Chapter 4

Discussion and Conclusions

4.1 The statistical modeling of distribution and abundance of phytoplankton

Spatial and temporal patterns of phytoplankton abundance and composition were marked at the Na Thap River during the period of June 2005 and December 2007. Cyanobacteria, chlorophytes and euglenophytes were the most common phytoplankton groups in the inland freshwater zone whereas diatoms and dinoflagellates were more abundant in the estuarine zone toward the mouth of the river. During the monsoon season, due to heavy rain and lower tidal variation, a large influx of fresh water from the rivers and streams carried excessive nutrients downstream, in turn influencing primary productivity in the lower estuary with the original inhabitants replaced by chlorophytes. This pattern is similar to those occurring in other estuaries in Thailand (Angsupanich and Rakkheaw, 1997), and in other countries (Jackson et al., 1987; Mallin et al., 1991; Mallin and Pearl, 1994). Physico-chemical variables varied across different spatial and temporal scales of the Na Thap River in response to influences of marine and riverine environments and differences in land use and geographical regions along the basin. The influence of tides extends much further inland than that of salinity, resulting in the upstream region being dominated by fresh water with high turbidity level and nutrient enrichment

(Muylaert, Tackx, and Vyverman, 2005). A similar characteristic was found in the Na Thap River with turbid water on the upstream riverine side and clear water on the downstream sea side. However, the nutrients were, on average, fairly stable across the basin, with inter-annual variations for phosphate-phosphorus, spatial variation for ammonium-nitrogen and temporal variation for nitrate-nitrogen (Figure 2). During the monsoon season in December, the Na Thap River received heavy precipitation and a large freshwater influx reaching the estuary and thus resulted in nutrient and turbidity enhancement and salinity dilution near shore areas (Mallin et al., 1993).

Furthermore, the concentration of dissolved iron decreased with increasing salinity. This tendency is common in other estuaries worldwide (Li et al., 1984; Powell, Landing, and Bauer, 1996), although an unusual trend of increased iron with increasing salinity has been observed in some estuaries (Wang and Liu, 2003) possibly due to sediment resuspension and/or to deflocculation of colloidal particles during estuarine mixing. In contrast, the concentration of dissolved cadmium and copper increased with increasing salinity, suggesting desorption of their cations from suspended solids (Duinker and Nolting, 1978; Comans and Van Dijk, 1988). The same behaviour of these elements was observed in our study and in other estuaries including the Rhine and Scheldt estuaries (Duinker and Nolting, 1978; Duinker, Nolting, and Michel, 1982). Other metals, including cobalt, lead, manganese, nickel and zinc, also have similar distribution patterns in estuarine systems (Matin et al., 1971; Paucot and Wollast, 1997).

Differences in land use and topography along the basin influenced water quality in the Na Thap River. A decreasing trend of total coliform bacteria and faecal coliform bacteria may be accounted for by a much higher density of residential population at the

upstream region with consequent sewage and animal waste draining directly into the water. Note that marked concentrations of coliform bacteria at Station 6, 9.5 km from the dense population station, may be explained by its reception of wastes and pollutants from intense marine shrimp farms and aquacultural production factories. This result correlates with biochemical oxygen demand, having a decreasing trend parallel for upstream and downstream stations. It has been suggested that concentrations of coliform bacteria are directly proportional to the biochemical oxygen demand in aquatic environments (Hiraishi, Saheki, and Horie, 1984). Similarly, a higher concentration of ammonium-nitrogen at the middle stations may be partially accounted for by human activities including changes in land use and water usage.

Relationships between phytoplankton abundance and the physico-chemical variables were investigated using multivariate multiple regression analysis, focusing on the determination of significant factors affecting the changes in density of an individual phytoplankton genus. Salinity and water clarity were the major factors. Other factors were related solely to a particular genus or a small group of genera, suggesting that they may be present in a certain habitat or can adapt to survive under environmental stress (Reynolds et al., 2002).

The salinity gradient played a major role in determining the distribution of communities of phytoplankton within the estuary. Estuarine species and communities are well adapted to the variations in salinity that are related to tidal cycles and seasonal rainfall patterns. Such variation reduces competition of different phytoplankton groups possibly causing high rates of estuarine primary productivity. The major estuarine inhabitants in the Na Thap River, as in the other estuaries, were diatoms and dinoflagellates that were positively correlated with the salinity factor, except for *Serirella* sp. Diatoms dominated

over dinoflagellates in cell concentrations and in species diversity all along the estuary. Small centric diatoms (*Rhizosolinia* spp. and *Thallasionema* spp.) were found in higher concentrations at the downstream sites whereas large centric diatoms (*Coscinodiscus* spp.) were present at the upper estuarine stations and even at the inland stations. Although dinoflagellates were found consistently with relatively low concentrations in our estuary, they have been occasionally reported as major species responsible for red-tide blooms in freshwater (Horne, Javornicky, and Goldman, 1971; Berman and Dubinsky, 1985; Hirabayashi et al., 2007) or estuarine (O'Shea et al., 1991; Skerratt et al., 2002) systems. Dinoflagellates are known to be dominated in the marine habitants and under favourable conditions they can develop into the red-tide blooms causing mass mortality of invertebrates, shellfish, fish, seabirds, and other animals, and adverse effects on human health from contaminated marine mammals (Anderson, 1995).

Our results show that *Cosmarium* sp. dominated the freshwater assemblages, and was correlated negatively to salinity and ammonium-nitrogen, and positively to heavy metal and turbidity factors. This finding is in accord with the study by Javed and Hayat (1999). Mixed assemblages dominated by cyanobacteria were observed occasionally in the middle stations having a high level of ammonium-nitrogen. Although cyanobacteria are known as predominantly freshwater species, our study found that *Oscillatoria* spp. was present over the entire study area. Cyanobacteria are commonly thought to represent a nuisance condition, the so-called harmful algae bloom, that affects the food chain in aquatic systems, and are usually linked to changes in nutrient levels defining the trophic status (Marshall, 2009). Cyanobacteria in our study area were low to moderate in density and dominated the phytoplankton community in very few occasions, indicating a healthy estuarine environment and habitat in the Na Thap River.

Water clarity was the second significant factor affecting variations in phytoplankton densities in the Na Thap River. Water with high turbidity reduces light to penetrate the water column and therefore limits phytoplankton photosynthesis. The light limitation controls phytoplankton biomass and prevents phytoplankton from using available nutrients. Nevertheless, mechanisms of development of phytoplankton blooms in the freshwater estuaries with high turbidity remain unknown (Cole et al., 1992; Kies, 1997).

In conclusion, the spatial and temporal distributions of phytoplankton density in the Na Thap River were found to be largely controlled by the salinity and turbidity gradients within the different regions of the ecosystem, with chlorophytes and cyanobacteria dominating in the turbid freshwater habitat and diatoms and dinoflagellates dominating in the clear estuarine environment. The developments of mixed assemblages of riverine and estuarine species varied seasonally over the study period, and varied predominantly during the monsoon periods when heavy rainfalls regulated the increasing amount of river flow and nutrient runoff from agricultural, aquacultural, and industrial land into the lower estuary, with subsequent changes in associated water characteristics, destruction of downstream habitats and loss of estuarine primary productivity. Although unexpected peaks of nutrients and pollutants during the pre-monsoon season in 2006 did not affect the distributions of phytoplankton, their causes are unclear and deserve further study, probably involving flow rates and the amount of rainfall. With such evidence, changes in phytoplankton densities and compositions in the Na Thap River have been controlled mainly by natural phenomena rather than human activities. Our study provides basic knowledge of variation in the abundance of the major groups and community structure of phytoplankton, and their relationship to the associated water characteristics in the Na Thap River. Understanding such variation provides a basis for further studies of the

distribution and abundance of upper aquatic predators, including zooplankton, fish, and other aquatic organisms, within the ecosystem studied and other freshwater estuaries.

4.2 The statistical modeling of Polychaeta density in Na Thap River

The Na Thap River is water body is a mixture of fresh and sea water subjecting it to receive 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 initial part of the river's body is narrow and rather deep with fresh water. The middle part is wider and shallower than the others and the estuarine part is narrow and deep and adjoins to the Gulf of Thailand.

At all stations Polychaete density was statistically significantly related to month and water salinity. The increase in the organism density was 2.81 percent (95% CI 1.01 – 4.61) for each unit increase in salinity. The salinity level increased with distance from station 5 (Tha Klong Cha Nong) to the Gulf of Thailand.

In November, 2009 – April, 2010, Thailand faced a drought. The average monthly rainfall in the Eastern part of Southern Thailand from November 2009 until April 2010 was lower than the average monthly rainfall from 1950 to 1997. From December 2009 to April 2010 the average monthly rainfall in Chana district of Songkhla province was 15.7 mm, while in the same months from 2005 to 2008, the average monthly rainfall was 76.9 mm (Sithicheewapaak, 2010). Thus, the drought led to intrusion of saltwater in Na Thap River, which can be observed from the increasing salinity along the river.

Sampling stations 2, 4 and 5 are surrounded by communities, shrimp farms, fish cage farms, pig farms, seafood processing factories, and rubber industry (Sapaeing, 2007).

Waste water containing organic matter from those areas may cause increasing density of Polychaete.

Polychaeta organism densities in the Na Thap River estuary increased by an average of 1.5 percent per month over the five-year period from June 2005 to May 2010 inclusive, corresponding to a 90% increase (95% CI 25 – 157 percent) over the duration of the study. Given the volatility in the distribution of such organism counts, and the corresponding wide range given by the confidence interval, this result is not particularly conclusive.

Further study is needed to obtain more conclusive results. However, such relationships are useful as basic knowledge for conservation planning that maintains sustainable ecosystems.

4.3 Limitations and suggestions for further study

This study of the essential identification of the various phytoplankton and macrobenthic fauna to genera or species level was an arduous task as there are very few experts on this field in Thailand. Study phytoplankton and macrobenthic fauna which show tolerance to various environments and complete species indices of phytoplankton or macrobenthic fauna in tropical regions as water quality indicators. Study survey and compile a list of the genera of phytoplankton or macrobenthic fauna from various water resources to form a data base for future benefit such as for water treatment of wastewater and study the quantity of ions of metals and find the relationship between dominant species of phytoplankton or macrobenthic fauna as indicator of the presence of high levels of salts in the Na Thap River estuary.