EFFECTS OF WATER QUALITY ON PERIPHYTON IN THE PATTANI RIVER, YALA MUNICIPALITY, THAILAND

VICHIT RANGPAN

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EFFECTS OF WATER QUALITY ON PERIPHYTON IN THE PATTANI RIVER, YALA MUNICIPALITY, THAILAND

by

VICHIT RANGPAN

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KESAN KUALITI AIR KE ATAS PERIPHYTON DI SUNGAI PATTANI, BANDAR YALA, THAILAND

oleh

VICHIT RANGPAN

Tesis Yang diserahkan untuk memenuhi keperluan bagi Ijazah

Doktor Falsafah

2008

Dedicated to my parents

For their Love and Inspiration

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Vichit Rangpan

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S I	Sampling station 1
S II	Sampling station 2
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S VI	Sampling station 6
ppm.	Parts per million
ppb	Parts per billion
°C	Degree Celsius
mm^2	Millimeters
H’	Shannon index
J’	Equitability
Rainy season	May, June, July, August, September, October, November, December, January.
Dry season	March, April, February
LN BIOMASS	Value of Biomass which Analysed Data from Natural Logarithm
LN BIOMAC	Biomass Accumulation
LN SPECIE	Species Richness
LN MAX	Maximum Diversity
LN EQUI	Equitability
LN CHLO	Chlorophyll- *a*

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ABSTRACT

Data collection and field surveys were carried out from March 1999 to February 2000 to study the effects of water quality on the periphyton populations in the Pattani River. Periphyton parameters that were used for the study include species richness, total density, biomass, biomass accumulation, chlorophyll *a* and Shannon-Wiener diversity index (H'). Periphytic algae were collected on standard artificial substrates (glass slides) at the six-sampling stations. Periphytic algae attached on the glass slides consisted of 43 species of Bacillariophyta (Diatom), 5 species of Cyanophyta , 6 species of Chlorophyta and 2 species of Euglenophyta.

There were temporal and spatial changes in some parameters. The relationship between water quality and periphyton as shown by Pearson Correlation Coefficient indicated that BOD and COD were significantly positively correlated with species richness (S), total density, species diversity (H'), maximum-diversity (H'max) ($p < 0.01$), and biomass, biomass accumulation and chlorophyll-*a* ($p < 0.05$). Total phosphate phosphorus had a significantly positive correlation with biomass, biomass accumulation and chlorophyll-*a* ($p < 0.01$). Alkalinity had a positively significant correlation with the Shannon equitability index ($p < 0.05$). DO and TSS (Total Suspended Solids) had a significantly negative correlation with species richness (S), the Shannon-Wiener species diversity index (H') and maximum diversity

(H'max). Zn and Hg had a significantly negative correlation with the Shannon equitability index ($p < 0.05$). Ammonia-nitrogen had a significantly negative correlation with species richness (S), (H')($p< 0.05$) and maximum diversity (H'max) ($p < 0.01$).

The study on the relationship between various parameters of water quality and periphyton found that total density had a positive relationship with total phosphate-phosphorus ($p < 0.05$). Biomass had a negative relationship with DO, NO^-_2-N and NH_3 – N ($p < 0.01$) and TSS ($p < 0.05$). Biomass accumulation had a negative relationship with DO, NO^-_2-N ($p < 0.01$) and HN_3 – N ($p < 0.05$). Biomass accumulation also had a positive relationship with total phosphate phosphorus ($p < 0.05$). In contrast, chlorophyll-*a* had a negative relationship with Fe, NH_3-N ($p < 0.05$) while the H' had a positive relationship with total phosphate phosphorus, NO^-_2-N, NO^-_3-N and Hg ($p < 0.05$). Finally, the equitability index had a positive relationship with alkalinity.

During rainy seasons, the results showed that diatoms were indicators of unpolluted water and the dominant species included *Achnanthes oblongella* Oesturp, *Achnanthes lanceolatat* (Brébisson ex Kützing) Grunow *and Fragilaria capucina* Desmaz. However in moderately polluted water the dominant species recorded were mainly from the Cyanophyta division of which *Oscillatoria tenuis* C.Agardh, *Lyngbya* sp., *Phormidium fiagile* (Meneghini Gomont) and *Chroococcus minutus* Kützing Naegeli were observed in large populations. From the parameters through different analysis it shows quality of water at the level from clean down to moderately polluted water.

KESAN KUALITI AIR KE ATAS PERIPHYTON DI SUNGAI PATTANI, BANDAR YALA, THAILAND

ABSTRAK

Survei lapangan dan pengambilan data ke atas perifiton di Sungai Pattani, Bandar Yala Thailand telah dijalankan daripada Mac 1999 sehingga Februari 2000. Nilai perifiton berdasarkan kekayaan spesies, jumlah densiti, biojisim, biojisim terkumpul, klorofil-*a* dan indek kepelbagaian Shannon-Wiener (H') serta beberapa komponen lagi telah dikumpul dengan menggunakan sisip kaca di enam stesen persampelan. Alga perifiton yang dikumpul di atas sisip kaca terdiri daripada 43 spesies Bacillariophyta (Diatom), 5 spesies Cyanophyta , 6 spesies Chlorophyta dan 2 Euglenophyta .

Dalam kajian ini terdapat perubahan masa dan ruang terhadap beberapa parameter yang mengikut musim dan kedudukan stesen persampelan. BOD dan COD mempunyai perhubungan signifikan dengan air dan perifiton mengikut "Pekali Korelasi Pearson". BOD dan COD juga mempunyai perhubungan positif dengan kekayaan spesis (S), jumlah densiti, indeks spesies Kepelbagaian Shannon (H'), diversiti maksimum (H' max) ($p < 0.01$), biojisim, biojisim terkumpul dan klorofil-*a* ($p < 0.05$). Jumlah fosfat-fosforus mempunyai korelasi positif yang signifikan dengan biomass, biomass terkumpul dan klorofil-*a* ($p < 0.01$). Alkaliniti mempunyai korelasi positif yang signifikan dengan indeks keseragaman Shannon ($p < 0.05$). DO dan TSS (sedimen terampai) mempunyai korelasi negatif yang signifikan dengan kekayaan spesis (S), H' dan diversiti maksimum (H'max). Zn dan Hg mempunyai korelasi negatif yang

signifikan dengan indeks keseragaman Shannon (p < 0.05). NH_3–N mempunyai korelasi negatif yang signifikan dengan kekayaan spesis (S), kepelbagaian spesies dan diversiti maksimum (H'max) (p < 0.01).

Hubungan antara parameter-parameter kualiti air dan perifiton juga dikaji dengan menggunakan analisis model regrasi. Jumlah densiti mempunyai perhubungan positif dengan jumlah fosfat-fosforus (p < 0.05). Biojisim mempunyai perhubungan negatif dengan DO, NO^-_2-N, NH_3-N (p < 0.01) dan TSS (p < 0.05). Biojisim terkumpul mempunyai perhubungan positif dengan fosfat-fosforus (p < 0.05). Klorofil-*a* mempunyai perhubungan negatif dengan Fe dan NH_3-N (p < 0.05). Indeks kepelbagain spesies Shannon (H') mempunyai perhubungan positif dengan jumlah fosfat-fosforus, NO^-_2-N, NO^-_3-N dan Hg (p<0.05) dan Indeks keseragaman Shannon mempunyai perhubungan positif dengan alkaliniti.

Pada musim hujan, keputusan menunjukkan diatommenjadi penunjuk air bersih dengan spesies dominen seperti *Achnanthes oblongella* Oesturp, *Achnanthes lanceolata* (Brébisson ex Kützing) Grunow dan *Fragilaria capucina* Desmaz. Tetapi dalam air yang sederhana tercemar spesis yang ditemui adalah dari divisi Cyanophyta termasuk *Oscillatoria tenuis, Lyngbya* sp., *Phormidium fiagile* Meneghini Gomont dan *Chroococcus minutus* Kutzing Naegeli. Daripada parameter yang didapati dari pelbagai analisis, ia menggambarkan qualiti air berada daripada tahap bersih sehingga sederhana kutur.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Periphyton is considered to be the primary producer and the most important sources of oxygen within flowing aquatic ecosystems and streams (Grzenda & Brehmer, 1960). They are occasionally considered to be more productive than other aquatic plants (Nelson, & Scott, 1962; and Odum, 1956). Periphyton has become a widely accepted indicator of water quality and stream conditions since two decades ago (Ho, 1979). However, it is not a consistant indicator for all stream systems (Nelson & Scott, 1962). Past of periphyton's basic function is the continuous replenishment and removal of nutrients and products (Hynes, 1972; Mc Connel & Sigler, 1959; Odum, 1956; and Whitford, 1960).

Periphyton can be found growing on any submerged objects (Hutchinson, 1975; and Hynes, 1972). Certain physico-chemical conditions can trigger the growth of certain components of the periphyton and favored over other periphyton . Depending on stream or lake origin, morphometry, conditions and time of year, periphyton may play a more important role in the primary production of O_2 (Wetzel, 1964).

Periphyton plays a significant role in aquatic systems through the production of oxygen and the utilisation of carbon dioxide. These are the significant stages of a oxygen-carbon dioxide cycle in aquatic ecosystems. Productivity is equated directly to "standing crop", or the biomass that an aquatic system can support at any time

(Ryther, 1956). However, more information about a community can be gathered by extensive observation of periphyton colonies over a long period.

The development of periphytic micro-communities is a function of factors regulating the growth of their components. The various components of periphyton are bacteria, yeast, fungi, protozoa, algae, and small invertebrates. These components are regulated by growth factors of unequal significance. Factors commonly considered as limiting, essential, or important to the development of periphytic assemblages include water bodies, availability of sun-light, transparency and turbidity; substrate condition, location, depth and availability; water movement, water current and velocity, pH, alkalinity and hardness. Nutrients (nitrogen, phosphorus and carbon), as well as other dissolved materials such as calcium, sulphur and silicon; metals and trace metals, (iron, copper, chromium, boron, vanadium and selenium), temperature, salinity, oxygen and carbon dioxide content also regulate the growth of periphyton colonies (Kolkwitz & Marsson, 1967; Prescott, 1956; Hutchinson, 1975; Nelson, 1973; Blum, 1956; Hynes, 1972; Patrick *et al*., 1975; Patrick, 1948a and Jones *et al*., 1976).

The biomass of the periphyton community has been studied in many countries, for example in Malaysia (Ho, 1976), Germany (Ho, 1979), India (Joy *et al*., 1990), New Zealand (Welch *et al*., 1992), and U.S.A. (Vymazal & Richardson, 1995 and Mc Cormick *et al*., 1998).

The population structure and diversity has been studied in several species such as in the *Chlorella* species (Anton, 1981), epilithic and epiphytic diatoms (Stevenson, 1984), water pollution diatom community (Nather Khan, 1990), *Diatom*a sp. (Nather Khan, 1991), and filamentous algae (Mansor & Lidun, 1992).

Apart from this, the composition and community structure of periphyton has been studied by many scientists (Stevenson, 1998; Sabater *et al*., 1998; Kelly *et al*., 1995, Hechman *et al*., 1990; Hill *et al*., 2000; Winter & Duthie, 2000; Stewart *et al*., 1999; and Wan Maznah & Mansor, 2000).

In addition, community metabolisms studies focused on several aspects such as net gross (Rier & King, 1996; Ho, 1976; Keithan & Lowe, 1985 and Rosenfeld & Roff, 1991), production (Keithan & Lowe, 1985; Shamsudin, 1987; Tease *et al*., 1983; Blanck, 1985; Napolitano *et al*., 1994; Rier & King, 1996; and Vadeboncouer & Lodge, 2002), bioaccumulation community metabolism (Grimshaw *et al*., 1993; and Knaeur *et al*., 1997), metabolism conditioned community metabolism (Hino, 1998), biomolecular community metabolism (Guckert *et al*., 1991 and Napolitano *et al*., 1994), and enzyme activity community metabolism (Guckert *et al*., 1991).

Population analysis was studied in areas of indicator species by Palmer (1969); Lange-Bertalot (1979); Descy (1979); Cox (1988); Whitmore (1989); Friedrich *et al*. (1992); Prygiel & Coste (1993); and Kelly *et al*. (1995), while growth potential was studied by Ho (1979); Pringle (1987); Lukavsky (1992); and Fujimoto & Sudo (1997).

1.2 OBJECTIVES OF THE STUDY

The main objective of the study is to correlate changes in water quality in the Pattani River with species richness and diversity of periphyton.

The objectives of the study are,

1. to assess the water quality of the Pattani River.
2. to study the abundance and diversity of periphyton in the Pattani River.
3. to assess land-use patterns along the Pattani River and how they relate to changes in water quality.
4. to correlate water quality parameters with periphyton abundance and diversity.
5. to study the suitability of periphytic algae as bioindicator in water quality assessment .

1.3 AIMS OF STUDY

The main aim of the study is to characterize the periphyton community in the Pattani River, which flows through Yala Province in Southern Thailand.

The focus of this study is on the community structures and distribution patterns of periphyton in the Pattani River . The study also investigated the functions, primary production and the nutrient relationships between periphyton communities. This study will provide information and guidelines for the planning and management of aquatic systems in Yala Municipality. The term periphyton in this study refers to algae growing on slides of artificial substrates, which are placed at the various sampling sites.

Based on the information, patterns and types of land use which take into account the features of river system will be established. The result will be used to forecast future planning especially in the early detection of destructive land use which sub frequency will affect the river ecosystem. Therefore, the study can be used as a gridline in order to conserve the river environment within the Yala Municipality area.

CHAPTER 2

LITERATURE REVIEW

2.1 Water Quality of the Pattani River

Since Pattani River flows to the Pattani Bay there for are several studies conducted at the Bay. For Example,

Hatta (1992) studied the problems of environmental pollution in the Pattani Bay area, which comprises a population of 95,000 inhabitants who lived around the bay. The main economic activities within the bay area include coastal and deep sea-fishing while timber is extracted from the mangrove forests nearby. The main environmental pollution sources were identified to be urban wastewater discharge. This survey was useful in providing input for the efficient management of resources based on environmental protection and preservation principles.

Arikul & Kooptanon (1993) studied the sources of heavy metals in the Pattani River. The heavy metal traces studied included lead, arsenic, cadmium, copper, zinc, iron and manganese which were found in stream sediments, water and suspended sediment in ground and water supply. Evidently, the source of lead in the Pattani River is from cassiterite mineral ores, which are mined at Bannangsata district, Yala Province. In addition to this, the existence of arsenic, copper and zinc the water were also recorded. Petchara (1990) found cadmium in green kite and sphalerite elements, a bronze metalwhich easily changes shape and which is generally found on the earth's surface. Apart from this, the quality of trace metals also depends on soil characteristics and origins. For instance, soil from a cross section of a rock had a higher cadmium concentration compared to soil from igneous rock and granite stone.

There is less cadmium in water as cadmium is not very soluble and is usually absorbed by clay particles. It should be noted that cadmium at concentrations higher than 0.10 mg/L is harmful to humans and animals. Sources of cadmium pollution include mineral and metallurgical industry emissions from plastic industries, metals and machine oil plants, battery industries as well as from cellular, anti-fungi chemicals and fertilizer industries.

Thuthep (1994) studied metal mixture in sediments from Pattani River. The results of the study showed that the presence of metal and arsenic in sand particles down stream were double than that in sand particles upstream. In contrast, metal and arsenic quantities were higher in particles of clay, silt and sand. The total metal concentration at the water processing plant in Yala was twice as high as that in Pattani.

Mahapol (1989) evaluated pollutant elements in 22 rivers that flow through the gulf of Thailand, between 1982 and 1988. He concluded that most of these rivers were affected by pollutant sources.

The average lead concentration in Pattani River, which flows into the gulf, was 265.6 tons per year. It ranked second behind the Tap Dompuang River, which had an average lead concentration of 566.3 tons per year. Everaats & Swenen (1989) studied heavy-metal quality in benthos and coastal sediments in Thailand (Bandon and Pattani) and in Malaysia (Jeram) and discovered the presence of heavy metals such as zinc, copper, cadmium and lead at the respective sampling sites.

2.2 Periphytic algal study

The number of periphyton species diversity is known to differ in different locations (Table 2.1). Table 2.2 shows the examples on the classification of algae in Thailand.

Table 2.1 Species of algae studied by various scientists at the different study areas.

Areas of study	Number of species	Researchers
French Mediterranean Rivers	52	Cazaubon Rolland & Loudiki (1995)
South – Western Australia	201	Jacob (1998)
Schohsee in West Germany	100	Ho (1979)
Penang River Basin	121	Wan Maznah & Mansor (2002)

Table 2.2 Examples on the classification of algae in Thailand.

Areas of study in Thailand	Number of species	Researchers
- Central part of Thailand	246	Wongrat (1998 b)
- Kancharoburi Province	224	Panboon (1998)
- Mae Sa Stream	87	Pekthong & Peerapornpisal (1999)
- Meangap Somboonchol Dam	47	Proongkiat & Traichaiyaporn (1999)
- Gulf of Pattani River	35	Leangthu-Praneat *et al.* (1998)

Other surveys on the diversity of phytoplankton in central Thailand (Kanchanaburi Province) were made by Panboon (1998). Ninety-two genera including 224 species of phytoplankton were recorded from 21 study sites. The phytoplankton detected consisted of 3 divisions namely, Cyanophyta, Chlorophyta and Chromophyta. Different seasons caused diversity changes in Phytoplankton species with the highest number of genera (64) found in April (1998). The overall dominant genera were *Oscillatoria, Microcystis, Anabaena, Eunotia, Scenedesmus, Trachelomonas, Pediastrum, Peridinium , Synedra* and *Ceratium.*

In the current area of study, there is no record of research regarding periphyton ever being conducted. However, a Prince of Songkla University team did a study on phytoplankton in the Pattani Bay area. The first part of their research commenced in 1989 while the second started in 1997. The researchers documented useful information, which was used as a source of reference in this study.

Leangthu - Praneat *et al.* (1998) surveyed phytoplankton in the Gulf of Pattani and in the Pattani River. The species of phytoplankton identified were from 54 genera; 12 genera of Cyanophyta (blue-green algae), 14 genera of Chlorophyta (green algae), 23 genera of Chrysophyta (diatom), and 5 genera of Pyrrophyta (dinoflagellate). Diatom plays an important role as a primary producer in the aquatic food web, and it is fortunate that its populations is quite abundant in the Pattani Bay. However, some blue-green algae such as *Oscillatoria* and other genera such as *Dinoflagellate, Ceratium* and *Peridinium* were also identified. The existence of these species indicate that the water may be polluted (Wongrat, 1998b).

2.3 Effects of Water Quality on Periphyton

Numerous studies have analysed the linkage between water quality and its effects upon the proliferation of Periphyton colonies. The details of these studies are outlined in the following subsections.

2.3.1 Periphyton growth

The relationship between water quality and periphyton growth was studied in Thailand by Wongrat (1998a) who examined the impact of water quality on algal growth according to physical and chemical factors. He noted that light, temperature, pH and current were main physical factors that determine growth.

Temperature can have a significant effect on the growth of phytoplankton colonies, because algae can grow well at 15-20 °C (Mansor & Lidun, 1997). Generally, temperature in natural water varies according to the seasons (Prokorb-waithaya, 1982). This is especially important as extreme temperature variations do have an impact on the survival of periphyton. Generally at 20°C, many species of diatoms thrive well. According to Saraisuwan (1981), most algae species grow better in alkaline water.

Chemical factors are mostly related to food or nutrient supply namely, macronutrient and micronutrient. In fact, turbulent water provides a good supply of dissolved nutrients, which are good for periphyton (Saraisuwan, 1981). Macronutrients consisting of carbon, nitrogen, phosphorus, calcium, magnesium, copper and potassium (K) are useful for phytoplankton growth.

Periphyton uses phosphorus for its metabolism especially for growth. In addition, zooplankton and phytoplankton, which live in coastal areas, also utilize phosphorus in the environment (Bonyawanit, 1983). At present, people regularly use detergents which are discharged into the water, and therefore increase phosphate concentrations, which in turn cause an increase in the growth of algae (Kuhl, 1968). The decreasing amount of nutrients, caused by diatoms such as *Asterionella* which normally uses large amounts of phosphate, can reduce other periphyton development (Roos, 1983). Horne & Goldman (1994) reported that nutrient-rich water does not have high periphyton colonies because of competition for light between phytoplankton and periphyton that generally profits the more abundant species. It is believed that phytoplanktons in eutrophic lakes compete for nutrients and this will decrease the growth of periphytic algae (Hansson, 1992). According to Patrick (1982) dissolved matter in the form of carbon, nitrogen, phosphorus and organic matter are essential in order to control the development and expansion of periphyton nutrients with each showing different effects. For instance, micronutrients, especially iron will support absorption of nitrogen and as such a lack of iron will affect the character of algal cells. Boron is one of the elements necessary for the growth of certain algae such as blue-green algae and diatoms. All these chemicals are the main requirements for photosynthesis, which produces oxygen. However, diatoms will die if these chemical elements exceed the normal required levels. Cobalt is the main component of Vitamin B-12 and is important to the growth of algae. Nickel is also important for photosynthesis in some kinds of algae particularly diatom and green algae (Round, 1975). If these two elements are high in concentrations, it will affect algal growth.

2.3.2 The use of algae to predict water quality

Biological data show that physical and chemical characteristics affect the distribution of periphyton in any area (Cazaubon *et al.,* 1995). Therefore any disruption of the environment and a high range of nutrient acquisition will affect peripyton populations. Periphyton is the primary producers for many dynamic food chains and, therefore disruption of its population growth, has adverse implications on the whole aquatic ecosystem (Napolitano *et al.*, 1994 and Horne & Goldman, 1994). Periphyton can adapt to various conditions and can live in all kinds of water from oligotrophic to eutrophic conditions. A highly populated periphyton community is suitable for pollution impact research due to their high rate of development and their unique characteristics (Stevenson & Lowe, 1986).

Various periphyton indices have been created and used in many countries (Kentucky Department of Environmental Protection, 1993 and Hill, 1997). For instance, community composition changes are used to determine environmental pollution since the ecological tolerance of many of these species is known (Stevenson, 1998 and Stevenson & Pan, 1999).

Certain kinds of algae can be utilized to predict the water quality of an aquatic ecosystem. For example, algae such as *Oscillatoria* sp. *Spirulina* sp. and *Euglena* sp. grow rapidly in water with little dissolved oxygen (Suksringam, 1988). Tubsisaod (1978) described that in low acidic or alkaline water, there is a possibility of tremendous growth of algae. With regard to the prediction of water quality by using diatoms, Tubsisaod (1978) found that *Achnanthes* sp. and *Achnanthes minutissima* were abundant in unpolluted locations and *Navicula cryptocephala* and

Gomphonema acuminatum were common and abundant in moderately polluted locations. *Nitzschia palea* W.Sm. and *Gomphonema parvulum* Grunow, which were documented as indicators of organic pollutant (DOE, 1998) were mainly found at severely polluted locations. Besides this, there was an exceptionally high number of *N. palea* at polluted locations. *N. cryptocephala* and *N.palea* were recorded by Cazaubon *et al.,* (1995) in puddles where eutrophication favors the bloom of a few pollutant-tolerant species. *N.palea* is often found in polluted waters where it may achieve dominance due to its tolerance of toxic conditions (Lowe, 1974). In fact, *Nitzschia palea* can thrive at sites with high levels of nutrient and organic pollution (Kelly *et al.*, 1995). Wan Maznah & Mansor (1999) also noted the presence of *G.parvulum* in mildly organic polluted areas. They postulated that increased urban and industrial waste at polluted locations probably eliminated or reduced the intolerant species leaving behind the more tolerant and hardy species to dominate such areas. However, these results of species diversity were different from reports by Nather Khan (1991) for diatoms in the Linggi River Basin, Malaysia. In his study, the diversity values at unpolluted stations were always lower than at mildly polluted stations.

2.3.3 The changes of periphyton regarding water quality

The growth of *Oedogonium* algae generally will result in the increase of diatoms such as *Achnanthes* and *Synedra* (Roos, 1983). Seasonal changes in diatom structures of periphyton, from two localities indices of the Lake Maarsseveen Community, found that the diatom composition of the diatom-dominated reed-periphyton from a Dutch lake varied temporally and separately. A seasonal shift in algal composition was demonstrated for those in the two reed stands as a whole as well as for those on the embankment and by the lakeside. Spatial variation in the center of the stands appeared to be greater than seasonal variation but the diversity indices of the two sides did not differ significantly (Roos, 1983). In many rivers, periphyton biomass shows a spring and fall maximum (Dunn, 1976, Ruhrmann, 1990).

The measurement of velocities close to the different periphyton elements in rivers showed the influence of current velocity on periphyton distribution. The results indicate that several algal species have a defined niche within the current velocity spectrum while other species can inhabit a very broad range of current velocities. Many macroscopic visual algal colonies exhibit better development at velocities > 20 cm/s, while only a few thrive at velocities > 100 cm/s (Traaen & Lindstrom, 1983).

The study of periphyton changes is important in determining the changes of physiological function rates and morphologies caused by chemical concentrations or by physical factors. Production changes and the structure of periphyton community are used to explain and identify environmental conditions, as well as to explain water quality variations from sampling locations (Weitzel *et al.*, 1975).

2.3.4. The structure and changes of periphyton communities

Szczepanska (1975) investigated the dynamics of change in reed periphyton colonies in six Polish lakes. He found that within the lakes, there were great differences in periphyton biomass patterned by different niches.

Lay & Ward (1987) performed a study on algal community dynamics in two streams having similar physical characteristics but located in different geological regions and compared them in terms of nutrient content, net primary productivity and algal species composition. Significant differences were found in concentrations of nitrate, alkalinity, DOC and algal biomass for the two study streams.

Uehlinger (1991) studied the dynamics of the periphytic biomass and evaluated the role of hydrological factors on the variability of periphyton in a flood prone pre-alpine river. Maximum periphytic biomass was observed at the end of 5 months study after the last streambed-altering flood. The resistance of the periphytic community was dependent on stone size, current velocity and depth. Similar results have been reported from a study of a Rocky mountain river and a third order stream (Mc Connel & Sigler, 1959).

2.3.5. Primary production

Kevren & Ball (1965) investigated the productivity of algal community in artificial streams. They found that a temperature increase resulted in a negligible increase in net production. On the other hand, increasing light intensity caused a significant increase in net productivity.

Rosenfeld & Roff (1991) measured primary productivity in a forested stream to identify the main factors influencing algal growth. The availability of light, as mediated by the development of riparian vegetation, appears to be the most important factor affecting primary production. This was followed by type and water temperature.

Hill & Boston (1991) studied the effects of biomass accumulation and community age on the photosynthesis-irradiance (P-I) response of periphyton. Their studies showed that light or metabolic substrate became progressively more limiting factors during the development of periphyton colonies. The result of this study is particularly relevant for assessing primary production in habitats where disturbance periodicity resets the succession processes in periphyton. Boston & Hill (1991) in another study on photosynthesis-irradiance relationship, concluded that P-I responses of algal periphyton under light and shade conditions differ substantially from those typically reported for phytoplankton.

CHAPTER 3

DESCRIPTION OF THE SAMPLING AREAS AND THE SAMPLING PROGRAMS

3.1 INTRODUCTION

3.1.1 Description of Yala Province

The word “Yala” comes from the Malay language, which means, “fishing net”, Yalor was the old town of Yala. Before 1933, Yala was a part of Pattani, which had been colonialised by Thailand since 1786. In 1933, Yala was separated from Pattani and officially became a province of Thailand in 1997 (Yala Municipality, 1997). Yala is located in the southern part of Thailand and encompasses an area of 4,521.007 square kilometers. It is located between latitude 5-7°N and longtitude 100-102°E. It is about 1,039 km from Bangkok by rail and is 1,395 km via the old Pechkasaem Road and 1,084 km via the new Pechkasaem Road.

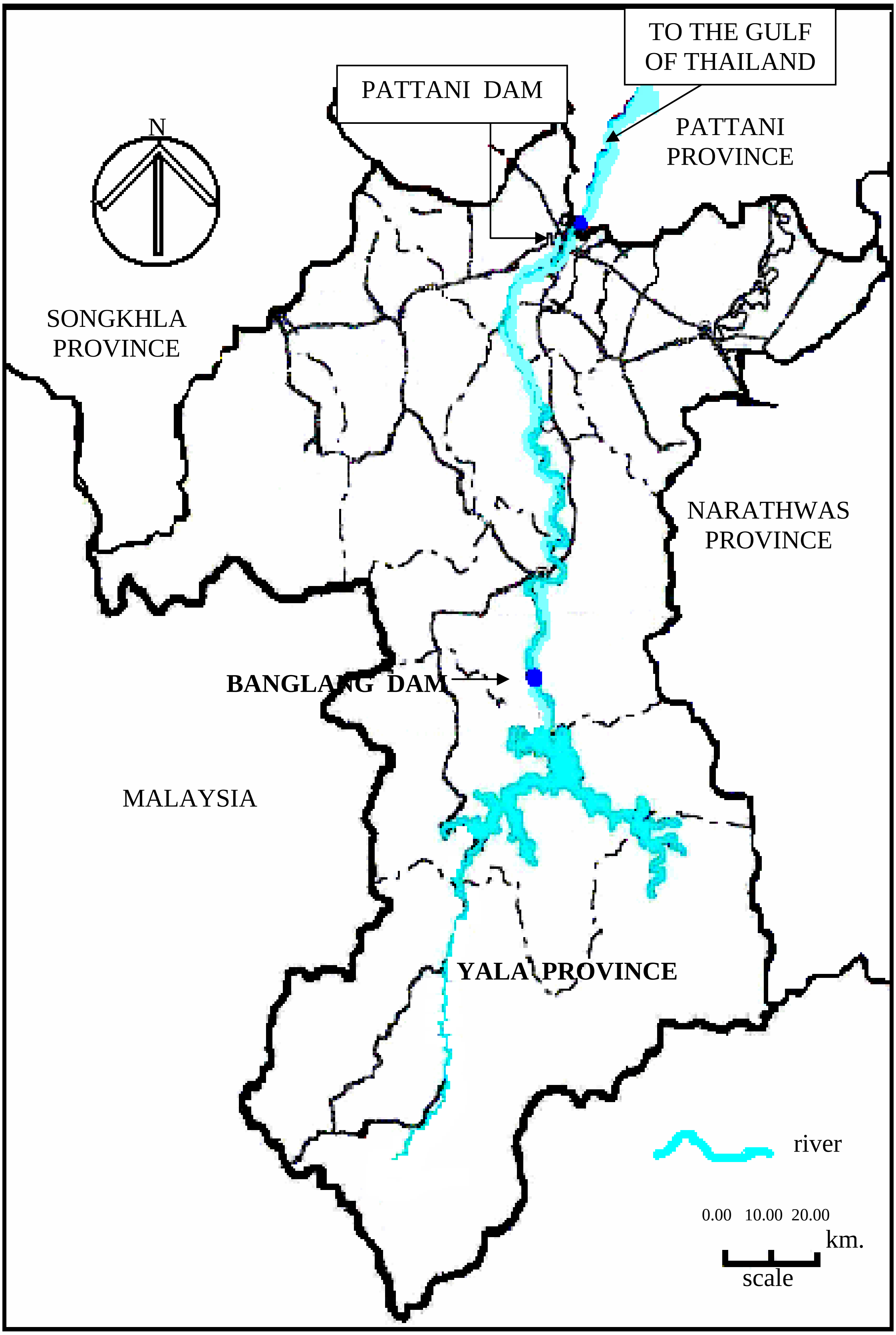

Figure 3.1 The location of Pattani River (Yala Municipality, 2000)

Yala is a predominantly mountainous district. The Pattani River and Saiburi River flow through the district, at a height of about 100-200 metres above sea level. Most of the area is covered by tropical forest and rubber plantations *(Hevea brazilliansis)*. Two mountain ranges namely Sankalakiri and Budo are located in Yala. The Province had 124,300 ha of forest in 1985 which declined to approximately 114,300 ha in 1996. The province has experienced much deforestation except in the Balah-Halah wildlife conservation area and in the Banglang National Park. There are 7 mines in Muang district which comprise 1 marble mine and 6 limestone mines. Additionally, there are 3 limestones mines in the Betong district. Yala Province has a population of 431,184 which consist of 216,859 male and 214,325 female residents (Yala Municipality, 1997).

Agriculture is the main occupation of the local populace and therefore it is not surprising that 262,081.28 ha or 57.96% of the whole provincial area is dedicated to agriculture. Cash crops such as *Hevea brazilliansis* (Rubber), *Durio zibethinus* Linn. (Durian), *Aglaia dookkoo* Griff. (longkong) and *Citrus reticulata* Blanco. (Chogun orange), are widely cultivated.

The three most important resources in the province are people, land and water. In recent times, industries have sprung up as farmers have began processing their raw produce. This has helped to increase product efficiency, reduce wastage, improve trading potential and elevate incomes as more money is made from processing raw produce (Tso, 2004).

Current agricultural initiatives involve the development of a better variety of *Hevea brazilliansis* and the adoption of modern technology to produce quality rubber products. Most of the rubber trees are planted on hill slopes where erosion always occurs. The nutrient runoffs continuously flow into the Pattani River and create non point sources of entry into the river system. Currently, the Office of Rubber Plant Aid Fund, under the Ministry of Agricultural Affairs, is directly involved in developing rubber plant breeds, investigating and controlling standards of rubber processing and encouraging producers not to cultivate on hill slopes in order to reduce the effects of erosion in the area.

In 1998, there were 323 rubber factories in Yala Province, mainly involved in the production of Para wood timber and latex products. In the lower regions of Yala near the Thai - Malaysian border, concentrated in the Betong district of Thailand and in the Baling district of Malaysia, are several Para wood processing industries involved in the production of furniture and charcoal as well as rubber drying mills. In central Yala, Para wood furniture factories and rubber latex industrial plants are sited along riverbanks and roads. The Office of Provincial Industrial Affairs is involved in controlling the environmental impact of these activities. However, some factories or industries illegally discharge effluents into the streams and adjoining small rivers which in turn flow into the Pattani River.

3.1.2 Description of Yala Municipality

Yala Municipality was officially gazetted on the 11th of February 1936. The total land area of 16 square kilometres increased to 19 square kilometres in 1966. Currently, the Yala Municipal office is on Suk Kha Yang Rd**.** Yala Municipality is located in Tambon Sateng, Muang district, north of Yala town. The municipality is bordered by Yarang district, Tambon Yupo, Tambon Sateng Nok and Tambon Tasab.

Yala Municipality is situated on rectangular line on Pattani River, which flows into the sea in Pattani Province. The Municipality is predominantly a flat area but is slightly hilly in its southern regions. Land is mostly utilized for market-based and business activities, constructions of buildings with certain portions left unused. Land use for agriculture encompasses an area of approximately 65.28 ha or 6.7% of the whole area. Revenue is derived from vegetable farming, horticulture and rubber cultivation *(Hevea brozilliansis).*

The climate of Yala town is humid. It rains continuously throughout the year but there are 2 distinct seasons. The dry season is between Feb.-April while the rainy season is between May-January. Meteorological data from the 1994 – 1998 period showed an average temperature of 32.71ºC, humidity of 67.5% while total rainfall was 2,281.6 mm^2 per year.

Table 3.1 Quantity of rain fall at the study areas (1986 - 2007)

months	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC	
YEAR.	(mm.)	Kg/d	(mm.)	Kg/d	(mm.)	Kg/d	(mm.)	Kg/d	(mm.)	Kg/d	(mm.)	Kg/d	(mm.)	Kg/d	(mm.)	Kg/d	(mm.)	Kg/d	(mm.)	Kg/d	(mm.)	Kg/d	(mm.)	Kg/d
1986	88.5	10	0	0	17	7	38.5	10	118	12	118	11	106	11	55.7	11	206	19	152	17	470	19	138.5	15
1987	23.2	9	0	0	67.7	7	21.9	8	266	11	138	11	71.5	8	200	12	216	15	220	19	273	17	728.2	17
1988	9.6	4	103	4	23	4	104	8	254	16	128	10	137	13	271	16	209	18	250	17	794	24	271.7	10
1989	36.8	5	16.8	2	38	4	298	11	205	15	23.7	14	200	13	55.3	14	131	15	139	16	150	19	63.9	11
1990	95.7	8	16.7	4	38.8	5	115	11	177	8	19.3	4	62.7	11	162	4	164	14	173	20	236	19	318.5	17
1991	99	10	0	0	91.1	2	22.8	6	300	14	105	7	68.3	10	84.7	12	70.7	14	260	17	400	17	409.3	15
1992	34.8	9	17.8	4	0	0	152	7	196	13	89.7	12	119	10	173	15	158	12	232	20	378	24	211.1	18
1993	56	9	11.8	3	248	14	106	8	137	13	270	15	52.6	9	297	17	161	19	350	19	354	21	652.8	21
1994	5.6	5	41.3	7	275	18	185	13	235	15	182	16	62.3	10	93	12	192	16	287	20	575	27	83.6	11
1995	35.9	10	36.4	5	80.4	6	26.8	4	121	13	306	14	164	14	236	20	84.7	16	228	21	510	25	454.2	21
1996	23	7	13.5	5	30	2	291	7	122	14	128	16	120	13	228	20	107	11	347	23	204	20	520.9	20
1997	0.8	2	71.2	10	21.5	4	103	11	89	6	273	16	118	16	137	16	483	17	68.1	14	178	20	510.7	19
1998	109	14	3	1	8.8	4	15.1	2	129	10	288	15	251	15	232	20	267	21	249	17	263	22	586.9	25
1999	150	17	266	9	74	11	152	18	197	11	129	10	162	9	131	15	116	18	239	24	482	26	790.3	24
2000	102	15	62.3	11	257	12	366	20	78.7	10	214	17	146	11	151	12	256	16	219	22	798	23	320.1	16
2001	287	16	47.8	3	209	13	125	9	232	17	88.7	10	204	14	132	13	230	18	447	24	266	20	449.4	15
2002	42.4	10	0	0	68.6	7	53.5	11	137	14	73	11	62.2	11	149	16	119	18	218	23	247	17	370.3	19
2003	48.9	14	69.1	6	139	8	57.3	7	173	13	190	12	132	19	170	13	122	10	438	24	206	21	298.3	24
2004	21.2	7	11.7	3	29.3	10	63	10	212	12	71.7	16	309	16	137	13	340	23	374	26	115	21	193.8	17
2005	30.3	4	6.4	2	83.2	8	66.7	6	220.2	20	111.6	16	276.1	11	275.9	11	160.1	17	112.1	25	347.0	23	1006.4	19
2006	89.8	10	236.7	9	148.4	10	218.8	16	147.2	19	76.0	14	157.0	11	169	14	304.9	18	245.5	17	155	21	266.2	19
2007	204	18	1.2	1	116.8	9	98.0	9	384.1	15	197.0	13	216.2	15	107	13	86.3	14	327.4	21	158	21	295	19

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Red Yellow Podzolic is the main type of soil in Yala Municipality. Most areas within the Municipality are earmarked for urban planning where land is utilized for residential, business or agricultural purposes.

Yala has two main rivers namely Pattani River and Saiburi River, and. two wetlands namely Bakoi and Bamoa. Pattani River is the main source of water supply in Yala Municipality.

Although Yala Municipality produces about 60-80 tonnes/ of solid waste daily from an area as large as 13.44 ha, it has been rated as “A Clean and Beautiful Town” (Yala Municipality, 1999).

Two zones have been developed into urban areas on the northwest around Muang Mai Street and Phutthapoom Street and on the east especially along Pang Muang 4 Street where several housing projects are situated near the railway station. This is where the Muslim community is mainly located. These places are flat and near the highway. The city planning zones are as follows: -

1) The unpopulated areas of 1101.92 ha are located in the northern part of Yala Municipality.

2) The areas which are moderately populated consist of a 606.95 ha plot which is situated on the southern and northern parts of Sirorot street and the northern part of Wae Luwan street.

3) The areas which are highly populated and assigned for commercial purposes encompass a 236 ha area situated to the south of the Yala railway junction.This area

consists of shops catering to communities on the left side of part of Sirorot street and Pang Muang 4 street, and on the west of Bakoi swamp (Kuan Muang Park).

4) Industrial and store areas of about 400 ha are located on the northwest of Yala Municipality where factories had been shut down and land use zones changed. Besides this, Yala Municipality contains designated areas for industrial development in the five southern border provinces of Thailand. The areas include parts of the northern city and the orange garden, Sateng Nok district and Muang Yala district areas.

5) Specific industrial areas of 46.08 ha are sited outside the municipality area and on the eastern part of both sides of the railway lines.

6) Rural and agricultural areas consisting of 3539.68 ha are located on the left side of the northern part of Pattani River and eastern part of the Bae Mok swamp.

7) Locations for recreation and environment conservation comprising 952.16 ha are provided namely at Bae Mok swamp, Bakoi Swamp (Kuan Muang Park), Youth Heath Center, and in areas fronting the Natham Tample Chok Banangluwa.