen-Khao Yai forest complex.

3.1.1 Sarika Waterfall

Sarika Waterfalls, situated approximately at 14°18'N 101°15'E, at elevation of 58 m above sea level in Nakhon Nayok province. The waterfall is located in Khao Yai

National Park. The forest type was dry evergreen forest. Plant species found were *Hopea ferrea*, *Hopea odorata*, *Lithocarpus calathiformis*, *Irvingia malayana*, *Nephelium hypoleucum*, *Myristica cinnamomea*, *Bombax anceps*, *Zizyphus* sp., *Adenanthera pavonina*, *Phyllanthus emblica* and *Hydrocarpus illicifolius*. The canopy trees attain 30 to 40 m. A large waterfall, streams falling from a cliff, fried, up to 9 floor pass to the highest height of 200 m (Figure 3.2). Each floor is the water reservoir. There are a lot of water during the rainy season but in dry season, water dry.

Figure 3.2 Sarika waterfall in Khao Yai National Park.

3.1.2 Wang Muang Waterfall

This is a small waterfall originated from Huai Wang Muang and located in Amphoe Pak Phli of Nakhon Nayok province in Khao Yai National Park. It is situated approximately at 14°20'N 103°15'E, at elevation of 51 m above sea level. The forest type near waterfall was dry evergreen forest. Plant species were *Hopea ferrea*, *Hopea odorata*, *Myristica cinnamomea*, *Bombax anceps*, *Zizyphus* sp., *Adenanthera*

pavonina and *Hydrocarpus illicifolius.* It features the water flowing down in numerous steeps in the shady woods, having the rocky hilly floor in the stream (Figure 3.3).

Figure 3.3 Wang Muang waterfall in Khao Yai National Park.

3.1.3 Haew Suwat Waterfall

This is a famous waterfall in Khao Yai National Park that cascades from a 20 m high cliff (Figure 3.4). The waterfall, which is located at the end of Thanarat Road, only 100 m by foot from the parking lot or a 3 km walk from Pha Kluai Mai Waterfall. It is situated approximately at 14°26'N 101°25'E and elevation of 653 m above sea level. The forest type near waterfall was moist evergreen forest. The plant species were *Dipterocarpus dyeri*, *Anisoptera costata*, *Duabanga grandiflora Pterocymbium javanicum*, *Litsea glutinosa*, *Duabanga grandiflora*, *Wrightia*

tomentosa, *Dendrocalamus longispathus*, *Paramichellia baillonii* and *Schima walllichii*.

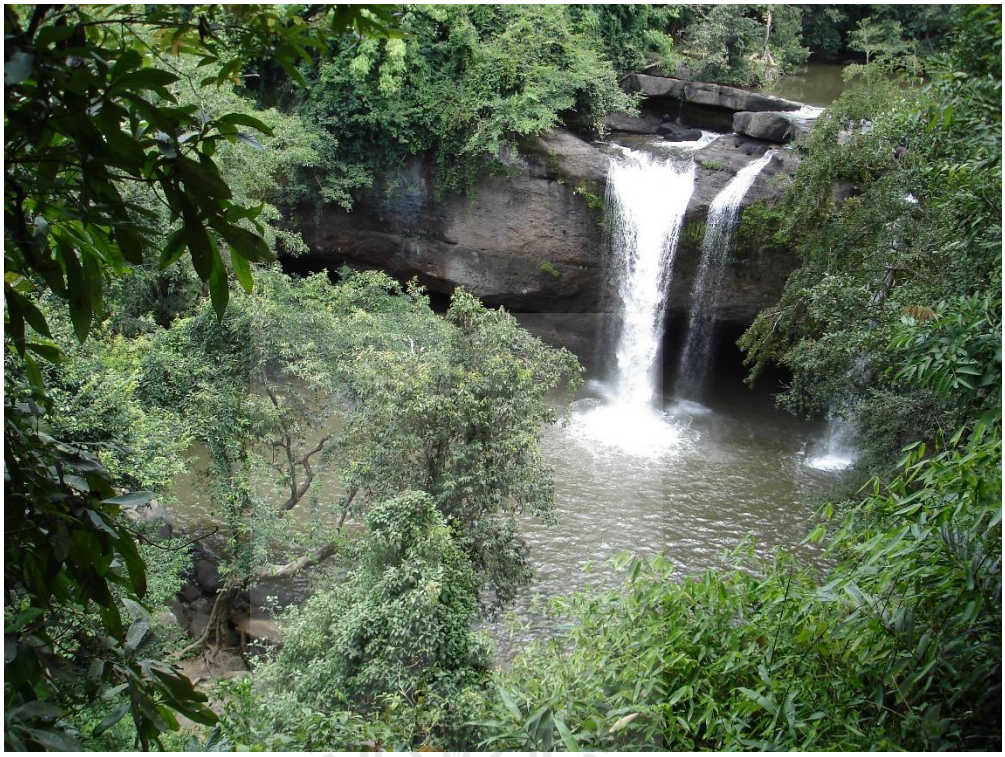


Figure 3.4 Haew Suwat waterfall in Khao Yai National Park.

3.1.4 Haew Narok Waterfall

This is the largest and highest waterfall in Khao Yai National Park with three levels. The first level is about 60 m high and water from this level flows straight down to the second and third levels, with a total drop of at least 150 m (Figure 3.5). It is situated approximately at 14°17'N 101°23'E and elevation of 411 m above sea level. The forest type nearby was moist evergreen forest. Most of the trees were *Dipterocarpus dyeri*, *Anisoptera costata*, *Duabanga grandiflora*, *Pterocymbium javanicum*, *Lithocarpus* sp., *Sandoricum Roctjape*, *Aquilaria crassna*, *Holoptelea integrifolia*, *Anthocephalus chinensis*, *Castanopsis acuminatissima*, *Nephelium*

hypoleucam, Gironniera nervosa and *Millettia* sp. The area around the waterfall is the usual feeding grounds of wild elephants. There have been occasional accidents when elephants drop from the cliff and die.

Figure 3.5 Haew Narok waterfall in Khao Yai National Park.

3.1.5 Pang Sida Waterfall

Pang Sida Waterfall is approximately 800 m from the office of Pang Sida National Park. It is situated approximately at 13°59'N 102°12'E and elevation of 176 m above sea level. The forest type nearby was dry evergreen forest. Plant species were *Hopea ferrea, Hopea odorata, Hydrocarpus illicifolius, Mitrephor thorelii, Wrightia tomentosa, Dipterocarpus alatus, Dipterocarpus turbinatus, Shorea henryana, Shorea roxburgii, Lagerstroemia calyculata, Afzelia xylocarpa, Tetrameles nudiflora, Erythrophloeum succirubrum, Linociera microstigma, Memecylon floribundum, Areca triandra, Phrynium* sp., *Cucurlico* sp., *Achasma* sp. and *Curcuma*

sp. It is a 3–tier waterfall with a height of 10 m. The water drops to the lower large water basin and stone terrace surrounded by shady atmosphere (Figure 3.6).

Figure 3.6 Pang Sida waterfall in Pang Sida National Park.

3.1.6 Huai Yai Waterfall

Huai Yai Waterfall is a beautiful and big waterfall in Thap Lan National Park. It is situated approximately at 14°20'N 101°53'E and elevation of 316 m above sea level. The forest type was disturbed forest. Plant species were *Imperata cylindrical, Shorea obtuse, Shorea siamensis, Dipterocarpus tuberculatus, Arundinaria pusilla, Bambusa arundinacea, Imperata cylindrical* and *Eupatorium odoratum*. The waterfall is 50 m high and 3 m wide (Figure 3.7). The cliff at the waterfall looks like a 150-degree curve. The waterfall is at the Km.79 from the highway 304, and about 6 km from the intersection at Km.79.

Figure 3.7 Huai Yai waterfall in Thap Lan Park.

3.2 Butterfly Survey

3.2.1 Transect Walk

At each site, the 1-km section of natural trail near waterfall was selected for this study (Figures 3.8-3.13). The transect walk was modified from Pollard (1977). The transects were walked both in the morning and afternoon once a month from June 2009 to December 2010. All the butterflies on line as well as 5 m on either side were recorded with time and number of individuals seen between 8:00 and 11:00 a.m., and then again between 1:00 and 4:00 p.m. Flight periods, seasonality and abundance of butterfly species in different sites were also recorded. Butterfly species were identified directly in the field or, in difficult cases, following capture or photography. Collection was restricted to those specimens that could not be identified directly.

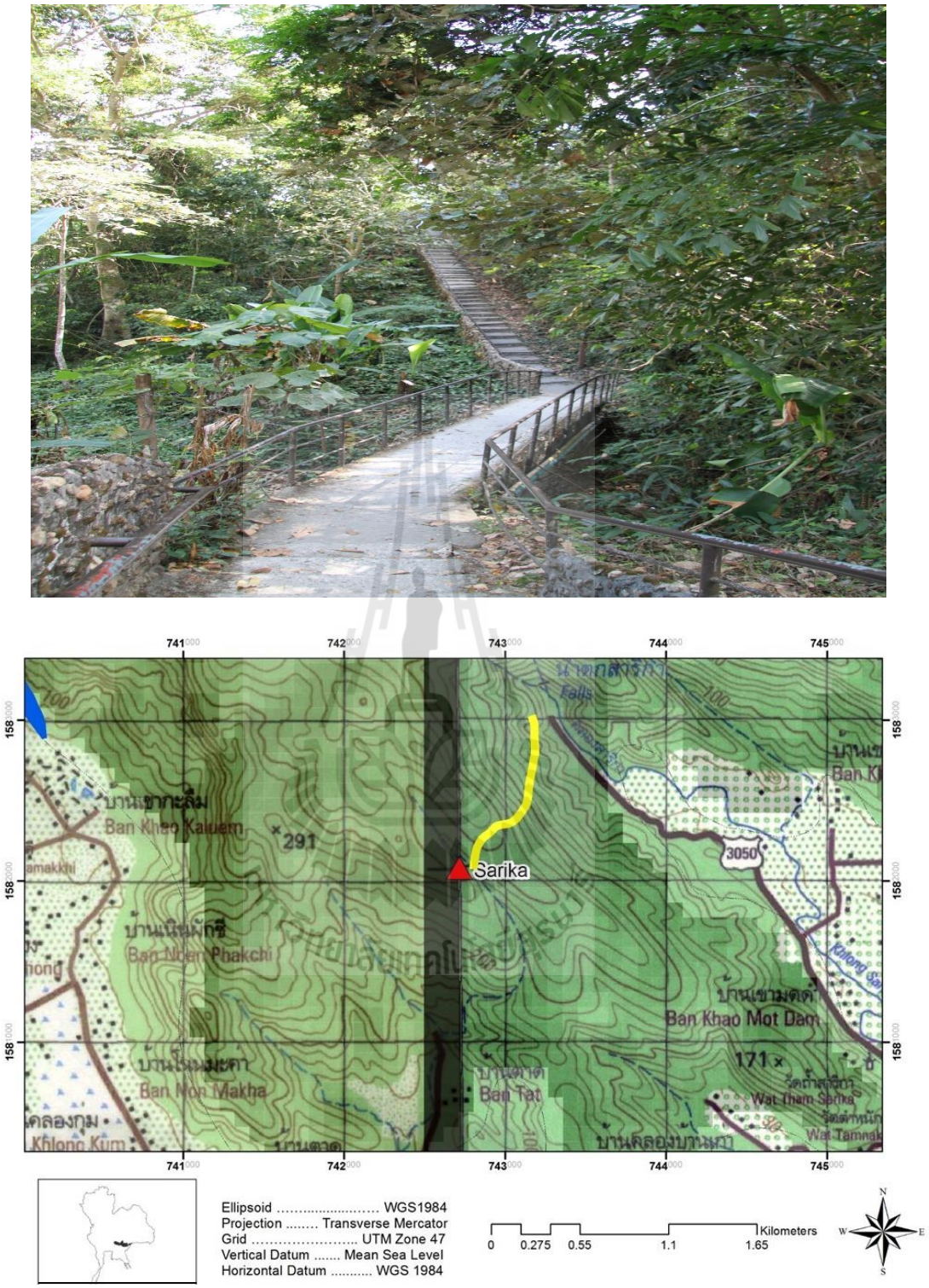
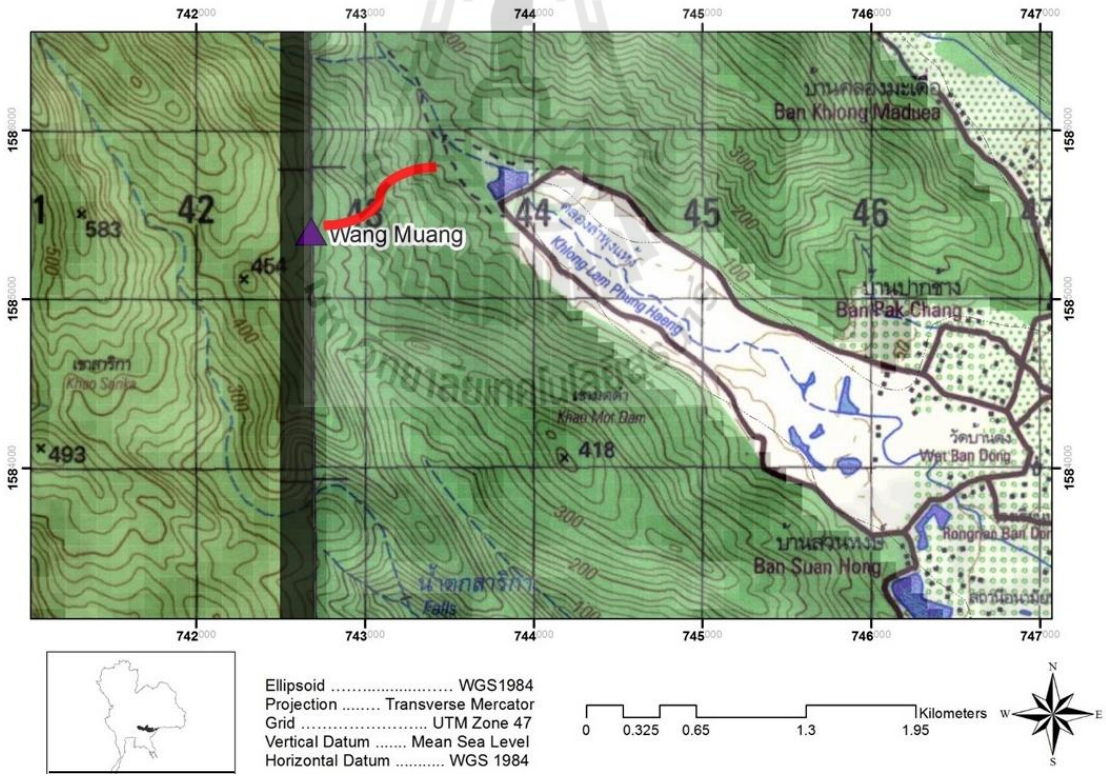


Figure 3.8 The survey trails at Sarika waterfall.



Ellipsoid WGS1984
Projection ..... Transverse Mercator
Grid ..... UTM Zone 47
Vertical Datum ..... Mean Sea Level
Horizontal Datum ..... WGS 1984

Figure 3.9 The survey trail at Wang Muang waterfall.

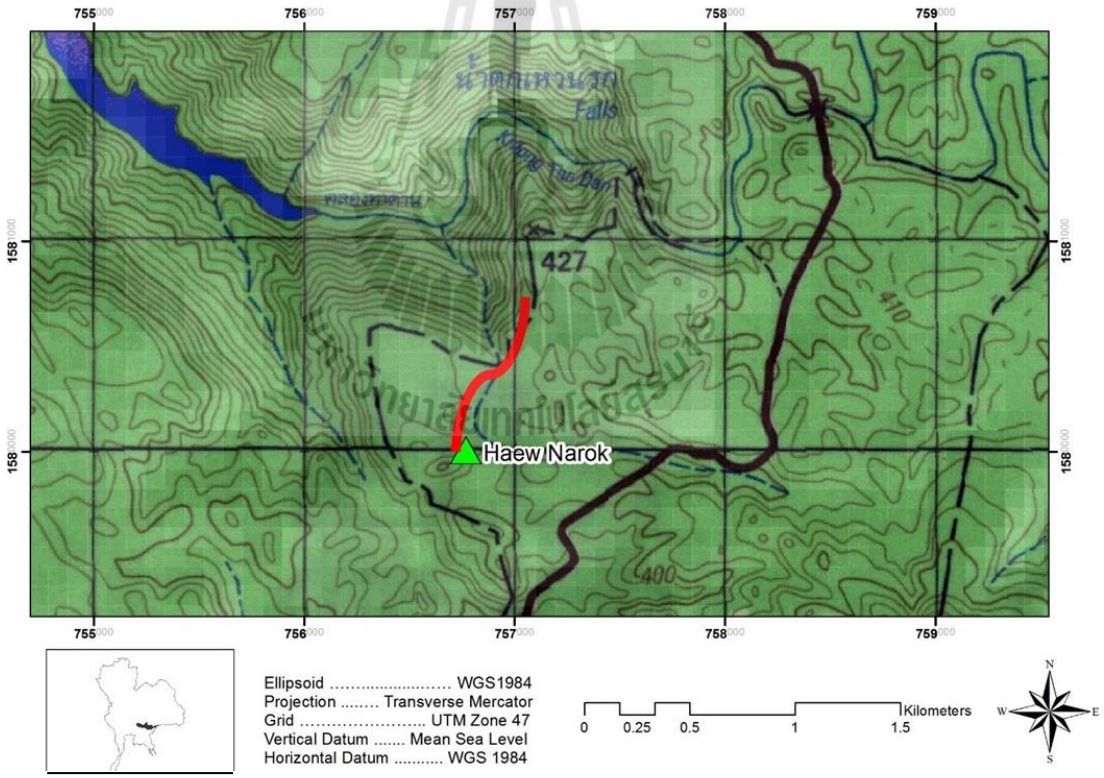


Figure 3.10 The survey trail at Heaw Narok waterfall.

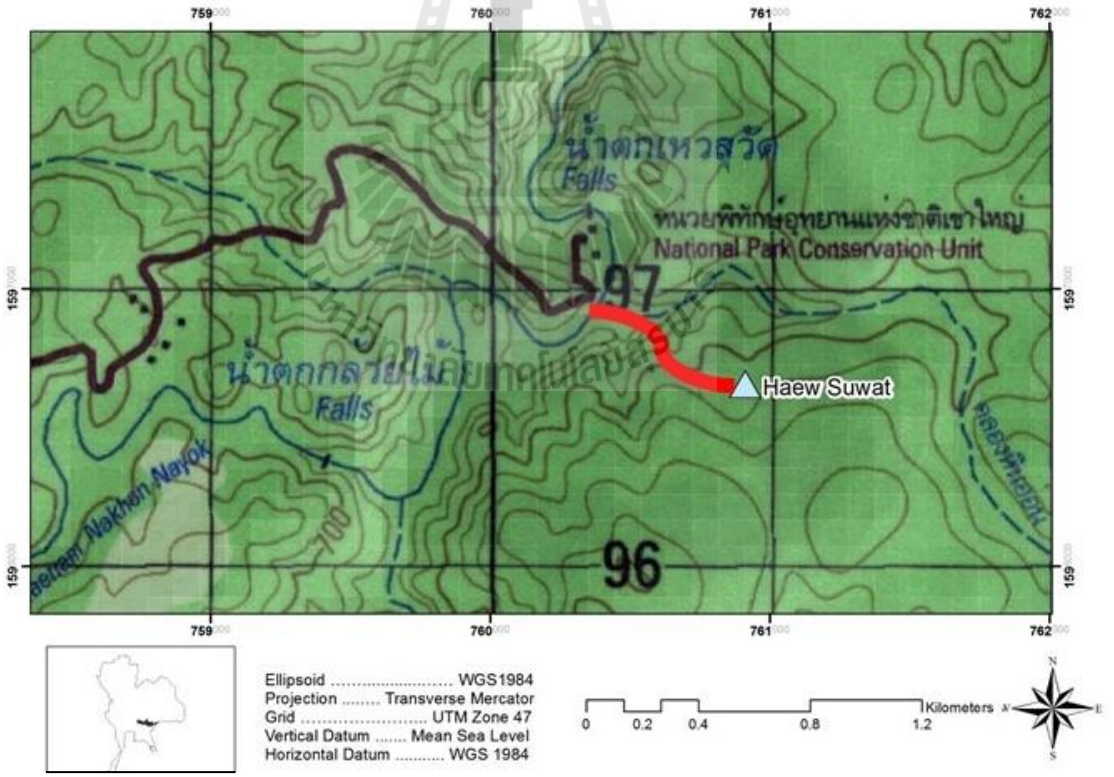


Figure 3.11 The survey trail at Heaw Suwat waterfall.

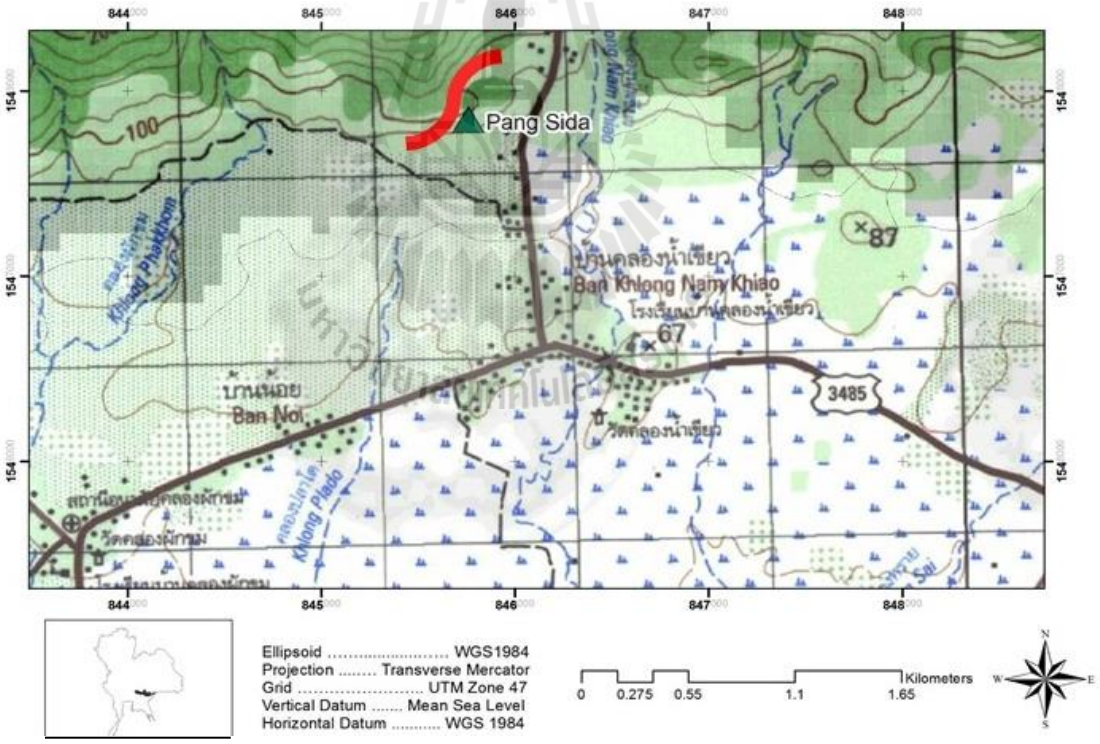


Figure 3.12 The survey trail at Pang Sida waterfall.

Figure 3.13 The survey trail at Huai Yai waterfall.

3.2.2 Bait Trap

All trapping activities were conducted between January and December 2010. The bait trap method (Caldas and Robbins, 2003; Batra, 2004) mainly involves using the traps baited with fermented fishes mixed pineapple (Boonvanno et al., 2000). The baited traps were hung 3-5 m above ground (Figure 3.14) and left for one night before collecting the trapped butterfly. Each line transect had three bait traps hanging at the beginning, middle and end. Each trap was checked two times per day: early morning (7:00-8:00) and late afternoon (15:00-16:00).

Figure 3.14 Butterfly bait trap.

3.2.3 Environmental Data Collection

Air temperature and humidity were recorded locally by a digital thermo-hygrometer (TH-02 Digicon, Japan) while light intensity was recorded by a digital lux meter (MS-1500 Voltcraft, Switzerland) at each transect two times (morning and afternoon) a day during the butterfly survey. Precipitation and climate data were provided from Royal Irrigation Department (Royal Irrigation Department, 2009)

3.2.4 Butterfly Identification

Identification of the butterflies was primarily made directly in the field. In critical condition, specimens were collected only with handheld aerial sweep nets. Each specimen was placed in plastic bags and carried them to the laboratory for further identification with the help of key books like Lekagul et al. (1977), Pinratana (1981, 1983, 1985, 1988), Pinratana and Eliot (1992, 1996) and Ek-amnauy (2006). The observed butterflies were grouped in four categories on the basis of number of individuals in the field. The butterflies were categorized as Very Common (VC= >500 individuals), Common (C=100-500 individuals), Rare (R=10-100 individuals), and Very Rare (VR= <10 individuals) (modified from Pozo et al., 2008).

3.3 Food Preference Experiment

Eight treatments, including fermented fish, fermented pineapple, fermented banana, fermented papaya, fermented watermelon, fish sauce, beer and fermented fish mixed with fermented pineapple, were used for butterfly preference test. Three replicates of each bait were hung 3 m above ground in open areas approximately 500 m apart. The baits were opened for 12 hours from 6:00 to 18:00. All butterflies captured were counted. We conducted the test once a month at two locations, dry

evergreen forest (DEF) at Pang Sida national park and disturbed forest (DF) at Thap Lan National Park, for six months from May to October 2010.

3.4 Data Analysis

3.4.1 Butterfly Diversity Comparison

Shannon-Weiner index, Simpson index, Fisher's alpha index and evenness (Magurran, 1988) were calculated from butterfly data of each site using Species Diversity and Richness version 4.1.2 (Pisces Conservation, 2007) as following.

1) Shannon-Weiner index

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

where H' = Shannon-Wiener index

P_i = The proportion abundance of the *i* species

i = Species 1, 2, 3,….

2) Simpson's index

$$D = \frac{1}{\sum_{i=1}^{S} p_i^2}$$

Where D = Simpson's diversity index

n_i = The proportion abundance of the *i* species

N = Total population abundance of all species

3) Fisher's alpha index

$$S = \alpha \ln\left(1 + \frac{N}{\alpha}\right)$$

Where S = Total number of species in the sample

N = Total number of individuals in the sample

α = Index of diversity

4) Species Evenness

$$J' = \frac{H'}{\ln S}$$

Where J' = Shannon equitability index

H' = Shannon-Weiner index

S = Number of species at each site

Differences in butterfly diversity between morning and afternoon were analyzed using paired t-test. While the difference among sites and months were tested by using one-way analysis of variance (ANOVA) with Duncan as *post hoc* statistics.

3.4.2 Cluster Analysis

Cluster analysis was done to investigate similarity of butterfly communities among waterfalls by using PC-ORD^{TM} version 6 (McCune and Mefford, 2011).

3.4.3 Relationship between Butterfly Diversity and Environmental Factors

The relationship between environmental factors and butterflies diversity by using Spearman rank correlation.

3.4.4 Food Comparison

The different among bait types, months and forest types were tested by multivariate analysis of variance (MANOVA). Duncan was used as *post hoc* statistics to differentiate each of factor.

All statistical tests were done using SPSS 18.0 for Windows.

CHAPTER IV

RESULTS AND DISCUSSIONS

4.1 Environmental Factors

Environmental data were collected from June 2009 to December 2010 (Appendix A). Temperature, relative humidity and light intensity were significantly different among sites but not monthly rainfall (Table 4.1). Huai Yai had the highest mean temperature and light intensity but lowest in humidity because it is in disturbed forest. In contrast, Heaw Narok had the highest humidity since it is in moist evergreen forest at high elevation. However, Pang Sida and Sarika are in dry evergreen forest because they are in lower elevation. All environmental factors were also significantly different among months (Table 4.2).

Table 4.1 Mean (±SE) of environmental factors in 6 waterfall Dong Phayayen-Khao Yai Forest Complex from June 2009 to December 2010 (n=107).

Waterfalls	Forest types	Temperature (ºC)	Humidity (%)	Light intensity (lux)	Rainfall (mm)	Elevation (m)
Pang Sida	DEF	29.1±0.3b	67.2±1.3b	952.9±16.8b	4.7±1.1	176
Heaw Suwat	MEF	27.5±0.4d	71.5±1.3a	884.7±14.1c	5.6±1.2	653
Heaw Narok	MEF	27.8±0.2cd	73.1±1.4a	869.5±18.4c	7.7±1.5	411
Sarika	DEF	28.6±0.3bc	66.0±1.3b	910.1±15.2bc	5.4±1.2	58
Huai Yai	DF	30.0±0.3a	58.6±0.7c	1,034.9±16.7a	2.6±0.5	316
Wang Muang*	DF	28.6±0.3bc	66.7±2.2b	901.3±27.0bc	5.5±1.6	51

Remark: Significant difference at $p < 0.05$ for one-way ANOVA are indicated by different small letter.
* 12 months, DEF = Dry evergreen forest, MEF = Moist evergreen forest, DF = Disturbed forest

Table 4.2 Average (±SE) environmental factors in each months from June 2009 to December 2010 (n=107).

Month	Temperature (°C)	Humidity (%)	Light intensity (lux)	Rainfall (mm)
Jun-09	27.2±1.4cde	69.9±3.3a	964.5±55.3abc	4.8±0.5ef
Jul-09	29.7±0.4a	69.5±2.7a	914.9±45.8bcde	4.0±1.2efg
Aug-09	29.6±0.4a	69.7±2.4a	929.0±35.7abcde	9.2±1.4bcd
Sep-09	29.6±0.4a	69.7±2.7a	928.5±30.2abcde	16.2±2.2a
Oct-09	29.2±0.4a	70.0±2.9a	935.7±26.3abcd	7.3±1.5bbcde
Nov-09	28.6±0.3abcd	70.3±2.6a	968.7±21.7abc	1.6±0.6fg
Dec-09	28.7±0.6abc	66.8±2.5a	966.4±43.2abc	0.0g
Jan-10	26.7±0.3e	62.8±1.6ab	831.3±28.8de	0.0g
Feb-10	29.0±0.7ab	64.3±2.6ab	819.0±19.9e	0.6±.02fg
Mar-10	29.4±0.4a	56.9±1.1b	852.0±37.00cde	3.0±0.8efg
Apr-10	29.0±0.8ab	57.7±1.6b	987.8±23.3ab	3.9±0.5efg
May-10	29.5±0.5a	71.5±3.1a	943.5±40.9abcd	6.4±1.3cde
Jun-10	29.0±0.3ab	68.8±3.6a	1,042.5±12.3a	9.6±2.6bc
Jul-10	28.6±0.4abcd	71.4±2.6a	896.1±53.6bcde	10.2±2.4bc
Aug-10	28.8±0.5abc	69.4±2.7a	936.6±26.9abcd	6.9±1.1bcde
Sep-10	28.9±0.4abc	69.7±2.7a	926.2±27.6abcde	11.1±2.4b
Oct-10	27.3±0.3bcde	71.0±2.8a	915.3±41.2bcde	5.0±0.5def
Nov-10	27.9±0.3abcde	66.4±3.6a	924.9±29.8abcde	1.3±0.3fg
Dec-10	27.0±0.3de	63.6±2.5ab	952.8±32.9abc	0.1±0.1g

Remark: Significant difference are indicated by different small letter at $p < 0.05$ for one-way ANOVA.

The mean monthly temperature were significant difference ($F=3.1$, $p<0.01$) (Table 4.2). Mean of temperature was the highest (28.6 °C) in Wang Muang waterfall and the lowest (27.5 °C) in Heaw Suwat waterfall. July 2009 was the highest temperature (29.7 °C) while the lowest was in January 2010 (26.7 °C; Figure 4.1).

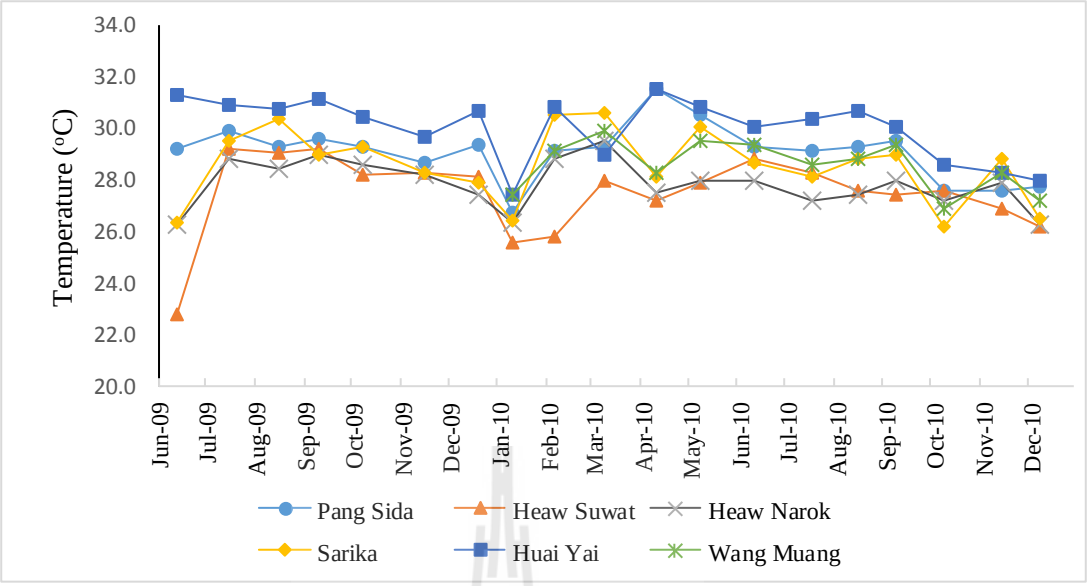


Figure 4.1 The average temperature in 6 waterfalls.

Mean of relative humidity was the highest (73.1 %) in Heaw Narok waterfall and the lowest (58.6 %) in Huai Yai waterfall. The highest mean relative humidity was in May (71.5 %) while the lowest was in March (56.9 %; Figure 4.2).

For light intensity, Huai Yai waterfall had the highest of 1,034.9 lux while Heaw Narok waterfall had the lowest of 869.5 lux. The highest mean of light intensity was in June 2010 (1042.50 lux) while the lowest was in February 2010 (819.00 lux; Figure 4.3).

The monthly rainfall between 0-11.06 mm. Heaw Narok waterfall had the highest of 7.7 mm while Huai Yai waterfall had the lowest of 2.6 mm. The highest monthly rainfall was in August 2010 (11.1 mm) while the lowest was in January (0.0 mm; Figure 4.4).

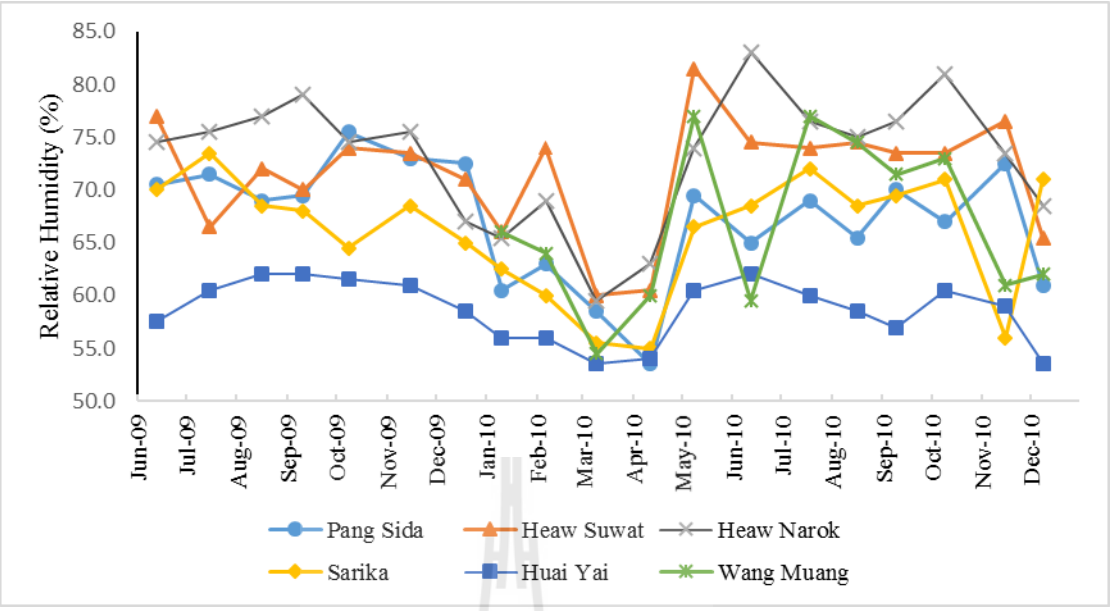


Figure 4.2 The average relative humidity in 6 waterfalls.

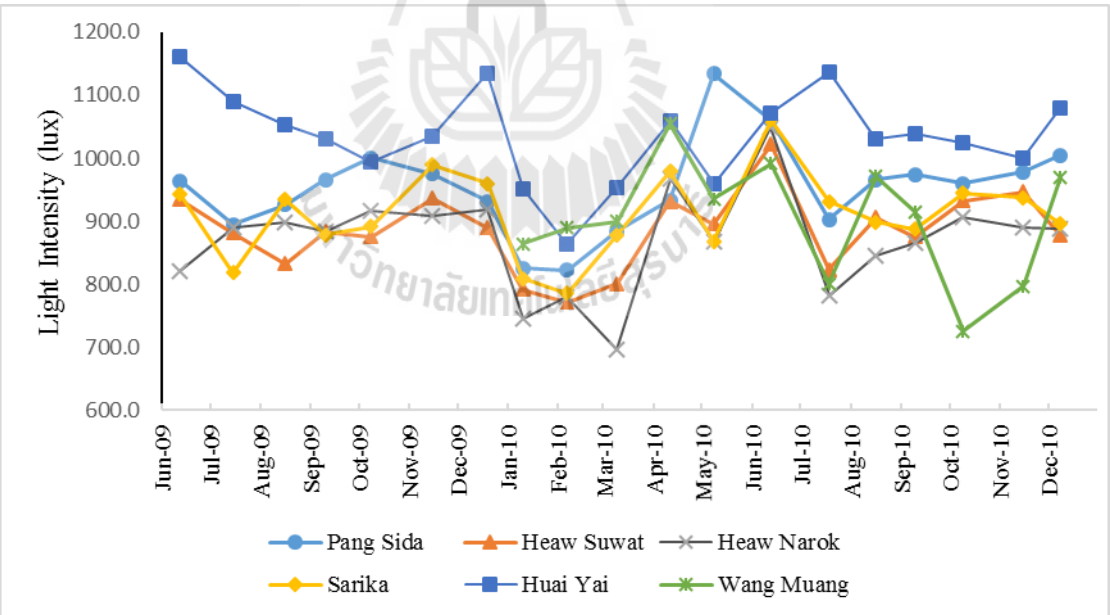


Figure 4.3 The average light intensity in 6 waterfalls.

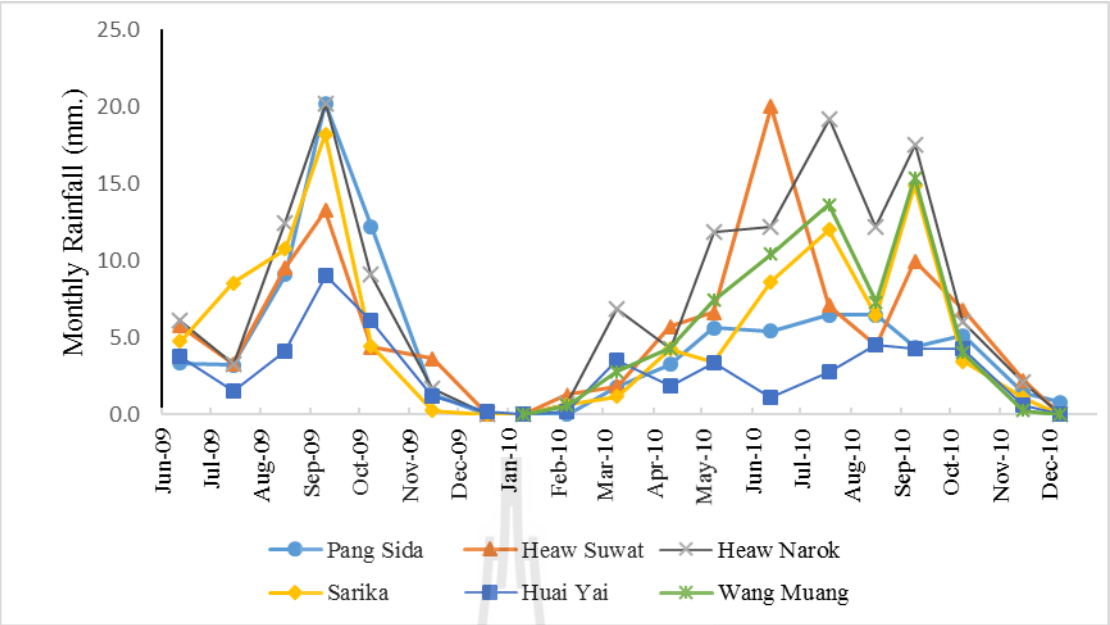


Figure 4.4 The monthly rainfall in 6 waterfalls.

4.2 Butterfly Diversity and Abundance

4.2.1 Total Number of Butterfly Species and Individual

After 19 months of sampling, a total of 306 species (Table 4.3) and 37,584 individuals (Table 4.4) were identified from six waterfalls in Dong Phayayen-Khao Yai Forest Complex World Heritage. The highest number of species and individuals were found in Pang Sida waterfall while Wang Muang waterfall had the lowest. Moreover, 303 species (33,098 individuals) were recorded during line transect sampling but only 91 species (4,486 individuals) were recorded in bait traps. However, three species were found only in bait traps.

Table 4.3 Total number of species of butterflies in 6 waterfalls at Dong Phayayen-Khao Yai Forest Complex World Heritage.

Waterfalls	Jun-Dec 2009	Jan-Dec 2010			Grand Total
	Transect	Transect	Bait Trap	Total	
Pang Sida	165	224	74	228	244
Heaw Suwat	139	177	42	182	201
Heaw Narok	124	159	48	167	195
Sarika	139	171	36	172	193
Huai Yai	107	146	33	155	169
Wang Muang	-	133	28	139	139
Total	165	288	91	291	306

Table 4.4 Total number of individual of butterflies in 6 waterfalls at Dong Phayayen-Khao Yai Forest Complex World Heritage.

Waterfalls	Jun-Dec 2009	Jan-Dec 2010			Grand Total
	Transect	Transect	Bait Trap	Total	
Pang Sida	4,214	6,653	1,213	7,866	12,080
Heaw Suwat	3,494	5,872	912	6,784	10,278
Heaw Narok	2,315	2,928	694	3,622	5,937
Sarika	1,605	2,606	661	3,267	4,872
Huai Yai	1,012	1,439	492	1,931	2,943
Wang Muang	-	960	514	1,474	1,474
Total	12,640	20,458	4,486	24,944	37,584

As a result, the number of butterfly species which were closed the study of Suwanwaree and Lapkratok (2010), which surveyed the butterflies in Environmental Research Station Sakaerat. In this study was found 304 species of butterflies. However it was less than the survey of Choldumrongkul and Chumnarnkid (1998), which conducted at Chern watershed area, Namnao National Park during October

1996 to September 1997 found 326 species to surveyed butterfly diversity every week. Boonvanno et al. (2000) had conducted butterfly diversity at Ton Nga-Chang Wildlife Sanctuary, Songkhla Province for one year from June 1997 to the month of May 1998. They found 147 species, which less than this study. Also, Ratiwiriyapong (2004) found 138 butterfly species Pha Kluai Mai Heae Suwat waterfall nature trail made bimonthly for period of one year during March 2002 to February 2003. Form the study in both areas, the number of butterfly species and individuals were less than six waterfalls at Dong Phayayen-Khao Yai Forest Complex World Heritage due to many reasons, such as the survey duration, survey methods, habitat types, or food plants for the caterpillars in each area.

4.2.2 Butterfly Diversity Indices

For Shannon-Weiner diversity index, Pang Sida waterfall had the highest while Wang Muang waterfall had the lowest (Table 4.5). Pang Sida waterfalls had the highest Simpson's index whereas the lowest was Wang Muang waterfall. Fisher's alpha index index was also highest in Pang Sida waterfall but Heaw Suwat waterfall had the lowest. The highest evenness was still found in Pang Sida waterfall while Wang Muang had the lowest.

Table 4.5 Diversity index of butterflies in Dong Phayayen-Khao Yai forest.

Waterfalls	Shannon-Weiner (*H'*)	Simpson's (D)	Fisher's alpha (S)	Species Evenness (*J'*)
Pang Sida	4.449	60.046	43.340	0.777
Heaw Suwat	4.383	57.817	35.456	0.766
Heaw Narok	4.302	49.971	38.729	0.752
Sarika	4.375	50.895	40.192	0.764
Huai Yai	4.291	45.958	39.002	0.749
Wang Muang	4.187	39.988	37.602	0.731
Total	4.531	62.372	45.587	0.792

4.2.3 Butterfly Species Composition

From 306 species found, family Nymphalidae had the highest proportion of 38 %, followed by Lycaenidae (22.5 %), Hesperiidae (21.5 %), Pieridae (8.8 %) and Papilionidae (8.8 %), respectively (Table 4.6). Nymphalidae is the largest family. Around 6,000 species are found worldwide and 401 species were found in Thailand (Ek-amnauy, 2006). Boonvanno et al. (2000) and Choldumrongkul and Chumnarnkid (1998) also found the highest butterfly species in family Nymphalidae, while the least common family varied from different studies.

Table 4.6 Total number of butterfly species and individual in five families from 6 waterfalls at Dong Phayayen-Khao Yai Forest Complex World Heritage.

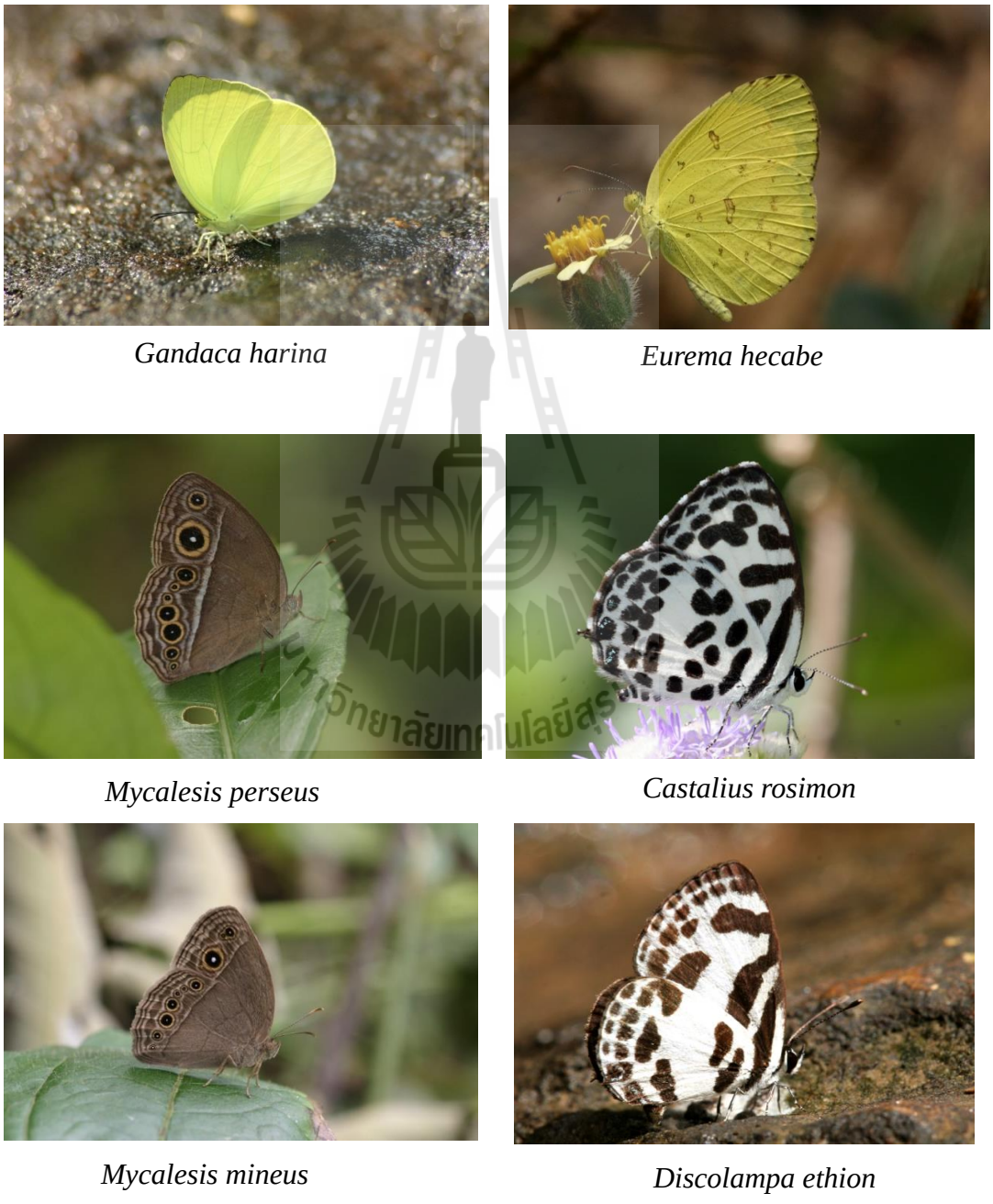
Family	Number of Species	Number of Individual
Papilionidae	27	4,647
Pieridae	27	8,954
Nymphalidae	117	13,449
Lycaenidae	69	10,017
Hesperiidae	66	517

Among 306 butterfly species, 24 species were very common (> 500 individuals, Table 4.7), 53 species were common (100-500 individuals), 105 species were rare (10-100 individuals) and 124 species were very rare (1-10 individuals, Appendix B1).

Table 4.7 The most common butterflies in 6 waterfalls at Dong Phayayen-Khao Yai Forest Complex World Heritage.

No.	Common name	Scientific name	Number of individual
1	Tree Yellow	*Gandaca harina*	1,374
2	Common Grass Yellow	*Eurema hecabe*	1,207
3	Common Bushbrown	*Mycalesis perseus*	1,172
4	Common Pierrot	*Castalius rosimon*	1,156
5	Dark-brand Bushbrown	*Mycalesis mineus*	1,107
6	Banded Blue Pierrot	*Discolampa ethion*	1,099
7	Common Ciliate Blue	*Anthene emolus*	1,081
8	Anderson's Grass Yellow	*Eurema andersonii*	973
9	Straight Pierrot	*Caleta roxus*	947
10	Dark-based Lineblue	*Prosotas gracilis*	877
11	Common Albatross	*Appias albina*	873
12	Common Indian Crow	*Euploea core*	850
13	Common Lineblue	*Prosotas nora*	809
14	Pointed Ciliate Blue	*Anthene lycaenina*	791
15	Magpie Crow	*Euploea radamanthus*	782
16	Dark Blue Tiger	*Tirumala septentrionis*	673
17	Common jay	*Graphium doson*	649
18	Orange Gull	*Cepora iudith*	607
19	Banded Lineblue	*Prosotas lutea*	607
20	Common Bluebottle	*Grapium sarpedon*	595
21	Plain Puffin	*Appias indra*	588
22	Blue King Crow	*Euploea camaralzeman*	561
23	Lesser Gull	*Cepora nadina*	549
24	Paris peacock	*Papilio paris*	537

The most abundant species was *Gandaca harina* with 1,374 individuals (3.7 % of all individuals), followed by *Eurema hecabe* (3.2 %), *Mycalesis perseus* (3.1 %), *Castalius rosimon* (3.1 %), *Mycalesis mineus* (2.9 %), *Discolampa ethion* (2.9 %) and *Anthene emolus* (2.9 %), respectively (Figure 4.5).



Gandaca harina *Eurema hecabe*

Mycalesis perseus *Castalius rosimon*

Mycalesis mineus *Discolampa ethion*

Figure 4.5 The most common butterflies in 6 waterfalls.

In contrast, 41 species were found only one individual including one species in family Papilionidae and Pieridae, 6 species in Nymphalidae, 10 species in Lycaenidae and 23 species in Hesperiidae (Table 4.8). Most of them were found in Pang Sida waterfall (11 species), followed by Heaw Narok (8 species) and Heaw Suwat waterfalls (7 species), respectively.

Table 4.8 List of butterfly species found only one individual in 6 waterfalls.

No.	Family	Common name	Scientific name	Waterfalls
1	Papilionidae	Burmese Batwing	*Parides zaleucus*	Heaw Suwat
2	Pieridae	Orange Albatross	*Appias nero*	Pang Sida
3	Nymphaldae	Yellow Glassy Tiger	*Parantica aspasia*	Heaw Narok
4		Long-Branded Bushbrown	*Mycalesis visala*	Sarika
5		Blue Pansy	*Junonia orithya*	Pang Sida
6		Tiger Lascar	*Lasippa monata*	Heaw Suwat
7		Malay Staff Sergeant	*Athyma reta*	Pang Sida
8		Common Courtesan	*Euripus nyctelius*	Huai Yai
9	Lycaenidae	Mixture Blue Brilliant	*Simiskina pediata*	Heaw Narok
10		Lesser Darkie	*Allotinus substrigosus*	Pang Sida
11		Vinous Oakblue	*Arhopala athada*	Pang Sida
12		Rededge	*Semanga superba*	Pang Sida
13		Common Silverline	*Spindasis vulcanus*	Heaw Narok
14		Brown Yam	*Drina donina*	Heaw Narok
15		Dark Posy	*Drupadia theda*	Pang Sida
16		Small Branded Royal	*Bullis stigmata*	Heaw Narok
17		Banded Royal	*Eliotia jalindra*	Pang Sida
18		Plush	*Sithon nedymond*	Huai Yai
19	Hesperiidae	Common Banded Awl	*Hasora chromus*	Wang Muang
20		Common Spotted Flat	*Celaenorrbinus leucocera*	Huai Yai
21		Himalayan Spotted Flat	*Celaenorrhinus munda*	Heaw Narok
22		Small baned Flat	*Celaenorrhinus nigricans*	Heaw Suwat
23		Unequal Banded Flat	*Celaenorrhinus inaequalis*	Heaw Suwat
24		Striated Angle	*Darpa striata*	Heaw Narok
25		Variable White Flat	*Gerosis phisara*	Pang Sida
26		Large White Flat	*Satarupa gopala*	Heaw Suwat

Table 4.8 List of butterfly species found only one individual in 6 waterfalls (Continued).

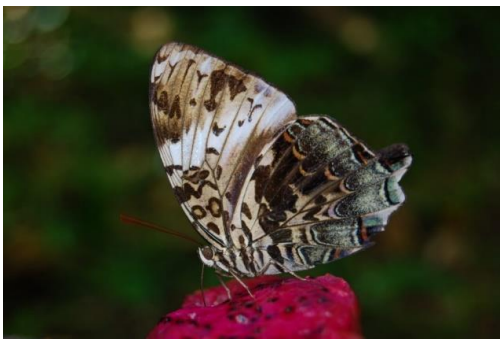
No.	Family	Common name	Scientific name	Waterfalls
27		Spotted Angle	*Caprona agama*	Huai Yai
28		Common Bush Hopper	*Ampittia dioscorides*	Huai Yai
29		Northern Ace	*Thoressa cerata*	Heaw Suwat
30		Silverbreast Ace	*Sovia albipecta*	Huai Yai
31		Red Demon	*Ancistroiedes armatus*	Sarika
32		Indian Plam Bob	*Suastus gremius*	Huai Yai
33		Wax Dart	*Cupitha purreea*	Wang Muang
34		Silver-spot Lancer	*Plastingia naga*	Sarika
35		Lesser Lancer	*Pyroneuea flavia*	Pang Sida
36	Hesperiidae	Hoary Palmer	*Unkana ambasa*	Heaw Narok
37		Orange Dart	*Potanthus chloe*	Heaw Suwat
38		Narrow-banded Plam Dart	*Telicota ohara*	Sarika
39		Conjoined Swift	*Pelopidas assamensis*	Wang Muang
40		Lesser Rice Swift	*Borbo bevani*	Pang Sida
41		Common Wight	*Iton semamora*	Wang Muang

Moreover, 23 butterfly species found in this study are under the Thailand Wildlife Protection Act, 1992 (Table 4.9 and Figure 4.6). Most of them were found in Pang Sida waterfall (20 species), followed by Heaw Suwat (18 species), Sarika (16 species), Heaw Narok (14 species), Huai Yai (12 species) and Wang Muang (11 species) waterfalls, respectively. However, one endangered species was listed in the CITES Appendix II, *Troides aeacus* was also found in this study.

The occurrence of rare and under the Thailand Wildlife Protection Act, 1992 species may provide important information for conservation, but a more accurate and rapid assessment of the condition of the habitat may be obtained by monitoring a carefully selected group of locally common species.

Table 4.9 List of butterflies in Wild Animal Reservation and Protection Act, 1992.

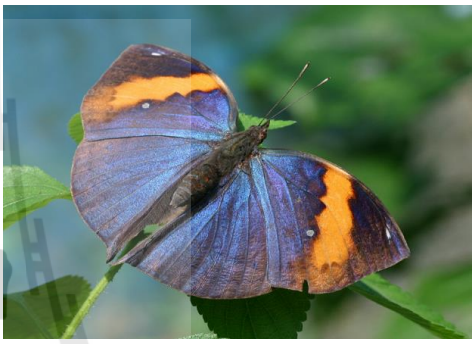
No.	Common name	Scientific name	Number on individuals
1	Common Bluebottle	*Grapium sarpedon*	595
2	Paris peacock	*Papilio paris*	537
3	Black and White	*Papilio nephelus*	411
4	Red Helen	*Papilio Helenus*	328
5	Fivebar Swordtail	*Graphium antiphates*	247
6	Large Assyrian	*Terinos atlita*	113
7	Royal Assyrian	*Terinos terpander*	83
8	Banded Swallotail	*Papilio demolion*	63
9	Great Nawab	*Polyura eudamippus*	60
10	Orange Oakleaf	*Kallima inachus*	53
11	Koh-i-noor	*Amathuxidia amythaon*	50
12	Blue Begum	*Prothoe franck*	34
13	Common Palmking	*Amathusia phidippus*	29
14	Common Archduke	*Lexias pardalis*	28
15	Jewelled Nawab	*Polyura delphis*	21
16	Fourbar Swordtail	*Graphium agetes*	17
17	Autumn Leaf	*Doleschallia bisaltide*	15
18	Great Archduke	*Lexias cyanipardus*	14
19	Golden Birdwing	*Troides aeacus*	12
20	Blue Kaiser	*Penthema darlisa*	4
21	Common Saturn	*Zeuxidia amethystus*	3
22	Lurcher	*Yoma sabina*	2
23	Burmese Batwing	*Parides zaleucus*	1



Prothoe franck

Parides zaleucus

Amathuxidia amythaon



Kallima inachus

Lexias pardalis

Penthema darlisa

Figure 4.6 Butterfly species are rare and under the Thailand Wildlife Protection Act, 1992

Eighty nine species of 306 species detected were found at all waterfalls but 59 species were found only at one site (Table 4.10). Seventy eight percent of butterfly

species (239 species) were found in open areas while 22 % (72 species) mostly in family Nymphalidae were found in closed areas (Appendix A1.).

Table 4.10 List species of butterflies found only in one site.

Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang
Delias pasithoe	*parides zaleucus*	*Parantica aspasia*	*Mycalesis visala*	*Euripus nyctelius*	*Hasora chromus*
Appias lalage	*Penthema darlisa*	*Simiskina pediata*	*Zizeeria maha*	*Sithon nedymond*	*Halpe flava*
Appias pandione	*Lasippa monata*	*Spindasis vulcanus*	*Ancistroiedes armatus*	*Celaenorrbinus leucocera*	*Cupitha sakawa*
Eurema simulatrix	*Heliophorus epicles*	*Bullis stigmata*	*Telicota ohara*	*Sovia albipecta*	*Iton semamora*
Junonia orithya	*Celaenorrhinus nigricans*	*Celaenorrhinus munda*	*Plastingia naga*	*Suastus gremius*	*Pithauria murdava*
Yoma sabina	*Celaenorrhinus inaequalis*	*Darpa striata*		*Caprona agama*	*Pelopidas assamensis*
Athyma zeroca	*Thoressa cerata*	*Drina donina*		*Ampittia dioscorides*	
Euthalia teuta	*Potanthus chloe*	*Unkana ambasa*			
Allotinus substrigosus	*Megisba malaya*				
Arhopala athada	*Satarupa gopala*				
Semanga superba	*Graphium agetes*				
Drupadia theda					
Eliotia jalindra					
Bindahara phocides					
Odina decorata					
Pyroneuea flavia					
Borbo bevani					
Appias nero					
Athyma reta					
Arhopala atosia					
Yasoda tripunctata					
Gerosis phisara					

In Pang Sida waterfall, the most abundant butterfly was *Gandaca harina* (480 individuals, Appendix A1), followed by *Eurema hecabe* (379 individuals), *Mycalesis perseus* (378 inudividals), *Appias albino* (338 individuals), *Castalius rosimon* (334 individuals), *Discolampa ethion* (305 individuals), and *Mycalesis mineus* (301 individuals). Moreover, 22 species were found only in this site (Table 4.8).

In Haew Suwat watwefall, the most abundant butterfly was *Prosotas gracilis* (344 individuals), followed by *Caleta roxus* (322 individuals), *Anthene emolus* (316 individuals), *Anthene lycaenina* (305 individuals), and *Gandaca harina* (302 individuals). Eleven species were found only in this site.

In Haew Narok waterfall, *Euploea core* (243 individuals) was the most abundant butterfly, followed by *Euploea radamanthus* (232 individuals), *Tirumala septentrionis* (231 individuals), *Anthene emolus* (221 individuals), *Gandaca harina* (205 individuals) and *Castalius rosimon* (200 individuals). Eight species were found only in this site.

In Sarika waterfall, *Mycalesis perseus* (226 individuals) was the most abundant butterfly, followed by *Eurema hecabe* (223 individuals), *Gandaca harina* (211 individuals), and *Anthene emolus* (204 individuals). Five species were found only in this site.

In Huai Yai waterfall, the most of abundant butterfly was *Mycalesis perseus* (160 individuals), followed by *Eurema andersonii* (139 individuals), *Mycalesis mineus* (137 individuals), *Castalius rosimon* (132 individuals), *Eurema hecabe* (131 individuals), *Discolampa ethion* (114 individuals), and *Gandaca harina* (102 individuals). Seven species were found only in this site.

And Wang Muang waterfall, the most of abundant butterfly was *Mycalesis mineus* (115 individuals), *Mycalesis perseus* (88 individuals), *Gandaca harina* (74 individuals), *Melanitis leda* (73 individuals), *Discolampa ethion* (60 individuals), *Melanitis phedima* (57 individuals) and *Anthene emolus* (51 individuals). Six species were found only in this site.

Pang Sida waterfall had the highest butterfly diversity, since it probably had more moisture, food, and refugee plants for butterflies.

4.3 Relationship between Environmental Factors and Butterfly Diversity

Temperature was significantly negative correlated with both butterfly species and individual. While relative humidity and elevation were significantly positive correlated with butterfly species and individual but rainfall and light intensity did not (Table 4.11; Figure 4.7-4.16).

Table 4.11 Relationship between environmental factors and butterfly diversity using Spearman rank correlation in 6 waterfalls from June 2009 to December 2010 (n=107).

	Number of species	Number of individuals
Temperature	-0.280**	-0.261**
Relative humidity	0.244*	0.344**
Light intensity	-0.123	-0.182
Monthly rainfall	-0.097	-0.028
Elevation	0.248*	0.405**

* Significant level at 0.05
** Significant level at 0.01

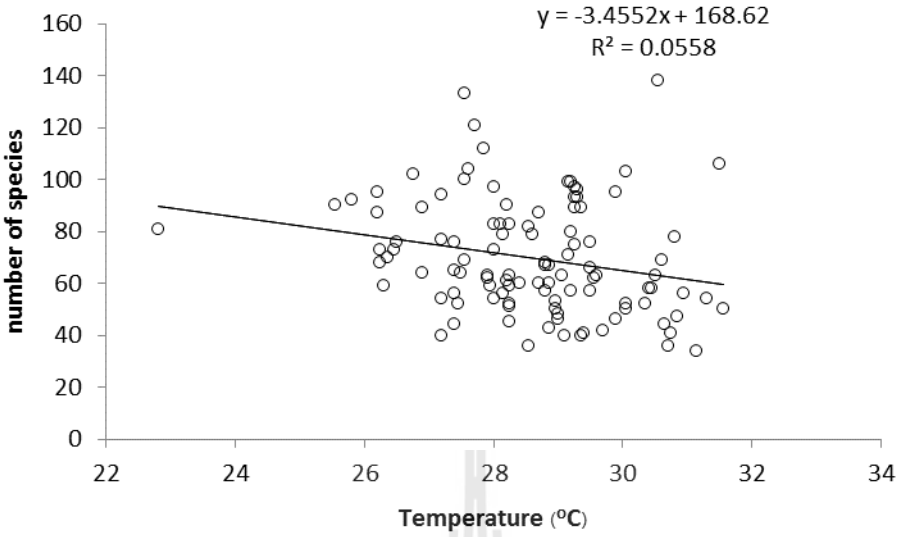


Figure 4.7 The relationship between temperature and number of butterfly species (n=107).

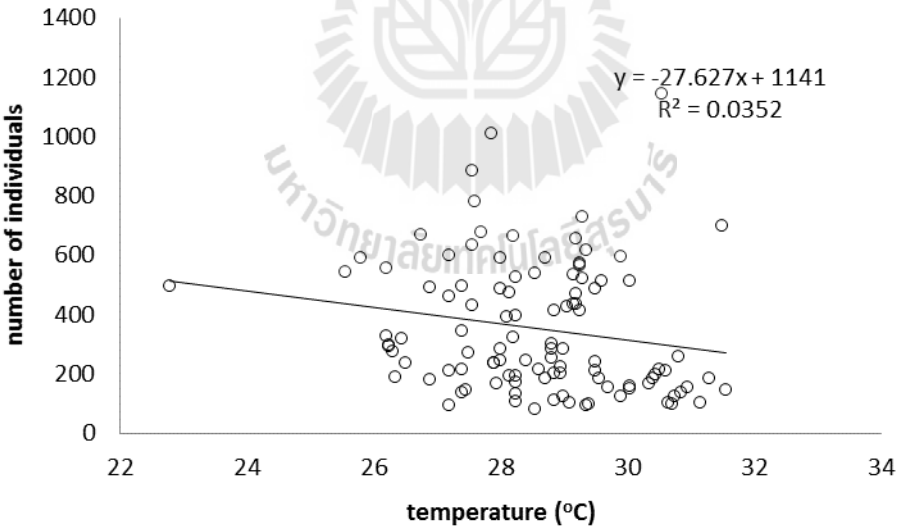


Figure 4.8 The relationship between temperature and number of butterfly individuals (n=107).

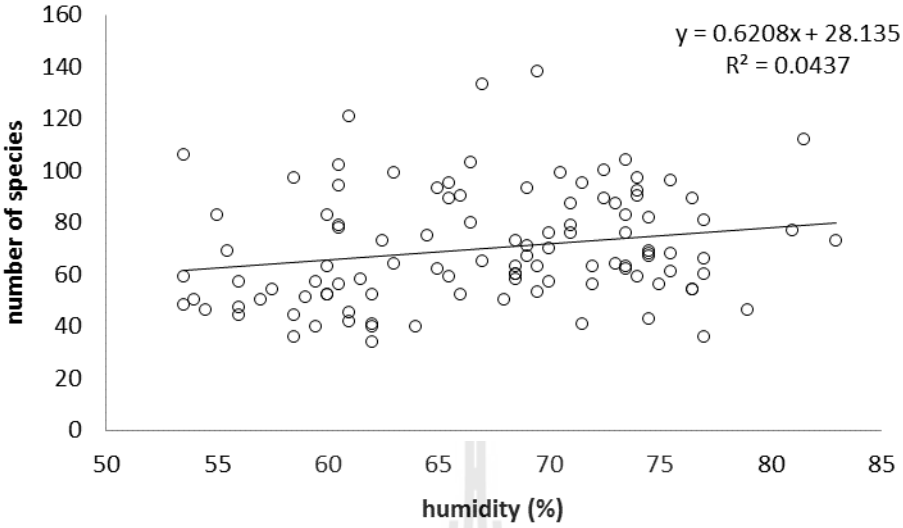


Figure 4.9 The relationship between humidity and number of butterfly species (n=107).

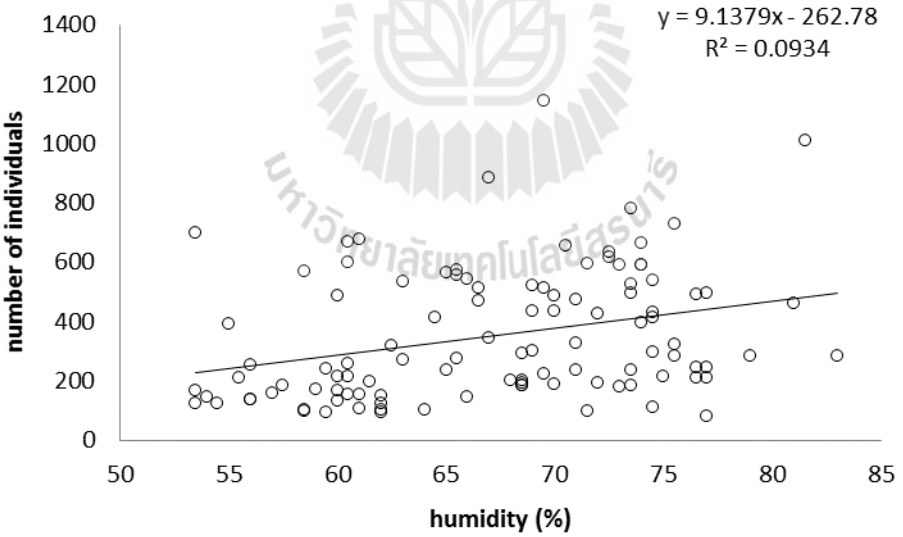


Figure 4.10 The relationship between humidity and number of butterfly individuals (n=107).

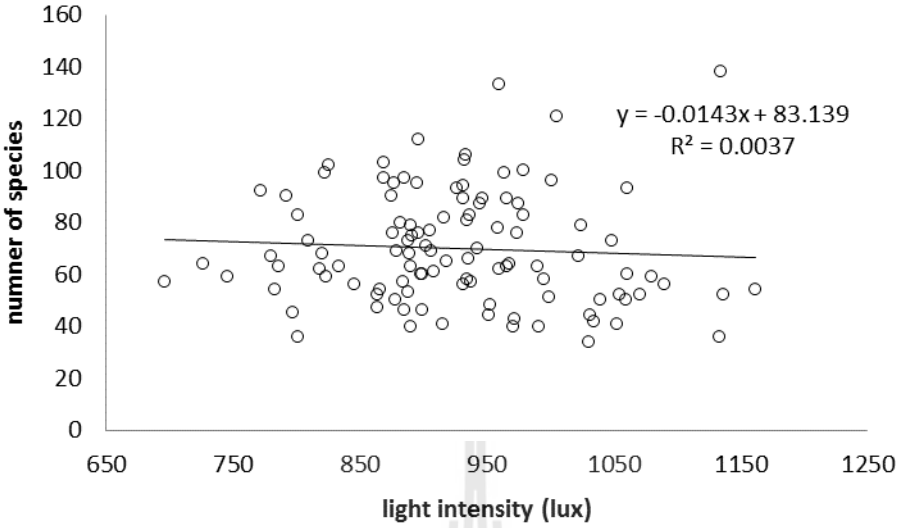


Figure 4.11 The relationship between light intensity and number of butterfly species (n=107).

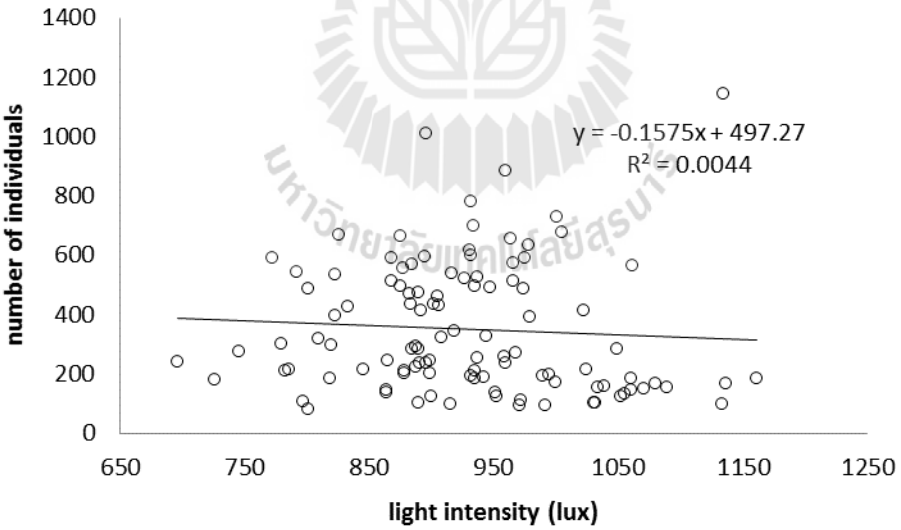


Figure 4.12 The relationship between light intensity and number of butterfly individuals (n=107).

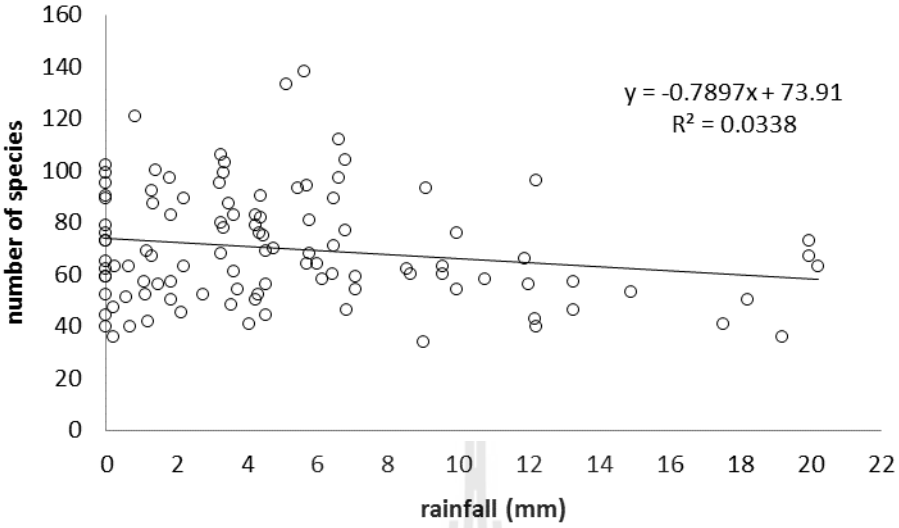


Figure 4.13 The relationship between monthly rainfall and number of butterfly species (n=107).

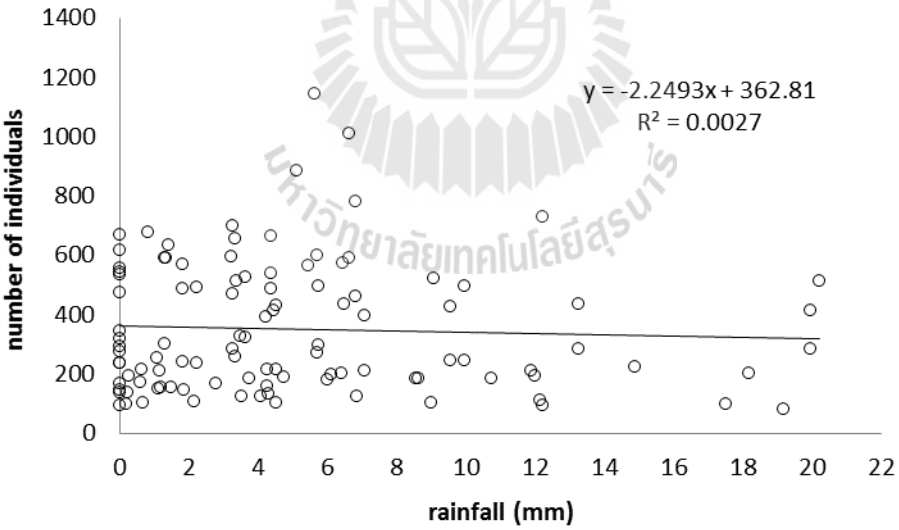


Figure 4.14 The relationship between monthly rainfall and number of butterfly individuals (n=107).

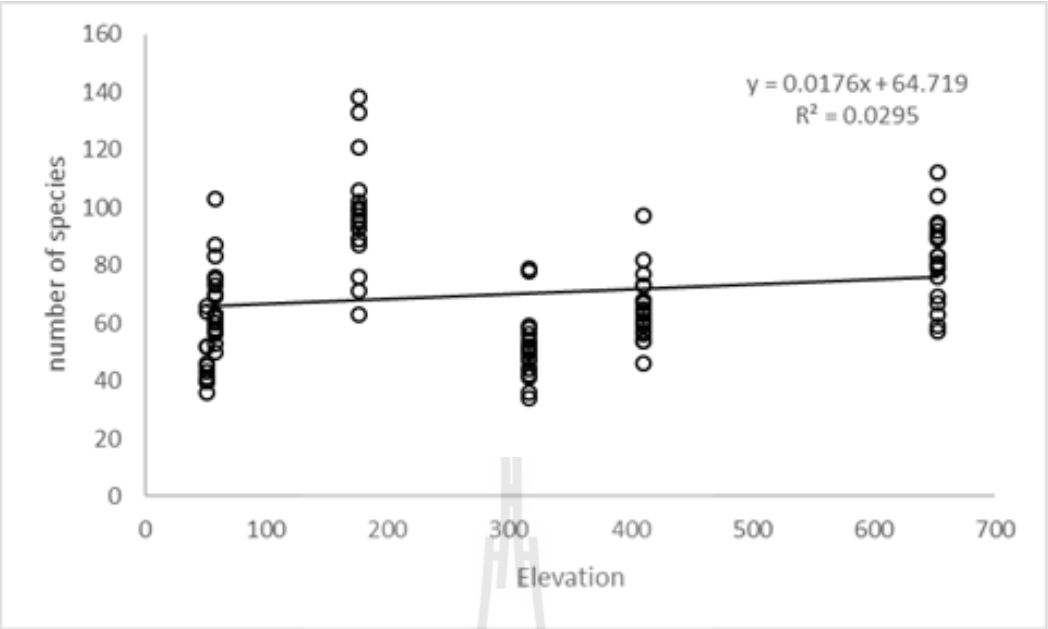


Figure 4.15 The relationship between elevation and number of butterfly species (n=107).

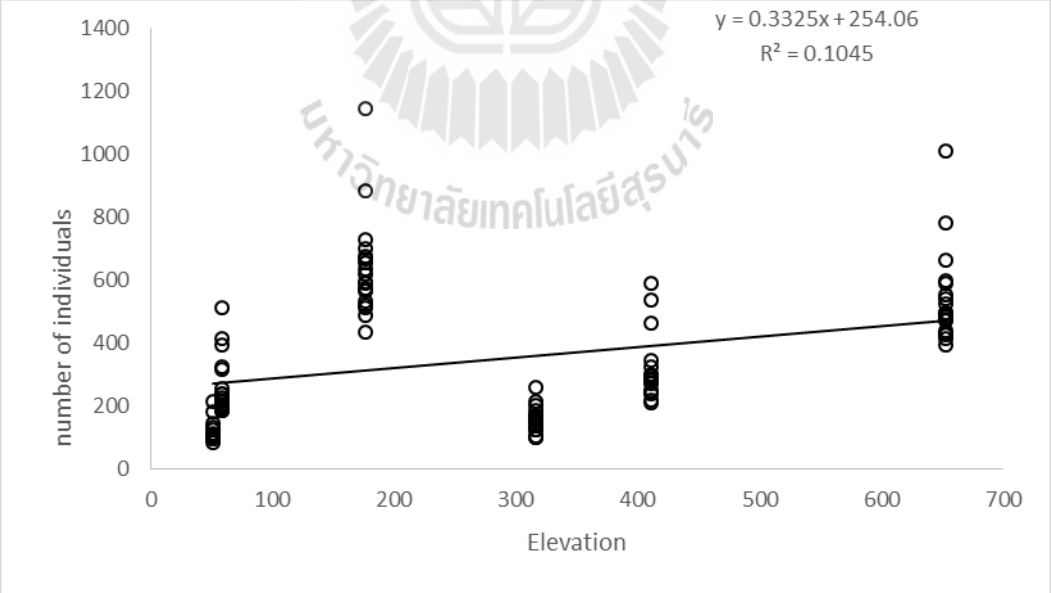


Figure 4.16 The relationship between elevation and number of butterfly individuals (n=107).

4.4 Butterflies Differ among Sites

Only line transect and bait traps data from June 2009 to December 2010 were used in these analyses. The means of butterfly species and individual were significantly different among six waterfalls ($F=23.2$, $p<0.01$; $F=36.5$, $p<0.01$, respectively). Pang Sida waterfall still had the highest mean butterfly diversity and individual, followed by Haew Suwat, Haew Narok, Sarika, Huai Yai and Wang Muang waterfalls, respectively (Table 4.12).

Table 4.12 The total and mean (±SE) per sampling date of butterfly species and individual at 6 waterfalls in Dong Phayayen-Khao Yai Forest Complex World Heritage from June 2009 to December 2010 (n=107).

Waterfalls	Total		Mean/sampling	
	Species	Individuals	Species	Individuals
Pang Sida	244	12,080	97.2±4.3a	635.8±36.6a
Heaw Suwat	201	10,278	82.3±3.4b	541.0±33.8b
Heaw Narok	195	5,937	65.5±2.7c	312.5±24.0c
Sarika	193	4,872	67.34±3.0c	256.4±21.3c
Huai Yai	163	2,943	51.3±2.7d	154.9±9.3d
Wang Muang	139	1,474	47.1±2.8d	122.8±11.2d

Remark: Significant difference are indicated by different small letter at $p< 0.01$ for one-way ANOVA.

DEF = Dry evergreen forest, MEF = Moist evergreen forest, DF = Disturbed forest

Huai Yai and Wang Muang had low butterflies because they are in disturbed forest closed to agriculture fields. They also had high temperature and light intensity but low humidity (Table 4.1). They probably have less food plant than those in other waterfalls. Heaw Suwat had higher butterflies because it is situated in moist evergreen

forest at higher elevation, it also had higher humidity but lower temperature. However, Heaw Narok had significantly lower butterflies than those of Heaw Suwat even they are in the same forest type and had the same environmental factors. This difference probably because Heaw Narok had more densed canopy area than Heaw Suwat since butterflies prefer more open area. Additionally, Sarika had lower butterflies since it is situated in very low elevation. It also had higher temperature and light intensity but lower humidity.

Although Pang Sida had lower elevation and humidity but higher temperature and light intensity more than Heaw Suwat and Heaw Narok (Table 4.1), this waterfall had the highest butterfly diversity of all. Since Pang Sida waterfall is in dry evergreen forest, it has more open area than moist evergreen forest. Moreover, park rangers regularly put baits, such as fish sauce and fermented fruits, to attract butterflies for tourists. We also found dung that attracted some butterfly species, similar to Choldumrongkul and Chumnarnkid (1998).

Heaw Narok and Sarika shared more than 75 % of butterfly similarity by cluster analysis (Figure 4.17) because they are closer in location. Surprisingly, Heaw Suwat and Pang Sida waterfalls shared 100 % similarity even they are very far from each other. Huai Yai and Wang Muang shared low similarity with others because they are in disturbed forest.

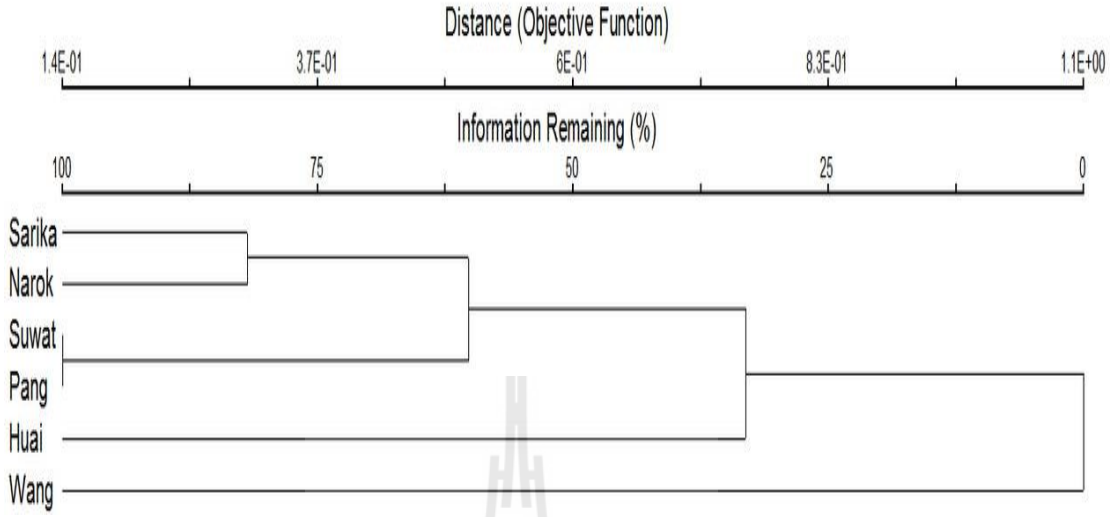


Figure 4.17 Cluster analysis of butterfly similarity among 6 waterfalls.

4.5 Butterflies Differ between Morning and Afternoon

After 19 months of sampling, butterfly species and individual in morning were significantly higher than those in the afternoon for all study sites (Table 4.13 and 4.14). Overall, the significant difference of species number was found between morning and afternoon ($t=34.9$, $d.f.=106$, $p<0.01$) and there was significant difference in individual numbers between morning and afternoon ($t=17.4$, $d.f.=106$, $p<0.01$).

In the morning, Pang Sida waterfall (235 species, 7,542 individuals) had the highest number of butterfly species and individuals, while the lowest was Wang Muang waterfall (127 species, 772 individuals). *Gandaca harina* (910 individuals) was the highest number of butterfly individuals, followed by *Eurema hecabe* (813 individuals), *Castalius rosimon* (740 individuals), *Discolampa ethion* (734 individuals), and *Anthene emolus* (691 individuals).

Table 4.13 The mean (±SE) number of butterfly species between morning and afternoon from June 2009 to December 2010 (n=107).

Waterfall	Total	Mean	
		Morning	Afternoon
Pang Sida	224	86.3±3.4	53.9±2.3
Heaw Suwat	177	73.5±3.2	46.1±2.2
Heaw Narok	159	56.8±2.3	32.3±2.6
Sarika	171	59.3±2.6	28.6±2.6
Huai Yai	146	43.2±2.2	18.1±1.6
Wang Muang	133	34.7±2.0	10.9±1.0
Total	288	60.5±2.0	33.0±1.7

Table 4.14 The Mean (±SE) number of butterfly individuals between morning and afternoon from June 2009 to December 2010 (n=107).

Waterfall	Total	Mean	
		Morning	Afternoon
Pang Sida	6,653	381.1±25.9	175.0±10.3
Heaw Suwat	5,872	350.2±20.8	142.8±9.4
Heaw Narok	2,928	192.5±14.5	83.4±9.2
Sarika	2,606	161.4±11.9	60.2±6.9
Huai Yai	1,439	97.7±6.0	31.3±2.9
Wang Muang	960	64.3±5.1	15.7±2.0
Total	20,458	217.3±13.2	89.2±6.3

The number of butterfly species and individuals in the afternoon, Pang Sida waterfall (150 species, 3,325 individuals) also had the highest numbers but Wang Muang waterfall (57 species, 188 individuals) had the lowest numbers. *Gandaca harina* (464 individuals) was still the highest number of butterfly individuals, followed by *Eurema hecabe* (394 individuals), *Castalius rosimon* (377 individuals), *Discolampa ethion* (344 individuals) and *Anthene emolus* (313 individuals).

Sixty nine percentage of butterfly species (209 species) were found in morning and afternoon, 29 % (89 species) were found in the morning alone whereas only 1.7 % (5 species) were found in the afternoon alone (Figure 4.18).

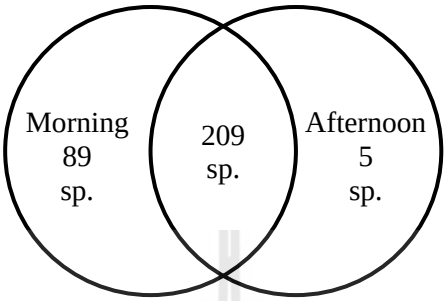


Figure 4.18 The number of butterfly species found in morning and afternoon.

For environmental factors between morning and afternoon. Temperature and light intensity were significantly lower in the morning than those in the afternoon but relative humidity was significantly higher in the morning than those in the afternoon (Table 4.15).

Table 4.15 Environment factor between morning and afternoon (n=107).

Environment factor	Morning	Afternoon	P-value
Temperature (ºC)	26.2±0.2	31.0±0.1	<0.001
Humidity (%)	77.3±0.8	57.1±0.8	<0.001
Light intensity (lux)	690.4±12.40	1,164.0±10.2	<0.001

In the morning found the number of butterfly species and individuals more than in the afternoon. According to Nisa et al. (2013), who studied butterfly diversity in three time observation (7.00 a.m.,11.00 a.m. and 3.30 p.m.) the highest abundance

of butterflies was observed at 11.00-12.30 a.m. Also, Ghazoul (2002) conducted butterfly activities were the highest appearance between 9.00 a.m. - 12.00 a.m. Beside that, it is the best time to produce nectar in great volume and precise sugar concentration for the butterflies' requirement (Devies, 2008). As for in the afternoon the sunlight is stronger, butterflies usually rest on the underside of the leaves and was less active (Ratiwiriyapong, 2004).

4.6 Butterflies Changes by Month

Butterfly species was significant difference between months (F=1.96, p=0.02) and number of butterfly individuals was not significant difference (F=1.03, p=0.44) (Table 4.16). The highest number of species was in May 2010 (195 species) while the lowest was in September 2009 (91 species; Figure 4.19). Butterfly individuals also fluctuated by month. The highest number of individuals was found in May 2010 (3,724 individuals) whereas the lowest was in July 2010 (1,479 individuals; Figure 4.20).

The total number of butterfly species and individuals were observed in each month. May 2010 had the highest butterfly diversity. According to Choldumrongkul and Chumnarnkid (1998), the highest peaks of butterflies were observed in October and May. The result perhaps relate to flowering of plants and the appropriate climatic conditions. Several species were involving an average temperature between 26-35 ^{o}C and relative humidity between 62–83 % (Ruchi et al., 2012). On the other hand, the number of species and individuals were the lowest in June and September. According to Boonvanno et al. (2000), the butterfly exhibited lowest diversity in September. The rain was pouring down during the rainy season caused by extensive plant damage and

even death. Moreover, butterflies presented low activities to flying depend on low temperature (Boonvanno et al., 2000). Some studies of tropical butterflies indicated that periods of very heavy rain may result to increased mortality of adults (Young, 1982). Thus it caused their numbers to decrease.

Table 4.16 Average (±SE) number of individual and species in each months from June 2009 to December 2010 (n=107).

Month	Species	Individual
Jun-09	74.4±7.5abcd	364.2±92.5
Jul-09	72.2±6.9abcd	337.6±84.5
Aug-09	63.0±8.4bcd	300.4±74.8
Sep-09	50.0±5.0d	306.8±75.4
Oct-09	80.2±6.6abd	508.2±94.1
Nov-09	67.2±8.2bcd	356.8±87.0
Dec-09	66.2±9.0bcd	354.0±90.1
Jan-10	70.0±9.2bcd	347.3±87.8
Feb-10	68.0±10.0bcd	312.7±83.6
Mar-10	66.7±8.3bcd	292.5±77.6
Apr-10	74.8±9.4abcd	372.3±96.6
May-10	99.0±10.4a	620.7±156.8
Jun-10	64.2±7.5bcd	281.7±72.7
Jul-10	54.7±4.6cd	246.5±56.3
Aug-10	60.2±7.0cd	272.2±76.9
Sep-10	58.3±5.9cd	285.2±68.9
Oct-10	90.7±10.0ab	474.2±121.2
Nov-10	67.5±9.0bcd	314.8±83.0
Dec-10	77.3±11.5abcd	337.3±93.3

Remark: Significant difference letter at $p < 0.05$ for one-way ANOVA are indicated by different small.

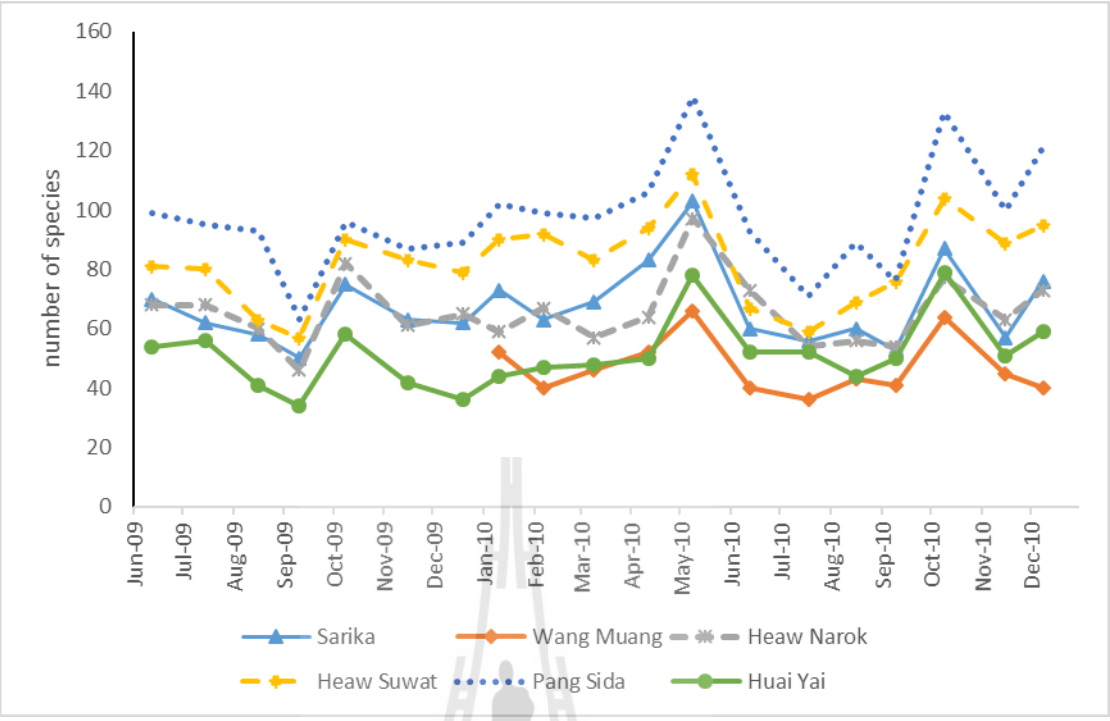


Figure 4.19 The number of butterfly species in each month.

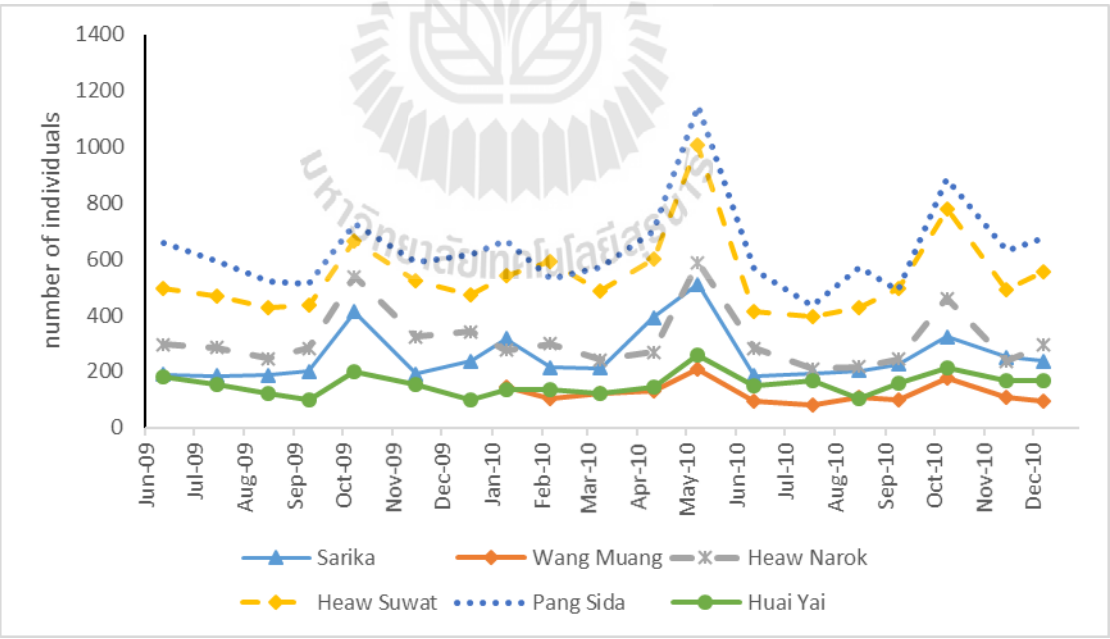


Figure 4.20 The number of butterfly individual in each month.

4.7 Food Preference Experiment

After 6 months of sampling, a total of 79 butterfly species (3,038 individuals), were found. The most common butterfly was *Euploea core* (427 individuals), followed by *Euploea radamanthus* (288) individuals), *Caleta roxus* (234 individuals), *Parantica aglea* (211 individuals), *Tirumala septentrionis* (123 individuals), and *Prosotas gracilis* (117 individuals), respectively. These species were found in all baits. Most butterflies were in family Nymphalidae, followed by Papilionidae, Lycaenidae, Pieridae, and Hesperiidae, respectively (Figure 4.21). Most Nymphalids are fruit-feeding butterflies so they are the most abundant in this study. Although most Papilionids and Lycaenids are nectar feeders, their adult butterflies can feed on rotten fruits for minerals and sugar. They both comprise of 35 % of this study.

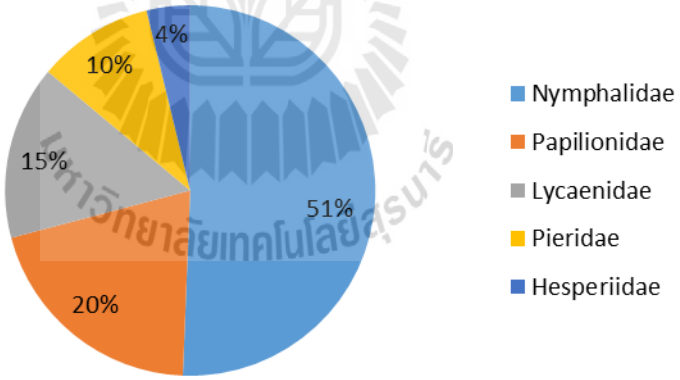


Figure 4.21 Percentage of butterfly families found in food preference experiment.

A total of 79 butterfly species (3,038 individuals) were bait traps (Table 4.17). DEF has more butterfly diversity (76 species) than DF (53 species). The average number of species and individual were significantly different among bait types (Table 4.18). Fermented fish mixed with fermented pineapple attracted most species (69 species), followed by fish sauce (49 species), fermented fish (46 species), pineapple

(35 species), banana (26 species), papaya (17 species), watermelon (11 species) and beer (8 species), respectively.

Table 4.17 Total number of species and individual of butterflies of two forest types.

Bait types	Dry evergreen forest		Disturbed forest		Total	
	Species	Individuals	Species	Individuals	Species	Individuals
Fermented fish vs. pineapple	64	486	39	419	69	905
Fish sauce	43	360	31	335	49	695
Fermented fish	35	291	24	246	45	537
Pineapple	29	222	17	122	35	344
Banana	20	164	13	70	26	234
Papaya	15	113	11	70	17	183
Watermelon	11	59	7	32	11	91
Beer	5	22	4	27	8	41
Total	76	1,717	53	1,321	79	3,038

Table 4.18 The monthly average species and individual of butterflies among different bait types (n=288).

Bait types	Species	Individual
Fermented fish mix pineapple	16.53a	24.86a
Fish sauce	14.89b	19.31b
Fermented fish	10.81c	14.92c
Pineapple	7.44d	12.33d
Banana	2.72e	5.08e
Papaya	2.72e	3.72ef
Watermelon	1.56ef	2.53fg
Beer	0.94f	1.36g

*Different characters among bait types shows significant differences at $p<0.05$

If use alone, fish sauce is the most attractive bait for butterflies in this area because it has sodium, the essential mineral for butterflies in which they cannot find from host plants when they are in larvae stage (Omura et al., 2000; Beck et al., 1999). However, the combination of mixed fermented fish and pineapple lured more butterflies than fish sauce and each of them alone. Fermented fish contains sodium as

fish sauce but has more calcium and amino acids. It attracts the same group of butterflies as fish sauce. While fermented pineapple has more sugar and volatile substances that can invite another group of butterflies. Therefore the mix of these foods attracts more butterflies than used alone. Fermented banana, papaya and watermelon probably contain less sugar and volatile substances than those in pineapple; hence, they attract less butterflies. However, the alcohol in beer did not draw many butterflies as anticipated.

The number of butterfly species and individual were significantly different between forest types ($p<0.05$). DEF had more number of butterfly species and individual than those in DF. DEF probably has more host, food and refugee plants than DF. It also has more moisture, more shade but less light which is suitable for decay materials. More fruit-feeding butterflies can be an indicator of forest restoration.

The number of butterfly species and individual were also significantly different among sampling months ($p<0.05$). October had the highest number of butterfly species, followed by May, August, September, June and July, respectively (Table 4.19). October also had the highest number of butterfly individual, followed by May, September, June, August and July, respectively. October and May are the most active months for butterflies in the tropic since they are the beginning and the end of rainy season. Water is abundant for plants to grow, flower and produce fruits in these periods.

Table 4.19 The monthly average species and individual of butterflies among different months (n=288).

Month	Species	Individuals
May	8.75a	13.00a
June	6.10b	9.31bc
July	5.71b	7.44c
August	6.52b	8.79bc
September	6.23b	9.50b
October	9.90a	15.04a

*Different characters among months shows significant differences at $p<0.05$

The diversity of butterflies during 6 months of this study (79 species) was more than those of Sakaerat Environmental Research Station, Thailand (Suwanwaree and Lapkratok, 2010) (Table 4.20). Butterfly species in this study also equals to South Kibale National Park, Uganda (Nyafwonoa et al., 2014) and Sacred forest groves, Ghana (Bossart and Opuni-Frinpong, 2009), but less than reported at Ecuadorian rainforest (130 species) (De Vries et al., 1997) and Tirimbina Biological Reserve, Costa Rica (101 species) (De Vries et al., 2012), while the studied at Serra da Canastra NP, Brazil (74 species) (Marini-Filho and Martins, 2012), Southeastern Brazil (73 species) (Ribeiro et al., 2010), Forest remnants, Ghana (56 species) (Bossart and Opuni-Frinpong, 2009), Danum Vally Field Centre (54 species) (Hill et al., 2001), and Sabah Atlantic Forest, Brazil (46 species) (Sant'Anna et al., 2014) had less than in this study, which the bait traps were fermented banana and sugar cane juice.

Table 20. Fruit-feeding butterflies comparison among different sites.

Sites	Trap days	Species	Individuals	References
Ecuadorian rainforest,	3,360	130	6,690	De Vries et al. (1997)
Tirimbina Biological Reserve, Costa Rica	3,600	101	6,984	De Vries et al. (2012)
South Kibale National Park, Uganda	2,160	79	10,092	Nyafwonoa et al. (2014)
Sacred forest groves, Ghana	1,184	79	6,836	Bossart et al. (2006)
Serra da Canastra NP, Brazil	3,465	74	3,415	Marini-Filhon and Martins (2010)
Sao Paulo State, Southeastern Brazil	4,800	73	6,488	Ribeiro et al. (2010)
Forest remnants, Ghana	580	56	2,634	Bossart and Opuni-Frinpong (2009)
Danum Vally Field Centre, Sabah	1,060	54	951	Hill et al. (2001)
Atlantic Forest, Brazil	384	46	1,483	Sant'Anna et al. (2014)
Sakaerat Environmental Research Station, Thailand	108	48	657	Suwanwaree and Lapkratok (2010)
Dong Phayayen- Khao Yai Forest Complex	288	79	3,038	This study

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

5.1.1 Diversity of Butterflies in 6 Waterfalls at Dong Phayayen-Khao Yai Forest Complex

After 19 months of sampling from June 2009 to December 2010, a total of 306 butterfly species (37,584 individuals), belonging to 5 families were found. Butterfly species and individual significantly differed among waterfalls. Pang Sida waterfall had the highest butterfly diversity (244 species, 12,080 individuals), followed by Haew Suwat (201 species, 10,278 individuals), Haew Narok (195 species, 5,937 individuals), Sarika (193 species, 4,872 individuals), Huai Yai (169 species, 2,943 individuals) and Wang Muang waterfalls (139 species, 1,474 individuals), respectively.

The most common butterflies were *Gandaca harina* (1,374 individuals), followed by *Eurema hecabe* (1,207 individuals), *Mycalesis perseus* (1,172 individuals), *Castalius rosimon* (1,156 individuals), *Mycalesis mineus* (1,107 individuals), *Discolampa ethion* (1,099 individuals) and *Anthene emolus* (1,081 individuals), respectively.

Morning significantly had more number of butterfly species and individuals (298 specie, 23,549 individuals) than those in the afternoon (214 species, 9,548 individuals).

Butterfly species significantly varied by month. The highest number of butterfly species was found in May 2010 (195 species), while the lowest was found in September 2009 (91 species). However, butterfly individuals did not differ by month. The highest number of individual was found in May 2010 (3,724 individuals) but the lowest was found in July 2010 (1,479 individuals).

5.1.2 The Relationship between Environmental Factors and Butterflies Diversity in 6 Waterfalls at Dong Phayayen-Khao Yai Forest Complex World Heritage

Physical factors were significantly different among waterfalls. The number of butterfly species and individual were significantly negative correlated with temperature but positive correlated with relative humidity and elevation. However, there are no significant relationship with monthly rainfall and light intensity.

5.1.3 Food Preference Experiment at Dong Phayayen-Khao Yai Forest Complex World Heritage, Thailand

After 6 months of sampling from May to October 2010 at Pang Sida National Park, a total of 79 butterfly species (3,038 individuals) were bait traps. DEF had more butterfly diversity (76 species) than those in DF (53 species). Fermented fish mixed with fermented pineapple was the most attractive food for butterflies (69 species), followed by fish sauce (49 species), fermented fish (46 species), pineapple (35 species), banana (26 species), papaya (17 species), watermelon (11 species) and beer (8 species), respectively. October 2010 had the highest number of butterfly species and individual. The most common butterfly was *Euploea core* (427 individuals).

5.2 Recommendation

For this study, additional work is needed to compare butterfly diversity among genera categories of vegetation types within forested ecosystems, to provide better baseline data. Butterfly-plant relationship are therefore being studied to further our understanding of biotic effects on butterfly number and diversity.

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APPENDICES

APPENDIX A

ENVIRONMENTAL FACTORS DATA

Table A.1 Temperature (°C) of 6 waterfalls by month.

Month	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Average
Jun-09	29.2	22.8	26.3	26.4	31.3	-	27.2
Jul-09	29.9	29.2	28.8	29.6	31.0	-	29.7
Aug-09	29.3	29.1	28.4	30.4	30.8	-	29.6
Sep-09	29.6	29.2	29.0	29.0	31.2	-	29.6
Oct-09	29.3	28.2	28.6	29.3	30.5	-	29.2
Nov-09	28.7	28.3	28.2	28.3	29.7	-	28.6
Dec-09	29.4	28.2	27.4	27.9	30.7	-	28.7
Jan-10	26.8	25.6	26.3	26.5	27.4	27.5	26.7
Feb-10	29.2	25.8	28.8	30.5	30.9	29.1	29.0
Mar-10	29.3	28.0	29.5	30.6	29.0	29.9	29.4
Apr-10	31.5	27.2	27.5	28.1	31.6	28.3	29.0
May-10	30.6	27.9	28.0	30.1	30.8	29.5	29.5
Jun-10	29.3	28.9	28.0	28.7	30.1	29.4	29.0
Jul-10	29.2	28.3	27.2	28.2	30.4	28.6	28.6
Aug-10	29.3	27.6	27.4	28.9	30.7	28.9	28.8
Sep-10	29.5	27.4	28.0	29.0	30.1	29.4	28.9
Oct-10	27.6	27.6	27.2	26.2	28.6	26.9	27.3
Nov-10	27.6	26.9	27.9	28.8	28.3	28.3	27.9
Dec-10	27.7	26.2	26.3	26.5	28.0	27.2	27.0
Average	29.1	27.5	27.8	28.6	30.0	28.6	28.6

Table A.2 Relative humidity (%) of 6 waterfalls by month.

Month	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Average
Jun-09	70.5	77.0	74.5	70.0	57.5	-	69.9
Jul-09	71.5	66.5	75.5	73.5	60.5	-	69.5
Aug-09	69.0	72.0	77.0	68.5	62.0	-	69.7
Sep-09	69.5	70.0	79.0	68.0	62.0	-	69.7
Oct-09	75.5	74.0	74.5	64.5	61.5	-	70.0
Nov-09	73.0	73.5	75.5	68.5	61.0	-	70.3
Dec-09	72.5	71.0	67.0	65.0	58.5	-	66.8
Jan-10	60.5	66.0	65.5	62.5	56.0	66.0	62.8
Feb-10	63.0	74.0	69.0	60.0	56.0	64.0	64.3
Mar-10	58.5	60.0	59.5	55.5	53.5	54.5	56.9
Apr-10	53.5	60.5	63.0	55.0	54.0	60.0	57.7
May-10	69.5	81.5	74.0	66.5	60.5	77.0	71.5
Jun-10	65.0	74.5	83.0	68.5	62.0	59.5	68.8
Jul-10	69.0	74.0	76.5	72.0	60.0	77.0	71.4
Aug-10	65.5	74.5	75.0	68.5	58.5	74.5	69.4
Sep-10	70.0	73.5	76.5	69.5	57.0	71.5	69.7
Oct-10	67.0	73.5	81.0	71.0	60.5	73.0	71.0
Nov-10	72.5	76.5	73.5	56.0	59.0	61.0	66.4
Dec-10	61.0	65.5	68.5	71.0	53.5	62.0	63.6
Average	67.2	71.5	73.1	66.0	58.6	66.7	67.2

Table A.3 Light intensity (lux) of 6 waterfalls by month.

Month	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Average
Jun-09	964.0	934.5	820.0	942.5	1161.5	-	964.5
Jul-09	895.0	882.0	889.5	818.5	1089.5	-	914.9
Aug-09	926.5	833.0	898.5	934.5	1052.5	-	929.0
Sep-09	965.5	883.5	885.0	878.0	1030.5	-	928.5
Oct-09	1001.0	875.0	916.0	891.5	995.0	-	935.7
Nov-09	975.0	936.5	908.5	989.5	1034.0	-	968.7
Dec-09	931.0	890.0	918.0	959.5	1133.5	-	966.4
Jan-10	825.5	792.0	746.0	809.0	951.5	864.0	831.3
Feb-10	822.5	772.0	780.0	786.0	863.5	890.0	819.0
Mar-10	884.5	801.0	696.0	878.5	952.5	899.5	852.0
Apr-10	933.5	931.5	968.0	979.0	1060.0	1055.0	987.8
May-10	1134.0	896.0	868.5	868.5	959.0	935.0	943.5
Jun-10	1061.0	1022.5	1049.0	1060.5	1071.0	991.0	1042.5
Jul-10	902.5	823.0	782.5	931.5	1136.0	801.0	896.1
Aug-10	966.0	906.0	845.5	899.0	1031.5	971.5	936.6
Sep-10	974.0	875.5	865.5	888.0	1039.0	915.0	926.2
Oct-10	960.0	932.0	905.5	944.5	1024.0	726.0	915.3
Nov-10	978.5	947.0	890.5	937.0	999.5	797.0	924.9
Dec-10	1005.0	877.0	888.0	896.0	1080.0	970.5	952.8
Average	952.9	884.7	869.5	910.1	1034.9	901.3	925.6

Table A.4 Monthly rainfall (mm) of 6 waterfalls by month.

Month	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Average
Jun-09	3.3	5.8	6.2	4.8	3.8	-	4.8
Jul-09	3.2	3.3	3.3	8.6	1.5	-	4.0
Aug-09	9.1	9.5	12.4	10.8	4.1	-	9.2
Sep-09	20.2	13.3	20.2	18.2	9.0	-	16.2
Oct-09	12.2	4.4	9.1	4.5	6.1	-	7.3
Nov-09	1.3	3.6	1.7	0.3	1.2	-	1.6
Dec-09	0.0	0.0	0.0	0.0	0.2	-	0.0
Jan-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb-10	0.0	1.3	0.7	0.7	0.2	0.6	0.6
Mar-10	1.8	1.8	6.8	1.2	3.5	2.8	3.0
Apr-10	3.3	5.7	4.3	4.2	1.9	4.3	3.9
May-10	5.6	6.6	11.9	3.4	3.3	7.4	6.4
Jun-10	5.4	20.0	12.2	8.7	1.1	10.4	9.6
Jul-10	6.5	7.1	19.2	12.0	2.8	13.6	10.2
Aug-10	6.5	4.5	12.2	6.4	4.5	7.3	6.9
Sep-10	4.4	10.0	17.5	14.9	4.3	15.4	11.1
Oct-10	5.1	6.8	6.0	3.5	4.3	4.0	4.9
Nov-10	1.4	2.2	2.2	1.1	0.6	0.2	1.3
Dec-10	0.8	0.0	0.0	0.0	0.0	0.0	0.1
Average	4.7	5.6	7.7	5.4	2.8	5.5	5.3

Table A.5 Temperature (°C) in the morning and afternoon of 6 waterfalls by month.

	Pang Sida			Heaw Suwat			Heaw Narok			Sarika			Huai Yai			Wang Muang			Average		
	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.
Jun-09	28.3	30.1	29.2	24.8	20.8	22.8	23.2	29.3	26.3	24.3	28.4	26.4	29.8	32.8	31.3	-	-	-	26.1	28.3	27.2
Jul-09	27.9	31.9	29.9	27.8	30.6	29.2	27.5	30.1	28.8	27.8	31.3	29.6	30.1	31.8	31.0	-	-	-	28.2	31.1	29.7
Aug-09	28.2	30.4	29.3	27.4	30.7	29.1	26.3	30.5	28.4	28.2	32.6	30.4	29.8	31.7	30.8	-	-	-	28.0	31.2	29.6
Sep-09	28.6	30.6	29.6	27.8	30.6	29.2	26.8	31.2	29.0	27.5	30.4	29.0	29.7	32.6	31.2	-	-	-	28.1	31.1	29.6
Oct-09	26.8	31.8	29.3	26.3	30.1	28.2	26.2	30.9	28.6	27.8	30.7	29.3	29.3	31.6	30.5	-	-	-	27.3	31.0	29.2
Nov-09	26.9	30.5	28.7	25.9	30.6	28.3	25.4	31.0	28.2	26.3	30.2	28.3	27.9	31.5	29.7	-	-	-	26.5	30.8	28.6
Dec-09	27.3	31.4	29.4	25.1	31.2	28.2	24.2	30.6	27.4	25.4	30.4	27.9	28.8	32.6	30.7	-	-	-	26.2	31.2	28.7
Jan-10	23.3	30.2	26.8	20.7	30.4	25.6	20.2	32.4	26.3	24.8	28.1	26.5	23.4	31.4	27.4	24.2	30.7	27.5	22.8	30.5	26.7
Feb-10	27.5	30.8	29.2	22.3	29.3	25.8	25.9	31.7	28.8	28.2	32.8	30.5	29.2	32.5	30.9	25.9	32.3	29.1	26.5	31.6	29.0
Mar-10	26.8	31.7	29.3	25.2	30.8	28.0	27.1	31.9	29.5	28.9	32.3	30.6	25.3	32.7	29.0	28.1	31.7	29.9	26.9	31.9	29.4
Apr-10	30.2	32.8	31.5	22.5	31.9	27.2	22.2	32.8	27.5	22.8	33.4	28.1	29.3	33.8	31.6	23.7	32.8	28.3	25.1	32.9	29.0
May-10	28.8	32.3	30.6	24.5	31.2	27.9	25.5	30.5	28.0	29.2	30.9	30.1	28.9	32.7	30.8	28.3	30.7	29.5	27.5	31.4	29.5
Jun-10	27.2	31.3	29.3	27.1	30.6	28.9	26.7	29.3	28.0	28.1	29.3	28.7	28.3	31.8	30.1	28.5	30.2	29.4	27.7	30.4	29.0
Jul-10	26.9	31.4	29.2	24.9	31.6	28.3	23.7	30.7	27.2	27.3	29.0	28.2	29.2	31.5	30.4	26.7	30.4	28.6	26.5	30.8	28.6
Aug-10	27.3	31.2	29.3	24.8	30.3	27.6	24.3	30.5	27.4	27.6	30.1	28.9	28.9	32.4	30.7	26.5	31.2	28.9	26.6	31.0	28.8
Sep-10	27.6	31.4	29.5	24.6	30.2	27.4	25.4	30.6	28.0	27.3	30.6	29.0	28.5	31.6	30.1	26.9	31.9	29.4	26.7	31.1	28.9
Oct-10	24	31.1	27.6	24.3	30.9	27.6	24.0	30.4	27.2	24.0	28.4	26.2	25.4	31.8	28.6	23.0	30.8	26.9	24.1	30.6	27.3
Nov-10	24.9	30.2	27.6	23.4	30.4	26.9	24.9	30.9	27.9	28.1	29.5	28.8	24.8	31.7	28.3	26.0	30.5	28.3	25.4	30.5	27.9
Dec-10	23.9	31.5	27.7	20.9	31.5	26.2	21.6	30.9	26.3	23.5	29.5	26.5	24.0	31.9	28.0	23.5	30.9	27.2	22.9	31.0	27.0
Average	27.0	31.2	29.1	24.8	30.2	27.5	24.8	30.9	27.8	26.7	30.4	28.6	27.9	32.1	30.0	25.9	31.2	28.6	26.2	31.0	28.6

Mor.= Morning, Aft. = Afternoon, Aver = Average

Table A.6 Relative humidity (%) in the morning and afternoon of 6 waterfalls by month.

	Pang Sida			Heaw Suwat			Heaw Narok			Sarika			Huai Yai			Wang Muang			Average		
	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.
Jun-09	86.0	55.0	70.5	85.0	69.0	77.0	86.0	63.0	74.5	78.0	62.0	70.0	72.0	43.0	57.5	-	-	-	81.4	60.6	71.0
Jul-09	84.0	59.0	71.5	71.0	62.0	66.5	86.0	65.0	75.5	80.0	67.0	73.5	72.0	49.0	60.5	-	-	-	78.6	62.7	70.7
Aug-09	84.0	54.0	69.0	79.0	65.0	72.0	86.0	68.0	77.0	77.0	60.0	68.5	79.0	45.0	62.0	-	-	-	81.0	62.7	71.8
Sep-09	82.0	57.0	69.5	81.0	59.0	70.0	89.0	69.0	79.0	78.0	58.0	68.0	77.0	47.0	62.0	-	-	-	81.4	63.5	72.4
Oct-09	87.0	64.0	75.5	87.0	61.0	74.0	87.0	62.0	74.5	75.0	54.0	64.5	75.0	48.0	61.5	-	-	-	82.2	63.9	73.1
Nov-09	85.0	61.0	73.0	85.0	62.0	73.5	88.0	63.0	75.5	76.0	61.0	68.5	73.0	49.0	61.0	-	-	-	81.4	63.8	72.6
Dec-09	81.0	64.0	72.5	81.0	61.0	71.0	75.0	59.0	67.0	73.0	57.0	65.0	72.0	45.0	58.5	-	-	-	76.4	60.0	68.2
Jan-10	73.0	48.0	60.5	85.0	47.0	66.0	93.0	38.0	65.5	74.0	51.0	62.5	69.0	43.0	56.0	73.0	59.0	66.0	77.8	62.5	70.2
Feb-10	74.0	52.0	63.0	75.0	73.0	74.0	80.0	58.0	69.0	70.0	50.0	60.0	61.0	51.0	56.0	75.0	53.0	64.0	72.5	61.9	67.2
Mar-10	69.0	48.0	58.5	68.0	52.0	60.0	66.0	53.0	59.5	65.0	46.0	55.5	65.0	42.0	53.5	58.0	51.0	54.5	65.2	54.0	59.6
Apr-10	62.0	45.0	53.5	70.0	51.0	60.5	69.0	57.0	63.0	68.0	42.0	55.0	62.0	46.0	54.0	71.0	49.0	60.0	67.0	57.8	62.4
May-10	82.0	57.0	69.5	94.0	69.0	81.5	86.0	62.0	74.0	75.0	58.0	66.5	78.0	43.0	60.5	85.0	69.0	77.0	83.3	69.6	76.5
Jun-10	79.0	51.0	65.0	81.0	68.0	74.5	87.0	79.0	83.0	77.0	60.0	68.5	72.0	52.0	62.0	58.0	61.0	59.5	75.7	61.4	68.5
Jul-10	80.0	58.0	69.0	87.0	61.0	74.0	90.0	63.0	76.5	80.0	64.0	72.0	71.0	49.0	60.0	85.0	69.0	77.0	82.2	70.4	76.3
Aug-10	78.0	53.0	65.5	81.0	68.0	74.5	80.0	70.0	75.0	76.0	61.0	68.5	70.0	47.0	58.5	81.0	68.0	74.5	77.7	67.8	72.7
Sep-10	81.0	59.0	70.0	83.0	64.0	73.5	85.0	68.0	76.5	77.0	62.0	69.5	69.0	45.0	57.0	80.0	63.0	71.5	79.2	65.9	72.6
Oct-10	73.0	61.0	67.0	85.0	62.0	73.5	97.0	65.0	81.0	86.0	56.0	71.0	70.0	51.0	60.5	82.0	64.0	73.0	82.2	68.8	75.5
Nov-10	80.0	65.0	72.5	92.0	61.0	76.5	80.0	67.0	73.5	55.0	57.0	56.0	69.0	49.0	59.0	63.0	59.0	61.0	73.2	60.7	66.9
Dec-10	71.0	51.0	61.0	76.0	55.0	65.5	80.0	57.0	68.5	87.0	55.0	71.0	58.0	49.0	53.5	68.0	56.0	62.0	73.3	60.3	66.8
Average	78.5	55.9	67.2	81.4	61.6	71.5	83.7	62.4	73.1	75.1	56.9	66.0	70.2	47.0	58.6	73.3	60.1	66.7	77.0	63.8	70.4

Mor.= Morning, Aft. = Afternoon, Aver = Average

Table A.7 Light intensity (lux) in the morning and afternoon of 6 waterfalls by month.

	Pang Sida			Heaw Suwat			Heaw Narok			Sarika			Huai Yai			Wang Muang			Average		
	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.	Mor.	Aft.	Aver.
Jun-09	801.0	1127.0	964.0	732.0	1137.0	934.5	693.0	947.0	820.0	771.0	1114.0	942.5	1002.0	1321.0	1161.5	-	-	-	799.8	1129.2	964.5
Jul-09	692.0	1098.0	895.0	739.0	1025.0	882.0	756.0	1023.0	889.5	602.0	1035.0	818.5	893.0	1286.0	1089.5	-	-	-	736.4	1093.4	914.9
Aug-09	659.0	1194.0	926.5	639.0	1027.0	833.0	761.0	1036.0	898.5	713.0	1156.0	934.5	877.0	1228.0	1052.5	-	-	-	729.8	1128.2	929.0
Sep-09	748.0	1183.0	965.5	642.0	1125.0	883.5	641.0	1129.0	885.0	732.0	1024.0	878.0	769.0	1292.0	1030.5	-	-	-	706.4	1150.6	928.5
Oct-09	774.0	1228.0	1001.0	726.0	1024.0	875.0	684.0	1148.0	916.0	642.0	1141.0	891.5	798.0	1192.0	995.0	-	-	-	724.8	1146.6	935.7
Nov-09	730.0	1220.0	975.0	681.0	1192.0	936.5	628.0	1189.0	908.5	753.0	1226.0	989.5	757.0	1311.0	1034.0	-	-	-	709.8	1227.6	968.7
Dec-09	717.0	1145.0	931.0	643.0	1137.0	890.0	749.0	1087.0	918.0	791.0	1128.0	959.5	1008.0	1259.0	1133.5	-	-	-	781.6	1151.2	966.4
Jan-10	638.0	1013.0	825.5	576.0	1008.0	792.0	549.0	943.0	746.0	671.0	947.0	809.0	699.0	1204.0	951.5	683.0	1045.0	864.0	636.0	1026.7	831.3
Feb-10	538.0	1107.0	822.5	560.0	984.0	772.0	537.0	1023.0	780.0	653.0	919.0	786.0	430.0	1297.0	863.5	708.0	1072.0	890.0	571.0	1067.0	819.0
Mar-10	550.0	1219.0	884.5	496.0	1106.0	801.0	388.0	1004.0	696.0	627.0	1130.0	878.5	597.0	1308.0	952.5	680.0	1119.0	899.5	556.3	1147.7	852.0
Apr-10	750.0	1117.0	933.5	726.0	1137.0	931.5	731.0	1205.0	968.0	744.0	1214.0	979.0	821.0	1299.0	1060.0	872.0	1238.0	1055.0	774.0	1201.7	987.8
May-10	990.0	1278.0	1134.0	516.0	1276.0	896.0	561.0	1176.0	868.5	547.0	1190.0	868.5	542.0	1376.0	959.0	505.0	1365.0	935.0	610.2	1276.8	943.5
Jun-10	894.0	1228.0	1061.0	840.0	1205.0	1022.5	896.0	1202.0	1049.0	846.0	1275.0	1060.5	915.0	1227.0	1071.0	873.0	1109.0	991.0	877.3	1207.7	1042.5
Jul-10	546.0	1259.0	902.5	529.0	1117.0	823.0	473.0	1092.0	782.5	596.0	1267.0	931.5	976.0	1296.0	1136.0	576.0	1026.0	801.0	616.0	1176.2	896.1
Aug-10	616.0	1316.0	966.0	593.0	1219.0	906.0	527.0	1164.0	845.5	563.0	1235.0	899.0	837.0	1226.0	1031.5	617.0	1326.0	971.5	625.5	1247.7	936.6
Sep-10	724.0	1224.0	974.0	583.0	1168.0	875.5	597.0	1134.0	865.5	629.0	1147.0	888.0	772.0	1306.0	1039.0	743.0	1087.0	915.0	674.7	1177.7	926.2
Oct-10	758.0	1162.0	960.0	639.0	1225.0	932.0	547.0	1264.0	905.5	575.0	1314.0	944.5	823.0	1225.0	1024.0	449.0	1003.0	726.0	631.8	1198.8	915.3
Nov-10	655.0	1302.0	978.5	716.0	1178.0	947.0	576.0	1205.0	890.5	672.0	1202.0	937.0	673.0	1326.0	999.5	566.0	1028.0	797.0	643.0	1206.8	924.9
Dec-10	781.0	1229.0	1005.0	733.0	1021.0	877.0	703.0	1073.0	888.0	767.0	1025.0	896.0	925.0	1235.0	1080.0	722.0	1219.0	970.5	771.8	1133.7	952.8
Average	713.7	1192.1	952.9	647.8	1121.6	884.7	631.4	1107.6	869.5	678.6	1141.5	910.1	795.5	1274.4	1034.9	666.2	1136.4	901.3	688.9	1162.3	925.6

Mor.= Morning, Aft. = Afternoon, Aver = Average

APPENDIX B

BUTTERFLY SPECIES DIVERSITY

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage**.**

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitats
Gandaca harina	Nym.	480	302	205	211	102	74	1374	VC	open
Eurema hecabe	Pie.	379	266	190	223	131	18	1207	VC	open
Mycalesis perseus	Nym.	378	175	145	226	160	88	1172	VC	close
Castalius rosimon	Lyc.	334	273	200	190	132	27	1156	VC	open
Mycalesis mineus	Nym.	301	195	165	194	137	115	1107	VC	close
Discolampa ethion	Lyc.	305	293	181	146	114	60	1099	VC	open
Anthene emolus	Lyc.	259	316	221	204	30	51	1081	VC	open
Eurema andersonii	Pie.	251	255	180	136	139	12	973	VC	open
Caleta roxus	Lyc.	283	322	128	113	84	17	947	VC	open
Prosotas gracilis	Lyc.	290	344	154	68	16	5	877	VC	open
Appias albina	Pie.	338	216	148	102	44	25	873	VC	open
Euploea core	Nym.	223	206	243	115	36	27	850	VC	close
Prosotas nora	Lyc.	241	269	95	98	81	25	809	VC	open
Anthene lycaenina	Lyc.	269	305	137	66	5	9	791	VC	open
Euploea radamanthus	Nym.	244	214	232	56	17	19	782	VC	close
Tirumala septentrionis	Nym.	189	203	231	33	12	5	673	VC	open
Graphium doson	Pap.	268	266	29	42	21	23	649	VC	open
Cepora iudith	Pie.	295	139	97	35	27	14	607	VC	open
Prosotas lutea	Lyc.	214	270	92	18	13	0	607	VC	open
Grapium sarpedon	Pap.	154	285	103	39	2	12	595	VC	open
Appias indra	Pie.	260	208	81	22	6	11	588	VC	open

Pap.= Papilionidae, Pie. = Pieridae, Nym. = Nymphalidae, Lyc. = Lycaenidae, Hes. = Hesperiidae

Status: Very Common (VC = >500 individuals), Common (C=100-500 individuals), Rare (R= 10-100 individuals), and Very Rare (VR= <10 individuals).

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage (Continued).

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitats
Euploea Camaralzeman	Nym.	235	98	196	20	4	8	561	VC	close
Cepora nadina	Pie.	253	125	93	41	23	14	549	VC	open
Papilio paris	Pap.	201	248	42	35	0	11	537	VC	open
Appias libythea	Pie.	254	100	64	27	8	3	456	C	open
Hebomoia glaucippe	Pie.	186	132	54	45	10	13	440	C	open
Catopsilia pomona	Pie.	196	119	25	43	42	11	436	C	open
Lxias pyrene	Pie.	171	158	41	44	9	9	432	C	open
Cirrochroa tyche	Nym.	114	106	74	76	42	16	428	C	open
Papilio nephelus	Pap.	124	190	35	41	15	6	411	C	open
Melanitis phedima	Nym.	77	73	66	77	29	57	379	C	close
Ypthima baldus	Nym.	88	45	57	68	83	25	366	C	close
Hypolycaena erylus	Lyc.	83	86	59	111	13	11	363	C	open
Cepora nerissa	Pie.	175	96	49	11	22	8	361	C	open
Euploea algea	Nym.	153	61	67	38	10	7	336	C	close
Neptis hylas	Nym.	103	57	28	55	74	13	330	C	open
Papilio helenus	Pap.	90	177	12	29	10	10	328	C	open
Polyura athamas	Nym.	72	51	71	42	69	19	324	C	open
Euploea mulciber	Nym.	116	77	57	37	7	14	308	C	close
Papilio memnon	Pap.	80	158	26	21	10	8	303	C	open
Zeltus amasa	Lyc.	68	49	61	69	9	13	269	C	open
Charaxes bernardus	Nym.	51	56	65	36	43	10	261	C	open
Melanitis leda	Nym.	34	1	38	71	39	73	256	C	close
Cyrestis themire	Nym.	63	57	12	99	12	5	248	C	open
Graphium antiphates	Pap.	84	145	0	17	1	0	247	C	open
Graphium aeycles	Pap.	149	68	5	14	8	0	244	C	open

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage (Continued).

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitat types
Tanaecia lipidea	Nym.	52	28	40	68	28	24	240	C	open
Graphium agamemnon	Pap.	100	84	14	33	4	0	235	C	open
Cheritra freja	Lyc.	67	43	6	70	19	16	221	C	open
Appias lyncida	Pie.	81	98	33	6	0	0	218	C	open
Papilio mahadeva	Pap.	87	81	25	13	7	4	217	C	open
Elymnias hypermnestra	Nym.	48	31	52	44	22	17	214	C	close
Acytolepis puspa	Lyc.	54	91	37	10	9	4	205	C	open
Euploea doubledayi	Nym.	115	42	32	10	1	0	200	C	close
Amblypodia anita	Lyc.	52	45	33	22	28	19	199	C	open
Cyrestis cocles	Nym.	70	44	17	60	0	4	195	C	open
Graphium eurypylus	Pap.	94	91	1	2	0	0	188	C	open
Euploea sylvester	Nym.	92	46	26	21	2	0	187	C	close
Catochrysops panormus	Lyc.	65	58	4	46	8	3	184	C	open
Melanitis zitenius	Nym.	25	49	18	34	16	41	183	C	close
Rohana parisatis	Nym.	31	36	30	47	16	18	178	C	close
Papilio polytes	Pap.	54	55	21	24	14	4	172	C	open
Appias paulina	Pie.	108	26	23	9	0	0	166	C	open
Euthalia recta	Nym.	27	9	101	14	10	0	161	C	close
Leptosia nina	Pie.	50	30	23	33	12	10	158	C	open
Tanaecia julii	Nym.	24	23	28	27	23	30	155	C	open
Polyura jalysus	Nym.	37	34	14	20	32	15	152	C	open
Surendra quercetorum	Lyc.	23	33	42	24	13	9	144	C	open
Lamproptera meges	Pap.	6	55	4	6	68	0	139	C	open
Athyma ranga	Nym.	46	37	15	32	3	3	136	C	open
Euploea modesta	Nym.	49	39	30	3	2	0	123	C	close

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage (Continued).

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitat types
Neptis hordonia	Nym.	23	13	23	26	25	9	119	C	open
Terinos atlita	Nym.	33	12	42	17	5	4	113	C	open
Junonia lemonias	Nym.	6	10	16	20	51	8	111	C	open
Neptis nata	Nym.	32	30	3	21	25	0	111	C	open
Rohana tonkiniana	Nym.	31	21	11	28	13	5	109	C	close
Ypthima similis	Nym.	29	24	25	6	18	2	104	C	close
Junonia almana	Nym.	12	14	13	20	33	6	98	R	open
Nacaduba kurava	Lyc.	49	37	1	9	0	0	96	R	open
Junonia atlites	Nym.	20	13	10	12	32	6	93	R	open
Lambrix salsala	Hes.	9	14	5	25	32	3	88	R	open
Loxura atymnus	Lyc.	15	28	11	10	16	7	87	R	open
Cupha erymanthis	Nym.	26	24	13	15	4	4	86	R	open
Terinos terpander	Nym.	25	22	18	13	1	4	83	R	open
Lebadea martha	Nym.	17	15	14	18	11	8	83	R	open
Udara dilecta	Lyc.	13	57	0	7	0	6	83	R	open
Dophla evelina	Nym.	24	3	24	2	15	10	78	R	close
Prosotas aluta	Lyc.	53	18	7	0	0	0	78	R	open
Parantica aglea	Nym.	22	29	9	13	3	0	76	R	open
Danaus genutia	Nym.	27	15	9	11	9	0	71	R	open
Neptis clinia	Nym.	21	20	6	9	12	3	71	R	open
Libythea myrrha	Lyc.	0	66	0	1	0	0	67	R	open
Graphium megarus	Pap.	30	35	0	1	0	0	66	R	open
Grapgium aristeus	Pap.	36	23	0	6	0	0	65	R	open
Papilio demolion	Pap.	61	0	0	2	0	0	63	R	open
Polyura eudamippus	Nym.	14	34	1	6	5	0	60	R	open

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage (Continued).

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitat types
Pithecops corvus	Lyc.	17	21	4	4	0	14	60	R	open
Nacaduba kurava	Lyc.	20	28	2	8	1	0	59	R	open
Nacaduba pactolus	Lyc.	14	6	16	7	15	0	58	R	open
Jamides alecto	Lyc.	11	2	6	13	20	5	57	R	open
Pachliopta aristolochiae	Pap.	11	10	12	12	11	0	56	R	open
Ariadne merione	Nym.	7	11	9	5	18	5	55	R	open
Mycalesis intermedia	Nym.	18	2	20	7	2	4	53	R	close
Kallima inachus	Nym.	8	24	11	6	2	2	53	R	close
Graphium xenocles	Pap.	22	27	2	0	0	1	52	R	open
Ancistroides nigrita	Hes.	5	4	15	8	17	3	52	R	open
Amathuxidia amythaon	Nym.	48	2	0	0	0	0	50	R	close
Parthenos sylvia	Nym.	8	16	8	13	4	1	50	R	open
Tanaecia jahnu	Nym.	13	4	14	8	5	5	49	R	open
Parantica melaneus	Nym.	7	28	7	5	1	0	48	R	open
Moduza procris	Nym.	10	6	15	9	5	3	48	R	open
Mycalesis anaxias	Nym.	1	37	9	0	0	0	47	R	close
Tanaecia cocytus	Nym.	13	6	7	16	0	4	46	R	open
Pareronia anais	Pie.	13	12	3	10	4	2	44	R	open
Jamides celeno	Lyc.	11	12	12	4	1	3	43	R	open
Ideopsis vulgaris	Nym.	14	9	14	3	0	0	40	R	open
Tanaecia flora	Nym.	9	18	3	5	0	4	39	R	open
Paduca fasciata	Nym.	14	10	4	6	0	4	38	R	open
Parantica agleoides	Nym.	4	21	3	5	4	0	37	R	open
Chilades pandava	Lyc.	1	0	11	0	25	0	37	R	open
Potanthus nesta	Hes.	2	14	6	5	9	1	37	R	close

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage (Continued).

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitat types
Neopithecops zalmora	Lyc.	12	1	11	7	0	5	36	R	open
Miletus boisduvali	Lyc.	1	0	4	6	24	0	35	R	open
Faunis canens	Nym.	16	1	3	4	10	0	34	R	close
Athyma selenophora	Nym.	8	5	14	7	0	0	34	R	open
Prothoe franck	Nym.	1	0	0	1	10	22	34	R	close
Danaus chrysippus	Nym.	9	10	6	2	6	0	33	R	open
Athyma larymna	Nym.	8	12	9	3	0	1	33	R	open
Cyrestis thyodamas	Nym.	5	17	1	8	0	0	31	R	open
Caleta elna	Lyc.	6	14	0	6	0	5	31	R	open
Zizina otis	Lyc.	0	0	6	13	12	0	31	R	open
Curetis dentata	Lyc.	6	6	2	5	8	4	31	R	open
Hasora schoenherr	Hes.	6	4	12	7	0	1	30	R	close
Amathusia phidippus	Nym.	19	0	0	9	0	1	29	R	close
Junonia iphita	Nym.	2	11	3	4	8	1	29	R	open
Lexias pardalis	Nym.	10	3	1	2	11	1	28	R	close
Odontoptilum angulatum	Hes.	7	13	1	3	0	4	28	R	open
Lethe europa	Nym.	6	0	0	3	17	0	26	R	close
Neptis columella	Nym.	8	7	6	4	1	0	26	R	open
Celastrina transpecta	Lyc.	12	6	5	3	0	0	26	R	open
Neptis miah	Nym.	9	14	0	2	0	0	25	R	open
Euthalia monina	Nym.	9	3	2	7	3	0	24	R	open
Symbrenthia lilaea	Nym.	4	7	0	0	12	0	23	R	open
Hypolimnas bolina	Nym.	4	2	8	2	6	1	23	R	open
Polyura delphis	Nym.	12	7	1	1	0	0	21	R	open
Gangrara thyrsis	Hes.	0	0	3	7	10	1	21	R	open

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage (Continued).

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitat types
Eurema brigitta	Pie.	7	11	1	1	0	0	20	R	open
Lampides boeticus	Lyc.	13	0	0	0	6	0	19	R	open
Coelites nothis	Nym.	8	3	6	0	0	1	18	R	close
Graphium agetes	Pap.	0	17	0	0	0	0	17	R	open
Taxila haquinus	Lyc.	6	2	8	0	1	0	17	R	open
Graphium macareus	Pap.	5	11	0	0	0	0	16	R	open
Elymnias nesaea	Nym.	4	0	0	2	7	3	16	R	close
Neptis sankara	Nym.	7	2	1	5	1	0	16	R	open
Tanaecia godartii	Nym.	4	0	8	3	0	1	16	R	open
Flos apidanus	Lyc.	0	0	0	15	1	0	16	R	open
Appias lalage	Pie.	15	0	0	0	0	0	15	R	open
Doleschallia bisaltide	Nym.	9	4	1	1	0	0	15	R	close
Neomyrina nivea	Lyc.	9	0	3	2	1	0	15	R	open
Chliaria othona	Lyc.	9	6	0	0	0	0	15	R	open
Orsotriaena medus	Nym.	8	0	1	0	0	5	14	R	close
Lexias cyanipardus	Nym.	4	3	5	0	2	0	14	R	close
Halpe zema	Hes.	5	0	1	2	6	0	14	R	open
Cathosia cyane	Nym.	2	3	0	2	5	1	13	R	close
Euthalia aconthea	Nym.	5	2	4	2	0	0	13	R	open
Heliophorus epicles	Lyc.	0	13	0	0	0	0	13	R	open
Drupadia ravindra	Lyc.	3	0	9	0	0	1	13	R	open
Badamia exclamationis	Hes.	2	5	3	0	1	2	13	R	open
Nptocrypta paralysos	Hes.	3	2	3	3	2	0	13	R	open
Metapa cresta	Hes.	1	0	4	2	3	3	13	R	close
Troides aeacus	Pap.	1	1	5	3	1	1	12	R	open

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage (Continued).

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitat types
Chersonesia risa	Nym.	4	1	3	4	0	0	12	R	open
Chilasa slateri	Pap.	6	5	0	0	0	0	11	R	open
Vindula erota	Nym.	6	0	1	3	0	1	11	R	open
Athyma asura	Nym.	6	4	0	1	0	0	11	R	open
Euthalia phemius	Nym.	8	0	1	2	0	0	11	R	open
Arhopala pseudocentaurus	Lyc.	5	0	0	0	4	2	11	R	open
Spindasis syama	Lyc.	3	2	3	0	2	1	11	R	open
Rapala pheretima	Lyc.	5	1	1	2	2	0	11	R	open
Zemeros flegyas	Lyc.	0	0	8	1	2	0	11	R	open
Bibasis sena	Hes.	4	0	1	5	0	1	11	R	close
Sarangesa dasahara	Hes.	0	0	5	3	1	2	11	R	open
Eurema sari	Pie.	3	1	0	3	3	0	10	R	open
Lethe mekara	Nym.	4	1	0	3	2	0	10	R	close
Hasora taminatus	Hes.	6	0	1	1	0	2	10	R	close
Tagiades japetus	Hes.	2	0	1	2	4	1	10	R	open
Papilio demoleus	Pap.	1	2	0	2	4	0	9	VR	open
Athyma pravara	Nym.	4	1	3	0	1	0	9	VR	open
Tagiades Iitigiosus	Hes.	3	1	1	1	2	1	9	VR	open
Halpe burmana	Hes.	1	1	0	6	1	9	VR	open
Matapa aria	Hes.	1	1	2	4	1	0	9	VR	close
Mycalesis mnasicles	Nym.	1	2	0	2	3	0	8	VR	open
Neptis tiga	Nym.	2	2	1	0	0	3	8	VR	close
Bindahara phocides	Lyc.	8	0	0	0	0	0	8	VR	open
Odina decorata	Hes.	8	0	0	0	0	0	8	VR	open
Tagiades menaka	Hes.	1	1	1	3	1	1	8	VR	open

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage (Continued).

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitat types
Chilasa paradoxa	Pap.	5	3	0	0	0	0	8	VR	open
Potanthus ganda	Hes.	2	3	0	0	1	2	8	VR	close
Athyma perius	Nym.	5	1	0	1	0	0	7	VR	open
Athyma nefte	Nym.	3	0	3	0	0	1	7	VR	open
Athyma cama	Nym.	3	4	0	0	0	0	7	VR	open
Euthalia teuta	Nym.	7	0	0	0	0	0	7	VR	close
Charaxes solon	Nym.	4	0	2	0	1	0	7	VR	open
Remelana jangala	Lyc.	3	2	0	2	0	0	7	VR	open
Tagiades gana	Hes.	3	0	1	1	0	2	7	VR	open
Potanthus trachala	Hes.	1	0	1	1	3	1	7	VR	close
Polyura schreiber	Nym.	3	0	3	0	0	0	6	VR	open
Libythea nirina	Lyc.	1	5	0	0	0	0	6	VR	open
Rapala iarbus	Lyc.	5	0	0	1	0	0	6	VR	open
Notocrypta curvifascia	Hes.	2	0	0	2	2	0	6	VR	open
Prioneris thestylis	Pie.	2	0	0	3	0	0	5	VR	open
Catopsillia scylla	Pie.	2	2	0	0	1	0	5	VR	open
Mycalesis francisca	Nym.	3	2	0	0	0	0	5	VR	close
Discophora sondaica	Nym.	0	0	4	0	1	0	5	VR	close
Acraea violea	Nym.	0	0	0	1	4	0	5	VR	open
Zizeeria maha	Lyc.	0	0	0	5	0	0	5	VR	open
Arhopala dispar	Lyc.	4	0	1	0	0	0	5	VR	open
Rapala elcia	Lyc.	1	1	3	0	0	0	5	VR	open
Zographetus satwa	Hes.	2	0	0	0	1	2	5	VR	open
Lotongus calathus	Hes.	1	0	3	0	1	0	5	VR	open
Papilio hipponous	Pap.	1	3	0	0	0	0	4	VR	open

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage (Continued).

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitat types
Delias descombesi	Pie.	1	1	2	0	0	0	4	VR	open
Appias pandione	Pie.	4	0	0	0	0	0	4	VR	open
Penthema darlisa	Nym.	0	4	0	0	0	0	4	VR	close
Athyma zeroca	Nym.	4	0	0	0	0	0	4	VR	open
Euthalia alpheda	Nym.	3	0	0	0	1	0	4	VR	open
Arhopala paraganesa	Lyc.	1	0	0	0	3	0	4	VR	open
Abisara echerius	Lyc.	3	0	0	1	0	0	4	VR	open
Pseudocoladenia dan	Hes.	0	0	0	0	2	2	4	VR	open
Pirdana hyela	Hes.	3	0	1	0	0	0	4	VR	close
Pelopidas mathias	Hes.	1	1	0	0	0	2	4	VR	close
Caltoris cormasa	Hes.	0	1	0	0	3	0	4	VR	close
Delias pasithoe	Pie.	3	0	0	0	0	0	3	VR	open
Delias hyparete	Pie.	0	2	1	0	0	0	3	VR	open
Zeuxidia amethystus	Nym.	1	0	2	0	0	0	3	VR	close
Neptis harita	Nym.	0	1	2	0	0	0	3	VR	open
Syntarucus plinius	Lyc.	0	0	1	0	2	0	3	VR	open
Arhopala democritus	Lyc.	1	0	1	0	1	0	3	VR	open
Spindasis lohita	Lyc.	0	0	1	1	0	1	3	VR	open
Flos diardi	Lyc.	2	0	0	0	1	0	3	VR	open
Tagiades vajuna	Hes.	2	1	0	0	0	0	3	VR	open
Halpe zola	Hes.	0	0	0	1	0	2	3	VR	open
Oerana microthyrus	Hes.	0	0	0	2	0	1	3	VR	open
Chilasa clytia	Pap.	1	0	1	0	0	0	2	VR	open
Eurema simulatrix	Pie.	2	0	0	0	0	0	2	VR	open
Elymnias malelas	Nym.	1	0	0	0	1	0	2	VR	close

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage (Continued).

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitat types
Vagrans egista	Nym.	1	0	0	0	1	0	2	VR	open
Yoma sabina	Nym.	2	0	0	0	0	0	2	VR	open
Chersonesia intermedia	Nym.	1	1	0	0	0	0	2	VR	open
Parasarpa dudu	Nym.	0	1	1	0	0	0	2	VR	open
Poritia erycinoides	Lyc.	0	0	1	1	0	0	2	VR	open
Megisba malaya	Lyc.	0	2	0	0	0	0	2	VR	open
Arhopala atosia	Lyc.	2	0	0	0	0	0	2	VR	open
Yasoda tripunctata	Lyc.	2	0	0	0	0	0	2	VR	open
Laxita thuisto	Lyc.	1	0	1	0	0	0	2	VR	open
Celaenorrhinus aurivittatus	Hes.	0	0	1	1	0	0	2	VR	open
Seseria strigata	Hes.	1	1	0	0	0	0	2	VR	open
Mooreana trichoneura	Hes.	0	1	0	1	0	0	2	VR	open
Halpe flava	Hes.	0	0	0	0	0	2	2	VR	open
Scobura isota	Hes.	0	1	0	1	0	0	2	VR	open
Udaspes folus	Hes.	0	0	1	0	0	1	2	VR	open
Taractrocera maevius	Hes.	0	1	0	0	1	0	2	VR	close
Potanthus omaha	Hes.	0	1	0	1	0	0	2	VR	close
Pithauria stramineipennis	Hes.	0	1	0	1	0	0	2	VR	close
Pithauria murdava	Hes.	0	0	0	0	0	2	2	VR	close
parides zaleucus	Pap.	0	1	0	0	0	0	1	VR	open
Appias nero	Pie.	1	0	0	0	0	0	1	VR	open
Parantica aspasia	Nym.	0	0	1	0	0	0	1	VR	open
Mycalesis visala	Nym.	0	0	0	1	0	0	1	VR	close
Junonia orithya	Nym.	1	0	0	0	0	0	1	VR	open
Lasippa monata	Nym.	0	1	0	0	0	0	1	VR	open

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage (Continued).

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitat types
Athyma reta	Nym.	1	0	0	0	0	0	1	VR	open
Euripus nyctelius	Nym.	0	0	0	0	1	0	1	VR	open
Simiskina pediata	Lyc.	0	0	1	0	0	0	1	VR	open
Allotinus substrigosus	Lyc.	1	0	0	0	0	0	1	VR	open
Arhopala athada	Lyc.	1	0	0	0	0	0	1	VR	open
Semanga superba	Lyc.	1	0	0	0	0	0	1	VR	open
Spindasis vulcanus	Lyc.	0	0	1	0	0	0	1	VR	open
Drina donina	Lyc.	0	0	1	0	0	0	1	VR	open
Drupadia theda	Lyc.	1	0	0	0	0	0	1	VR	open
Bullis stigmata	Lyc.	0	0	1	0	0	0	1	VR	open
Eliotia jalindra	Lyc.	1	0	0	0	0	0	1	VR	open
Sithon nedymond	Lyc.	0	0	0	0	1	0	1	VR	open
Hasora chromus	Hes.	0	0	0	0	0	1	1	VR	close
Celaenorrbinus leucocera	Hes.	0	0	0	0	1	0	1	VR	open
Celaenorrhinus munda	Hes.	0	0	1	0	0	0	1	VR	open
Celaenorrhinus nigricans	Hes.	0	1	0	0	0	0	1	VR	open
Celaenorrhinus inaequalis	Hes.	0	1	0	0	0	0	1	VR	open
Darpa striata	Hes.	0	0	1	0	0	0	1	VR	close
Gerosis phisara	Hes.	1	0	0	0	0	0	1	VR	open
Satarupa gopala	Hes.	0	1	0	0	0	0	1	VR	close
Caprona agama	Hes.	0	0	0	0	1	0	1	VR	open
Ampittia dioscorides	Hes.	0	0	0	0	1	0	1	VR	open
Thoressa cerata	Hes.	0	1	0	0	0	0	1	VR	open
Sovia albipecta	Hes.	0	0	0	0	1	0	1	VR	open
Ancistroiedes armatus	Hes.	0	0	0	1	0	0	1	VR	open

Table B.1 Butterflies diversity in 6 waterfalls at Dong Phayayen Khao Yai world Heritage (Continued).

Scientific name	Family	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Status	Habitat types
Suastus gremius	Hes.	0	0	0	0	1	0	1	VR	open
Cupitha purreea	Hes.	0	0	0	0	0	1	1	VR	open
Plastingia naga	Hes.	0	0	0	1	0	0	1	VR	open
Pyroneuea flavia	Hes.	1	0	0	0	0	0	1	VR	open
Unkana ambasa	Hes.	0	0	1	0	0	0	1	VR	close
Potanthus chloe	Hes.	0	1	0	0	0	0	1	VR	close
Telicota ohara	Hes.	0	0	0	1	0	0	1	VR	close
Pelopidas assamensis	Hes.	0	0	0	0	0	1	1	VR	close
Borbo bevani	Hes.	1	0	0	0	0	0	1	VR	close
Iton semamora	Hes.	0	0	0	0	0	1	1	VR	close
Total number of individuals		12,080	10,278	5,937	4,872	2,943	1,474	37,584		
Total number of species		244	201	195	193	169	139	306		

Table B.2 Butterfly species found only in the morning or afternoon.

Family	Common name	Scientific name	Number of individuals
		Morning	
Papilionidae	Golden Birdwing	*Troides aeacus*	12
	Banded Mormon	*Papilio hipponous*	4
	Burmese Batwing	*parides zaleucus*	1
	Common Mime	*Chilasa clytia*	2
Pieridae	Red-base Jezebel	*Delias pasithoe*	3
	Red-spotJezebel	*Delias descombesi*	4
	painted Jezebel	*Delias hyparete*	3
	Banded Puffin	*Appias pandione*	4
	Orange Albatross	*Appias nero*	1
	Orange Emigrant	*Catopsillia scylla*	5
	Hill Grass Yellow	*Eurema simulatrix*	2
	Chocolate Grass Yellow	*Eurema sari*	10
Nymphalidae	Yellow Glassy Tiger	*Parantica aspasia*	1
	Long-Branded Bushbrown	*Mycalesis visala*	1
	Lilacine Bushbrown	*Mycalesis francisca*	5
	Common Cruicer	*Vindula erota*	11
	Vagrant	*Vagrans egista*	2
	Blue Pansy	*Junonia orithya*	1
	Lurcher	*Yoma sabina*	2
	Common Maplet	*Chersonesia risa*	12
	Intermediate Maplet	*Chersonesia intermedia*	2
	Dingiest Sailor	*Neptis harita*	3
	Cambodian Lascar	*Neptis tiga*	8
	Tiger Lascar	*Lasippa monata*	1
	Lance Sergeant	*Athyma pravara*	8
	Malay Staff Sergeant	*Athyma reta*	1
	Studded Sergeant	*Athyma asura*	11
	Small Staff Sergeant	*Athyma zeroca*	4
	Orange Staff Sergeant	*Athyma cama*	7
	Common Courtesan	*Euripus nyctelius*	1
	Black Rajah	*Charaxes solon*	6
Lycaenidae	Blue Gem	*Poritia erycinoides*	2
	Lesser Darkie	*Allotinus substrigosus*	1
	Pale Grass Blue	*Zizeeria maha*	5
	Malayan	*Megisba malaya*	2
	Zebra Blue	*Syntarucus plinius*	3
	Siamese Oakblue	*Arhopala dispar*	5
	Tailed Dise Oakblue	*Arhopala atosia*	2
	Vinous Oakblue	*Arhopala athada*	1
	Dusky Bushblue	*Arhopala paraganesa*	4

Table B.2 Butterfly species found only in the morning or afternoon (Continued).

Family	Common name	Scientific name	Number of individuals
Lycaenidae	Rededge	*Semanga superba*	1
	Common Silverline	*Spindasis vulcanus*	1
	Small Long-banded Silverline	*Spindasis lohita*	3
	Bifid Plushblue	*Flos diardi*	3
	Brown Yam	*Drina donina*	1
	White Imperial	*Neomyrina nivea*	5
	Dark Posy	*Drupadia theda*	1
	Threespot Yamfly	*Yasoda tripunctata*	2
	Chocolate Royal	*Remelana jangala*	5
	Small Branded Royal	*Bullis stigmata*	1
	Banded Royal	*Eliotia jalindra*	1
	Plush	*Sithon nedymond*	1
	Lesser Harlequin	*Laxita thuisto*	2
Hesperiidae	*Orange-tailed Awl*	*Bibasis sena*	11
	Common Banded Awl	*Hasora chromus*	1
	White-banded Awl	*Hasora taminatus*	10
	Common Spotted Flat	*Celaenorrbinus leucocera*	1
	Himalayan Spotted Flat	*Celaenorrhinus munda*	1
	Small baned Flat	*Celaenorrhinus nigricans*	1
	Unequal Banded Flat	*Celaenorrhinus inaequalis*	1
	Dark Yellow-banded Flat	*Celaenorrhinus aurivittatus*	2
	Fulvous Pied Flat	*Pseudocoladenia dan*	4
	Variable White Flat	*Gerosis phisara*	1
	Large White Flat	*Satarupa gopala*	1
	New Snow Flat	*Tagiades vajuna*	3
	Spotted Snow Flat	*Tagiades menaka*	8
	Common Bush Hopper	*Ampittia dioscorides*	1
	Northern Ace	*Thoressa cerata*	1
	Swinhoe's Ace	*Halpe burmana*	9
	Couple Yellow Ace	*Halpe flava*	2
	Long-banded Ace	*Halpe zola*	3
	Silverbreast Ace	*Sovia albipecta*	1
	Swinhoe's Forest Bob	*Scobura isota*	2
	Red Demon	*Ancistroiedes armatus*	1
	Common Banded Demon	*Nptocrypta paralysos*	13
	Grass Bob	*Udaspes folus*	2
	Indian Plam Bob	*Suastus gremius*	1
	Wax Dart	*Cupitha*	1
	Silver-spot Lancer	*Plastingia naga*	1
	Lesser Lancer	*Pyroneuea flavia*	1

Table B.2 Butterfly species found only in the morning or afternoon (Continued).

Family	Common name	Scientific name	Number of individuals
Hesperiidae	White-tipped Palmer	*Lotongus calathus*	5
	Hoary Palmer	*Unkana ambasa*	1
	Common Grassdart	*Taractrocera maevius*	2
	Orange Dart	*Potanthus chloe*	1
	Narrow-banded Plam Dart	*Telicota ohara*	1
	Conjoined Swift	*Pelopidas assamensis*	1
	Lesser Rice Swift	*Borbo bevani*	1
	Common Wight	*Iton semamora*	1
	Dark Straw Ace	*Pithauria murdava*	2
		Afternoon	
Nymphalidae	Common Saturn	*Zeuxidia amethystus*	2
	Blue Nawab	*Polyura schreiber*	2
Lycaenidae	Mixture Blue Brilliant	*Simiskina pediata*	1
	Striated Angle	*Darpa striata*	1
	Spotted Angle	*Caprona agama*	1

APPENDIX C

BUTTERFLY SPECIES AND INDIVIDUAL BY MONTH

Table C.1 Total number of butterfly species by month.

	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Average
Jun-09	99	81	68	70	54	-	150	74.4
Jul-09	95	80	68	62	56	-	144	72.2
Aug-09	93	63	60	58	41	-	138	63.0
Sep-09	63	57	46	50	34	-	91	50.0
Oct-09	96	90	82	75	58	--	143	80.2
Nov-09	87	83	61	63	42	-	125	67.2
Dec-09	89	79	65	62	36	-	118	66.2
Jan-10	102	90	59	73	44	52	158	70.0
Feb-10	99	92	67	63	47	40	163	68.0
Mar-10	97	83	57	69	48	46	151	66.7
Apr-10	106	94	64	83	50	52	162	74.8
May-10	138	112	97	103	78	66	195	99.0
Jun-10	93	67	73	60	52	40	162	64.2
Jul-10	71	59	54	56	52	36	141	54.7
Aug-10	89	69	56	60	44	43	151	60.2
Sep-10	76	76	54	53	50	41	135	58.3
Oct-10	133	104	77	87	79	64	181	90.7
Nov-10	100	89	63	57	51	45	163	67.5
Dec-10	121	95	73	76	59	40	182	77.3
Total	244	201	195	193	170	139	306	190.3
Average	97.2	82.3	65.5	67.4	51.3	47.1	150.2	69.7

Table C.2 Total number of butterfly individuals by month.

	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Average
Jun-09	656	497	296	189	183	-	1821	364.2
Jul-09	593	471	285	185	154	-	1688	337.6
Aug-09	520	427	246	186	123	-	1502	300.4
Sep-09	513	436	284	201	100	-	1534	306.8
Oct-09	727	663	538	414	199	-	2541	508.2
Nov-09	589	525	323	192	155	-	1784	356.8
Dec-09	616	475	343	238	98	-	1770	354.0
Jan-10	668	541	276	317	137	145	2084	347.3
Feb-10	532	590	300	215	136	103	1876	312.7
Mar-10	570	485	242	212	123	123	1755	292.5
Apr-10	699	599	270	392	143	131	2234	372.3
May-10	1145	1009	589	511	259	211	3724	620.7
Jun-10	563	415	283	184	151	94	1690	281.7
Jul-10	434	394	210	193	168	80	1479	246.5
Aug-10	572	429	216	203	104	109	1633	272.2
Sep-10	488	497	244	225	159	98	1711	285.2
Oct-10	886	780	461	325	214	179	2845	474.2
Nov-10	633	491	237	252	169	107	1889	314.8
Dec-10	676	554	294	238	168	94	2024	337.3
Total	12080	10278	5937	4872	2943	1474	37584	6264.0
Average	635.8	540.9	312.5	256.4	154.9	122.8	1978.1	337.2

Table C.3 Number of butterfly species in the morning and afternoon by month.

	Pang Sida			Heaw Suwat			Heaw Narok			Sarika			Huai Yai			Wang Muang			Total		
	Mor.	Aft.	Total	Mor.	Aft.	Total	Mor.	Aft.	Total	Mor.	Aft.	Total	Mor.	Aft.	Total	Mor.	Aft.	Total	Mor.	Aft.	Total
Jun-09	89	63	99	77	47	81	66	41	68	65	30	70	48	29	54	-	-	-	149	87	150
Jul-09	87	63	95	77	42	80	66	39	68	58	33	62	51	20	56	-	-	-	140	85	144
Aug-09	90	60	93	62	42	63	58	36	60	57	28	58	37	22	41	-	-	-	131	82	138
Sep-09	62	48	63	56	44	57	46	41	46	49	31	50	32	15	34	-	-	-	88	76	91
Oct-09	91	70	96	88	61	90	78	55	82	74	57	75	55	29	58	-	-	-	136	103	143
Nov-09	85	55	87	81	51	83	57	46	61	60	25	63	42	23	42	-	-	-	122	87	125
Dec-09	89	58	89	77	46	79	61	45	65	61	28	62	35	13	36	-	-	-	116	78	118
Jan-10	90	53	90	81	46	81	46	20	48	65	35	69	30	10	31	38	10	40	147	83	148
Feb-10	89	45	89	80	47	82	60	24	60	55	24	58	36	12	38	28	12	34	151	81	156
Mar-10	85	42	85	73	49	75	48	22	49	57	20	61	37	6	37	37	11	40	139	80	143
Apr-10	92	60	92	85	44	86	49	27	51	73	41	75	42	17	45	39	13	42	153	93	155
May-10	118	70	121	97	71	102	75	49	77	85	53	97	66	31	68	46	17	50	174	130	185
Jun-10	75	47	78	52	33	53	60	23	62	44	12	48	43	16	45	31	8	31	144	74	153
Jul-10	60	37	61	46	30	47	44	22	46	49	16	52	43	13	44	28	4	29	125	61	127
Aug-10	77	45	77	55	36	58	49	19	50	52	19	55	36	10	37	36	15	37	139	73	142
Sep-10	63	40	65	63	35	64	44	22	44	42	23	46	37	23	40	25	7	26	120	71	124
Oct-10	113	61	117	89	57	94	63	34	64	72	24	74	60	25	64	47	11	50	161	96	169
Nov-10	85	46	85	76	46	80	49	23	52	49	23	52	42	13	42	31	11	34	148	82	151
Dec-10	99	62	109	82	49	90	60	26	62	59	21	67	49	17	51	30	12	32	165	103	176
Total	235	150	240	192	134	197	185	118	190	181	124	192	154	103	160	127	57	133	298	214	303
Average	86.26	53.95	89.00	73.53	46.11	76.05	56.79	32.32	58.68	59.26	28.58	62.84	43.21	18.11	45.42	34.67	10.92	37.08	139.37	85.53	144.11

Mor = Morning, Aft = Afternoon

Table C.4 Number of butterfly individuals in the morning and afternoon by month.

	Pang Sida			Heaw Suwat			Heaw Narok			Sarika			Huai Yai			Wang Muang			Total		
	Mor.	Aft.	Total	Mor.	Aft.	Total	Mor.	Aft.	Total	Mor.	Aft.	Total	Mor.	Aft.	Total	Mor.	Aft.	Total	Mor.	Aft.	Total
Jun-09	445	211	656	350	147	497	200	96	296	146	43	189	130	53	183	-	-	-	1,271	550	1821
Jul-09	404	189	593	338	133	471	188	97	285	125	60	185	114	40	154	-	-	-	1,169	519	1688
Aug-09	351	169	520	315	112	427	171	75	246	133	53	186	90	33	123	-	-	-	1,060	442	1502
Sep-09	352	161	513	292	144	436	178	106	284	140	61	201	71	29	100	-	-	-	1,033	501	1534
Oct-09	506	221	727	457	206	663	356	182	538	274	140	414	152	47	199	-	-	-	1,745	796	2541
Nov-09	409	180	589	371	154	525	207	116	323	145	47	192	114	41	155	-	-	-	1,246	538	1784
Dec-09	125	191	616	332	143	475	222	121	343	171	67	238	77	21	98	-	-	-	1,227	543	1770
Jan-10	391	175	566	330	119	449	138	50	188	180	64	244	66	17	83	77	18	95	1,182	443	1625
Feb-10	328	124	452	389	139	528	194	61	255	131	48	179	73	20	93	55	21	76	1,170	413	1583
Mar-10	332	157	489	307	133	440	154	48	202	132	34	166	73	11	84	66	18	84	1,064	401	1465
Apr-10	419	193	612	389	148	537	159	58	217	235	98	333	91	29	120	71	21	92	1,364	547	1911
May-10	676	309	985	623	271	894	337	155	492	290	126	416	150	59	209	98	30	128	2,174	950	3124
Jun-10	341	136	477	243	106	349	176	62	238	105	26	131	91	29	120	59	8	67	1,015	367	1382
Jul-10	262	115	377	240	96	336	137	45	182	129	34	163	97	24	121	45	4	49	910	318	1228
Aug-10	343	143	486	268	106	374	139	48	187	131	46	177	68	15	83	61	15	76	1,010	373	1383
Sep-10	285	127	412	320	111	431	144	51	195	129	53	182	85	33	118	44	9	53	1,007	384	1391
Oct-10	525	214	739	474	183	657	257	105	362	192	50	242	116	39	155	94	17	111	1,658	608	2266
Nov-10	384	148	532	291	122	413	136	38	174	150	54	204	98	25	123	52	14	66	1,111	401	1512
Dec-10	364	162	526	324	140	434	165	71	236	129	40	169	101	29	130	50	13	63	1,133	455	1588
Total	7,542	3,325	10867	6,653	2,713	9366	3,658	1,585	5243	3,067	1,144	4211	1,857	594	2451	772	188	960	23,549	9,549	33098
Average	381.2	175.0	571.9	350.2	142.8	491.4	192.5	83.4	275.9	161.4	60.2	221.6	97.7	31.3	129.0	64.3	15.7	80.0	1239.4	502.6	1742.0

Mor = Morning, Aft = Afternoon

Table C.5 Number of butterfly species from bait trap by month.

	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Average
Jan-10	33	26	25	18	17	15	47	22.3
Feb-10	25	22	18	12	13	11	37	16.8
Mar-10	23	15	16	14	14	12	38	15.7
Apr-10	26	22	19	18	10	16	40	18.5
May-10	47	35	33	27	23	21	72	31.0
Jun-10	28	25	18	17	11	11	51	18.3
Jul-10	21	20	13	8	11	9	39	13.7
Aug-10	23	17	16	11	11	8	39	14.3
Sep-10	21	18	16	12	14	15	38	16.0
Oct-10	51	31	25	29	21	20	67	29.5
Nov-10	37	25	21	15	15	14	56	21.2
Dec-10	34	24	20	18	13	11	49	20.0
Total	74	42	48	36	33	28	91	43.5
Average	30.8	23.3	20.0	16.6	14.4	13.6	47.8	19.8

Table C.6 Number of butterfly individuals from bait trap by month.

	Pang Sida	Heaw Suwat	Heaw Narok	Sarika	Huai Yai	Wang Muang	Total	Average
Jan-10	102	92	88	73	54	50	459	76.5
Feb-10	80	62	45	36	43	27	293	48.8
Mar-10	81	45	40	46	39	39	290	48.3
Apr-10	87	62	53	59	23	39	323	53.8
May-10	160	115	97	95	50	83	600	100.0
Jun-10	86	66	45	53	31	27	308	51.3
Jul-10	57	58	28	30	47	31	251	41.8
Aug-10	86	55	29	26	21	33	250	41.7
Sep-10	76	66	49	43	41	45	320	53.3
Oct-10	147	123	99	83	59	68	579	96.5
Nov-10	101	78	63	48	46	41	377	62.8
Dec-10	150	90	58	69	38	31	436	72.7
Total	1213	912	694	661	492	514	4,486	747.7
Average	101.1	76.0	57.8	55.1	41.0	42.8	373.8	62.3

APPENDIX D

STATISTIC ANALYSES

Table D.1 ANOVA of butterfly species, individual and environmental factors among study sites.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
sp	Between Groups	30378.586	5	6075.717	31.969	.000
	Within Groups	19195.022	101	190.050		
	Total	49573.607	106			
no	Between Groups	3780077.257	5	756015.451	61.327	.000
	Within Groups	1245080.930	101	12327.534		
	Total	5025158.187	106			
Temperature	Between Groups	78.612	5	15.722	10.371	.000
	Within Groups	153.114	101	1.516		
	Total	231.725	106			
Humidity	Between Groups	2432.133	5	486.427	15.409	.000
	Within Groups	3188.246	101	31.567		
	Total	5620.379	106			
lux	Between Groups	344264.606	5	68852.921	12.629	.000
	Within Groups	550632.282	101	5451.805		
	Total	894896.888	106			
rainfall	Between Groups	238.542	5	47.708	1.821	.115
	Within Groups	2645.430	101	26.192		
	Total	2883.972	106			
height	Between Groups	4749091.196	5	949818.239	.	.
	Within Groups	.000	101	.000		
	Total	4749091.196	106			

Table D.2 ANOVA of butterfly species, individual and environmental factors among months.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
sp	Between Groups	14206.541	18	789.252	1.964	.020
	Within Groups	35367.067	88	401.898		
	Total	49573.607	106			
no	Between Groups	874232.254	18	48568.459	1.030	.436
	Within Groups	4150925.933	88	47169.613		
	Total	5025158.187	106			
Temperature	Between Groups	89.940	18	4.997	3.101	.000
	Within Groups	141.786	88	1.611		
	Total	231.725	106			
Humidity	Between Groups	2028.187	18	112.677	2.760	.001
	Within Groups	3592.192	88	40.820		
	Total	5620.379	106			
lux	Between Groups	298263.555	18	16570.197	2.444	.003
	Within Groups	596633.333	88	6779.924		
	Total	894896.888	106			
rainfall	Between Groups	1982.448	18	110.136	10.751	.000
	Within Groups	901.523	88	10.245		
	Total	2883.972	106			

Table D.3 Pair t-test of species, number, temperature, humidity and light intensity between morning and afternoon.

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 sp_mor - sp_af	2.75234E1	8.15226	.78811	25.96086	29.08587	34.923	106	.000
Pair 1 no_mor - no_af	1.28037E2	76.28187	7.37445	113.41683	142.65794	17.362	106	.000
Pair 1 Tem_mor - Tem_af	-4.78598	2.42967	.23488	-5.25166	-4.32030	-20.376	106	.000
Pair 1 hum_mor - hum_af	2.01308E1	8.03305	.77658	18.59119	21.67049	25.922	106	.000
Pair 1 lux_mor - lux_af	-4.73598E2	146.05523	14.11969	-501.59179	-445.60447	-33.542	106	.000

Table D.4 Correlation analysis between butterfly species, number and environmental factors.

Correlations

			sp	no	Temperature	Humidity	lux	rainfall	height
Spearman's rho	sp	Correlation Coefficient	1.000	.920**	-.280**	.244*	-.123	-.097	.248*
		Sig. (2-tailed)	.	.000	.003	.011	.206	.322	.010
		N	107	107	107	107	107	107	107
	no	Correlation Coefficient	.920**	1.000	-.261**	.344**	-.182	.028	.405**
		Sig. (2-tailed)	.000	.	.007	.000	.061	.771	.000
		N	107	107	107	107	107	107	107
	Temperature	Correlation Coefficient	-.280**	-.261**	1.000	-.382**	.349**	.166	-.264**
		Sig. (2-tailed)	.003	.007	.	.000	.000	.088	.006
		N	107	107	107	107	107	107	107
	Humidity	Correlation Coefficient	.244*	.344**	-.382**	1.000	-.281**	.481**	.282**
		Sig. (2-tailed)	.011	.000	.000	.	.003	.000	.003
		N	107	107	107	107	107	107	107
	lux	Correlation Coefficient	-.123	-.182	.349**	-.281**	1.000	.023	-.147
		Sig. (2-tailed)	.206	.061	.000	.003	.	.812	.130
		N	107	107	107	107	107	107	107
	rainfall	Correlation Coefficient	-.097	.028	.166	.481**	.023	1.000	.067
		Sig. (2-tailed)	.322	.771	.088	.000	.812	.	.494
		N	107	107	107	107	107	107	107
	height	Correlation Coefficient	.248*	.405**	-.264**	.282**	-.147	.067	1.000
		Sig. (2-tailed)	.010	.000	.006	.003	.130	.494	.
		N	107	107	107	107	107	107	107

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2 tailed).

Table D.5 MANOVA of butterfly food preference experiment.

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.897	8.315E2[a]	2.000	191.000	.000
	Wilks' Lambda	.103	8.315E2[a]	2.000	191.000	.000
	Hotelling's Trace	8.707	8.315E2[a]	2.000	191.000	.000
	Roy's Largest Root	8.707	8.315E2[a]	2.000	191.000	.000
Month1	Pillai's Trace	.360	8.435	10.000	384.000	.000
	Wilks' Lambda	.647	9.294[a]	10.000	382.000	.000
	Hotelling's Trace	.535	10.161	10.000	380.000	.000
	Roy's Largest Root	.513	19.714[b]	5.000	192.000	.000
forest	Pillai's Trace	.347	50.807[a]	2.000	191.000	.000
	Wilks' Lambda	.653	50.807[a]	2.000	191.000	.000
	Hotelling's Trace	.532	50.807[a]	2.000	191.000	.000
	Roy's Largest Root	.532	50.807[a]	2.000	191.000	.000
food1	Pillai's Trace	.962	25.434	14.000	384.000	.000
	Wilks' Lambda	.139	45.960[a]	14.000	382.000	.000
	Hotelling's Trace	5.478	74.344	14.000	380.000	.000
	Roy's Largest Root	5.342	1.465E2[b]	7.000	192.000	.000
Month1 * forest	Pillai's Trace	.051	1.009	10.000	384.000	.435
	Wilks' Lambda	.949	1.005[a]	10.000	382.000	.438
	Hotelling's Trace	.053	1.001	10.000	380.000	.442
	Roy's Largest Root	.036	1.371[b]	5.000	192.000	.237
Month1 * food1	Pillai's Trace	.331	1.088	70.000	384.000	.306
	Wilks' Lambda	.692	1.101[a]	70.000	382.000	.283
	Hotelling's Trace	.411	1.114	70.000	380.000	.262
	Roy's Largest Root	.296	1.626[b]	35.000	192.000	.021
forest * food1	Pillai's Trace	.392	6.687	14.000	384.000	.000
	Wilks' Lambda	.624	7.269[a]	14.000	382.000	.000
	Hotelling's Trace	.579	7.855	14.000	380.000	.000
	Roy's Largest Root	.532	14.588[b]	7.000	192.000	.000
Month1 * forest * food1	Pillai's Trace	.290	.930	70.000	384.000	.636
	Wilks' Lambda	.728	.940[a]	70.000	382.000	.615
	Hotelling's Trace	.350	.949	70.000	380.000	.595
	Roy's Largest Root	.254	1.391[b]	35.000	192.000	.085

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

c. Design: Intercept + Month1 + forest + food1 + Month1 * forest + Month1 * food1 + forest * food1 + Month1 * forest * food1

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Publication

Sukanya Lapkratok and Pongthep Suwanwaree. (2014). Bait selection of butterflies at Dong Phayayen-Khao Yai Forest Complex World Heritage, Thailand. Advanced Materials Research. V.1030-1032:683-686.

Position and Place of Work

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