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Fish 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 Fish

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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, southern of Thailand. The samples were collected between March 2006 to June 2007at six sampling sites (three sites each from above and below the dam). A total of 70 fish species belonging to 68 genera and 44 families were sampled. To analyze patterns of fish assemblages, an artificial neural network (ANN) in the form of a self-organizing map (SOM) was applied. The sample-combinations (sluice gate regime (opening or closing), sampling stations and months of sampling) were classified into four 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 opportunistic marine fish (21 species) followed by true brackish water fish (17 species). Others comprised of steno- and eury-haline fish as well as the anadromy. The likely impacts of each guild due to the dam regulations and further studies for conserving these fish were also discussed.

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

INTRODUCTION

More than 70% of river systems in tropical areas are regulated (Revenga and Kura, 2003). Water management and infrastructure development are the main driving forces on the modification of rivers worldwide (Welcomme *et al.*, 2006). The inevitable consequent impacts on the "goods and services" of the river from such modifications, especially to fish, are experienced and reported elsewhere and the most serious cases have occurred when the morphology, hydrology and functioning of a river were changed by damming the mainstream *per se* (Marmulla, 2001). Along the river course, the greatest species richness is situated at the interface between the freshwater and marine domains, in the hypopotamon zone (Blaber, 2002), which is comprised of marine-, freshwater- and estuarine-origin fish species. Therefore, once the lower course of the river is fragmented, not only the fish from a single origin will be affected, but from all

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of the three categories. Among these fish, the diadromous and amphidromous species are the groups that should be taken care of, 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 a fertile basin on the southern east coast of Thailand. The Pak Panang River runs to the sea at Pak Panang Bay in the Gulf of Thailand. In the past couple of decades, an increase in urbanization, deforestation and the needs of household consumption and agricultural activities incorporated with the characteristic of the low gradient of the lower course of the river have resulted in the longer periods of intrusion of seawater for greater lengths of water into the Pak Panang River, 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 acidic, 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 developed and operations commenced in 1999. The water gates *per se* are located 6 km upstream of the delta (Figure 1), with a size of 9×20 m^2. There are 10 sluice gates, whose major purposes are to prevent intrusion of the saline water into the inner area along the river and to maintain a freshwater supply for irrigation (Prabnarong and Kaewrat, 2006). After construction, sluice gate operation has been irregular, depending on the water level upstream. Consequently, the possibility of marine and brackish water species moving upstream from the lower river portion varied according to their tolerance to changes in environmental factors, especially salinity. This paper, therefore, presents the guild classification of the marine and brackish water fish in the Pak Panang area using self- organizing maps according to their assemblages from the bay area to the upper area of the river and discussion of the likely effects on each guild due to the Uthokawiphatprasid watergate management.

MATERIALS AND METHODS

Sampling stations and sampling protocols

Six sampling stations were selected with three stations in each component (the estuarine and the river) (Figure 1). The stations were mapped using a Garmin-GPSmap 76CSx. Sampling was conducted monthly during the spring-tide period. Fish sampling, in the estuarine/marine component, was conducted using push net dragging in the sampling area for around 30 min. Meanwhile, a beach net was used as well as various mesh sizes of gillnets to cover the water column, being left overnight before harvest for the freshwater stations. Fish samples were packed in ice and brought to Walailak University 50 km from the watergates. Fish were then taxonomically classified to the species level, or as far as possible (Nelson, 1976; Froese and Pauly, 2007). All the fish were weighed and the number in each species counted. Salinity at the sampling stations was obtained from a portable YSI 63-50FT. Field sampling was 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 of techniques and is one of the best-known neural networks with unsupervised learning rules (Penczak *et al.,* 2004). This method has been increasingly used by ecologists and successful results in aquatic ecology using this model have been well documented (Lek *et al.,* 2005). The detail of the sequential SOM algorithm process can be retrieved from Kohonen (1995) and Lek and Guégan (1999). In this study, a species abundance dataset was arranged as a matrix of 96 rows (6 sites sampled for 16 months) and 70 columns (fish species, consisting of 44

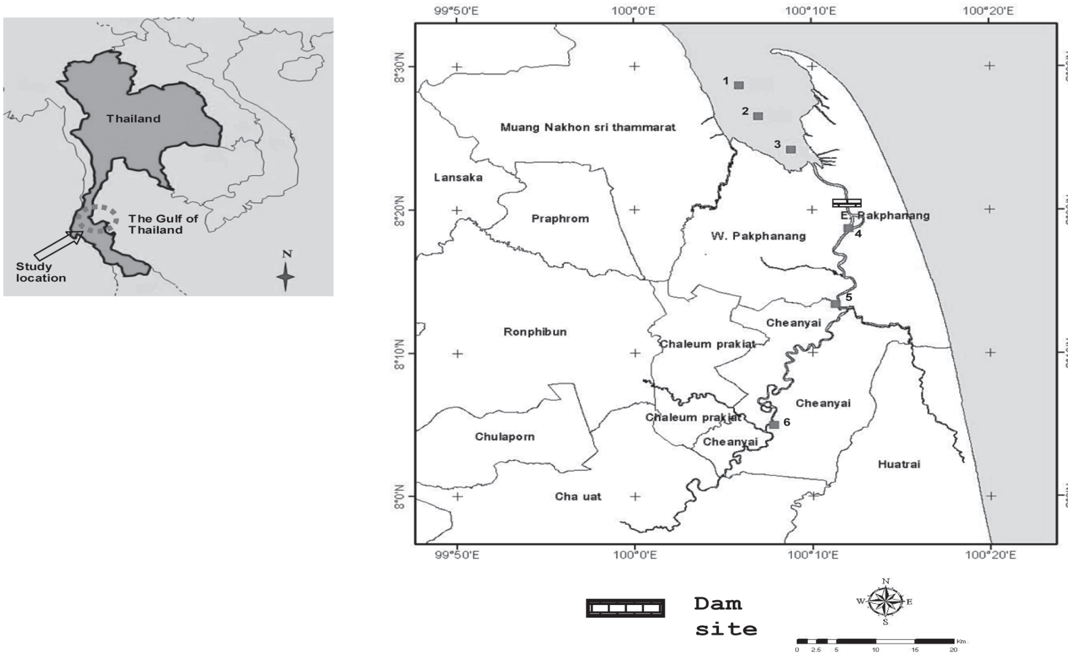


Figure 1 Location of study area and map of sampling stations.

brackish water species and 26 marine species as shown in Table 1). Each of the 96 samples of the dataset can be considered as a vector of 70 dimensions and the samples were presented in the form of a combination among sluice gate regimes (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 carried out using various types of fishing gear and tried to cover all fish species, which avoided the bias of species abundance in calculations that could occur by using a single type of 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 dataset and ii) the two-dimensional output layer composed of 56 neurons (a rectangular grid with 8 by 7 neurons laid out 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 were modified to minimize the distance between the weight and input vectors (Gevrey *et al.,* 2004). When an input vector $\boldsymbol{x}$ (densities of species) is sent through the network, each neuron $\boldsymbol{k}$ of the output layer computes the summed distance between the weight vector $\boldsymbol{w}$ and the input vector $\boldsymbol{x}$ (Park *et al.,* 2005). In this study, the analysis was carried out using the MATLAB software version 7® with the 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 differences in each studied parameter. Calculations and graphics were conducted using Program R (R Development Core Team, 2008)

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

Family	Scientific name	Abbrev.	Origin	Economic importance	Occurrence I	II	III	IV	V	VI	Number	Weight of individual ± sd (g)
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
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

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: ES = estuarine and MA = marine).

Family	Scientific name	Abbrev.	Origin	Economic importance	Occurrence I	II	III	IV	V	VI	Number	Weight of individual ± sd (g)
Hemirhamphidae	*Hyporhamphus dussumieri*	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*	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
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 details of the Uthokvibhajaprasid water gates 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

RESULTS

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

The hierarchical cluster analysis applied to the output matrix extracted from the SOM, classified the sample 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 stations 3 and 4 during the opening scheme. Cluster **IV** was exclusively the stations further down to the sea during the closing phase of the sluice gates. The remaining combinations of 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 other clusters (Mann-Whitney test, $p < 0.01$). There was no statistical difference in species richness among the remaining clusters (Mann-Whitney test, $p > 0.05$). The outliners in Cluster **I** and the wide range of Cluster **II** indicated the occurrence of the marine and brackish water fish in the river component.

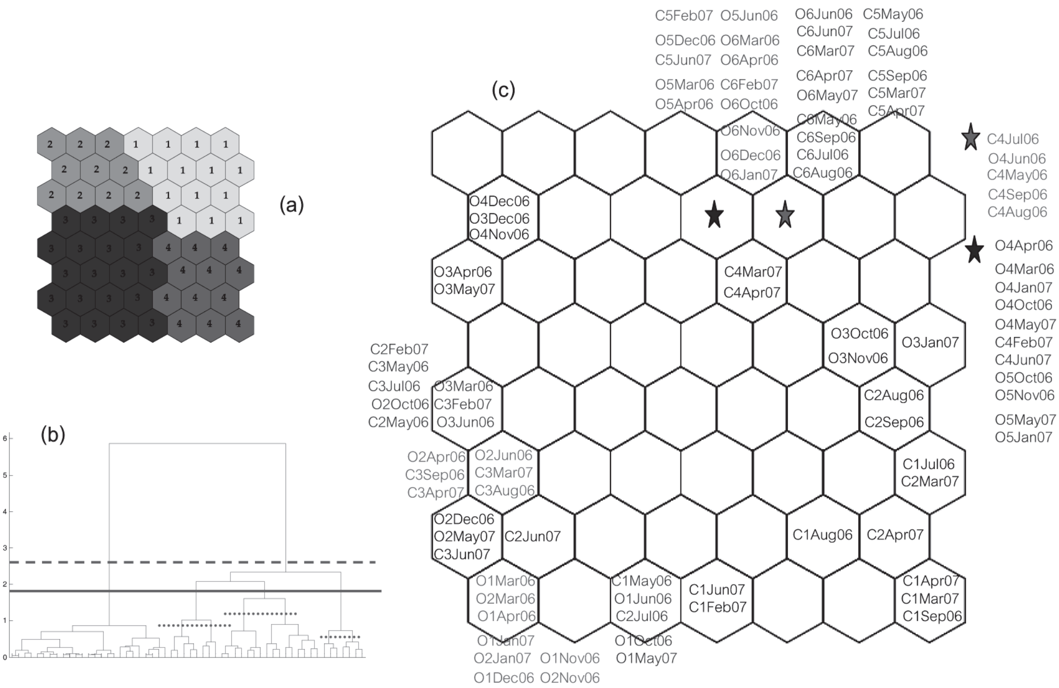


Figure 2 **(a)** Self-organizing map with the four colors corresponding to the clusters **(b)** Hierarchical clustering of the SOM nodes with the Ward-linkage method **(c)** Classification of combinations through the learning process of the self-organizing map.

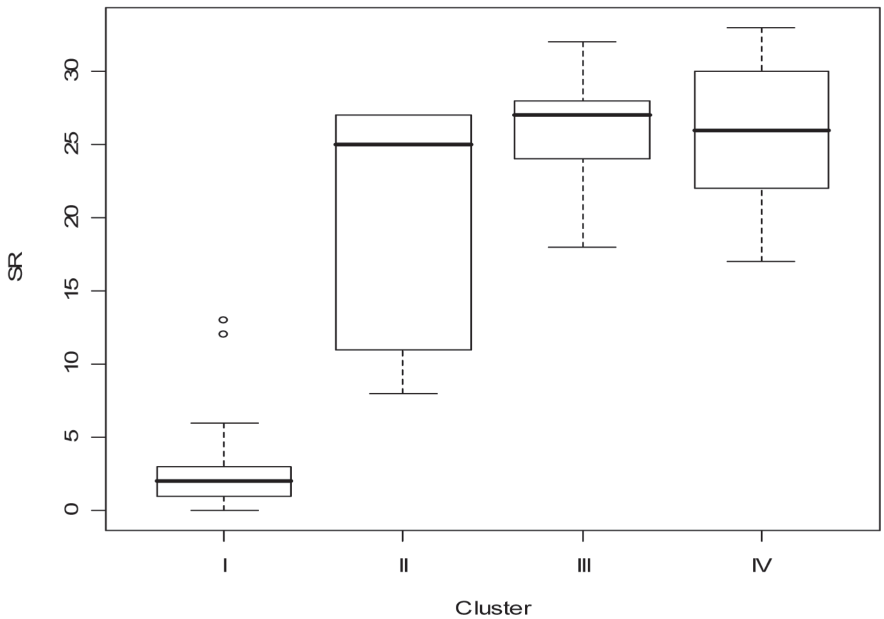


Figure 3 Boxplot comparing fish species richness (SR) in the four clusters defined by the self-organizing map.

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

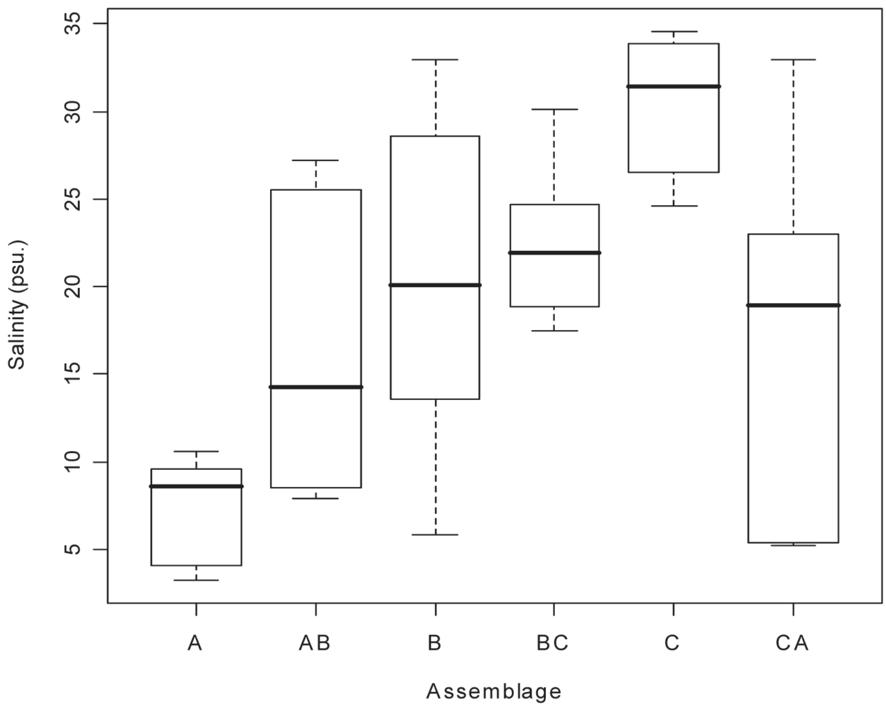


Figure 4 Boxplot comparing fish salinity in the six assemblages.

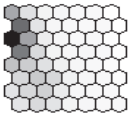
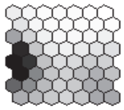
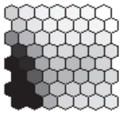
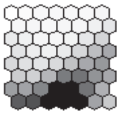
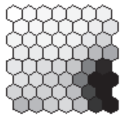
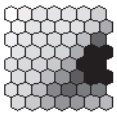
	Assemblage A: *Acentrogobius caninus*, *Acanthosphex leurynnis* and *Parapocryptes serperaster*
	Assemblage Ab: *Vespicula trachinoides*, *Trypauchen vagina*, *Tetraodon nigroviridis*, *Takifugu oblongus*, *Butis butis*, *Platycephalus indicus*, *Parambassis siamensis* and *Siganus canaliculatus*
	Assemblage 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 assemblage defined by the hierarchical clustering applied to the self-organizing map (SOM) units. Dark areas represent high probability of occurrence; light areas indicate lower probability.

DISCUSSION

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

Although the hierarchical cluster analysis showed four obvious clusters, the SOM maps exhibited a pattern suggesting that the marine and brackish water fish assemblages in the Pak Panang area could 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 to 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) spawning (Riede, 2004) or mixed. Moreover, during the prevalence of seawater intrusion into the river portion, the stenohaline fishes in Assemblage **A** would have had a serious impact. Among the samples, three species in Assemblage **Ca** (*Anodontostoma chacunda*, *Liza oligolepis* and *Valamugil cunnesius*) were reported as anadromy (McDowall, 1999). Two more species, *Pomadasys kaakan* and *Megalop cyprinoid*, were also claimed to be anadromous by the local fishers. Thus, it is recommended that successful management to achieve viable diadromy populations will require study of their life cycles and analysis of carbon and nitrogen stable isotopes, especially in otolith, to confirm the hypotheses that these fish species inhabit both marine and freshwater environments (Hogan *et al.,* 2007).

As discussed earlier on the need for freshwater to complete the life cycle of fish 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, fish would result in lower abundance in the area (Fukushima *et al.,* 2007) if the opening period did not comply with the period when the fish moved up- and down- stream. For the remaining assemblages, the regulations for the dam near the river mouth had no direct effect. However, there could be an impact on their food resources. During the closing phase of the sluice gates, the nutrients from the river system would be trapped in the fore-bay area (MacIntyre *et al.,* 2000) and high turbidity and sediment would be flushed into the delta during the opening phase (Cloern, 1987). Both situations would “more or less” impact the primary productivity (phytoplanktons, Cloern, 1987; MacIntyre *et al.,* 2000) and secondary production (zooplanktons and benthoses, Champalbert *et al.,* 2007) in the estuary.

CONCLUSION

Classifying marine and brackish water fish in the Pak Panang area, according to location and salinity level, provided a clear picture on the likely impacts of anti-salt dam operations near the river mouth. Impacts could range from the serious case of the fish being unable to complete their life cycle to the extirpation of the species due to reduced food resources, which would both lead to a decrease in fish abundance. It could be argued that over-fishing could be the main source of problem. However, There was evidence that small- and medium- sized fish were unlikely to become extinct due to fishing alone, as long as habitat and migration routes were kept intact (Mattson and Jutagate, 2005) as they showed low to medium resilience (Froese and Pauly, 2007). Another aspect, beyond this study, that should be of concern, is the role the mangrove and near shore area plays as a nursery ground, with suitable habitat and range of salinity to suit the fish larvae of various species Tongnunui *et al.* (2002). This issue should be further investigated to guarantee recruitment to sustain fish stocks in addition to the fisheries in Pak Panang Bay.

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