# CHAPTER 2

# LITERATURE REVIEWS

## Lotic Ecosystems

Freshwater ecosystems comprise both lentic (standing water) and lotic (running water) ecosystems. Lotic ecosystems, such as streams and rivers, contain a small fraction of the overall water that is stored within the biosphere, but are vitally important to the vast majority of all living organisms (Allen and Flecker, 1993; Giller and Malmqvist, 2002; Hauer and Lamberti, 2010). For humans, these ecosystems provide a consumable water resource, agricultural and industrial support, waterway transportation, waste removal and sources for renewable energy (Allen and Flecker, 1993). Lotic ecosystems are dynamic, existing in a spatially and temporally heterogeneous and hierarchical environment. One of the unique characteristics of lotic ecosystems, relates to the direction of water flow from upstream to downstream, and the subsequent influence of this flow to channel morphology. Lotic ecosystems are also strongly influenced by the type and condition of nearby ecosystems, and this is an important consideration when assessing water quality. Stream/river systems comprise of many dimensions. Longitudinal dimension, from headwaters and streams connect to rivers and ocean eventually. Lateral dimension, instream water has interaction with surrounding watershed. Moreover water in channels (surface water) effluent and influent by groundwater (Giller and Malmqvist, 1998).

There are many hypotheses that have aimed at unifying the patterns of heterogeneity over environmental gradients in riverine ecosystems. One of the famous and fundamental concepts is the 'River Continuum Concept, proposed by Vannote *et al.* (1980). The River Continuum Concept states that biological community structures will shift gradually in relation to water flow from headwater zones to transitional zones, and in relation to changes in geomorphology as a result of this water flow. To date, most research related to the River Continuum Concept has been developed and used in temperate areas. Therefore using the concept in other areas will require further empirical research (Boulton, 2008). For example in Thailand, Malicky and Chantaramongkol (1993) mentioned that Rhithron (stream zonation *sensu* Illies and Botosaneanu) occurs at all elevations. Based on Trichoptera species occurrence in the Mae Klang catchment, Doi Inthanon National Park, Chiang Mai (1,200 - 1,700 m asl), this study has showed that the highest number of species coincides with small temperature variations.

**Biodiversity and Lotic ecosystem structure and services**

As a result of high spatio-temporal heterogeneity, and due to complex biological interactions, lotic ecosystems contain high levels of biological diversity(Palmer and Poff, 1997). Theoretically, natural disturbance regimes and environmental gradients occurring across different spatial and temporal scales will influence patterns (e.g. abundance, distribution, diversity and production) and processes (e.g. predation, competition, dispersal and habitat selection) in population, community and ecosystem structures (figure 2.1). Patterns such as this can provide predictable information for lotic ecosystem management, conservation and also restoration programs.

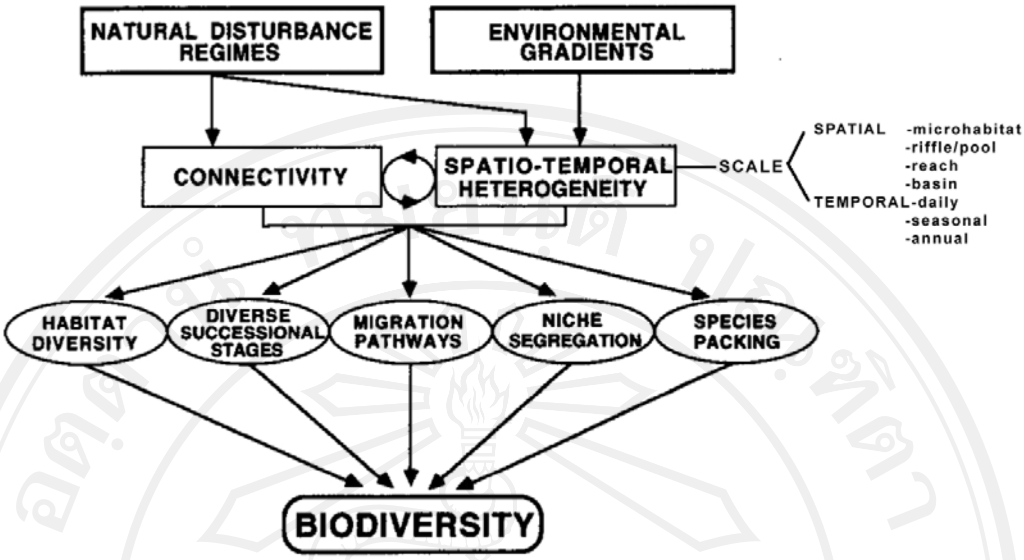


Figure 2.1 Interaction and factors that influence biodiversity patterns in lotic ecosystem (adapt from Palmer and Poff, 1997 and Ward, 1998).

Globally, biodiversity in freshwater ecosystem, particularly in lotic ecosystems, is under threat from a variety of factors, such as urbanization, industry, land-use change and channel alterations (Chantaramongkol, 1983; Chaibu, *et al.*, 2002; Cheunbarn and Chantaramongkol, 2002; Malmqvist and Rundle, 2002). In addition, over-harvesting, the invasion of introduced species (Dudgeon, 2002, 2003) and the impacts climate change pose considerable threats. There are many documented cases of lotic ecosystems being permanently destroyed as a result to changes in stream and river structures and functions. Freshwater biodiversity was outlined as a conservation priority during the International Decade for Action 'Water for life' 2005 to 2015 by the UN. As a result of inland waters and freshwater biodiversity form a valuable natural resources, in economic, cultural, aesthetic, scientific and educational terms (Dudgeon *et al.*, 2006). A number of publications revealed the factors often associated with the degradation of lotic ecosystems.

However, it is difficult to identify a single cause, or threat, of degradation, due either to an inadequacy of data, or simply because of the complexity of the problem (Allen and Flecker, 1993). In particular, evaluating the future impacts of climate change on lotic ecosystems requires the study of long term data. (Durance and Ormerod, 2007; Kojiri *et al.*, 2008).

South East Asia contains a large portion of the earth's biological diversity (Myers, 2000). Unfortunately, conservation of biodiversity is not a priority concern for many of governments in the region, where policy more often focuses on human welfare and economic development. Issues on biodiversity are noticed only when the affect to human welfare and economic development is realized. As a consequence, lotic ecosystems are experiencing severe degradation. For example, in the Mekong river delta, specialist riverine birds have declined, turtles are highly endangered, and the overharvesting of fisheries has caused severe decline in numbers and species. Besides the major constraints of funding and policy for conservation programs, there is also a lack of scientific rigor and ecological knowledge in relation to biodiversity assessment and monitoring. (Dudgeon, 2000, 2002, and 2003). Recent biodiversity conservation campaigns have promoted the benefits of biodiversity for the quality of life and well-being of people. Biodiversity assessment can be used indicate the health and functionality of an ecosystem. Healthy, functional ecosystems can also be equated to healthy human communities, by way of resources such as food, medicine, and other regulated services (Millennium Ecosystem Assessment, 2005). Conservation of biodiversity and ecosystem services will require an investment in assessment and monitoring, developed at all scales (local, region and global).

The procedures for assessing and monitoring the health of lotic ecosystems have been developed in many parts of the world for physico-chemical and biological methods. Procedures that use sensitive organisms as bioindicators, to assess environmental deterioration, and to track changes in community composition have been widely used for the past 30 years. Such procedures have low overheads for the costs of implementation and require relatively low levels of scientific skill (Rosenberg and Resh, 1993). Macroinvertebrates are often chosen as bioindicators due to their great diversity, abundance, and instream functional component. Moreover, these organisms have been well studied in developed countries (Bonada *et al.*, 2006). Species of Trichoptera have a great ecological diversity and fit a variety of ecological monitoring and assessment purposes (Mackay and Wiggins, 1979).

**Order Trichoptera Kirby, 1813**

**common name : caddisflies**

Trichoptera is a sister taxon of Lepidoptera (butterflies and moths). The adult form has hair covering the body and reduced mouthpart. The larval form is worm-like, with true legs, and produces silk. Trichoptera maintains the second largest diversity among all true aquatic insect orders (Hozenthal *et al.*, 2007). Larvae inhabit a wide range of aquatic habitats, in particular lotic ecosystems. They are classified into three groups, based on case building behavior. The first group constructs their portable cases using silk, which holds the vicinity materials (such as sand, small gravel, leaves and twigs) together. The variety in shape and type of materials is indicative of genus, or species(Suborder Integripalpia). The second group makes fixed retreat and silken capture nets (Suborder Annulipalpia). The last group is free living and uses silk as a safety line (Suborder Spicipalpia) (Morse, 2004; Hozenthal *et al.*, 2007). Adults emerge and, for the most part, live close to their larval habitat. Nevertheless, some Trichoptera typically inhabiting large rivers have been caught several hundred meters away from their original water source (Malicky in Chantaramongkol, 1983). Principally, adult Trichoptera are active at night and demonstrate light attractive behaviour. Research has shown that black light tubes have attracted Trichoptera more effectively than blue light tubes (Urbanic, 2002). Studies by Luadee *et al.* (1999) of diel flight periods in northern Thailand streams revealed that highest species richness were captured after sunset, whilst the lowest species richness were captured after midnight. Sufficient research has been carried out which addresses appropriate methods for light trap collection of adult Trichoptera for biodiversity, water quality assessing and monitoring and also conservation purposes.

Morphological characteristics commonly used to identify Trichoptera to family and genera include number of segments of antennae and maxilary palps, presence or absence of ocelli, spur formula, setose warts and wing venation. The primary characteristics used for identify to species level is the male genitalia (segment 9 and 10 on abdomen) (Hozenthal *et al.*, 2007, Malicky, 2010a).

Early interest in Trichoptera focused on their use as bait for stream/river fishing. Later, biologists and limnologists were intrigued by their case building behaviour, their great species diversity and abundance, and also their role in the function of the lotic ecosystem (Wiggins, 1996; Hozenthal *et al.*, 2007). Both the larva and adult forms of Trichoptera are now commonly used as bioindicators of various anthropogenic disturbances (Chantaramongkol, 1983; Chaibu *et al.*, 2002;

Cheunbarn and Chantaramongkol, 2002; Nawvong and Chantaramongkol, 2005; Schmera, 2001 and 2003).

**Biodiversity of Trichoptera**

Recently, Trichoptera has been considered as one of well studied insect group around the world. In 2009, the global online database, Trichoptera World Checklist, recorded 13,574 extant species, 609 genera of 47 families of Trichoptera (Morse, 2011). Trichoptera specimens have also been observed in most parts of the world, except the Antarctic region (de Moore and Ivanov, 2008; Morse, 2011). The Oriental and Neotropical regions are the two most species diverse, with 4,865 (35.8% worldwide distribution) and 2,562 species (13.9% worldwide distribution), respectively (figure 2.2). High species endemism has been recorded in tropical or mountainous regions, and this has been correlated with humid or high rainfall conditions (Holzenthal *et al.*, 2007, de Moor and Ivanov, 2008).

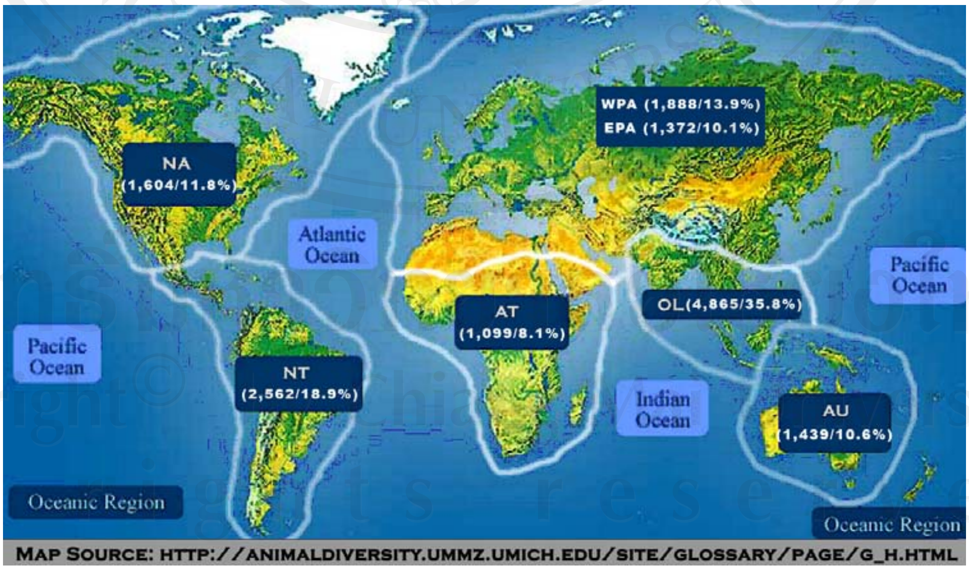


Figure 2.2 The number of species and percentage in each major biogeographic regions. Note: NA=Nearctic, NT=Neotropical, AT=Afrotropical, EPA=East Palearctic, WPA=West Palearctic, OL=Oriental, and AU=Australasian.

In Europe, a long history of studies provide adequate information about using Trichoptera species as tools for stream/river system conservation and restoration programs. For example, in Hungary, a total of 207 Trichoptera species have been recorded, based on 10,000 samples that were collected across the entire country. As a result of this study, the endangerment status of Trichoptera in Hungary has been categorized into 6 groups due to abundance, historical occurrence and distribution. Additionally, 9 species have been classified as threatened species and are now protected by law (Nogradi and Uherkovich, 1999). Based on well represented knowledge of Trichoptera, Schmera (Schmera, 2002a, 2002b, 2004; Schmera and Kiss, 2004) developed and proposed procedures to measure the conservation value of Trichoptera assemblages and habitats by using light trapping, calculation based on abundance, and the frequency and occurrence of rare species (e.g. Rarity and Ecological Diversity index). The conclusions revealed that streams were the most suitable habitats for maintaining rare caddisfly species, while ponds and rivers were less suitable.

In Australia, approximately 480 species of Trichoptera have been recorded (belonging to 25 families). In Tasmania there are 189 known species and nearly 70% are endemic. Seventeen species are listed under the Tasmanian Threatened Species Protection Act 1995 due to their small number in population and restricted distribution (Threatened Species Unit, 2005).



**Trichoptera diversity in Thailand**

Significant research about Trichoptera in Thailand has now been carried out for 30 years, with important work in taxonomy being provided by Assoc. Prof. Dr.

Porntip Chantaramongkol, Dr. Decha Thapanya, and several graduated students from Chiang Mai University (Environmental Monitoring: Aquatic Insects Research Unit, Biology Department, Faculty of Science, Chiang Mai University with kindly support from Prof. Hans Malicky, world Trichoptera expert from Austria). To date, the majority of taxonomic publications are included in the 43 series publication, "Studies on caddisflies from Thailand".

From their eleven years of study in Thailand, Malicky and Chantaramongkol (1999) reported 491 species, mostly from mountainous areas in northern Thailand, of which 74% were new to science and described by authors. Three major families have not yet been completed (Hydroptilidae, Hydropsychidae and Leptoceridae) and it is estimated that a minimum of 700 species would be discovered. A study on Hydropsychidae specimens from many Asian countries has been carried out, resulting in 55 new species being described, and 21 new species being found in Thailand. Leptoceridae was mainly reported in 2005 - 2006 (Malicky, 2005, 2006; Malicky and Chantaramongkol, 2005). Asian Trichoptera in Hydroptilidae was mainly described in 2007 (Malicky and Chantaramongkol, 2007). To date, the achievements of long and continuous research has revealed a key to adult Trichoptera, down to species level; **Atlas of Southeast Asian Trichoptera** (Malicky, 2010a). An illustration of male genitalia in dorsal, ventral, and lateral view were shown. This book comprised not only a pictorial key for Trichoptera in Thailand, but also a distribution range for each species in Thailand and neighboring countries; Laos, Cambodia, Vietnam, Malaysia (including Andamanen), Nikobaren, Sumatra, Borneo, Jawa, Bali and nearby small islands (table 2.2). The highest species richness was found in Thailand, perhaps due to the fact that many intensive studies that have been done there (figure 2.3). In female

Trichoptera, there is still insufficient knowledge for species level identification, except for some species that show obvious species-specific characteristics, such as prominent wing colour patterns (e.g. *Macrostemum* spp. and *Oecetis* spp.).

So far Trichoptera larvae identification is still lacking in Thailand, even at the genus level, and the available key mainly relies on neighboring regions, such as China (Morse *et al.*, 1994 ) and Malaysia (Morse, 2004) which results in unreliable and misinterpreted conclusions. There are some larvae descriptions in the literature, such as *Trichomacronema paniae* Malicky & Chantaramongkol 1991 (Malicky, 1991), *Himalopsyche acharai* Malicky & Chantaramongkol 1989 (Rhyacophilidae), *Arctopsyche hynreck* Malicky & Chantaramongkol 1991 (Arctopsychidae) and *Eoneureclipsis* spp. (Psychomyiidae) (Thamsenanupap *et al.*, 2005), *Hydromanicus (Hydatonamicus) klanklini* Malicky & Chantaramongkol 1993, *Hydromanicus (Hydatonamicus) adonis* Malicky & Chantaramongkol 1996 (Prommi *et al.*, 2006a), *Pseudoleptonema quinquefaciatum* Martynov 1935 and *Pseudoleptonema supalak* Malicky & Chantaramongkol 1998 (Prommi et al., 2006b) *Potamyia phaidra* Malicky & Chantaramongkol 1997 (Prommi *et al.*, 2006c) and *Ugandatrichia* spp. (Laudee, 2008). Life history of *Stenopsyche siamensis* (Luadee and Chantaramongkol, 2003), *Anisocentropus janus* (Thamsenanupap, 2001), *Limnocentropus* spp. (Sompong and Chantaramongkol, 2001), *Ugandatrichia maliwan* (Thani and Chantaramongkol, 2001).

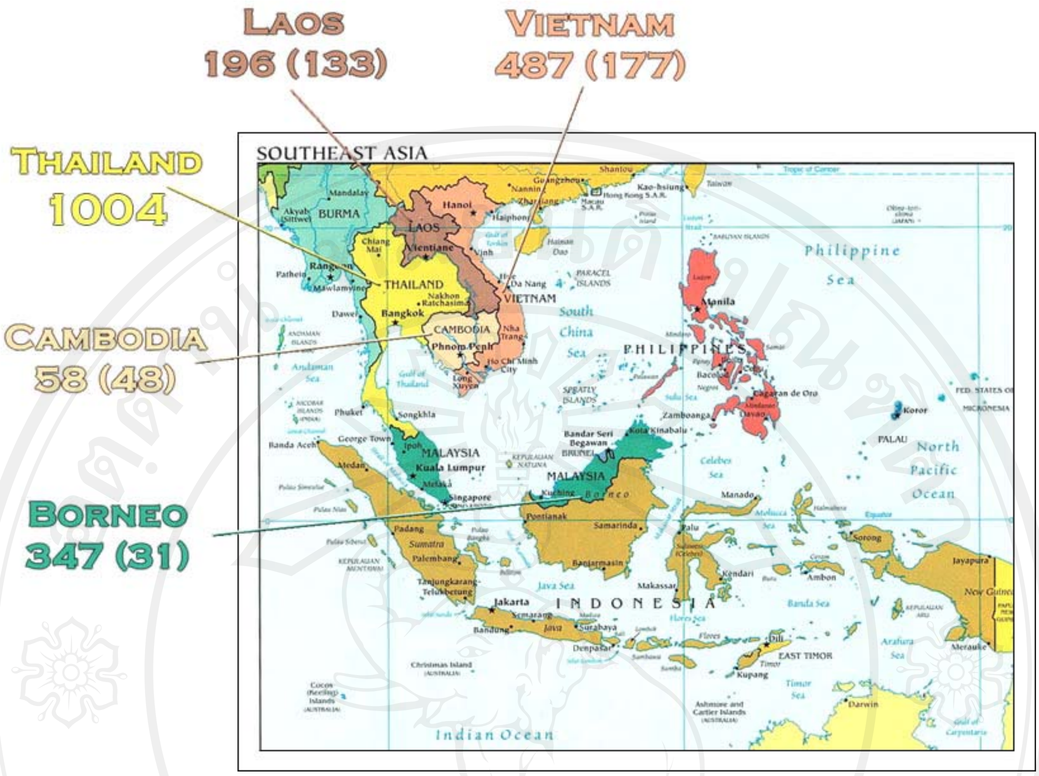


Figure 2.3 Number of species found in Thailand and number of shared species with some Southeast Asia countries (number in parentheses) (data from Malicky, 2010a).

Many studies were conducted in natural and protected areas, such as National Parks and Nature Reserves, with minimal anthropogenic influences. Doi Inthanon and Doi Suthep-Pui National Parks were pristine study sites, due to mountainous area, natural forest and plentiful streams. The first publication in Doi Suthep-Pui National Park was a description of *Rhyacophila* spp. (Malicky and Chantaramongkol, 1987).

In 1997, Chantaramongkol and Malicky compiled information for Trichoptera species in Doi Suthep-Pui NP, and found a total 131 species, of which 96 were new species. Using only light (pan) traps, Prommi (1999) reported 153 species (belonging to 18 families) from monthly collections at 6 sites over 16 months, describing 25 new species. Species richness and abundance peaked at the end of wet season and only 10 species were found in every month during this time. Thamsenanupap (2001) reported 86 species from Huai Kaew and 57 species from Huai Palad using monthly light traps over the period of a year. The life history and secondary productivity of *Anisocentropus janus* (family Calamoceratidae) was also studied.

In Doi Inthanon NP, Malicky and Chantaramongkol (1993) listed 173 species at different altitudes in the Mae Klang catchment, with the highest species richness being observed at 1,200 - 1,700 m asl. In 1998, Sompong reported 109 species from Huai Sai Lueng and 55 species from Huai Sob Ab, while studying the life history of *Limnocentropus* spp. in both locations. Thamsenanupap (2005) collected monthly in 4 sites using light traps and Malaise traps. Huai Sai Luang and Siribhum were more similar in terms of Trichoptera species assemblages than Mae Pan and Mae Klang streams. For existing Trichoptera in both Doi Suthep-Pui and Doi Inthanon NPs, Thapanya *et al.* (2004) reported 345 species (199 and 249 species from Doi Suthep-Pui and Doi Inthanon, respectively). The study also showed an altitudinal distribution and abundance status for each species.

In comparison of Trichoptera diversity to other areas, in the Chiang Dao watershed at the upper part of the Ping River, 127 species were reported ( Luadee, 2002; Nuntakwang, 2006). In Phu Hin Rong Kla NP (Phitsanulok Province) by Changthong (2005), who used monthly light traps (operated only one night of each month) and Malaise traps (operated over the whole month) at 4 sites for 15 months, recording a total of 64 species (belonging to 19 families), with 23% of the total species being caught by Malaise trap only.

In Northeastern Thailand, Nam Nao and Pu Pan NPs, Sangpradub *et al*. (2001) reported a habitat preference of Trichoptera species, and also larval to adult forms association of *Pseudoleptonema supalak* Malicky and Chantaramongkol 1998, *Macrostemum fenestratum* Albarda 1887, and *Hydromanicas klanklini* Malicky and Chantaramongkol 1993 (family Hydropsychidae) and *Chimarra akkaorum* Chantaramongkol and Malicky 1989 and *Chimarra khamuorum* Chantaramongkol and Malicky 1989 (family Philopotamidae).

Prommi (2006) observed 24 sites, covering a large part of southern Thailand (total 65 light traps), and recorded 215 species (46 genera in 18 families). 29 species were reported as new to science and described (Malicky and Prommi, 2006). This evidence demonstrates that future endeavors to collect specimens will likely facilitate new species discovery.

Streams and rivers ecosystem hold the greatest Trichoptera diversity, while fringing wetlands also provide habitat for Trichoptera. Cheapudee (2005) operated monthly light traps in 5 permanent wetlands and 2 temporary wetlands (e.g. paddy fields) over the period of a year. 55 species (belonging to 21 genera and 10 families) were observed , with the highest species richness in family Leptoceridae and Hydropsychidae, respectively. Regarding Trichoptera assemblages, permanent ponds and temporary ponds were separated.

According to the number of Trichoptera studies in Thailand, the compilation and summary of each species in terms of their abundance, occurrence, and distribution preference may provide a holistic picture for further research that may fulfill the knowledge gap and provide useful information towards the assessment and monitoring of biodiversity and habitat quality, particularly for lotic ecosystem conservation.