Chapter 5

Conclusions and discussion

This chapter includes the conclusions from the investigation. It also includes discussions of the finding and limitations and suggestions for further study.

5.1 Catch weights in Songkhla Lake 1977-2006

Results from our study found that between 1977 and 2006 the average monthly fish catches from Songkhla Lake weighed 219.9 tonnes (range 60.8 – 651.9). The model showed statistically significant seasonal effects fluctuating from low values in February, April and August to a high value in December. This seasonal fluctuation in fish catches and thus fish abundance could be related to both regional climatic changes and human activities. However, these findings can only be generalized to fish catches in Songkhla Lake basin, revealing only variation of quantity of the monthly commercial fish catches from the fisheries industry. Fluctuation of fish numbers may have various causes, such as change in lake ecological parameters, euthophication phenomena, variation of offshore migratory species, change in fishing power and strength of law enforcement of authorized agents. Thus, the model can be used for short–term and possibly medium–term fish catch forecasting and for continual monitoring. The seasonal fish catch fluctuation found in this study was similar to studies reported by Ciepielewski (1999) conducted in Pomeranian lakes of the South Baltic region, Potier and Drapeau (2000) on catch of the scads in the Javanese purse seine fishery, and Ngochera el al (2001) on fish catches in Lake Chiuta of Malawi.

Gobally, approximately 25% of marine fish stocks are considered over-exploited and an additional 50% are entirely exploited (to the maximum possible and still sustainable). Analysis of fish stocks data has revealed decreases in the mean size of individual fish and in the value of the catches. With the numbers of large, valuable fish on the decrease, fishermen are now targeting smaller and often less valuable species. As a result, larger fish are sequentially removed at the top of the food chain and the catch consists of smaller sized fish (World Bank 2006).

Our model illustrates that from 1996 to 2002 the trend of catches has steadily decreased about fourfold. It is possible that catches in the Songkhla Lake basin may have reached the limit of over-exploitation. Over-fishing is being driven by over-capacity and excess fishing power, such as fishing traps, traditional push net and set bag nets. Nowadays, lake fisheries management is not limited to satisfying the commercial fishing business. A wide range of stakeholders who inhabit the basin have to be accommodated. Therefore, an appropriate management action, such as strengthening the political will to enforce fisheries regulation and implementation of an integrated lake resources management, is needed.

5.2 Catch weights from 2003-2006 using species and month

Monthly catch weights in Songkhla Lake were analyzed from January 2003 to December 2006 for 127 fish species, including 72 marine vertebrates, 22 freshwater vertebrates, 21 marine invertebrates, 10 diadromous and 2 catadromous. A linear regression model was fitted to the logarithms of catch weights, classifying species and month, using these factors as multiplicative determinants thus enabling assessment of species clustering. The statistical model involved four components and gave an r-squared value of 87.7%.

Our statistical model was effective in clearly separating four distinctive fish community clusters. The first two components showed purely seasonal patterns. The first has a spike occurring in March and the second shows a peak in February with a gradual decline to December followed by a sharper increase. The third and fourth components show less pronounced seasonal effects with a trend increasing in the most recent year (2006).

Freshwater fish, together with black tiger shrimp, giant freshwater prawn, white sea bass and mullets showed increasing catch weights, while other Penaeid shrimp (greasy back shrimp, green tiger prawn and small white shrimp), Mantis shrimp, Hamilton's thryssa (*Thryssa dussumieri*), and Chacunda gizzard shad had decreasing catch weights. In fact, the overall fishing effort in the lake was fairly stable over the 4-year period because both fishing gear and number of fishermen did not change substantially (NICA 2007). Therefore, the increasing trend of black tiger prawns, giant freshwater prawns, white sea bass, and freshwater catfish might be due to increased seeding, stock enhancement and fishery rehabilitation projects by governmental agencies (NICA 2007). However, increasing catch quantities may signal over-fishing and sizable quantities of by-catch fish. Catch weights of large tooth flounder (*Pseudorhombus arsius*), big-eyed sand goby (*Gnatholepis alliurus)*, short-nosed pony fish (*Leiognathus brevirostris*), naked-head glassy perchlet (*Ambassis gymnocephalus*) and starry triggerfish (*Abalistes stellaris*) increased whereas most estuarine and marine invertebrates and some high value freshwater fish had overall declines.

The plots of regression coefficients show two distinct clusters of freshwater and saltwater fish. Some estuarine species (invertebrate and vertebrate) appear in both clusters because diadromous and euryhaline fish can adapt to a wide range of salinities and migrate between fresh and salt water (McDowall 1995; Musick et al 2001; Welcomme et al 2006). For example, different life stages of Penaeid shrimp have distinct salinity preferences despite being marine invertebrate (Dall et al 1990). Wirth et al (2004) reported that Penaeid shrimp can be raised in low salinity (1.56 ppt) geothermal water at inland sites without adverse effect on growth and survival. Furthermore, these estuarine and marine invertebrates are usually found in shallow, semi-enclosed estuarine bays in the southern Gulf of Thailand (Hajisamae et al, 2006), and generally spawn and spend much of their adult life in saltwater or offshore, but enter the lake seasonally (Yanez-Arancibia et al 1994; Hajisamae et al 2003; Khongchai et al 2003).

The croaking gourami (*Trichopsis vittata*) is very sensitive to salinity change (Liengpornpan et al, 2004). The high salinity offshore marine vertebrates such as Spanish mackerel (*Scomberomorus commerson*), Dusky Jack (*Caranx sexfasciatus*), and Indopacific mackerel (*Scomberomorus guttatus*) are found from the edge of the continental shelf to shallow coastal waters (Froese and Pauly, 2004). The spotted green puffer fish, spotted codlet, lined silver grunt, greasy back shrimp and sand goby appear as singletons disconnected to other major marine vertebrates, and have less regular catches with substantial seasonal variation in monthly catch weights.

The salinity in various locations in Songkhla Lake also depends on the season, dropping substantially during the heavy monsoon that usually occurs from October to December (Chesoh and Lim, 2008). These seasonal patterns affect fish distribution and food web structure from different habitats (Winemiller and Jepsen 1998; Thompson and Townsend 1999; Gibson et al 2000), and encourage major events in the life cycle of each species that take advantage of increased productivity. Alien fish species, namely Mozambique tilapia, hybrid red tilapia and African walking catfish, are increasingly found in the lake and might destroy native species or alter the gene pool (Balon and Bruton 1986; Salonen and Mutenia 2007).

Our model reflects the broad band of fish assemblage distribution according to distance from the Lake's junction with the Gulf of Thailand from saline to brackish water to freshwater, with some species confined to specific salinity bands. Some euryhaline marine invertebrate species prefer to feed in low salinity biotopes, while others dwell everywhere. Generally, the lake fishing is based on trapping the fish on their passage from their feeding ground to spawning and nursery grounds (Katselis et al 2003). This seasonal pattern reinforces the fact that these migratory fish species in tropical shallow lakes need to be managed for sustaining their diversities.

5.3 Catch weights from 2003-2006 by species and season-gear

When type of gear used was taken into account in the statistical model, much clearer patterns of clustering became evident. The model then identified only three component patterns, but gave a substantially higher r-squared value of 92.3%. The model was very effective in clearly separating fish community clusters with absolutely no overlap between the two clusters, namely freshwater and saltwater fish. The patterns for each typical component showed that bi-monthly fluctuations in abundance of fish species assemblages depended on the fishing gear used, especially for the first component, and for the second component depended on the interaction between season and type of gear. The third component pattern focused on the seasonal fluctuation in catch weight, not exactly followed by any species found.

Clearly, the relationship between climatic and aquatic environmental factors and fish assemblage is significantly complicated (Pombo et al 2005). Fish diversity, recruitment and production depend greatly on lake ecotones. Fish species composition in a tropical shallow lake, like Songkhla Lake, requires a species-specific environment. Frequent fluctuations of the abiotic parameter will cause the species of the composition to either be resistant to remain in that environment or migrate to other environments (Katselis et al 2003; Labropoulou et al 2004). Generally, fishing in the lake is based on trapping the fish on their passage from their feeding ground to spawning and nursery grounds. Traditionally, fish barrier traps are stationary passive gears and catch depends on their physical features and placement location. Catch landings also depend on the selectivity of the type of gear used. Selectivity of gear affects the intra-specific diversity of fish population by selecting against certain traits, such as individual fish size and schooling behavior.

In the final analysis, the first cluster contains all typical species of the first model component and some of those in the third component. The representative example, the pugnose ponyfish (*Secutor insidiator*), is a schooling and plankton feeder species always found in shallow waters, usually near the lake bottom. Another example species, the bigeye trevally (*Caranx sexfasciatus*) is a reef-associated amphidromous that frequently migrates from fresh waters to brackish and to marine, and dwells in water depths under 146 meters. It inhabits coastal and oceanic waters associated with reefs (FishBase 2009).

The second cluster contained all typical species of the second component and a few of the third component. Freshwater fish shows a slight decline occurring from January-February to May-June of each year, followed by a gradual increase until November-December, for each gear type. Gill nets have high catchability because they are the majority gear in the upper lake zone, where the water is always turbid and windswept, and reducing visibility for freshwater fish. In contrast, the freshwater giant prawn (*Macrobrachium rosenbergii*), some marine shrimps and crabs were mostly caught in traps. Plots of catch weight also indicate that freshwater fish numbers increased, while marine invertebrates decreased. These are the signals for lake fisheries that resources need to be regulated. Restricting the number and placement of set bag nets will increase the stocks of all estuarine and marine fish, blue swimming crab, acetes, cross-marked swimming crab, serrated swimming crab, squid, cuttlefish and octopus. Restricting the use of gill nets will be highly effective in increasing fish stocks of all freshwater fish, while trap restrictions should be highly effective in increasing fish stocks of all estuarine and marine shrimps and giant freshwater prawn.

Although several species are ubiquitous in all habitats, some are anadromous, catadromous, amphidromous, and oceanodromous fish species and so have specific habitats in Songkhla Lake.

5.4 Limitations and suggestions

There are several limitations in our model. Firstly, environmental factors, types of fishing gear used, and fishing location were not included in the models. Our data were obtained from fish catch landing records from three regional fisheries offices within the Department of Fisheries of Thailand, a non-specific lake fishing location. Usually landings data alone are limited and are frequently used to indicate the real situation of the fisheries industry. Declines or increases in catch landings may imply that fish populations or fishing power has been changed in the fisheries industry. Landing fluctuation in abundance may be due to (1) instabilities of the environment: oceanic current or upwelling amplitude fluctuated movement, and (2) biotic factors where competition, fishing mortality, predation or disease results in one species being supplanted by another (Caddy 1983). Fish are a common property resource and many fishermen are frustrated by unwanted regulations by government officials. Thus, it is very difficult to directly obtain catch data or biological information from fishermen. The ecosystem-based management of fisheries is now the most modern approach for resources assessment (Cadima 2003). Although Songkhla Lake's catch assessment have played a vital role for aquatic resources management, only two technical papers have been published (Tookwinas et al, 1985; Choonhapran, 1996) but were conducted in short periods. Similarly, in the Asia-pacific region, most research was conducted in the open sea. Therefore, it is difficult to compare findings reported by different studies. However, in this study, several questionnaires were constructed to interview the fishermen and authorized officers for enhancing lake fishing information.

The model of fish catch weight from 2003-2006 using species and an interaction term of season-gear as predictor did not include fishing grounds and fish habitats in the model. Entry into Songkhla Lake is free for everyone and fisher products can be landed and sold at various fishing ports around the lake. Also, sites of fishery landings do not necessarily respond to the fishing ground. Therefore, we did not include fish catch landing site in the model.

The explanatory variables in the multivariate regression models were eigenvectors of the data covariance matrix obtained after adjusting for row means corresponding to species. The final model, with factors involving both season and gear but not year, provided an excellent fit to the catch weights and could be interpreted in a practical way. However, further studies are needed to evaluate the effectiveness of this type of regression approach for modeling fishery catch weight data.

In the first model involving just the monthly seasonal period and two lagged observations as predictors, the fit was adequate at best. The r-squared increased as additional terms, first species and then type of fishing gear, were included in the model. The first model was used for forecasting, but these forecasts were not particularly good. The second and third models fitted the data much better, but were not used for forecasting. It would thus be of interest in further studies to investigate the accuracy of the final model for forecasting.