Chapter 1

Introduction

1.1 Background and rationale

The Na Thap River is a river in Chana district, Songkhla province of southern Thailand, with a watershed of approximately 232 km^2. It originates at the confluence of Klong Pho Ma and Klong Luek, and after 26.5 kilometers flows into the Gulf of Thailand. Therefore, its water body is a mix of fresh water and sea water, subjecting it to many influences including tidal regimes, salinity influx, river flows, and surface runoff from the upland regions, resulting in unique characteristics of both the marine and freshwaters. The Na Thap River serves as a major source of water for more than 45,000 residents in the community. Uses of water are irrigation, transportation, fishing, recreation, and other household, agricultural, aquaculture and industrial purposes. Current land uses in the basin involve cattle grazing, rice paddies, rubber plantations, inland marine shrimp farms, activities of local fisheries, and aquaculture production industries. Furthermore, the basin is surrounded by many types of wetlands, such as melaleucas and mangrove swamps, providing critical habitats for a wide variety of plant and animal species.

In estuaries, as in other aquatic systems, primary productivity is generated by phytoplankton. Phytoplankton are primary producers in the food chain, acting as a source of food or primary energy in the ecology of natural resources (Boney, 1975). The density of phytoplankton in estuaries not only depends on the availability of sunlight and nutrients but also relies on tides, salinity, turbidity, and river flows (Madhu et al., 2007). Differences in geographical location, season, and pollutant substances from urban, industrial, and agricultural sources have an effect on declining water quality and, therefore, influence species richness and the density of phytoplankton in estuaries.

Macrobenthic fauna are primary consumers in the food chain. They are eaten by organisms at higher trophic levels (Mann, 1982). Macrobenthic animals are relatively sedentary or immobile, have relatively long life spans, are abundant and diverse in most marine benthic habitats, and display interspecific differences in environmental stress tolerance (Pearson, 1975). Structural changes of macrobenthic communities caused by environmental disturbance can be understood by examining species distributions and diversity in time and space (Sanders, 1958). The abundance of macrobenthic fauna mainly depends on physical and chemical properties of the substratum. Further, macrobenthic communities are known to respond to changes in the quality of water or habitat. Because of their extended residency period in specific habitats and presence or absence of particular benthic species in a particular environment, these can be used as bio-indicators of specific environment and habitat conditions. There are many different ways to relate macrobenthic fauna community structure to water quality with many new analysis systems. The macrobenthic fauna community has been used as an indicator of water quality (Roback, 1974; Hellawell, 1986).

In the first study, we used multivariate multiple regression to simultaneously analyze multiple species of phytoplankton data collected from the Na Thap River between

June 2005 and December 2007, thus aiming to determine the relationships between their density and physicochemical variables. In the second study, we used linear regression to investigate the trend of Polychaeta abundance and its relation with salinity variation in the Na Thap River during a 5-year period from June 2005 to May 2010. Such relationships are useful as basic knowledge for conservation planning that maintains sustainable ecosystems.

1.2 Review of literature

1.2.1 Phytoplankton knowledge

Phytoplankton is a primary producer which converts inorganic matter into organic compounds through photosynthesis, enabling transfers of energy and nutrients to zooplankton and other aquatic animals in the food chain. Each species of phytoplankton inhabits different environments. Some phytoplankton species can thus be used as water quality indicators since most plankton organisms have short life cycles and can quickly respond to changing environments such as in the case of water pollution (Wongrat, 1998).

Phytoplankton are living organisms forming one group of algae which drift in the water currents. Autotrophic organisms are thallophytes that have chlorophyll a as their primary photosynthetic pigment. (Van Dan Hoek et al., 1995 and Vymazal, 1995). Phytoplankton consist of small algae composed of 7 divisions i.e. Cyanophyta (blue green algae), Chlorophyta (green algae), Bacillariophyta (diatom), Chrysophyta (yellow-green algae), Pyrrophyta (dinoflagellate), Euglenophyta (euglenoid) and Cryptophyta (cryptomonad) (Wetzel, 1975). Phytoplankton have several types such as single cells, colony, filament, movement by using flagella or the current (Lewmanomont, 1984; Wongrat, 1995).

1.2.2 Macrobenthic fauna

Macrobenthic fauna are bottom dwelling animals. Benthos can be divided into three groups, which are those attached to or resting on sediments, those moving on sediment beds and those that bore or burrow into the sediment. They play an important role in the food chain as food sources for aquatic animals at higher trophic levels. Benthos varies in size, shape and characteristics between reservoirs, due to the need to make use of their specific environments. Macrobenthic fauna such as Polychaeta, Decapoda and Mollusca are important sea-bed fauna. Some species of this group are considered to be useful biological indicators for aquatic ecosystems. Macrobenthic fauna are mostly non-migrant inhabitants, and can be used as indices of ecological changes in the sea water environment. Creeks are considered to be amongst the most complex and richest locations in terms of the biodiversity of aquatic ecosystems. They are also some of the most environmentally disturbed areas. Human activities associated with industries, cities and farming have adversely affected aquatic ecosystems. Detrimental effects include high organic matter in the water and the loss of habitat for aquatic organisms. Information on benthic macrofauna will help provide an integrative measure for assessing and improving the ecological health of the ecosystem (Pearson and Rosenberg, 1978).

Polychaeta is a class of macrobenthic fauna that inhabits estuaries of rivers, and its abundance is a biological index of the health of the estuarine environment. Polychaeta densities are related to temperature, transparency, salinity, oxygen demand, pH and minerals (Edgar, 1991). Polychaeta such as *Capitella* sp. and *Theora lubrica* in the family Capitellidae (Kikuchi, 1991; Ferraro et al., 1991) and *Polydora* sp. are biological indicators of organic pollutants. They are usually found in estuaries that contain hydrogen sulfide (H_2SO_4) and high organic mater (Chareonpanich et al., 1994).

1.2.3 Factors affecting growth of phytoplankton

1.2.3.1 Physical factors

1.2.3.1.1 Light

Light is an essential factor for photosynthesis of phytoplankton. (Shirota, 1966). Each phytoplankton requires different light intensity (Smith, 1950). When the light intensity is optimum, phytoplankton will grow well but in case of high light intensity phytoplankton will move in a vertical migration into the deep areas of the water (Lorenzen, 1963). Phytoplankton can use light wave length 400-650 mm for photosynthesis. The rate of photosynthesis is highest on the surface of the water and decrease with the increasing depth of the water (Moss, 1980). In water resources, If transparency value is lower than 30 cm, the water is very cloudy or it has too many phytoplankton. This will cause a decrease in the amount of oxygen. (Duangsawasdi and Somsiri, 1985).

1.2.3.1.2 Temperature

The sunlight penetrating the water causes different temperatures in the water (Menasveta, 1996). Phytoplankton will grow well at optimum temperature (25-35^{o}C) (Boney, 1975). The temperature is essential for any increase and decrease of the rate of growth and reproduction of algae (Smith, 1950). Various algae will grow well in different temperatures: diatoms will grow well at 20-28°C, green algae will grow in abundance at 30-35°C and blue green algae will flourish at 34-35°C (Welch,1952).

1.2.3.1.3 Turbidity

Turbidity in the water is caused by suspended matter such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds and plankton and other microscopic organisms. (APHA, AWWA and WEF, 1998). Increase in human activities, particularly urbanization, agricultural, and industrial activities has led to increasing eutrophication, i.e. to an increase of nutrients (NO_2, NO_3, NH_4, PO_4), the proportions of which depend on the type of wastes, and a higher level of suspended solids make the water increasingly turbid (Lundin and Linden, 1993). In running water such as rivers and brooks, there is more turbidity than in standing water (Hynes, 1970). The cloudy water causes low algae growth because the algae has low photosynthesis (Hobson, 1966). The light can penetrate only a little into the water. It causes a decrease in productivity of the water resources. (Duangsawasdi and Somsiri, 1985). The rate of turbidity will also increase or decrease the number of diatoms. If the water is very turbid there will be fewer diatoms present although the river has more nutrients (Kaweeka, 1980). Turbidity limits the growth of benthic algae (Round, 1973).

1.2.3.1.4 Conductivity

Conductivity is ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions; their total concentration, mobility and valence; and on the temperature (APHA, AWWA and WEF, 1998). Natural water resources have a conductivity from 150-300 microsiemen/cm (Duangsawasdi and Somsiri, 1985).

Conductivity in the water is favorable at 25°C. Factors that affect the value of conductivity are salinity, pH, the chemical characteristics of the soil, precipitation, landscape conditions and the activity of humans.

1.2.3.2 Chemical factors

1.2.3.2.1 Salinity

Salinity is the saltiness or dissolved salt content of a body of water. It is a general term used to describe the levels of different salts such as sodium chloride, magnesium and calcium sulfates, and bicarbonates. Phytoplankton may adapt to a wide range of salinity. Many species do not tolerate a large sudden change in salinity. For some varieties of cyanobacteria a sudden drop or increase in salinity may resolve a problem bloom, but for most it does not, and filamentous green and red algae tolerate salinity changes quite well. The impact of increasing salinity on phytoplankton varies widely, because different species have different preferences. Some phytoplankton are freshwater species while others are marine, so some prefer environments that are more saline than others. Like other marine and aquatic species, however, many phytoplankton will exhibit a tolerance range or range of solute concentrations that suit them. Salinity levels outside of that range may inhibit their growth (Jackson et al., 1987).

1.2.3.2.2 pH

pH is defined as the negative log of the hydrogen–ion concentration. An acid solution is one with pH of 0 to 7 and alkaline from 7 to 14. Some very eutrophic lakes and some soda lakes have pH values as high as 10 to 11.5 (Horne and Goldman, 1994). The pH of the water can control the activity of living organisms in the water

(Duangsawasdi and Somsiri, 1985). Optimum pH (6-8) is suitable for living organisms in the water (Kochasaney, 1993). The value of pH is very important for the variables of each species and the quantity of phytoplankton. In acid water, there are dominant phytoplankton i.e. desmid, but there are also some species of blue green algae such as *Scytonema ocellatum, Hapalosiphon pumilus* and *Chroococcus prescotti* and there are a few green algae filaments such as *Microspora* and *Oedogonium.* (Prescott, 1962). Scagel (1977) studied the distribution of diatoms related to pH of the water. In acidic water (pH = 4-6.5), there were many species of diatoms but less in quantity, whereas in alkaline water (pH = 7.5-9) each species was found in abundance but there were very few species of diatoms.

1.2.3.2.3 Alkalinity

Alkalinity of water is its acid–neutralizing capacity (APHA, AWWA and WEF, 1998). The property of alkalinity is usually imparted by the presence of bicarbonates, carbonates and hydroxides. Bicarbonates and carbonates are found in abundance in natural water while hydroxide levels are rather low. The CO_2-HCO_3-CO_3-equilibrium system is the major buffering mechanism in freshwater (Wetzel, 1975). Bicarbonates and carbonates are mostly ions in the water and they function as a buffer in the water. The value of these three alkalines combined is called total alkalinity. In natural water alkalinity varies between 10-200 mg.l^{-1} (Kochasaney, 1993). Hynes (1970) reported that some species of algae can adapt to alkaline water and acid water. In running water of alkaline condition many species of diatom, exist (*Amphora ovalis*, *Calonies amphisbaena*, *Navicula crytocephala*, *Navicula gregaria, Navicula radiosa, Cymatopleura soleci, Cymtopleura* sp., *Gyrosigma acuminatum* and *Nitzschia* *sigmoidea*), whereas in acidic streams *Eunotia* sp., *Actinella punetata, Frustulia rhomboides*, *Pinnularia* sp. and *Surirella* sp. can be found. Alkalinity measurements are used in the interpretation and control of water and wastewater treatment processes (APHA, AWWA and WEF, 1998).

1.2.3.2.4 Dissolved oxygen (DO)

Both plants and animals have to use oxygen for respiration. Furthermore, the amount of dissolved oxygen can be used as an indication of the quality of water resources (Menasveta, 1996; Loigu and Leisk, 1996). Dissolved oxygen is obviously essential to the metabolism of all aquatic organisms that possess aerobic respiratory biochemistry (Wetzel, 1975). Dissolved oxygen comes from the air or in the last product of photosynthesis of aquatic plants and phytoplankton. Dissolved oxygen is used for respiration and the metabolism of inorganic compounds. The amount of dissolved oxygen depends on many factors such as temperature, the pressure of the air the velocity of the water and the rate of respiration of living organisms in the water resources. In general the optimum of dissolved oxygen value of 5 $mg.l^{-1}$ is suitable for living organisms in the water but dissolved oxygen at a low of 3 $mg.l^{-1}$ is dangerous for living organisms in the water (Kochasaney, 1993).

1.2.3.2.5 Biochemical oxygen demand (BOD)

BOD is the quantity of oxygen utilized expressed in $mg.l^{-1}$, by the effluents during the microbial degradation of its organic content (Abel, 1989). This value is used to determine the relative oxygen requirements of waste water, effluents, and polluted waters (APHA, AWWA and WEF, 1998). The BOD shows the level of contamination or waste water by organic substances. If the water has high levels of BOD, it shows there is a corresponding high level of organic substances in the water. BOD values are generally useful as indicators of the organic loading of water. (Loigu and Leisk, 1996). They typically range from one or two milligrams per litre in unpolluted water, to 50,000 milligrams per litre or more in effluents or severely polluted receiving waters (Abel, 1989).

1.2.3.2.6 Nutrients

In nature, nutrients come from rain exposed minerals, stone and soil. The increase of nutrients in the water depends on the circulation of water which beings the nutrients up from the bottom of the lake to the surface and input nutrients from the external system to the water resources. Nutrients are important and essential for the growth of phytoplankton. Nitrogen and phosphorus are essential nutrients for the growth of algae (Talling, 1962; Wetzel, 1975). Macronutrients are C, H, O, N, P, K, S, Si, Mg, Na and Ca whereas Cl and Fe, Mn, Zn, Cu, Mo and Bo are micronutrients. They are consumed in small amounts by phytoplankton but they are essential nutrients.

1.2.3.2.6 Nitrogen

Phytoplankton can use nitrogen for protein and amino acid synthesis. Phytoplankton can consume various types of nitrogen such as nitrate, ammonia, urea and amino acid (Carpenter et al., 1972). Phytoplankton can use nitrate and ammonia more than other forms (Keeney, 1970). In natural water resources, some species of diatoms such as *Melosira varians, Synedra ulna* and *Navicula viridis* can grow in high nitrate water (2-3 $mg.l^{-1}$) but *Navicula cryptocephala* and *Nitzschia palea* can adapt to waste water consisting of high nitrogen phosphorus and carbon. High total N:P ratios were found to result in an increase in cryptophyte and chrysophyte populations and coupled with high Si:P ratio resulted in a marked increase in diatoms. (Patrick, 1977)

1.2.3.2.7 Phosphorus

Phosphorus is essential for all living organisms; living matter contains about 0.3 percent dry weight phosphorus. It plays an irreplaceable structural like role in the genetic materials DNA and RNA. In adenosine triphosphate (ATP) phosphorus is involved as short term energy in biochemical reactions and it is a component in the phospholipids membranes of cell walls. So phosphorus is a common growth limiting factor for phytoplankton in lakes because it is often present in low concentrations. Phytoplankton can use only soluble phosphate for growth (Goldman and Horne, 1994).

1.2.3.3 Biological factors

1.2.3.3.1 Coliform bacteria

Bacteria have been used in the assessment of water quality largely to indicate the presence of fecal pollution, and the reliability of coliform detection has been of great benefit to public health (Bott, 1973). Coliform bacteria are the facultative bacteria, gram negative, rod-shaped, nonspore forming bacteria that can ferment lactose with gas production within 48 hours at 35^{o}C (Abel, 1989; Bott, 1973; Goldman and Horne, 1994). Members of the coliform group are normally present in large numbers in the fecal flora of warm–blooded animals, whereas only a small percentage of the population will carry pathogens at a given time. In addition, techniques for the isolation and identification of pathogens are less amenable to routinization than those used for coliforms. Therefore, coliform detection is used to indicate fecal pollution and potential exposure to pathogens (Bott, 1973). Distribution of bacteria in the water resources can be studied and indicate water quality especially the distribution of intestinal bacteria i.e. *Escherichia coli* and *Enterobacter aerugenus* etc. WHO determined the standard of coliform bacteria in the water 2.2 cell/water 100 ml., total bacterial plate count which incubate at 37^{o}C not exceeding 500 colony/ml. at water with no indication of *E. coli*. (NWC, 1983).

1.3 Objectives for studies

The aim of these studies was to investigate methods for modeling the abundance of estuarine organisms in Thailand. Such statistical analysis can provide a better understanding of the effect of environmental change on such living organisms in their environment. The statistical methods apply to two outcomes: (1) The statistical modeling of distribution and abundance of phytoplankton: influence of salinity and turbidity gradients in the Na Thap River, Songkhla province, Thailand, and (2) The statistical modeling of Polychaeta density and its relation with salinity variation in the Na Thap River, Songkhla province, Thailand. Such statistical methods are useful as basic knowledge for conservation planning and managing the Na Thap River in order to maintain its sustainable ecosystem.

1.4 Study site

The Na Thap River is situated in southern Thailand, located between UTM 683000E and 694000E in the west-east direction and between UTM 784000N and 765000N in the north-south direction (Figure 2.1). The river originates from several short and narrow streams in the eastern part of the Khao Rieng Wildlife Sanctuary, is 26.5 km in length and flows downstream into the Gulf of Thailand, serving as a multiple use of water source for over 45,000 people in seven sub-districts of Chana district.

The watershed is located on the lower plain of Nathawee River Basin surrounded by Khao Rieng and Khao Roob Chang in the west, Khao Pa Chang or Khao Jom Hae in the east and Khao Nam Kang in Nathawee district in the south. Land use along the river banks consists of evergreen rain forests, agriculture, settlement communities, local businesses, industries, shrimp farming, tourism, and mining. The river can be divided into three sections. The details are as follows.

The initial section of the river (stations 1-3), has tributaries such as Klong Pho Ma and Klong Luek. This section is about 7.5 km in length, with three villages: Pa Ching, Kok Muang and Kuan Hao Chang. The major topography is mountainous, comprising tropical evergreen forests, rubber plantations, mining, several small latex factories and garden villages. This mountain area has several steep and narrow streams flowing directly into the tributaries of the river. In this zone, the river's body is narrow and rather deep, water is fresh water, with strong acid soil and surrounded by peat swamp forests.

The middle section (stations 3-6) is about 9 km in length, with five villages: Ma Ngon, Tha Both, Thung Kruad, Plye Mueang and Tha Klong (Cha Nong sub-district). This section is wider and shallower than the others. The land use is wide-ranging, with wet and dry season paddy fields, rubber plantations, secondary or disturbed forest, wetlands of Melaleuca swamp, pasture land, mangrove forest, hills and sand dunes, and settled areas comprising garden villages, small private businesses and intensive marine shrimp farms. Many of these wetland habitats have been disturbed through cutting of forest for firewood, clearing for agriculture, and grazing and foraging activities. Some swamps and patches of forest still remain intact. However, these wetlands connect to Chana's industrial zone comprising of several latex and frozen seafood factories. There are abundant fishing gears on the riverbed such as floating seine and fish pots, due to the abundance of aquatic animals.

The estuarine section (stations 7-10) is about 10 km in length, with 9 villages: Pak Bang, Klong Kha, Tha Yang, Tha Wat, Tao-it, Tha Klong, Na Sameian, Koo Nam Rob and Ma Ngon. The major topography is a sandy beach and sand dune forest, with settled areas of fisherman households, a fishing port, fish meal factories and communities. It has the highest population density when compared with the other zones. There are stationary fishing gears on the riverbed such as bush pile for catching fish and abundant fish traps.

1.5 Road map of the present study

This thesis contains four chapters, including this introductory chapter. It begins with the background and rationale. This chapter also includes a review of relevant literature, scope and objectives of study undertaken and discussed in this thesis.

Chapter 2 provides a description of the methodology, including an overview of the statistical methods for data analysis aligned to the statistical models.

Chapter 3 shows preliminary data analysis and includes two publication articles comprising statistical modeling of distribution and abundance of phytoplankton: influence of salinity and turbidity gradients in the Na Thap River, Songkhla province, Thailand and modeling of Polychaeta abundance and its relation with salinity variation in the Na Thap River, Songkhla province, Thailand.

Chapter 4 presents the summarization and conclusions of the study.