CHAPTER 2

LITERATURE REVIEW

Mae Kham River is a branch of the Mae Chan River which then joins a great important river of South East Asia, the Mekong River. The location of the study sites is at 20^0 $09^{'}$ $192^{''}$ N - 20^0 $14^{'}$ $496^{''}$ N and 99^0 $45^{'}$ $025^{''}$ E - 99^0 $49^{'}$ $719^{''}$ E, covering 2 districts, which were Mae Chan and Mae Fah Laung in Chiang Rai Province. The geography of the area is a high mountain range in the west with a sloped area from west to east and a flat area in the west of Mae Chan District (http://chiangrai.doae.go.th). The upper stream is on the mountain which is a boundary line between Thailand and the Union of Burma, in Therd Thai Sub-district and the other stream with its head in Mae Salong Nai Sub-district, Mae Fah Laung District. Both streams flow from west to east and then combine to form Mae Kham River in Mae Kham Sub-district. Mae Kham River runs through the plain area to join Mae Chan River at Chiang San District and drains to the Mekong River. The river is approximately 85 kilometer long and has 3 watersheds; 1) Mae Kham Laung Watershed located in the west with many heads of stream, 2) Nam Mae Kham Watershed, east of Mae Kham Laung Watershed, with the catchments area 407.76 $kilomaters^2$, and 3) the last watershed is the low land area in the east of Mae Chan and Chiang San Districts. Most study sites of this research were located in Mae Kham Watershed and some were in Mae Kham Laung Watershed and the low land area. The watershed of this stream is classified by using the definition of the watershed class of the Office of Environmental Policy and Planning (OEPP) Thailand. The areas which are classified as class 1A have heads of stream with abundant forestry and are for conservation only. The areas with different land use along the stream are classified as class 1B, 2, 3, 4 and 5 respectively (Land Development Department, 2002) (Thai version).

The climate of the study area is that of Savanna climate. It has been affected by the north-east and south-west monsoon. In January it is very cold with the peak of rain in August. Most of the areas have high mountains and forests, thus the temperature and climate are different in each season. The hot dry season begins in mid-February and ends in mid-May. The rainy season starts from the middle of May and runs until the middle of October and the cool dry season runs from mid-October until mid-February with the lowest temperature of 8^0C and the average temperature being 24^0C, recorded in 2000 (http://chiangrai.doae.go.th). The database of the Meteorological Department from 1971- 2000 showed the average amount of precipitation in one year as 1,719.8 mm. The data was collected in Mae Chan District.

The study area contains several communities such as Akha, Yao, Lahu, Lisu, Hmong and Northern Thai people. Their occupation is mainly of agriculture such as rice, corns, beans, tobacco, tea, coffee, vegetables like tomato and cabbages and fruits like pineapple, orange, longan and lichee growing. In addition, they raise cows, buffalos, pigs, chickens, ducks and goats. The economy of this area is expended rapidly. Many medium-sized and small food factories have been constructed and receive raw materials from the nearly agricultural areas. Therefore, each community needs a lot of water to sustain its activities, resulting in a lack of fresh water for consumption throughout the year. Soil erosion is another problem as it brings about the deterioration of soil quality because nutrients are discharged to the water basin (Land Development Department, 2002) (Thai version).

Aquatic ecosystems are unstable systems and it is difficult to describe the conditions of the water. Therefore, we need to combine the physical, chemical and biological data to evaluate the quality of the water system. Water enters and exist the system as groundwater or from small streams, canals and rivers (Goldman and Horne, 1983). There are many methods used to monitor water quality in the streams. The physical, chemical and biological properties can be measured such as temperature, turbidity, total suspended solids for physical parameters, dissolved oxygen (DO), biochemical oxygen demand (BOD), pH, conductivity and nutrient values for chemical parameters and total coliform bacteria for biological parameters (Wannathong, 2001). Many years ago most developed countries had the problem of water pollution as a result of industrial growth. The uses of physical and chemical parameters were not good enough to detect the water quality. Therefore, they used the biological methods with physico-chemical parameters to detect the impact to the water (Inmuong, 1996).

Bioindicators are widely used to evaluate water quality. Many groups of bioindicators are used in freshwater ecosystems with plants and animals, for example, aquatic plants, fish, macroalgae, phytoplankton and macroinvertebrates. The organisms can be applied to study the water quality by using several indices for evaluation and can also be used to study the effect of the pollutants. Aquatic insects are insects that live in water or have some period of their life cycle in water, when most of them are in their larva and pupa stage. Generally, the larvae of aquatic insects are less mobile and therefore respond to environmental changes. This can explain the relationship of aquatic insects with water quality. The study using aquatic insects related to physical and chemical properties may better assess water quality rather than using only physico-chemical parameters that can only explain one specific sampling time (MaCafferty, 1981; Hellawell, 1986).

Tochimoto *et al.* (2003) studied the accumulation of trace metals in the aquatic mayfly, *Stenopsyche marmorata* Navas. The fifth instar larvae of *Stenopsyche marmorata* were transferred between a non-contaminated site and a contaminated site and changes in the accumulation of nickel, copper, zinc, and lead in larvae were monitored for 30 days. In this case, the amount of metal uptake from food was more than that from water and concentrations of the four metals rapidly increased or decreased within 10 days in the transferred larvae and approached concentrations of the native larvae living in the transfer sites. Furthermore, in 1983, Jhantarawaree studied the respiratory rate of mayfly nymphs in water with different oxygen concentrations by comparing 6 different conditions; boiled distilled water, distilled water, distilled water with oxygen added, boiled rain water, rain water and rain water with oxygen added. The results of the study revealed that the rate of gill movement of these insects in less oxygen dissolved water was lower than in more oxygen dissolved water.

It is not simply whether to use dissolved oxygen that affects macroinvertebrate as indicated in Rajchapakdee's research in 1992. This research also studied the relationship between benthic macroinvertebrate of altitude and water quality at Doi Suthep. Samples were collected from 2 streams on Doi Suthep in the altitude ranging from 380 to 1485 meters above sea level. Aquatic insects were dominant and comprised from 59.88 to 93.88 percent of benthic fauna at each site. Physical and chemical properties were more suitable in the upper reaches than in the lower areas. Less taxa and greater density of invertebrates were collected from the lower reaches in the hot dry season. From the data analysis, the samples were separated primarily based on altitude. Further, the water current may have an effect on the number of species present. In the rainy season, aquatic insects moved with high velocity and may have an effect on density and number of species to decrease. In the hot dry season, the density and number of species of insects decreased because many aquatic insect species changed from the larva stage to adult and then flew as terrestrials (Sangpradub and Hnugnan, 1998) (Thai version).

The study of water quality using macroinvertebrate species or communities as indicators and to compare with the measurement of basic physical and chemical parameters is the common practice in many countries (Tang, 2003). Many biotic indices were applied to be used in several countries such as Biological Monitoring Working Party (BMWP) Score with Average Score Per Taxa (ASPT), Ephemeroptera Plecoptera Trichoptera (EPT) Index, %EPT, EPT abundance/Chironomid abundance, % abundance of Chironomid larvae, Shannon's Diversity Index, The modified Hilsenhoff Biotic Index (HBI) and Taxa richness (http://www.mchd.com/wq/html /macro.htm).

The BMWP Score was set up by the Department of the Environmental Standing Technical Advisory Committee on Water Quality (STACWQ) from the United Kingdom in 1978 to identify the macroinvertebrate to family and give the score from 1 to 10 following the tolerance of organisms to pollution with 1 score as high tolerance families and 10 score as low tolerance families. The BMWP score is likely to be used with ASPT to assess water quality. A low ASPT indicates good water quality (Hawkes, 1997). Now there are several applied BMWP scores and ASPT from the originals of Britain, such as the BMWP' and ASPT' of Spain. 60 sites were sampled over a 2 year cycle, and the biotic index BMWP' and ASPT' were calculated for the Iberian Peninsula. Adaptations included the addition of new families, changes in some scores and correlations of particularly significant values representing the degree of pollution (Munoz, 1995). The Indian BMWP Score is popularly used in the tropical zone as indicated in Wongkham (2000) (Thai version). They studied water resources assessment using biological indices to study the environmental impact to the Mae Klang upland streams at Doi Inthanon National Park. They assessed water quality by physio-chemical and biological properties such as groups of bacteria, phytoplankton, unicellular animals and benthic macroinvertabrate. They collected samples in 3 seasons; the hot dry season, the rainy season and the cool dry season from 10 study sites in 1994. For the part of benthic macroinvertebrate they used Indian BMWP score, applied for tropical ecosystems by Zwart *et al.* in 1995. In addition, Chantaramongkol *et al.* (Thai version) studied the same method using 4 groups of biological organisms to assess the water quality of 10 sites at Doi Inthanon and 11 sites from the Mae Ping River in 1990. They also used Indian BMWP score and the result indicated a fairly good water quality at Doi Inthanon, except for some study sites which were contaminated by communities and agricultural areas. The upstream of the Mae Ping River had fairly good to moderate water quality and a decrease in quality when it passed by communities.

In Thailand, the score was applied as $BMWP^{Thai}$ by Mustow in 2002. The 23 study sites from 4 rivers of the Ping Watershed were sampled; the main Ping River, a highly polluted tributary (Kha Canal), a relatively unpolluted tributary (Taeng River) and an upland stream tributary (Klang River). Samples were collect from 1990 to 1993. The $BMWP^{Thai}$ score was therefore modified by removing 15 taxa not present in Thailand and adding 11 taxa which are more suitable to be used in Thailand. Jitmanee (2004) studied the diversity of aquatic insects in the area of the Golden Jubilee Thong Pha Phum Project, Thong Pha Phum District, Kanchanaburi Province. She assessed water quality by using $BMWP^{Thai}$ score. Eleven orders 91 families and 197 morphospecies from 10 sites were identified. $BMWP^{Thai}$ score and ASPT indicated that the water quality was not different in each site and season, which was moderately clean quality. $BMWP^{Thai}$ score is widely used in Thailand such as Tang (2003). There was also the study of water quality at Chiang Mai Water Works Pumping Station by using physical, chemical and biological parameters.

Hilsenhoff Biotic Index (HBI) is popularly used to evaluate water quality in lotic ecosystems. The index was developed by Dr. William Hilsenhoff in 1977. The Wisconsin Department of Natural Resources (WIDNR) began using the HBI in 1979 to assess water quality in streams and rivers as part of several non-point source pollution monitoring programs within the agency. The HBI is a quantitative method to assess water quality by giving a score of 1-10 following the tolerance values of each macroinvertebrate species, that is, low score shows low tolerance values and high score shows high tolerance values. The problems of this index include the season that affects the number of macroinvertebrate, several sampling habitats, sampling bias during field picking of insects and the main problem is the inability to identify some organisms to genus or species (http://www.uwsp.edu/cnr/research/gshepard/History/History.html). Thus in 1988, Hilsenhoff modified the Field Biotic Index (FBI) based on family level. Tolerance values for each family were developed by weight species according to their relative abundance in the State of Wisconsin. This index is easier to use than HBI because it identifies only at the family level. In unpolluted streams the FBI was higher than the HBI (http://www.lakes.chebucto.org/ZOOBENTH/BENTHOS/benthos.html). Thus, the FBI is more suitable to be used in environmental education programs than HBI. At present, many organizations use this index in their programs such as Volunteer Stream Monitoring Partnership (VSMP) of Water Resources Center, University of Minnesota. The VSMP partners consist of several volunteer groups in the Twin Cities' counties of Anoka, Carver, Dakota, Hennepin, and Washington (http://www.vsmp.org). In unpolluted streams the FBI was higher than the BI, suggesting lower water quality, and in polluted streams it is lower, suggesting higher water quality. These results occurred because the more intolerant genera and species in each family predominate in clean streams, whereas the more tolerant genera and species predominate in polluted streams. Thus the FBI usually indicates greater pollution of clean streams by overestimating BI values and usually indicates less pollution in polluted streams by underestimating BI values. The FBI is intended to be used only as a rapid field procedure. It should not be substituted for the BI because it is less accurate and can frequently lead to erroneous conclusions about water quality (Hilsenhoff, 1988 reference by http://www.lakes.chebucto.org/ZOOBENTH/BENTHOS/benthos. html).

In addition, an EPT index has been calculated for the Arlington County sites. This is another common water quality assessment index. This is based on the abundance of three orders of macroinvertebrate present in the stream, Ephemeroptera, Plecoptera and Trichoptera. The index is the number of EPT taxa found at sampling sites. The numbers of these EPT taxa can also be compared to the abundance of other macroinvertebrates in the stream to calculate the EPT to total ratio index (Department of Environmental Services, 2002). The EPT index, which is currently widely used in North America, also exposed significant differences between sampling methods and habitat characteristics. However in Thailand, Stonefly (Plecoptera) is very rare, thus it might be appropriate to use the ET rather than the EPT (Sangpradub *et al.*, 1996).

A diversity index, which measures the biodiversity of aquatic organisms present in the stream, was calculated for the monitoring sites. The Shannon-Weiner Index of Species Diversity was selected because it is one of the most commonly used indices. With the Shannon-Weiner index, a score of greater than 3 is good, a score from 1 to 3 indicates moderate pollution, and scores below 1 indicates polluted streams with low diversity (Department of Environmental Services, 2002). In 2000, Guerold studied the suitability and efficiency of some diversity/community structures and similar indices based on high determination levels of macroinvertebrates. In this context, Ephemeroptera, Plecoptera and Trichoptera of eight headwater streams from the Vosges Mountains were sampled 11 times during one year. Richness, abundance Shannon's Diversity Index, Margalef's Diversity Index, Simpson's Index, McIntosh's Index, coefficient of community loss and Jaccard's Similarity Index were compared when calculated from species, genus and family determination levels. The Shannon indices showed lower values when calculated at higher taxonomic levels. Mean Shannon Index calculated from determination to species-level was always significantly higher than values from genus or family-level determinations. However, the use of species, genus or family level determination will depend on the objectives of the studies. If the purpose of a study is simply enough to detect an impact of a perturbation on macroinvertebrate communities, determination to family-level may be used. On the other hand, there is an increasing need for rapid and low-cost methods to assess water quality. In this way, determinations to low taxonomic levels are difficult and are performed only by specialists who are becoming less and less numerous.

An interesting article is The Effects of a Basic Effluent on Macroinvertebrate Community Structure in a Temporary Mediterranean River (Coimbra *et al.*, 1996). In this article, macroinvertebrate communities and environmental variables were assessed seasonally for 1 year in a temporary river in South Portugal receiving an effluent with high conductivity, pH, sulphates, nitrates and low oxygen content. The ordination method canonical correspondence analysis (CCA) and the classification method cluster analysis (UPGMA) were used. Several methods for the assessment of water quality were also applied: taxon richness (S), Shannon-Wiener Diversity Index (H'), Belgium Biotic Index (BBI), Biological Monitoring Working Party Score System adapted to the Iberian Peninsula, Average Score Per Taxon derived from BMWP' (ASPT'), percentage abundance of Chironomidae (% Chir) and percentage of Ephemeroptera-Plecoptera-Trichoptera (% EPT) and ratio of EPT/(Chir + EPT). A total of 117 macroinvertebrate taxa were recorded. The most abundant taxa during the year were Chironomidae (Diptera). Macroinvertebrate samples were segregated along the first ordination axis by CCA, which in turn correlated with sulphates and nitrates. The downstream sites had a community similar to the reference sampling locations. Only the percentage of Ephemeroptera, Plecoptera and Trichoptera (%EPT) and the ratio EPT /(Chironomidae + EPT) were significantly correlated with CCA axis one. This suggests that ordination methods outperform benthic indices in detecting pollution during low flows and segregated pollution from clean or recovered sites in all periods.

Since the late 1980s there have been commercially available multivariate analysis programs that directly relate biological variations to environmental measurements (Ruse, 1996). The ordination method canonical correspondence analysis (CCA) examines variations in the community composition by constraining ordination axes to be linear combinations of environmental variables. In the ordination diagram, environmental variables are represented by arrows pointing in the direction of maximum change and the arrow length indicates the importance of the environmental variable (Palmer, 1993; Gower *et al.,* 1994 reference by Coimbra *et al.* 1996). Weighted intra-set correlation coefficients were used to identify ecological explanations of the ordination axes derived from the biological data. As a classification method, cluster analysis was applied to the same data to extract discrete groups. The distances were calculated by an un-weighted average linked procedure (UPGMA). Resemblance among data sets was calculated using the Bray-Curtis dissimilarity method, which has the desirable property of not depending on joint absences of species in the samples (Boesch, 1977 reference by Coimbra *et al.* 1996).

There are many researches that use the multivariate analysis program to analyze data of macroinvertebrates as in the work of Ruse in 1996, "Multivariate Techniques Relating Macroinvertebrate and Environmental Data from A River Catchment". The organisms were collected over 4 years from the Mole Catchment. Contemporary environmental data were used to explain biological variations using multivariate techniques provided by the program CANOCO Variations in macroinvertebrate taxa composition, BMWP and ASPT primarily reflected changes in habitats across the Mole catchment. For the result, BMWP score and ASPT were most correlated with variations in water quality. Significant correlations between the presence of certain taxa and measurements of dissolved oxygen (DO) provided support for the relative scores attributed to these taxa by the BMWP. The month in which a macroinvertebrate sample was collected was relatively unimportant as an influence on taxa composition.

For several indices, some are not suitable to use in the river and there are some that can satisfy, following the research of Royer *et al.* (2001). As can be predicted, the composition of benthic fauna in rivers will be different from that of headwater streams. There exists a need to modify, for use on larger rivers, the bioassessment techniques commonly used on small streams. Using aquatic macroinvertebrates and the reference condition approach, to develop and tested a multi-metric index for use on the rivers of Idaho. Reference sites were selected among Idaho Rivers to represent the best current conditions for the least impact. The purposes of this research were to 1) select metrics relevant to the rivers of interest; 2) expand the field sampling to encompass the greater habitat area and, potentially, the heterogeneity of rivers; and 3) select an appropriate form of data analysis. The result showed that 9 of the initial 24 metrics thought to be applicable to rivers in Idaho did not satisfy the first criterion: the metrics were either too variable or too low to be reliable indicators of habitat degradation. Of the remaining 15 metrics, strong correlations ($r \geq 0.90$) were observed between Simpson's Dominance Index, percent dominant taxon, percent Chironomidae, and percent miners. Twelve of the initial 24 metrics satisfied the first and second criteria. Evaluation of the box plots revealed that taxa richness, EPT taxa richness, Ephemeroptera taxa richness, Plecoptera taxa richness, Trichoptera taxa richness, and percent Elmidae displayed different values between reference and test sites. HBI metric displayed considerable overlaps in inter quartile ranges, indicating little or no ability to distinguish between reference and test sites and thus were not included.