required. To date, riverine fish assemblage patterns from the head water to the river mouth, both intact and regulated, have been widely developed in temperate areas, which are determined by environmental factors (e.g. the slope and the width of the river section) and may be characterized by the dominant species (e.g. Santos *et al.*, 2004; Olden *et al.*, 2006; Lasne *et al.*, 2007a). Studies of this kind in tropical areas are very few, except for the neotropic (e.g. Barella and Petere, 2003),) and Africa (e.g. Konan et al. 2007), especially studies in regulated rivers, which are important because the assemblage patterns could fluctuate due to the flow control systems.

Damming a river mouth is mostly to prevent the intrusion of salt water to the river upstream. The exclusive mechanism of river regulation for this dam type is sluice gates that are opened occasionally, especially during periods of high water levels (Champalbert *et al.*, 2007). In the natural condition, it would be expected that the fish assemblages show a strong seasonal change. At the start of the low water periods, the marine influences increase, with estuarine species moving into the river. During periods of high water levels, the mass of the freshwater volume decreases the salinity significantly and the secondary freshwater fish can occupy the river mouth. Lasne *et al.* (2007b) mentioned that to understand the responses of the river's biota to habitat alteration, field studies with statistical support are required. This is especially true for the hypopotamon reach, which is rare compared to the other sections. Therefore, this study aimed to evaluate the spatio-temporal variations in a tropical riverine fish community according to their environmental guilds (Welcomme *et al.*, 2006), and to the flow regulation schemes of an anti-salt dam (i.e. opening and closing phases). The opening phase is when the sluices are opened and the water flows freely between the upstream and the downstream areas, allowing the passage of fish in both directions and the closing phase is when the sluices are closed. The study was carried out in the Pak Panang River of Thailand, where a dam was constructed near the river mouth to prevent the intrusion of the salt water into the upstream area.

MATERIALS AND METHODS

Study area

The Pak Panang River is in the South-East of Thailand and it runs into the sea at Pak Panang Bay in the Gulf of Thailand (Fig. 1). The river is 147 km long and its basin has an area of about 300,000 ha. The basin is in an area with a tropical monsoon climate consisting of a short dry season (February to April) and a long rainy season (May to January). The average annual rainfall is 2,380 mm and the average air temperature is 27.3

^{o}C. There is a high rate of water discharge to the sea, as well as intrusion of salt water, which had been recorded as far as 80-100 km upstream (Coastal Resources Institute, 1991). In addition, the water in the downstream area of the river is slightly acid, because of peat areas in the floodplain along the river banks. In 1995, the construction of the *Uthokawiphatprasit* (meaning "effectively divide fresh- and marine- waters") anti-salt dam started and it has operated since 1999. The dam is located 6 km upstream from the river mouth (Fig. 1), and its size is 9 x 200 m^2 and it contains 10 sluice gates. The major purposes are to prevent the intrusion of salt water into the inner area along the river, to neutralize the pH of the river and to maintain freshwater for irrigation (Prabnarong and Kaewrat, 2006).

Data collection

Field samplings were carried out monthly at 7 stations along the middle to lower courses of the Pak Panang River for 18 months, *i.e.* between January 2006 and June 2007. Station 1 was the boundary between the freshwater and marine water, during the saline intrusion in the dry season, before the dam was constructed (Coastal Resources Institute, 1991). Fish were caught using beach seine nets (30 mm mesh) as well as various mesh size gillnets (5 nets at each station, mesh size from 20 to 100 mm, i.e. by 20 mm interval), were set to cover the water column and left overnight before being taken out in the early morning. For the last station (station 7) in the wide river mouth area, additional samplings were also conducted by dragging a push net (30 mm mesh) for 30 min. to circumscribe the sampling area. Fish samples were packed in ice and brought to Walailak University 50 km from the sampling site. Fish were then taxonomically classified to species level (Nelson 1976; Froese and Pauly, 2008) and then into the environmental guilds proposed by Welcomme *et al.* (2006). The biological aspects, to define the guild into each species, were retrieved from FishBase (Frosse and Pauly, 2008) and supplemented with other related publications (e.g. Taki, 1978; Vidthayanon C. 2008; among others). Then the authors discussed assigning guilds to individual species. Although there were difficulties in assigning species among guilds for some species, the criterion of four out of seven researchers to finalize the guild was applied. To make the fish data matrix, species presence/absence was preferred to describe fish abundance because of the selectivity of the fishing gear sampling techniques, which can bias the calculation of species abundance (Hugueny *et al.*, 1996). As the total numbers of sampled fish species were large, the rare taxa (i.e. a percentage occurrence of less than 5 % or less than five specimens) were removed to prevent analysis distortion (Penczak, 2004). Finally, there were 71 fish species used in the analysis (Table I).

The water quality parameters that related to the objectives of dam construction *viz.* salinity and pH as well as water temperature of the sampling stations were obtained from a portableYSI 63-50FT at the fish sampling sites. These variables were studied by sampling the water at three depths *viz.* surface, mid-water and 1 m above the bottom from three sub-sampling points in each station area. The sampled water was pooled asrepresentative of a station. On the days of the sluice gates' opening, the water discharge volumes and rainfalls were obtained from the *Uthokawiphatprasit* irrigation office (*Unpublished data*).

Data analysis

Fish assemblages and the environmental patterns were classified by the self-organizing maps (SOM). This non-supervised artificial neural network method allows the analysis of complex data sets (Kohonen, 2001) and is a powerful tool for describing species distribution and assemblages (Lek *et al.,* 2005; Suryanarayana *et al.,* 2008). The SOM consists of input and output layers connected with computational weights (i.e. weight vector). The array of input neurons operate as a flow-through layer for input vectors and the output layer consists of two dimensional networks of neurons arranged on the map of a hexagonal lattice since it does not favor horizontal or vertical directions (Park *et al*., 2005). The advantages of SOMs are a visual result in a more usable form and with more potential to analyze a non-linear relationship (Kohonen, 2001). Additionally, the SOM averages the input dataset in weight vectors through the learning process and thus removes noise (Park *et al*., 2006).

The principle of SOM analysis is to classify the sample vectors (SVs), described by a set of descriptors on the map according to the similarities between the descriptors (i.e. fish species and water quality parameters). Two SVs that are similar (from the descriptor point of view) are classified in the same or neighboring cells, whereas two different SVs are classified in separated cells that could be distant from each other (Tudesque *et al.*, 2008). The sequential algorithm used and the protocol for SOMs are widely described (e.g. Lek and Guégan, 1999; Kohonen, 2001; Park *et al.*, 2006). In this study, the SVs are represented by the surveys, i.e. combinations of sluice gate openings/closings, stations and months of sampling. The input layer comprised of 71 neurons for fish species connected to 102 surveys (i.e. 102 SVs). The output layer of 56 neurons organized in an array with 8 rows and 7 columns of cells. The map size of 56 output neurons was defined according to the compromise between the values of two evaluation criteria to quantify the resolution and topology preservation (i.e. the quantization and topographic errors) and the figure retrieved from the formula $c = 5\sqrt{n}$ proposed by the Laboratory of Computer and Information Science (CIS), Helsinki University of Technology, where c is the number of cells and n is the number of training samples (sample vectors, Tudesque *et al.*, 2008). The software package for the SOM is available from the website http://www.cis.hut.fi/projects/somtoolbox/.

On the trained SOM map, it is difficult to distinguish subsets because there are still no boundaries between possible clusters. Therefore, a hierarchical cluster analysis (Ward distance) was used to detect the cluster boundaries on the SOM map by calculating the Euclidean distance between the weight vectors of each SOM unit (Park *et al.*, 2006). To analyze the contribution of each descriptor to the cluster structures of the trained SOM, the weight vector of each input vector calculated during the training process was visualized in each neuron on the trained SOM map in a grey scale, whereby dark represents a high value and light is a low value (Park *et al.*, 2005).

The statistical differences in the proportion of environmental fish guilds in each cluster were analyzed by the Kruskal-Wallis (KW) chi-squared test and Mann-Whitney's (MW) test was applied to test the statistical differences of each pair-cluster when the p-value of KW was less than 0.05. The linear discriminant analysis (LDA), which is the best method to identify linear combinations of water variables that distinguish the spatial and temporal patterns in the fauna assemblage patterns (Fuhrman, 2006) was used to determine whether the clusters of sites discriminated based on the water parameters considered. The significance of the results was tested by a Monte-Carlo method with 1000 random permutations. LDA was also used to assess the ability of water variables to predict the cluster of fish communities by means of leave-one-out cross validation (Lasne *et al.*, 2007a). All the statistical analyses and graphics were carried out by using R Program (R Development Core Team, 2008).

RESULTS

Fish assemblage patterning of the surveys

Through the learning process of the SOM, 102 surveys were patterned on the 8 x7 SOM map according to the similarity of species occurrences. The final quantization error (0.235) and topographical error (0.029) of the SOM map were low enough to make the map authentic. The sampling surveys were classified on the SOM map according to their similarity of species present in each survey, and thus the similar surveys were mapped close together and the dissimilar apart. It can be seen that the distribution of the surveys on the map were scattered but the dense areas located in the top and bottom left (Fig 2a). The trained SOM, according to the U-matrix distances (Fig. 2b), showed two major clusters, i.e. cluster I and II. Two and three subsets, in the respected cluster I and II, were obtained by a hierarchical cluster analysis with the Ward linkage method (Fig. 2c).

Cluster I contains all the surveys of fish assemblage patterns from the upstream of the dam and *vice versa* in cluster II, which also associated the fish assemblage patterns in the brackish water zone. When refining into subsets, cluster Ia is characterized by the surveys in the furthest upstream stations (i.e. stations 1 and 2) and contrary to cluster IIc, in which all the surveys from station 7 are homogenously included, whether the dam was closed or open. Surveys from stations 3 to 6 were not uniform in any single cluster. It is also worthwhile to note that the fish assemblage patterns from the 9 surveys of stations 4 and 5, that were included in cluster Ia, are all during the closed phase of the dam. The most diverse cluster is cluster Ib, which contains surveys from all the stations except Station 7. Cluster IIa is limited to the surveys of station 6, either at the closing or opening phases of the dam. Cluster IIb shows the pattern of surveys from the downstream river-channel stations (i.e. station 5 and 6) during the opening phase of the dam in the flood season.

Species characteristic of clusters

Species richness in each cluster was varied and differed significantly ($P < 0.001$, Tukey's HSD test) between clusters (Fig. 3). The lowest species richness was obtained from cluster Ia, which contained mostly the surveys in stations 1 and 2. Meanwhile, the highest value was from cluster IIc, which comprised exclusively of the surveys at station 7. It is also showed an increase in species richness from cluster Ia to clusters IIb and IIc which accorded with the longitudinal gradient of the river, i.e from upstream to downstream stations. SOM maps drawn for individual species also varied according to their contributions in the map, in which dark represents a high value and light is a low value (Park *et al.*, 2005) Using the VUs of SOM trained cells, Figure 4 showed the probability of occurrence of individual species in each cluster. The dotted lines of 30% and 60% of the probability of occurrence were arbitrarily set to present the low (< 30%), medium (30 - 60%) and high (>60%) probabilities. It was found that the fish in the brackish water estuarine guild and marine guilds had limited access to clusters Ia and Ib. In the case of some species in amphidromous and diadromous guilds *viz.*, *Acanthopagrus berda* (ACB), *Anodonstoma chacunda* (ANC), *Lates calcarifer* (LAC), *Mystus gulio* (MYG), *Osteogenius millitaris* (OSMi), *Pomadasys kaakan* (POK), *Scatophagus argus* (SCA) and *Stolephorus dubiosus* (STD) the probability of their occurrence exceeded 10% to around 30% in clusters Ia and Ib. Meanwhile the substantial probability of occurrence of some fish in eurytopic guilds, that are secondary freshwater fish such as *Notopterus notopterus* (NON) and *Oxyeleotris marmorata* (OXM), was found in clusters IIa and IIb, but the probabilities of these fish dropped drastically in cluster IIc. Between the two exotic species, i.e. *Oreochromis mossambicus* (ORM) and *Oreochromis niloticus* (ORN), ORN showed a higher probability of occurrence than ORM in clusters Ia and Ib but *vice versa* in clusters IIa and IIb.

The relative proportion of each environmental guild varied among clusters and most of the guilds involved clusters Ib and IIb (Table II). The lowland river (potamonic) guilds, *viz.* paleopotamic, plesiopotamonic, parapotamic, eupotamonic phytophilic, eupotamonic benthic, eupotamic riparian, dominated in cluster I. Meanwhile in Cluster II, the estuarine and coastal lagoon guilds *viz.* freshwater estuarine, brackish water estuarine, catadromous, semi-anadromous estuarine, amphidromous and marine visitors were the major contributors. Although, there was no statistical differences among clusters (KW: p-value > 0.05) in the two diadromy guilds, i.e. catadromous (only one species, LAC) and the semi-anadromous estuarine, both guilds tended to increase in cluster II.

Water quality parameters and prediction of the community clustering

For the periods when the sluice gates were opened, water discharge volumes and rainfall during the study area are shown in Table III. The gates were opened irregularly (i.e. totally closed in some months) and rainfall was scattered and occurred almost every month during the study period. Two water quality parameters, *viz.* salinity and pH, varied between the major clusters (i.e. clusters I and II) but overlapped in the sub-clusters, especially within cluster Ib and in cluster IIb (Fig. 5). Meanwhile, there was no statistical difference for water temperature. Cluster Ia characterized by most of the surveys at stations 1 and 2 and some of the surveys at stations 3 and 4 during the closing phase, when the water tended to be freshwater (i.e. salinity less than 1 psu) of neutral pH (i.e. most pH values were around 7). Meanwhile, the slightly basic and salty water (i.e. pH over 7.5 and salinity above 20 psu) was observed in cluster IIc.

LDA (Fig. 6) showed that the assemblage pattern of cluster IIb was the transition and there was high overlap between clusters Ia and Ib. The Monte-Carlo permutation test showed that the assemblages were highly significantly separated ($p < 0.001$). In terms of the contribution of the flow regulation scheme and water quality parameters, the five assemblage patterns were ordered along the first axis F1 (i.e. horizontal axis) of the analysis. The gradients of salinity and pH were laid along this axis and were important controlling variables which explained 94.0 % of the total inertia. Meanwhile the flow regulation pattern and water temperature were along the second axis, F2 (i.e. vertical axis) and explained 4.5 % of the total inertia. The three water quality parameters were able to predict the clusters and types of fish assemblage patterns (i.e. global performance of prediction) at 84.3 %. The prediction success was relatively good for Clusters Ia, IIa and IIc (i.e. over 80%) but poor for Clusters Ib and IIb (Table IV). About 28.1% of the surveys that had been classified in cluster Ib, indeed, belonged to cluster Ia. For cluster IIb, about 28.6 % of the surveys predicted to involve this cluster belonged to other clusters.

DISCUSSION

It is widely accepted that distinct fish assemblages are associated with particular habitats. There was an experience in decreasing in fish abundance, as well as richness, from the river mouth to headwater, related to the absence of potamon habitats upstream (Ribeiro *et al.*, 1995). The fish assemblages, in the intact hypopotamon, are characterized by the alternation, in space and time, and concordance with the environmental and hydrological conditions (Simier *et al.*, 2006; Lasne *et al.*, 2007b). During the low water period the estuarine and coastal lagoon guilds prevailed, and during the high water period (i.e. flood season) the potamonic guilds dominated (Martino and Able, 2003; Konan *et al.*, 2007). Construction of a dam in this zone alters the physical habitat and hydrological conditions in reaches both upstream and downstream of the dam (Fievet *et al.*, 2001). Areas downstream of the dam can experience decreased river flow and water depth (Fievet *et al.*, 2001). This decrease in freshwater can result in increased salinity, especially at sites near the upstream boundary of estuarine tidal influence, while areas upstream experience decreased flow rates and increased water depth (March *et al.*, 2003). The consequences are the alterations of the relative abundance and distribution of aquatic faunas and floras both downstream and upstream of the dam (Pringle 1997, March *et al.*, 2003).

The main objective of this study was to investigate whether the fish assemblages in the hypopotamon *per se* had different assemblage patterns and fluctuations in species richness due to the pressure from the anti-salt damming in the lower course of the river by defining them into environmental guilds (Welcomme *et al.*, 2006). Results from the SOM showed that, although the sluice gates were opened occasionally, there were two major distinct clusters along the longitudinal gradient of the river. Surveys from the furthest upstream stations (i.e. stations 1 and 2) showed stability in fish assemblages. Meanwhile fluctuations were found in stations 3 to 6, but a stable spatial and temporal assemblage structure was found in station 7. This implied that the fish assemblage patterns in the lower and upper area of the *Uthokawiphatprasit* anti-salt dam were fairly separated. No single species could be found in every station compared with the time before construction, when fish in estuarine and coastal lagoon guilds could be occasionally found further upstream during the dry season (Coastal Resources Institute, 1991). Low species richness could be related to the alternation of habitats, as well as river flow patterns (Lasne *et al.*, 2007b). Increase in water residence time upstream would positively affect the lentic fish species but not the lotic ones (Fukushima *et al.*, 2007). However, the more the water was retained, the greater the biotic uptake by freshwater vegetation and if in excess, this would lead to anoxic conditions (Downing *et al.*, 1999) that only specific fish guilds such as paleopotamonic guild could tolerate.

The brackish water species could widely distribute in the estuary and penetrate into the lower river portion as high as the salinity could approach (Simier *et al.*, 2006). Konan *et al.* (2007) mentioned that the fish in estuarine and coastal lagoon guilds could contribute as much as 25% of the species in the intact lower river course. In our study, however, these species had a limited and low probability of occurrence in cluster I, i.e. upstream of the dam. Fukushima et al. (2007) simulated that the presence of anadromous fish would be significantly reduced in the upstream area, although fish ladders were constructed. In this current study, opening the dam occasionally allowed the diadromous fish to move up and downstream of the dam resulting in no statistical difference among clusters.

Temperature is recognized as one of the most important factors affecting fish assemblages in temperate climes for the longitudinal and seasonal gradient, not only for the river (Jackson *et al.*, 2001, Lasne *et al.*, 2007a) but also in the connected estuary (Hagan and Able, 2003). However, in a lower reach of a tropical river, water temperature always showed non-significance along the longitudinal gradient (Ecotin *et al.*, 2005) but not salinity (Champalbert *et al.*, 2007) and, in this case, pH (Coastal Resources Institute, 1991). A large volume of freshwater upstream made the explicit difference between further upstream (although sluice gates were opened) and downstream stations. The pH of all surveys in the upstream stations, was not as low as 3 as was the case in the upstream station during the dry season before the dam was constructed (Coastal Resources Institute, 1991). It is obviously seen from the findings that salinity played the major role in the homogenization of the fish assemblage patterns. From LDA, salinity lay along the F1 axis and accounted for 97% of the between cluster variability. Thus, if the system was intact and under seasonal influence, the fish in estuarine and coastal lagoon guilds would move further upstream during the dry season (Jaureguizar *et al.*, 2003; Ecotin *et al.*, 2005) and the assemblage patterns in the upstream stations during that period would be similar to Cluster II. However, in the case where a substantial amount of freshwater is retained and then discharged during the opening phase, the possibility of the fish in potamonic guilds to move downward is likely to occur as in during the high flood season in coastal lagoons (Garcia *et al.*, 2003).

Damming rivers downstream is not the sole anthropogenic pressure in the hypopotamon area but this habitat fragmentation could lead to serious affects on fish life cycles (Agostinho *et al.*, 2004; Fukushima *et al.*, 2007) and destabilization of the food web dynamics (Greathouse *et al.*, 2005). The irregular pattern of dam operation will impact on the reproductive strategies of the fish. Although the statistical analysis showed no difference in the probability of occurrence of the diadromy among clusters, the success in reproduction and recruitment is still questioned. This is also a problem for the fish in potamonic guilds, especially those that need to occupy the floodplain in hypopotamon, since their reproduction and recruitment success are totally depended on the flow and flood pattern of the river systems (Agostinho *et al.*, 2004; Craig *et al.*, 2004). The survival of brackish and marine juveniles in the river mouth and mangroves should be taken into account given that the juveniles can only tolerate a specific range of salinity (Ikejima *et al.*, 2003), which is associated to the water discharge from the river.

CONCLUSION

The results of this study demonstrated the significant trade-offs in the break-up of fish assemblage patterns between upstream and downstream areas of the dam, although the dam was opened irregularly. The near dam area is the transitional zone and salinity plays the most important role in assemblage discrimination. The difference was greatest between the stations at the river mouth and farthest station upstream, with each station relatively homogeneous in fish species, i.e. belonging to the similar or close guilds. These dramatic shifts will not only impact on the aquatic ecosystem but could eventually negatively affect the fisheries, at least in the species composition both in the river and estuary (Baisre and Arboleya, 2006), which changes with the river flow pattern and the loss of a flood pulse would greatly impact on the fish, especially the migratory species (Agostinho *et al.*, 2004; Craig *et al.*, 2004). In contrast, Lalli and Parsons (1997) argued that a reduction in freshwater input, due to damming in the hypopotamon, can encourage further population of the estuary by stenohaline, in addition to euryhaline faunas, thereby increasing the number of species found within the estuarine environment. Therefore, further in-depth studies on the impact on the life history strategies of the representatives of each fish guild should be carried out, especially in relationship to salinity and flows. For conservation purposes, compromising the dam operation to open the dam at appropriate times and the duration would improve the survival of fish and the integrity of the ecosystem (Agostinho *et al.*, 2004; Juatagate *et al.*, 2007).

ACKNOWLEDGEMENTS

This research article was supported by the Thailand Research Fund (TRF) under the Program *Research and Development of Pak Panang River Basin*. The analyses were conducted under the Franco-Thai Academic Collaboration (Grant **PHC 16598RJ** *Conservation of Freshwater Ecosystems to Sustain Fish Biodiversity, a Food Resource for the Near Future*). We are very grateful to the assistance during the field work of the local fishermen. We also thank Prof. Saowapa Angsupanich (Prince of Songkla University), Drs. Kan Janphromma (Walailak University), Padermsak Jaruyabhand (Chulalongkorn University) and Srilaporn Buasai (TRF) for their constructive comments to improve our research work and Prof. M.D. Hare (Ubon Ratchathani University) and Dr. John Woodley (Université Toulouse) for editing and improving the English in the manuscript.

REFERENCES

Agostinho AA, Gomes LC, Veríssimo S, Okada EK. 2004. Flood regime, dam regulation and fish in the Upper Paraná River: effects on assemblage attributes, reproduction and recruitment. *Review in Fish Biology and Fisheries* **14:** 11-19.

Baisre JA, Arboleya Z. 2006. Going against the flow: Effects of river damming in Cuban fisheries. *Fisheries Research* **81:** 283–292

Barella W, Petere M., 2003. Fish community alterations due to pollution and damming in Tietê and Paranapanema rivers (Brazil). *River Research and Applications* **19:** 59–76.

Blaber SJM. 2002. ‘‘Fish in hot waters’’: the challenges facing fish and fisheries research in tropical estuaries. *Journal of Fish Biology* **61:** 1-20.

Champalbert G., Pagano M, Sene P, Corbin D. 2007. Relationships between meso- and macro-zooplankton communities and hydrology in the Senegal River Estuary. *Estuarine, Coastal and Shelf Science* **74:** 381-394.

Craig JF, Halls AS, Barr JJF, Bean CW. 2004. The Bangladesh floodplain fisheries. *Fisheries Research* **66:** 271-286.

Coastal Resources Institute 1991. *Coastal management of the Pak Panang Estuarine. Songkla*. Prince of Songkla Nakarind University: Songkla.

Cowx IG, Welcomme RL (eds). 1998. *Rehabilitation of rivers for fish*. Fishing News Books, Blackwell: Oxford.

De Leeuw JJ, Buijse AD, Hadivogl G, Lapinska M, Noble RAA, Repecka R, Virbickas T, Wiśniewolski W, Wolter C. 2007. Challenges in developing fish-based ecological assessment methods for large floodplain rivers. *Fisheries Management and Ecology* **14:** 483-494.

Downing JA, Mcclain M, Twilley R, Melack JM, Elser J, Rabalais NN, Lewis WM, Turner RE, Corredor J, Soto D, Yanes-Arencibia A, Kopaska JA, Howarth RW. 1999. The impact of accelerating land-use change on the N-cycle of tropical aquatic ecosystems: current conditions and projected changes. *Biogeochemistry* **46**: 109–148.

Dynesius M, Nilsson C. 1994. Fragmentation and flow regulation of river systems in the Northern Third of the World. *Science* **266:** 753–762.

Ecoutin JM, Richard E, Simier M., Albaret JJ. 2005. Spatial versus temporal patterns in fish assemblages of a tropical estuarine coastal lake: The Ebrié Lagoon (Ivory Coast). *Estuarine, Coastal and Shelf Science* **64**: 623-635.

Fievet E, Tito de Morais, L, Tito de Morais A., Monti D, Tachet H. 2001. Impacts of an irrigation and hydroelectric scheme in a stream with a high rate of diadromy (Guadeloupe,Lesser Antilles): Can downstream alterations affect upstream faunal assemblages? *Archiv für Hydrobiologie* **151**, 405–425.

Froese R, Pauly D. 2008. *FishBase, World Wide Web electronic publication*. URL http://www.fishbase.org

Fukushima M, Kameyama S, Kaneko M, Nakao K, Steel A. 2007. Modelling the effects of dams on freshwater fish distributions in Hokkaido, Japan. *Freshwater Biology* **52**: 1511-1524.

Fuhrman, JA. 2006. Annually reoccurring bacterial communities are predictable from ocean conditions. *Proceedings of the National Academy of Sciences* **103:**13104–13109.

Garcia AM, Raseira MB, Vieira JP, Winemiller KO, Grimm AM. 2003. Spatiotemporal variation in shallow-water freshwater fish distribution and abundance in a large subtropical coastal lagoon. *Environmental Biology of Fishes* **68**: 215-228.

Greathouse EA, Pringle CM, McDowell WH, Holmquist JG 2005. Indirect upstream effects of dams: consequences of migratory consumer extirpation in Puerto Rico. *Ecological Applications* **16:** 339-352.

Guégan JF, Lek S, Oberdoff T. 1998. Energy availability and habitat heterogeneity predict global riverine fish diversity. *Nature* **391:** 382-384

Hagan SM, Able KW. 2001. Seasonal changes of the pelagic fish assemblage in a temperate estuary. *Estuarine, Coastal and Shelf Science* **56:**15-29.

Henle K, Davies KF, Kleyer M, Margules C, Settele J. 2004. Predictors of species sensitivity to fragmentation. *Biodiversity Conservation* **13**: 207–251

Hogan Z, Baird IG, Radtke R and Vander Zanden MJ. 2007. Long distance migration and marine habitation in the tropical Asian catfish, *Pangasius krempfi*. *Journal of Fish Biology* **71:** 818–832

Hugueny B., Camara S., Samoura B. and Magassouba M., 1996. Applying an index of biotic integrity based on fish assemblage in West African river. *Hydrobiologia* **331:** 71-78.

Ikejima K, Tongnunui P, Medej T, Taniuchi T. 2003. Juvenile and small fishes in a mangrove estuary in Trang province, Thailand: seasonal and habitat differences. *Estuarine, Coastal and Shelf Science* **56:** 447-457.

Jackson DA, Peres-Neto PR, Olden JD. 2001. What controls who is where in freshwater fish communities; the roles of biotic, abiotic and spatial factors. *Canadian Journal of Fisheries and Aquatic Sciences* **58**: 157–170.

Jaureguizar AJ, Menni R, Bremec C, Mianzan H, Lasta C. 2003. Fish assemblage and environmental patterns in the Rio de la Plata estuary. . *Estuarine, Coastal and Shelf Science* **56**: 921-933.

Joy MK, Death RG. 2002. Predictive modelling of freshwater fish as a biomonitoring tool in New Zealand. *Freshwater Biology* **47:** 2261-2275.

Jutagate, T. Thappanand, T. and Tabthipwan, P. 2007. Is the sluice gates' management beneficial for spawning migration? The case of shark catfish (*Helicophagus waandersii*) in the Mun below Pak Mun Dam, Thailand *River Research and Applications* **23:** 87-97.

Kohonen T (ed.). 2001. *Self-organizing maps*. Springer-Verlag: Heidelberg

Konan FK, Leprieur F, Ouattara A, Brosse S, Grenouillet G, Gourène G, Winterton P, Lek S. 2007. Spatio-temporal patterns of fish assemblages in coastal West African rivers: a self-organizing map approach. *Aquatic Living Resources* **19:** 361–370.

Lalli C. M., Parsons TR. 1997. *Biological Oceanography: An Introductio (2nd edition).* Butterworth-Heineman: Oxford.

Lasne E, Bergerot B, Lek S, Laffaille P. 2007a. Fish zonation and indicator species for the evaluation of the ecological status of rivers: example of the Loire basin (France). *River Research and Applications* **23:** 877-890.

Lasne E, Lek S, Laffaille P. 2007b. Patterns in fish assemblages in the Loire floodplain: The role of hydrological connectivity and implications for conservation. *Biological Conservation* **139:** 258–268.

Lek S, Guégan J.F., 1999. Artificial neural networks as a tool in ecological modelling, an introduction. *Ecological Modeling* **120:** 65–73.

Lek S, Scardi M, Verdonschot PFM, Descy JP, Park YS. (eds.), 2005. *Modelling Community Structure in Freshwater Ecosystems*. Springer-Verlag: Heidelberg

March JG, Benstead JP, Pringle CM, Scatena FN. 2003. Damming tropical island streams: problems, solutions and alternatives. *BioScience* **53:** 1069-1078.

Martino EJ and Able KW. 2003 Fish assemblages across the marine to low salinity transition zone of a temperate estuary. *Estuarine, Coastal and Shelf Science* **56**: 969–987.

Miles NG. *Biology and ecology of diadromous fishes in south eastern Australia*. Ph.D. thesis, University of Woolongong.

Nelson JS. 1976. *Fishes of the world*. The University of Alberta: Edmonton

Olden JD, Joy MK, Death RG. 2006. Rediscovering the species in community-wide predictive modeling. *Ecological Applications* **16:** 1449–1469.

Paller MC. 1994. Relationships between fish assemblage structure and stream order in South Carolina coastal plain streams. *Transactions of the American Fisheries Society* **123:** 150-161.

Park YS, Grenouillet G, Esperance B, Lek S. 2006. Stream fish assemblages and basin land cover in a river network. *Science of the Total Environment* **365:** 140-153.

Park YS, Oberdoff T, Lek S. 2005. Patterning riverine fish assemblages using an unsupervised neural network. In *Modelling Community Structure in Freshwater Ecosystems*, Lek S, Scardi M, Verdonschot PFM, Descy JP, Park YS. (eds.) Springer-Verlag: Heidelberg; 43-53.

Penczak T, Lek S, Godinho F, Agostinho AA. 2004. Patterns of fish assemblages in tropical streamlets using SOM algorithm and conventional statistical methods. *Ecohydrology and Hydrobiology* **4:** 139-146.

Prabnarong P, Kaewrat J. 2006. The Uthokawiphatprasit Watergate: a man-made change in Pak Panang River Basin. *Walailak Journal of Science and Technology* **3:** 131-143.

Pringle CM. 1997 Exploring how disturbance is transmitted upstream: going against the flow. *Journal of North American Benthological Society* **16**: 425-438.

R Development Core Team. 2008. '*R: A Language and Environment for Statistical Computing.*' URL http://www.R-project.org.

Ribeiro MCLB, Petrere M, Juras AA. 1995. Ecological integrity and fisheries ecology of the Araguaia-Tocantin river basin, Brazil. *Regulated River: Research and Management* **11:** 325-350.

Santos JM, Godinho F, Ferreira MT, Cortes R. 2004. The organisation of fish assemblages in the regulated Lima basin, Northern Portugal. *Limnologica - Ecology and Management of Inland Waters* **34:** 224-235.

Simier M, Laurent C, Ecoutin JM, Albaret JJ. 2006. The Gambia River estuary: a reference point for estuarine fish assemblages studies in West Africa. *Estuarine, Coastal and Shelf Science* **69**: 615-628.

Sparks RE. 1995. Need for ecosystem management of large rivers and their floodplains. *Bioscience* **45:** 168-182.

Suryanarayana I, Braibanti A, Rao RS, Ramam VA, Sudarsan D, Rao GN. 2008. Neural networks in fisheries research. *Fisheries Research* **92**: 115–139.

Taki Y. 1978. *An Analytical Study of Fish Fauna of the Mekong Basin as a Biological Production System of the Nature*. Tokyo University of Fisheries, Tokyo.

Tudesque L, Gevrey M, Grenouillet G, Lek S. 2008. Long-term changes in water physiochemistry in the Adour-Garonne hydrographic network during the last three decades. *Water Research* **42:** 732-742.

Vidthayanon C. 2008. *Field guide to fishes of the Mekong Delta*. Mekong River Commission, Vientiane.

Welcomme RL, Winemiller KO, Cowx IG. 2006. Fish environmental guilds as a tool for assessment of ecological condition of rivers. *River Research and Applications* **22:** 377–396.

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FIGURE CAPTIONS

Fig. 1 Map of the Pak Panang River Basin and location of the sampling stations

Fig. 2 Distribution Pattern of survey samples in the self-organizing map (SOM) cells (a). The similarity of neighboring cells can be grouped in clusters (bold line) and sub-clusters (dashed line) using a U-matrix algorithm (b) and hierarchical clustering using the Ward linkage method (c) from Euclidian distance matrix.

Fig. 3 Species richness among clusters of the SOM model. The same letter on each box shows the values that are not significantly different when applying the Mann-Whitney (MW) test, p-value < 0.05

Fig. 4 Box plots showing occurrence probability (%), vertical axis, of each species in each of five clusters. Values were obtained from the weight of virtual vectors of the trained SOM.

Fig. 5 Average and SD values of water quality parameters in five clusters (distinguished by SOM) The same letter on each box shows the values that are not significantly different when applyingthe Mann-Whitney (MW) test, p-value < 0.05

Fig. 6 Results from PCA analysis showing (a) the contribution of water quality parameters to F1 and F2 *and* (b) the distribution and overlap of groups of clusters (ellipsoid)

Table I. List of fish species, their environmental guilds (Welcomme *at al.*, 2006), their economic importance and percentage of occurrence from 102 surveys in the downstream area of the Pak Panang River

Family	Scientific name	Abbrev.	Environmental Guild	Economic importance	% of occurrence in total surveys
Ambassidae	*Ambassis gymnocephalus*	AMG	Brackish water estuarine	N	22.5
	Parambassis siamensis	PASi	Parapotamic (semi-lotic)	N	11.8
Anabantidae	*Anabas testudineus*	ANT	Paleopotamic	Y	27.5
Ariidae	*Arius maculatus*	ARM	Amphidromous	Y	47.1
	Osteogeneiosus militaris	OSMi	Freshwater estuarine	Y	31.4
Atherinidae	*Hypoatherina valenciennesi*	HYV	Marine visitor	N	12.7
Bagridae	*Hemibagrus nemurus*	HEN	Eupotamonic benthic	Y	25.5
	Mystus armiger	MYA	Eupotamonic benthic	Y	19.6
	Mystus filamentus	MYA	Eupotamonic benthic	Y	48.0
	Mystus gulio	MYG	Semi-anadromous estuarine	Y	43.1
	Mystus singaringan	MYS	Eupotamonic benthic	Y	24.5
Carangidae	*Carangoides praeustus*	CAP	Marine visitor	Y	8.8
Channidae	*Channa micropeltes*	CHM	Paleopotamic	Y	21.6
	Channa lucius	CHL	Paleopotamic	N	22.5
	Channa striata	CHS	Paleopotamic	Y	45.1
Cichlidae	*Oreochromis niloticus*	ORN	Eupotamic riparian	Y	16.7
	Oreochromis mossambicus	ORM	Eupotamic riparian	Y	11.8
Clariidae	*Clarias macrocephalus*	CLM	Paleopotamic	Y	39.2
Clupeidae	*Anodontostoma chacunda*	ANC	Semi-anadromous estuarine	Y	21.6
	Escualosa thoracata	ENT	Amphidromous	Y	13.7
	Hilsa kelee	HIK	Amphidromous	Y	9.8
	Sardinella gibbosa	SAG	Marine visitor	Y	11.8

Table I (cont.) List of fish species, their environmental guilds (Welcomme *at al.*, 2006), their economic importance and percentage of occurrence from 102 surveys in the downstream area of the Pak Panang River

Family	Scientific name	Abbrev.	Environmental Guild	Economic importance	% of occurrence in total surveys
Cynoglossidae	*Cynoglossus arel*	CYAr	Amphidromous	Y	13.7
Cyprinidae	*Barbonymus gonionotus*	BAG	Parapotamic (semi-lotic)	Y	42.2
	Cyclocheilichthys apogon	CYA	Eupotamonic phytophilic	Y	35.3
	Hampala macrolepidota	HAM	Parapotamic (semi-lotic)	Y	43.1
	Labiobarbus lineata	LAL	Eupotamonic phytophilic	Y	18.6
	Osteocheilus hasselti	OSH	Eupotamonic phytophilic	Y	28.4
	Osteocheilus melanopleura	OSM	Eupotamonic phytophilic	Y	15.7
	Puntius brevis	PUB	Eupotamonic phytophilic	Y	21.6
	Puntius orphoides	PUO	Eupotamonic phytophilic	Y	19.6
Eleotridae	*Butis butis*	BUB	Brackish water estuarine	N	14.7
	Oxyeleotris marmorata	OXM	Eupotamonic benthic	Y	50.0
Engraulidae	*Encrasicholina devisi*	END	Marine visitors	Y	15.7
	Stolephorus dubiosus	STD	Brackish water estuarine	Y	27.5
	Thryssa hamiltonii	THH	Marine visitor	N	6.9
Gobiidae	*Papilogobius reichei*	PARe	Freshwater estuarine	N	11.8
	Parapocryptes serperaster	PASe	Brackish water estuarine	Y	10.8
	Pseudapocryptes lanceolatus	PSL	Brackish water estuarine	N	15.7
	Trypauchen vagina	TRV	Brackish water estuarine	Y	16.7
Haemulidae	*Pomadasys kaakan*	POK	Amphidromous	Y	14.7
Lactariidae	*Lactarius Lactarius*	LALa	Marine visitor	Y	7.8
Latidae	*Lates calcarifer*	LAC	Catadromous	Y	16.7
Leiognathidae	*Leiognathus equulus*	LEB	Amphidromous	N	33.3
	Secuter insidiator	SEI	Marine visitor	N	5.9

Table I (cont.) List of fish species, their environmental guilds (Welcomme *at al.*, 2006), their economic importance and percentage of occurrence from 102 surveys in the downstream area of the Pak Panang River

Family	Scientific name	Abbrev.	Environmental Guild	Economic importance	% of occurrence in total surveys
Lutjanidae	*Lutjanus russelli*	LUR	Amphidromous	Y	10.8
Mastacembelidae	*Mastacembelus armatus*	MAA	Plesiopotamonic	N	17.6
Megalopidae	*Megalops cyprinoides*	MEC	Amphidromous	Y	18.6
Mugilidae	*Liza oligolepis*	LIO	Brackish water estuarine	Y	11.8
	Liza subviridis	LIS	Brackish water estuarine	Y	25.2
	Valamugil cunnesius	VAC	Brackish water estuarine	Y	8.8
Muraenesocidae	*Muraenesox cinereus*	MUC	Amphidromous	Y	11.8
Nandidae	*Pristolepis fasciatus*	PRF	Eupotamic riparian	Y	62.7
Notopteridae	*Notopterus notopterus*	NON	Eupotamonic phytophilic	Y	58.8
Ophichthidae	*Pisodonopis boro*	PIB	Brackish water estuarine	Y	16.7
Osphronemidae	*Trichogaster pectoralis*	TRP	Paleopotamic	Y	7.8
Platycephalidae	*Grammoplites scarber*	GRS	Marine visitor	N	16.7
Plotosidae	*Plotosus canius*	PLC	Amphidromous	Y	20.6
Polynemidae	*Eleutheronema tetradactylum*	ELT	Amphidromous	Y	11.8
Scatophagidae	*Scatophagus argus*	SCA	Amphidromous	Y	31.4
Sciaenidae	*Panna micron*	PAM	Marine visitor	Y	15.7
Scorpaenidae	*Vespicula trachinoides*	VET	Brackish water estuarine	N	13.7
Siganidae	*Siganus canaliculatus*	SIC	Brackish water estuarine	Y	18.6
Sillaginidae	*Sillago sihama*	SIS	Brackish water estuarine	Y	15.7
Siluridae	*Ompok krattensis*	OMK	Eupotamonic phytophilic	Y	20.6
Sparidae	*Acanthopagrus berda*	ACB	Brackish water estuarine	Y	23.5
Sphyraenidae	*Sphyraena jello*	SPJ	Marine visitor	Y	8.8
Teraponidae	*Therapon jabua*	THJ	Brackish water estuarine	N	8.8

Table I (cont.) List of fish species, their environmental guilds (Welcomme *at al.*, 2006), their economic importance and percentage of occurrence from 102 surveys in the downstream area of the Pak Panang River

Family	Scientific name	Abbrev.	Environmental Guild	Economic importance	% of occurrence in total surveys
Tetraodontidae	*Tetraodon nigroviridis*	TEN	Eupotamic riparian	N	21.6
	Tetraodon leiurus	TEL	Eupotamic riparian	N	9.8
Toxotidae	*Toxotes chatareus*	TOC	Eupotamic riparian	Y	8.8

Table II Mean values (±SD) of the occurrence probability of each fish environmental guild (Welcomme *et al*., 2006) in the five clusters of surveys

Guilds	Kruskall- Wallis (KW)	p-value	Cluster				
			Ia	Ib	IIa	IIb	IIc
Paleopotamic	59.60	< 0.001	0.27 (0.14) a	0.12 (0.10) b	0.00 (0.00) c	0.02 (0.02) bc	0.00 (0.00) c
Plesiopotamonic	25.43	< 0.001	0.01 (0.02) a	0.02 (0.03) b	0.00 (0.00) a	0.03 (0.02) ab	0.00 (0.00) a
Parapotamic (semi-lotic)	33.39	< 0.001	0.10 (0.08) a	0.10 (0.07) a	0.01 (0.03) b	0.05 (0.04) ab	0.00 (0.00) b
Eupotamonic phytophilic	59.09	< 0.001	0.25 (0.11) a	0.24 (0.10) a	0.01 (0.02) b	0.08 (0.07) b	0.01 (0.01) b
Eupotamonic benthic	35.99	< 0.001	0.14 (0.09) ab	0.18 (0.08) a	0.09 (0.08) bc	0.12 (0.05) ab	0.01 (0.02) c
Eupotamic riparian	30.19	< 0.001	0.12 (0.07) a	0.11 (0.06) a	0.08 (0.06) ab	0.10 (0.04) ab	0.03 (0.02) b
Freshwater estuarine	25.37	< 0.001	0.01 (0.03) a	0.06 (0.06) b	0.03 (0.03) ab	0.04 (0.03) ab	0.02 (0.02) a
Brackish water estuarine	78.84	< 0.001	0.02 (0.05) a	0.02 (0.05) a	0.32 (0.10) bc	0.24 (0.09) b	0.38 (0.05) c
Catadromous	5.74	> 0.05	0.01 (0.01)	0.01 (0.03)	0.02 (0.03)	0.01 (0.02)	0.01 (0.02)
Semi-anadromous estuarine	4.24	> 0.05	0.03 (0.05)	0.05 (0.05)	0.02 (0.03)	0.06 (0.02)	0.05 (0.03)
Amphidromous	54.11	< 0.001	0.06 (0.07) a	0.08 (0.09) a	0.29 (0.07) b	0.22 (0.07) b	0.26 (0.06) b
Marine visitors	89.69	< 0.001	0.00 (0.00) a	0.00 (0.00) a	0.14 (0.09) b	0.03 (0.04) a	0.22 (0.05) c

Note On each cluster column, for each guild, the letters (a, b, c) show the Mann-Whitney (MW) test results. The same letter (e.g. c and c between clusters IIa and IIc for Paleopotamic guilds) means no significant different (p-value > 0.05). The different letters (e.g. a and b between clusters Ia and Ib for Paleopotamic guild) mean statistically different (p-values<0.05).

Table III Operation of the *Uthokawiphatprasit* water gates (opening days, opening hours and discharges) and rainfall during the study period.

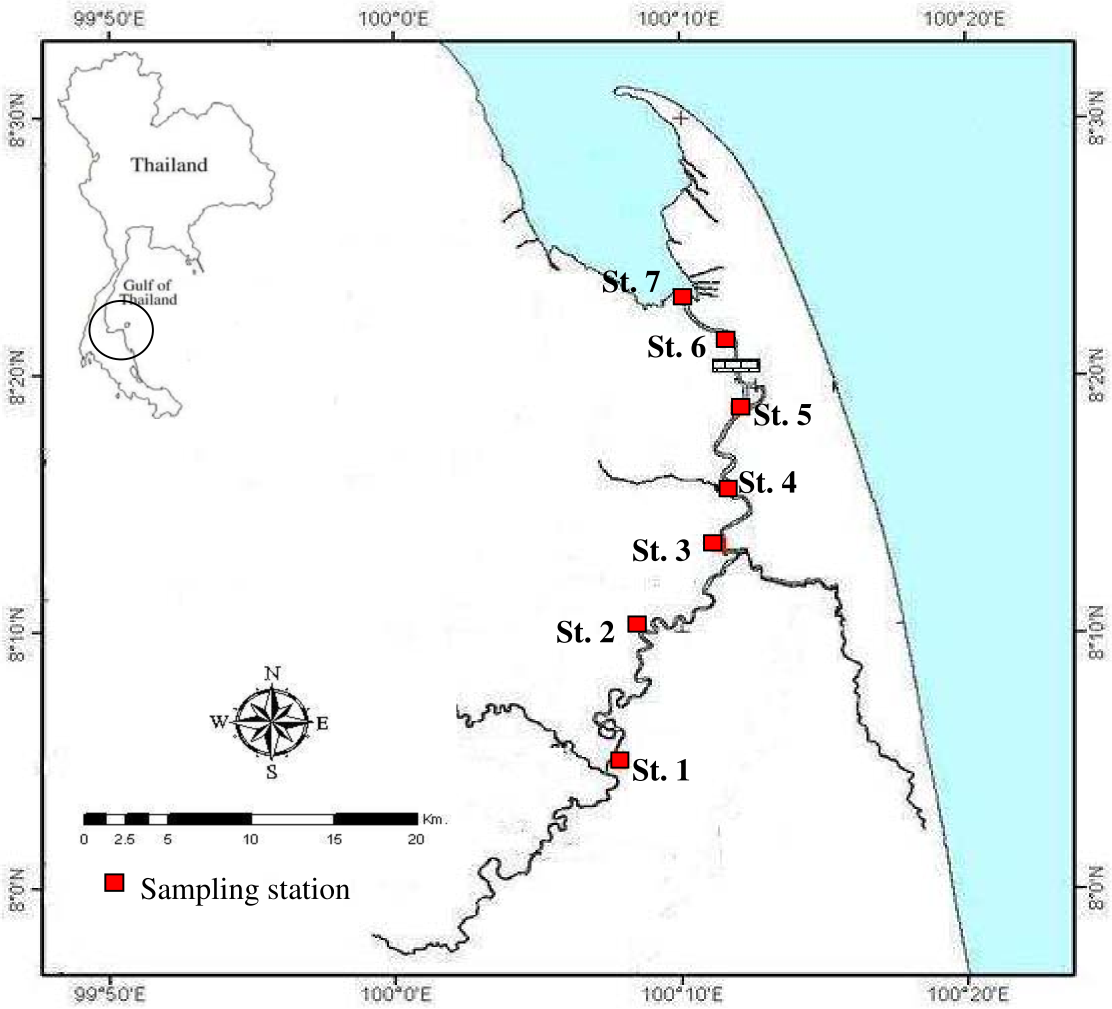
Month	Duration of opening (days)	Opening period (hours)	Discharged volume (10^6 m^3)	Rainfall (mm)
Jan-06	16	303	470.5	170.1
Feb-06	15	236	465.6	141.1
Mar-06	7	76	22.9	95.0
Apr-06	18	177	84.3	150.8
May-06	0	0	0.0	70.8
Jun-06	6	117	36.0	201.4
Jul-06	0	0	0.0	30.6
Aug-06	0	0	0.0	29.1
Sep-06	0	0	0.0	128.5
Oct-06	24	217	176.2	199.7
Nov-06	26	341	453.2	316.6
Dec-06	9	112	104.1	98.2
Jan-07	22	208	163.5	237.9
Feb-07	0	0	0.0	3.7
Mar-07	0	0	0.0	45.3
Apr-07	0	0	0.0	121.5
May-07	18	217	236.1	415.0
Jun-07	0	0	0.0	94.2

Table IV Confusing matrix showing leave-one-out cross validation of the linear discriminant model (LDA) using the regulation scheme and three water quality parameters with a global performance of prediction = 84.3 %

Observed	Predicted					% success
	Ia	**Ib**	**IIa**	**IIb**	**IIc**	
Ia	39	9	0	0	0	97.5
Ib	1	23	0	1	0	71.9
IIa	0	0	6	1	3	85.7
IIb	0	0	0	5	0	71.4
IIc	0	0	1	0	13	81.3

Note The grey shade indicates the numbers of survey that showed good prediction.

Fig. 1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100°10'E
100°20'E
8°30'N
8°20'N
8°10'N
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Thailand
Gulf of Thailand
St. 7
St. 6
St. 5
St. 4
St. 3
St. 2
St. 1
N
W
E
S
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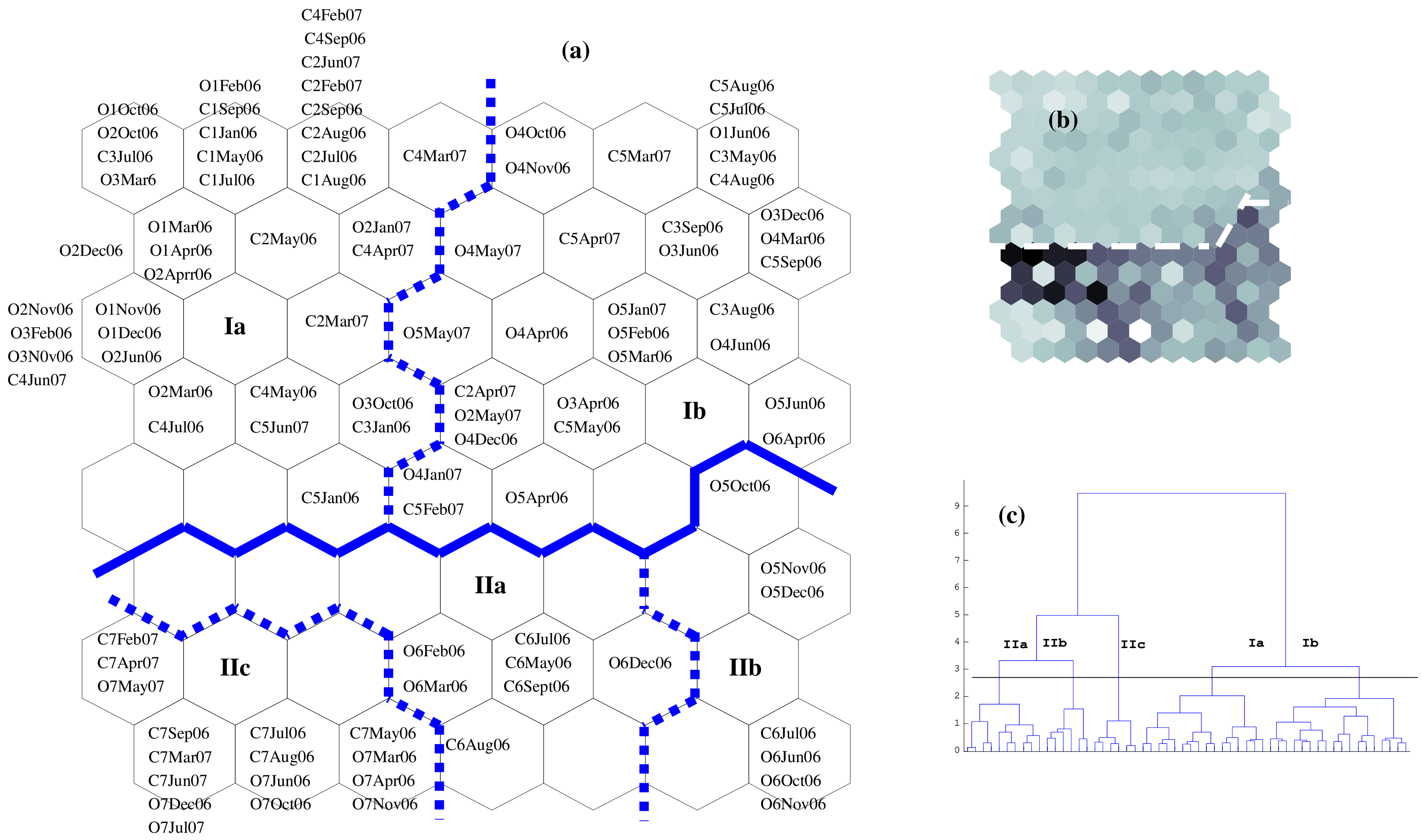
Sampling station


(a)
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C4Sep06
C2Jun07
O1Feb06
C2Feb07
C5Aug06
O1Oct06
C1Sep06
C2Sep06
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O2Oct06
C1Jan06
C2Aug06
O4Oct06
O1Jun06
C3Jul06
C1May06
C2Jul06
C4Mar07
C5Mar07
C3May06
O3Mar6
C1Jul06
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O2Jan07
C3Sep06
O2Dec06
O1Apr06
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C4Apr07
O4May07
C5Apr07
O3Jun06
O4Mar06
O2Aprr06
C5Sep06
O2Nov06
O1Nov06
O5Jan07
C3Aug06
O3Feb06
O1Dec06
Ia
C2Mar07
O5May07
O4Apr06
O5Feb06
O3N0v06
O2Jun06
O5Mar06
O4Jun06
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O2Mar06
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O3Oct06
O3Apr06
Ib
O5Jun06
C4Jul06
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O5Oct06
C5Feb07
IIa
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O5Dec06
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C6Jul06
O6Feb06
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IIc
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IIb
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O7Apr06
O6Oct06
O7Dec06
O7Oct06
O7Nov06
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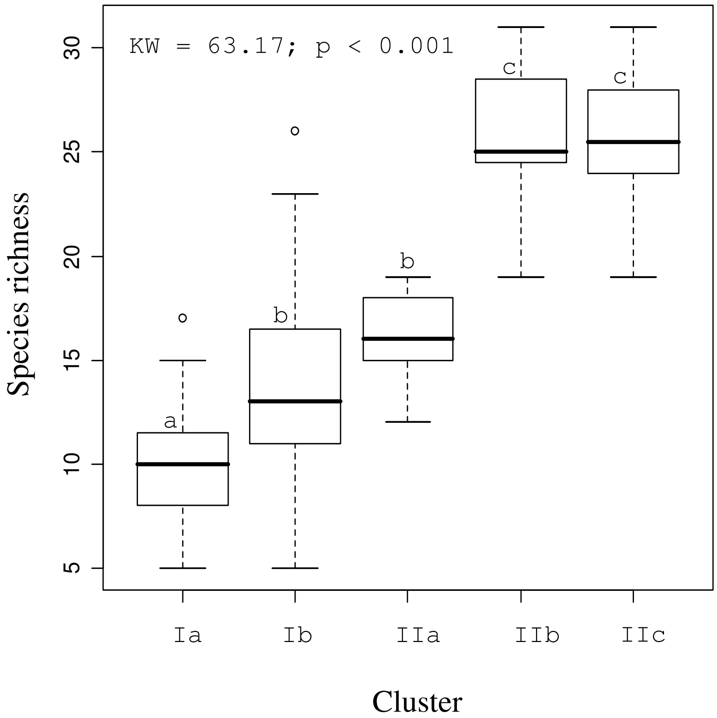
(b)
(c)
IIa
IIb
IIc
Ia
Ib

Fig. 2

Fig. 3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b
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c
c
Ia
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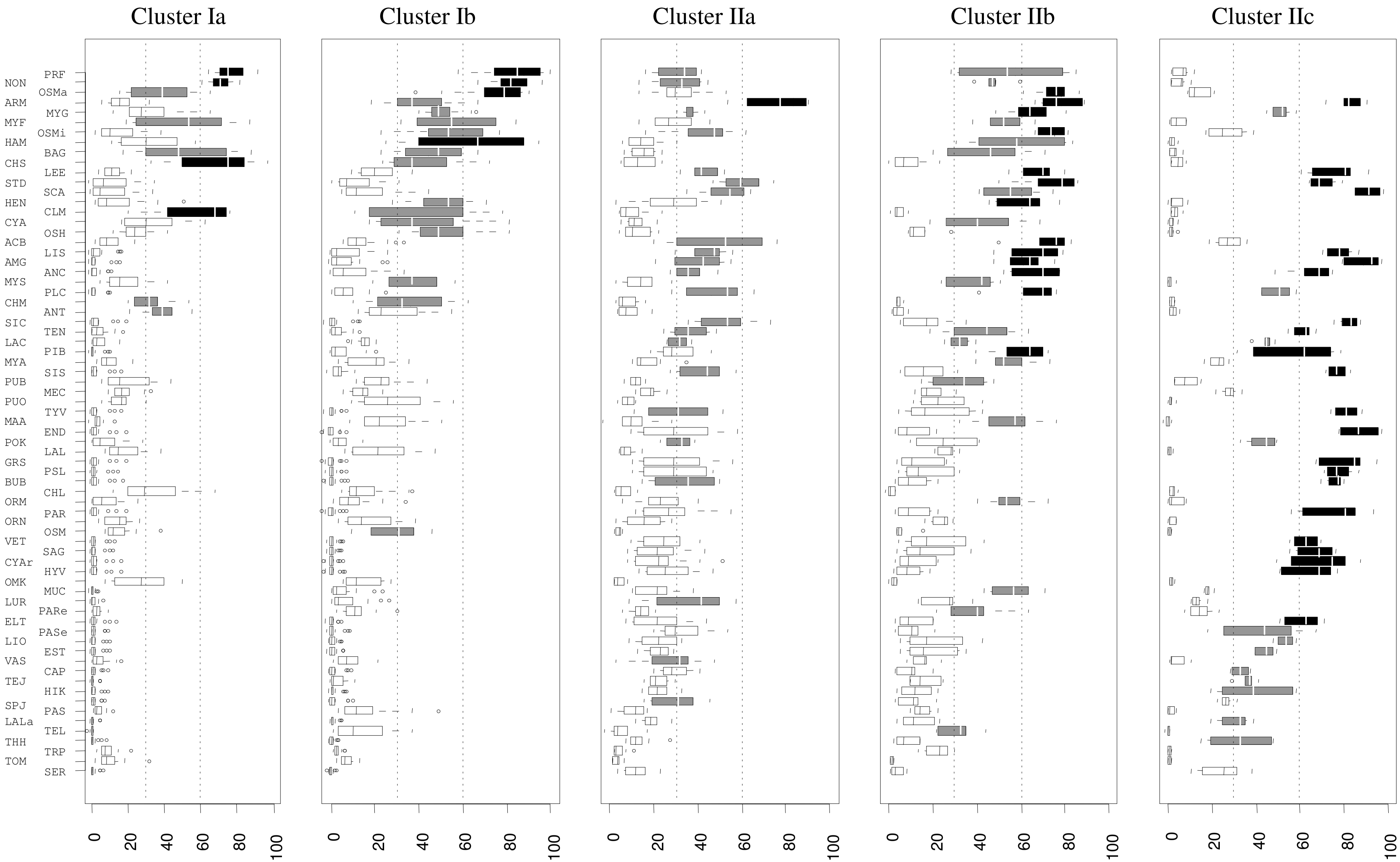
IIb
IIc
Cluster

Fig. 4


Cluster Ia
Cluster Ib
Cluster IIa
Cluster IIb
Cluster IIc
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NON
OSMa
ARM
MYG
MYF
OSMi
HAM
BAG
CHS
LEE
STD
SCA
HEN
CLM
CYA
OSH
ACB
LIS
AMG
ANC
MYS
PLC
CHM
ANT
SIC
TEN
LAC
PIB
MYA
SIS
PUB
MEC
PUO
TYV
MAA
END
POK
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GRS
PSL
BUB
CHL
ORM
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ORN
OSM
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SAG
CYAr
HYV
OMK
MUC
LUR
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ELT
PASe
LIO
EST
VAS
CAP
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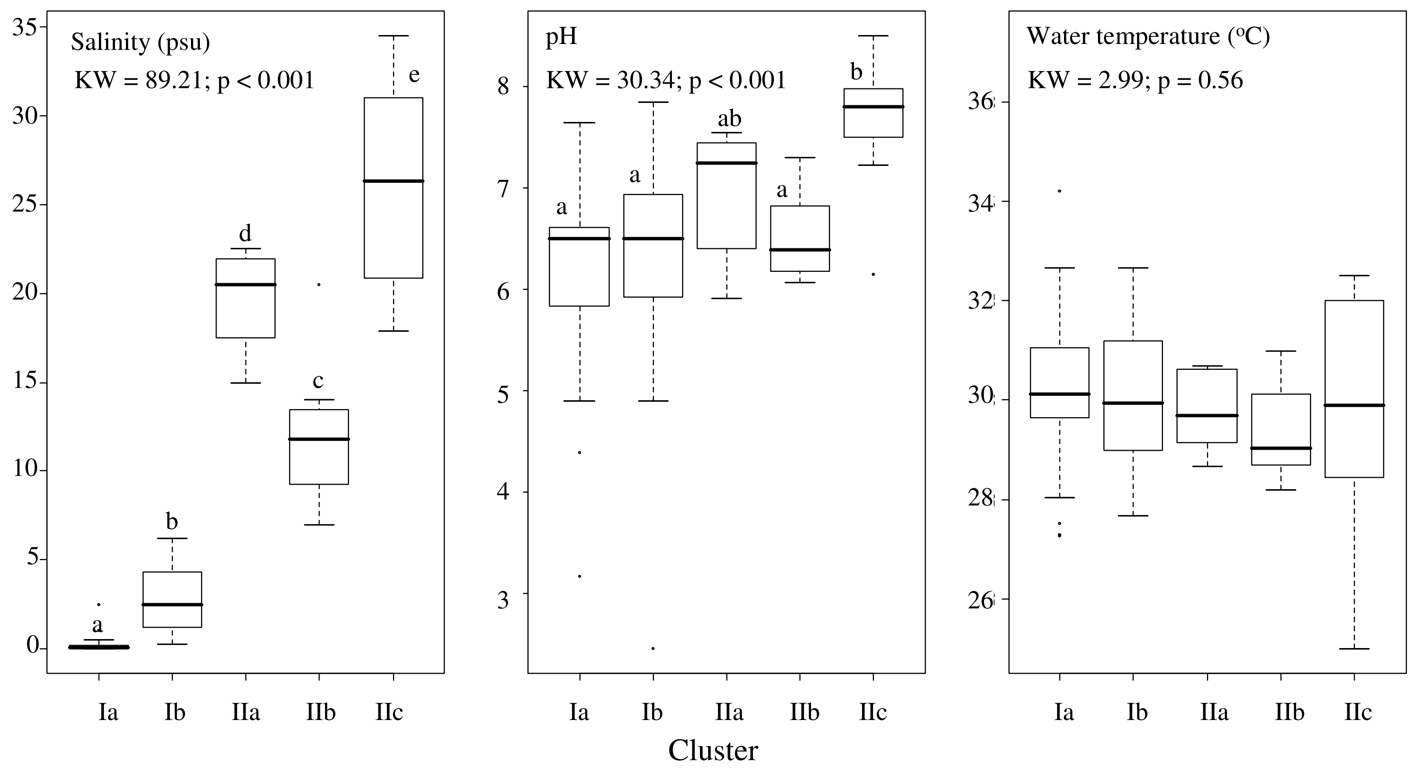
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pH
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Water temperature (ºC)
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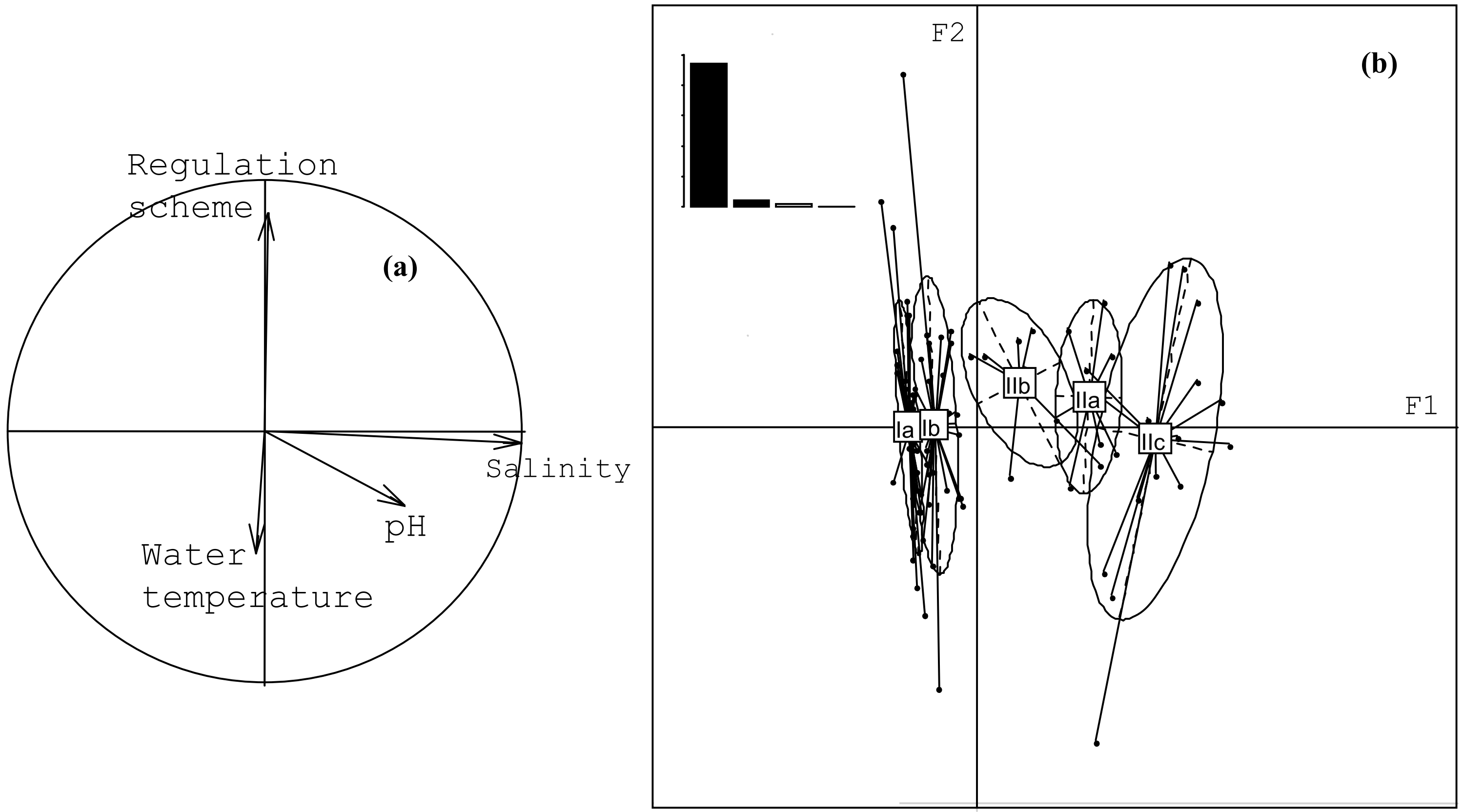
b
d
c
e
a
a
ab
a
b
Ia
Ib
IIa
IIb
IIc
Cluster

Fig. 6


Regulation scheme
(a)
Salinity
pH
Water temperature
F2
(b)
F1
Ia
Ib
IIb
IIa
IIc

Original Manuscript (Modified version)

Submitted to Marine and Freshwater Research

EFFECT OF AN ANTI- SALT-INTRUSION DAM ON TROPICAL FISH ASSEMBLAGES

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With 4 TABLES and 6 FIGURES

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Abstract

When anti-salt intrusion dams are constructed for agricultural irrigation and household consumption in the lower portion of a river, changes arise in environmental components and the pattern of fish assemblages, both in the estuary and the river. In the present study, the spatio-temporal changes of both aspects due to the anti-salt damming of the Pak Panang River, Thailand, were monitored between March 2006 and June 2007. The study was conducted during two different periods: (a) the opening phase, i.e. when the sluices are opened (i.e. the water flows freely between the upstream and the downstream areas) and (b) the closing phase, i.e. when the sluices are closed. Salinity levels in the estuary declined ($P = 0.0005$) but increased in the river during the opening phase ($P = 0.0023$). In the river, the pH increased ($P < 0.0001$) during the closing phase but was relatively constant in the estuary. No differences ($P > 0.05$) were found for water temperatures, chlorophyll-a and abundance of phytoplankton. During the closing phase, the abundance of zooplankton was substantially higher in the estuary but the abundance of benthos in the river declined. Ninety-four fish species were collected. The species richness and the diversity index did not differ ($P > 0.05$) in the estuary but were significantly different in the river, where more abundance was found during the opening phase. The index of relative importance showed that the small phytoplankton feeders were notably abundant in the estuary, while the secondary freshwater fishes were the major habitants in the river. Cluster analyses plotted the movement of fish between the two systems during the opening phase. A co-inertia analysis revealed the trend of changes in fish assemblages complying with salinity gradient and food sources.

Additional keywords: dam, salinity, community composition, multivariate analysis, Thailand

Introduction

Changes in aquatic communities are likely to occur when the system is disturbed by modifications of any physical structures and the chemical quality of the water (Ector and Rimet 2005). This situation may be more serious in the aquatic ecotone of the hypopotamon zone of the river course, which is the lower course of the river channel connected to the brackish-water estuary (Welcomme *et al.* 2006). This zone generally has a high species richness situated at the interface between the freshwater and marine domains (Guegan *et al.* 1998; Blaber 2002). The fish assemblages of this environment are fairly heterogeneous and comprise marine coastal species, strictly estuarine species and freshwater species, depending on the degree of connection with adjacent environments such as size, shape, seasonal changes and history of the connections (Ecoutin *et al.* 2005). It is known that the assemblages and movements of fish in this area result from temporal and spatially structured environmental gradients (Jaureguizar *et al.* 2003).

Damming in the hypopotamon area, either large or low-head dams, always significantly alters the distribution, composition and abundance of the fish fauna by blocking migratory pathways (March *et al.,* 2003). Da Costa *et al.* (2000) reported that damming a river channel near the estuarine/delta area, in the Bia River Basin, West Africa, impeded estuarine/marine fish from migrating upstream during floods and *vice versa*, which seriously disturbed their life cycle. This also occurred in Europe where the Alqueva Dam in the Guadiana River, Portugal, resulted in changes of fish assemblages in the estuary (Veiga *et al.* 2006) and the trophic relationship of fish in that ecosystem (Sa´ *et al.* 2006). Recently, it was reported that the effects of the river's downstream dam resulted in the absence of some fish species in the upstream area in Hokkaido, Japan (Fukushima *et al.* 2007).

The construction of dams in the lower river course also alters the physical habitat and hydrological regime in reaches both upstream and downstream of dams. Areas downstream of dams can experience decreased river flow and water depth (Fievet *et al.*, 2001). This decrease in freshwater can result in increased salinity, especially at sites near the upstream boundary of estuarine tidal influence. Areas upstream of dams experience decreased flow rates and increased water depth (March *et al.,* 2003). The reduction in river flow lessens nutrient loads to the estuary (Vörösmarty *et al.* 1997) but leads to an excess of nutrients in the upstream area (Downing *et al.* 1999). Moreover, due to the regulation mechanisms at the dam, the environmental conditions in this area are highly variable, thus affecting the structure and function of fish faunas (Sheaves *et al.*, 2007).

In South East Asia, previous studies compared the fish assemblages as well as the trophic organizations in the intact and polluted estuarine environments (e.g. Chong *et al.*1990; Tongnunui *et al.* 2002; Hajisamae *et al.* 2003). Pringle (1997) mentioned that downstream influences on upstream communities remain little explored. However, in recent years, there has been increasing concern about the impacts of lower river course abstraction on the role of the area as nursery and feeding areas for young and adult fish in the lowland floodplain and estuary (Jutagate *et al.,* 2007; Atapattu and Kodituwakku 2009). However, there is no information on the effect on the assemblages of the riverine and estuarine fish faunas in this region.

In this study we investigated environmental components (i.e. water quality parameters and fundamental food sources for fish) and fish compositions at the *Uthokawiphatprasit* anti-salt dam in the Pak Panang River, Southern of Thailand. We studied the upstream from the dam (i.e. river course) and the downstream (i.e. estuary/delta area) to understand the impacts on these parameters of two different environmental conditions according to the regulation of water at the dam (i.e. opening and closing phases). The opening phase is when the sluices are opened and the water flows freely between the upstream and the downstream areas, allowing the passage of fish in both directions and the closing phase is when the sluices are closed. It is hypothesized that (a) there are the differences in environmental components and fish assemblages due to the operation of the dam and (b) the patterns of fish assemblages corresponded to the variation in the environmental components.

Material and Methods

Study area

The Pak Panang River Basin (Fig. 1) is a fertile basin on the south east coast of Thailand. The Pak Panang River runs through to the sea at Pak Panang Bay in the Gulf of Thailand, which is one of the most productive and heavily exploited marine fishing areas in the world (Christensen 1998). The basin experiences a tropical monsoon climate with a short dry season (February to April) and a long rainy season (May to January). The average annual rainfall is 2,380 mm and average air temperature is 27.3 ^{o}C. Although there is a high rate of precipitation in the area, many areas experience soil-moisture deficits because of the high evaporation rates of soil and plants. There is a high rate of water discharge to the sea (maximum at 1,426 m^3 sec^{-1}), as well as the intrusion of salt water, which has been recorded as far as 100 km upstream (Coastal Resources Institute 1991), resulting in inadequate freshwater for agricultural and domestic consumption. In addition, the water in the downstream area of the river is slightly acid, because of peaty areas along the river banks. Therefore, in 1995, the construction of the *Uthokawiphatprasit* (meaning “effectively divide fresh- and marine- waters”) anti-salt dam was started and it commenced operation in 1999. The dam is located 6 km upstream from the delta (Fig. 1), is 9 x 200 m^2 in size and containing 10 sluice gates, each being 20 m wide. The water elevation during the full storage at the dam site is 8 m. The major purposes are to prevent intrusion of salt water into the inner areas along the river, to neutralize the pH of the river and keep freshwater for irrigation (Prabnarong and Kaewrat 2006). The sluice gates are opened occasionally when there is excessive water in the wet season, resulting in flooding and destruction of the paddy fields and villages along the river.

Data collections and fish samplings

The study area covered the area that had had fluctuations in salinity levels because of the flush of freshwater into the estuary and the intrusion of salt water into the river before the dam was constructed (Coastal Resources Institute 1991). Six sampling stations were selected, i.e. three stations in the estuary and three stations in the river (Table 1 and Fig.1). The stations were fixed by using the Garmin-GPSmap 76CSx. Data collections and fish sampling were conducted monthly during the period of highest water level in the estuary in each month. Water quality parameters that related to the objectives of the dam's construction, i.e. salinity and pH, as well as chlorophyll-a concentrations and water temperature were monitored. Moreover, the abundance of fundamental food sources for the fish, i.e. phytoplankton, zooplankton and benthos were also investigated.

Water quality parameters were studied by sampling the water at three depths *viz.* surface, mid-water and 1 m above the bottom from three sub-sampling points in each station area. The sampled water was pooled as representative of a station. Salinity, pH and water temperature of the sampling stations were obtained from a portable YSI 63-50FT apparatus and salinity was expressed in terms of practical salinity unit (psu). Chlorophyll-a was analyzed by the method described in ROPME (1999). The method consisted of the filtration of the seawater sample (1000 ml) through a nylon net of 300-µ mesh (to remove zooplankton), and then the phytoplankton were filtered on 0.45 µm membrane filter paper using about 10 mg $MgCO_3.cm^{-2}$ suspension of filter surface. The pigment was then extracted using 90 % acetone and the extinction measured spectrophotometrically at 750, 663, 645 and 630 nm against a 90 % acetone blank. Extinctions were corrected using the extinction measured at 750 nm. Chlorophyll-a was calculated using the following equations

$$Chlorophyll - a = 11.64E_{663} - 2.16E_{645} + 0.10E_{630}$$

where E refers to the extinction measured at the next number in nm. The results obtained were expressed as $\mu g.L^{-1}$ of seawater ($\equiv mg.m^{-3}$).

Phytoplankton and zooplankton were collected by using plankton net mesh sizes 22 and 69 µm, respectively. Both nets were 30 cm diameter and were vertically dragged from 1 m depth to the surface at three sub-sampling points in each station area and then pooled together. In total, 288 samples were collected for each phytoplankton and zooplankton sampling. The biomasses of planktons were estimated by means of biovolume (Lorenzen 1967). The samples were filtered through a piece of clean and dry netting material. The interstitial water between the organisms was removed with blotting paper. The filtered plankton was then transferred with a spatula to a measuring cylinder with a known volume of 4 % buffered formalin. The plankton was allowed to settle for at least 24 hours before recording the settled volume. The biomasses of benthos were studied by using a grab (225 cm^2 covered area), three grabs at each station, and then sieved (0.5 and 1.0 mm apertures) to collect and weigh the samples.

To collect all the fish species in each area, the non-selective and efficiency fishing gear was used, i.e. active surrounding fishing gear (Verdoit *et al.* 2003). For fish sampling in the estuary (i.e. Pak Panang Bay), it was done by dragging a push net, 30 mm mesh, for 30 min. to circumscribe the sampling area. Because the push net could not operate in the river, a beach seine net, 30 mm mesh was used to collect fish, as well as various mesh size of gillnets (5 nets at each station, mesh size from 20 to 100 mm, i.e. 20 mm interval) that were set to cover the water column and left overnight before being taken off at the freshwater stations (i.e. Pak Panang River) to sample fish. Fish samples were packed in ice and brought to Walailak University, 85 km from the dam. The fish were then taxonomically classified to species level as far as possible (Nelson 1976; Froese and Pauly 2007). Numbers of individuals by species were counted and then the fish were weighed (nearest 0.01 g). Both the environmental measurements and fish sampling were carried out from March 2006 to June 2007. During the study period, the sluice gates of the *Uthokawiphatprasit* dam were opened occasionally but they were all closed during the months of May, July, August and September in 2006 and February, March, April and June in 2007.

Data analysis

The statistical differences in environmental variables according to the regulation of the dam were analyzed by Kruskal-Wallis chi-squared test. Species richness (SR) and the Shannon-Wiener diversity index (H'-index: Magurran 2004) were calculated for each sampling site and period. Temporal changes in the ecological dominance of fish species in each area were presented as the Percentage of Index of Relative Importance (%IRI), which aggregates the main evaluation methods *viz.* abundance (%N), biomass (%W), and frequency of occurrence (%F) within a single index to reduces bias in description (Pinkas *et al.* 1971).

$$\%IRI = \left(\frac{(\%W_i + \%N_i) \times \%F_i}{\sum_{i=1}^{n} (\%W_i + \%N_i) \times \%F_i} \right) \times 100$$

Hierarchical agglomerative clustering was used to classify sets of the fish assemblages in each survey with Ward's method (Ward 1963) attempting to optimize the minimum variance within clusters using the within-groups sum of squares. Co-inertia analysis (Doledec and Chessel 1994), a way to examine species-environment relationships when many species and several environmental variables are sampled in few sites, was performed to show the link between fish assemblage structure and the environmental variables. This technique is used to demonstrate whether a co-structure exists between environmental and fish data sets. The co-structure is determined by the maximization of the square-rooted projected inertia and of the correlation between the two new sets of projected coordinates (Merigoux *et al.* 1998). The significance of the resulting co-structure between environmental and fish data sets was checked by means of a Monte-Carlo permutation test. This procedure consisted in repeating 1,000 co-inertia analyses of two data sets after permutations of their rows. The P-value given represented the probability of the same covariance between environmental and fish axes by chance (Cattanéo *et al.* 2001). All the statistical analyses and graphics were carried out with R software (R Development Core Team 2008).

Results

Differences in water quality parameters between the opening and closing phases

For the variation in the salinity (Fig. 2a), the highest difference between the opening and closing phases, was at Station 3 (14 psu) followed by Station 2 (12 psu). Thus, salinity in the estuary during the opening phase was significantly lower than during the closing phase (χ^2_5 = 22.057, $P < 0.001$). Salinity levels within the river were higher during the opening phase (χ^2_5 = 18.627, P = 0.002) but the difference was less than 1 psu. The pH values (Fig. 2b) obtained during the closing phase in the river were significantly higher than during the opening phase (χ^2_5 = 30.449, P < 0.001) and tended to be neutral (pH ≈ 7) but there was no statistical difference between phases in the estuary (χ^2_5 = 4.421, P = 0.491). The average water temperature was about 30 °C during the study and there was no statistical difference in both the estuary and river areas (P > 0.05) between the opening and closing times (Fig. 2c: χ^2_5 = 8.269 in the estuary and χ^2_5 =7.140 in the river). Chlorophyll-a was higher in the estuary but there was no statistical difference in both areas between the opening and closing periods (Fig. 2d: χ^2_5 = 0.985 and χ^2_5 = 0.968 in the estuary and river, respectively).

Differences in fundamental food sources between the opening and closing phases

The abundance of the fundamental food sources (i.e. phytoplankton, zooplankton and benthos: Fig. 3a to 3c) was higher in the estuary than in the river but changes due to the operation of the dam (i.e. opening/closing) in each parameter were dissimilar. No statistical differences were obtained for the abundance of phytoplankton between the areas (P > 0.05, χ^2_5 = 5.950 and 6.457, respectively, in the estuary and river areas). A high correlation between chlorophyll-a (*X*) and phytoplankton (*Y*) was found (r^2 = 0.78) and the predicting model was $Y = 157.71+39.36X$. The abundance of zooplankton significantly differed in the estuarine area (χ^2_5 = 14.929, P = 0.011) but not in the river (χ^2_5 = 4.507, P = 0.479) since during the closing phase the zooplankton tended to be dropped in the stations further offshore (i.e. Stations 1 and 2). In contrast to zooplankton, the abundance of benthos did not differ in the estuary (χ^2_5 = 1.838, P = 0.871), while it significantly differed in the river (χ^2_5 = 16.723, P = 0.005) as their abundance tended to be increased during the opening phase

Composition, abundance and importance index of fish

A total of 109,466 individual fish (414,889 g) were sampled. Ninety four fish species belonging to 48 families were identified, comprising 44, 26 and 24 estuarine, marine and freshwater fish species, respectively (Table 2). Most of the species caught were economically important (71.2 %). Many sub-adult fish were collected in the samples, as observed by the low weight of individuals in many large-sized species. No true marine species were found in the stations upstream of the dam and no freshwater species were found in downstream Stations 1 and 2. The most diverse families were estuarine and freshwater fish such as

Gobiidae and Cyprinidae (8 species each), followed by Clupeidade and Engraulidae (5 species each) (Table 2). In terms of weight, *Notopterus notopterus* (46,504 g), *Ambassis gymnocephalus* (30,020 g), *Escualosa thorocota* (26,117 g), *Scatophagus argus* (22,275 g), *Liza subviridis* (20,955 g), *Pristolepis fasciatus* (17,765 g) and *Leiognathus* spp. (16,516 g) dominated the fish fauna, which accounted for 43.4 % of the weight of the total samples. However, in terms of individual fish, the most abundant species were all schooling small-size (i.e. adult less than 10 cm) marine fish species (70.4%) such as *Secuter insidiator* (20,706 g), *Encrasicholina devisi* (16,488 g), *Escualosa thorocota* (15,704 g), *Leiognathus* spp. (12,241 g) and *A. gymnocephalus* (11,948 g) (Table 3).

The highest average species richness (SR) value (28) was obtained at Station 3 during the open sluice regime and the lowest value (4) was observed at Station 6 during the closed period. For the diversity index (H'-index) the highest average value (2.1) and the lowest average value (0.9) were obtained during the closing phase at Stations 2 and 6, respectively. Between the closing/opening phases, there were no significant differences in SR (χ^2_5 = 3.2153, P = 0.6668) and H'-index (χ^2_5 = 9.3622, P = 0.0955) in the estuary (Fig. 4). By contrast, statistical differences were found in both SR (χ^2_5 = 15.964, P = 0.0069) and the H'-index (χ^2_5 = 15.5228, P = 0.0083) in the river, with the higher values being obtained during the opening phase (Fig. 4)

E. devisi, *Leiognathus* spp., *A. gymnocephalus*, *S. insidiator* and *S. argus* were dominant in catches from the estuarine/marine area throughout most of the study period, and together accounted for 55.0 % of the total %IRI. The %IRI values of *E. devisi* were significantly higher during the months when freshwater flushed into the delta. On the other hand, *Leiognathus* spp. and *A. gymnocephalus* showed high %IRI values during the period when the sluice gates were closed (Table 3). Meanwhile in the freshwater area, the major catches were *N. notopterus*, *P. fasciatus*, *Mystus gulio*, *Hampala macrolepidota* and *Barbonymus gonionotus*, which contributed to 66 % of the total %IRI. During the months of sluice gates opening, the numbers of fish that contributed to over 80 % of the total %IRI, were higher than those when the sluice gates were closed. Also during this period, the euryhaline species such as *Osteogeneinosus militaris*, *Leiognathus* spp. and *M. gulio* showed a higher proportion in the contribution to the %IRI (Table 4) However, no freshwater fish species showed any substantial presence in the estuarine/marine area during the whole study period.

Fish assemblages in relation to environmental factors

The cluster analysis of fish assemblages corresponding to combinations of sluice gate functions (closing/opening) at each station and sampling period allowed 4 clusters to be identified as represented in Fig. 5 and Table 6. Cluster **A** included most of the combinations of the river area. Three combinations of the estuarine area, during the opening phase in the river mouth area (i.e. Station 3), were included in this cluster *viz.*, O3Oct06, O3Nov06 and O3Jan07. Cluster **B** was mixed between the stations 3 and 4 during the opening period, which implied the extensive movement of fish between these two stations. Cluster **D** was exclusively the stations further down towards the sea during the closing phase of sluice gates. The remaining combinations of the fish assemblages in the estuary were in Cluster **C**.

Due to its high correlation with phytoplankton, chlorophyll-a was excluded from the co-inertia analysis matching environmental variables and fish data. The co-structure between the environmental and fish data sets was significantly linked (Monte-Carlo permutation test, $P < 0.001$). The first two axes explained 48% of the total inertia. A clear influence of salinity, fundamental food sources and pH was apparent along the first axis (F1, 40.3% of explanation). Meanwhile, water temperature was taken into consideration by axis F2 (17.7% of explanation). All fundamental food sources, as well as pH, showed a positive correlation with salinity. Therefore, the first axis could mainly be summarized by a salinity gradient, with high salinity (estuary) associated with high richness of food sources on the left, and low salinity (river) on the right (Fig. 6a). There is a clear separation between freshwater species (on the right) and estuarine-marine species (on the left), which is obviously linked to the gradient of salinity. Meanwhile, the species around the center are the secondary freshwater species such as *N. notopterus* (NON), *Oxyeleotris marmorata* (OXM) and *O. militaris* (OSM) and the euryhaline estuarine species such as *Platycephalus indicus* (PLI) *Glossogobius giuris* (GLG) and *M. gulio* (MYG).

Discussion

Due to a high demand for freshwater, many anti-salt dams were constructed to prevent saline water intrusion into upstream freshwater and storage freshwater by closing the water gates during the dry season (Pringle *et al*., 2000; March *et al.* 2003). Understanding the changes in environmental parameters and fish assemblages according to the dam operation (opening/ closing) is necessary. The results of this kind of study can be used by water resource management teams to make more informed decisions regarding the operation of dams to minimize their negative effects and sustain the integrity of the aquatic ecosystem (March *et al.* 1998).

Spatio-temporal changes in water quality and fundamental food sources

Salinity in the river upstream significantly dropped from the average 19 psu (Preedalumprabult *et al.* 1999) to an average of 0.65 psu in this study after the dam was operated. Fluctuations in salinity in both areas caused by opening and closing the sluice gates occasionally depended on the water level in the river, resulting in massive freshwater inflows (Champalbert *et al.* 2007). Another objective of the Pak Panang Project was to neutralize the pH in the river (Prabnarong and Kaewrat 2006) and this was also successful as the pH tended to increase during the closing period. A more productive (i.e. high chlorophyll-a concentration) estuarine area and less productive river area were obviously observed and tended to increase during the opening period in the estuary, which was most likely caused by the nutrient-rich effluent from the river (MacIntyre *et al.* 2000; Struski and Bacher 2006). Although there was no significant difference in temperature during the whole study period, the temperature in the river decreased slightly during the opening phase compared with the closed phase.

There have been no reports on the condition of phytoplankton bloom in the Pak Panang Estuary, either before (Sirimontraporn *et al.* 1997; Preedalumpaburt *et al.* 1999) or after the construction of the dam (Prabnarong and Kaewrat 2006). The fluctuation in the abundance of phytoplankton correlated with the chlorophyll-a concentration. The decrease in both abundance of phytoplankton and chlorophyll-a in Station 3 during the sluice opening compared with the other combinations in the estuary was probably due to light limitation caused by the suspended matter from the river (MacIntyre *et al.* 2000). Thebundance of zooplankton during the closed period in the estuary was similar to the results at the river mouth from the anti-salt dam case in Senegal (Champalbert *et al.* 2007). Champalbert et al. (2007) reported that during the low flow and closing period, marine and euryhaline zooplankton colonized the estuary and moved to the dam. Meanwhile, during the high flow and when freshwater was released, zooplankton in the estuary were less abundant but more diverse and were dominated by freshwater species. The abundance of benthos in the upper dam area is controlled by the fluctuations in water level and sedimentation, which make the bottom unstable (De Brouwer 2000) and this consequently causes a reduction in the benthos in the river zone during the closed period. Moreover, the anoxic condition due to the denitrification process in the upper dam (Downing *et al.* 1999) would also be a response to the change in benthic faunas.

Fish assemblages

Sirimontraporn *et al.* (1997) reported that before the dam was built, 45 estuarine, 39 marine and 34 freshwater species were recorded from the same studied areas (i.e. Stations 1 to 6). The freshwater species, which were not found in the current study, included the rheophilic species such as *Botia* spp. and *Rasbora* spp., which had been abundant in the area even a few years after impoundment (Sritakon *et al.* 2003) and there were many lotic fish species, especially in the Family Cyprinidae (Sirimontraporn *et al.* 1997). Welcomme *et al.* (2006) mentioned that damming near the mouth of a river can either have negative or positive impacts for the fish species in the river system. The lotic species tend to disappear because of an inappropriate rate of river flow and amplitude and duration of flooding. The brackish portion, within the river, is removed from impounded freshwater, which cause the in disappearance of brackish water fish. Meanwhile, the freshwater estuarine fish (i.e. secondary freshwater fish) would benefit since the impounded water would have low salinity and less saline intrusion into the river portion.

In the estuarine area, the species found were similar to the previous study, especially the species of economic importance (FAO 2000; Barbier *et al.* 2002). Low H'-index values in the freshwater portion indicated that it was dominated by few species. Meanwhile the distribution of the fishes in the estuarine area during the closing period was more evenly distributed than during the open period, since the estuarine/marine species dispersed over the whole estuarine sampling area and there were less freshwater visitors. Duldic *et al.* (1997) mentioned that estuarine areas are usually comprised of low trophic level species with high ecological efficiency and productivity, and this was also true in this study as the small-size phytoplankton feeders, such as *E. devisi*, *Leiognathus* spp. and *A. gymnocephalus* were shown to be major contributors to the %IRI in the estuary.

It is widely accepted that the major key factor controlling the fish assemblages in the hypotamonic zone is salinity (Jaureguizar *et al.* 2003; Martino and Able 2003), which also influences the diversity and distribution of the phytoplankton (Huang *et al.* 2004), zooplankton (Champalbert *et al.* 2007) and benthic fauna (Wu and Richards 1981). The high correlation to axis F1 of fish species implies that most of the fish in this study were distributed along the salinity gradient and had complex feeding habits, which were observed in the hypotamonic zone (Hajisamae *et al.* 2003). Diet flexibility is also observed in the freshwater fish, which may relate to fish size, season and location within the system or a combination of all three (Pusey *et al.* 1995). It is also evident that many freshwater fish species show better larvae development and growth when the water is slightly saline (Varsamos *et al.* 2005), especially the secondary freshwater fish (Johnson 1967).

Conclusion

This study illustrates the impacts of water abstraction in the lower river course on key ecological components (i.e. water quality parameters, fundamental food sources for fish and fish assemblages) in the tropical area. Although, the dam is not a permanent barrier, (i.e. opening occasionally), obvious differences due to the operation of the dam (opening/ closing) were observed. The findings concurred with the suggestions by Pringle (1997) that damming the lower reach of a river has effects in terms of ecosystem changes (e.g. water quality, nutrient recycling, and primary productivity) and fish community level changes. Two major topics must be the subject for further study on the effect of the dam operation on (a) the life cycle of diadromy species and (b) the development of marine fish larvae in the delta area, since many larvae occupy that area as the nursery ground and require the optimum salinity and abundance of food resources.

Acknowledgements

This work was supported by the Thailand Research Fund (Grant **TRF RDG 4940011**) for the field data collection. The analyses were conducted under the Franco-Thai Academic Collaboration (Grant **PHC 16598RJ**). We are very grateful to the assistance during the field works of the local fishermen. We thank Prof. Saowapa Angsupanich (Prince of Songkla University), Drs. Kan Janphromma (Walailak University), Padermsak Jaruyabhand (Chulalongkorn University) and Srilaporn Buasai (TRF) for their constructive comments to improve our research work. We also thank Prof. Michael Hare (Ubon Ratchathani University) and Dr. John Woodley (Université Toulouse) for editing and improving the English in the manuscript. Finally, we are grateful to two anonymous referees for providing constructive and valuable comments on the manuscript.

References

Atapattu, S.S. and Kodituwakku D.C. (2009) Agriculture in South Asia and its implications on downstream health and sustainability: A review. *Agricultural Water Management* **96,** 361-373.

Barbier, E. B., Strand, I. and Sathirathai, S. (2002). Do open access conditions affect the valuation of an externality? Estimating the welfare effects of mangrove-fishery linkages in Thailand. *Journal of Environmental and Resource Economics* **21**, 343–367.

Blaber, S.J.M. (2002) ''Fish in hot waters'': the challenges facing fish and fisheries research in tropical estuaries. *Journal of Fish Biology* **61** (Supplement A), 1-20.

Cattanéo, F., Carrel, G. Lamouroux, N. and Breil, P. (2001) Relationship between hydrology and cyprinid reproductive success in the lower Rhône at Montélimar, France. *Archiv für Hydrobiologie* **151,** 427-450.

Chong, V., Sasekumar, A., Leh, M.U.C. and D' Cruz, R. (1990). The fish and prawn communities of a Malaysian coastal mangrove system, with comparison to adjacent mud flats and inshore waters. *Estuarine, Coastal and Shelf Science* **31,** 703-722.

Coastal Resources Institute (1991). Coastal management of the Pak Panang Estuary. Songkla. Prince of Songkla Nakarind University: Songkla (*In Thai*)

Champalbert, G., Pagano, M., Sene, P. and Corbin, D. (2007). Relationships between meso- and macro-zooplankton communities and hydrology in the Senegal River Estuary. *Estuarine, Coastal and Shelf Science* **74,** 381-394.

Christensen, V. (1998). Fishery-induced changes in marine ecosystem: insight from models of the Gulf of Thailand. *Journal of Fish Biology* **53** (Supplement A), 128-142.

Da Costa, K.S., Gourène, G., De Morais, L.T. and Van Den Audenaerde, D. F. E. T. (2000). Caractérisation des peuplements ichtyologiques de deux fleuves côtiers ouest-africains soumis à des aménagements hydroagricoles et hydroélectriques. *Vie Milieu* **50**, 65-77.

De Brouwer, J.F.C., Bjelic, S., De Deckere, E.M.G.T. and Stal, L.J. (2000). Interplay between biology and sedimentology in a mud flat (Biezelingse Ham, Westerschelde, The Netherlands). *Continental Shelf Research* **20**, 1159-1177.

Doledec, S. and Chessel, D. (1994). Co-inertia analysis: an alternative method for studying species-environment relationships. *Freshwater Biology* **31**, 277-294.

Downing, J.A., Mcclain, M., Twilley, R., Melack, J.M., Elser, J., *et al.* (1999). The impact of accelerating land-use change on the N-cycle of tropical aquatic ecosystems: current conditions and projected changes. *Biogeochemistry* **46**, 109–148.

Duldic, J., Kraljevic, M., Grbec, B. and Pallaoro, A. (1997). Composition and temporal fluctuations of inshore juvenile fish populations in the Kornati Archipelago, eastern middle Adriatic. *Marine Biology* **129,** 267-277.

Ecoutin, J.M., Richard, E., Simier, M. and Albaret, J.J. (2005). Spatial versus temporal patterns in fish assemblages of a tropical estuarine coastal lake: The Ebrie´ Lagoon (Ivory Coast). *Estuarine, Coastal and Shelf Science* **64,** 623-635.

Ector L. and Rimet F. (2005). Using bioindicators to assess river in Europe: an overview. In ´Modelling community structure in freshwater ecosystem´. (Eds S. Lek, M. Scardi, P.F.M. Verdonchot, J.P. Descy and Y.S. Park) pp. 7-19. (Springer: Berlin)

FAO (2000) Report of a workshop on the status and management of anchovy fisheries in the Gulf of Thailand. FAO, Field Report No. F6, Rome.

Fievet, E., Tito de Morais, L., Tito de Morais, A., Monti, D. and Tachet H. 2001. Impacts of an irrigation and hydroelectric scheme in a stream with a high rate of diadromy (Guadeloupe,Lesser Antilles): Can downstream alterations affect upstream faunal assemblages? *Archiv für Hydrobiologie* **151**, 405–425.

Froese, R. and Pauly, D. (2007). ‘FishBase, World Wide Web electronic publication’ Available at http://www.fishbase.org (Accessed May to August 2006)

Fukushima, M., Kameya, S., Kaneko, M., Nakao, K. and Steel, E.A. (2007). Modelling the effects of dams on freshwater fish distributions in Hokkaido, Japan. *Freshwater Biology* **52**, 1511-1524.

Guegan, J.F., Lek, S. and Oberdoff, T. (1998). Energy availability and habitat heterogeneity predict global riverine fish diversity. *Nature* **391**, 382-384.

Hajisamae, S., Chou, L.M. and Ibrahim, S. (2003). Feeding habits and trophic organization of the fish community in shallow waters of an impacted tropical habitat. *Estuarine, Coastal and Shelf Science* **58,** 89-98.

Huang, L., Jian, W., Song, X., Huang, X., Liu, S., *et al.* (2004). Species diversity and distribution for phytoplankton of the Pearl River estuary during rainy and dry seasons. *Marine Pollution Bulletin* **49**, 588-596.

Jaureguizar, A.J., Menni, R., Bremec, C., Mianzan, H. and Lasta, C. (2003). Fish assemblage and environmental patterns in the Rı´o de la Plata estuary. *Estuarine, Coastal and Shelf Science* **56,** 921-933.

Johnson, D.S. (1967). Distributional patterns of Malayan freshwater fish. *Ecology* **48,** 722-730.

Jutagate, T., Thappanand, T. and Tabthipwan, P. (2007). Is the sluice gates' management beneficial for spawning migration? The case of shark catfish (*Helicophagus waandersii*) in the Mun below Pak Mun Dam, Thailand. *River Research and Applications* **23,** 87-97.

Lorenzen, C. J. (1967). Determination of chlorophyll and phaeopigments, spectrophotometric equations. *Limnological Oceanography* **12**, 343–346

MacIntyre, H., Kana, T. and Geider, R. (2000). The effect of water motion on short term rates of photosynthesis by marine phytoplankton. *Trends in Plant Science* **5**, 12-17.

Magurran, A.E. (2004). 'Measuring Biological Diversity.' (Blackwell Publishing Company: Oxford)

March, J.G., Benstead, J.P., Pringle, C.M. and Scatena, F.N. (1998) Migratory drift of larval freshwater shrimps in two tropical streams, Puerto Rico. *Freshwater Biology* **40**, 261–273.

March, J., Jonathan G., Benstead, P., Pringle, C.M., and Scatena F.N. 2003. Damming tropical island streams: problems, solutions, and alternatives. *BioScience* **53**, 1069-1078.

Martino, E.J. and Able, K.W. (2003). Fish assemblages across the marine to low salinity transition zone of a temperate estuary. *Estuarine, Coastal and Shelf Science* **56,** 969-987.

Merigoux, S., Ponton, D. and de Merona, B. (1998) Fish richness and species-habitat relationships in two coastal streams of French Guiana, South America. *Environmental Biology of Fishes* **51**, 25–39.

Nelson, J.S. (1976). 'Fishes of the World.' (The University of Alberta: Edmonton)

Pinkas, L., Oliphant, M.S. and Iverson, I.L.K. (1971). Food habits of albacore, blue-fin tuna, and bonito in California waters. *Fish Bulletin* **152**, 1-105.

Prabnarong, P. and Kaewrat, J. (2006). The *Uthokawiphatprasit* Watergate: a man-made change in Pak Panang River Basin. *Walailak Journal of Science and Technology* **3**, 131-143.

Preedalumpaburt, Y., Vorasaya, W. and Thompholkrang, P. (1999). Water quality in Pakpanang River before water gate installation, Nakhon Srithammarat Province. National Institute of Coastal Aquaculture, Technical Paper No. 5/1999, Songkla. (*In Thai*)

Pringle, C.M. (1997) Exploring how disturbance is transmitted upstream: going against the flow. *Journal of North American Benthological Society* **16**, 425-438.

Pringle, C.M., Freeman, M.C. and Freeman, B.J. (2000) Regional effects of hydrologic alterations on riverine macrobiota in the New World: Tropical–temperate comparisons. *BioScience* **5**, 807-823.

Pusey, B.J., Read, M.G. and Arthington, A.H. (1995). The feeding ecology of freshwater fishes in two rivers of the Australian Wet Tropics. *Environmental Biology of Fishes* **43**, 85–103.

R Development Core Team (2008). 'R: A Language and Environment for Statistical Computing.' (R Foundation for Statistical Computing: Vienna)

ROPME (1999) 'Regional Report of the State of the Marine Environment.' Kuwait, (Regional Organization for the Protection of the Marine Environment: Kuwait City)

Sa´, R., Bexiga, C.,Veiga, P., Vieira, L. and Erzini, K. (2006). Feeding ecology and trophic relationships of fish species in the lower Guadiana River Estuary and Castro Marim e Vila Real de Santo Anto´nio Salt Marsh. *Estuarine, Coastal and Shelf Science* **70**, 19-26.

Sheaves, M., Johnston, R., Molony, B. and Shepard, G. (2007) The effect of impoundments on the structure and function of fish fauna in a highly regulated dry tropics estuary. *Estuaries and Coasts* **30**, 507-517.

Sirimontraporn, P., Choonhaparn, A., Sukanan, S., Sritakon, T., Meechukun, A., *et al.* (1997). Surveying on fisheries status in Pakpanang River and delta. National Institute of Coastal Aquaculture, Technical Paper 24/1997, Songkla. (*In Thai*)

Sritakon, T., Ratanachai, C. and Assava-Aree, A. (2003). Species diversity and fishery production in Pak Panang River on 2002. National Institute of Coastal Aquaculture, Technical Paper 1/2003, Songkla. (*In Thai*)

Struski, C. and Bacher, C. (2006). Preliminary estimate of primary production by phytoplankton in Marennes-Ole´ron Bay, France. *Estuarine, Coastal and Shelf Science* **66**, 323-334.

Tongnunui, P., Ikejima, K., Yamane, T., Horinouchi, M., Medej, T., *et al.* (2002). Fish fauna of the Sikao creek mangrove estuary, Trang, Thailand. *Fisheries Science* **68**, 10-17.

Veiga, P., Vieira, L., Bexiga, C., Sa´, R. and Erzini, K. (2006). Structure and temporal variations of fish assemblages of the Castro Marim salt marsh, southern Portugal. *Estuarine, Coastal & Shelf Science* **70**, 27-38.

Varsamos, S., Nebel, C. and Charmantier, G. (2005). Ontogeny of osmoregulation in postembryonic fish: A review. *Comparative Biochemistry and Physiology, Part A* **141**, 401– 429.

Verdoit, M., Pelletier D. and Bellail R. (2003) Are commercial logbook and scientific CPUE data useful for characterizing the spatial and seasonal distribution of exploited populations? The case of the Celtic Sea whiting. *Aquatic Living Resources* **16**, 467-485.

Vörösmarty, C.J., Sharma, K.P., Fekete, B.M., Copeland, A.H., Holden, J., *et al.* (1997) The storage and aging of continental runoff in large reservoir systems of the world. *Ambio* **26**, 210–219.

Ward, J.H. (1963). Hierarchical grouping to optimize and objective function. *American Statistical Association Journal* **58**, 236-244.

Welcomme, R.L., Winemiller, K.O. and Cowx, I.G. (2006). Fish environmental guilds as a tool for assessment of ecological condition of rivers. *River Research and Applications* **22**, 377-396.

Wu, R.S.S. and Richards, J. (1981). Variations in benthic community structure in a sub-tropical estuary. *Marine Biology* **64,** 191-198.

Table 1. Locations and detail of the sampling stations

Station	Co-ordinates (UTM)		Detail of the sampling station
	X	Y	
1	620,901.000	937,198.978	The outer zone of the Pak Panang Bay, where freshwater extremely flushed during the low flood season before the dam was operated
2	622,909.994	933,188.978	The middle zone of the Pak Panang Bay
3	626,281.994	928,891.979	The inner zone of the Pak Panang Bay, where connected to the river mouth
4	632,280.438	918,831.595	The front dam area, where the water is stagnant occasionally.
5	630,948.744	909,096.659	The station that connected to the small creek and peat area
6	624,609.190	893,562.629	The boundary zone in the Pak Panang River, where the saline water extremely intruded during the low flow period before the dam was operated

Table 2. Species composition, occurrence (✓ = presence and o = absence), number and weight of fish collected in the hypopotamon of the Pak Panang River – Bay between March 2006 and June 2007. (Origin: ES = estuarine, FW = freshwater and MA = marine)

Scientific name	Abbrev.	Origin	Economic importance	Occurrence						Number	Weight of individual ± sd (g)
				1	2	3	4	5	6		
Ambassidae											
Ambassis gymnocephalus (Lacepède, 1802)	AMG	ES	N	✓	✓	✓	✓	✓	o	11948	2.51 ± 0.57
Parambassis siamensis (Fowler, 1937)	PASi	ES	N	o	✓	✓	o	o	o	125	0.96 ± 0.63
Anabantidae											
Anabas testudineus (Bloch, 1792)	ANT	FW	Y	o	o	✓	✓	✓	o	4	57.81 ± 5.26
Aploactinidae											
Acanthosphex leurynnis (Jordan and Seale, 1905)	ACL	ES	N	o	o	✓	o	o	o	10	1.80 ± 1.62
Ariidae											
Arius caelatus Valenciennes, 1840	ARC	ES	Y	✓	✓	o	o	o	o	56	79.39 ± 11.19
Hemipimelodus bicolor Fowler, 1935	HEB	ES	Y	✓	o	✓	✓	o	o	12	77.83 ± 6.27
Osteogeneiosus militaris (Linnaeus, 1758)	OSM	ES	Y	✓	✓	✓	✓	✓	o	71	53.87 ± 8.04
Atherinidae											
Atherinomorus duodecimalis (Valenciennes, 1835)	ATD	ES	N	✓	o	o	o	o	o	6	4.78 ± 1.13
Hypoatherina valenciennesi (Bleeker, 1853)	HYV	MA	N	✓	✓	✓	o	o	o	2366	1.84 ± 0.39
Bagridae											
Hemibagrus nemurus (Valenciennes, 1840)	HEN	FW	Y	o	o	o	✓	✓	✓	5	371.28 ± 60.22
Mystus gulio (Hamilton, 1822)	MYG	ES	Y	✓	✓	✓	✓	✓	o	303	63.21 ± 25.68
Mystus singaringan (Bleeker, 1846)	MYS	FW	Y	o	o	o	✓	✓	✓	80	39.07 ± 20.16
Belonidae											
Tylosurus crocodylus (Lesueur, 1821)	TYC	ES	N	✓	✓	✓	o	o	o	70	63.50 ± 31.11
Bregmacerotidae											
Bregmaceros mcclellandi Thompson, 1840	BRM	MA	Y	o	✓	o	o	o	o	10	9.42 ± 0.66

Table 2 (cont.). Species composition, occurrence (✓ = presence and o = absence), number and weight of fish collected in the hypopotamon of the Pak Panang River – Bay between March 2006 and June 2007. (Origin: ES = estuarine, FW = freshwater and MA = marine)

Scientific name	Abbrev.	Origin	Economic importance	Occurrence						Number	Weight of individual ± sd (g)
				1	2	3	4	5	6		
Carangidae											
Carangoides praeustus (Bennett, 1830)	CAP	MA	Y	✓	✓	✓	o	o	o	66	33.41 ± 23.21
Parastromateus niger (Bloch, 1795)	PAN	MA	Y	✓	✓	o	o	o	o	8	82.49 ± 15.03
Channidae											
Channa micropeltes (Cuvier, 1831)	CHM	FW	Y	o	o	o	✓	✓	✓	20	90.77 ± 38.56
Cichlidae											
Oreochromis niloticus Linnaeus, 1758	ORN	FW	Y	o	o	o	✓	✓	o	3	64.26 ± 29.12
Clariidae											
Clarias macrocephalus Günther, 1864	CLM	FW	Y	o	o	o	✓	✓	✓	14	184.14 ± 21.08
Clupeidae											
Anodontostoma chacunda (Hamilton, 1822)	ANC	ES	Y	✓	✓	✓	✓	o	o	2662	55.24 ± 35.03
Coilia macrognathus Bleeker, 1858	COM	MA	N	✓	✓	✓	o	o	o	738	7.09 ± 1.67
Escualosa thoracata (Valenciennes, 1847)	ENT	ES	Y	✓	✓	✓	o	o	o	15704	1.66 ± 0.78
Hilsa kelee (Cuvier, 1829)	HIK	ES	Y	✓	✓	✓	✓	o	o	3247	48.74 ± 11.28
Sardinella gibbosa (Bleeker, 1849)	SAG	MA	Y	✓	✓	✓	o	o	o	402	35.99 ± 6.57
Cobitidae											
Acanthopsis sp.	ACS	FW	Y	o	o	o	o	✓	o	2	34.91 ± 16.22
Cynoglossidae											
Cynoglossus arel (Bloch and Schneider, 1801)	CYAr	ES	Y	✓	✓	✓	o	o	o	1065	9.58 ± 2.47
Cyprinidae											
Barbodes gonionotus (Bleeker, 1850)	BAG	FW	Y	o	o	o	✓	✓	✓	164	76.50 ± 36.34
Cyclocheilichthys apogon (Valenciennes, 1842)	CYA	FW	Y	o	o	o	✓	✓	✓	138	66.39 ± 19.54

Table 2 (cont.). Species composition, occurrence (✓ = presence and o = absence), number and weight of fish collected in the hypopotamon of the Pak Panang River – Bay between March 2006 and June 2007. (Origin: ES = estuarine, FW = freshwater and MA = marine)

Scientific name	Abbrev.	Origin	Economic importance	Occurrence						Number	Weight of individual ± sd (g)
				1	2	3	4	5	6		
Hampala dispar Smith, 1934	HAD	FW	Y	o	o	o	✓	✓	✓	219	97.56 ± 26.39
Hampala macrolepidota (Valenciennes, 1842)	HAM	FW	Y	o	o	o	✓	✓	✓	88	114.12 ± 40.16
Labiobarbus lineata (Sauvage, 1878)	LAL	FW	Y	o	o	o	✓	o	✓	20	42.36 ± 20.17
Osteocheilus hasselti (Valenciennes, 1842)	OSH	FW	Y	o	o	o	✓	✓	✓	64	69.69 ± 17.88
Parachela siamensis (Günther, 1868)	PASa	FW	N	o	o	o	o	o	✓	11	7.82 ± 1.95
Puntius brevis (Bleeker, 1850)	PUB	FW	Y	o	o	✓	✓	✓	✓	4	129.73 ± 28.24
Dasyatidae											
Himantura imbricata (Bloch and Schneider, 1801)	HII	ES	Y	o	✓	✓	o	o	o	5	256.31 ± 28.25
Eleotridae											
Butis butis (Hamilton, 1822).	BUB	ES	N	✓	✓	✓	o	o	o	481	3.19 ± 0.93
Oxyeleotris marmorata (Bleeker, 1852)	OXM	FW	Y	o	o	✓	✓	✓	✓	14	416.34 ± 98.72
Engraulidae											
Encrasicholina devisi (Whitley, 1940)	END	MA	Y	✓	✓	✓	✓	o	o	19488	0.97 ± 0.57
Encrasicholina heteroloba (Rüppell, 1837)	ENH	MA	N	✓	✓	✓	o	o	o	1872	1.79 ± 0.31
Lycothrissa crocodilus (Bleeker, 1851)	LYC	FW	N	o	o	o	✓	o	o	5	3.12 ± 0.56
Stolephorus dubiosus Wongratana, 1983	STD	ES	Y	✓	✓	✓	✓	o	o	2547	3.82 ± 1.17
Thryssa hamiltonii (Gray, 1835)	THH	ES	N	✓	✓	✓	o	o	o	833	0.97 ± 0.34
Gerreidae											
Gerres abbreviatus Bleeker, 1850	GEA	ES	Y	✓	✓	✓	✓	o	o	56	13.11 ± 4.65
Gobiidae											
Acentrogobius caninus (Valenciennes, 1837)	ACC	ES	Y	✓	o	✓	o	o	o	10	6.53 ± 3.71
Aulopareia chlorostigmatoides (Bleeker, 1849)	AUC	ES	Y	o	o	✓	o	o	o	3	10.33 ± 3.95
Glossogobius giuris (Hamilton, 1822)	GLG	ES	N	✓	✓	✓	o	o	o	1582	3.02 ± 1.24

580 Table 2 (cont.). Species composition, occurrence (✓ = presence and o = absence), number and weight of fish collected in the hypopotamon of the Pak Panang River – Bay between March 2006 and June 2007. (Origin: ES = estuarine, FW = freshwater and MA = marine)

Scientific name	Abbrev.	Origin	Economic importance	Occurrence						Number	Weight of individual ± sd (g)
				1	2	3	4	5	6		
Papilogobius reichei	PAR	ES	N	✓	✓	✓	✓	o	o	279	2.50 ± 1.62
Parapocryptes serperaster (Richardson, 1846)	PASe	ES	Y	✓	✓	✓	o	o	o	147	9.75 ± 3.22
Pseudapocryptes lanceolatus (Bloch and Schneider, 1801).	PSL	MA	N	✓	✓	✓	o	o	o	503	5.46 ± 1.65
Taenioides cirratus (Blyth, 1860)	TAC	ES	Y	✓	o	✓	o	o	o	2	5.75 ± 2.03
Trypauchen vagina (Bloch and Schneider, 1801)	TRV	ES	Y	✓	✓	✓	o	o	o	1143	9.81 ± 3.25
Haemulidae											
Pomadasys kaakan (Cuvier, 1830)	POK	ES	Y	o	o	✓	✓	✓	o	5	1,461.68 ± 125.76
Hemirhamphidae											
Hyporhamphus dussumieri (Valenciennes, 1847)	HYD	MA	Y	✓	✓	✓	o	o	o	39	4.62 ± 1.21
Holocentridae											
Sargocentron sp.	SAS	MA	N	o	✓	o	o	o	o	2	0.70 ± 0.14
Leiognathidae											
Leiognathus spp.	LEB	ES	N	✓	✓	✓	✓	✓	o	15241	1.35 ± 0.79
Secuter insidiator	SEI	MA	N	✓	✓	✓	o	o	o	20706	0.64 ± 0.12
Lutjanidae											
Lutjanus russelli (Bleeker, 1849)	LUR	MA	Y	✓	✓	✓	o	o	o	5	74.64 ± 15.23
Mastacembelidae											
Mastacembelus armatus (Lacepède, 1800)	MAA	FW	N	o	o	o	o	✓	o	3	159.42 ± 33.85
Megalopidae											
Megalops cyprinoides (Broussonet, 1782)	MEC	ES	Y	o	o	✓	✓	✓	o	4	296.78 ± 65.32

Table 2 (cont.). Species composition, occurrence (✓ = presence and o = absence), number and weight of fish collected in the hypopotamon of the Pak Panang River – Bay between March 2006 and June 2007. (Origin: ES = estuarine, FW = freshwater and MA = marine)

Scientific name	Abbrev.	Origin	Economic importance	Occurrence						Number	Weight of individual ± sd (g)
				1	2	3	4	5	6		
Mugilidae											
Liza oligolepis (Bleeker, 1859).	LIO	ES	Y	✓	✓	✓	o	o	o	181	10.99 ± 5.24
Liza subviridis (Valenciennes, 1836)	LIS	ES	Y	✓	✓	✓	o	o	o	1350	19.96 ± 10.04
Valamugil cunnesius (Valenciennes, 1836)	VAC	MA	Y	o	✓	✓	o	o	o	3	46.37 ± 19.02
Muraenesocidae											
Muraenesox cinereus Forsskål, 1775)	MUC	MA	Y	✓	✓	✓	o	o	o	31	61.95 ± 10.04
Nandidae											
Pristolepis fasciatus (Bleeker, 1851);	PRF	FW	Y	o	o	✓	✓	✓	✓	188	94.49 ± 33.27
Notopteridae											
Notopterus notopterus (Pallas, 1769)	NON	FW	Y	o	o	o	✓	✓	✓	426	109.16 ± 24.56
Ophichthidae											
Pisodonopis boro (Hamilton, 1822)	PIB	ES	Y	✓	✓	✓	o	o	o	44	41.57 ± 24.63
Osphronemidae											
Osphronemus goramy Lacepède, 1801	OSG	FW	Y	o	o	o	o	✓	o	2	81.51 ± 14.33
Trichogaster pectoralis (Regan, 1910).	TRP	FW	Y	o	o	o	o	✓	✓	2	140.05 ± 50.14
Trichogaster trichopterus (Pallas, 1770)	TRT	FW	Y	o	o	o	o	✓	o	2	15.14 ± 3.97
Platycephalidae											
Grammoplites scarber	GRS	MA	N	✓	✓	✓	o	o	o	655	2.22 ± 0.56
Platycephalidae											
Platycephalus indicus (Linnaeus, 1758)	PLI	ES	Y	✓	✓	✓	o	o	o	92	2.46 ± 0.56
Plotosidae											
Plotosus canius Hamilton, 1822	PLC	ES	Y	✓	✓	✓	o	o	o	49	40.69 ± 17.72

Table 2 (cont.). Species composition, occurrence (✓ = presence and o = absence), number and weight of fish collected in the hypopotamon of the Pak Panang River – Bay between March 2006 and June 2007. (Origin: ES = estuarine, FW = freshwater and MA = marine)

Scientific name	Abbrev.	Origin	Economic importance	Occurrence						Number	Weight of individual ± sd (g)
Polynemidae											
Eleutheronema tetradactylum (Shaw, 1804)	ELT	MA	Y	✓	✓	✓	o	o	o	158	5.99 ± 1.85
Scatophagidae											
Scatophagus argus (Linnaeus, 1766)	SCA	ES	Y	✓	✓	✓	✓	o	o	1481	15.04 ± 12.02
Sciaenidae											
Panna perarmatus (Chabanaud, 1926)	PAP	MA	Y	✓	✓	✓	o	o	o	5339	1.18 ± 0.32
Scombridae											
Rastrelliger brachysoma (Cuvier, 1817)	RAB	MA	Y	✓	✓	o	o	o	o	4	45.00 ± 9.14
Scomberomorus commerson (Lacepède, 1800)	SCC	ES	Y	✓	o	o	o	o	o	2	51.57 ± 7.29
Scorpaenidae											
Vespicula trachinoides (Cuvier, 1829)	VET	ES	N	✓	✓	✓	o	o	o	254	1.02 ± 0.47
Siganidae											
Siganus canaliculatus (Park, 1797).	SIC	ES	Y	✓	✓	✓	o	o	o	6430	1.04 ± 0.65
Sillaginidae											
Sillago sihama (Forsskål, 1775).	SIS	MA	Y	✓	✓	✓	o	o	o	124	6.34 ± 2.21
Siluridae											
Ompok bimaculatus Bloch, 1794)	OMB	FW	Y	o	o	o	o	✓	✓	15	55.71 ± 3.26
Sparidae											
Acanthopagrus berda (Forsskål, 1775).	ACB	MA	Y	✓	✓	✓	o	o	o	20	10.33 ± 4.42
Sphyraenidae											
Sphyraena jello Cuvier, 1829	SPJ	MA	Y	✓	✓	✓	o	o	o	16	71.06 ± 7.01
Stromateidae											
Pampus argenteus (Euphrasen, 1788)	PAA	MA	Y	✓	✓	o	o	o	o	8	55.11 ± 12.12

Table 2 (cont.). Species composition, occurrence (✓ = presence and o = absence), number and weight of fish collected in the hypopotamon of the Pak Panang River – Bay between March 2006 and June 2007. (Origin: ES = estuarine, FW = freshwater and MA = marine)

Scientific name	Abbrev.	Origin	Economic importance	Occurrence						Number	Weight of individual ± sd (g)
Synbranchidae											
Macrotrema caligans (Cantor, 1849)	MAC	ES	Y	✓	✓	✓	o	o	o	34	3.37 ± 1.05
Ophisternon bengalense McClelland, 1844	OPB	ES	Y	✓	o	✓	o	o	o	3	58.43 ± 13.67
Syngnathidae											
Hippichthys penicillus	HIP	ES	N	o	✓	o	o	o	o	11	0.75 ± 0.24
Teraponidae											
Therapon jabua (Forsskål, 1775)	THJ	ES	N	✓	✓	✓	o	o	o	31	38.59 ± 12.41
Tetraodontidae											
Lagocephalus spadiceus (Richardson, 1845)	LAS	MA	N	✓	✓	✓	o	o	o	16	1.26 ± 0.46
Takifugu oblongus (Bloch, 1786)	TAO	ES	N	o	o	✓	o	o	o	7	18.19 ± 6.75
Tetraodon nigroviridis Marion de Procé, 1822	TEN	ES	N	✓	✓	✓	✓	o	o	145	9.43 ± 4.51
Toxotidae											
Toxotes chatareus (Hamilton, 1822)	TOC	ES	Y	o	o	o	✓	✓	✓	10	74.47 ± 20.09
Triacanthidae											
Triacanthus biaculeatus (Bloch, 1786)	TRB	MA	N	o	✓	✓	o	o	o	6	4.96 ± 1.05
Trichiuridae											
Trichiurus lepturus Day, 1865	TRL	MA	Y	✓	✓	✓	o	o	o	73	1.98 ± 0.65

Table 3. Percentage of Index of Relative Importance (%IRI) of fish species (comprising together ≥ 80%) caught in the Pak Panang Bay from March 2006 to June 2008

Mar-06		**Apr-06**		**May-06**		**Jun-06**	
Species	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**
E. devisi	50.1	*S. insidiator*	40.9	*E. devisi*	24.8	*S. insidiator*	34.7
L. subviridis	12.9	*E. devisi*	29.1	*A. chacunda*	16.1	*E. devisi*	20.5
G. guiaris	7.3	*A. gymnocephalus*	6.5	*S. argus*	11.8	*S. argus*	9.4
S. argus	6.8	*S. dubiosus*	5.0	*Leiognathus spp.*	7.7	*A. gymnocephalus*	4.8
C. macrognathus	3.2			*P. perarmatus*	7.4	*A. chacunda*	2.6
				S. dubiosus	6.1	*P. serperaster*	2.3
				A. gymnocephalus	5.1	*P. perarmatus*	2.0
				L. subviridis	3.9	*G. guiaris*	2.0
						M. gulio	1.1
						P. canius	0.8

Jul-06		**Aug-06**		**Sep-06**		**Oct-06**	
Species	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**
A. gymnocephalus	34.9	*Leiognathus spp.*	27.6	*Leiognathus spp.*	42.2	*S. canaliculatus*	39.7
S. insidiator	20.2	*S. dubiosus*	19.0	*A. gymnocephalus*	12.2	*Leiognathus spp.*	18.1
S. dubiosus	10.9	*S. insidiator*	13.6	*E. devisi*	9.7	*T. vagina*	16.7
E. thoracata	7.4	*A. gymnocephalus*	8.8	*S. dubiosus*	9.2	*A. gymnocephalus*	4.2
E. devisi	3.1	*A. chacunda*	8.8	*S. argus*	6.3	*S. argus*	3.8
P. larceolotus	3.1	*E. devisi*	5.1	*P. perarmatus*	6.2		
A. chacunda	2.7						

Table 3 (cont.). Percentage of Index of Relative Importance (%IRI) of fish species (comprising together ≥ 80%) caught in the Pak Panang Bay from March 2006 to June 2008

Nov-06		**Dec-06**		**Jan-07**		**Feb-07**	
Species	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**
Leiognathus spp.	21.4	*Leiognathus spp.*	20.4	*E. devisi*	27.8	*S. argus*	22.3
E. devisi	14.4	*E. devisi*	19.3	*H. valenciennesi*	19.9	*E. devisi*	13.0
A. gymnocephalus	18.3	*P. perarmatus*	13.8	*Leiognathus spp.*	16.5	*C. macrognathus*	12.3
H. kelee	6.6	*A. gymnocephalus*	9.0	*P. perarmatus*	9.2	*P. perarmatus*	9.5
S. argus	5.7	*S. argus*	6.3	*S. gibbosa*	4.1	*E. thorocota*	8.9
L. subviridis	5.2	*A. chacunda*	4.8	*T. vagina*	3.4	*H. valenciennesi*	6.0
L. oligolepis	3.4	*T. vagina*	4.5			*S. canaliculatus*	5.4
S. gibbosa	3.1	*S. canaliculatus*	4.2			*Leiognathus spp.*	2.8
P. serperaster	3.1						

Mar-07		**Apr-07**		**May-07**		**Jun-07**	
Species	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**
T. vagina	15.3	*E. thorocota*	46.1	*E. thorocota*	36.4	*E. thorocota*	39.8
Leiognathus spp.	13.1	*L. subviridis*	13.8	*A. gymnocephalus*	21.3	*A. gymnocephalus*	15.6
Cynoglossus spp.	10.0	*A. gymnocephalus*	7.6	*Leiognathus spp.*	14.3	*L. subviridis*	12.7
Butis spp.	8.9	*Leiognathus spp.*	7.4	*S. argus*	6.1	*H. kelee*	8.4
E. devisi	8.4	*Cynoglossus spp.*	6.4	*Cynoglossus spp.*	5.6	*Leiognathus spp.*	4.7
P. perarmatus	4.3						
G. guiaris	4.2						
S. argus	3.8						
A. gymnocephalus	3.5						
E. thoracata	2.7						
S. subviridis	2.7						
P. larceolotus	2.6						
P. indicus	2.6						

Table 4. Percentage of Index of Relative Importance (%IRI) of fish species (comprising together ≥ 80%) caught in the lower Pak Panang River from March 2006 to June 2008

Mar-06		Apr-06		May-06		Jun-06	
Species	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**
O. militaris	21.8	*N. notopterus*	39.9	*N. notopterus*	33.2	*H. macrolepidota*	35.3
P. fasciatus	20.1	*M. gulio*	14.0	*M. gulio*	17.1	*N. notopterus*	17.5
O. marmorata	15.0	*P. fasciatus*	12.7	*O. hasselti*	14.6	*M. gulio*	14.1
N. notopterus	7.5	*O. hasselti*	10.4	*H. macrolepidota*	9.1	*M. singaringan*	12.0
M. cyprinoides	7.5	*O. militaris*	5.5	*O. militaris*	6.9	*B. gonionotus*	4.9
M. gulio	5.0						
O. hasselti	4.8						

Jul-06		Aug-06		Sep-06		Oct-06	
Species	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**
B. gonionotus	30.5	*N. notopterus*	52.4	*N. notopterus*	32.4	*H. dispar*	42.3
M. gulio	18.0	*O. hasselti*	11.2	*M. gulio*	20.0	*N. notopterus*	22.4
H. dispar	13.6	*P. fasciatus*	6.5	*H. dispar*	10.3	*B. gonionotus*	9.6
N. notopterus	9.3	*B. gonionotus*	5.3	*P. fasciatus*	8.5	*M. gulio*	8.7
M. singaringan	8.8	*H. dispar*	4.6	*H. macrolepidota*	7.7		
				B. gonionotus	6.9		

Table 4 (cont.). Percentage of Index of Relative Importance (%IRI) of fish species (comprising together ≥ 80%) caught in the lower Pak Panang River from March 2006 to June 2008

Nov-06		**Dec-06**		**Jan-07**		**Feb-07**	
Species	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**
M. gulio	22.7	*H. macrolepidota*	23.2	*C. apogon*	25.6	*N. notopterus*	38.0
Leiognathus spp.	15.1	*C. apogon*	20.2	*N. notopterus*	18.4	*B. gonionotus*	20.2
C. apogon	15.0	*N. notopterus*	19.0	*P. fasciatus*	10.8	*M. gulio*	11.8
O. marmorata	7.8	*L.limeata*	16.9	*M. gulio*	8.2	*P. fasciatus*	10.7
T. chatoreus	7.1	*O. militaris*	5.8	*B. gonionotus*	7.5		
H. bicolor	6.2			*O. hasselti*	7.3		
C. macrocephalus	4.3			*H. macrolepidota*	7.0		
O. hasselti	4.0						

Mar-07		**Apr-07**		**May-07**		**Jun-07**	
Species	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**	**Species**	**%IRI**
N. notopterus	50.7	*N. notopterus*	55.3	*N. notopterus*	61.6	*P. fasciatus*	42.0
P. fasciatus	25.6	*P. fasciatus*	20.1	*P. fasciatus*	26.1	*H. dispar*	23.6
B. gonionotus	10.0	*O. militaris*	6.3			*N. notopterus*	17.7

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Figure captions

Fig. 1 Location and map of the Pak Panang River Basin

Fig. 2 Environmental attributes of sampling stations, comparing between sluice closing (C) and opening (O) periods based on mean values among all measured water parameters (numbers indicate the sampling stations)

Fig. 3 Variation in abundance of fundamental food sources, comparing between sluice closing (C) and opening (O) periods among stations (numbers indicate the sampling stations)

Fig. 4 Fluctuations in fish species richness and diversity index between sluice closing (C) and opening (O) periods among stations (numbers indicate the sampling stations)

Fig. 5 Dendrogram of the cluster analysis results corresponding to the combination of stations and months of sampling. The first character represent closed (C) or open (O) periods, the second character represents the sampling stations followed by month of sampling.

Fig. 6 Results of the co-inertia analysis of environmental variables to fish species found in the study (showing only the ecologically dominant species)

Fig.1

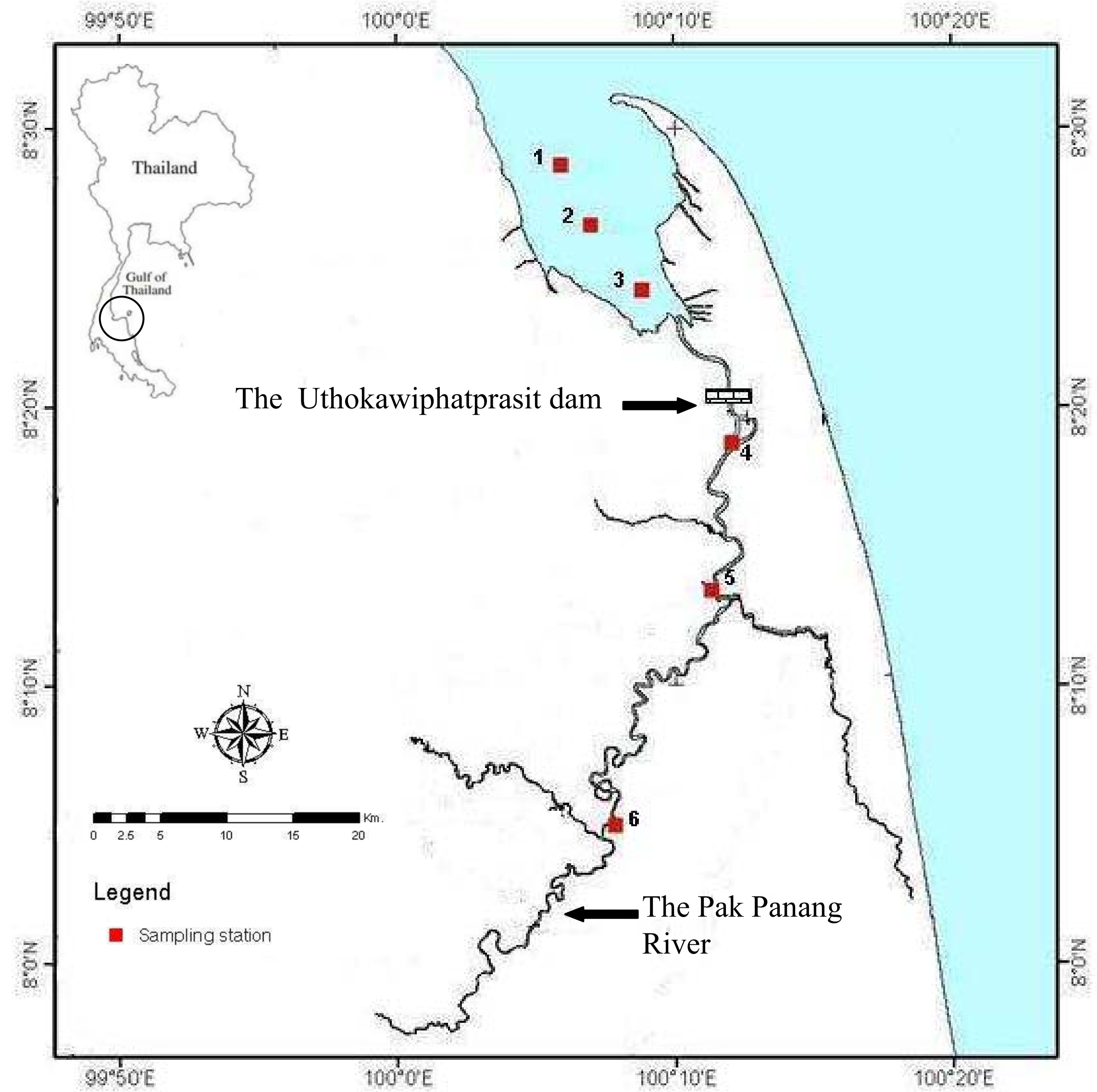

99°50'E
100°0'E
100°10'E
100°20'E
8°30'N
8°20'N
8°10'N
8°0'N
Thailand
Gulf of Thailand
1
2
3
4
5
6
The Uthokawiphatprasit dam
The Pak Panang River
N
E
S
W
0 2.5 5 10 15 20 Km.
Legend
Sampling station

Fig.2

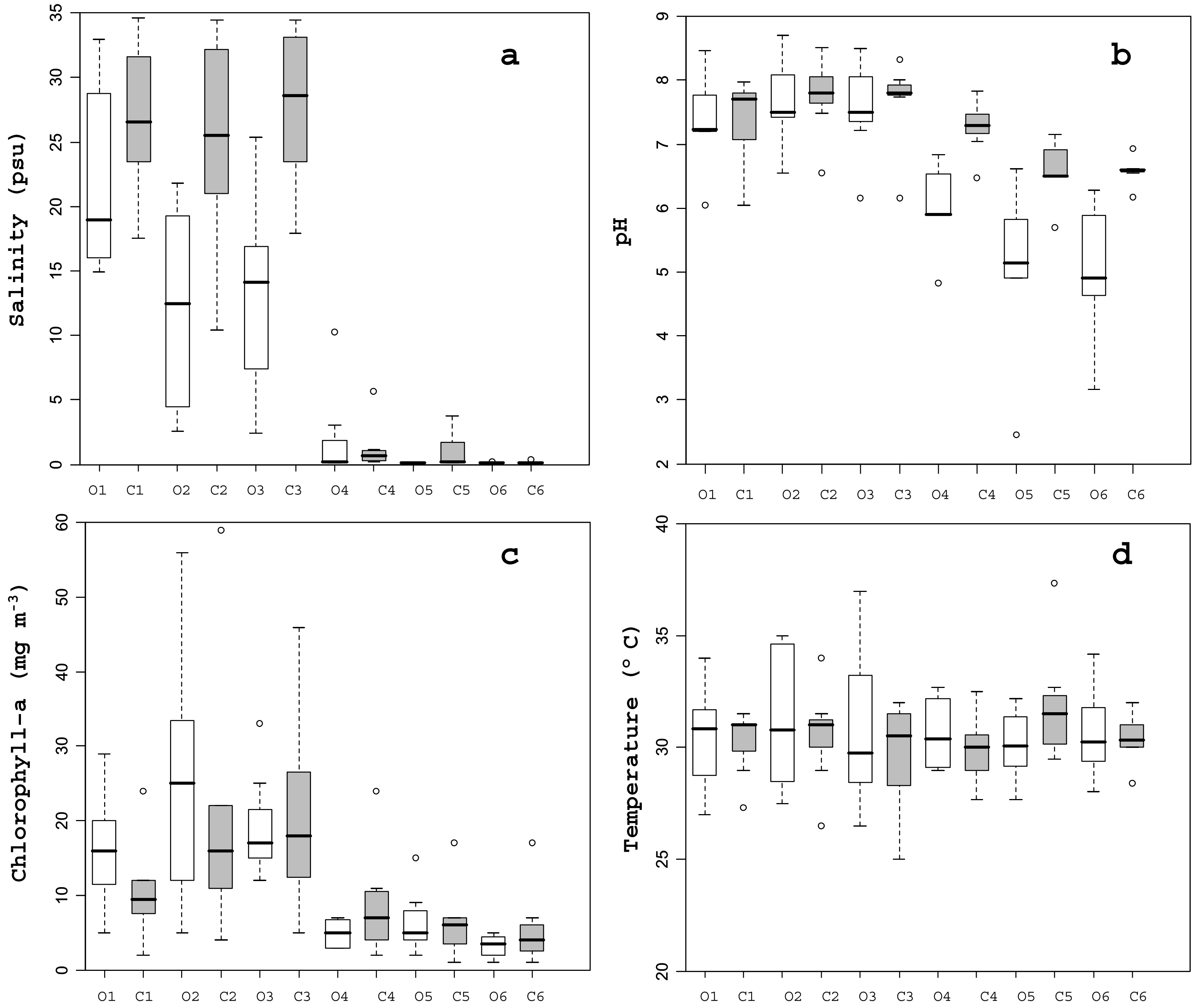

a
b
c
d
Salinity (psu)
pH
Chlorophyll-a (mg m-3)
Temperature (° C)
O1 C1 O2 C2 O3 C3 O4 C4 O5 C5 O6 C6

Fig.3

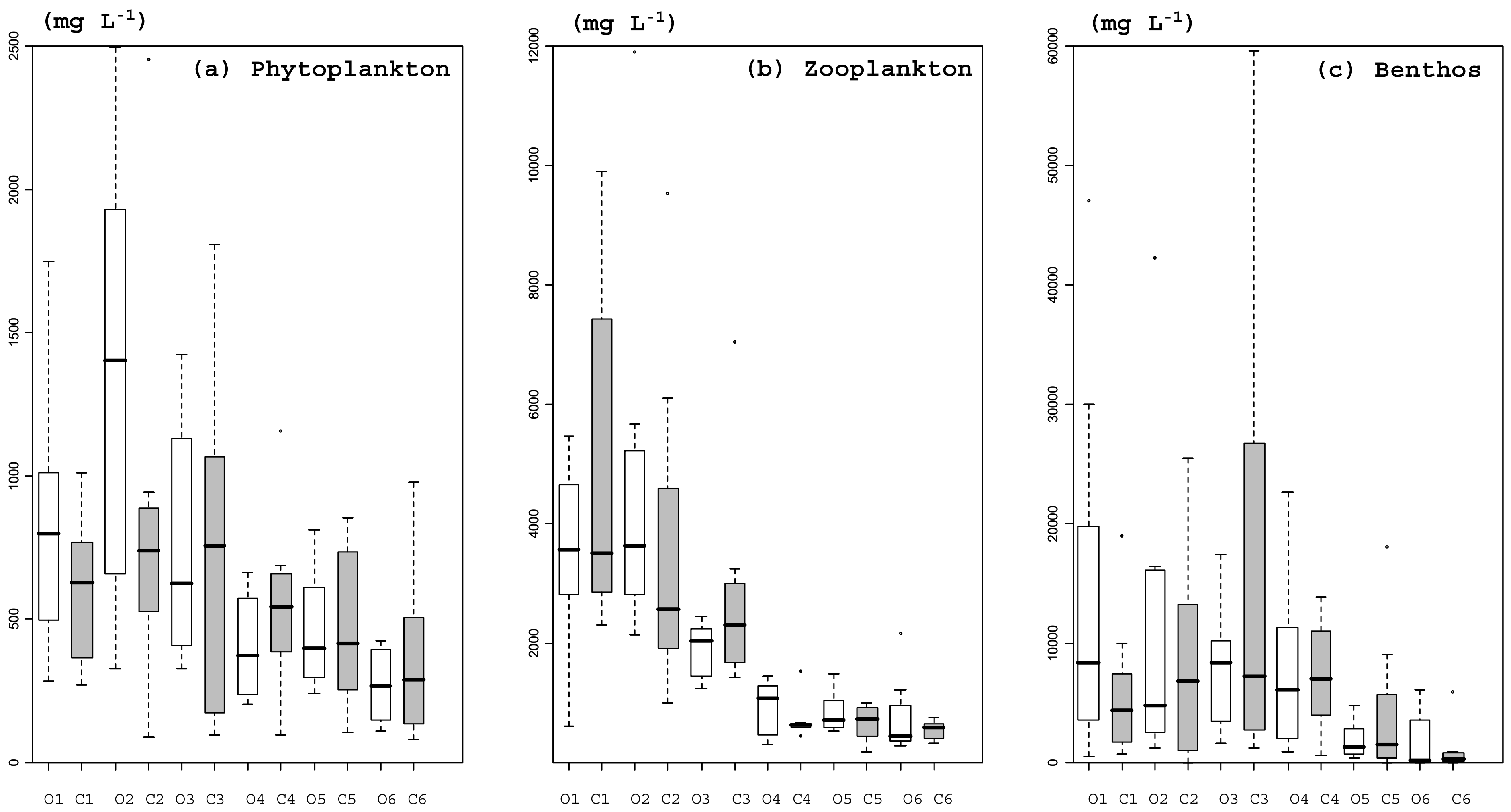

(mg L-1)
(a) Phytoplankton
(b) Zooplankton
(c) Benthos
O1 C1 O2 C2 O3 C3 O4 C4 O5 C5 O6 C6

Fig.4

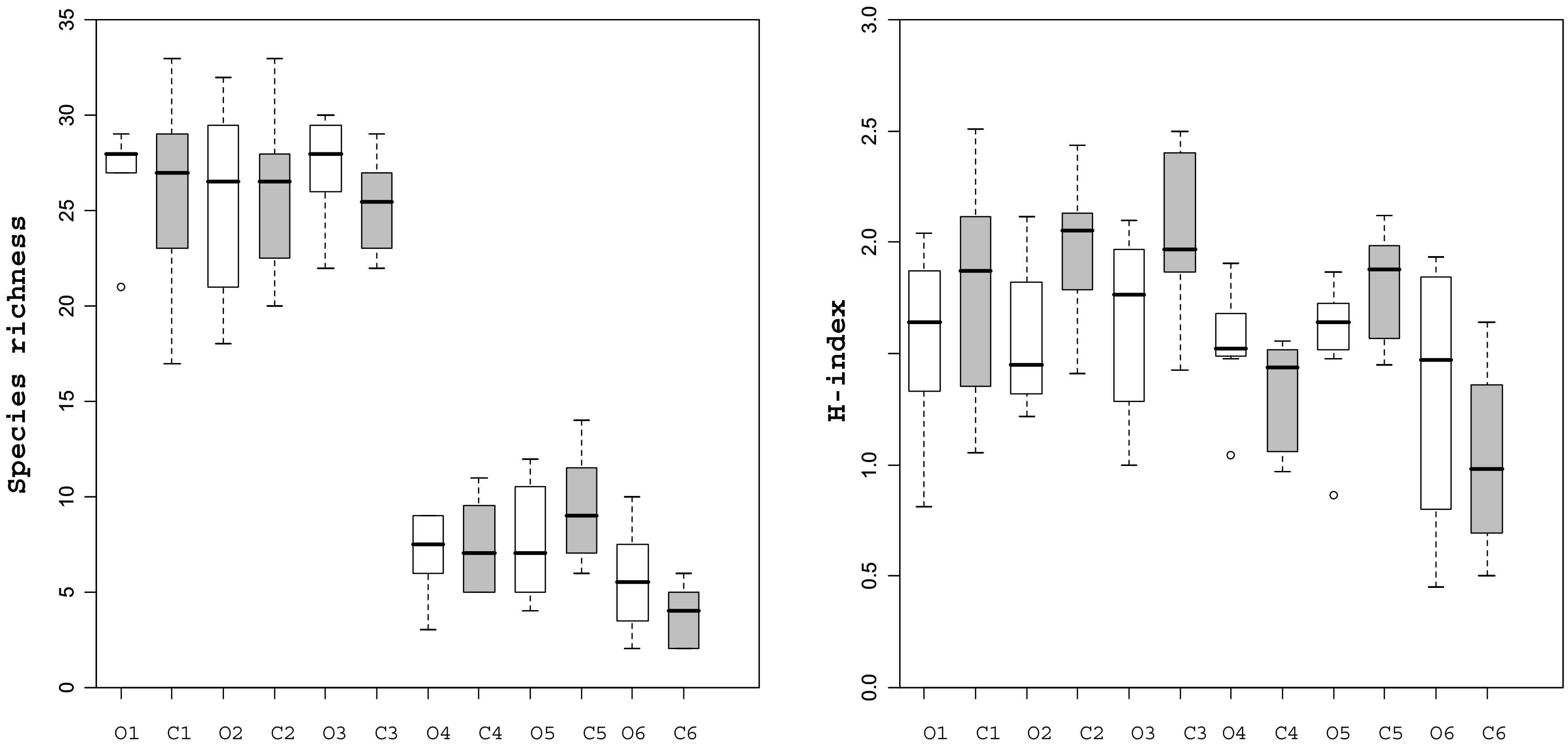
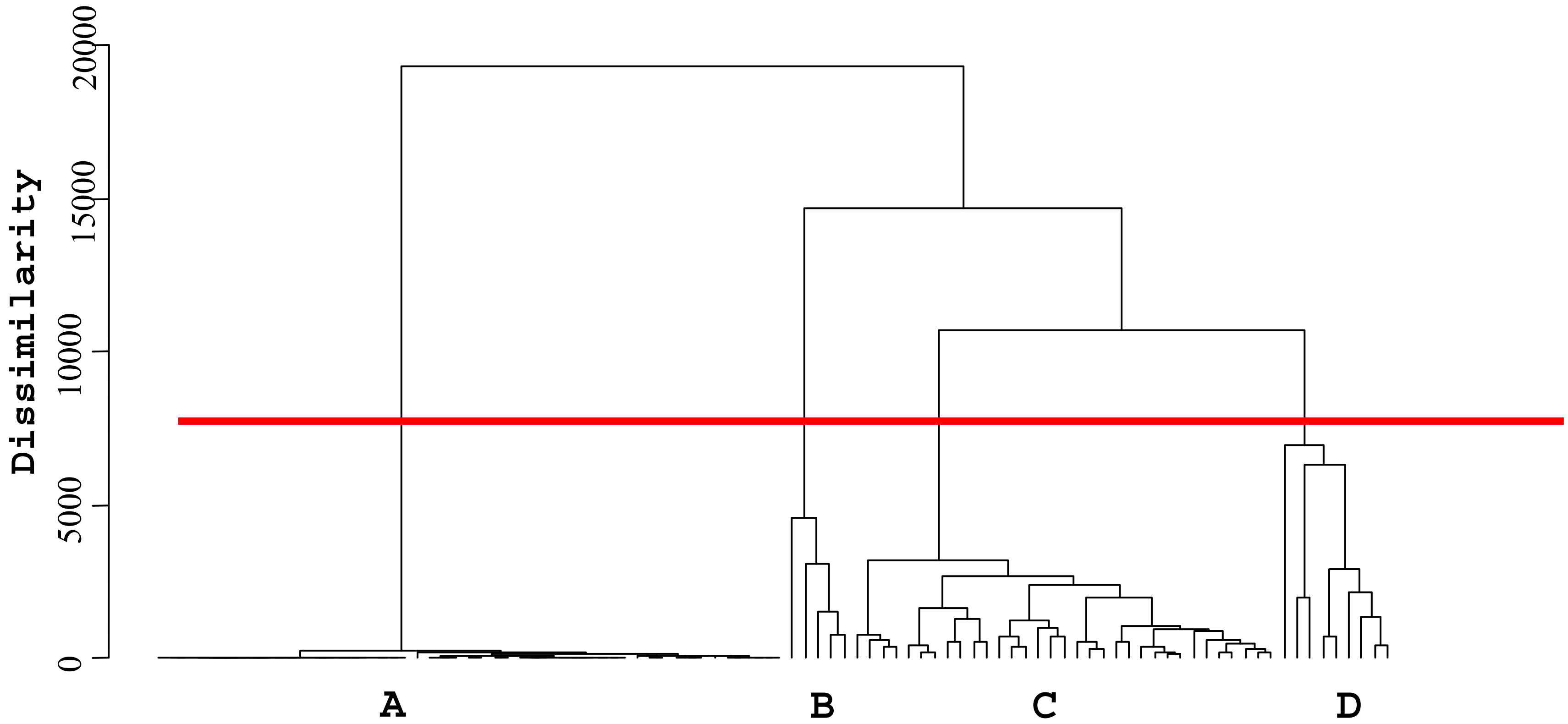

Species richness
0
5
10
15
20
25
30
35
O1 C1 O2 C2 O3 C3 O4 C4 O5 C5 O6 C6
H-index
0.0
0.5
1.0
2.0
2.5
3.0
O1 C1 O2 C2 O3 C3 O4 C4 O5 C5 O6 C6

Fig.5



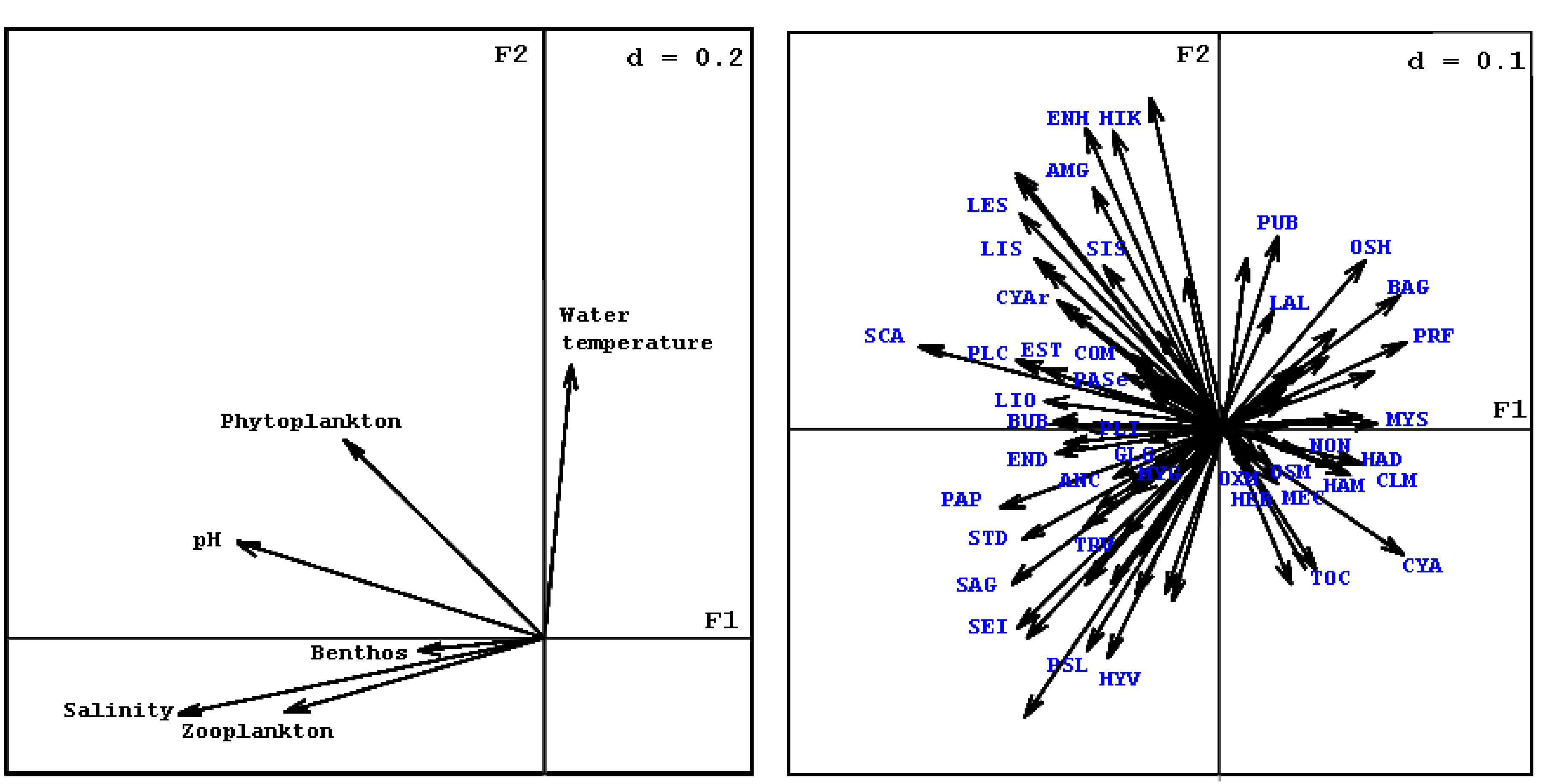
A: C5Feb07, O4Jun06, C4Jul06, O4Oct06, O5Jun06, O5Nov06, O6Jan07, C6Jun07, O5Oct06, C5Jul06, O5May07, C6Apr07, O4Jan07, C5Mar07, C4May06, O4May07, C4Apr07, O5Apr06, C5Jun07, C4Jun07, C4Mar07, C5Sep06, C5Aug06, C4Feb07, C4Aug06, C4Sep06, O6Nov06, C5May06, O4Mar06, O6Oct06, C6Mar07, O6Jun06, C5Apr07, O6Apr06, O4Apr06, O5Jan07, O6Dec06, O5Dec06, C6Feb07, C6May06, O6May07, C6Sep06, C6Aug06, C6Jul06, O6Mar06, O5Mar06, O3Oct06, O3Nov06 and O3Jan07

B: O3Dec06, O3Apr06, O3May07, O4Nov06 and O4Dec06

C: C3Mar07, O2May07, O1May07, O1Jun06, C3Feb07, C1Jun07, O1Nov06, O2Oct06, O2Nov06, C3Sep06, C3Aug06, O1Dec06, C2May06, C1May06, O2Apr06, O3Jun06, C2Jul06, C3Apr07, C2Feb07, C1Feb07, C2Jun07, C3Jun07, O2Jan07, O2Dec06, C3May06, O2Jun06, O1Jan07, O1Oct06, C3Jul06, O1Apr06, O3Mar06, O2Mar06 and O1Mar06

D: C2Mar07, C1Aug06, C1Jul06, C2Sep06, C2Apr07, C2Aug06, C1Mar07, C1Sep06, and C1Apr07

Fig.6


F2
d = 0.2
F1
Water temperature
Phytoplankton
pH
Benthos
Salinity
Zooplankton
F2
d = 0.1
F1
ENH HIK
AMG
LES
LIS
SIS
CYAr
SCA
PLC
EST
COM
PASe
LIO
BUB
PLI
END
GLS
ANC
MYG
PAP
STD
TRV
SAG
SEI
PSL
HYV
PUB
OSH
BAG
LAL
PRF
MYS
NON
HAD
OSM
HAM
CLM
OXM
HEB
MEC
TOC
CYA

ปลาในบริเวณอ่าวและแม่น้ำปากพนังกับการจัดการเขื่อนกั้นความเค็ม, ส่วนที่ 1: การจัดกลุ่มของปลาทะเลและปลาน้ำกร่อย

Fishes in the Pak Panang Bay and River in relation to the anti-salt dam operation, Part I: Assemblage patterns of the marine and brackish water fishes

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Sutheera Thongkhoa[2] and Piyapong Chotipuntu[4]

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บทคัดย่อ

รูปแบบของการจัดกลุ่มของปลาทะเลและปลาน้ำกร่อย ในเชิงพื้นที่และระยะเวลา จากบริเวณแม่น้ำจนถึงอ่าวปากพนัง จ.นครศรีธรรมราช อันเนื่องมาจากการจัดการประตูระบายน้ำเขื่อนอุทกวิภาชประสิทธิ์ เก็บตัวอย่างในช่วงเดือนมีนาคม 2549 ถึงมิถุนายน 2550 จาก 6 สถานีสำรวจ (เหนือเขื่อนและใต้เขื่อน บริเวณละ 3 สถานี) ตัวอย่างที่เก็บจำแนกได้ 70 ชนิดจาก 68 สกุล และ 44 ครอบครัว การวิเคราะห์การจัดกลุ่มของปลาใช้วิธีโครงข่ายประสาทเทียมในรูปแบบแผนที่การจัดรูปแบบตนเอง การผสมผสานของรูปแบบการเปิดและปิดประตูระบายน้ำ-สถานี-เดือนสำรวจ ทำให้สามารถแยกได้ 4 กลุ่ม ซึ่งสัมพันธ์กับบริเวณที่สำรวจและช่วงการเปิดปิดประตูระบายน้ำ ในส่วนของรูปแบบของการจัดกลุ่มของปลาทะเลและปลาน้ำกร่อยสามารถแยกย่อยได้ 4 กลุ่ม ตามความน่าจะเป็นในการปรากฏในแต่ละการผสมผสานและช่วงของความเค็ม กลุ่มทีใหญ่ที่สุดเป็นปลาทะเลที่เข้ามาในบริเวณอ่าวปากพนัง (21 ชนิด) ตามด้วยกลุ่มปลาน้ำกร่อยที่แท้จริง (17 ชนิด) ที่เหลือเป็นกลุ่มปลาน้ำกร่อยที่สามารถทนการเปลี่ยนแปลงความเค็มในช่วงแคบและช่วงกว้างได้ รวมทั้งกลุ่มที่มีแนวโน้มในการอพยพเข้าสู่แม่น้ำเพื่อการสืบพันธุ์ ผลกระทบที่อาจจะเกิดขึ้นในแต่ละกลุ่มเนื่องจากการจัดการประตูระบายน้ำ และแนวทางการศึกษาในอนาคตเพื่อการอนุรักษ์ปลาในกลุ่มดังกล่าวได้อภิปรายไว้ในเอกสารนี้แล้ว

คำสำคัญ: แหล่งน้ำกร่อย, การจัดกลุ่ม, โครงข่ายประสาทเทียม, แผนที่การจัดรูปแบบตนเอง และกลุ่มปลา

Abstract

Spatio-temporal patterns of marine and brackish water fish assemblages gradated from the upstream of the anti-salt dam “Uthokawiphatprasid” dam to the Pak Panang Bay, Nakhon Si Thammmarat Province, southern of Thailand. The samples were collected during March 2006 to June 2007at 6

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sampling sites (each 3 sites, above and below the dam). A total of 70 fish species belonging to 68 genera and 44 families were identified. To analyze patterns of fish assemblages, an artificial neural network (ANN) in the form of the self-organizing map (SOM) was applied. The sample-combinations, i.e. sluice gate regime (opening or closing), sampling stations and months of sampling) were classified into 4 clusters, related to the spatial location and sluice gate regimes. Six assemblage patterns were further explained by the probability of occurrences and ranges of salinity levels. The largest group was the opportunistic marine fishes (21 species) followed by the true brackish water fishes (17 species). Others comprised steno- and eury-haline fishes as well as the anadromy. The likely impacts of each guild due the dam regulations and further studies for conserving these fishes were also discussed.

Key Words: estuary, clustering, artificial neural network, self-organizing map and fish guild

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Introduction

More than 70% of river systems in the tropical area are regulated (Revenga and Kura, 2003), which the water management and infrastructure development are the main driving forces on the modification of the river worldwide (Welcomme *et al.*, 2006). The inevitably consequent impacts on the “goods and services” of the river form such modifications, especially to fish, are experienced and reported elsewhere and the most serious case was occurred when the morphology, hydrology and functioning of river were changed by damming the mainstream *per se* (Marmulla, 2001). Along the river course, the greatest species richness situated at the interface between the freshwater and marine domains, i.e. hypopotamon zone (Blaber, 2002), which comprises of marine-, freshwater- and estuarine- origin fishes. Therefore, once the lower course of the river is fragmented, not only the fish from single origin will be affected but also all the three categories. Among these fishes, the diadromous and amphidromous fishes are the groups that should be taken care since they need to migrate up and down between the estuarine and river portions to complete their life cycles.

The Pak Panang River Basin (Figure 1) is the fertile basin in the southern east coast of Thailand. The Pak Panang River runs through the sea at the Pak Panang Bay in the Gulf of Thailand. In the past couple decades, the increasing of urbanization, deforestation and the needs for household consumption and agricultural activities incorporated with the characteristic of low slope of the lower course of the river results in the longer, both period and time, intrusion of seawater to the Pak Panang River, i.e. from about 50 to 100 km and from 3 to 9 months (Coastal Resources Institute, 1991). In addition, the water in the downstream area of the river is slightly acid, because of peat areas along the river banks (Prabnarong and Kaewrat, 2006). Therefore, in 1995, the plan to construct the Uthokawiphatprasid (meaning “effectively divide fresh- and marine- waters”) Watergate was set and started to operate in 1999. The water gates *per se* locate at 6 km upstream to the delta (Figure 1), with the size of 9 x 20 m^2 and comprises of 10 sluice gates. The major purposes are to prevent intrusion of the saline water into the inner area along the river and keep the freshwater for irrigation (Prabnarong and Kaewrat, 2006). After the construction, the sluice gate operation is in the irregular manner depending on the water level upstream. By doing so, the possibility to move upstream to the lower river portion of the marine and brackish water species are varied according to their tolerance on the changes of environmental factors especially salinity. This paper, therefore, presents the guild classification of the marine and brackish water fishes in the Pak Panang area by using the self-organizing maps according to their assemblages from the bay area to the upper area of the watergate and discussing on the likely affects on each guild due to the Uthokawiphatprasid water gate management.

Materials and methods

Sampling stations and sampling protocols

Six sampling stations were selected as 3 stations in each component, i.e. the estuarine and the river (Figure 1). The stations were fixed by using the Garmin-GPSmap 76CSx. Samplings were conducted monthly during the spring-tide period. The fish sampling, in the estuarine/marine component, the samplings were conducted by using the push net dragging circumscribe the sampling area around 30 min. Meanwhile, the beach net as well as the various mesh size of gillnets were employed by set covering the water column and left overnight before taken off for fish samplings in the freshwater stations. Fish samples were packed in ice and brought to Walailak University 50 km from the Watergate. Fishes were then identified into species level or as far as possible (Nelson 1976; Froese and Pauly, 2007). All fish in the species level was weighed and the numbers in each species were counted. Salinity of water at the sampling stations were obtained from a portable YSI 63-50FT. The field samplings were conducted from March 2006 to June 2007.

Data processing

The self-organizing map (SOM) of Kohonen (Kohonen, 1982) belongs to the artificial neural network (ANN) class technique and is one of the best know neural networks with unsupervised learning rules (Penczak *et al.* 2004). This method is being increasing used by ecologists and successful results in aquatic ecology using this model had been well documented (Lek *et al.* 2005). The detail of sequential SOM algorithm can be retrieved from Kohonen (1995) and Lek and Guégan (1999). In this study, first, a species abundance data set was arranged as a matrix of 96 rows (i.e., the 6 sites sampled on 16 months) and 70 columns (i.e. fish species, which were 44 brackish water species and 26 marine species as shown in Table 1). Each of the 96 samples of the data set can be considered as a vector of 70 dimensions and the samples were presented inform of the combination among sluice gate regime (opening or closing: Table 2), sampling stations and months of sampling (e.g. O3Jan07 or C4Sep07). Species abundance was used in the study since the sampling was done by various gear types and tried to cover all fish species, which can be avoid the bias in calculation of species abundance by using single gear (Hugueny *et al.* 1996). Then, the species data set was patterned by training the SOM.

The architecture of the SOM consisted of two layers of neurons (or nodes): (i) the input layer that was composed of 70 neurons connected to each vector of the data set and (ii) the two-dimensional output layer was composed of 56 neurons (i.e. a rectangular grid with 8 by 7 neurons laidbout on a hexagonal lattice). The 56-neuron grid was chosen because this configuration presented minimum values of both quantization (final quantization error = 0.008) and topographic errors (final topographic error = 0.010), which are used to assess classification quality (Park *et al.* 2003). In the learning process, the data were subjected to the learning network. Then, the weights were trained for a given dataset of the assemblage data matrix and the SOM weights are modified to minimize the distance between weight and input vectors (Gevrey *et al.*, 2004). When an input vector ***x*** (densities of species) is sent through the network, each neuron ***k*** of the output layer computes the summed distance between the weight vector ***w*** and the input vector ***x*** (Park *et al.*, 2005). In this study, the analysis was carried out using the MATLAB software version 7® with ANN-SOM routine developed by S. Lek (Universite´ Paul Sabatier (Toulouse III), France. The Kruskal-Wallis chi-squared test and Mann-Whitney test were used to analyze the statistical difference in each studied parameters. Calculations and graphics were conducted by using Program R (R Development Core Team, 2008)

Results

The species composition of the ichthyofauna collected during this study is shown in Table 1. A total of 70 fish species belonging to 68 genera and 44 families were identified. The most diverse families were brackish water fish species as Gobiidae (8 species) followed by Clupeidade (5 species) and Engraulidae and Tetraodontidae (4 species each). Among the 70 fish species collected, 14 species appeared at least with 50% of occurrence (i.e. found both in estuarine and river components) such as *Ambassis gymnocephalus*, *Osteogeneiosus militaris*, *Leiognathus* spp., *Scatophagus argus* and *Encrasicholina devisi*. Three species were caught only once and they were excluded from the guild classification, which were *Aulopareia chlorostigmatoides*, *Sargocentron* sp. and *Scomberomorus commerson*.

The hierarchical cluster analysis applied to the output matrix extracted from the SOM, classified the samples periods and stations into four clusters (Figure 2). Cluster I included most of the combinations of the river area. Three combinations of the estuarine area, during the opening phase in the river mouth area (i.e. station 3), were included in this cluster *viz*., O3Oct06, O3Nov06 and O3Jan07. Cluster **II** was mixed between the stations 3 and 4 during the opening scheme. Cluster **IV** was exclusively the stations further down to the sea during the closing phase of sluice gates. The remaining combinations of the fish assemblages in the estuarine were in Cluster **III**. The Kruskal-Wallis test showed highly significant differences in species richness between clusters ($p < 0.001$, Figure 3). Cluster **I** displayed the lowest species richness and was significantly different from the rest clusters (Mann-Whitney test, $p < 0.01$). There is no statistical difference among species richness in the remaining clusters (Mann-Whitney test, $p > 0.05$). The outliners in Cluster **I** and wide range of Cluster **II** indicated the occurrence of the marine and brackish water fishes to the river component.

The samples were classified by the SOM according to their species composition in the 56 output nodes, so that each node included samples with similar species. In each SOM map, the dark represents a high occurrence probability of occurrence in each neuron, whereas light is low (Park *et al.*, 2005). A clear gradient distribution on the SOM map can be classified into 6 patterns of assemblages, which the distribution patterns in each assemblage was shown in Figure 4. It can be seen that most of the assemblages were belonged to Cluster **II** to **IV**. In the estuary, fish guilds are distinguished by their responses to water salinity (Welcomme *et al.*, 2006). Therefore, according to the map patterns and range of water salinity of the combinations in each assemblage (Figure 5), the marine and brackish water fishes can be classified into 6 assemblages. In Assemblage **A** (3 species) was the species that intensively abundance in the lower saline area and likely to be the stenohaline species, which can enter to the freshwater portion. Assemblage **Ab** (7 species) represented the small to medium size fishes that prefer in the low salinity but euryhaline. Assemblage **B** (17 species) was the, so called, "true brackish water species", which were permanent residents of estuary system with euryhaline character. Assemblage **Bc** (6 species) was the brackish water fishes, which preferred the higher salinity condition. Assemblage **C** (21 species) was the opportunistic marine fishes, which sometimes enter to the estuary for the feeding and breeding purposes. Lastly, Assemblage **Ca**, which should be the most focus group that comprised marine species that showed the possibility to occasionally enter to the freshwater component. There were 10 species involved in this assemblage.

Discussion

In this study, the numbers of marine and brackish water fish species found were lower than the reported by Sirimontraporn *et al.* (1997) and the diversity of these fishes were lessen in the river portion comparing to the previous study (Sritakon *et al.*, 2003). This difference could be related to the sampling procedure and the types of habitats prospected (Koné *et al.*, 2003) or the affects by the Water gates regulation *per se*. The most diverse of gobies in the delta area is the usual phenomenon in the tropic such as 37 species in Vietnam Delta (Vidthayanon, 2008). The occurrence of many adult pelagic fishes such as *Sphyraena jello* and *Rastrelliger brachysoma* in the estuarine component is likely for the feeding purpose (Blaber, 2002; Hajisamae *et al*., 2003).

Although the hierarchical cluster analysis showed the 4 obvious clusters, the SOM maps exhibited the pattern that the marine and brackish water fish assemblages in the Pak Panang area can be further subdivided into six assemblages according to their probability of occurrence in each neuron. The SOM maps showed the probability of the movement between the brackish water and freshwater of many fish species especially in Assemblages **A**, **Ab**, and **Ca**. The purposes of movement could be feeding (Hajisamae *et al*., 2003), growth out (Varsamos *et al*., 2005) or spawning (Riede, 2004) or mixed together. Moreover, during the prevalence of seawater intrude to the river portion, the stenohaline fishes in Assemblage **A** would have the serious impact. Among the samples, three species in Assemblage **Ca** viz., *Anodontostoma chacunda*, *Liza oligolepis* and *Valamugil cunnesius* were reported as anadromy (McDowall, 1997). Two more species, *Pomadasys kaakan* and *Megalop cyprinoid*, were also claimed by the local fishers that they are anadromy. Thus, to success on the managing for viable diadromy populations, the study on their life cycles and the analysis of carbon and nitrogen stable isotopes, especially in otolith, to confirm the hypotheses that these fishes inhabits both marine and freshwater environments (Hogan *et al*., 2007) are recommended.

As discuss earlier on the involving of the freshwater system to complete their life cycle of fishes in Assemblages **A**, **Ab**, and **Ca**, these species are likely to be Influenced negatively by river mouth dams that impound freshwater in the estuary and remove the brackish component (Welcomme *et al.* 2006). Moreover, the blockage on the upstream migration routes of the anadromous, as well as catadromous, fishes would result in less abundance in the area (Fukushima *et al*., 2007) if the opening period does not comply to the period of fishes moving up- and down- stream. For the remaining assemblages, though the near river-mouth dam regulations have no directly affected to them. It would be envisaged on the impact of the regulation on their food resources. During the closing phase of sluice gates, the nutrients from the river system will be trapped at the fore-bay area (MacIntyre *et al*., 2000) and high turbidity and sediment will be flushed to the delta during the opening phase (Cloern, 1987). Both situations will “more or less” impact the primary producers, i.e. phytoplanktons (Cloern, 1987; MacIntyre *et al*., 2000) and secondary producers, i.e. zooplanktons and benthoses (Champalbert *et al*., 2007) in the estuary.

Conclusion

Classifying marine and brackish water fishes in the Pak Panang area, according to the locations and range of salinity level they occurred, can be made a clear picture on the likely impacts of anti-salt dam operation near the river mouth. Impacts could be ranged from the serious case of the fish cannot complete their life cycle to the extirpation of the species due to reduction in food sources, which both lead to decrease in fish abundance. One would argue that over-fishing could be the main source of problem. However, it is evidence that small and medium sized fishes are unlikely to go extinct from fishing alone as long as the habitats and migration routes are intact (Mattson and Jutagate, 2005) as they showed low to medium resilience (Froese and Pauly, 2007). Another aspect, beyond this study, that should be concerned is the role as nursery ground of the mangrove and near shore area, which the suitable habitat and range of salinity preference of the fish larvae are varied species by species (Tongnunui *et al*., 2002). This issue should be further focused and studied to guarantee the recruitment to sustain the fish stocks as well as the fisheries in Pak Panang Bay.

Acknowledgement

This research article was supported by the Thailand Research Fund (Grant: TRF RDG 4940011 Community Structure of Fishery Resources and Salinity Distribution in Pak Panang River Basin: A Case Study on the Effects of Uthokvibhajaprasid Operation) for the field data collection. The analysis processes were conducted under the Franco-Thai Academic Collaboration (Grant: PHC 16598RJ Conservation of Freshwater Ecosystems to Sustain Fish Biodiversity, a Food Resource for the Near Future, led by Prof. Sovan Lek). We are very grateful to local fishers for their assistance during the field works. We also thank Prof. Saowapa Angsupanich (Prince of Songkla University), Drs. Kan Janphromma (Walailak University), Padermsak Jaruyabhand (Chulalongkorn University) and Srilaporn Buasai (TRF) for their constructive comments to improve our research work.

References

Blaber S.J.M. (2002) "Fish in hot waters": the challenges facing fish and fisheries research in tropical estuaries. Journal of Fish Biology 61 (Supplement A), 1-20.

Champalbert G., Pagano M., Sene P., Corbin D. 2007. Relationships between meso- and macro-zooplankton communities and hydrology in the Senegal River Estuary. Estuarine, Coastal and Shelf Science 74: 381-394.

Cloern J.E. 1987. Turbidity as a control on phytoplankton biomass and productivity in estuaries. Continental Shelf Research 7, 1367-1381.

Froese, R. and Pauly, D. 2007. FishBase, World Wide Web electronic publication. URL http://www.fishbase.org.

Fukushima M., Kameya S., Kaneko M., Nakao K. and Steel E.A. 2007. Modelling the effects of dams on freshwater fish distributions in Hokkaido, Japan. Freshwater Biology 52: 1511-1524.

Gevrey, M., Rimet ,F., Park, Y.S., Giraudel, J.L., Ector L. and Lek S., 2004. Water quality assessment using diatom assemblages and advanced modelling techniques. Freshwater Biology 49, 208–220.

Hajisamae, S., Chou, L.M. and Ibrahim, S. 2003. Feeding habits and trophic organization of the fish community in shallow waters of an impacted tropical habitat. Estuarine, Coastal and Shelf Science 58: 89-98.

Hogan Z., Baird I.G., Radtke, R. and Vander Zanden, M.J. 2007. Long distance migration and marine habitation in the tropical Asian catfish, *Pangasius krempfi*. Journal of Fish Biology 71: 818–832.

Hugueny B., Camara S., Samoura B. and Magassouba M., 1996. Applying an index of biotic integrity based on fish assemblage in West African river. Hydrobiologia 331: 71-78.

Kohonen T. 1982. Self-organized formation of topologically correct feature maps. Biological Cybernetic 63: 201-208.

Kohonen T. 1995. Self-organizing maps. Springer Series in Information Sciences, 2nd edition. Springer, Berlin. 362 pp.

Koné T., Teugels G.G., N'Douba V., Kouamelan E.P. and Gooré Bi G. 2003. Fish assemblages in relation to environmental gradients along a small West African coastal basin, the San Pedro River, Ivory Coast. African Journal of Aquatic Science 28: 163-168.

Lek S. and Guégan J.F. 1999. Artificial neural networks as a tool in ecological modelling, an introduction. Ecological Modelling 120: 65–73.

Lek S., Scardi M., Verdonschot P.F.M., Descy J.P. and Park Y.S. (eds.) 2005. Modelling community structure in freshwater ecosystems. Springer, Berlin. 518 pp.

MacIntyre H., Kana T. and Geider R. 2000. The effect of water motion on short term rates of photosynthesis by marine phytoplankton. Trends in Plant Science 5: 12-17.

Marmulla G. (ed.). 2001. Dams, fish and fisheries: opportunities, challenges and conflict resolution. FAO Fisheries Technical Paper No. 419. 164 pp.

Mattson, N.S. and Jutagate, T. 2006. Integrated Basin Flow Management Specialist Report IBFM7-10: Fisheries Water Utilization Program / Environment Program. Mekong River Commission, Vientiane, Lao PDR. 65 p.

McDowall R.M., 1999. Different kinds of diadromy: different kinds of conservation problems. ICES Journal of Marine Science 56:410-413.

Nelson, J.S. 1976. Fishes of the World. The University of Alberta, Edmonton. 416 pp.

Park Y.S., Cereghino R., Compin A. and Lek S. 2003. Applications of artificial neural networks for patterning and predicting aquatic insect species richness in running waters. Ecol. Model. 160, 265-280.

Park, Y.S., Chang, J., Lek, S., Cao, W., Brosse, S., 2003. Conservation strategies for endemic fish species threatened by the Three George Dam. Conservation Biology 17, 1748-1758.

Penczak T., Lek S., Godinho F. and Agostinho A.A. 2004. Patterns of fish assemblages in tropical streamlets using SOM algorithm and conventional statistical methods. Ecohydrology and Hydrobiology 4: 139-146.

R Development Core Team, 2008. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna. URL http://www.R-project.org.

Riede K. 2004. Global register of migratory species-from global to regional scales. Federal Agency for Nature Conservation, Bonn. 330 pp.

Revenga C. and Kura Y. 2003. Status and Trends of Biodiversity of Inland Water Ecosystems. Secretariat of the Convention on Biological Diversity, Montreal Technical Series No. 11. 119 pp.

Sirimontreporn P., Choonhaparn A., Sukanan S., Sritakon T., Meechukun A. and Choosrirat L. 1997. Surveying on fisheries status in Pakpanang River and delta. National Institute of Coastal Aquaculture, Technical Paper 24/1997, Songkla.64 pp. (In Thai)

Sritakon T., Ratanachai C. and Assava-Aree A. 2003. Species diversity and fishery production in Pak Panang River on 2002. National Institute of Coastal Aquaculture, Technical Paper 1/2003, Songkla. 22 pp. (In Thai)

Tongnunui P., Ikejima K., Yamane T., Horinouchi M., Medej T., Sano M., Kurokura H. and Taniuchi T. 2002. Fish fauna of the Sikao creek mangrove estuary, Trang, Thailand. Fisheries Science 68, 10-17.

Varsamos S., Nebel C. and Charmantier G. 2005. Ontogeny of osmoregulation in postembryonic fish: A review. Comparative Biochemistry and Physiology, Part A 141: 401– 429.

Vidthayanon, C. 2008. Field guide to fishes of the Mekong Delta. Mekong River Commission, Vientiane. 288 pp.

Welcomme R.L., Winemiller, K.O. and Cowx, I.G. (2006) Fish environmental guilds as a tool for assessment of ecological condition of rivers. River Research and Applications (22): 377-396.

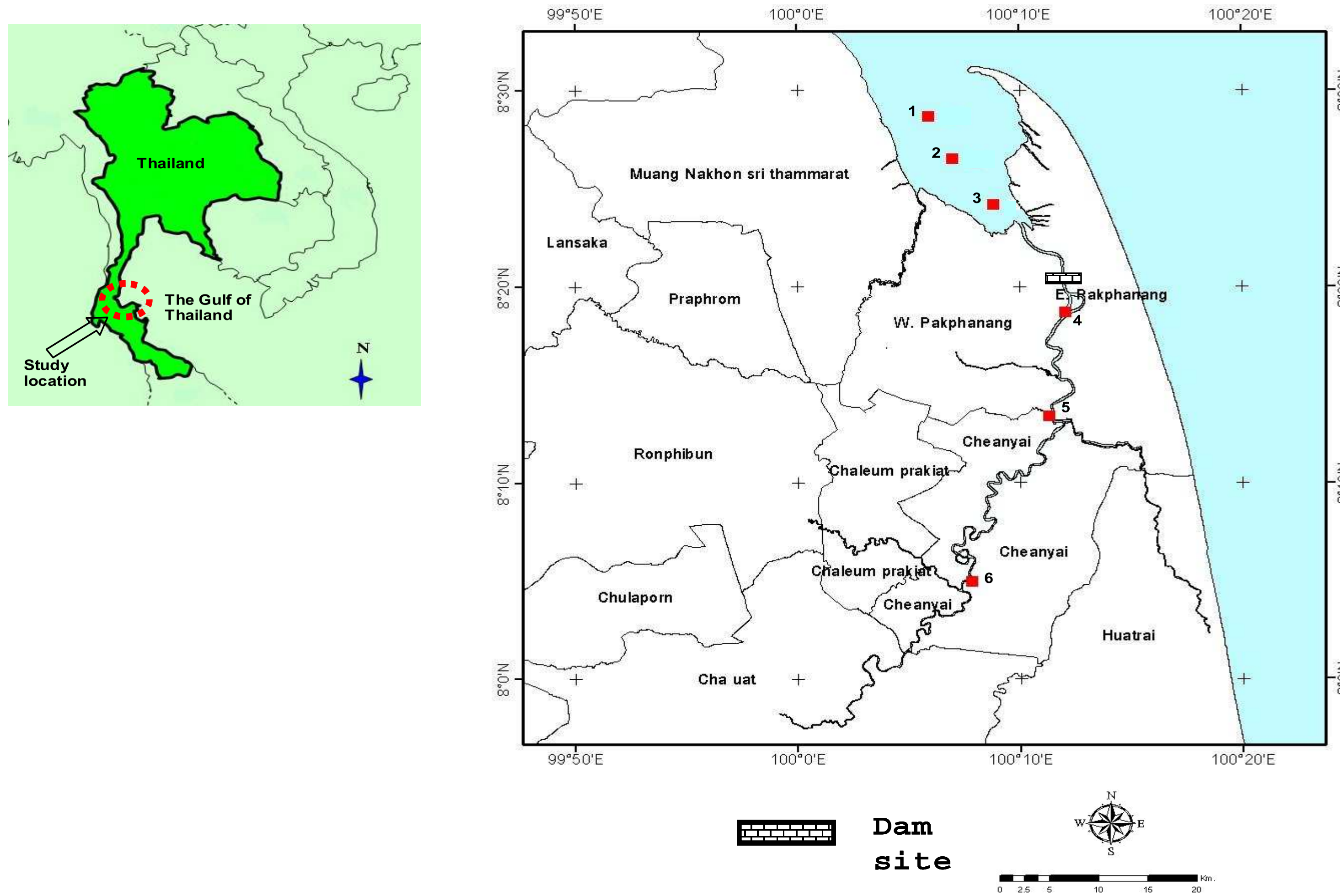


Figure 1 Location of study area and sampling stations

Table 1. Species composition, occurrence (✓ = presence and o = absence), number and weight of fish collected in the Pak Panang River – Bay in March 2006 to June 2007. (Origin: BR = brackish water and MA = marine)

Family	Scientific name	Abbrev.	Origin	Economic importance	Occurrence						Number	Individual weight (g) ± sd
					I	II	III	IV	V	VI		
Ambassidae	*Ambassis gymnocephalus*	AMG	ES	N	✓	✓	✓	✓	✓	o	11948	2.51 ± 0.57
	Parambassis siamensis	PASi	ES	N	o	✓	✓	o	o	o	125	0.96 ± 0.63
Aploactinidae	*Acanthosphex leurynnis*	ACL	ES	N	o	o	✓	o	o	o	10	1.80 ± 1.62
Ariidae	*Arius caelatus*	ARC	ES	Y	✓	✓	o	o	o	o	56	79.39 ± 11.19
	Hemipimelodus bicolor	HEB	ES	Y	✓	o	✓	✓	o	o	12	77.83 ± 6.27
	Osteogeneiosus militaris	OSM	ES	Y	✓	✓	✓	✓	✓	o	71	53.87 ± 8.04
Atherinidae	*Atherinomorus duodecimalis*	ATD	ES	N	✓	o	o	o	o	o	6	4.78 ± 1.13
	Hypoatherina valenciennesi	HYV	MA	N	✓	✓	✓	o	o	o	2366	1.84 ± 0.39
Bagridae	*Mystus gulio*	MYG	ES	Y	✓	✓	✓	✓	✓	o	303	63.21 ± 25.68
Belonidae	*Tylosurus crocodylus*	TYC	ES	N	✓	✓	✓	o	o	o	70	63.50 ± 31.11
Bregmacerotidae	*Bregmaceros mcclelandi*	BRM	MA	Y	o	✓	o	o	o	o	10	9.42 ± 0.66
Carangidae	*Carangoides praeustus*	CAP	MA	Y	✓	✓	✓	o	o	o	66	33.41 ± 23.21
	Parastromateus niger	PAN	MA	Y	✓	✓	o	o	o	o	8	82.49 ± 15.03
Clupeidae	*Anodontostoma chacunda*	ANC	ES	Y	✓	✓	✓	✓	o	o	2662	55.24 ± 35.03
	Coilia macrognathus	COM	MA	N	✓	✓	✓	o	o	o	738	7.09 ± 1.67
	Escualosa thoracata	ENT	ES	Y	✓	✓	✓	o	o	o	15704	1.66 ± 0.78
	Hilsa kelee	HIK	ES	Y	✓	✓	✓	✓	o	o	3247	48.74 ± 11.28
	Sardinella gibbosa	SAG	MA	Y	✓	✓	✓	o	o	o	402	35.99 ± 6.57

Table 1 (Cont.) Species composition, occurrence (✓ = presence and o = absence), number and weight of fish collected in the Pak Panang River – Bay in March 2006 to June 2007. (Origin: BR = brackish water and MA = marine)

Family	Scientific name	Abbrev.	Origin	Economic importance	Occurrence I	II	III	IV	V	VI	Number	Individual weight (g) ± sd
Cynoglossidae	*Cynoglossus arel*	CYAr	ES	Y	✓	✓	✓	o	o	o	1065	9.58 ± 2.47
Dasyatidae	*Himantura imbricata*	HII	ES	Y	o	✓	✓	o	o	o	5	256.31 ± 28.25
Eleotridae	*Butis butis*	BUB	ES	N	✓	✓	✓	o	o	o	481	3.19 ± 0.93
Engraulidae	*Encrasicholina devisi*	END	MA	Y	✓	✓	✓	✓	o	o	19488	0.97 ± 0.57
	Encrasicholina heteroloba	ENH	MA	N	✓	✓	✓	o	o	o	1872	1.79 ± 0.31
	Stolephorus dubiosus	STD	ES	Y	✓	✓	✓	✓	o	o	2547	3.82 ± 1.17
	Thryssa hamiltonii	THH	ES	N	✓	✓	✓	o	o	o	833	0.97 ± 0.34
Gerreidae	*Gerres abbreviatus*	GEA	ES	Y	✓	✓	✓	✓	o	o	56	13.11 ± 4.65
Gobiidae	*Acentrogobius caninus*	ACC	ES	Y	✓	o	✓	o	o	o	10	6.53 ± 3.71
	Aulopareia chlorostigmatoides	AUC	ES	Y	o	o	✓	o	o	o	3	10.33 ± 3.95
	Glossogobius giuris	GLG	ES	N	✓	✓	✓	o	o	o	1582	3.02 ± 1.24
	Papillogobius reichei	PAR	ES	N	✓	✓	✓	✓	o	o	279	2.50 ± 1.62
	Parapocryptes serperaster	PASe	ES	Y	✓	✓	✓	o	o	o	147	9.75 ± 3.22
	Pseudapocryptes lanceolatus	PSL	MA	N	✓	✓	✓	o	o	o	503	5.46 ± 1.65
	Taenioides cirratus	TAC	ES	Y	✓	o	✓	o	o	o	2	5.75 ± 2.03
	Trypauchen vagina	TRV	ES	Y	✓	✓	✓	o	o	o	1143	9.81 ± 3.25
Haemulidae	*Pomadasys kaakan*	POK	ES	Y	o	o	✓	✓	✓	o	5	1,461.68 ± 125.76
Hemirhamphidae	*Hyporhamphus dussumieri*	HYD	MA	Y	✓	✓	✓	o	o	o	39	4.62 ± 1.21

Table 1 (Cont.) Species composition, occurrence (✓ = presence and o = absence), number and weight of fish collected in the Pak Panang River – Bay in March 2006 to June 2007. (Origin: BR = brackish water and MA = marine)

Family	Scientific name	Abbrev.	Origin	Economic importance	Occurrence						Number	Individual weight (g) ± sd
					I	II	III	IV	V	VI		
Holocentridae	*Sargocentron* sp.	SAS	MA	N	o	✓	o	o	o	o	2	0.70 ± 0.14
Leiognathidae	*Leiognathus spp.*	LEB	ES	N	✓	✓	✓	✓	✓	o	15241	1.35 ± 0.79
	Secuter insidiator	SEI	MA	N	✓	✓	✓	o	o	o	20706	0.64 ± 0.12
Lutjanidae	*Lutjanus russelli*	LUR	MA	Y	✓	✓	✓	o	o	o	5	74.64 ± 15.23
Megalopidae	*Megalops cyprinoides*	MEC	ES	Y	o	o	✓	✓	✓	o	4	296.78 ± 65.32
Mugilidae	*Liza oligolepis*	LIO	ES	Y	✓	✓	✓	o	o	o	181	10.99 ± 5.24
	Liza subviridis	LIS	ES	Y	✓	✓	✓	o	o	o	1350	19.96 ± 10.04
	Valamugil cunnesius	VAC	MA	Y	o	✓	✓	o	o	o	3	46.37 ± 19.02
Muraenesocidae	*Muraenesox cinereus*	MUC	MA	Y	✓	✓	✓	o	o	o	31	61.95 ± 10.04
Ophichthidae	*Pisodonopis boro*	PIB	ES	Y	✓	✓	✓	o	o	o	44	41.57 ± 24.63
Platycephalidae	*Grammoplites scarber*	GRS	MA	N	✓	✓	✓	o	o	o	655	2.22 ± 0.56
Platycephalidae	*Platycephalus indicus*	PLI	ES	Y	✓	✓	✓	o	o	o	92	2.46 ± 0.56
Plotosidae	*Plotosus canius*	PLC	ES	Y	✓	✓	✓	o	o	o	49	40.69 ± 17.72
Polynemidae	*Eleutheronema tetradactylum*	ELT	MA	Y	✓	✓	✓	o	o	o	158	5.99 ± 1.85
Scatophagidae	*Scatophagus argus*	SCA	ES	Y	✓	✓	✓	✓	o	o	1481	15.04 ± 12.02
Sciaenidae	*Panna perarmatus*	PAP	MA	Y	✓	✓	✓	o	o	o	5339	1.18 ± 0.32
Scombridae	*Rastrelliger brachysoma*	RAB	MA	Y	✓	✓	o	o	o	o	4	45.00 ± 9.14
	Scomberomorus commerson	SCC	ES	Y	✓	o	o	o	o	o	2	51.57 ± 7.29

Table 1 (Cont.) Species composition, occurrence (✓ = presence and o = absence), number and weight of fish collected in the Pak Panang River – Bay in March 2006 to June 2007. (Origin: BR = brackish water and MA = marine)

Family	Scientific name	Abbrev.	Origin	Economic importance	Occurrence						Number	Weight of individual ± sd (g)
					I	II	III	IV	V	VI		
Scorpaenidae	*Vespicula trachinoides*	VET	ES	N	✓	✓	✓	o	o	o	254	1.02 ± 0.47
Siganidae	*Siganus canaliculatus*	SIC	ES	Y	✓	✓	✓	o	o	o	6430	1.04 ± 0.65
Sillaginidae	*Sillago sihama*	SIS	MA	Y	✓	✓	✓	o	o	o	124	6.34 ± 2.21
Sparidae	*Acanthopagrus berda*	ACB	MA	Y	✓	✓	✓	o	o	o	20	10.33 ± 4.42
Sphyraenidae	*Sphyraena jello*	SPJ	MA	Y	✓	✓	✓	o	o	o	16	71.06 ± 7.01
Stromateidae	*Pampus argenteus*	PAA	MA	Y	✓	✓	o	o	o	o	8	55.11 ± 12.12
Synbranchidae	*Macrotrema caligans*	MAC	ES	Y	✓	✓	✓	o	o	o	34	3.37 ± 1.05
	Ophisternon bengalense	OPB	ES	Y	✓	o	✓	o	o	o	3	58.43 ± 13.67
Syngnathidae	*Hippichthys penicillus*	HIP	ES	N	o	✓	o	o	o	o	11	0.75 ± 0.24
Teraponidae	*Therapon jabua*	THJ	ES	N	✓	✓	✓	o	o	o	31	38.59 ± 12.41
Tetraodontidae	*Lagocephalus spadiceus*	LAS	MA	N	✓	✓	✓	o	o	o	16	1.26 ± 0.46
	Takifugu oblongus	TAO	ES	N	o	o	✓	o	o	o	7	18.19 ± 6.75
	Tetraodon nigroviridis	TEN	ES	N	✓	✓	✓	✓	o	o	145	9.43 ± 4.51
Toxotidae	*Toxotes chatareus*	TOC	ES	Y	o	o	o	✓	✓	✓	10	74.47 ± 20.09
Triacanthidae	*Triacanthus biaculeatus*	TRB	MA	N	o	✓	✓	o	o	o	6	4.96 ± 1.05
Trichiuridae	*Trichiurus lepturus*	TRL	MA	Y	✓	✓	✓	o	o	o	73	1.98 ± 0.65

Table 2 Operation of the Uthokvibhajaprasid water gates and discharges during the study period.

Month	Duration of opening (days)	Opening period (hours)	Discharged volume (10^6 m^3)
Mar-06	7	76	22.9
Apr-06	18	177	84.3
May-06	0	0	0
Jun-06	6	117	36
Jul-06	0	0	0
Aug-06	0	0	0
Sep-06	0	0	0
Oct-06	24	217	176.2
Nov-06	26	341	453.2
Dec-06	9	112	104.1
Jan-07	22	208	163.5
Feb-07	0	0	0
Mar-07	0	0	0
Apr-07	0	0	0
May-07	18	217	236.1
Jun-07	0	0	0

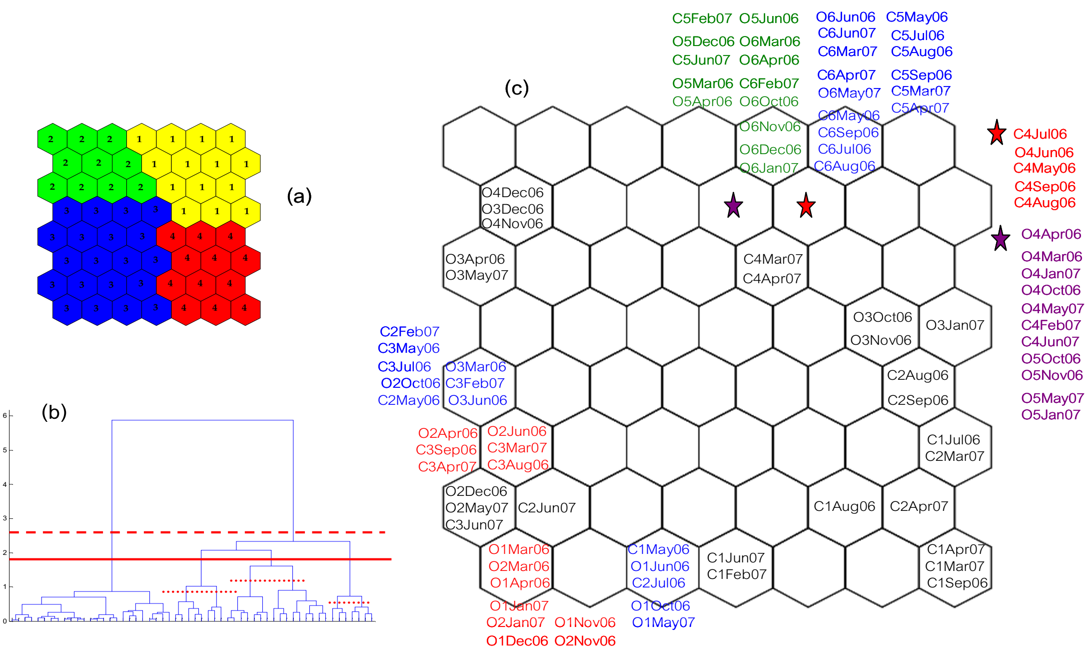


Figure 2 **(a)** Self-organizing map with the four colors correspond to the clusters **(b)** Hierarchical clustering of the SOM nodes with a Ward linkage method **(c)** Classification of combinations through the learning process of the self-organizing map.

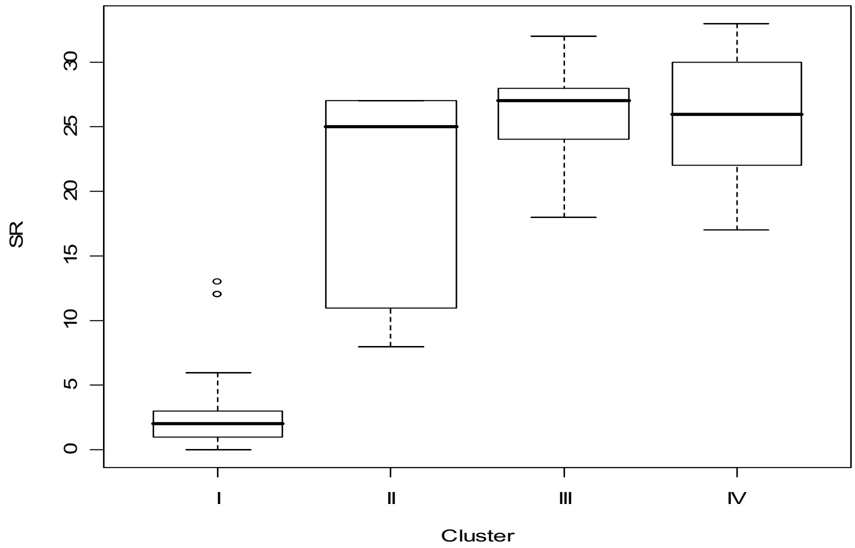


Figure 3 Boxplot comparing fish species richness (SR) in the four clusters defined by the self-organizing map.

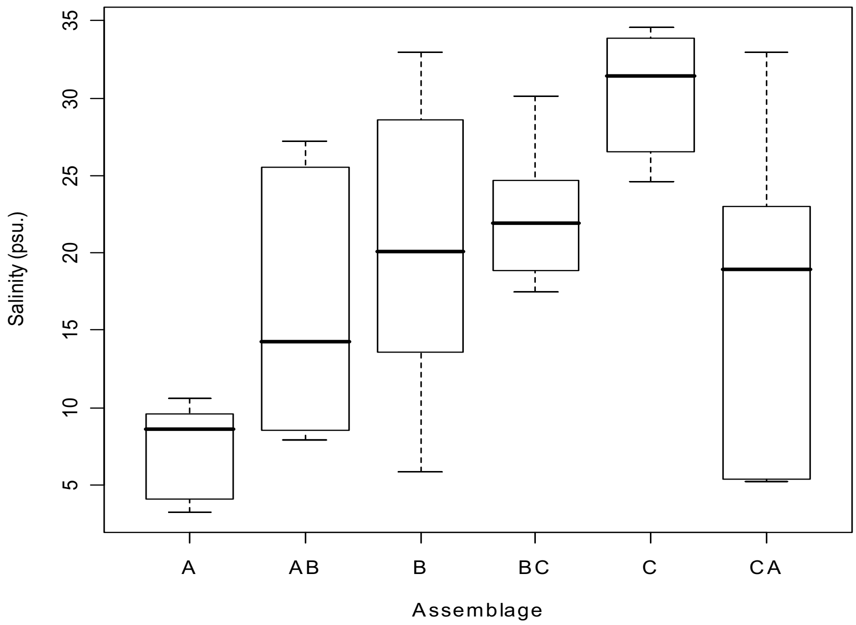


Figure 4 Boxplot comparing fish salinity in the six assemblages.

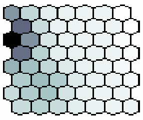
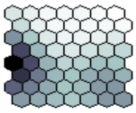
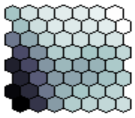
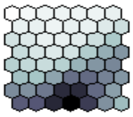
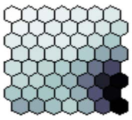
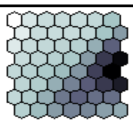
	**Assemblage A:** *Acentrogobius caninus*, *Acanthosphex leurynnis* and *Parapocryptes serperaster*
	**Assemblage Ab:** *Vespicula trachinoides*, *Trypauchen vagina*, *Tetraodon nigroviridis*, *Takifugu oblongus*, *Butis butis*, *Platycephalus indicus, Parambassis siamensis* and *Siganus canaliculatus*
	**Assemblage B:** *Hilsa kelee*, *Gerres abbreviatus*, *Ambassis gymnocephalus*, *Encrasicholina devisi*, *Cynoglossus arel*, *Glossogobius guiaris*, *Leiognathus* spp., *Mystus gulio*, *Liza subviridis*, *Lutjanus russelli*, *Sillago sihama*, *Gerres abbreviatus*, *Osteogeneiosus militaris*, *Pisodonophis boro*, *Atherinomorus duodecimalis*, *Taenioides cirratus, Ophisternon bengalensa, Hippichthys penicilus,* and *Thryssa hamiltonii*
	**Assemblage Bc:** *Scatophagus argus*, *Escualosa thoracata*, *Coilia macrognathus*, *Plotosus canius*, *Himantura imbricata* and *Tylosurus crocodilus*
	**Assemblage C:** *Pampus argenteus, Eleutheronema tetradactylum, Bregmaceros mcclellandi, Parastomateus niger, Sardinella gibbosa, Muraenesox cinereus, Hypoatherina valenciennei, Trichiurus lepturus, Sphyraena jello, Rastrelliger brachysoma, Terapon jarbua, Acanthopagrus berda, Encrasicholina devisi, Panna perarmatus, Pseudapocryple larceolotus, Triacanthus biaculeatus, Hyporhamphus dussumieri, Carangoides praeustus, Lagocephalus spadiceus, Grammoplites scarber* and *Papilogobius reichei*
	**Assemblage Ca:** *Anodontostoma chacunda, Liza oligolepis, Valamugil cunnesius, Pomadasys kaakan, Megalop cyprinoids, Arius caelatus, Macrotrema caligans, Secuter insidiator , Stolephorus dubiosus* and *Hemipimelodus bicolor*

Figure 5 Distribution patterns of fish species in each assemblages defined by the hierarchical clustering applied on the self-organizing map (SOM) units. Dark represents high probability of occurrence, and light indicates lower probability.

ปลาในบริเวณอ่าวและแม่น้ำปากพนังกับการจัดการเขื่อนกั้นความเค็ม, ส่วนที่ 2: แบบจำลองการกินอาหาร

Fishes in the Pak Panang River and Bay in relation to the anti-salt dam operation, Part II: Trophic model

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อมรศักดิ์ สวัสดี[1], ทวนทอง จุฑาเกตุ[2], ธนิษฐา ทรรพนันทน์ ใจดี[3], สุธีระ ทองขาว[1] และ ปิยะพงษ์ โชติพันธุ์[4]

บทคัดย่อ

โปรแกรมสำเร็จรูป ECOPATH ได้ถูกใช้เป็นเครื่องมือในการศึกษาโครงสร้างของชั้นลำดับการกินอาหารในสภาวะสมดุล และการดำรงชีวิตของสัตว์น้ำในแหล่งน้ำ 2 บริเวณ ได้แก่ อ่าวปากพนัง และ แม่น้ำปากพนังตอนล่าง เพื่อที่จะศึกษาสภาพของระบบนิเวศน์ภายใต้การจัดการประตูระบายน้ำอุทกวิภาชประสิทธิ์ ค่าประมาณต่างๆที่ได้จากการวิเคราะห์แสดงให้เห็นถึงความน่าเชื่อถือของแบบจำลอง องค์ประกอบสิ่งมีชีวิตที่ใช้ในการศึกษามีทั้งสิ้น 20 และ 25 ชนิด ในระบบนิเวศน์อ่าวปากพนังและแม่น้ำปากพนัง ตามลำดับ ค่าลำดับชั้นในการกินอาหารของสัตว์น้ำมีค่าตั้งแต่ 1 จากผู้ผลิต จน 3.0 ในผู้ล่าขั้นสูงในทั้ง 2 บริเวณ ค่าประสิทธิภาพในการประมงสุทธิแสดงให้เห็นถึงการทำการประมงที่หนาแน่นในทั้ง 2 บริเวณ ในสภาวะปัจจุบัน ระบบนิเวศน์ทั้งสองอยู่ในระดับที่สมบูรณ์โดยพิจารณาได้จากค่าเฉลี่ยของประสิทธิภาพในการส่งผ่านพลังงานในแต่ละลำดับชั้นที่มีค่าอยู่ระหว่างร้อยละ 10 ถึง 15 กลุ่มปลาขนาดเล็กที่กินแพลงก์ตอนเป็นอาหารเป็นผู้มีบทบาทที่สำคัญในการเชื่อมระหว่างสิ่งมีชีวิตในลำดับชั้นการกินอาหารลำดับล่างและผู้ล่าชั้นสูง การเปิดและปิดประตูระบายน้ำควรคำนึงถึงผลกระทบที่จะมีต่อสัตว์น้ำเหล่านี้ทั้งอาจมีผลกระทบต่อความสมดุลของระบบนิเวศทั้ง 2 บริเวณ

คำสำคัญ : แบบจำลองการกินอาหาร, ECOPATH

Abstract

ECOPATH software programe was used to study the mass-balanced trophic structures and functioning of the aquatic organisms for Pak Panang - Bay and – River (lower portion) to insight the ecosystems according to the operation of the Uthokvibhajaprasid Dam. The resulting models were authentic as indicated by the output parameters. There were 20 and 25 compartments for the estuary and river models, respectively. The trophic levels varied from 1.0 for primary producers and detritus

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to about 3.0 for carnivorous fishes. Gross efficiency of the fishery indicated the intensive efforts in both areas. Both systems were considered as intact condition since the transfer efficiency is between 10 to 15%. Small sized brackish water plankton feeders played the important role in linkage between lower trophic organism and top predators. Improper regulation of the sluice gates should impact these groups and then result in the unbalance of the ecosystems.

Key Words: Trophic model, ECOPATH

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Introduction

The hypopotamon zone (i.e. lower river portion connected to the estuary) is a productive and extremely dynamics, in which environmental fluctuations and changing species compositions are common. Food webs, and the pathways of energy flow within the food web, are temporally variable due to changes in river flow, water temperature, water column stratification, salinity gradients and seasonal variation in biota (Althauser, 2003). Apart from the natural factors, human activities are also affected to the ecosystem such as urbanization, sewages as well as coastal and infrastructure developments. Among the anthropogenic activities, damming in this area is recognized as the most influential activity to fishes (Vasconcelos *et al*., 2007) since it will block of migratory routes of the diadromy fishes and alter a flow pattern, which is very crucial to maintain the integrity of the ecosystem (i.e. environmental flow: IUCN, 2003). Regarding to the environmental problems from infrastructure development in the hypopotamon zone, there is a case in Thailand, where the Uthokvibhajaprasid Dam was constructed for the purpose of anti-salt intrusion into the upriver of the Pak Panang River, Nakhon Srithammmarat, which started in 1995. The dam locates at 6 km to the confluence to Pak Panang Bay. It is irregularly operated depending on the demand of freshwater in the upstream (Prabnarong and Kaewrat, 2006), which consequence in the inevitably changes in the ecosystem.

To understand the possible impacts on ecological changes in aquatic ecosystem calls for quantification of the trophic relationships between different living groups in the system (Chookajorn *et al*., 1994). Ecosystem modeling is an alternative approaches that can be used to predict ecosystem responses to perturbations of any factors (Althauser, 2003) and the ECOPATH model (Christensen *et al*., 2005) is widely applied to describe the ecosystem in form of multi-species trophic model under the balancing and static ecosystems (JØrgensen and Bendorichchio, 2001). Moreover, when the model is properly used, it can be also explained the evolution of the fish stock in the ecosystem in the long time period (Chookajorn *et al*., 1994). In this study, The trophic networks will be constructed under two difference areas, i.e. the upstream and downstream of the Uthokvibhajaprasid dam by using ECOPATH program (Christensen and Pauly, 1992; Christensen *et al*., 2005) to provide a quantitative description for **understanding different functions and interrelationships of various components** within the two ecosystems.

Materials and methods

Fish Samples

The fish sampling were conducted from March 2006 to June 2007 from 6 stations in the estuarine and the river (Figure 1), i.e. 3 stations in each area. Sampling protocols were already described in Jutagate *et al*. (2009). After taxonomical identification, all the fish in the same species level was weighed and the numbers in each species were counted then standardize to t.km^{-2} fresh weight (Jackson and Harvey, 1997)

The ECOPATH model

In structuring the model, the various organisms inhabiting the ecosystem have to be grouped into boxes or functional groups according to their common physical habitats, similar food preferences and life history characteristics (Yodzis and Winemiller, 1999; Villanueva *et al*, 2008).The basic condition considered for ECOPATH model is that input to each group is equal to the output from it (i.e equilibrium conditions).Therefore, the biomass budget equations for each group are

$$B_i \times (P/B)_i \times EE_i - \sum_j \left(B_j \times (Q/B)_j \times DC_{ji}\right) - EX_i = 0 \quad \text{------------------------- (1)}$$

Where B_i is the biomass of the group (i); $(P/B)_i$ is the production/biomass ratio, EE_i is the ecotrophic efficiency, i.e. the proportion of the ecological production which is consumed by predators or exported and usually assumed to range from 0.7 to 0.99 (Polovina, 1984); B_j the biomass of predator (j); $(Q/B)_j$ is the food consumption per unit of biomass for predator j and DC_{ji} is the fraction of i in the diet of j; EX_i is the export of (i).

Production/biomass ratio (P/B)

All values of P/B were presented in annual term, i.e. per year. Two methods of PB-estimation were applied viz. (a) P/B is equal to the total mortality (Z_i) (Allen, 1971) when the von Bertalanffy growth function (VBFG) of the species can be obtained and (b) for a few groups, PB was taken from the estimation of $(Q/B) \times EE$ (Chookajorn *et al*., 1994). For the other groups than fish were derived from literatures (Christensen, 1998; Froese and Pauly 2008; Villanueva *et al*, 2008 among others).

Diet composition

Diet compositions of each consumer group was estimated by stomach content analyses of the dominant species, and were recorded in percentage of weight of prey groups. When the data was not available for some groups, the information from the published articles were assembled (Yamashita *et al*., 1987; Froese and Pauly, 2008)

Food consumption/biomass ratio (Q/B)

Q/B can be obtained from (a) field data on the variation of abundance of food within a 24-hour diel survey by using Maxims (Jarre *et al*., 1990) and (b) estimation from the model of Palomares and Pauly (1998), which was applied in this study, using the formula

$$\log(Q/B) = 5.847 - 0.52\log(W_{\infty}) + 0.28\log(P/B) - 1.36T + 0.062A + 0.51H + o.39D \text{ ---- (2)}$$

W_{∞} is the asymptotic weight of fish in gram, where W_{∞} of individual species were calculated from the length-weight relationship, assuming that all groups are isometric and L_{∞} was equal maximum length divided by 0.95 of individual species (Sparre and Venema, 1998). T is the mean habitat temperature (^{o}C) which was 30.2 ^{o}C in this study; A is an index of activity of the fish related to the aspect ratio of its caudal fin as:

$$A = h^2 / S \text{ ---------- (3)}$$

where h and S are height and surface area of the caudal fin, respectively. Finally, the parameters H and D express the diet, where H = 1 for a phytophagous species (D = 0) and H = 0 for a detritivorous species (D =1)

Balancing the model

The equilibrium assumption implicit to Equation (1) is very crucial. Therefore, the balance of the model was authenticated by two steps. The first step in verifying the realism of the model was to check whether the EE was less than 1.0 for all groups, since it was assumed for any group not to be consumed in excess of its production and should be close to 1 for most groups. In this study, EE was set at 0.95 for all groups reflected the fact that there is high fishing intensity in this area as well as the emigration of the brackish fishes from the upstream area.

The second step was to check if the gross food conversion efficiency (i.e. the ratio between production and consumption, GE) was in the range of 0.1–0.3, as the consumption of most groups is about 3–10 times higher than their production. In general, the GE cannot be higher than the net efficiency (the ratio between production and assimilated food), except that it may be lower for the top predators and higher for fish larvae (Christensen *et al.*, 2005).

Results

For the two reservoirs considered here, estimates of *B*, *EE*, gross conversion rates (*GE*), *P/B*, *Q/B* and trophic level (*TL*) obtained from the input parameters for each group are presented in Tables 1 and 2. The total fish biomass in the estuary (2.767 $t.km^{-2}.yr^{-1}$) was slightly higher than the biomass obtained from the river portion (2.600 $t.km^{-2}.yr^{-1}$). Interestingly, the proportion of the brackish water species in the upstream area was very high (68 %), which indicated the importance of this fish to the ecosystem. Gross efficiency of the fishery *(GEF* = actual catch/primary production) estimated in the river portion (0.0079) was higher than in the bay (0.0045), which implied the intensively exploited of the fisheries resources in both areas. The mean trophic level from fisheries operation in both areas was about three (2.79 and 2.94 in the estuary and the river portion, respectively). This mean the zoophagous fish are targets.

Transfer efficiency at trophic level II was high (Table 3), which pointed out the high utilization of primary producers by the herbivores in both areas. However, it is revealed that the food webs of the two systems are quite intact since the average transfer efficiency is between 10% and 15%. Figures 2 and 3 show the compartment model for the “balanced situation” of the both ecosystems, the boxes are aligned along the y-axis as a function of the estimated trophic level and the area is proportional of the square root of the biomass. Trophic levels estimated by ECOPATH model from the weighted average of prey trophic levels varied from 1.0 for primary producers and detritus to about 3.5 for carnivorous fishes in both areas.

The effect of change in the biomass of one group on the biomass of other groups in a system can be indicated from the mixed trophic impacts (Figures 4 and 5). In the estuary, an increase in phytoplankton biomass resulted in increase biomass of almost all groups. Then the increase of zooplankton made more abundance of the higher trophic level species. In the river system, an increase in phytoplankton biomass has a great positive effect on the small size brackish water species (i.e. *Stolephorus* sp., *Leiognathus* sp. and *Ambassis* sp.), which they feed largely on phytoplankton. Consequently, in an increase of these small fishes, which is a feed for carnivores species, the biomass of the fishery targets would increase. An increase in detritus in the estuary had larger positive effect on the biomasses of other groups than those in the river portion.

Discussion

From the simulations, both systems were balanced and validated as it was obtained that (a) the estimated EE value of detritus was much less than 1, which indicates that the detritus group was entering more than leaving (Lin *et al*., 2007) and (b) GE values were physiologically realistic as suggested by Christensen et al. (2005) that the consumption of most groups are about 3-10 times higher than their reproduction, i.e. GE ranges from 0.1 to 0.3 (Christensen *et al*., 2005). The biomass of 2.8 $t.km^{-2}.yr^{-1}$ in the Pak Panang estuary was reasonable compared to the biomass of 7.2 $t.km^{-2}.yr^{-1}$ in the whole inner area of the Gulf of Thailand (Christensen, 1998) and 3.1 $t.km^{-2}.yr^{-1}$ from the coastal area of Terenganu, Malaysia (Liew and Chan, 1987). However, the biomass estimated in the river portion (2.6 $t.km^{-2}.yr^{-1}$) was very low compared to the value got from Pasak Jolasid Reservoir (10.1 $t.km^{-2}.yr^{-1}$: Thapanand *et al*., 2007), which impounded during the relatively nearby period (i.e. in 1998). This is due to the fact that the vast littoral zone for the lake-type reservoir of the latter case.

Duldic *et al*. (1997) mentioned that estuarine areas are usually comprised of low trophic level species with high ecological efficiency and productivity, which support the carnivores within or beyond the system (i.e. the lower river area and open sea). In the lower river portion, the high trophic level freshwater species are always found (Pusey *et al*., 1995). The slightly mean lower trophic level than 3 would come from two reasons. Firstly, the proliferation of the benthic herbivores, which was likely caused by the nutrient-rich trap from the river near the dam (MacIntyre *et al*. 2000) that made the expansion of aquatic plant. Secondly, it would from the raising of the importance of the small sized plankton feeders in system as experience in Ubolratana Reservoir, NE of Thailand (Chookajorn *et al*., 1994). The maximum trophic position in the estuary was 3.49 compared to 4.1 for the inner Gulf of Thailand, except shark at 4.5 (Christensen, 1998). This estimated figure was in the range of 3.6–4.0 of the top predator recorded in tropical estuaries (Wolff *et al*., 2000; Lin *et al*., 2004). For the river portion, the maximum trophic level of 3.61 confirmed the importance of the small sized fish to the system, while the other inland water bodies in Thailand the value was about 3.4 (Chookajorn *et al*., 1994; Jutagate *et al*., 2002).

The average transfer efficiency of a 12.2 and 14.2 in the respective estuary and river portion were within the range (8–14%) reported by Christensen and Pauly (1993) for 41 aquatic systems. The mixed trophic impact shows that an increase of fishing activities in both areas would have a negative impact on carnivorous fishes. For the long run, the long-term over-exploitation of top predators would result in low total catches and gross efficiency and then lowered food-chain length (Pauly *et al*., 1998; Lin *et al*, 2007). The small size brackish water fishes seem to have little impact from increasing of fishing intensity. This is because of the prohibit of various fishing gears, especially the gear with luring light, that employed to catch these fishes 3,000 m offshore.

Conclusion

Two difference areas, which are connected but divided by the fragmentation of river course, were described by the ECOPATH model. The more complexity of the ecosystem was found in both areas. Fisheries had been found to strongly influence food webs directly through the exploitation of top predators. Moreover, the fragmentation of the system comes in addressing an important question on the impact to the small sized brackish water plankton feeders on ecosystem functioning. As these fishes supports the fishery targets in both area. If the changing in flow pattern and salinity do not suitable for them, it would be resulted in unbalancing of the systems and finally collapse of the ecosystem (Layman *et al*., 2007).

Acknowledgement

This research was supported by the Thailand Research Fund (Grant: TRF RDG 4940011 Community Structure of Fishery Resources and Salinity Distribution in Pak Panang River Basin: A Case Study on the Effects of Uthokvibhajaprasid Operation). We are very grateful to the local fishers for their assistance during the field works. We also thank Prof. Saowapa Angsupanich (Prince of Songkla University), Drs. Kan Janphromma (Walailak University), Padermsak Jaruyabhand (Chulalongkorn University) and Srilaporn Buasai (TRF) for their constructive comments to improve our research work.

References

Allen K.F. 1971. Relation between production and biomass. Journal of the Fisheries Research Board of Canada 20: 1573-1581.

Althauser, L.L. 2003. An ecopath/ecosim analysis of an estuarine food web: seasonal energy flow and response to river-flow related perturbations. M.Sc. thesis, Agricultural and Mechanical College, Louisiana State University, Louisiana.

Chookajorn T., Leenanond Y., Moreau J. and Sricharoendham. 1994. Evolution of trophic relationships in Ubolratana Reservoir (Thailand) as describing using a multispecies trophic model. Asian Fisheries Science 7:201-213.

Christensen, V. 1998. Fishery-induced changes in a marine ecosystem: insight from models of the Gulf of Thailand. Journal of Fish Biology 53: 128–142.

Christensen V. and Pauly D., 1992. ECOPATH II: a software for balancing steady state ecosystems models and calculating network characteristics. Ecological Modeling 61: 169–185

Christensen V. and Pauly D. (eds.) 1993. Trophic models of aquatic ecosystems. ICLARM Conference Proceedings No. 26. ICLARM, Manila.

Duldic J., Kraljevic M., Grbec B. and Pallaoro A. 1997. Composition and temporal fluctuations of inshore juvenile fish populations in the Kornati Archipelago, eastern middle Adriatic. Marine Biology 129: 267-277.

Froese, R. and Pauly, D. 2008. FishBase, World Wide Web electronic publication. URL http://www.fishbase.org.

IUCN. 2003. Flow: the essentials of environmental flows. IUCN Publication service unit, London.

Jackson D.A. and Harvey H.H. 1997. Qualitative and quantitative sampling of lake fish communities. Canadian Journal of Fisheries and Aquatic Science 54(12): 2807–2813.

Jarre A., Palomares M.L., Soriano M.L., Sambilay V.C., Christensen V. and Pauly, D. 1990. A user's manual for MAXIMS. A computer program for estimating the food consumption of fishes from diel stomach contents data and population parameters (ICLARM Software 4). International Center for Living Aquatic Resources Management, Manila, Philippines.

Jutagate T., Mattson N.S., Moreau J., Srichareondham B. and Kumsri, M. 2002. Ecosystem of Sirindhorn and Nam Ngum Reservoirs: a comparison. Kasetsart Fisheries Research Bulletin No. 24: 1-14.

Jutagate T., Sawusdee, A., Thappanand-Chaidee T., Thongkhoa S. and Chotipuntu P. 2009. Fishes in the Pak Panang Bay and River in relation to the anti-salt dam operation, Part I: Assemblage patterns of the marine and brackish water fishes. Paper presented at the 49th Kasetsart University Annual Conference, 17-20 March 2009

Layman C.A., Quattrochi J.P. Peyer C.M. and Allgeier J.E. 2007. Niche width collapse in a resilient top predator following ecosystem fragmentation. Ecology Letters 10: 937–944.

Liew H.C. and Chan E.H. 1987. ECOPATH model of a tropical shallow-water community in Malaysia. Fisheries and Marine Science Centre, IJniversiti Pertanian Malaysia.

Lin H.J., Shao K.T., Hwang J.S., Lo W.T., Cheng I.J. and Lee, L.H., 2004. A trophic model for Kuosheng Bay in northern Taiwan. Journal of Marine Science and Technology 12: 424–432.

Lin H.J., Shao K.T., Jan R.Q., Hsieh H.L., Chen C.P., Hsieh, L.Y. and Hsiao Y.T. 2007. A trophic model for the Danshuei River Estuary, a hypoxic estuary in northern Taiwan. Marine Pollution Bulletin 54: 1789–1800.

MacIntyre H., Kana T. and Geider R. 2000. The effect of water motion on short term rates of photosynthesis by marine phytoplankton. Trends in Plant Science 5: 12-17.

Palomares M.L. and Pauly, D 1998. Predicting food consumption of fish populations as functions of mortality, food type, morphometrics, temperature and salinity. Marine and Freshwater Research 49(5): 447-453.

Pauly D., Christensen V., Dalsgaard J., Froese R. and Torres F. 1998. Fishing down marine food webs. Science 279: 860–863.

Polovina J.J. 1984. Model of a coral reef ecosystem I: the ECOPATH model and its application to French Frigate Shoals. Coral Reefs 3 (1): 1–11.

Pusey B. J., Read M.G. and Arthington A.H. 1995. The feeding ecology of freshwater fishes in two rivers of the AustralianWet Tropics. Environmental Biology of Fishes 43: 85–103.

Thapanand T., Moreau J., Jutagate, T., Wongrat, P., Lekchonlayuta, T., Meksumpun, C., Janekitkarn, S., Rodloi, A., Dulyapruk, V. and Wongrat, L. 2007. Towards possible fishery management strategies in a newly impounded man-made lake in Thailand. Ecological Modelling 204: 143–155.

Vasconcelos R.P., Reis-Santos P., Fonseca V., Maia A., Ruano M., França S., Vinagre C., Costa M.J., Cabral H. 2007. Assessing anthropogenic pressures on estuarine fish nurseries along the Portuguese coast: A multi-metric index and conceptual approach. Science of the Total Environment 374, 199–215

Villanueva M.C., Moreau J., Amarasinghe U.S. and Schiemer F. 2008. Foodweb and the trophic structure of two Asian reservoirs using Ecopath with Ecosim and Ecospace: A comparative study *In*: Schiemer F., Simon D., Amarasinghe U.S. and Moreau J. (eds.) Aquatic ecosystems and development: Comparative Asian perspectives, pp. 413-434. Backhuys Publishers, Leiden.

Wolff M., Koch V., and Isaac V. 2000. A trophic flow model of the Caete´ Mangrove Estuary (North Brazil) with considerations for the sustainable use of its resources. Estuarine, Coastal and Shelf Science 50: 789–803.

Yamashita, Y., Piamthipmanus N. and Mochiuzuki K. 1987. Gut contents analysis of fishes sampled from the Gulf of Thailand *In*: Kawagushi K. (ed.) Studies on the mechanism of marine productivity in the shallow waters around the South China Sea, with special reference to the Gulf of Thailand, pp. 33–35.. (ed.). Ministry of Education,Science and Culture of Japan, Tokyo.

Yodzis P. and Winemiller K.O. 1999. In search of operational trophospecies in a tropical aquatic food web. Oïkos 87: 327-340.

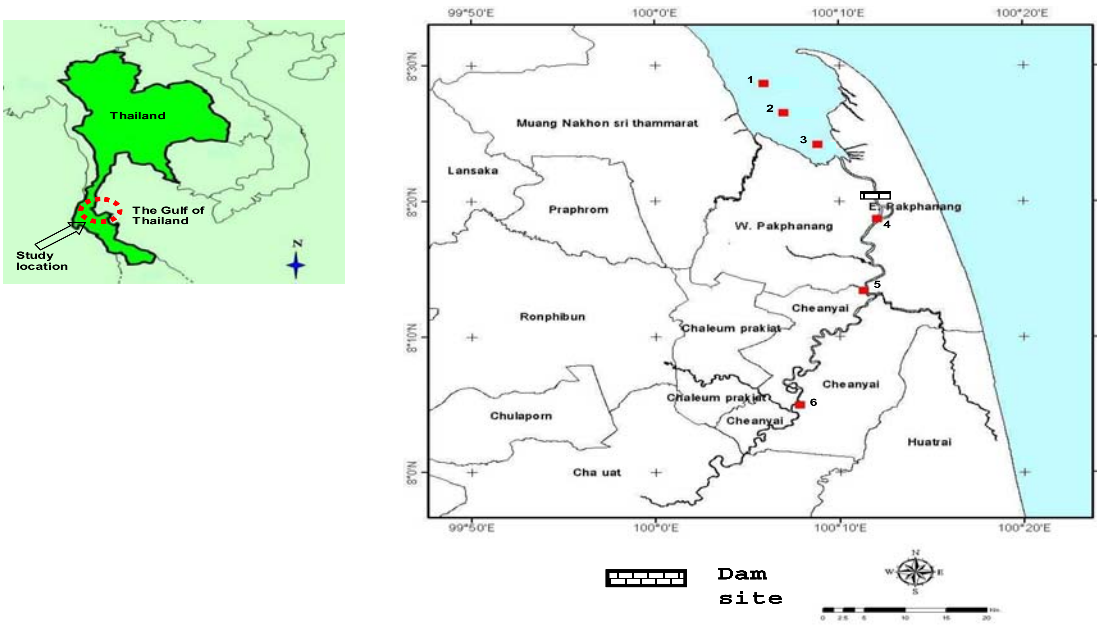

Figure 1 Location of study area and sampling stations

Table 1 Basic parameters inputs and outputs (in bold) from ECOPATH of Pak Panang Bay form March 2006 to June 2007

Groups	Habitat area	TL	Catch ($t\ km^{-2}$)	Biomass ($t\ km^{-2}$)	P/B	Q/B	EE	GE
Acanthopagrus berda	1.00	**3.49**	0.002	**0.0015**	1.42	8.9	0.95	**0.160**
Plotosus canius	1.00	**3.19**	0.020	**0.0141**	1.49	13.4	0.95	**0.111**
Mystus gulio	1.00	**3.23**	0.068	**0.0281**	2.61	10.1	0.95	**0.258**
Osteogeniosus millitaris	1.00	**3.48**	0.038	**0.0580**	0.89	10.5	0.95	**0.085**
Acentrogobius caninus	1.00	**3.27**	0.001	**0.0012**	9.84	42.0	0.95	**0.234**
Trypauchen vagina	1.00	**3.18**	0.112	**0.0623**	2.08	18.2	0.95	**0.114**
Scattophagus argus	1.00	**2.73**	0.223	**0.0371**	7.28	45.5	0.95	**0.160**
Liza subviridis	1.00	**2.39**	0.190	**0.0536**	3.82	13.4	0.95	**0.285**
Thryssa hamiltonii	1.00	**2.79**	0.008	**0.0069**	6.83	19.7	0.95	**0.347**
Panna sp.	1.00	**3.09**	0.063	**0.5001**	0.18	20.8	0.95	**0.009**
Siganus sp.	1.00	**2.00**	0.067	**0.0050**	18.87	61.5	0.95	**0.307**
Cynoglossus arel	1.00	**2.72**	0.102	**0.0163**	8.05	19.3	0.95	**0.417**
Encrasicholina devisi	1.00	**2.70**	0.159	**0.0709**	12.7	32.4	0.95	**0.392**
Leiognathus sp.	1.00	**2.87**	0.116	**0.2584**	7.04	18.6	0.95	**0.378**
Ambassis sp.	1.00	**2.87**	0.210	**1.4320**	1.29	25.7	0.95	**0.050**
Stolephorus sp.	1.00	**2.87**	0.068	**0.2206**	10.7	65.6	0.95	**0.163**
benthic fauna	1.00	**2.40**		**2.7499**	5	25.0	0.95	**0.200**
Zooplankton	1.00	**2.00**		**1.6924**	40	160.0	0.95	**0.250**
Phytoplankton	1.00	**1.00**		**1.6120**	200	8.9	0.95	
Detritus	1.00	**1.00**		**0.0015**	1.42	13.4	**0.23**	
Gross efficiency of the fishery	= 0.0045							
Mean trophic level	= 2.79							

Table 2 Basic parameters inputs and outputs (in bold) from ECOPATH of Pak Panang River (lower portion) form March 2006 to June 2007

Groups	Habitat area	TL	Catch ($t\ km^{-2}$)	Biomass ($t\ km^{-2}$)	P/B	Q/B	EE	GE
Channa spp.	1.0	**3.61**	0.0164	**0.0185**	1.09	14.8	0.95	**0.074**
Clarias spp.	1.0	**3.32**	0.0258	**0.0145**	1.87	9.8	0.95	**0.191**
Hampala spp.	1.0	**3.53**	0.1765	**0.1573**	1.20	10.5	0.95	**0.114**
Mystus singaringan	1.0	**3.21**	0.0213	**0.0147**	1.72	12.9	0.95	**0.133**
Mystus gulio	0.6	**3.20**	0.0290	**0.0453**	1.01	6.7	0.95	**0.151**
Pomadasys kaakan	0.6	**3.29**	0.0088	**0.0194**	1.07	5.5	0.95	**0.196**
Megalop cyprinoides	0.6	**3.32**	0.0032	**0.0122**	1.41	27.1	0.95	**0.052**
Toxotes chatoreus	1.0	**3.30**	0.0074	**0.0185**	1.60	45.1	0.95	**0.035**
Oxyeleotris marmorata	1.0	**3.38**	0.0583	**0.1015**	0.85	12.1	0.95	**0.070**
Pristolepis fasciatus	1.0	**2.54**	0.1776	**0.1009**	2.10	9.9	0.95	**0.212**
Notopterus notopterus	1.0	**2.98**	0.4650	**0.2662**	1.94	7.2	0.95	**0.269**
Puntius brevis	1.0	**2.88**	0.0172	**0.0183**	2.65	14.7	0.95	**0.180**
Cyclochelichthys apogon	1.0	**3.09**	0.0316	**0.0206**	3.41	40.6	0.95	**0.084**
Osteochilus hasselti	1.0	**2.10**	0.0446	**0.0265**	3.70	22.3	0.95	**0.166**
Labiobarbus lineata	1.0	**2.21**	0.0085	**0.0185**	3.25	32.2	0.95	**0.101**
Oreochromis niloticus	1.0	**2.21**	0.0019	**0.0148**	3.59	17.2	0.95	**0.209**
Barbodes gonionotus	1.0	**2.37**	0.0949	**0.0183**	8.24	49.0	0.95	**0.168**
Acanthopsis sp.	1.0	**2.19**	0.0007	**0.0115**	6.12	28.3	0.95	**0.216**
Leiognathus sp.	0.3	**2.79**	0.1395	**1.4424**	2.04	12.5	0.95	**0.164**
Stolephorus sp.	0.3	**2.79**	0.0292	**0.2595**	10.70	43.7	0.95	**0.245**
Aquatic insects	1.0	**2.10**		**1.3003**	7.00	50.0	0.95	**0.140**
Zooplankton	1.0	**2.10**		**0.4822**	50.00	200.0	0.95	**0.250**
Aquatic plant	1.0	**1.00**		**8.0115**	7.00	14.8	0.5	
Phytoplankton	1.0	**1.00**		**0.3158**	365.00	9.8	0.95	
Detritus	1.0	**1.00**				10.5	**0.37**	
Gross efficiency of the fishery	= 0.0079							
Mean trophic level	= 2.94							

Note: (a) *Leiognathus* spp. included *Ambasis* spp. and (b) *Mystus gulio* include *Plotosus canius*

Table 3 Transfers efficiency obtained from the ECOPATH model

(a) Pak Panang Bay

Source/TL	II	III	IV	V	VI
Producer	22.8	12.6	6.6	3.6	6
Detritus	17.8	7.7	3.4	5.8	13.1
All flows	22.4	12.3	6.5	3.6	6.1

Proportion of total flow originating from detritus: 0.16

Transfer efficiencies (calculated as geometric mean for TL II-IV)

From primary producers: 12.4

From detritus: 7.8

Total: 12.2

(b) Pak Panang River (lower portion)

Source/TL	II	III	IV	V	VI
Producer	20.7	12.8	11.5	10.6	9.8
Detritus	13.3	12.7	10.9	9.9	8.8
All flows	19.4	12.8	11.5	10.6	9.8

Proportion of total flow originating from detritus: 0.24

Transfer efficiencies (calculated as geometric mean for TL II-IV)

From primary producers: 14.5%

From detritus: 12.3%

Total: 14.2%

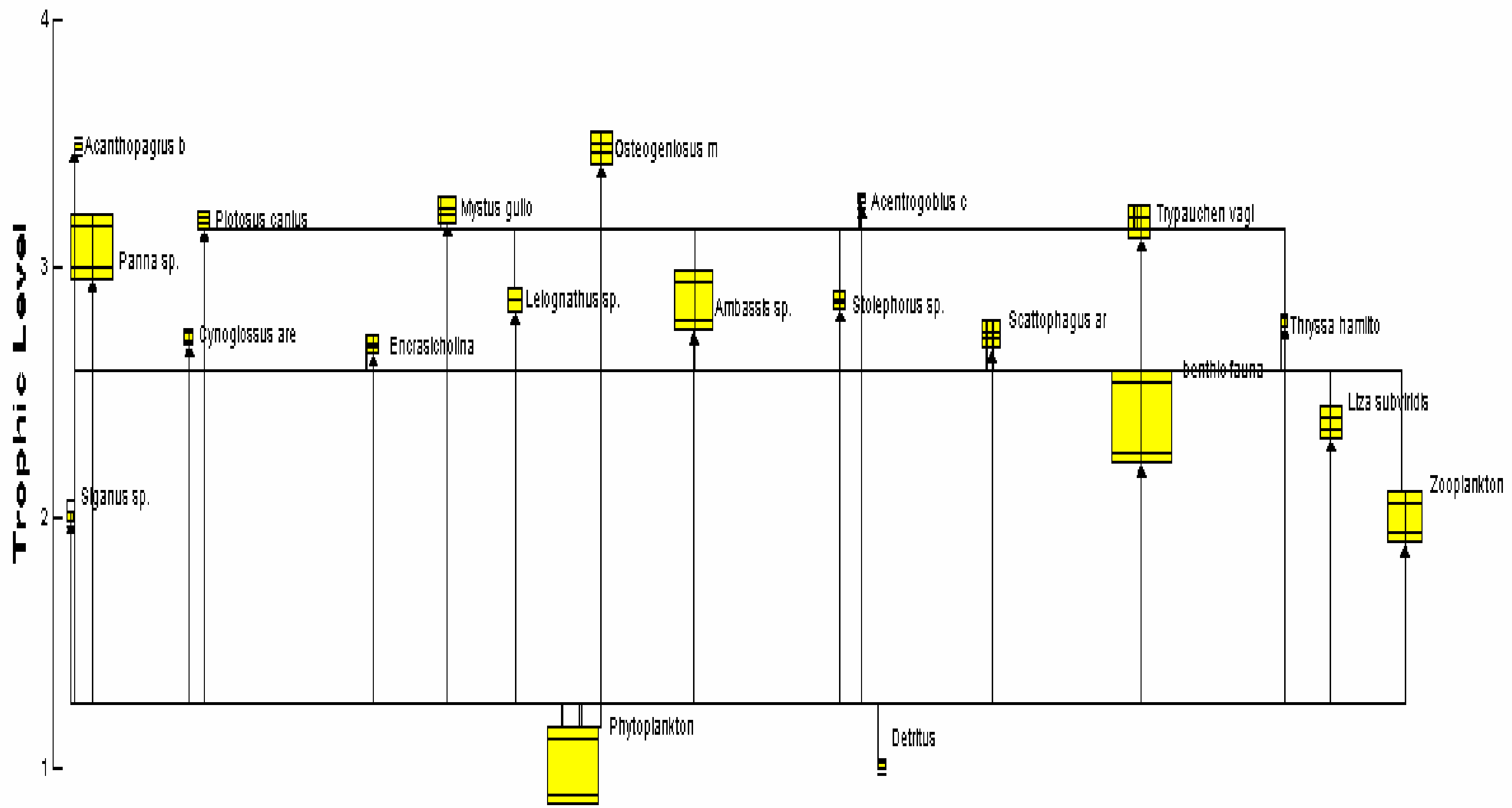

Figure 2 Trophic model of Pak Panang Bay from form March 2006 to June 2007, indicating the relative biomass of each group (box proportional to log *B* in t/km^{-2}) and the major flows connecting them.

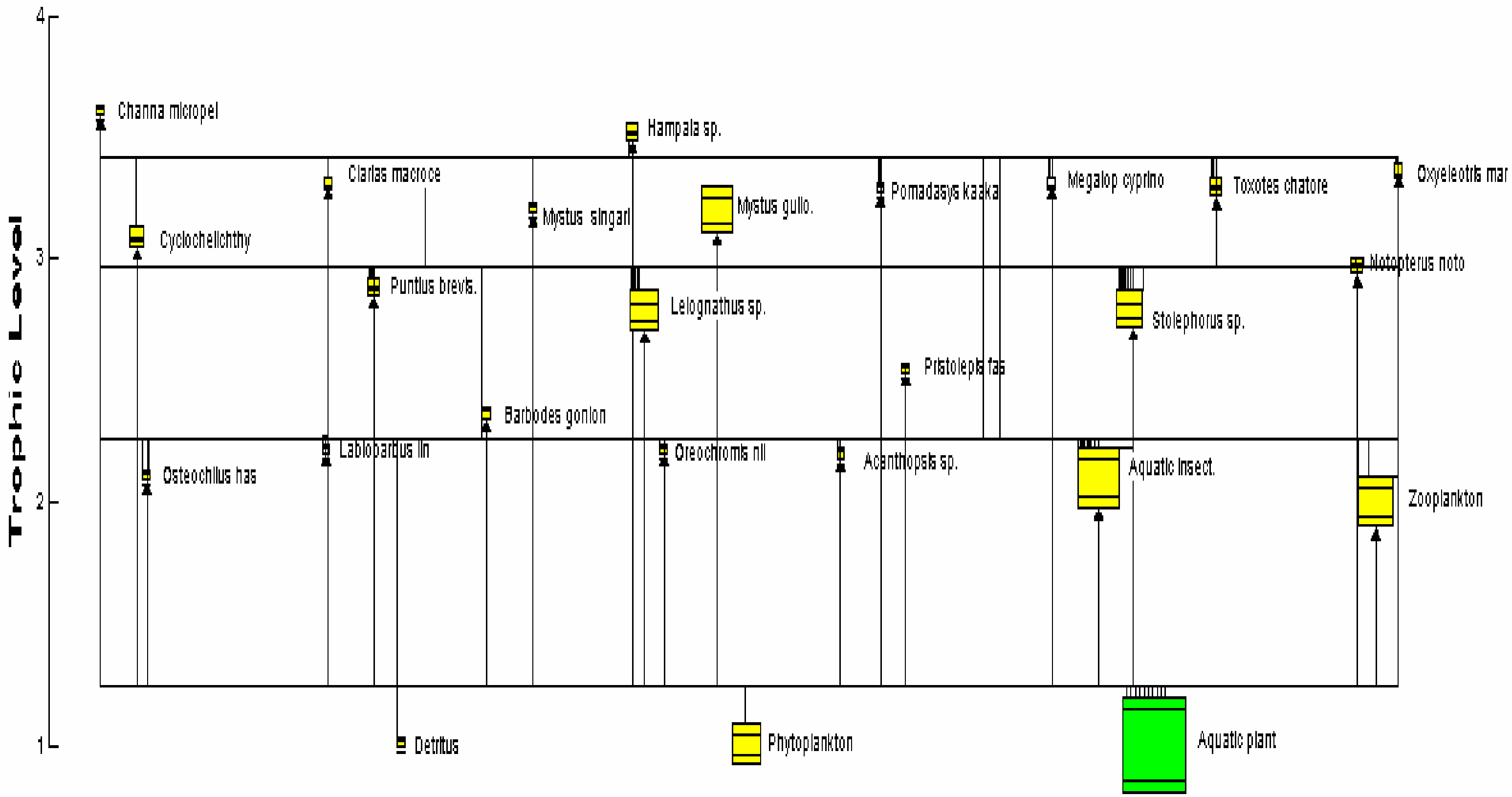

Figure 3 Trophic model of Pak Panang River (lower portion) from form March 2006 to June 2007, indicating the relative biomass of each group (box proportional to log B in t./km^{-2}) and the major flows connecting them.

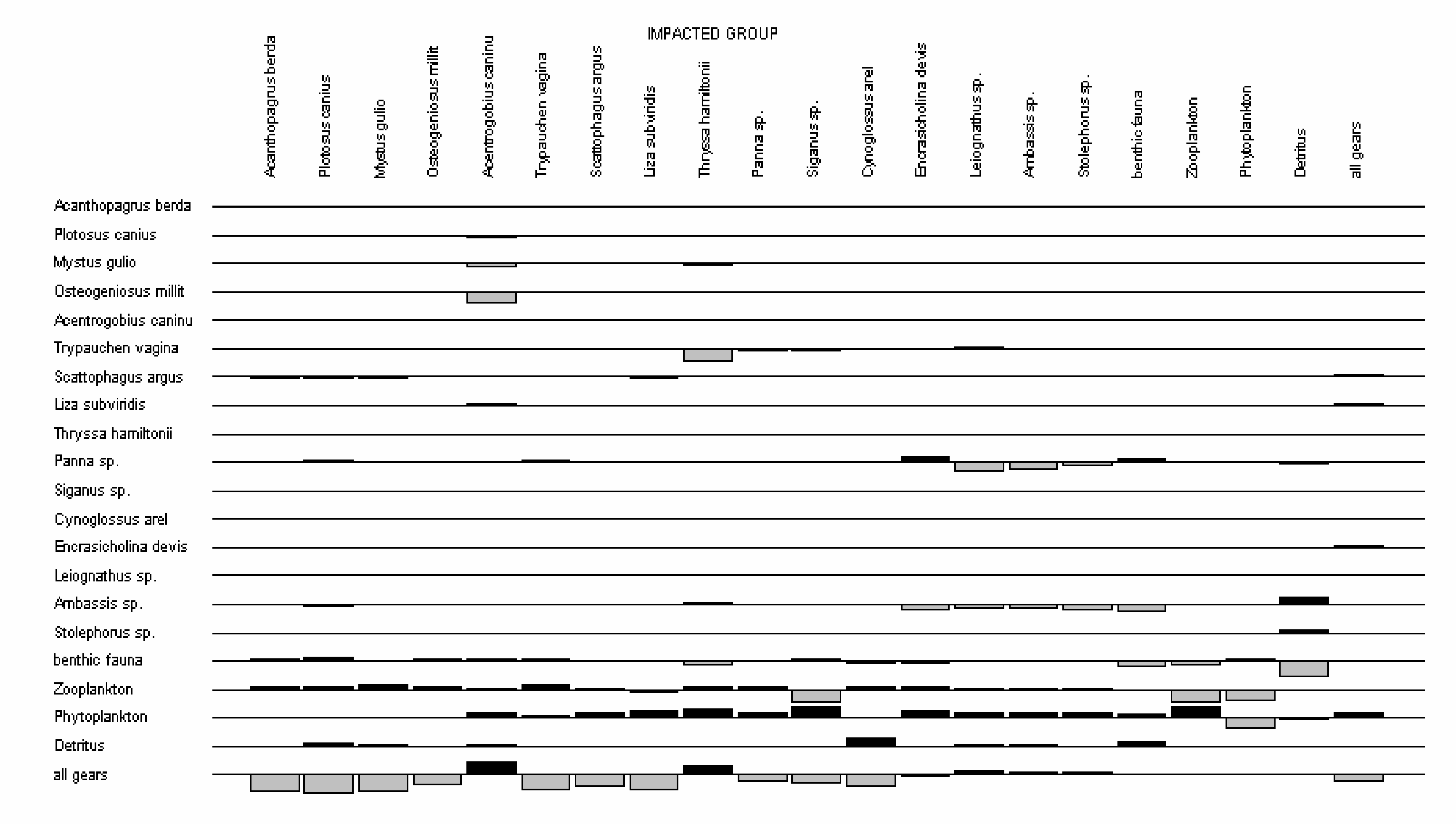

Figure 4 Mixed trophic impacts of the Pak Panang Bay model. Direct and indirect impacts an increase in the biomass of groups to the left of the histograms would have on the groups positioned above them. The bars pointing upwards show positive impacts, while those pointing downwards show negative impacts.

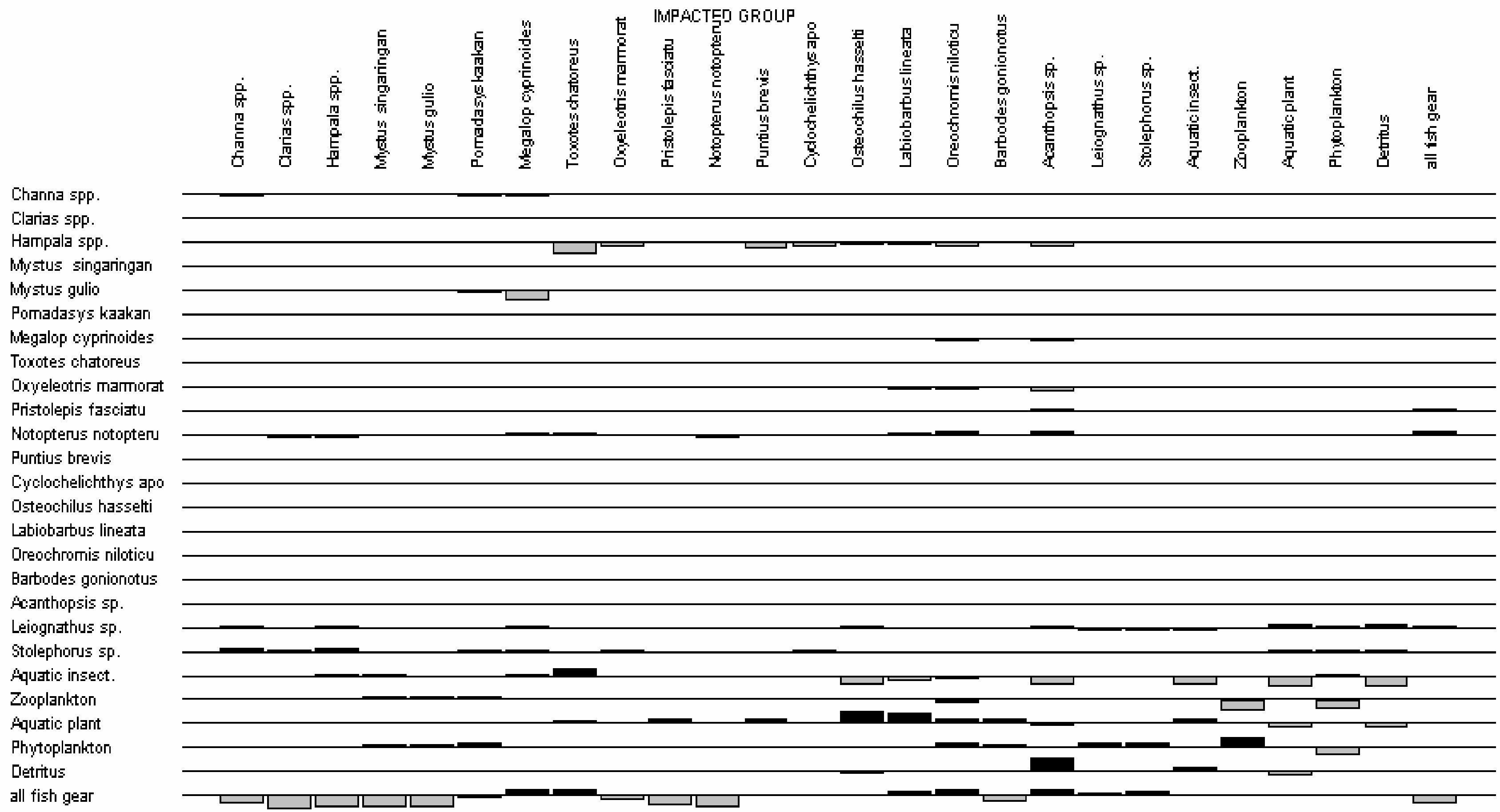

Figure 5 Mixed trophic impacts of the Pak Panang River (lower portion) model. Direct and indirect impacts an increase in the biomass of groups to the left of the histograms would have on the groups positioned above them. The bars pointing upwards show positive impacts, while those pointing downwards show negative impacts.

ความสัมพันธ์ระหว่างความยาวกับน้ำหนัก ปัจจัยสภาวะสัมพัทธ์ และพารามิเตอร์ของประชากรปลากะตักสีเนื้อ (*Encrasicholina devisi* Whitley, 1940) ในอ่าวปากพนัง

Length-weight relationship, relative condition factor and population parameters of Devis' anchovy (*Encrasicholina devisi* Whitley, 1940) in Pak Phanang Bay

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<u>Thanitha Thapanand-Chaidee</u> and Sauwalak Sae Teaw

บทคัดย่อ

เก็บตัวอย่างปลากะตักสีเนื้อ (*Encrasicholina devisi* Whitley, 1940) โดยใช้เครื่องมืออวนรุน และโพงพาง จำนวน 3 สถานี ในระหว่างเดือนสิงหาคม พ.ศ. 2549 ถึงเดือนมิถุนายน พ.ศ. 2550 เป็นประจำทุกเดือน รวม 11 เดือน ในบริเวณอ่าวปากพนัง จังหวัดนครศรีธรรมราช ได้ตัวอย่างทั้งสิ้น 1,518 ตัว มีความยาวเหยียด (TL) ระหว่าง 2.5 – 9.5 ซม. ผลการศึกษาพบว่า รูปแบบการเติบโตของปลากะตักสีเนื้อเป็นแบบไอโซเมตริก และมีความสัมพันธ์ระหว่างความยาวและน้ำหนักเป็น $W = 0.0062TL^{3.0611}$ มีปัจจัยสภาวะสัมพัทธ์สูงสุดในเดือนตุลาคม พ.ศ. 2549 พารามิเตอร์การเติบโตของปลากะตักสีเนื้อ มีค่าความยาวอนันต์ (L_∞) 10.0 ซม. ค่าพารามิเตอร์การเติบโต (K) 1.40 ต่อปี ค่าไฟไพรม์ ($\varnothing'$) 2.17 ค่าน้ำหนักอนันต์ (W_∞) 7.14 กรัม ค่าพารามิเตอร์การตายรวม 6.85 ต่อปี พารามิเตอร์การตายโดยธรรมชาติ ที่อุณหภูมิของน้ำเฉลี่ย 29.0°C 3.06973 ต่อปี และมีอัตราการใช้ประโยชน์ร้อยละ 55

ABSTRACT

Devis' anchovy (*Encrasicholina devisi* Whitley, 1940) was monthly sampled by push net and set bag net in 3 stations during August 2006 to June 2007 in Pak Phanang Bay, Nakhon Si Thammarat Province. One thousand five hundred and eighteen (1,518) fishes ranged from 2.5 – 9.5 cm (TL) were sampled. The growth pattern of this species was identified as isometric growth with length-weight relationship was $W = 0.0062TL^{3.0611}$. The highest peak of relative condition factor was in October 2006. For the growth parameters; the asymptotic length (L_∞) was 10.0 cm, growth parameter (K) 1.40 year^{-1}, phi-prime ($\varnothing'$) 2.17 and the asymptotic weight (W_∞) 7.14 g. For the mortality parameters; total mortality was 6.85 year^{-1}; natural mortality, at the average temperature was 29.0°C, 3.06973 and the exploitation rate was 55%.

Key Words: *Encrasicholina devisi*, Devis' Anchovy, Growth, Pak Phanag Bay, Gulf of Thailand

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ภาควิชาชีววิทยาประมง คณะประมง มหาวิทยาลัยเกษตรศาสตร์

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คำนำ

โครงการพัฒนาพื้นที่ลุ่มน้ำปากพนัง อันเนื่องมาจากพระราชดำริ จังหวัดนครศรีธรรมราช เป็นโครงการที่รัฐบาลรับสนองพระราชดำริของพระบาทสมเด็จพระเจ้าอยู่หัว เพื่อแก้ไขปัญหาความเดือดร้อนของราษฎรในท้องที่ต่างๆของจังหวัดนครศรีธรรมราช ซึ่งแต่เดิมประสบปัญหาการขาดแคลนน้ำจืดในการอุปโภคบริโภค และการเกษตร ปัญหาการรุกตัวของน้ำทะเลเข้าไปในแม่น้ำปากพนังทำให้เกิดสภาพน้ำเค็มในแม่น้ำปากพนัง เป็นระยะเวลาประมาณ 9 เดือน ต่อปี จึงได้มีการสร้างประตูระบายน้ำอุทกวิภาชประสิทธิขึ้นที่บริเวณอ่าวปากพนัง แล้วเสร็จและเปิดดำเนินการตั้งแต่พ.ศ. 2542 ต่อมาได้มีการก่อสร้างประตูระบายน้ำที่สำคัญอีก 3 ประตูได้แก่ ประตูระบายน้ำท่าพญา ประตูระบายน้ำคลองปากพนัง (เสือหึง) และประตูระบายน้ำแพรกเมือง แล้วเสร็จเมื่อ พ.ศ. 2547 รวมทั้งก่อสร้างฝายกั้นน้ำ ขุดคลองต่างๆ ซึ่งทำให้ภาพรวมสภาพการระบายน้ำในพื้นที่ลุ่มน้ำปากพนังเปลี่ยนแปลงไปจากเดิม การเปิดดำเนินการประตูระบายน้ำอุทกวิภาชประสิทธิ ได้ก่อให้เกิดการเปลี่ยนแปลงของคุณภาพสิ่งแวดล้อมในหลายประการเช่น คุณภาพน้ำ การแพร่กระจายของวัชพืช การประมง พื้นที่ป่าจาก เป็นต้น (โครงการติดตามการแก้ไขปัญหาสิ่งแวดล้อม, 2549) เนื่องจากทรัพยากรธรรมชาติและสิ่งแวดล้อมในบริเวณลุ่มน้ำปากพนังมีระบบนิเวศที่ซับซ้อน และเชื่อมโยงกันทั้งระบบน้ำจืด น้ำเค็ม น้ำเปรี้ยว และน้ำกร่อย ดังนั้น เมื่อมีการดำเนินการของประตูระบายน้ำรวมทั้งระบบ อาจก่อให้เกิดผลกระทบต่อระบบนิเวศดังกล่าวได้ จึงมีความจำเป็นจะต้องรวบรวมข้อมูลสภาพปัจจุบันของทรัพยากรธรรมชาติและสิ่งแวดล้อมที่มีความสำคัญในพื้นที่ เพื่อประเมินการเปลี่ยนแปลงที่เกิดขึ้นจากการพัฒนาโครงการ โดยเฉพาะอย่างยิ่ง พลวัตของทรัพยากรประมงที่สำคัญในพื้นที่ เพื่อติดตามการเปลี่ยนแปลงในระยะยาว อันเป็นผลมาจากการพัฒนาดังกล่าว

ปลากะตักสีเนื้อ (*Encrasicholina devisi* Whitley, 1940) เป็นทรัพยากรประมงชนิดหนึ่งที่พบได้ทั่วไปในอ่าวปากพนัง และจับได้ด้วยเครื่องมืออวนรุน และโพงพางเป็นหลัก ในพื้นที่อ่าวปากพนัง การใช้ประโยชน์ปลาชนิดนี้ยังไม่ชัดเจนนัก อย่างไรก็ตาม ปลากะตักสีเนื้อสามารถพบได้มาก และเป็นส่วนหนึ่งของห่วงโซ่อาหารในระบบนิเวศน์อ่าวปากพนัง การศึกษาในครั้งนี้ จึงมีวัตถุประสงค์เพื่อที่จะศึกษารูปแบบการเติบโตโดยการวิเคราะห์ความสัมพันธ์ระหว่างน้ำหนักกับความยาว ศึกษาความสมบูรณ์ของปลากะตักโดยการวิเคราะห์ปัจจัยสภาวะสัมพัทธ์ ประมาณค่าพารามิเตอร์การเติบโต และการตาย ผลการศึกษาดังกล่าวจะเป็นข้อมูลพื้นฐานสำหรับสต็อคปลากะตักสีเนื้อในบริเวณอ่าวปากพนัง และสามารถนำไปเปรียบเทียบกับประชากรปลากะตักสีเนื้อในบริเวณอื่นๆ ต่อไป

อุปกรณ์และวิธีการ

1. <u>การกำหนดจุดเก็บตัวอย่างสัตว์น้ำ</u>

แบ่งพื้นที่อ่าวปากพนังออกเป็น 3 สถานี (B 1-1, B 2-1 และ B 3-1) ตามลักษณะทางกายภาพของอ่าว (Figure 1) การกำหนดพิกัดทางภูมิศาสตร์ของสถานี ใช้เครื่องจีพีเอส รุ่น Garmin V. map 76CSx กำหนดจุดเก็บตัวอย่างเพื่อให้เป็นตัวแทนของทั้งอ่าวในหน่วยพิกัดแบบ UTM (WGS84)

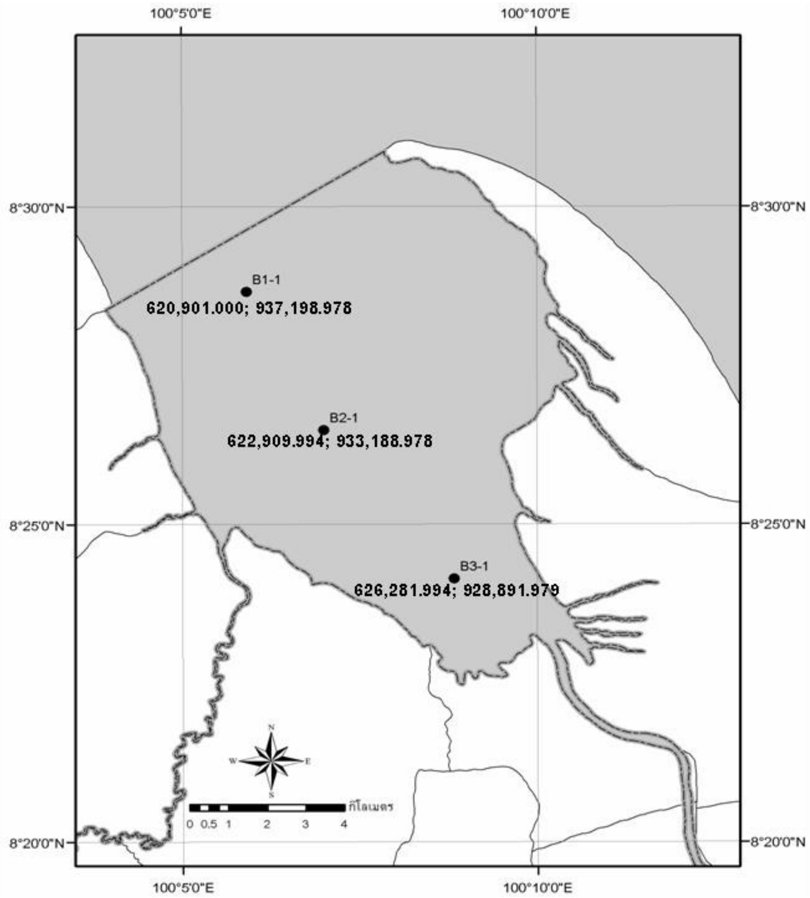


Figure 1 Study area with geographical coordinates.

2. การเก็บรวบรวมตัวอย่าง

เพื่อให้ได้ตัวอย่างปลากะตักสีเนื้อที่ครอบคลุมความยาว และพื้นที่ให้มากที่สุด จึงเก็บรวบรวมตัวอย่างปลากะตักสีเนื้อจากเครื่องมือประมงสองชนิด ได้แก่ อวนรุน และโพงพาง ซึ่งเครื่องมือประมงทั้งสองชนิดจะมีพื้นที่ในการทำการประมงต่างกัน โดยอวนรุนจะทำประมงบริเวณพื้นที่ใกล้ฝั่ง และโพงพางจะทำประมงบริเวณร่องน้ำอ่าวปากพนัง และเครื่องมือทั้งสองประเภทนี้ เป็นเครื่องมือหลักในบริเวณที่ศึกษา การเก็บรวบรวมตัวอย่างจะกระทำเดือนละหนึ่งครั้งต่อเนื่องกัน ตั้งแต่เดือน สิงหาคม 2549 ถึงเดือนมิถุนายน 2550 เป็นประจำทุกเดือน รวมทั้งสิ้น 11 เดือน แยกเฉพาะข้อมูลปลากระตักสีเนื้อ มาแจกแจงความถี่ของความยาวเป็นรายเดือนให้มีความกว้างอันตรภาคชั้นเท่ากับ 0.5 ซม. ชั่งน้ำหนักตัว (กรัม) และวัดความยาวเหยียดเป็นรายตัว (ซม)

3. การวิเคราะห์ข้อมูล

3.1 ความสัมพันธ์ระหว่างความยาวและน้ำหนัก: นำข้อมูลความยาวและน้ำหนักเป็นรายตัวตลอดการเก็บตัวอย่าง วิเคราะห์ความสัมพันธ์ และตรวจสอบรูปแบบการเติบโต

3.2 ปัจจัยสภาวะสัมพัทธ์: นำข้อมูลความยาว และน้ำหนักเป็นรายตัวแต่ละเดือน มาวิเคราะห์ค่าน้ำหนักคาดคะเน โดยอาศัยความสัมพันธ์ระหว่างความยาวและน้ำหนักจาก (3.1) จากนั้นคำนวณค่าปัจจัยสภาวะสัมพัทธ์จาก $K_n = \frac{W_{observed}}{W_{expected}}$ (Le Cren, 1951) แล้วหาค่าเฉลี่ย และส่วนเบี่ยงเบนมาตรฐาน

3.3 พารามิเตอร์การเติบโต และการตาย: นำข้อมูลการแจกแจงความถี่ของความยาวเป็นรายเดือน ประมาณค่าพารามิเตอร์การเติบโต และการตาย โดยใช้โปรแกรม FiSAT (Gayanilo *et al*., 1995)

ผลและวิจารณ์

1. ความสัมพันธ์ระหว่างความยาวและน้ำหนัก

ปลากะตักสีเนื้อจำนวน 1,518 ตัว ความยาวเหยียดระหว่าง 0.2 – 9.5 ซม. นำมาวิเคราะห์ความสัมพันธ์ระหว่างความยาวและน้ำหนัก ได้ความสัมพันธ์ดังนี้ (Figure 2)

$$W = 0.0062TL^{3.0611}, R^2 = 0.872....................(1)$$

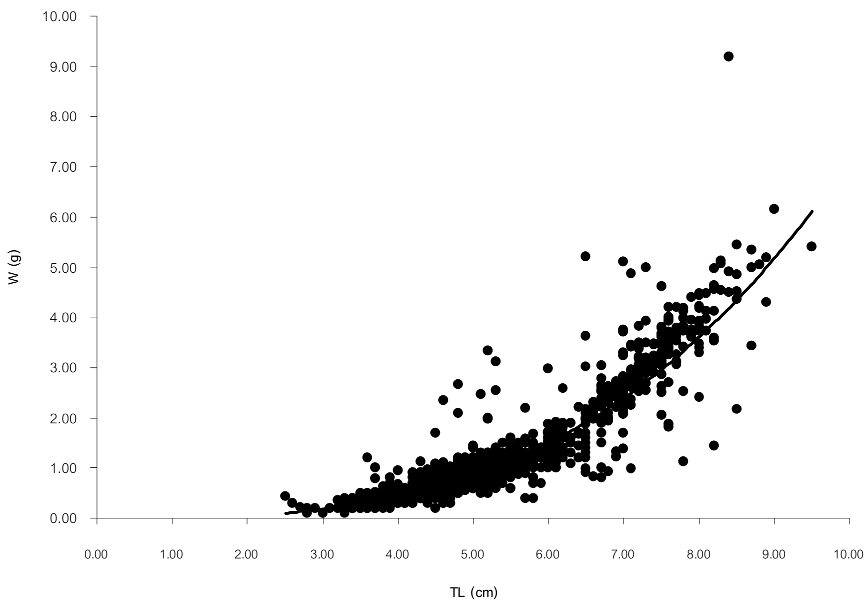


Figure 2 Length-weight relationship of Devis' anchovy

เนื่องจากปลากะตักสีเนื้อที่นำมาศึกษาในครั้งนี้ มีขนาดเล็กมากเกินกว่าจะแยกเพศได้ จึงจำเป็นต้องวิเคราะห์ความสัมพันธ์ระหว่างน้ำหนักกับความยาวแบบรวมทั้งสองเพศ ผลการทดสอบรูปแบบการเติบโตพบว่าช่วงความเชื่อมั่นที่ร้อยละ 99 ของค่ายกกำลังอยู่ระหว่าง $2.98 \le n \le 3.14$ ซึ่งครอบคลุมค่า 3 จึงสรุปได้ว่ารูปแบบการเติบโตของปลากะตักสีเนื้อในบริเวณอ่าวปากพนังเป็นแบบไอโซเมตริก

เมื่อเปรียบเทียบค่าคงที่ (a และ b) ของสมการความสัมพันธ์ระหว่างน้ำหนักกับความยาว $\left(W = aL^b\right)$ ของปลากะตักสีเนื้อ ที่รายงานไว้ใน www.fishbase.org ดังนี้ (Table 1)

Table 1 Constant values of length-weight relationship of Devis' anchovy (unsexed).

a	b	Country	Locality
0.0016	3.328	New Caledonia	-
0.0028	3.340	Papua New Guinea	Ysabel Passage
0.0015	3.490	Papua New Guinea	Farfax Harbour
0.0062	**3.061**	**Thailand**	**This Study**

จะเห็นได้ว่า ค่าคงที่ที่ได้จากการศึกษาครั้งนี้ มีค่า b ต่ำที่สุด แต่มีค่า a สูงที่สุด ซึ่งค่าคงที่ทั้งสองค่า (a และ b) ในความสัมพันธ์ระหว่างน้ำหนักกับความยาว จะแตกต่างกันไปในสัตว์น้ำแต่ละชนิดพันธุ์ ต่างสต็อค และช่วงความยาวของปลาที่นำมาวิเคราะห์ความสัมพันธ์ ส่วนค่า a คือ ค่าปัจจัยสภาวะ (condition factor) เป็นค่าที่ใช้ประโยชน์ในการตรวจสอบความสมบูรณ์ของสัตว์น้ำทั้งความสมบูรณ์ที่เกิดจากอาหาร และความสมบูรณ์เพศ ซึ่งมีวิธีการวิเคราะห์ได้หลายรูปแบบ (ธนิษฐา และอมรศักดิ์, 2550)

2. **ปัจจัยสภาวะสัมพัทธ์** (Relative Condition Factor: K_n)

ผลการวิเคราะห์ค่าปัจจัยสภาวะสัมพัทธ์ได้ผลดังนี้ (Figure 3)

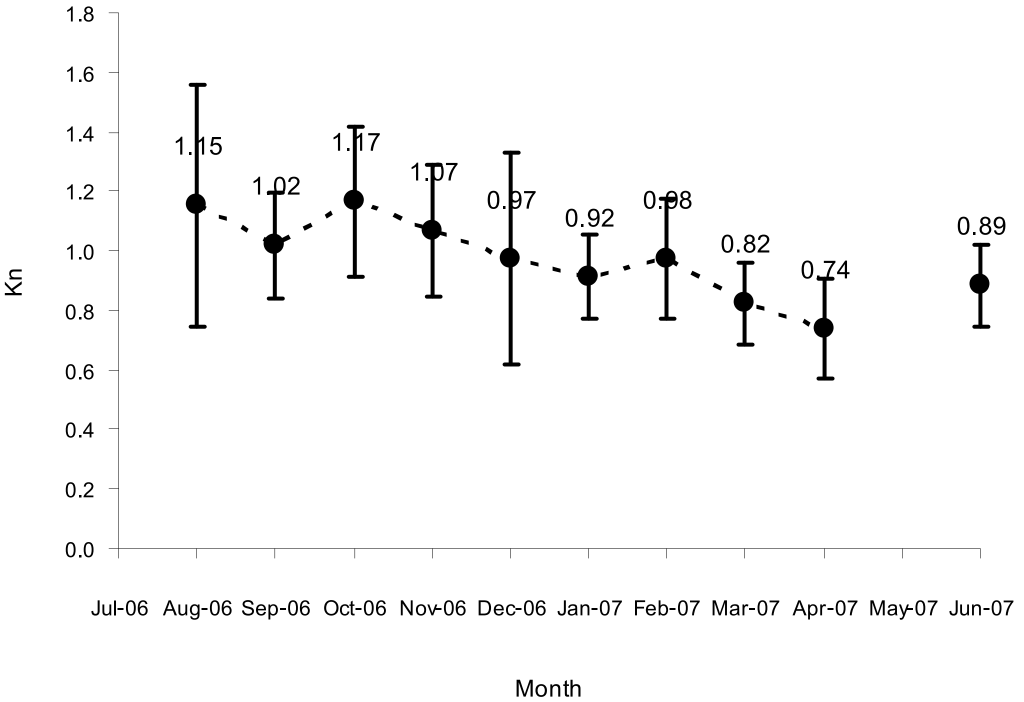


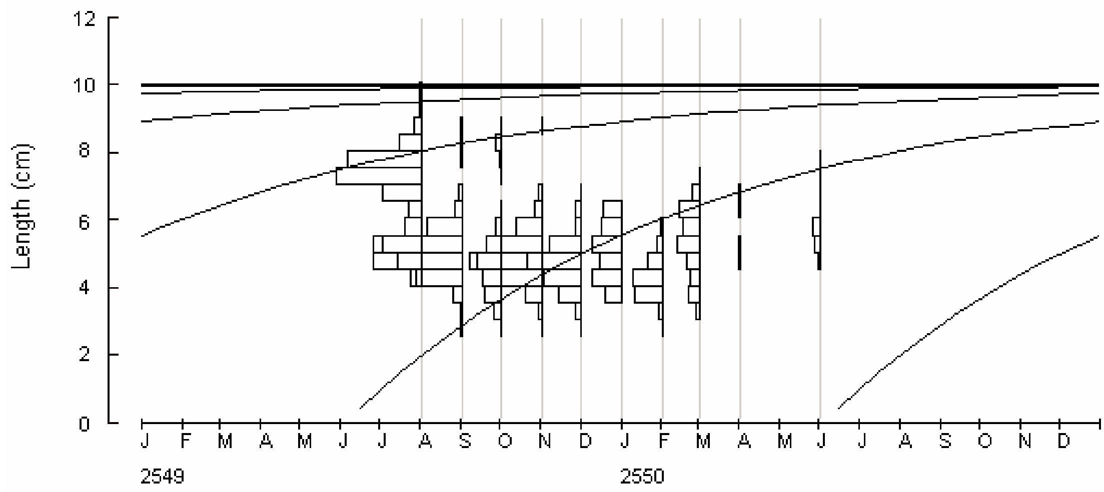
Figure 3 Relative condition factors (mean ± s.d.) of Devis' anchovy following by month

จาก Figure 3 จะเห็นได้ว่า ปลากะตักสีเนื้อ มีความสมบูรณ์ค่อนข้างสม่ำเสมอตลอดช่วงเวลา 11 เดือนของการเก็บตัวอย่าง แต่มีแนวโน้มเพิ่มขึ้นเรื่อยๆจากเดือนสิงหาคม จนกระทั่งสูงสุดในเดือนตุลาคม แสดงว่า ปลา

กะตักสีเนื้อมีน้ำหนักตัวซึ่งเป็นค่าสังเกต สูงกว่าน้ำหนักคาดคะเนจากสมการความสัมพันธ์ระหว่างน้ำหนักกับความยาว ที่ได้จากสมการ (1) การที่ปลามีความสมบูรณ์ อาจเกิดจากสองสาเหตุคือ ปลาอ้วนเพราะกินอยู่ดี หรืออีกกรณีหนึ่งคือ ปลาเข้าสู่ช่วงสืบพันธุ์ทำให้มีการพัฒนาของอวัยวะสืบพันธุ์ ซึ่งจากการศึกษาครั้งนี้ คาดว่าน่าจะเกิดจากสาเหตุประการหลัง เพราะปลากะตักสีเนื้อสืบพันธุ์ได้ตลอดทั้งปี และมีการทดแทนที่ตลอดทุกเดือน (Milton *et al*.,1996) และมีช่วงการสืบพันธุ์ (peak of spawning) ในเดือนกันยายน ถึง พฤศจิกายน (Whitehead *et al*.,1988)

พารามิเตอร์การเติบโต

จากข้อมูลการแจกแจงความถี่ของความยาวรายเดือนของปลากะตักสีเนื้อพบว่า ปลาขนาดใหญ่ที่สุดในข้อมูลคือ ความยาว 9.5 ซม. เมื่อนำมาประมาณค่าความยาวอนันต์ (L_∞) โดยใช้ค่าความยาวสูงสุด หารด้วย 0.95 (Sparre and Venema, 1997) จะได้ค่า L_∞ 10.0 ซม. จากนั้น นำค่า L_∞ ที่ได้ เข้าโปรแกรม FiSAT โดยใช้คำสั่ง scan K-value เพื่อประมาณค่าพารามิเตอร์การเติบโต (K) ได้ค่า K 1.4 ต่อปี จากนั้นเข้าชุดคำสั่ง automatic search routine ในโปรแกรมย่อย ELEFAN-1 เพื่อติดตามการเติบโตพบว่า เส้นโค้งการเติบโตที่ประมาณได้ สอดรับกับกราฟการแจกแจงความถี่ของความยาวเป็นรายเดือน ดัง Figure 4



<u>Figure 4</u> Output of progressive mode from FiSAT of Devis' anchovy

ผลจากการประมาณค่าพารามิเตอร์การเติบโตให้ค่าไฟไพรม์ (ϕ') 2.17 ซึ่งเมื่อเทียบกับการศึกษาที่รายงานไว้ใน www.fishbase.org พบว่า ค่า ϕ' ที่ใช้สำหรับการประมาณค่าพารามิเตอร์ต่างๆคือ 2.13 จึงได้ทดลองใช้ค่า ϕ' 2.13 ร่วมกับค่า L_∞ มาประมาณค่า K ตามสูตร $\Phi' = \log K + 2\log L_\infty$ (Hustler and Marshall, 1990) พบว่า ได้ค่า K 1.35 ต่อปี แต่เมื่อนำไปติดตามการเติบโตพบว่า เส้นโค้งการเติบโตไม่สอดรับกับกราฟ จึงได้เลือกใช้ค่า K เท่ากับ 1.4 ต่อปี เช่นเดิม

นำค่าพารามิเตอร์การเติบโตที่ได้มาประมาณค่าอายุสมมติเมื่อสัตว์น้ำไม่มีความยาว (t_0) ที่เหมาะสมและใกล้เคียงกับความเป็นจริงให้มากที่สุด โดยดำเนินการคำนวณเป็น 3 วิธีการ คือ

1. ใช้สูตรการคำนวณของ Hustler and Marshall (1990) ได้แก่

$$\log(-t_0) = -0.3922 - 0.2752 \log L_\infty - 1.038 \log K$$

ค่า t_0 ที่ได้จากวิธีการนี้เท่ากับ -0.1517 ปี

2. ใช้ค่ามัธยฐานของความยาวแรกฟักของปลากะตัก (L_0) ที่ 1.65 ซม. (www.school.net.th/library/) ค่า t_0 ที่ได้จากวิธีการนี้เท่ากับ -0.1288 ปี

3. ใช้ค่าเวลาที่ไข่ปลากะตักฟักเป็นตัวที่ 24 ชั่วโมง (www.school.net.th/library/) ค่า t_0 ที่ได้จากวิธีการนี้เท่ากับ -0.0027 ปี

เมื่อนำค่าพารามิเตอร์ทั้งหมดมาสร้างสมการการเติบโตพบว่า ค่า ค่า t_0 ที่ได้จากทั้ง 3 วิธีการ ให้ค่าอายุขัยของสัตว์น้ำเท่ากันที่ 2 ปี 1 เดือน 22 วัน แต่ค่า t_0 ที่ได้จากวิธีการแรก ให้ค่าความยาวแรกฟัก 1.91 ซม. ซึ่งสูงกว่าที่ควรจะเป็น ค่า t_0 ที่ได้จากวิธีการที่สาม ให้ค่าความยาวแรกฟักเท่ากับ 0.04 ซม. ซึ่งต่ำกว่าที่ควรจะเป็น ดังนั้น จากการศึกษาในครั้งนี้ จึงตัดสินใจใช้ ค่า t_0 ที่ได้จากวิธีการที่สอง ซึ่งให้ค่าความยาวแรกฟักที่สมเหตุสมผลมากที่สุด (Figure 5)

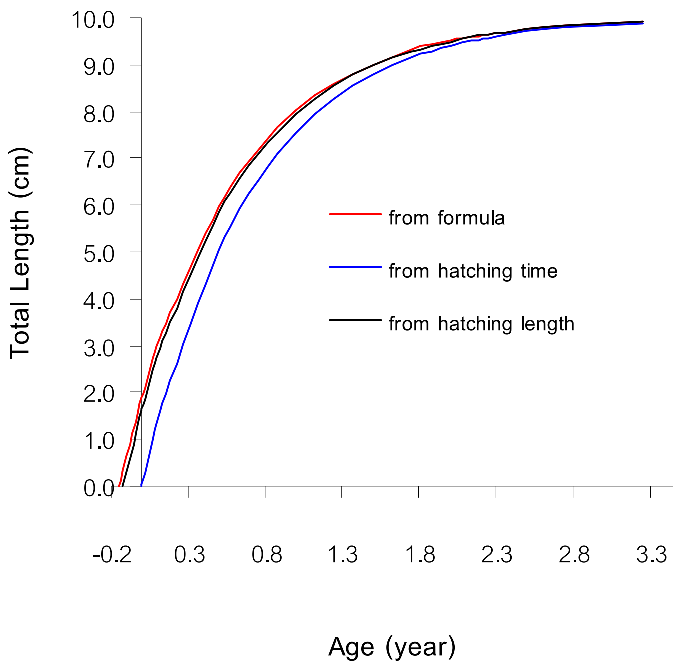


Figure 5 Growth curve of Devis' anchovy

ผลสรุปของค่าพารามิเตอร์การเติบโต จากที่รวบรวมไว้ใน www.fishbase.org เปรียบเทียบกับการศึกษาในครั้งนี้ มีดังนี้ (Table 2)

Table 2 Growth parameters for Devis' anchovy (Data obtained from fishbase).

L_∞ (cm)	Length type	K $(\text{year})^{-1}$	t_0 (year)	$\varnothing'$	Country	Locality
7.40	FL	2.10	-0.07	2.06	Papua New Guinea	Ysabel Passage
7.50	FL	2.40	-0.07	2.13	Papua New Guinea	Cape Lambert
7.80	*ND*	2.23		2.13	Solomon Island	Munda Baitground
7.80	FL	2.00	-0.07	2.09	Papua New Guinea	Fairfax Harbour
7.90	*ND*	2.25		2.15	Solomon Island	Munda Baitground
8.00	*ND*	2.30		2.17	Solomon Island	Munda Baitground
8.20	FL	5.04		2.53	Papua New Guinea	Yasbel Passage, New Ireland Province
10.20	TL	1.24		2.11	Philippines	Corregidor Islands
10.00	**TL**	**1.4**	**-0.1288**	**2.17**	**Thailand**	**This Study**

Note: FL = forked length; TL = total length

จาก Table 2 จะเห็นได้ว่า ปลากะตักสีเนื้อที่ศึกษาในครั้งนี้มีค่า L_∞ และ K ใกล้เคียงกับประเทศฟิลิปปินส์ และมีค่า $\varnothing'$ อยู่ในช่วงที่สามารถยอมรับได้

นำสมการความสัมพันธ์ระหว่างน้ำหนักกับความยาว และค่า L_∞ คำนวณค่าน้ำหนักอนันต์ (W_∞) ของปลากะตักสีเนื้อ ได้ 7.14 กรัม

พารามิเตอร์การตาย

จากข้อมูลการแจกแจงความถี่ของความยาวรายเดือนของปลากะตักสีเนื้อ นำมาประมาณค่าพารามิเตอร์การตายรวม (Z) โดยวิธีวิเคราะห์เส้นโค้งผลจับในรูปของความยาว (linearized catch curve) โดยใช้โปรแกรม FiSAT ได้ค่า Z 6.85 ต่อปี เมื่อใช้ค่าอุณหภูมิเฉลี่ยของน้ำตลอดปีในอ่าวปากพนัง 29.0°C ประมาณค่าสัมประสิทธิ์การตายโดยธรรมชาติ (M) โดยในสมการของ Pauly (Sparre and Venema, 1997) ได้ค่า M 3.06973 ต่อปี และมีอัตราการใช้ประโยชน์ (E) ร้อยละ 55 แสดงว่า ปลากะตักสีเนื้อในบริเวณอ่าวปากพนังมีแนวโน้มการใช้ประโยชน์จากการประมงค่อนข้างมาก

คำนิยม

ผู้วิจัย ขอขอบพระคุณ สำนักงานกองทุนสนับสนุนการวิจัย (โครงการวิจัยเลขที่ RGD 4940011) ที่ได้ให้การสนับสนุนทุนวิจัยภายใต้โครงการ “โครงสร้างประชาคมของทรัพยากรประมง และการแพร่กระจายของความเค็มในบริเวณลุ่มน้ำปากพนัง: กรณีศึกษาผลกระทบของการเปิด และปิดประตูระบายน้ำอุทกวิภาชประสิทธิ” ขอขอบคุณ อาจารย์อมรศักดิ์ สวัสดี สำหรับการสังเคราะห์ข้อมูลเบื้องต้นเพื่อการวิเคราะห์ผล และอำนวยความสะดวกเป็นอย่างดีตลอดการทำงานภาคสนาม ขอขอบคุณ นส.จิรา อนุศิลป์ และนายปิยะเทพ อาวะกุล สำหรับความช่วยเหลือในการเก็บตัวอย่าง

เอกสารอ้างอิง

โครงการติดตามการแก้ไขปัญหาสิ่งแวดล้อม. 2549. **โครงการพัฒนาพื้นที่ลุ่มน้ำปากพนัง อันเนื่องมาจากพระราชดำริ จังหวัดนครศรีธรรมราช**. เอกสารโรเนียว. 41 หน้า.

ธนิษฐา ทรรพนันทน์ ใจดี และอมรศักดิ์ สวัสดี. 2550. **คู่มือชีววิทยาประมงภาคปฏิบัติ**. ภาควิชาชีววิทยาประมง คณะประมง มหาวิทยาลัยเกษตรศาสตร์, กรุงเทพฯ. 92 หน้า.

Froese, R. and D. Pauly. Editors. 2007.FishBase. World Wide Web electronic publication. www.fishbase.org. Downloaded on **27 November 2007**

Gayanilo Jr., Sparre, P. and D. Pauly. 1995. **The FAO-ICLARM Stock Assessment Tools (FiSAT) User’s Guide.** FAO Computerized Information Series (Fisheries), ICLARM Contribution No. 1048. ICLARM, Manila.

Hustler, K. and B.E. Marshall. 1990. Population dynamics of two small cichlid fish species in a tropical man-made lake (Lake Kariba). **Hydrobiologia**, 190: 253-262.

Le Cren, E.D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). **J. Anim. Ecol.**, 20: 201-219.

Milton, D.A., Rawlinson, N.J.F. and S. J.M. Blaber. 1996. Recruitment patterns and factors affecting recruitment of five species of short-lived clupeoids in the tropical South Pacific. **Fish. Res.**, 26: 239-255.

Sparre, V. and S.C. Venema. 1997. Introduction to fish stock assessment Part 1, Manual. **FAO Fish. Tech. Pap.** 306/1 Rev. 1. FAO, Rome.

Tiroba, G. 1990. A preliminary account of the population dynamics of *Stoloephorus devisi* (Engraulidae) at Munda baitground, Solomon Islands. **Fishbyte**, 8(1): 26-27.

Whitehead, P.J.P., G.J. Nelson and T. Wongratana, 1988. FAO species catalogue. Vol. 7. Clupeoid fishes of the world (Suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. Part 2 - Engraulididae. **FAO Fish. Synop.** 125(7/2):305-579.

ชีววิทยาและพลวัตประชากรบางประการปลาแป้นแก้ว *Ambassis kobsii* (Bleeker, 1858) ในบริเวณอ่าวปากพนัง จังหวัดนครศรีธรรมราช

Some Biological and Population dynamics Aspects of Grassy Fish, *Ambassis kobsii* (Bleeker, 1858) in Pak Panang Bay, Nakhon Si Thammarat Province

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บทคัดย่อ

การศึกษาชีววิทยาและพลวัตประชากรบางประการของปลาแป้นแก้ว บริเวณอ่าวปากพนัง จังหวัดนครศรีธรรมราช ในครั้งนี้เพื่อเป็นข้อมูลพื้นฐานสำหรับการจัดการทรัพยากรปลาชนิดนี้ในอนาคต พบว่าความสัมพันธ์ระหว่างความยาวเหยียดและน้ำหนักตัวของปลาแป้นแก้วมีความสัมพันธ์ดังสมการ $W = 0.0186TL^{2.8622}$ ซึ่งความสัมพันธ์ดังกล่าวชี้ให้เห็นว่ารูปแบบการเติบโตของปลาแป้นแก้วเป็นแบบอัลโลเมทริก โดยมีค่าพารามิเตอร์การเติบโต L_∞ เท่ากับ 10.47 เซนติเมตร K เท่ากับ 0.64 ต่อปี t_0 เท่ากับ -0.00055 ต่อปี จากค่าพารามิเตอร์การเติบโตดังกล่าวสามารถคำนวณค่าสัมประสิทธิ์การตายรวม สัมประสิทธิ์การตายโดยการประมง และสัมประสิทธิ์การตายโดยธรรมชาติ ได้ค่าเท่ากับ 3.16 3.14 และ1.82 ต่อปี ตามลำดับ ขนาดความยาวที่สมบูรณ์เพศอย่างน้อย 50 เปอร์เซ็นต์ คือ 5.48 เซนติเมตร โดยองค์ประกอบผลจับสัตว์น้ำเกือบครึ่ง (ร้อยละ 48.70) มีขนาดเล็กกว่าขนาดแรกสืบพันธุ์ ผลการศึกษาชี้ให้เห็นว่าปลาแป้นแก้วเป็นปลากินเนื้อ โดยอาหารหลักเป็นพวกครัสเตเชียน ปลา และแพลงค์ตอนสัตว์

ABSTRACT

The study on some biological and population dynamic aspects of Glaasy fish (*Ambassis kobsii* Bleeker, 1858) in Pak Panang Bay, Nakhon Si Thammarat Province was carried out which aiming to find basic information for future management strategic of this species. Results revealed that the relationships between total length and body weight were $W = 0.00186SL^{2.8622}$. The result revealed that growth pattern of Glassy fish is allometric. The asymptotic length, growth constant and theoretical age at length zero were estimated to be 10.47 cm. (total length) and 0.64 $year^{-1}$ and -0.00055 0.64 $year^{-1}$, respectively. Base on these growth parameters, the natural mortality rate during the study period was determined to be 1.82 $year^{-1}$ .Total mortality rate was calculated as 3.16 $year^{-1}$ and hence fishing mortality rate was 1.37 $year^{-1}$. The length at 50% maturity, L_m of *A. kobsii* in the Pak Panang bay was 5.48 cm. 40.47 % of catch composition show that total length lower than length at 50% maturity. It feed mainly on crustacean fishes and zooplankton.

Keywords : Glassy fish, Population dynamic, Pak Panang Bay

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บทนำ

สภาวการณ์ของการใช้ประโยชน์จากทรัพยากรสัตว์น้ำของประเทศไทยในปัจจุบัน อยู่ในสภาวะที่การใช้ประโยชน์มากเกินประสิทธิภาพการผลิตทดแทนโดยธรรมชาติของทรัพยากรสัตว์น้ำเกือบทุกชนิด เนื่องจากมีการทำการประมงที่หลากหลายชนิดเครื่องมือประมงและเครื่องมือประมงแต่ละชนิดสามารถทำการประมงจับสัตว์น้ำได้หลากหลายชนิดและขนาด จึงมักจะพบว่าองค์ประกอบผลจับสัตว์น้ำจากการทำการประมงในปัจจุบันจะมีสัดส่วนสัตว์น้ำพลอยถูกจับซึ่งเป็นสัตว์น้ำที่ไม่ค่อยมีมูลค่าทางเศรษฐศาสตร์เป็นองค์ประกอบมากกว่าครึ่ง สัตว์น้ำขนาดเล็กเหล่านี้เป็นกลุ่มปลาเหยื่อที่มีความสำคัญในเชิงนิเวศวิทยาและห่วงโซ่อาหารโดยเป็นอาหารที่สำคัญของปลาใหญ่ซึ่งเป็นปลาเศรษฐกิจ ปัจจุบันเครื่องมือประมงโดยเฉพาะกลุ่มเครื่องมือประมงแบบทำลายล้างเช่น อวนรุน อวนลากและโพงพางสามารถจับสัตว์น้ำในกลุ่มพลอยถูกจับได้เป็นจำนวนมากเนื่องจากพยายามลดขนาดตาอวนเพื่อให้สามารถจับสัตว์น้ำได้จำนวนมากขึ้นดังนั้นหากมีการทำการประมงในลักษณะนี้โดยไม่มีแนวทางในการบริหารจัดการทรัพยากรประมงที่เหมาะสม ก็อาจจะสาเหตุให้เกิดการเสื่อมโทรมหรือสูญพันธุ์ของสัตว์น้ำกลุ่มนี้ได้

สัตว์น้ำกลุ่มพลอยถูกจับที่สำคัญชนิดหนึ่งในบริเวณอ่าวปากพนังคือปลาแป้นแก้ว (*Ambassis kobsii* Bleeker, 1858) เป็นกลุ่มปลาหน้าดิน ครอบครัว Ambassidae (asiatic glassfishes) ซึ่งสามารถอาศัยอยู่ได้ทั้งในบริเวณใกล้ฝั่งที่เป็นน้ำเค็มหรือน้ำกร่อยรวมทั้งน้ำจืด ปลาแป้นแก้วจะถูกจับได้เป็นจำนวนมากจากเครื่องมืออวนรุน อวนลาก และโพงพาง โดยชาวประมงจะนำไปขายเป็นปลาป่น นอกจากประโยชน์ด้านการบริโภคแล้วในด้านนิเวศวิทยาปลาแป้นแก้วยังมีความสำคัญในแง่ของการเป็นตัวรักษาความสมดุลของระบบนิเวศน์ในเชิงห่วงโซ่อาหาร ปัจจุบันการศึกษาทางพลวัตประชากรของปลาแป้นแก้วในประเทศไทยยังมีน้อยมากเนื่องจากเป็นสัตว์น้ำที่ไม่ค่อยมีมูลค่าทางเศรษฐกิจจึงไม่ได้รับความสนใจทำการศึกษา ดังนั้นจึงจำเป็นต้องมีการศึกษาพลวัตประชากรของปลาแป้นแก้ว โดยเฉพาะในด้านเกี่ยวกับ การเจริญเติบโต การตาย วัยเจริญพันธุ์ และการกินอาหารซึ่งนับเป็นประเด็นที่สำคัญเพื่อนำไปเป็นข้อมูลเบื้องต้นที่จำเป็นที่ผู้เกี่ยวข้องสามารถใช้ประโยชน์เพื่อการจัดการทรัพยากรปลาแป้นแก้วอย่างเหมาะสมและยั่งยืนต่อไป

วัตถุประสงค์งานวิจัย

1. ศึกษาพารามิเตอร์การเติบโตของปลาแป้นแก้ว
2. ศึกษาพารามิเตอร์การตายของปลาแป้น
3. ศึกษาขนาดเจริญพันธุ์ 50 เปอร์เซ็นต์ของปลาแป้นแก้ว
4. ศึกษาพฤติกรรมการกินอาหารของปลาแป้นแก้ว

วิธีดำเนินการวิจัย

1. การสุ่มตัวอย่าง

ใช้ระเบียบวิธีการวิจัยเชิงสำรวจ (survey research) โดยใช้วิธีการสุ่มตัวอย่างแบบหลายขั้นตอน (multi-stage sampling) โดยสุ่มให้ครอบคลุมทุกพื้นที่ทำการประมง (cluster sampling) โดยกำหนดจุดเก็บตัวอย่างจำนวน 3 สถานี (Figure 1) และสุ่มให้ครอบคลุมประเภทของเครื่องมือประมงทั้งเครื่องมือประมงแบบเคลื่อนที่โดยใช้เครื่องมือประมง ประมงอวนรุน (push net) เป็นเครื่องมือตัวแทน และเครื่องมือประมงแบบประจำที่โดยใช้โพงพาง (set bag net) เป็นเครื่องมือตัวแทน ซึ่งทั้งสองเครื่องมือจัดเป็นเครื่องมือประมงแบบไม่เลือกจับ (non-selective gears) โดยทำการสุ่มเก็บตัวอย่างทุกเดือน และคำนวณหาขนาดตัวอย่างโดยใช้สมการ Taro Yamane (1970) ที่ความเชื่อมั่น 99 เปอร์เซ็นต์ ความคลาดเคลื่อน 5 เปอร์เซ็นต์ พบว่าขนาดตัวอย่างทั้งหมด 900 ตัว เนื่องจากการศึกษาครั้งนี้ทำการเก็บข้อมูลเป็นระยะเวลา 11 เดือน ตั้งแต่เดือนสิงหาคม พ.ศ. 2549 ถึงเดือนมิถุนายน พ.ศ. 2550 จึงสุ่มเก็บตัวอย่างอย่างน้อยเดือนละ 90 ตัวอย่าง แต่อย่างไรก็ตามการศึกษาครั้งนี้เก็บตัวอย่างปลาแป้นแก้วศึกษาทั้งสิ้น 1,016 ตัว

2. การศึกษาตัวอย่างในห้องปฏิบัติการและการวิเคราะห์ข้อมูล

ปลาที่สุ่มเก็บมาได้จะถูกนำมาศึกษาในห้องปฏิบัติการและวิเคราะห์ข้อมูล ในหัวข้อต่อไปนี้

1. การเจริญเติบโต ทำการศึกษาโดยการชั่งน้ำหนักและวัดความยาวเหยียด และวิเคราะห์หาความสัมพันธ์ระหว่างความยาวเหยียดและน้ำหนักตัวของปลาแป้นแก้ว และหารูปแบบการเจริญเติบโตตามวิธีของ Ricker (1971) หาค่าพารามิเตอร์การเติบโต L_∞ โดยใช้วิธีการ Length converted catch curve ในชุดโปรแกรม FiSAT2 (FAO-ICLARM Stock Assessment Tool) และหาค่า K ตามขั้นตอนการวิเคราะห์ของ Amarasinghe and De Silva (1992) หาค่า t_0 ตามวิธีการของ Pauly (1983) ดังสมการที่......(1)

$$\log_{10}(-t_0) = -0.3922-0.2752\log_{10}(L_\infty)-1.038\log_{10}(K) \quad ......(1)$$

2.. ศึกษาการตาย โดยหาค่าสัมประสิทธิ์การตายรวมโดยใช้วิธีการ John and Van Zalinge Plot และหาค่าสัมประสิทธิ์การตายโดยธรรมชาติโดยใช้วิธีการ Pauly’s M Equation ในชุดโปรแกรม FiSAT 2

3.. การศึกษาขนาดเจริญพันธุ์ 50 เปอร์เซ็นต์ (Lm_{50}) โดยใช้สมการของ Mattson (1997) ดังสมการที่ 2

$$L_m = L_\infty[1/(1+(M/3K))] \quad ....(2)$$

4. การศึกษาเกี่ยวกับการกินอาหาร องค์ประกอบอาหารในกระเพาะอาหาร โดยใช้วิธีการประมาณโดยสายตา ตามวิธีของ ธนิษฐา (2543)

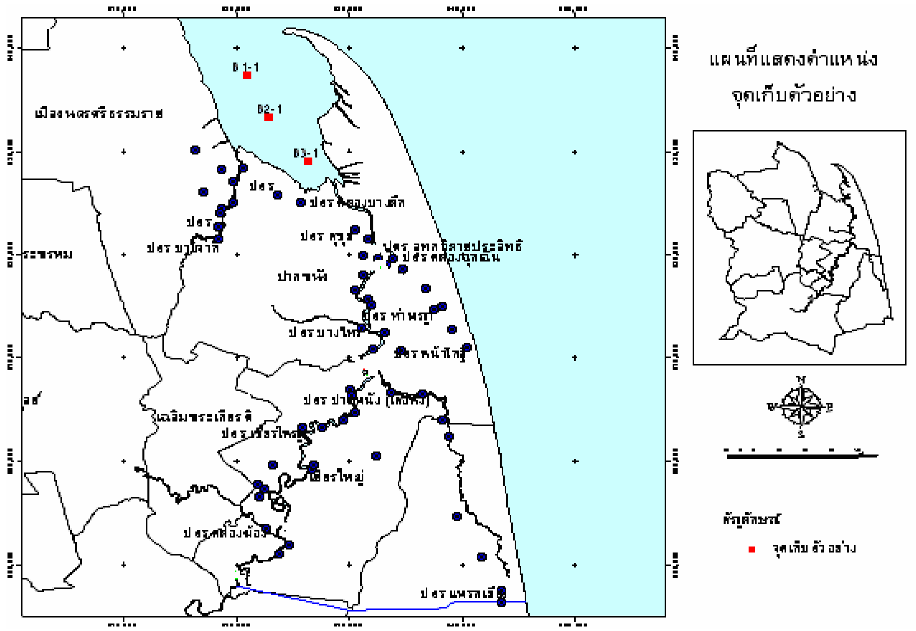

Figure 1. Sampling stations in Pak Panang Bay.

ผลและวิจารณ์ผลการศึกษา

ผลการศึกษาชีววิทยาและพลวัตประชากรบางประการของปลาแป้นแก้วในบริเวณอ่าวปากพนัง จังหวัดนครศรีธรรมราช โดยเก็บรวบรวมตัวอย่างระหว่างเดือน สิงหาคม พ.ศ. 2549 ถึงเดือนมิถุนายน พ.ศ. 2550เพื่อศึกษา การเติบโต การตาย ขนาดเจริญพันธ์ 50 เปอร์เซ็นต์ (Lm_{50}) และการกินอาหาร ได้ผลการศึกษาดังนี้

1. ความสัมพันธ์ระหว่างความยาวและน้ำหนักตัวของปลาแป้นแก้ว

ผลการศึกษาความสัมพันธ์โดยการวิเคราะห์ข้อมูลด้วยเส้นถดถอยในรูปสมการลอการิทึมและแปลงสมการให้อยู่ในรูปฟังก์ชันยกกำลัง พบว่าความสัมพันธ์ระหว่างความยาวเหยียดและน้ำหนักตัวของปลาแป้นแก้วมีความสัมพันธ์ดังสมการ $W = 0.0186TL^{2.8622}$ (Figure 2)

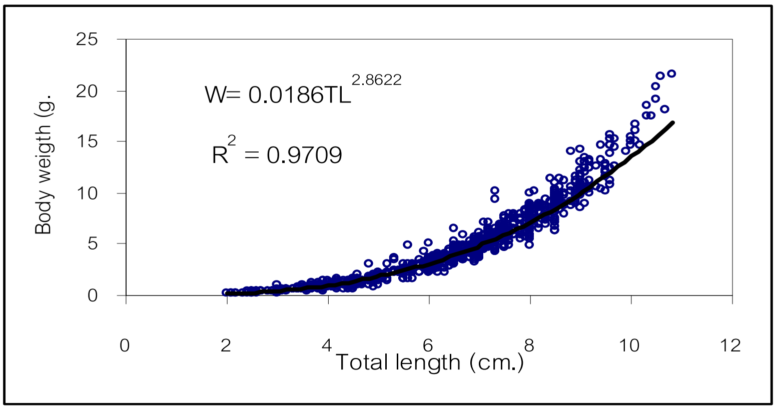

Figure 2 Relationship between total length (cm.) and body weight (g.) of *A. kobsii*

ผลการทดสอบค่ายกกำลัง (b) ของสมการความสัมพันธ์ระหว่างความยาวเหยียดกับน้ำหนักตัวว่ามีค่าเท่ากับ 3 หรือไม่ โดยใช้ t-test เพื่อวิเคราะห์รูปแบบการการเจริญเติบโต พบว่าค่า t-test ของปลา เท่ากับ -8.55 และเมื่อเปิดค่า t-table ที่ระดับนัยสำคัญ 0.05 ซึ่งมีค่า df เท่ากับ 1,014 พบว่าค่า t-table มีค่าเท่ากับ 1.96 ดังนั้นจึงสามารถสรุปได้ว่าการเจริญเติบโตของปลาแป้นแก้วเป็นแบบอัลโลเมทริก (allometric) เนื่องจากมีค่า b น้อยกว่า 3 ที่ระดับนัยสำคัญ 0.05

2. **พารามิเตอร์การเติบโต**

ผลการศึกษาค่าพารามิเตอร์การเติบโตโดยการจัดช่วงการแพร่กระจายความถี่ของความยาวเหยียด 1.8 -10.8 เซนติเมตร ซึ่งการแพร่กระจายความถี่ของความยาวของปลาแป้นแก้วทั้งหมดเป็นดัง (Figure 3) ซึ่งได้ผล การศึกษาค่าพารามิเตอร์การเติบโตดังแสดงใน Table 1 โดยประมาณค่า L_∞ โดยวิธีการ Length converted catch curve (Figure 4) ได้ L_∞ เท่ากับ 10.27 เซนติเมตร (r = 0.974) และประมาณค่า K โดยใช้ K-Scan (Figure 5) ได้ค่า K เท่ากับ 0.64 ต่อปี และเมื่อใช้ชุดโปรแกรม Automatic Search เพื่อปรับค่า L_∞ กับ K ที่ได้ในตอนแรกให้เหมาะสมกับเส้นโค้งการเติบโตที่สุด พบว่าค่า L_∞ เท่ากับ 10.47 เซนติเมตร และ K เท่ากับ 0.64 ต่อปี (R_n = 0.192) ค่า Phi prime เท่ากับ 1.846 ซึ่งมีค่าใกล้เคียงกับการศึกษาของ Kottelat, et al. (1993) ซึ่งมีค่าเท่ากับ 1.88 ทั้งนี้ค่าพารามิเตอร์ t_0 เท่ากับ -0.00055 ต่อปี โดยกราฟเส้นโค้งการเติบโตของปลาแป้นแก้วเป็นดัง Figure 6

Table 1 Demographical growth parameters status of *A. kobsii* in Pak Panang Bay

พารามิเตอร์						
L_∞ (cm.)	K (yr^{-1})	t_0 (yr^{-1})	f'	C	WP	R_n
10.47	0.64	-0.00055	1.846	0	0	0.192

Note: Growth performance indices

(f') = $\log_{10}K+2\log_{10} L_\infty$ (Moreau et al, 1986); Rn is an index of goodnees-of-fit of growth come to the LFD in the ELEFAN II (Electronic Length frequency Analysis) method (Gayanilo et al, 1995)

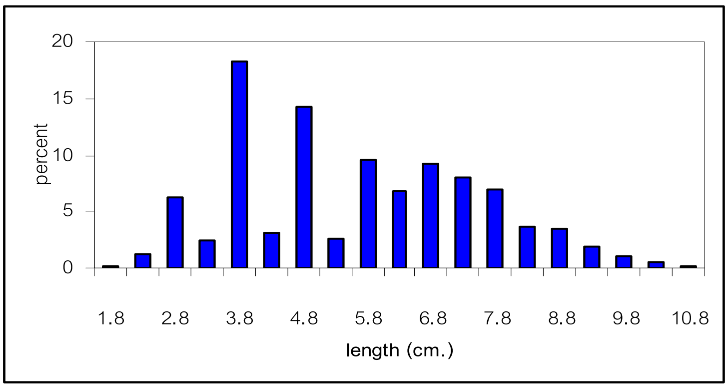

Figure 3 Overall length frequency distribution of *A. kobsii* in the study

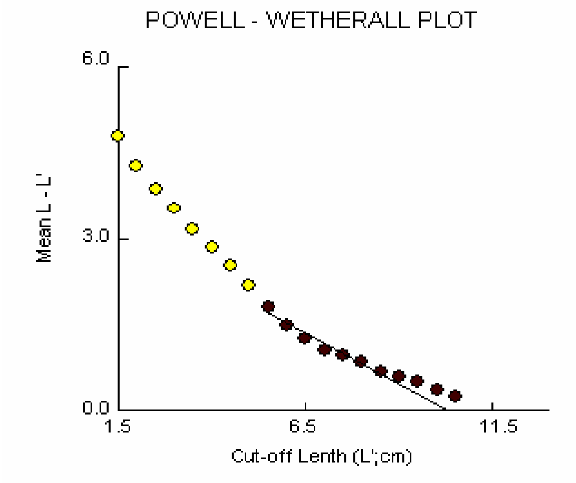

Figure 4 Length converted catch curve of *A. kobsii* in Pak Panang Bay estimated by ELEFAN II

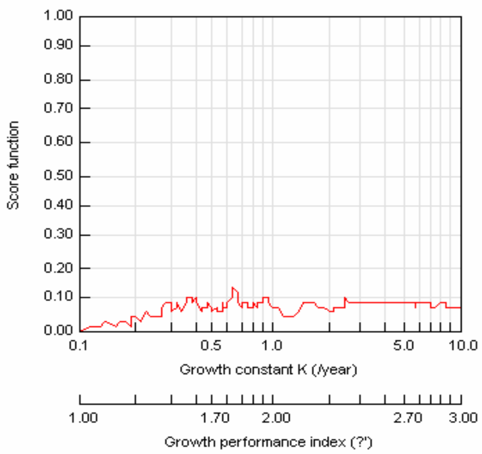

Figure 5 K parameter scan of *A. kobsii* in Pak Panang Bay estimated by ELEFAN II

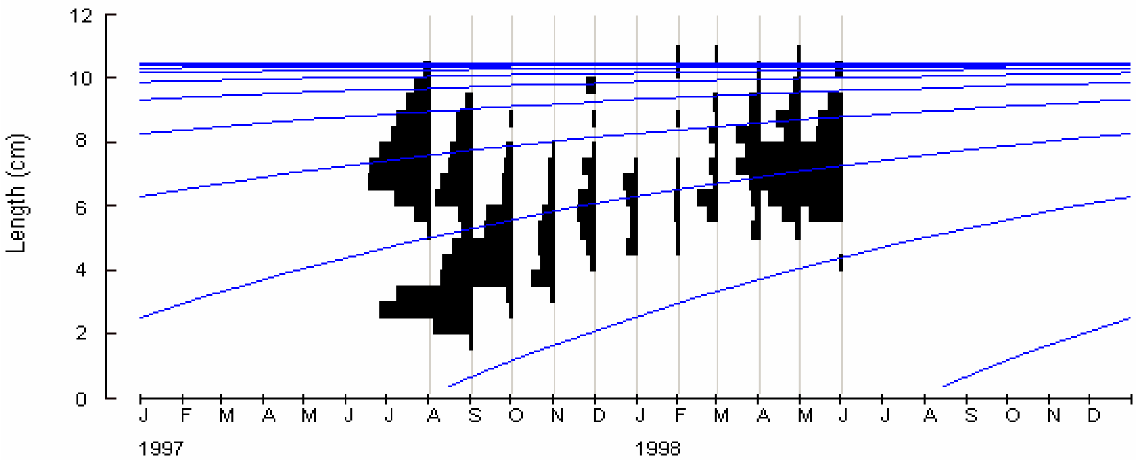

Figure 6 Growth curves of *A. kobsii* superimposed on the length frequency distributions of the sample

3. **สัมประสิทธิ์การตาย**

ผลการศึกษาค่าสัมประสิทธิ์การตายรวม (Z) สัมประสิทธิ์การตายเนื่องจากการประมง (F) และสัมประสิทธิ์การตายโดยธรรมชาติ (M) ของปลาแป้นแก้วเป็นดัง Table 2 โดยหาค่าสัมประสิทธิ์การตายรวมจากวิธีการ John and Van Zalinge Plot (Figure 6) ได้ค่าสัมประสิทธิ์การตายรวม เท่ากับ 3.16 ต่อปี (r^2= 0.9988) และคำนวณหาค่าสัมประสิทธิ์การตายโดยธรรมชาติโดยใช้สมการ Pauly (1983) พบว่ามีค่าเท่ากับ 1.82 ต่อปี ทั้งนี้ค่าสัมประสิทธิ์การตายเนื่องจากการประมง เท่ากับ 1.34 ต่อปี

Table 1 Mortality parameters status of *A. kobsii* in Pak Panang Bay

ค่าสัมประสิทธิ์การตาย		
Z (yr^{-1})	F (yr^{-1})	M (yr^{-1})
3.16	1.34	1.82

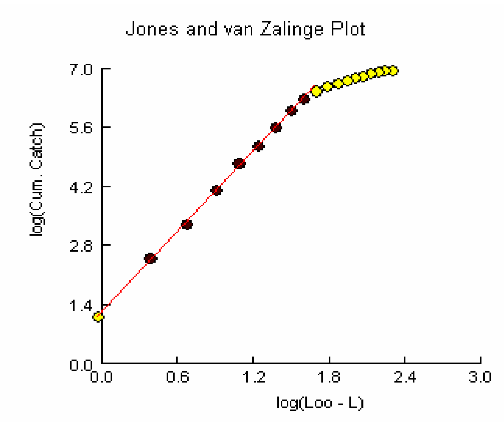

Figure 7 Jones and van Zalinge plot for estimated total mortality of *A. kobsii* by ELEFAN II

4. **ขนาดวัยเจริญพันธุ์ 50 เปอร์เซ็นต์** (Lm_{50})

ผลการศึกษาขนาดเจริญพันธุ์ 50 เปอร์เซ็นต์ (Lm_{50})ซึ่งจะนำค่าพารามิเตอร์การเติบโตจากผลการศึกษาในส่วนของการเติบโตมาคำนวณหาโดยใช้สมการของ Mattson (1997) พบว่า ขนาดวัยเจริญพันธุ์ 50 เปอร์เซ็นต์ของปลาแป้นแก้ว เท่ากับ 5.48 เซนติเมตรซึ่งแสดงว่าที่ความยาวนี้ปลาแป้นแก้วจะสืบพันธุ์วางไข่แล้วอย่างน้อย 50 เปอร์เซ็นต์ ซึ่งเมื่อพิจารณาผลจับปลาแป้นที่จับขึ้นมาใช้ประโยชน์พบว่าจำนวนปลาแป้นเกือบครึ่ง (ร้อยละ 48.70) มีขนาดเล็กกว่าขนาดแรกสืบพันธุ์

5. **องค์ประกอบของอาหารในกระเพาะอาหาร**

จากการสุ่มเก็บตัวอย่างปลาแป้นแก้วจำนวน 115 ตัว มาศึกษา พบว่า กระเพาะอาหารของปลาแป้นแก้วมีลักษณะเป็นรูปตัววี ขนาดเล็ก ผนังด้านในกระเพาะอาหารเป็นสีเนื้อ พบว่าเป็นปลาที่มีอาหารอยู่ในกระเพาะอาหารจำนวน 102 ตัว คิดเป็นร้อยละ 88.70 ของกระเพาะอาหารทั้งหมด และปลาที่ไม่มีอาหารอยู่ใน

กระเพาะอาหารจำนวน 13 ตัว คิดเป็นร้อยละ 11.30 จากการวิเคราะห์องค์ประกอบอาหารในกระเพาะของปลาแป้นแก้ว พบว่าในกระเพาะปลาแป้นแก้วมีอาหารหลายกลุ่มดังนี้ กลุ่มครัสเตเชียน (Figure 8) กลุ่มปลา (Figure 9) กลุ่มแพลงค์ตอนสัตว์ (Figure 10) และกลุ่มเบ็ดเตล็ด (Figure 11) ซึ่งปลาแป้นแก้วอาจจะกินโดยบังเอิญ ได้แก่ แมลง นอกจากนี้ยังพบว่ามีชิ้นส่วนของอาหารที่ถูกย่อยไปบ้างแล้ว และไม่สามารถจำแนกชนิดได้ (Figure 12) ทั้งนี้พบว่าเปอร์เซ็นต์ความถี่ที่พบตัวอย่างอาหารแต่ละกลุ่มจากตัวอย่างกระเพาะอาหารแป้นแก้วที่มีอาหารอยู่ในกระเพาะจำนวน 102 ตัว เท่ากับ 56.86 29.41 29.41 และ 4.90 เปอร์เซ็นต์ ตามลำดับ และผลการศึกษาพบว่าอัตราร้อยละของอาหารที่พบในกระเพาะอาหารของแต่ละกลุ่มมีผลดังนี้ กลุ่มครัสเตเชียน ประมาณร้อยละ 52.67 กลุ่มปลา ประมาณร้อยละ 23.73 กลุ่มแพลงค์ตอนสัตว์ ประมาณร้อยละ 20.93 และกลุ่มเบ็ดเตล็ด ประมาณร้อยละ 2.67

Figure 8 Crustaceans

Figure 11 Other

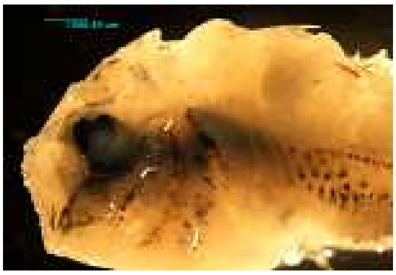

Figure 9 Fishes

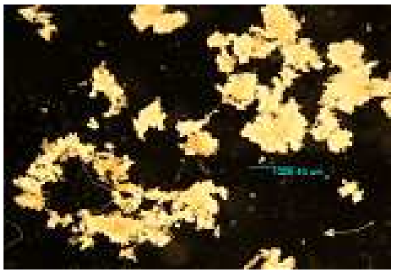

Figure 12 Unidentified

Figure 10 Zooplankton

สรุป

ผลการศึกษาชีววิทยาและพลวัตประชากรบางประการของปลาแป้นในบริเวณอ่าวปากพนัง จังหวัดนครศรีธรรมราช ตั้งแต่เดือน สิงหาคม พ.ศ. 2549 ถึงเดือนมิถุนายน พ.ศ. 2550 สามารถสรุปได้ว่า ความสัมพันธ์ระหว่างความยาวเหยียดและน้ำหนักตัวของปลาแป้นแก้วมีความสัมพันธ์ดังสมการ $W = 0.0186TL^{2.8622}$ ซึ่งเมื่อทดสอบรูปแบบการเจริญเติบโตของปลาแป้นแก้วพบว่ารูปแบบการเจริญเติบโตของปลาแป้นแก้วเป็นแบบอัลโลเมทริก โดยมีค่าพารามิเตอร์การเติบโต L_∞ เท่ากับ 10.47 เซนติเมตร K เท่ากับ 0.64 ต่อปี t_0 เท่ากับ -0.00055 ต่อปี สามารถเขียนสมการการเติบโตของปลาแป้นคือ $Lt = 10.47[1-exp^{-0.64(t-(-0.00055)}]$ ค่าสัมประสิทธิ์การตายรวม สัมประสิทธิ์การตายโดยการประมง และสัมประสิทธิ์การตายโดยธรรมชาติ มีค่าเท่ากับ 3.16 3.14 และ1.82 ต่อปี ตามลำดับ ทั้งนี้ขนาดวัยเจริญพันธุ์ 50 เปอร์เซ็นต์ของปลาแป้นแก้ว เท่ากับ 5.48 เซนติเมตรซึ่งแสดงว่าที่ความยาวนี้ปลาแป้นแก้วจะสืบพันธุ์วางไข่แล้วอย่างน้อย 50 เปอร์เซ็นต์ และเมื่อพิจารณาผลจับปลาแป้นที่จับขึ้นมาใช้ประโยชน์พบว่าจำนวนปลาแป้นเกือบครึ่ง (ร้อยละ 48.70) มีขนาดเล็กกว่าขนาดแรกสืบพันธุ์ ผลการศึกษาพฤติกรรมการกินอาหารสรุปได้ว่าปลาแป้นเป็นปลากินเนื้อเนื่องจากผนังด้านในกระเพาะอาหารเป็นสีเนื้อและองค์ประกอบอาหารในกระเพาะของปลาแป้นแก้วมีอาหารหลายกลุ่ม คือ กลุ่มครัสเตเชียน กลุ่มปลา กลุ่มแพลงค์ตอนสัตว์ และกลุ่มเบ็ดเตล็ด ซึ่งปลาแป้นแก้วอาจจะกินโดยบังเอิญ ได้แก่ แมลง นอกจากนี้ยังพบว่ามีชิ้นส่วนของอาหารที่ถูกย่อยไปบ้างแล้ว และไม่สามารถจำแนกชนิดได้ พบว่าเปอร์เซ็นต์ความถี่ที่พบตัวอย่างอาหารแต่ละกลุ่มจากตัวอย่างกระเพาะอาหารแป้นแก้วที่มีอาหารอยู่ในกระเพาะ เท่ากับ 56.86 29.41 29.41 และ 4.90 เปอร์เซ็นต์ ตามลำดับ และผลการศึกษาพบว่าอัตราร้อยละของอาหารกลุ่มครัสเตเชียน ประมาณร้อยละ 52.67 กลุ่มปลา ประมาณร้อยละ 23.73 กลุ่มแพลงค์ตอนสัตว์ ประมาณร้อยละ 20.93 และกลุ่มเบ็ดเตล็ดประมาณร้อยละ 2.67

เอกสารอ้างอิง

ธนิษฐา ทรรพนันทน์. 2543. ชีววิทยาประมง. คณะ ประมง, มหาวิทยาลัยเกษตรศาสตร์, กรุงเทพมหานคร.

Amarasinghe, U.S. and S.S. De Silva. 1992. Population dynamics of *Oreochromis mossambicus* and *O. niloticus* (Cichlidae) in two reservoirs in Sri Lanka. Asian Fisheries Science 5: 37-61.

Gayanilo Jr., F.C., P. Sparre and D. Pauly. 1995. The FAO-ICLARM stock assessment tools(FiSAT) user's guide. FAO Computerized Information Series (Fisheries), ICLARM Contribution No.1048. ICLARM, Manila. 126 p.

Kottelat, M., A.J. Whitten, S.N. Kartikasari and S. Wirjoatmodjo, 1993. Freshwater fishes of Western Indonesia and Sulawesi. Periplus Editions, Hong Kong. 221 p.

Mattson, N.S. 1997. Fish production and ecology in African small water bodies with emphasis on tilapia. Ph.D. thesis, Stockholm University. 36 pp. with annex.

Moreau, J., C. Bambino and D. Pauly. 1986. Indices of overall growth performance of 100 tilapia (Cichlidae) population. In: The first Asian Fisheries Forum Zeds. Maclean, J.L., Dizon, L.B. and Hosillos, V.), pp. 201-206. Asian Fisheries Society, Manila Pauly, D. 1983. Some simple methods for the assessment of tropical fish stock. FAO Fisheries Technical Paper No. 234. 54 pp.

Ricker, W.E. 1971. Methods for assessment of fish production in freshwater. Backwell scientific publications, Oxford.