CHAPTER 2

LITERATURE REVIEW

2.1 Geography of Thailand

Continental SE Asia is an assemblage of small and large terrains, which rifted off from the northern margin of Gondwana and were accreted to Laurasia and/or Protochina. In the previous decade, several models for how the SE Asia region become assembled were proposed. They differ mainly from one another on the timing of rift, drift and collision histories of the terrains. But all agree that the amalgamating process forming SE Asia was due to a series of arrivals of northward moving of many microcontinents (Mey, 1998). This process may already have started in the early Palaeozoic (~ 400 Ma). Most of Southeast Asia was already in the current form in the late Cretaceous (~ 70 Ma). But the major parts of Southeast Asia were submerged several times during the Tertiary (66-1.6 Ma) (Turner *et al.*, 2001). Among these drifted microcontinents, the Indochina and Sibumasu (some literature call Sibumasu as Shan-Thai (Buffetaut and Suteethorn, 1998) were northward drifted, combined and became the land where as the location of the recent Thailand (Fig 2.1). In this thesis, the models of SE Asia microcontinent formation from Metcalfe (1998) was selected and modified to briefly explain the geological formation of the plates becoming Thailand.

Indochina and Sibumasu had been the outer margin of Gondwana in early Palaeozoic era. Indochina and Sibumasu were separated from Gondwana in Devonian and Permain, respectively. They traveled northward and joined with Eurasia in Triassic period (Metcalfe, 1998). The details of these geological processes with the biological events along the geological time are showed as follow.

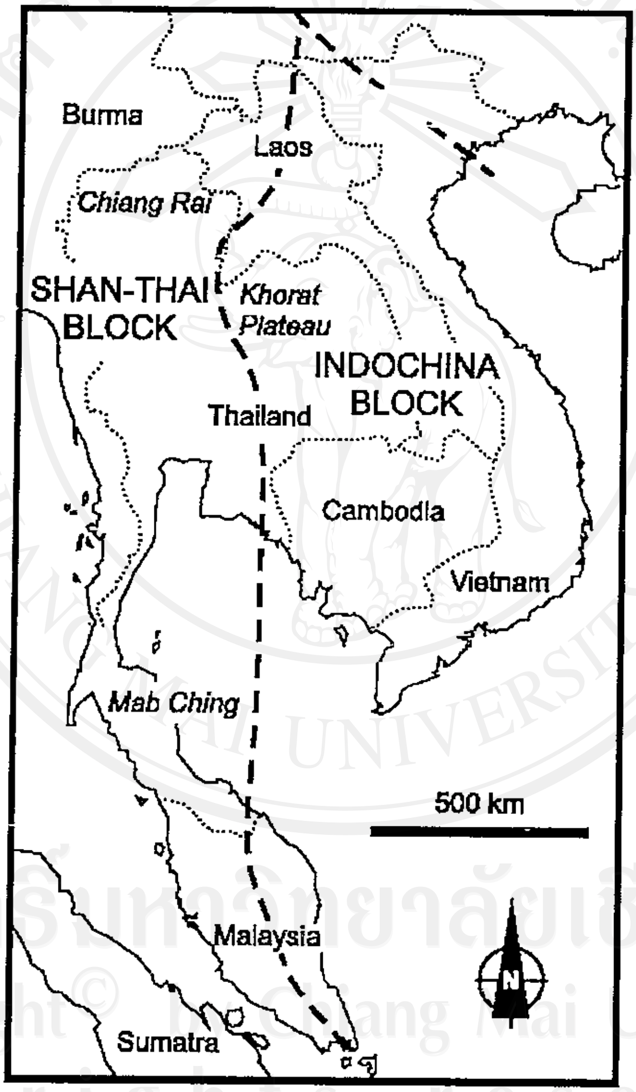

Fig 2.1 Map of SE Asia showing microcontinents; Indochina and Shan-Thai (Sibumasu) blocks that becoming the base of recent Thailand (Reference: Buffetaut and Suteethorn, 1999).

2.2.1 Thailand in Pre-Cambrian and Paleozoic

The oldest geological ages Pre-Cambrian (>570 Million Years Ago; Ma), at that time the earth crusts became cooler. The primitive invertebrates are hypothesized that were the living-things occupied on the earth (Borror *et al.*, 1989; William and Feltmete, 1992).

In the age of Palaeozoic (570-245 Ma), the most important event in this era was the forming of Pangea; the joining between two major plates Laurasia and Gondwana. Pangea was completing forming in Permian era (Metcalfe, 1998). The trichopterans (Wiggins, 1984) and other insect orders (William and Feltmate, 1992) were hypothesized that were originated in this period.

In the early of Palaeozoic, Indochina and Sibumasu located at the Palaeo-equator. Both block were the outer margin of Gondwana (Fig 2.2). Indochina block initially traveled apart from Gondwana in Devonian period (Fig 2.3). At the same time, Sibumasu still gradually drifted southward together with the Gondwana. In the late of Permian (Palaeozoic), Sibumasu was derived apart from Gondwana (Fig 2.4). The details of the traveling of the Indochina and Sibumasu blocks with geological and biological events in each period of Palaeozoic are showed in Table 2.1.

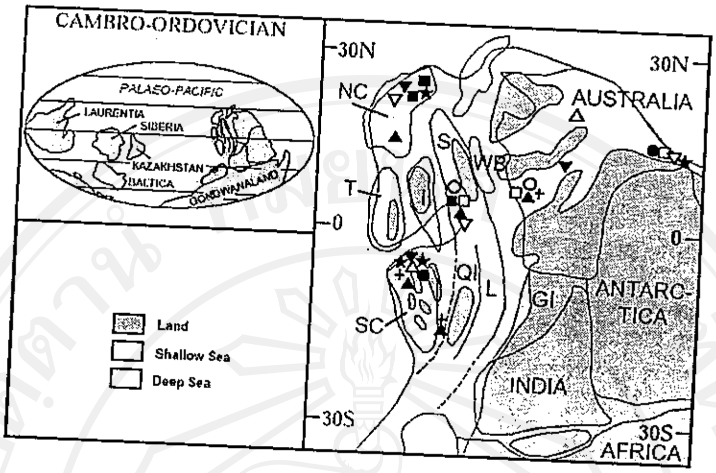

Fig 2.2 Distribution of land and sea in Cambrian and Ordovician (Cambro-Ordocician). NC = North China, SC = South China, T = Tarim, **I = Indochina**, QI = Qiangtang, L = Lhasa, S = **Sibumasu**, WB = West Burma, GI = Greater India (Reference: Metcalfe, 1998).

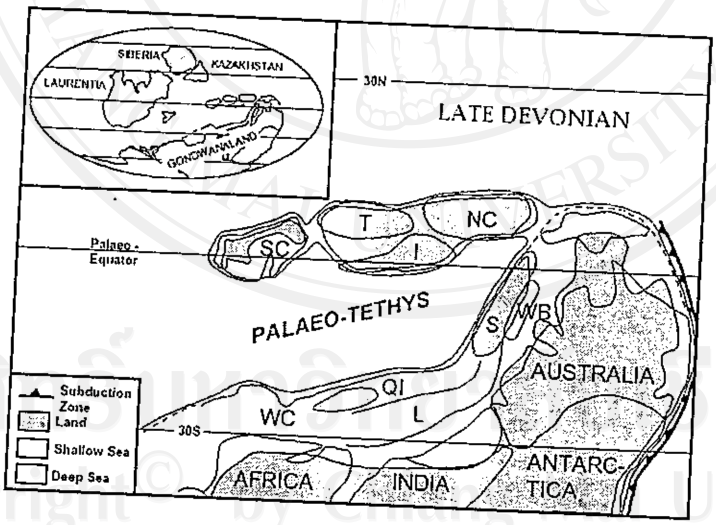

Fig 2.3 Distribution of land and sea in Late Devonian. NC = North China, SC = South China, T = Tarim, **I = Indochina**, QI = Qiangtang, L = Lhasa, **S = Sibumasu**, WB = West Burma (Reference: Metcalfe, 1998).

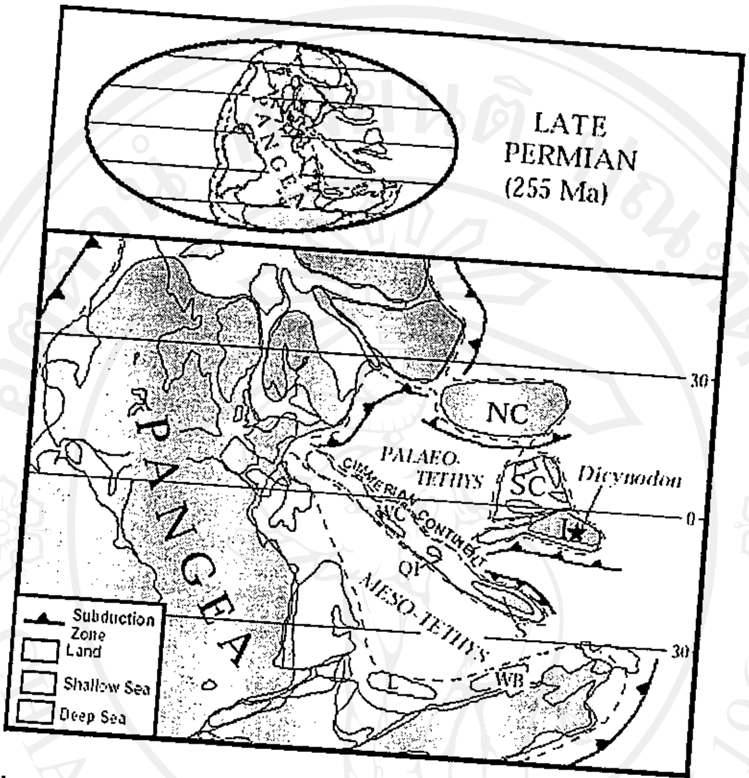

Fig 2.4 Distribution of land and sea in Late Permian. The Pangea was the combination continent between the Gondwana and Laurasia. Meanwhile, the microcontinents of SE Asia including Indochina and Sibumasu blocks were rifted apart from the Gondwana. NC = North China, SC = South China, T = Tarim, **I = Indochina**, QI = Qiangtang, L = Lhasa, **S = Sibumasu**, WB = West Burma (Reference: Metcalfe, 1998).

Table 2.1 The traveling steps of Indochina and Sibumasu blocks with geological and biological events in each period of Palaeozoic (References; Wiggins, 1984; Borror *et al.*, 1989; William and Feltmate, 1992; Metcalfe, 1998).

Period	Geological Events	Biological Events
Cambrian (570-505 Ma)	Indochina and Sibumasu located at 0°, attached with Gondwana	First arthropod (Marines; trilobites, xiphosurans)
Ordovician (505-438 Ma)		First vertebrate
Silulian (438-408 Ma)	Indochina drifted northward and situated at 10°N. Sibumasu located at 0°. Both still connected with Gondwana.	First arthropod (Scorpion & Millipede)
Devonian (408-360 Ma)	Indochina separated from Gondwana and located around 0°. Sibumasu drifted southward reach 10°S with Gondwana.	First insects (springtails)
Carboniferous (360-286 Ma)		First wing insects
Permian (286-245 Ma)	Indochina located at 0°. Sibumasu completely separated apart from Gondwana, located at 20°S. Gondwana collided with Laurasia to form Pangea.	Origin of many modern insects order. Trichoptera is also believed that is originated in this period (Wiggins, 1984).

2.1.2 Thailand in Mesozoic

The important geological event in Mesozoic was the breaking down of the Pangea. In the early of the era, Pangea was separated into Laurasia and Gondwana. Indochina and Sibumasu were completely collided and situated at the Thailand recent position, 5-20 ^{o}N. Both plates also collided with Eurasia in Triassic (Fig 2.5) and completely combined in Jurassic (Fig 2.6). In the Cretaceous, both great continents become breaking down to recent form of the world continents (Metcalfe, 1998). There were the existing of some aquatic insects such as Ephemeroptera, Odonata (William and Feltmate, 1992), Trichoptera (Mey, 1998) widespread around the earth. In the late of this era, there were a rising of the modern insects with the co-evolution with the flower plants (William and Feltmate, 1992). The content of this section is presented in table 2.2.

Table 2.2 The traveling of the Indochina and Sibumasu blocks with geological and biological events in each period of Mesozoic (References: Borror *et al.*, 1989; William and Feltmate, 1992; Metcalfe, 1998; Mey, 1998).

Period	Geological Events	Biological Events
Triassic (245-208 Ma)	The initial breaking down of Pangea. Indochina collided with Sibumasu and both approached Eurasia.	The existing of Ephemeroptera, Odonata, Trichoptera
Jurassic (208-144 Ma)	Indochina and Sibumasu collided Eurasia.	
Cretaceous (144-65 Ma)	The break-up of Gondwana and Laurasia to continent fragments.	Rising of modern insects and the flower plants.

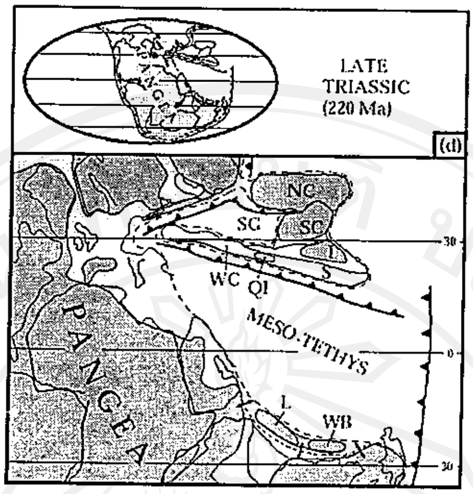

Fig 2.5 Distribution of land and sea in Triassic. NC = North China, SC = South China, T = Tarim, **I = Indochina**, QI = Qiangtang, L = Lhasa, S = **Sibumasu**, WB = West Burma (Reference: Metcalfe, 1998).

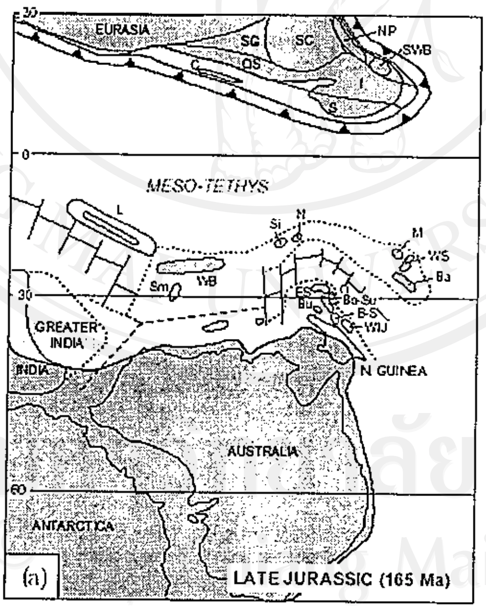

Fig 2.6 Distribution of land and sea in Jurassic. NC = North China, SC = South China, T = Tarim, **I = Indochina**, QI = Qiangtang, L = Lhasa, S = **Sibumasu**, WB = West Burma (Reference: Metcalfe, 1998).

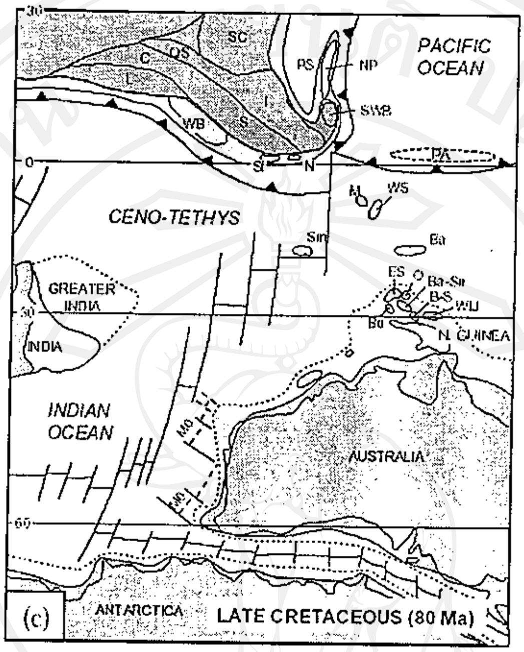

Fig 2.7 Distribution of land and sea in Cretaceous. NC = North China, SC = South China, T = Tarim, **I = Indochina**, QI = Qiangtang, L = Lhasa, **S = Sibumasu**, WB = West Burma (Reference: Metcalfe, 1998).

2.1.3 Thailand in Cenozoic

After the Cretaceous, the microcontinents of SE Asia were become in position. The most important geological event that was influenced to the Thailand geography was the drifted morthward of the India plate from around 30 °S in Cretaceous and collided the Eurasian plate at 30 °N in the Tertiary (Hall, 1998). This impact caused the development of the Himalayan and related mountain ranges, the model is demonstrated in Fig 2.8. The result of this collision also caused the uplifting of the northern region and sinking of the terran in Thai Gulf (Hall, 1998) (Fig 2.9). A lot of insect genera evolved as well as the first human rise in this era (William and Feltmate, 1992).

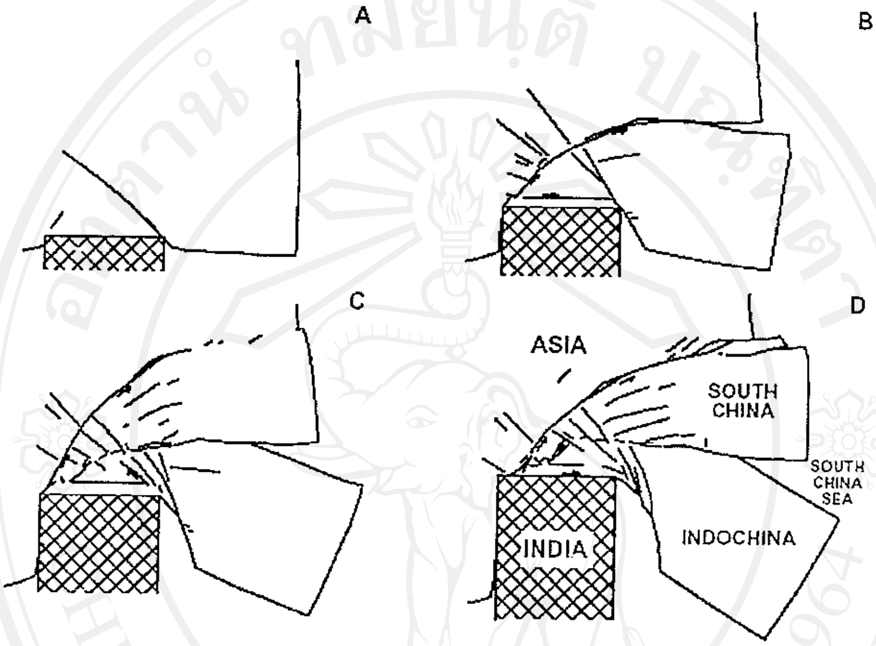

Fig 2.8 The simplified model for an explanation of the impact of India plate collision with the Eurasia that caused the development of major strike-slip faults on SE Asia (Reference: Hall, 1998).

Table 2.3 Geological and biological events in each period of Cenozoic (References: Borror *et al.*, 1989; William and Feltmate, 1992; Mey, 1998; Hall, 1998).

Period	Geological Events	Biological Events
Tertiary (66-1.6 Ma)	India plate drifted northward from 30°S to 30°N. Thailand landmass was changing as the Fig 2.9.	Rise of Modern insect genera
Quaternary (1.6 Ma-Recent)	-	First human

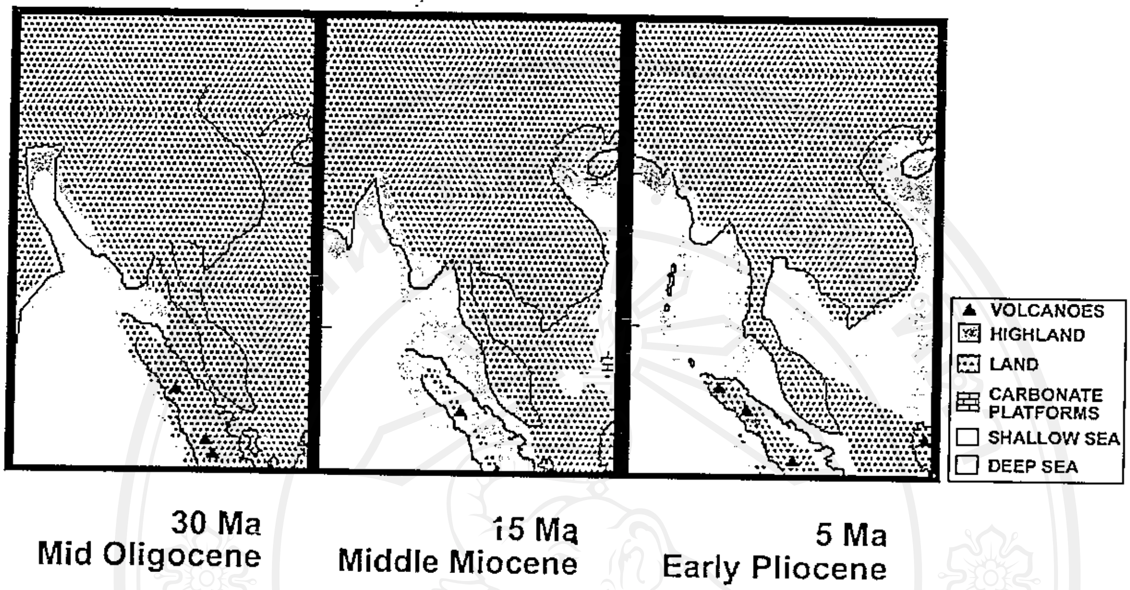

Fig 2.9 Model shows the simulation of land and sea formation of SE Asia in the epoch; Oligocene, Miocene and Pliocene in Tertiary era. This plate tectonic movement simulation model was created by Hall, 1998.

2.1.4 Thailand at present day

Thailand locates in the tropical zone of Southeast Asia or in the Oriental region (Fig 2.10) and occupies around 517,000 km^2 or an area 20% larger than California, USA (Parnell *et al.*, 2003). Thailand has long held a key position in Southeast Asian biogeography because of its location at the boundary of the Indochinese and Sundaic provinces, the major biogeographical regions of Southeast Asia (Fig 2.11). It is also centrally located in the Indo-Burma biodiversity hotspot which ranks sixth among the 25 such hotspots of the world and is home to 13,500 plant species (Myers *et al.*, 2000).

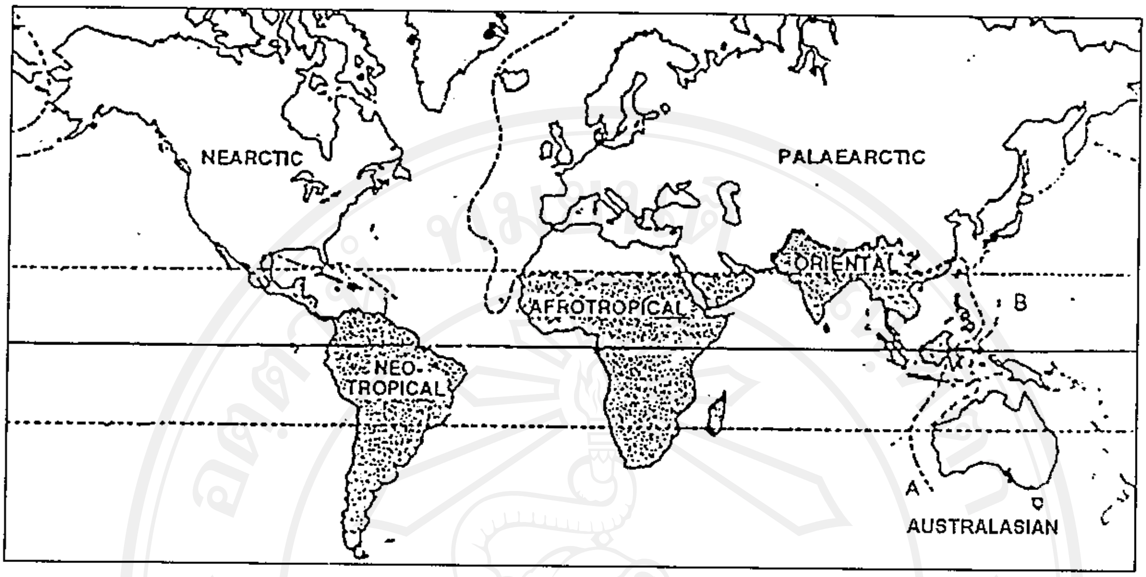

Fig 2.10 Map of the recent world with major Biogeographic regions; Palaearctic, Oriental, Nearctic, Australasian, Afrotropical and Neotropical (Reference: William and Feltmate, 1992).

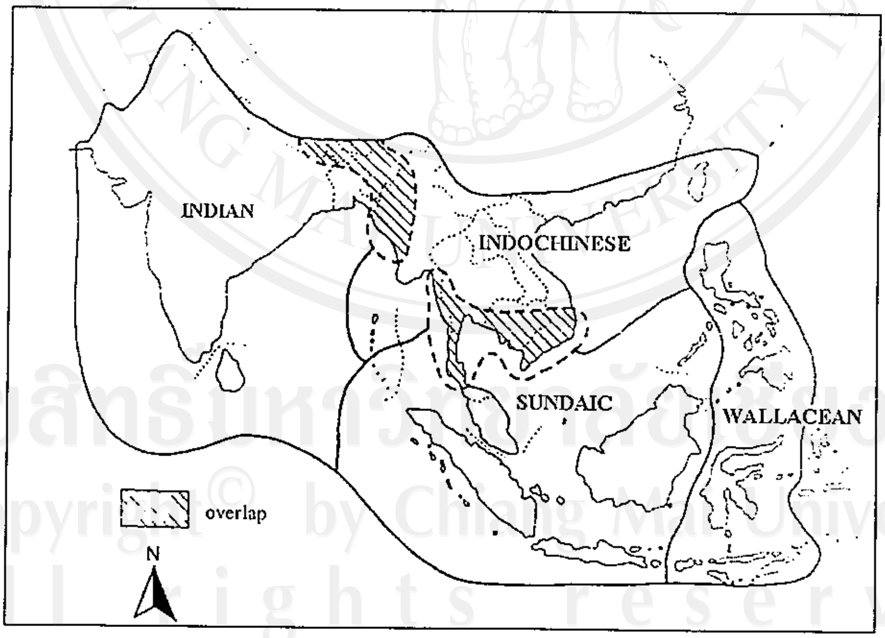

Fig 2.11 Map shows the division of Oriental region into 4 sub-regions; Indian, Indo-Chinese, Sundaic and Wallacean (Reference: Simpson and Bugna, 2001).

The southernmost of Thailand locate at 6°N the southern of Thailand, then it is influenced by the tropical rain forest. In contrast, the northern part Thailand is the highland, which was forming with the mountain ranges continuing from the Himalayan range. These mountain ranges continuously cover on the part of western, central, northeastern and eastern of Thailand (Fig 2.12). The remaining regions are mostly planes. These geographical characteristics of Thailand cause the complex of geographical characters region that support the high diversity of flora and fauna.

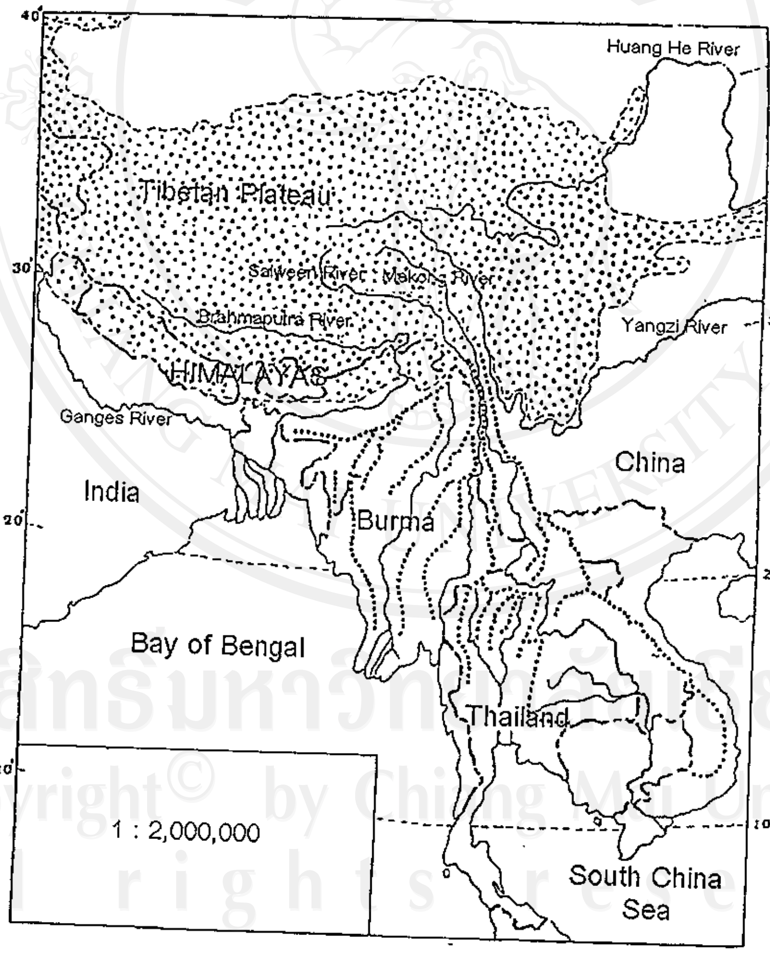

Fig 2.12 Map showing the mountain system of the connection and continuity of mountain ranges in Southeast Asia with the Great Himalayan range.

The complex geology, topography and strategic location of Thailand, together with the richness of botanical diversity, suggests that it should have a great deal of diversity of insects in this region. However, the human activities in this land rapidly deteriorate the forest and the fauna habitats. At the present, there is around 20% of forest remaining in this country (Fig 2.13) (Parnell *et al.*, 2003). Almost of the remaining forest patches are carefully preserved and protected under Thailand government as the national parks or wildlife sanctuaries.

2.1.5 Climatic condition of recent Thailand

The climates of Asian lands between the latitudes of 0° and approximately 30° are dominated by high inputs of solar energy. Mean annual temperatures at low altitudes generally exceed 20 °C. This region has high intensities of rainfall and the heaviest amount of rainfalls of any region on earth, averaging more than 2,000 mm per year (Dudgeon, 1999).

The climate of SE Asia is primarily governed by monsoon winds, which are recognized as Northeastern and Southwestern monsoons. The Northeast monsoon comprise with dry, cool air moving southwestward from the interior of continental Asia (Dudgeon, 1999). This monsoon caused by air from cold high pressure areas in Siberia and the Tibetan plateau blowing to the hot low pressure zone over Australia (Gathorne-Hardy *et al.*, 2002).

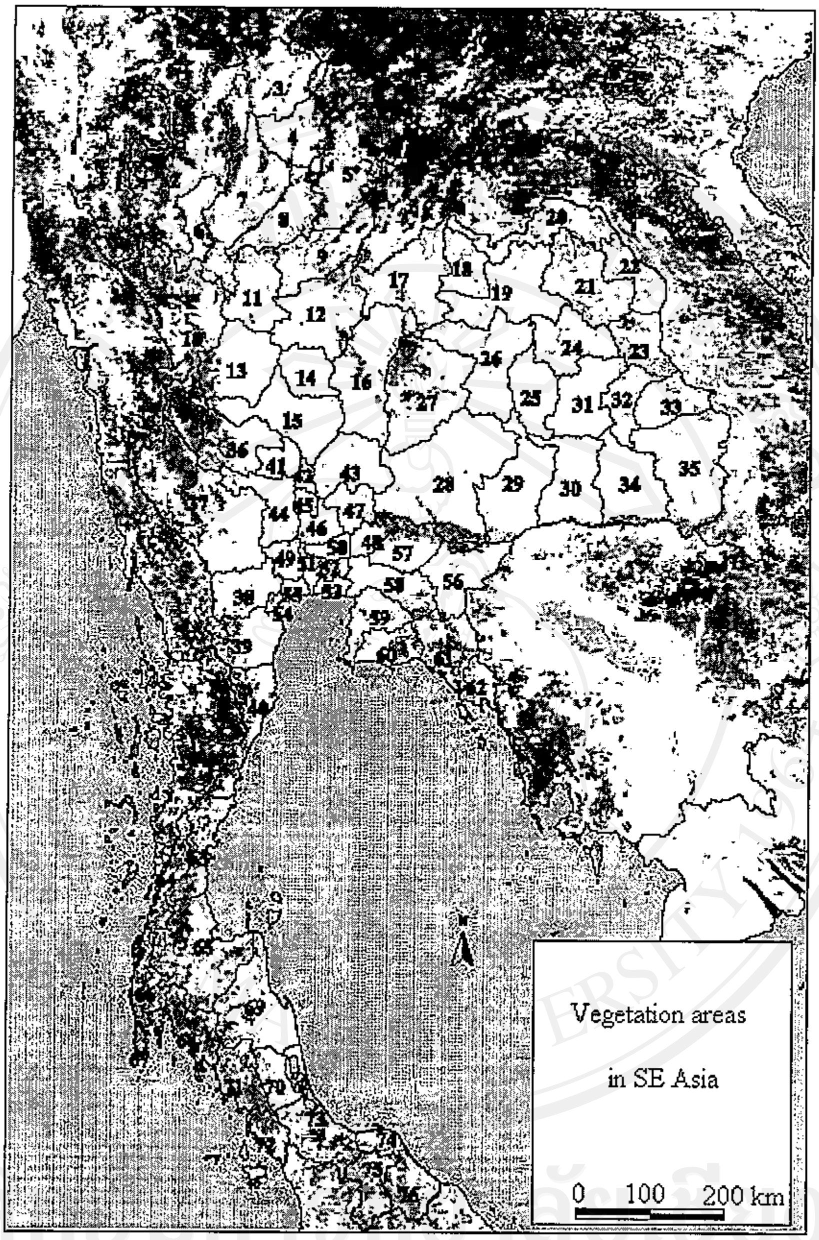

Fig 2.13 This map shows the 20% of the remaining forest patches in Thailand and nearby countries. The remaining forest patches are roughly indicated with the shaded region in the map. The number in the map indicate each provinces in Thailand (Reference: Parnell *et al.*, 2003).

The Southwestern monsoon bring the warmth and moist air moving northeastward out of the Indian and Pacific Oceans, causing rain in the SE Asia continent (Gathorne-Hardy *et al.*, 2002). This monsoon also influences on Thailand. The Northeastern and Southwestern monsoons blow across Thailand during November to April and May to October, respectively. The influence of the monsoons causes 3 seasons *viz* cold, hot and rainy season, in this region. The scheme of the monsoons and seasons of Thailand can be concluded as the Fig 2.14.

The effect of the monsoons or seasonal variation in SE Asia on the dynamic of fauna was also indicated. There was a strong seasonal variation among aquatic invertebrates living in streams at low altitude (600-800 m), where monsoon rainfall was greatest and catchments were dominated by terraced agriculture of Nepal. At these areas, a significant reduction in benthic density (on average by 77%) and taxon richness (by 20%) occurred between the winter and pre-monsoon periods, so that aquatic invertebrate diversity were already low before the monsoon (Brewin *et al.*, 2000).

MONTH	MONSOON	SEASON
January	NORTHEAST	COLD
February		
March	transition period 1	HOT
April		
May	SOUTHWEST	RAIN
June		
July		
August		
September		
October	transition period 2	
November	NORTHEAST	COLD
December		

Fig 2.14 Schematic of the Northeastern and Southwestern monsoons and seasons of Thailand.

2.2 Geography of Northern Thailand

The northern of Thailand consists of high mountains around 70% of the area. These mountains lay continuously from the southeast of Himalayan (Fig 2.12). These mountains contain the important natural resources and water supplies for Thailand people. These mountains locate on 4 major mountain ranges *viz* Dan Lao, Thanon Thong Chai, Pee Pan Nam, Luang Pra Bang at the upper, western, middle and southern part of northern Thailand, respectively (Fig 2.15).

The geological structure of northern Thailand is quite complex, because there is the mixing with many rock series from Precambrian to Coenozoic rock. It is indicated that these terrains ever faced the seriously movement of the earth crusts for many times. There are all type of rocks; igneous, sedimentary and metemorphic rock series in northern Thailand.

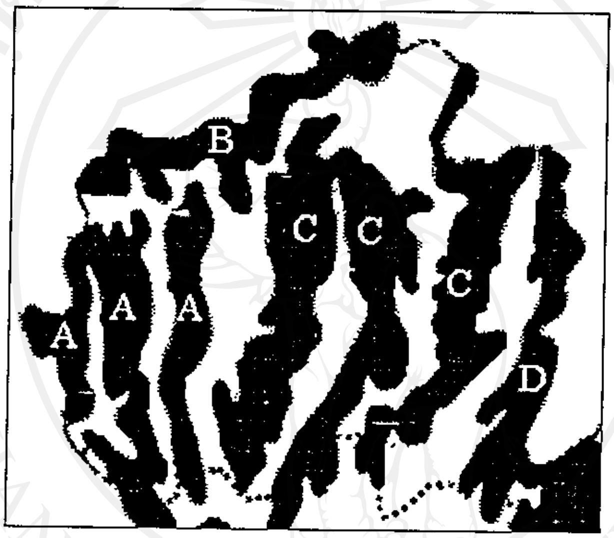

Fig 2.15 Map presents the position of 4 major mountain range in Northern Thailand. A = Thanon Thong Chai, B = Dan Lao, C = Pee Pan Nam and D = Luang Pra Bang.

The montane areas in Northern Thailand are the part of the foothills of the Himalayan massif and are separated from other montane ranges of tropical south eastern Asia by the low-lying plain of peninsular Thailand (Wolseley and Aquirre-Hudson, 1997). These mountains support a high diversity of flora and fauna where the combination of warmth and moisture allows abundant plant growth and animal activity to evolve the unique biodiversity. The elevated regions collect and absorb high levels of rainfall and feed the headwaters of many streams and rivers.

The mountain ranges in this region act like a barrier blocking the humidity carried from Gulf of Thailand and Andaman Sea to produce a rain. They collect and absorb a rainfall and then produce the headwater of streams. The accumulation of water and humidity encourage the diversity of flora. The result of the suitable climatic and fertility of primary producer are also encourage the diversity of the next trophic organisms, herbivore and the next trophic species.

Thanon Thong Chai range is selected for study. It is 880 km long, locate as a boundary between Thailand and Burma. The major geological structure of this range is the Precambrian rock (Dunning *et al.*, 1995). Many high mountain peaks distribute along this range. The two famous mountains; Doi Suthep-Pui (98° 47′E - 98° 56′E, 18° 47′N - 18° 55′N; highest peak 1,685 m) and Doi Inthanon (98° 27′E -98° 40′E, 18° 19′N - 18° 40′N; highest peak 2,565 m) were selected for the monitoring. The climate in these mountains are similar with temperate condition. Both mountains are also covered with the evergreen flora that expanding northward from equator (Whitmore, 1990).

However both Doi Suthep-Pui and Doi Inthanon locate on the same mountain range, their geographical relationship with the main range are different. Doi Inthanon locate in the middle of the range with the continuity of the area above 1000 m. In the other hands, the area above 1000 m of Doi Suthep-Pui is not continue with the main range. Then Doi Suthep-Pui look like an island, surrounded with the valley. This is proposed that, Doi Inthanon is the Himalaya-inlier, where as Doi Suthep-Pui is the Himalayan-outlier.

2.3 Biodiversity

2.3.1 The definition of biodiversity

Biodiversity is a term that expresses, qualitatively and quantitatively, all animals and plants, from the tiniest insects to the tallest tree and to the top predator in the food webs, both terrestrial and marine, which can be rich and varied as in tropical rain forests and pristine coastal waters, or sporse as tundra, or minimal as the desert sands or deep oceans (Simpson and Bugna, 2001). A large number of organisms is defined "biodiversity"; the property of living systems of being distinct, that is, different, unlike. Biodiversity is contraction of Biological Diversity (Sorbrig *et al.*, 1994). Some definitions are presented as follows.

Biodiversity is a comprehensive word for the degree of nature's variety, including both the number and frequency of ecosystems, species and genes in a given assemblage. It is a word which embraces both species richness and genetic diversity, both of which are being threatened throughout the world (Spellerberg, 1992).

Biodiversity comprises all life forms that have adapted to survive the variety of climatic and physical conditions currently found on earth. Biodiversity encompasses the whole range of genetic variability among individuals within a species in different ecosystems (Simpson and Bugna, 2001)

Biodiversity of organisms is considered at all level, from genetic variants belonging to the same species through arrays of species to arrays of genera, families, and still higher taxonomic levels; including the variety of ecosystems, which comprise both communities of organisms within particular habitats and the physical conditions under which they live (Spellerberg, 1996).

2.3.2 The need of biodiversity

The diversity of organisms directly serves people in northern of Thailand as food or as items for sale in markets. This natural production provide many benefits to the world economy and human well-being as the food, spices, herbs, medicines and raw materials for industries. The Dipterocarp forests of Southeast Asia have been the largest source of tropical hardwood, species like ebony, mahogany and teak, which have a long tradition of export from Burma, India, Malaysia, the Philippines and Thailand (Simpson and Bugna, 2001).

More importantly, their indirect values are necessary to both human well-being and ecosystem functioning. The natural processes such as the reduction or removal of the contamination, hydrological cycles and bio-geochemical pathways that drive climate and weather events are regulated with the complex food webs and interactions of living organisms (Simpson and Bugna, 2001).

The organisms in the world contribute to the non-consumption values to human such as scientific research, education, aesthetics and playing an important role as the energy transmitter in ecosystems. They also are the gene banks that being the challenger species to face with the uncertain future. In an ethical context, they are a valuable inheritance for the benefit of our descendants (modified from McNeely *et al.*, 1990).

2.3.3 The lost of biodiversity; extinction

The dynamic on earth has been occur sometimes this dynamic cause the deteriorate on species. Many phenomena cause the stress and force some species to be devastated, it is called extinction. The extinction of species on earth is a natural process and an integral part of evolution. Extinctions have taken places since life began and throughout many millions years of evolutionary history (Spellerberg, 1996). In the age of Peleozoic, Mesozoic and Cenozoic the average species extinction rate has been around a species per 5 years or (9% per million years from 2 million living species) (Raup, 1988). This rate included 4-5 times of mass extinctions.

The famous mass extinction occurred in Permian (254 Ma), when 52% of living things were eliminated, (77-96% of the extinction species was the marine animals). The another famous extinction is in Cretacous-Tertiary era (65 Ma). At this time around 50% of world species were eradicated (Raup, 1988)

Nowadays this species extinction is going on and the rate is higher than that has ever been occurred before. The causes of the recent extinction are performing under the human activities. It is accepted that human are the accelerator in the process of the extinction of other organisms.

WCMC, 1990 reported that the current anthropogenic extinction rate is comparable with those of major extinction rate in the past. The impact of human approximately started for 40,000 years ago in the late of Pleistocene. A lot of large mammals were extinct by hunting concurrently with the arid climate period. The expansion and colonization of human caused the continuously extinction until the 18th century such as the extinction in Hawaii and New Zealand. In the 19th and 20th century, the extinction still occurred but the causes were the introduction of the exotic species and changing of landscape. The estimation on the extinction of species on earth was reportedly one species per day since 1970s. The rate in the 1970s was the one species per day. The rate was dramatically increasing to one species per hours in middle of 1980s. Under this rate, at the end of 20th century, our planet could loss 20 to 50% of the remaining species (Lugo, 1988).

The cause of the rapidly expansion world population is the core of the extinction of the other species. The broad headings of the human deterioration on the world biodiversity are list as follow (Spellerberg, 1992).

1. Pollution, disturbance and the human-made perturbations.
2. Excessive exploitation of species and natural areas for food, collections, materials and other purpose and directs extirpation of pests.
3. Reduction and fragmentation of natural area (habitat and ecosystem).

SE Asia is the most densely populated region of the world with by far the greatest majority of people inhabiting the mega-cities of the coastal plains. Bangkok, Bombay, and Manila each containing many millions of people, more than 60% of the total regional population are rural dwellers, relying on the land for subsistence and trying to meet the urban demand for food and other resources (Simpson and Bugna, 2001).

The population growth rate in SE Asia is around 2.5-3.5% per year, which is high enough to impede economic growth and social services. The demand for living space and agricultural land are rapidly increasing, while real productivity declines. Whereas, the economic interests in these region still carelessly to the obvious negative impacts of deforestation, over-fishing, poor disposal of hazardous wastes and chemical pollution of air, land and water (Simpson and Bugna, 2001).

The result of the development causes the depletion of forests and other natural resources, both terrestrial and marine. Less than one-third of the region's forest cover remains. Changes in hydrological function, soil erosion and land degradation have had seriously destructive effects on coral reefs, mangroves and the fish stocks dependent upon them for feeding and reproduction (Simpson and Bugna, 2001).

Meanwhile, these mega-cities face with pollution on a grand scale, from industrial effluents and wastes, and untreated sewage. Bangkok, Bombay, Calcutta, Jakarta, Manila and New Delhi are among the worst polluted cities in the world, as a result of poverty, uncontrolled traffic and vehicle exhausts and inefficient waste disposal (Simpson and Bugna, 2001).

2.3.4 The way to maintain the biodiversity

The conservation and pollution controls are the ways to maintain the remaining biodiversity. The congenial between natural resources and human populations can be heal the impact of global environmental change and better provide for human needs long into the future (Simpson and Bugna, 2001).

The human is the main key for enhancement the activities for conservation the remaining species on earth. For the academic fellows, the study on biodiversity is an important activity for encouragement of the conservation and management strategy. The basic scope of biodiversity study includes "what we have, where it exist, how many of them, why they are important how it display when have a disturbance and so on". Those for the objective tools to provide the conservation or management strategies for keeping or using and reusing substantially.

2.4 The study of insects

The insects are the most diverse species and abundant organisms on earth. They are more than 1 million species of terrestrial and freshwater to be described (William and Feltmate, 1992). But there is estimated that a great number of them have not yet to be described. The total number of them may be approach 30 million species (Borror *et al.*, 1989). The insects are also the popular case study in many ways of science.

Although insects have the highest abundance and diversity of any animal group, individual species are often restricted to specific habitats to which they are adapted. Adaptation, driven by evolution, is a response for the different levels of insect diversity in various habitats. Environmental factors may become limiting condition to the distribution and survival of many species once certain limits are exceeded. These factors are divided into two main groups, *viz* physical factors such as temperature, light, and wetness, and biotic factors such as competition, predation, or the presence or absent of suitable food (Cox and Moore, 1985). This interaction between species and their environment not only causes the different levels of insect diversity, but also affects their distribution.

The high productivity sources like the tropical forests encourage the diversity of next trophic level; the herbivores such as insects. In turn, these also support large numbers of predators and parasites, which regulate their numbers *via* complex interactions. In 1970 to 1990, European scientists came to tropical zone the amaze in the massive diversity of insects and their attribute. The fruitful of the studies were the basic knowledge in ecology; science that seeking a relation between all component in the environmental system. Some studies about insects' diversity in tropical areas are revised. These articles try to explain the effect of spatial, duration, elevation e.g. on the diversity and distribution of tropical insects.

A variety factors can be responsible for determining the nature of the insect fauna at a particular location. There are seasonal changes in the pattern of diversity and abundance of some tropical insect groups, which mostly reflect the seasonal availability of their food supplies. This synchronization was closely correlated in herbivorous insects such as Homoptera (Wolda, 1978). A similar pattern would be expected in groups such as geometrid moths which have well-developed hostplant preferences. On the other hand, non-herbivore insects such as Blattodea showed a non-seasonal response (Wolda, 1983).

Elevation can also affect insect diversity. Forest insect families, such as Blattidae and Scarabaeidae, gradually declined in diversity as the elevation increased from 100 to 2000 m (Wolda, 1987). However, the seasonal and altitudinal trends in insect diversity were modified by human disturbance of the habitat. Study sites near human activities had significantly reduced insect abundance compared with undisturbed areas remote from humans (Wolda, 1983; 1987).

Habitat disturbance is an important factor in ecology (Spizer *et al.*, 1993). Various insect groups have been important tools in the study of disturbance and its role in promoting species diversity. "Flagship taxa" such as butterflies have been useful in studying the conservation of biodiversity in forests (Lawton *et al.*, 1998). For example, forest areas that have been slashed and burnt then left for recover, were found to slowly increase their biodiversity in the process of succession. Although the diversity of butterflies gradually increased with succession time (Bowman *et al.*, 1990), the recovery of insects was not fully synchronous with tree recovery. It was found that the logged area that was left to recover until it had a similar structure to the unlogged area, had not fully recovered its original diversity of insects (Hill *et al.*, 1995).

Sometimes the abundance of insects may show an inverse effect with the time elapsed since disturbance (Connell, 1978). Some studies report that butterfly diversity in secondary forest is higher than in primary forest, and higher in open areas than in the closed forest (Hamer *et al.*, 1997; Spizer *et al.*, 1997; Willott *et al.*, 1999). Undisturbed areas often have narrowly endemic species that do not range widely, while disturbed sites can have a variety of common and opportunistic species (Spizer *et al.*, 1993). The intermediate, recovering, areas had mixed environmental conditions that support numerous species while in the climax site only selected and specialized species may survive (Connell, 1978).

2.5 The study of insects in Thailand

There were 3,867 species of insects documented from Thailand's forests by Hutacharern and Tubtim (1995). They cautioned that this was only a fraction of the insects in Thailand and pointed out the need for more study to add to the number of them in the future. The greatest biodiverity of insects caused the difficulties and complexities of the identification. The aim of this Thesis is to present and encourage the knowledge on Trichoptera and Geometridae (Lepidoptera), which the author is able to identify.

2.5.1 Trichoptera

Trichoptera or caddisflies are the insects that can be found throughout the world. These insects were believed to be firstly evolved in the Permian period (Wiggins, 1984), they should be had the co-ancestor an Amphiesmenopterida with the Lepidoptera (Weaver III, 1984). The taxonomic knowledge of this insects are continuously developing. There are a lot of articles of this insects in many journals. There is also the regular international symposium especially in these insects every 3 years. At present, the existent species are divided to 46 families, each family has the distribution in each biogeographical region as shows in Table 2.4.

From the Checklist of World Trichoptera by Morse (1997), some Trichoptera family; Electralbertidae, Necrotauliidae, Cladochoristidae, Microptysmatidae, Prosepididontidae, Protomeropidae, Uraloptysmatidae, Prorhyacophilidae, Baissoferidae, Dysoneuridae, Kalophryganeidae, Taymyrelectronidae, Vitimotauliidae were the extinct family but their fossil were discovered and identified. From the literature also contained the extra family that not indicated in Table 2.4 *viz* Apataniidae and Pisuliidae.

Table 2.4 The distribution of Trichoptera in Chiang Mai (CM) and biogeographical region PA = Palaearctic, OR = Oriental, NA = Nearctic, AU = Australasian, AF = Afrotropical and NT = Neotropical.

Family	CM**	PA	OR	NA	AU	AF	NT
Rhyacophilidae	27	a,b	a,b	a,b			
Hydrobiosidae			a,b		a,b		a,b
Glossosomatidae	16	a,b	a,b	a,b	a,b	a,b	a,b
Hydroptilidae	7	a,b	a,b	a,b	a,b	a,b	a,b
Philopotamidae	56	a,b	a,b	a,b	a,b	a,b	a,b
Stenopsychidae	4	a,b	a,b		a,b	a,b	b
Polycentropodidae	25	a,b	a,b	a,b	a,b	a,b	a,b
Hyalopsychidae*		b	b	b	b	b	
Dipseudopsidae	3		a,b	a		a,b	
Ecnomidae	8	a,b	a,b		a,b	a,b	a,b
Psychomyiidae	19	a,b	a,b	a,b	a,b	a,b	a
Xiphocentronidae	7	b	a,b	a,b		a,b	a,b
Arctopsychidae	3	b	b	b			
Hydropsychidae	64	a,b	a,b	a,b	a,b	a,b	a,b
Phryganeidae	1	a,b	a,b	a,b			
Brachycentridae	4	a,b	a,b	a,b			a
Limnocentropodidae	4	a,b	a,b				
Goeridae	11	a,b	a,b	a,b		a,b	
Limnephilidae	4	a,b	a,b	a,b	b	a	a,b
Uenoidae	2	a,b	a,b	a			

(Table 2.4 Continue)

Family	CM**	PA	OR	NA	AU	AF	NT
Lepidostomatidae	31	a,b	a,b	a,b		a,b	a,b
Helicopsychidae	6	a,b	a,b	a,b	a,b	a,b	a,b
Odontoceridae	9	a,b	a,b	a,b	a,b		a,b
Leptoceridea	25	a,b	a,b	a,b	a,b	a,b	a,b
Sericostomatidae	1	a,b	a,b	a,b		a,b	a,b
Calamoceratidae	1	a,b	a,b	a,b	a,b	a,b	a,b
Molanidae	4	a,b	a,b	a,b			
Phryganopsychidae		a,b	a,b				
Chathamiidae					a,b		
Tasimiidae					a,b		a,b
Thremmatidae*		a,b	b				
Oeconesidae					a,b		
Kokiriidae					a,b		a,b
Plectrotarsidae					a,b		
Beraeidae		a,b		a,b			
Conoesucidae					a,b		
Antipodoecidae					a,b		
Calocidae					a,b		
Helicophidae					a,b		
Atriplectididae					a,b		
Philorheithridae					a,b		a,b
Anomalopsychidae							b
Pycnocentrellidae*					b		
Barbarachthonidae						b	
Hydrosalphingidae						b	
Petrotrincidae						b	
Total (46 Family)	25	28	29	24	27	21	22

Note:

* indicate the Family that were not indicated in the Checklist of World Trichoptera (Morse, 1997).

** the number in this column is the number of species of Trichoptera found in Doi Suthep-Pui and Doi Inthanon, Chiang Mai Province.

a = indicate the source of data from William and Feltmate, 1992.

b = indicate the source of data from Bănărescu, 1990.

The pioneering publication of the study on caddisflies in Thailand was that of Martynov in 1931, in which three species, *Stenopsyche siamensis, Macronema fastosum, Asotocerus ochracellus* were the first record. In 1987 intensive studies on the Trichoptera fauna were begun by Prof. Hans Malicky and Dr. Porntip Chantaramongkol. Twelve years later they gave a progress summary of their results in which 491 species in Thailand were listed (Malicky & Chantaramongkol, 1999).

The most intensively studied areas in Thailand are Doi Suthep-Pui (98°47′-98°56′E, 18°47′-18°55′N; 1,685m) and Doi Inthanon (98°27′-98°40′E, 18°19′-18°40′N; 2,565m) National Park, on the Thanon Thong Chai range of northern Thailand. They are the important natural hotspots of biodiversity in northern Thailand and most of their forests and streams are in good natural condition.

A preliminary survey of Doi Suthep-Pui resulted in 131 species (Chantaramongkol and Malicky, 1997), and of Doi Inthanon in 171 species (Malicky and Chantaramongkol, 1993). The studies of diversity and taxonomic on Trichoptera in

Thailand was developed by Aquatic Insects lab Unit, Chiang Mai University (Sompong, 1998; Thani, 1998; Prommi, 1999; Kaewtapee, 2001; Thamsenanupap, 2001) under the continuously research conducted by Prof. Hans Malicky and Dr. Porntip Chantaramongkol since 1987. Many scientific articles were released continuously for 35 papers for the series of the studies of Trichoptera in Thailand (Malicky, 1987; 1989a; 1989b; 1994; 1995; 1997a; 1997b; 1998a; 1998b; 1999a; 1999b; 2002; Chantaramongkol and Malicky, 1989; 1995; 1997; Luadee and Malicky, 1999; Malicky and Chantaramongkol, 1989a; 1989b; 1990; 1991a; 1991b; 1992a; 1992b; 1993a; 1993b; 1993c; 1994; 1996; 1997; 1999; 2000; 2003; Malicky *et al*, 2000; 2001; 2002) and the extra series around 7 papers (Martynov, 1931; Denning and Schmid, 1971; Schmid and Denning, 1979; Denning, 1982; Weaver III and Malicky, 1994; Chantaramongkol *et al*, 1999; Chantaramongkol and Malicky, 2000). The taxonomic knowledge of Trichoptera species in Thailand was also developed to be handbook "A preliminary Picture Atlas for the Identification of Trichoptera of Thailand" by Prof. Hans Malicky.

The recent study has significantly increased the known Trichoptera fauna of Thailand. There were only 494 species reported in year 1999, but these increased to 572 species in 2000, with a minimum expectation of 700 species in the total fauna (Chantaramongkol and Malicky, 2000).

Nine taxa, *Himalopsyche acharai, Dolophiloides torrentis, Stenopsyche himalayana, Kambaitipsyche hykrion, Arctopsyche variabilis, Eubasilissa maclachlani, Liomnocentropus* spp., *Uenoa hiberna, Molannodes alticola* were found on Doi Inthanon and Himalayan range (Malicky and Chantaramongkol, 1999). Of these, only

Himalopsyche acharai has been found on Doi Suthep-Pui (Chantaramongkol and Malicky, 1997). A similar pattern occurs in the Himalayan plant genus *Rhododendron*, which grows above 1,200 m. It is widespread on Doi Inthanon and nearby ranges, but rarely found on Doi Suthep-Pui. Therefore it is hypothesized that the flora and fauna cn Doi Suthep-Pui above 1,000 m may evolved with the lower influence from Himalayan.

2.5.2 Geometridae; Lepidoptera

The butterflies and moths (Lepidoptera) are common insects and well known to everyone. They are also the popular organisms in scientific researches. The larva of most species are phytophagous that mean they play a role as the 1st consumer in the ecosystem. Some of them become the serious pests in agriculture process, but these are no arguments that this insects are serve the human for knowledge in science and art, and the silk production (modified from Borror *et al.*, 1989). The taxonomic knowledge of them is fairy good because this study was developed for 2 centuries ago.

The complex geology, topography and strategic location of Thailand, together with its rich of botanical diversity, suggests that it should have a diverse of moth fauna. However, studies on the moth fauna of Thailand are in their infancy. Although occasional Lepidoptera specimens collected in Thailand ("Siam") found their way to the European collections more than a century ago, the earliest systematic study on moths in Thailand appears to be the study on Emperor moths (family Saturniidae) published by Edward J. Godfrey in 1924, reported in the National History Society of Siam Vol.VI, No.3. (Pinratana and Lampe, 1990). An Englishman, Godfrey (1877-1933) was a teacher at

Suan Kularb College in Bangkok. There are only the Emperor moths (Family Saturniidae) and Hawk moths (Family Sphingidae) that were well studied and published in the Moths of Thailand Vol. I (Pinratana and Lampe, 1990) and Vol. II (Inoue *et al.*, 1997), respectively. In this study, the moths in family Geometridae were selected for case studies.

The family Geometridae is one of the three most diverse families of the order Lepidoptera, with around 20,000 described species worldwide over 2 centuries ago (Scoble, 1999).

Many geometirds are relatively easy to distinguish from member of others families of lepidoptera. At rest the wings typically with the dorsal surfaces of the wings touching. There are, however exception to the general rule. Many species are brightly coloured, but most are dull color. Frequently wavy lines traverse the wings effective, but strong, distinct patterns occur often.

The most effectively distinct character is the present a paired tympanal organ at the abdomen. The larva of them also have a unique character. They can be distinguished from the "looping moths". This distinctive movement is caused by the loss or reduction of the number of pairs or prolegs on abdominal segment 6 and 10.

The adults of Geometridae also share some characters with other moth, the present of chaetosemata (sensory organ), the absent of external ocelli, the present of a probosis, the wing are coupled my means of a frenulum and a retimaculum. These characters might be reduced in some geometrid moth (Scoble, 1999).

The distribution along the Biogeographical Regions is show in Table 2.5. There were all together 20,000 of them were recognized. The Neotropical region contain the highest species of geometrid moths with the almost complete studying (Pitkin, 2002). the species number of them in Nearctic region cannot be mentioned.

Table 2.5 The approximated species number of Geometridae in each biogeographical region (Reference: Scoble, 1999).

Biogeographical Region	Approximated number of species
Neotropic	6,450
Oriental	4,150
Palaearctic	3,500
Afrotropic	3,100
Australasia	2,520
Nearctic	?
Total	**19,720 (~20,000)**

Taxonomic knowledge about the group is proceeding at a regional level (e.g. Pitkin, 2000). The knowledge of this moths in Thailand are very little comparing with the very high diversity of them in this land. This moths is well-known as the pest of many economical plant species.

Geometrid larvae are herbivores on foliage and play a role as the nutrient transmitter to the next trophic levels. A very few geometrid moths in Thailand are significant pests in agriculture and plantations such as *Ascotis selenaria* which attacks *Casuarina equisetifolia* (Australian pine) and *Ectropis bhurmitra* which is a pest of *Aleurites moluccana* (Eagle wood) (Hutacharern and Tubtim, 1995). However, a number of genera which have pest species elsewhere in Asia, such as *Cleora* and *Hyposidra* (Shunli *et al.*, 1994), are present in Thailand also. But the vast majority of geometrid species are restricted to natural and semi-natural vegetation types forest. Geometrid moths are sufficiently diverse and widespread in Southeast Asia to be applied as bioindicators study on the ecology and biogeography (Chey *et al.*, 1997; Holloway, 1984; Holloway, 1985; Holloway & Barlow, 1992; Holloway & Stork, 1991; Holloway *et al.*, 1992).

The studies on Geometridae of Thailand were mostly carried out by Japanese scientists (Inoue, 1984; 1985; 1986; 1987; 1990; 1992; 1993a; 1993b; 1994a; 1994b; 1994c; 1999; Sato, 1984; 1987a; 1987b; 1989a; 1989b; 1990; 1991; 1992a; 1992b; 1993; 1995; 1996a; 1996b; 1996c; 1997a; 1997b; 1999; Hashimito, 1995). The arcticle belong to the scientist working closely Thailand such as Holloway, 1993; 1996; 1997; Stüning, 2000 were also referred to Thailand. These articles were revised the name of Geometridae and combine with the new record from this study.

2.6 Riparian zones

Terrestrial and aquatic ecosystems are intimately linked through physical processes and fluxes of energy and nutrients across the riparian ecotone (Lynch *et al.*, 2002). These areas have been recognized as valuable terrestrial habitats of wildlife for a variety of reasons. They usually contain the equal or greater primary productivity than surrounding upland areas and, consequently, have the potential to be areas of greater secondary production (Lynch *et al.*, 2002). In contrast, these areas are also the integrate area of the impacts of change in atmospheric and terrestrial ecosystems, both from natural disaster and anthropogenic impacts (Sear and Newson, 2003).

Riparian communities have often been shown to display high structural and compositional diversity and they have been identified as potential serving a keystone role in the landscape conservative measurements. Thus, they are the focus of specific management guidelines that attempt to protect terrestrial and aquatic ecosystems (Macdonale *et al.*, 2004).

Riparian zones are thought to be important habitats areas for several arthropod taxa (Winchester *et al.*, 2002). The comparison between the shaded and unshadded area, showed the difference of macroinvertebrate communities between completely shaded stream by riparian forest between low degree of shaded and unshaded stream. This result was analyzed by the ordination between the macroinvertebrate community from shaded with unshaded areas (Dudgeon, 1994).

There was not the specific distance of the riparian zone apart from the water body edge. But for the study of aquatic insects in riparian zone, in the area between 0 to 15 m found the accumulation of aquatic insects more than the area apart from the stream edge. Some of aquatic insects were able to travel apart from water body for 160 m (Lynch *et al.*, 2002). In case of Trichoptera, most of them were colonized near the water bodies. The study on Trichoptera in temperate rainforest show the highest species number and abundance of trichoptera in the area between 0 to 10 m apart from stream edges. The trichoptera still found in the area of 10 – 75 m apart from the stream but the species number and abundance were gradually reduced along the distance apart from the water bodies (Winchester *et al.*, 2002).

In summary, the riparian zones are composed with 2 ways dynamics; terrestrial to aquatic ecosystems and *vice versa*. The details of these relationships are revised in the next section.

2.6.1 Terrestrial to aquatic ecosystems

The riparian forest influences channel from and stream function by contributing particulate organic matter and large woody debris, providing shade, bank stability, site for storage organic matter, sediment and water, and by regulating the movement and transformation of nutrients (Fetherston *et al.*, 1995). The input from riparian sources in the form of dissolved organic matter, leaf litter, fruits, woody debris and invertebrate, are recognitized as important food resources for aquatic food webs (Lynch *et al.*, 2002) we usually call this term as "Allochthonous". The large wood from terrestrial area also enhance the biological diversity in streams by creating pools and other hydraulic features food and habitat for microbes, algae and invertebrates. (Acker *et al.*, 2003).

2.6.2 Aquatic to terrestrial ecosystems

Many aquatic insects emerge from the water do not return back to the water body but they become an energy sources for the food-web in terrestrial ecosystem. A large numbers of adult aquatic insects could further increase the value of riparian-stream corridors for insectivorous fauna. The larger emerged aquatic insects may be consumed by web-building spiders of the genus *Argiope* and family Tetragnathidae, the webs of which were found to by abundant over and along streams during the present study and frequently contained adult of Odonata. In addition, several bird species and bats were observed to take aerial prey from over streams in the study area. However, a substantial portion of the ariel insect assemblage was made up of very small chironomis midges and many of these may be overlooked or avoided by vertebrate predators. These small flies may be consumed by small riparian spiders and other predatory invertebrates, which, in turn, may become the prey of terrestrial. However, very few studies have investigated the importance of exports from streams into terrestrial riparian food webs. (Lynch *et al.*, 2002).