Chapter 5

Discussion and conclusions

5.1 Prevalence of imposex in gastropods in the Gulf of Thailand

This investigation of the prevalence of imposex in gastropods is the most extensive survey in the Gulf of Thailand. It shows that TBT concentrations in the Gulf are so high that imposex in female gastropods was recorded in all sample areas. Logistic regression modeling was used to compare the imposex levels between area and species. The outcome of interest for this statistical method must be binary as this study divided the imposex outcome into two groups, there being (1) normal female, and (2) imposex female (female exhibiting imposex).

The prevalence of imposex differed somewhat across areas sampled, by species composition sampled, and number of individuals collected - which makes a detailed comparison for each area difficult. Hence, to determine the real imposex level for each area, the logistic model was adjusted by ignoring species differences. The findings showed that the highest imposex levels occurred at the eastern part of the Bight of Bangkok. This area had the largest port, the most intensive boating activity, and the biggest far seas commercial vessel harbor in the Gulf of Thailand (Kan-Atireklap et al 1997, Bhatt et al 2006). On the other hand, other areas of concern were found in many locations along the coastal line in Pattani province. This could be related to dumping of highly polluted harbour sediments in the shallow coastal area (see more details, Publication 1, in Appendix 1).

Since we considered gastropod females with stage 1 and 2 of imposex as showing no imposex, this might be have caused underestimation in areas B (Namrin), G (Songkhla), L (Panare), and M (Tak Bai), see more details, Publication 3, in Appendix 3.

The suspicion that the local species may differ in sensitivity to TBT (Swennen et al 1997) has been strengthened by this study, which involved larger samples at each site. In order to study imposex prevalence by species, a simplified model was used that ignored areas. The results indicated that *Morula musiva, P. cochlidium,* and *B. areolata* seem less sensitive for developing imposex while *T. lacera, M. occa,* and *L. blosvillei* seem most sensitive among the species studied (see more details, Publication 1, in Appendix 1).

5.2 Macrobenthic fauna density in the Middle Songkhla Lake

This study used data collected for a previous study to develop a statistical regression model for data analysis. The data structure is one commonly used in ecology and involves measurements of densities of aquatic organisms collected on various occasions at various locations, together with measurements of levels of environmental determinants taken at corresponding times and places. The objective of this second study is to account for variation in organism abundances using the environmental determinants. Multivariate multiple regression (MMR) was used to model these multiple outcomes and multiple determinants. The advantages of its application are that (a) it separates the effects of observed environmental predictor variables on density outcomes; (b) it gives standard errors for these estimated effects, thus

providing a firmer statistical basis for clustering; and (c) it provides a predictive model for the outcomes.

To reduce the problem of outcome with too many zeros, we used the data at the family level instead of using species level. Hence, the outcome variables were the log-transformed densities of the 24 families of macrobenthic fauna selected as having the most coverage (seen on at least 35% of occasions) from 81 families observed at 9 sites during 6 bimonthly periods.

The environmental variables (12 physico-chemical characteristics of water and sediments) were defined as environmental factors. In our second study, factor analysis was used to represent a set of variables by a smaller number of variables (called "factor"). The analysis gave three main factors (Factor 1: mainly salinity, Factor 2: sand-clay excess, and Factor 3: physico-chemical properties of sediments and water) and also a high uniqueness variable (TSS) that were allowed to model fitting as the multiple predictor variables also.

Of the 96 regression coefficients in the regression model (24 families × 4 predictor variables), 8 were statistically significant at the 0.01 level and 17 were significant at the 0.05 level.

These environmental factors and total suspended solids were all found to be associated with the densities of polychaetes, crustaceans and mollusks. The finding is consistent with results reported for a coastal lagoon in Ghana (Lamptey and Armah 2008), where salinity, percent clay, pH and turbidity were significant variables structuring the macrobenthic fauna.

The salinity factor was positively associated with the abundance of Goniadidae, Hesionidae, Spionidae, and unidentified species in Bivalvia, while negatively associated with Pholoidae and Pseudotanaidae. In general, salinity is an important factor affecting the distribution of macrobenthic fauna in estuary. Although the Middle Songkhla Lake is not connected to the sea directly, this zone receives the effect of salinity from the saltwater inflow through the Lower Lake which is open to the Gulf of Thailand. Salinity is often regarded as a primary descriptor in estuarine ecosystems (Gaston 1988, Lamptey and Armah 2008).

A sedimentary habitat contains information mirroring the functional biodiversity and activity patterns of macrobenthic fauna (Rosenberg et al 2009). The main characteristics at the bottom of the Middle Songkhla Lake are clay and silt (Angsupanich et al 2005a) except for station six, which is mainly sand (84.6%). We found that sand/clay excess was positively associated with the densities of Pseudotanaidae, Anthuridae, Isaeidae, Aoridae, Terebellidae, Cirolanidae, and Nereididae at station six. In contrast, sand-clay excess was associated with low densities of Pilargiidae at station six.

A typical genus *Sigambra* within Pilargiidae (Angsupanich et al 2005a), was found to be negatively related with sand-clay excess, a finding supported by a study in the southeastern Gulf of California reporting that *Sigambra* was dominant in the areas where sand percentage was 1%, or mud was 60-70% (Méndez 2007). The dominant genus *Cyathura* within Anthuridae (Angsupanich et al 2005a) was found to be positively related with sand habitat, in agreement with an evaluation of the physical and biological conditions of sea bed habitats at the Charleston Offshore Dredge Material Disposal Site, South Carolina (Zimmerman et al 2002). In addition,

Marginella within Marginellidae was also listed as being present in the Middle Songkhla Lake (Angsupanich et al 2005a), thus showing a positive association with sand. This finding also agrees with a study of invertebrate species identified in Fresh Creek, Bahamas where *Marginella* was listed as most commonly having the habitat type of 'sandflat' (Layman and Silliman 2002).

Statistical analysis did not always show evidence of association between macrobenthic fauna communities and environmental variables in the system, probably due to a high degree of variability in both biotic and abiotic components of the system (Pillay and Perissinotto 2009). Furthermore, many families used in this study had a high frequency of zeros. These included Alpheidae, Skeneopsidae, and Oedicerotidae. Modeling abundances with a zero inflated distribution implies that replicated observations are a mixture of two different types; ones where organisms of a taxon do not occur, and ones where the organisms do occur (Warton 2005), but at low levels. In this study, the families with high frequency zero count mentioned earlier showed no evidence of association with the environmental predictors, possibly due to their scarcity. For example, although Alpheidae was found to have the lowest density among the families included in our study, it is commonly found in the stomach contents of the dominant bottom feeding fish (*Osteogeneiosus militaris* and *Arius maculates*) in the Middle Songkhla Lake. Angsupanich et al (2005b) implied that these catfish species feed opportunistically on a variety of prey in their environment coupled with preferential feeding. So the low occurrence of Alpheidae may have been due to its swift movement and consequent catching difficulty.

Furthermore, Nereididae is one of the most important polychaete families due to its diversity and abundance, found not only in marine environments (Gonzalez-Escalante

and Salazar-Vallejo 2003) but also in brackish water such as occurs in the Middle Songkhla Lake. Fourteen species of Nereididae were reported in a former study (Angsupanich et al 2005a) and it seems that Nereididae is widespread in the Middle Songkhla Lake, where it had the highest species richness. No evidence of Nereididae variation with salinity was found, possibly due to species diversity within this family. Some species, such as *Ceratonereis hircinicola*, were widely spread in the high salinity areas (Angsupanich and Kuwabara 1995), whereas *Namalycastis indica* has been found to inhabit fresh to slightly brackish water in cisterns, pools and lagoons (Glasby 1999). As for Nephtyidae, which was not correlated with any factors, it can survive in a wide range of salinity and environmental conditions, and thus may be relatively insensitive to the environmental factors considered in this study.

This study has provided information regarding the influence of environmental conditions and seasonal variations on the macrobenthic fauna assemblages of the Middle Songkhla Lake. A data analysis procedure for monitoring associations has been provided, and this method can be used generally in estuaries to determine the complex interaction between biotic and abiotic factors. The results clearly showed relationships between macrobenthic fauna density and the major environmental factors of salinity, sand-clay excess, total nitrogen and total suspended solids.

This knowledge is useful for the natural resource management that needs to be conducted on this lake in the future, because the Songkhla Lake nowadays suffers from the use of coastal land and water resources for uncontrolled shrimp farming, the destruction of both mangrove areas and peat swamp forest, construction of intake and outfall structures, and the construction of a deep sea port (Chufamanee et al 2003).