Part 1:

Species composition and distribution pattern of demersal fish and other benthic organisms assemblage along coastal area off Pattani and Narathiwas Provinces

Abstract

Community structure of trawl catches including fishes and other macro-invertebrates in different depth zones and months and evaluation of an influence of environmental factors in structuring their composition in southern part of the South China Sea were assessed. A total of 151,799 fishes, representing 59 families and 157 species were collected by bottom trawls during daylight hours between November 2005 and July 2007 from 16 sites along coastal waters off Pattani and Narathiwas provinces, Thailand. Of these, the ten most dominant species accounted for 90.7% of the catch. A great domination of Leiognathidae, principally *Leiognathus splendens* (51.5%) and *Leiognathus brevirostris* (16.5%) was recorded. Families with the greatest number of species were Leiognathidae (10 species) and Carangidae (8 species). A highly significant difference ($P<0.001$) between fish density collected at different zones indicates that depth is a major factor structuring the community. Highly significant differences ($P<0.001$) between months on fish species richness and biomass were found ($P< 0.05$). Cluster dendogram indicated further that the difference was based mainly on seasonal and annual impacts. Temperature has an impact on fish species richness and density, whilst dissolved oxygen influenced only on fish biomass. For macro-invertebrates, 5,574 individuals belonging to three main groups including decapoda, mollusca, echinodermata and other phyla were recorded. Analysis of variance indicated site differences for macro-invertebrate density ($P<0.05$) and biomass ($P<0.005$) and monthly difference for species number ($P<0.0005$). Mollusks and crabs were the largest group together with shrimps and other organisms and could be divided by cluster into two different depth communities.

Key words

Gulf of Thailand; Fish ecology, Demersal species; Fish and environment

Introduction

The importance of tropical coastal habitats as productive areas used by larvae, juveniles and adults of many estuarine-dependent fish species for reproductive activities, foraging and shelter are well-recognized (Blaber, et al., 1995; Peterson and Whitfield, 2000; Harris et al., 2001). Fishes living in these habitats are subject to a complex matrix of interacting physical and biological factors that determine their occurrence, distribution and movement pattern (Blaber, 2000). Among the main parameters to affect the spatial and temporal organization of fish communities in these habitats are salinity, temperature, turbidity, substrate type, benthic composition and depth. Seasonal recruitment and migration of young fishes from shallow estuaries and coastal area to deeper waters and adults moving to spawning areas produce a great change in local near-shore fish community structure (Cladridge et al., 1986). Analysis of community structure of demersal species is important for an understanding of ecological processes and functions of a particular ecosystem and providing a basis for management of fisheries resources. Several approaches have been used in the description of fish assemblages and their explanatory factors. Some studies focus on environmental influences (Howell and Simpson, 1994; Gelwick et al., 2001; Griffiths, 2001; Jaureguizar et al., 2004), some investigates seasonal and spatial patterns of community structure (Maes et al., 1998; Rhodes, 1998) and some determines both factors simultaneously (de Azevedo et al., 2007).

The huge estuarine coastal areas of South China Sea support the largest and most productive of the world's tropical estuarine fisheries and the area especially the Gulf of Thailand, which is part of the South China Sea, is subjected to heavily fishing pressure from various types of gears used (Blaber, 2000). Although there are some studies investigated knowledge on assemblages and ecological aspects of fishes in shallow sheltered-estuarine habitats of the region (Pinto, 1988; Chong et al., 1990; Sasekumar et al., 1992; Ikejima, 2003; Hajisamae and Chou, 2003), information on fish community of deeper near-shore waters, up to 30m depth which is considered one of the busiest fishing ground exploited by most fishermen, is poorly investigated in Asia and none of the literature found in Southeast Asia.

The objectives of this study are to examine diversity, distribution, density and biomass of fishes and benthic macro-invertebrates and to clarify how important is depth zones, months and environmental parameters that shape their community.

Materials and Methods

Study area

Sampling sites are located along the coasts of Pattani and Narathiwat provinces, southern Thailand. This area coincides with southern area of the South China Sea, considered to be heavily over-fished (Blaber, 2001). The coastline is characterized by long sandy beaches, semi-diurnal tides with approximately 0.3-0.9m tidal ranges and experiences two different tropical monsoons; the North-East monsoon from November to February and South–West monsoon from May to August. Freshwater inputs from four main rivers including the Takbai, Bangnara, Saiburi and Pattani Rivers drain into this area. Pattani bay, a 74 km^2 semi-enclosed estuarine bay with several ecosystem types, provides shelter for juveniles of many taxa before migrating to deeper areas (Hajisamae et al., 2006). Four different line transects parallel to the shoreline were selected; sites A, B, C and D. At each site, four different depth contours were marked as zones 1, 2, 3 and 4 (Figure 1). The average depths at these zones were 12.3±1.0m, 15.8±1.0m, 19.8±1.0m and 23.3±1.5m, respectively. These areas are unobstructed by formations except for a small island between stations D3 and D4.

Collection of samples

Fishes and macro-invertebrate samplings were conducted bimonthly by a bottom trawl towing during daylight hours at a approximately 2.3 knot for 60 minutes, between November 2005 and July 2007, defined as a unit effort. A total of 144 hauls were repeated. Each trawl followed a depth contour to minimize the impact of depth changes (de Azevedo, et al., 2007). The trawl was constructed with a 14m headline, 15m ground rope, and 2.20cm mesh cod-end liner. The catches were immediately iced and transported to the laboratory for sorting, identifying and determining of total length. All materials were deposited in Fishery Technology collection, Faculty of Science and Technology, Prince of Songkla University, Thailand for future reference.

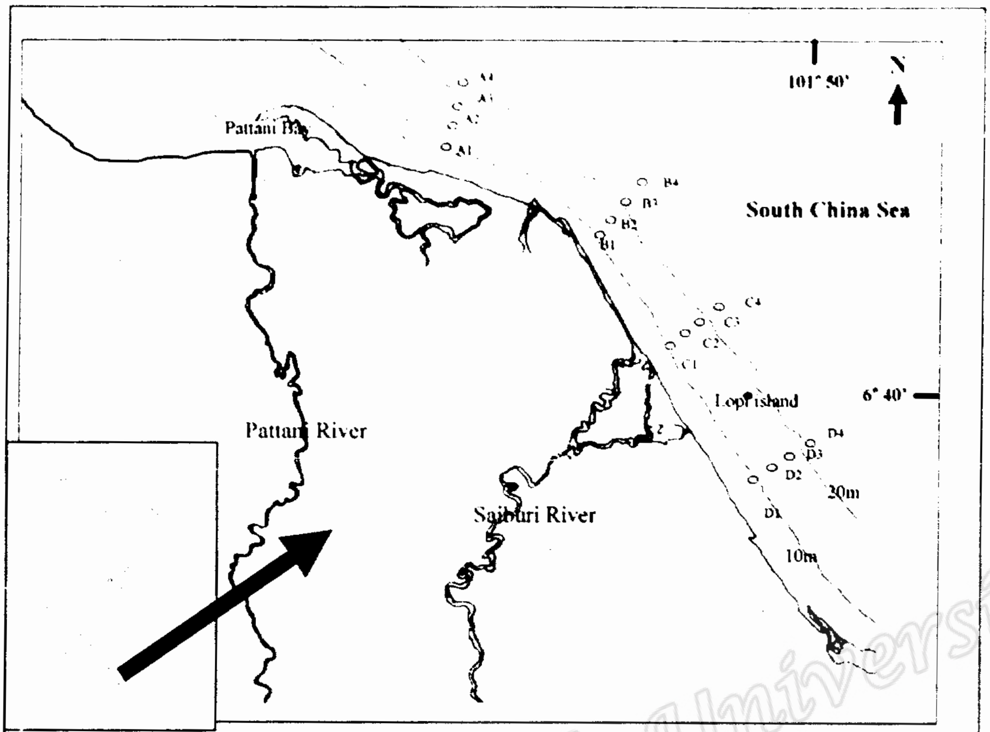


Figure 1 Map of the study area.

Hydrological parameters

Dissolved oxygen, pH, salinity and temperature were measured *in situ* by a YSI 556 MPS meter at the depth of 1.0m below sea surface. Salinity was measured using the Practical Salinity Scale.

Statistical Analysis

Fish catch data was analyzed for: (1) community parameters; Shannon Weiner's diversity index (H') and mean species richness per sampling occasion (SR), (2) relative abundance and (3) ecotypes, indicating either the fish is pelagic, semi-pelagic or demersal species based on adult inhabitancy. Analysis of variance (ANOVA) was used to compare density of fish, numbers of species and biomass between all sites and months. Catch data, found non-normalized distributed, both number of individuals and species were log (X+1) transformed to reduce non-normality. To test for the difference in community assemblages between sites and months, a cluster Analysis was carried out using PRIMER statistical package version 5.0 (Clarke and Gorley 2001), with a Bray-Curtis similarity and a complete linkage cluster mode, to construct a cluster dendogram. Analysis of similarity (ANOSIM) was used to determine whether the community separated by the dendogram differed significantly. Once the significant difference was detected, a Similarity Percentage (SIMPER) was used to examine which species contributed most to the classification. To test for preference over sites and months of 30 dominant fish species, a Cluster Analysis constructed the dendogram and ANOSIM tested a difference of the groupings. SIMPER examined which sampling sites or months the identified species are likely to inhabit or distribute. Regression analysis was performed on log-transformed data to examine relationship between fish community structure and environmental parameters

Abundance and distribution at each depth zones of macro-invertebrates were analyzed. Analysis of variance (ANOVA) was used to compare; (1) density, numbers of species and biomass between all sites and months. Cluster analysis was applied to test for community structure at different depth before SIMPER was used to identify which taxa contributing to the formation of cluster group on the dendogram.

Results

Hydrological parameter

Mean surface water temperature, pH, DO and salinity were 31.4±1.0°C, 7.7±1.2, 6.3±0.7ppm and 34.5±2.8, respectively. Detail of average hydrological parameters is presented in **Table 1**.

Table 1 Water parameters collected off Pattani and Narathiwas provinces between November 2005 and July 2007

Site	Water parameter			
	Temperature	**pH**	**DO**	**Salinity**
A1	31.3± 1.1	7.8± 1.3	6.2± 0.7	34.7± 3.3
A2	31.3± 1.0	7.8± 1.3	6.1± 0.7	34.6± 3.3
A3	31.0± 0.9	7.8± 1.3	6.3± 0.6	35.0±35.0
A4	30.9± 0.8	7.6± 1.4	6.2± 0.6	35.0± 2.6
B1	31.8± 0.5	7.8± 1.3	6.2± 0.6	34.1± 3.1
B2	31.5± 0.7	7.8± 1.3	7.0±1.4	34.3±3.0
B3	31.1±0.8	7.7±1.5	6.2±0.7	34.2±3.0
B4	30.8±1.0	7.6±1.2	6.3±0.6	34.6±2.7
C1	32.0±0.9	7.8±1.1	6.3±0.7	34.4±2.8
C2	31.7±0.9	7.7±1.2	6.4±0.8	34.3±2.8
C3	31.5±1.1	7.6±1.4	6.1±0.7	34.3±2.9
C4	30.9±1.1	7.1±1.1	6.1±0.6	34.6±3.0
D1	31.8±0.9	7.8±1.1	6.2±0.6	34.7±2.9
D2	31.6±1.0	7.8±1.2	6.2±0.6	34.6±2.8
D3	31.4±1.0	7.8±1.0	6.2±0.6	34.5±2.6
D4	31.0±1.0	7.4±1.3	6.3±0.5	33.7±3.0
Average ± SE	**31.4±1.0**	**7.7±1.2**	**6.3±0.7**	**34.5±2.8**

General catch data

A total of 151,799 fishes representing 59 families and 157 species were collected in this study. Ten most numerically dominant species accounted for 90.7% of the total catch (**Tables 2, 3 and 4**). Leiognathidae, principally, *Leiognathus splendens* and *Leiognathus brevirostris* dominated the catch with 51.5% and 16.5%, respectively. It was followed by *Priacanthis macracanthus* (5.4%), *Secutor ruconius* (5.0%), *Upeneus tragula* (3.7%), *Leiognathus stercorarius* (2.3%) and *Scolopsis taeniopterus* (2.1%). Families with the greatest number of species were Leiognathidae (10 species), followed by Carangidae (8 species) and Monacanthidae, Apogonidae, Lutjanidae and Tetraodontidae (6 species each). Twenty five families represented by only a single species.

Mean species richness (SR), individual per unit effort and biomass per unit effort were 16.0±0.9 species, 1054.2±406.4 individual/haul and 11.8±3.7 kg/haul, respectively. H' value for overall catch was 1.98. Details for ecological attributes for each depth zones and months are presented in **Table 5**.

Based on eco-type analysis, fishes could be categorized into three different ecological groups; demersal, pelagic and semi-pelagic (**Figure 2**). Of these, semi-pelagic species was the largest group both as total number of species (93.9%) and overall catch (51.3%).

Table 2 Fish families with total number of individual and number of fish species collected off Pattani and Narathiwas provinces between November 2005 and July 2007

Family	No. of individuals	%	No. of species	%	Family	No. of individuals	%	No. of species	%
Leiognathidae	118516	78.07	10	6.3	Ostraciidae	16	0.01	2	1.3
Carangidae	201	0.13	8	5.1	Scombridae	15	0.01	2	1.3
Monacanthidae	151	0.10	6	4.4	Hemiscylliidae	9	0.01	2	1.3
Apogonidae	2404	1.58	6	3.8	Blenniidae	3	0.00	2	1.3
Lutjanidae	481	0.32	6	3.8	Stromateidae	2	0.00	2	1.3
Tetraodontidae	236	0.16	6	3.8	Caesionidae	1262	0.83	1	0.6
Mullidae	6857	4.52	5	3.2	Centriscidae	828	0.55	1	0.6
Nemipteridae	3419	2.25	5	3.2	Bothidae	446	0.29	1	0.6
Labridae	633	0.42	5	3.2	Parolichthyidae	121	0.08	1	0.6
Sciaenidae	67	0.04	5	3.2	Sillagiridae	107	0.07	1	0.6
Clupeidae	6	0.00	5	3.2	Pinguipedidae	31	0.02	1	0.6
Soleidae	752	0.50	4	2.5	Trichiuridae	25	0.02	1	0.6
Platycephalidae	505	0.33	4	2.5	Ephipidae	16	0.01	1	0.6
Gobiidae	213	0.14	4	2.5	Dasyatidae	13	0.01	1	0.6
Serranidae	135	0.09	4	2.5	Cepolidae	10	0.01	1	0.6
Cynoglossidae	93	0.06	4	2.5	Lethrinidae	10	0.01	1	0.6
Haemulidae	187	0.12	4	2.5	Polynemidae	10	0.01	1	0.6
Callionymidae	2488	1.64	3	1.9	Samaridae	9	0.01	1	0.6
Synodontidae	1049	0.69	3	1.9	Glaucosomatidae	6	0.00	1	0.6
Synanceiidae	214	0.14	3	1.9	Narcinidae.	5	0.00	1	0.6
Gerreidae	65	0.04	3	1.9	Sphyraenidae	5	0.00	1	0.6
Engraulididae	13	0.01	3	1.9	Fistularidae	4	0.00	1	0.6
Terapontidae	8	0.01	3	1.9	Menidae	4	0.00	1	0.6
Priacanthidae	8198	5.40	2	1.3	Syngnathidae	4	0.00	1	0.6
Ariidae	633	0.42	2	1.3	Dactylopteridae	3	0.00	1	0.6
Siganidae	565	0.37	2	1.3	Antennariidae	2	0.00	1	0.6
Plotosidae	548	0.36	2	1.3	Chirocentridae	2	0.00	1	0.6
Scorpaenidae	100	0.07	2	1.3	Diodontidae	2	0.00	1	0.6
Pegasidae	64	0.04	2	1.3	Exocoetidae	1	0.00	1	0.6
Batrachoididae	27	0.02	2	1.3	**Total**	**151799**		**157**	**100.0**

Table 3 Ten most dominant fishes at each zone collected off Pattani and Narathiwas provinces between November 2005 and July 2007

Species	Zone 1	Species	Zone 2	Species	Zone 3	Species	Zone 4
Leiognathus splendens	51612	*Leiognathus splenden*	20224	*Priacanthus macracanthus*	6945	*Upeneus tragula*	2900
Leiognathus brevirostris	9035	*Leiognathus brevirostris*	15282	*Leiognathus splenden*	6350	*Caesio cuning*	969
Secutor ruconius	6422	*Scolopsis taeniopterus*	1313	*Upeneus tragula*	1809	*Scolopsis taeniopterus*	863
Gazza minuta	1754	*Leiognathus stercorarius*	1249	*Scolopsis taeniopterus*	804	*Apogon quadrifasciatus*	582
Callionymus planus	1631	*Secutor ruconius*	1171	*Leiognathus brevirostris*	500	*Leiognathus stercorarius*	418
Leiognathus stercorarius	1503	*Priacanthus macracanthus*	1039	*Siaganus canaliculatus*	470	*Upeneus sulphureus*	392
Arius venosus	631	*Gazza minuta*	684	*Xyrichtys trivittatus*	470	*Liachirus melanospiles*	229
Plotosus anguillaris	520	*Aeroliscus strigatus*	589	*Apogon quadrifasciatus*	398	*Leiognathus brevirostris*	163
Upeneus tragula	453	*Lieognathus decorus*	558	*Saurida micropectoralis*	350	*Upeneus sundaicus*	158
Lieognathus decorus	368	*Upeneus tragula*	498	*Liachirus melanospiles*	338	*Apogon niger*	149

Table 4 Fishes collected off coastal waters of Pattani and Narathiwas provinces between November 2005 and July 2007.

Family	Species	Number	%	Family	Species	Number	%	Family	Species	Number	%
Antennariidae	*Antennarius hispidus*	2	0.00	Gobiidae	*Yongeichthys nebulosus*	5	0.00	Pegasidae	*Parapegasus natans*	26	0.02
Apogonidae	*Apogon endekataenia*	269	0.18		*Oxyurichthys saru*	163	0.11		*Pegasus volitans*	38	0.03
	Apogon niger	268	0.18		*Valenciennea wardi*	40	0.03	Pinguipedidae	*Parapercis alboguttata*	31	0.02
	Apogon quadrifasciatus	1564	1.03	Haemulidae	*Diagramma pictum*	63	0.04	Platycephalidae	*Elates ransonneti*	2	0.00
	Apogon striatus	107	0.07		*Plectorhinchus vittatus*	9	0.01		*Inegocia japonica*	479	0.32
	Archamia lineolata	191	0.13		*Pomadosys maculatus*	106	0.07		*Platecephalus indicus*	13	0.01
	Vincentia chrysura	5	0.00		*Pomadasys kaakan*	9	0.01		*Grammoplites scaber*	11	0.01
Ariidae	*Arius venosus*	632	0.42	Hemiscylliidae	*Chiloscyllium griseum*	2	0.00	Plotosidae	*Plotosus anguillaris*	546	0.36
	Arius maculatus	1	0.00		*Chiloscyllium punctatum*	7	0.00		*Plotosus lineatus*	2	0.00
Batrachoididae	*Bastrichthys grunniens*	25	0.02	Labridae	*Halichoeres bicolar*	17	0.01	Polynemidae	*Polynemus tetradactylum*	10	0.01
	Batrachomoeus trispinosus	2	0.00		*Halichoeres nigrescens*	5	0.00	Priacanthidae	*Priacanthus macracanthus*	8172	5.38
Blenniidae	*Plagiotremus phenax*	1	0.00		*Leptojulis cyanopleura*	1	0.00		*Priacanthus tayenus*	26	0.02
	Xiphasia setifer	2	0.00		*Xyrichtys evides*	21	0.01	Samaridae	*Samaris cristatus*	9	0.01
Bothidae	*Engyprosopon grandisquamis*	446	0.29		*Xyrichtys trivittatus*	589	0.39	Sciaenidae	*Dendrophysa russelli*	9	0.01
Caesionidae	*Caesio cuning*	1262	0.83	Leiognathidae	*Gazza minuta*	2622	1.73		*Otolithes ruber*	3	0.00

Family	Species	Number	%	Family	Species	Number	%	Family	Species	Number	%
Callionymidae	*Callionymus planus*	2153	1.42		*Lieognathus decorus*	1070	0.70		*Pennahia macrocephalus*	8	0.01
	Callionymus schaapii	6	0.00		*Leiognathus brevirostris*	24980	16.46		*Nibea soldado*	26	0.02
	Dactylopus dactylopus	329	0.22		*Leiognathus equulus*	39	0.03		*Johnius dussumieri*	21	0.01
Carangidae	*Alectis indicus*	31	0.02		*Leiognathus leuciscus*	3	0.00	Scombridae	*Rastrelliger brachysoma*	9	0.01
	Alepes kleinii	14	0.01		*Leiognathus splendens*	78230	51.54		*Scomberomorus commerson*	6	0.00
	Alepes vari	49	0.03		*Leiognathus stercorarius*	3484	2.30	Scorpaenidae	*Pterois russelii*	37	0.02
	Apolectus niger	23	0.02		*Lieognathus moretoniensis*	15	0.01		*Scorpaeniopsis cirrhosus.*	63	0.04
	Megalaspis cordyla	1	0.00		*Secutor insidiator*	457	0.30	Serranidae	*Epinephelus areolatus*	1	0.00
	Selaroides leptolepis	6	0.00		*Secutor ruconius*	7616	5.02		*Epinephelus bleekeri*	17	0.01
	Carangoides hedlandensis	76	0.05	Lethrinidae	*Lethrinus lentjan*	10	0.01		*Epinephelus coioides*	30	0.02
	Carangoides armartus	1	0.00	Lutjanidae	*Lutjanus biguttatus*	305	0.20		*Epinephelus sexfasciatus*	87	0.06
Centriscidae	*Aeroliscus strigatus*	828	0.55		*Lutjanus erythropterus*	35	0.02	Siganidae	*Siganus canaliculatus*	559	0.37
Cepolidae	*Acanthocepola abbreviata*	10	0.01		*Lutjanus johnii*	3	0.00		*Siaganus javus*	6	0.00
Chirocentridae	*Chirocentrus dorab*	2	0.00		*Lutjanus lutjanus*	94	0.06	Sillaginidae	*Sillago sihama*	107	0.07
Clupeidae	*Anodontostoma chacunda*	1	0.00		*Lutjanus madras*	39	0.03	Soleidae	*Asereggodes dubius*	63	0.04
	Escualosa thoracata	1	0.00		*Lutjanus russelli*	5	0.00		*Liachirus melanospiles*	604	0.40
	Herklotsichthys dispilonotus	1	0.00	Menidae	*Mene maculata*	4	0.00		*Solea stanalandi*	84	0.06
	Sardinella albella	2	0.00	Monacanthidae	*Anacanthus barbatus*	19	0.01		*Synaptura commersoniana*	1	0.00
	Sardinella gibbosa	1	0.00		*Chaetodermis penicilligerus*	4	0.00	Sphyraenidae	*Sphyraena jello*	5	0.00
Cynoglossidae	*Cynoglossus macrolepidotus*	12	0.01		*Monacanthus tomentosum*	5	0.00	Stromateidae	*Pamphus argenteus*	1	0.00
	Cynoglossus bilineatus	6	0.00		*Monacanthus chinensis*	77	0.05		*Pampus chinensis*	1	0.00
Cynoglossidae	*Cynoglossus semifasciatus*	4	0.00		*Paramonacanthus choirocephalus*	28	0.02	Synanceiidae	*Minous monodactylus*	198	0.13
	Cynoglossus puncticeps	71	0.05		*Paramonacanthus curtorhynchus*	18	0.01		*Inimicus didactylus*	3	0.00
Dactylopteridae	*Dactyloptena orientalis.*	3	0.00	Mullidae	*Upeneus bensasi*	110	0.07		*Inimicus cuvieri*	13	0.01
Dasyatidae	*Himantura bleekeri*	13	0.01		*Upeneus sulphureus*	847	0.56	Syngnathidae	*Hippichthys penicillus*	4	0.00
Diodontidae	*Diodon holocanthus*	2	0.00		*Upeneus sundaicus*	222	0.15	Synodontidae	*Saurida micropectoralis*	526	0.35
Engraulididae	*Stolephorusi indicus*	6	0.00		*Upeneus tragula*	5675	3.74		*Saurida undrosquamis*	298	0.20
	Stolephorus sp.	1	0.00		*Parupeneus heptacanthus*	3	0.00		*Trachinocephalus myops*	225	0.15

Family	Species	Number	%	Family	Species	Number	%	Family	Species	Number	%
	Thryssa hamiltonii	6	0.00	Narcinidae	*Temera hardi*	5	0.00	Terapontidae	*Terapon jarbua*	1	0.00
Ephipidae	*Drepane punctata*	16	0.01	Nemipteridae	*Nemipterus hexodon*	199	0.13		*Terapon theraps*	6	0.00
Exocoetidae	*Cypselurus sp.*	1	0.00		*Pentapodus setosus*	67	0.04		*Terapon puta*	1	0.00
Fistularidae	*Fisturaria villosa*	4	0.00		*Scolopsis taeniopterus*	3117	2.05	Tetraodontidae	*Arothron immaculatus*	1	0.00
Gerreidae	*Gerres abbreviatus*	8	0.01		*Scolopsis vosmeri*	3	0.00		*Arothron meleagris*	1	0.00
	Gerres filamentosus	56	0.04		*Nemipterus virgatus*	33	0.02		*Arothron stellatus*	1	0.00
	Gerres oyena	1	0.00	Ostraciidae	*Lactoria cornuta*	8	0.01		*Lagocephalus lunaris*	179	0.12
Glaucosomatidae	*Gnatoplis nystromi*	6	0.00		*Ostraction orbiculatus*	8	0.01		*lagocephalus sceleratus*	49	0.03
Gobiidae	*Acentrogobius caninus*	5	0.00	Parolichthyidae	*Pseudorhombus arsius*	121	0.08		*Takifugu oblongus*	5	0.00
								Trichiuridae	*Trichiurus lepturus*	25	0.02

Table 5 Summary of ecological indices of fish community at different zones and in different months collected off Pattani and Narathiwas provinces between November 2005 and July 2007.

Depth zones	CPUE/haul ±SE	Species richness±SE	Biomass (kg±SE)	Total No. of species	Total No. of individuals	H'
1	2124.1±505.6	14.9±0.9	20.2±4.8	111	76466	1.33
2	1263.5±538.2	16.3±1.1	13.6±4.6	112	45487	1.71
3	594.0±262.0	16.6±1.0	8.6±2.4	99	21383	2.26
4	235.1±40.3	16.2±1.0	4.9±0.6	101	8428	2.65
Months						
Nov-05	1281.3±533.9	19.4±1.8	21.5±6.9	95	20500	2.03
Jan-06	127.8±33.9	12.5±1.3	3.4±0.6	73	2044	2.63
Mar-06	918.6±563.8	13.9±1.3	8.2±4.2	71	14698	1.48
May-06	1664.9±636.1	19.1±1.4	23.4±7.9	80	26638	1.76
Jul-06	615.9±164.2	17.4±1.1	5.7±1.1	72	9854	2.25
Sep-06	1522.2±590.5	16.3±1.1	14.5±5.9	76	24355	1.07
Mar-07	1309.4±1147.8	11.9±1.1	9.1±6.1	64	20950	1.40
May-07	1160.1±627.8	16.6±1.3	10.6±4.9	66	18562	1.45
Jul-07	887.4±570.1	16.9±1.1	9.8±6.1	72	14198	1.49
Average/Total	1054.2±406.4	16.0±0.9	11.8±3.7	157	151799	1.98

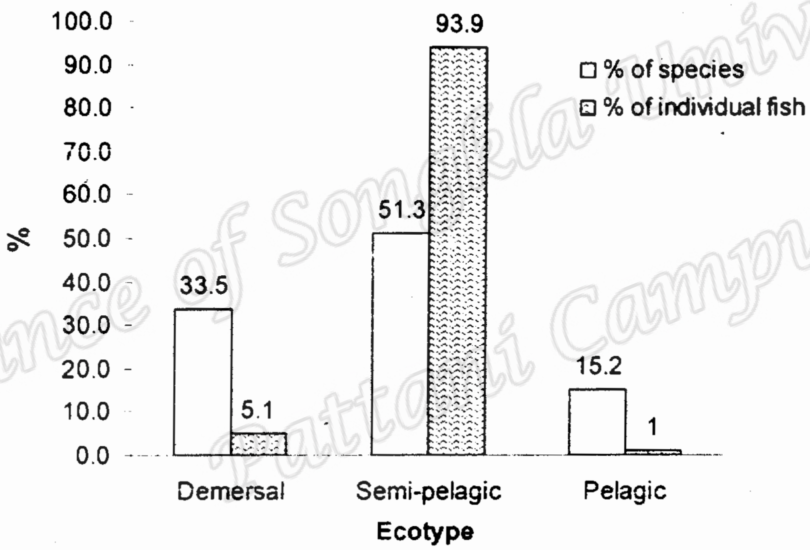


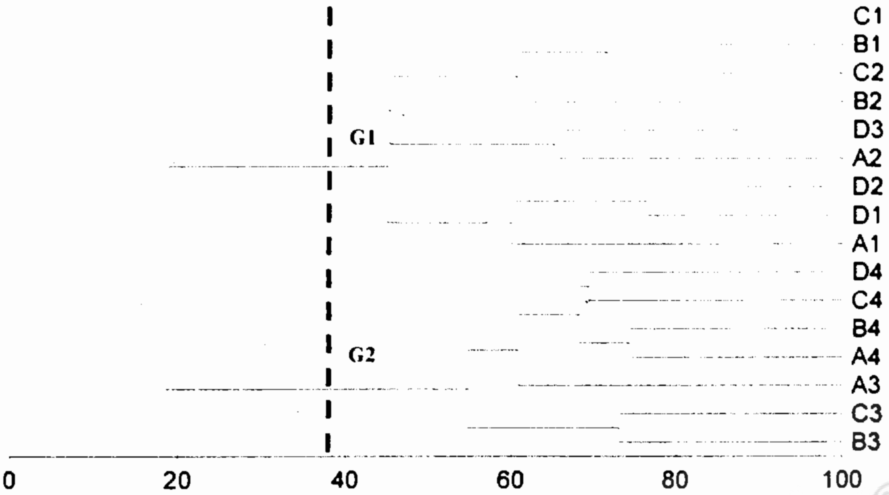
Figure 2 Relative number of fish species and total number of individuals of different eco-types collected bimonthly off Pattani and Narathiwas provinces between November 2005 and July 2007.

Effect of depth zones

Analysis of variance indicated a highly significant difference between fish density collected from four different zones (df = 3, F = 6.87, P=0.0002). The largest density was in zone 1, followed by zones 2, 3 and 4, respectively. There was no difference for species richness (df = 3, F = 0.495, P = 0.686) and fish biomass (df = 3, F = 2.51, F = 0.061).

Cluster dendogram separated fish community into two main groups (**Figure 3**a). The first group consisted almost entirely of sites from zones 1 and 2. The second group comprised entirely of sites from zones 3 and 4. Analysis of similarity (ANOSIM) demonstrated a significant difference between compositions of fish samples from these two groups (Global R = 0.899, P <0.01). A similarity percentage analysis (SIMPER) showed, in the case of group 1, that the fish species made up of >70% of the definitive group including *Leiognathus splendens, Leiognathus brevirostris, Scolopsis taeniopterus, Leiognathus stercorarius, Apogon quadrifasciatus* and *Secutor ruconius*. For the second group, SIMPER indicated that fishes that made up of >70% of this group including *Upeneus tragula, Scolopsis taeniopterus, Apogon quadrifasciatus, Caesio cuning, Leiognathus stercorarius, Saurida micropectoralis, Upeneus sulphureus, Liachirus melanospiles* and *Trachinocephalus myops*.

(a)



(b)

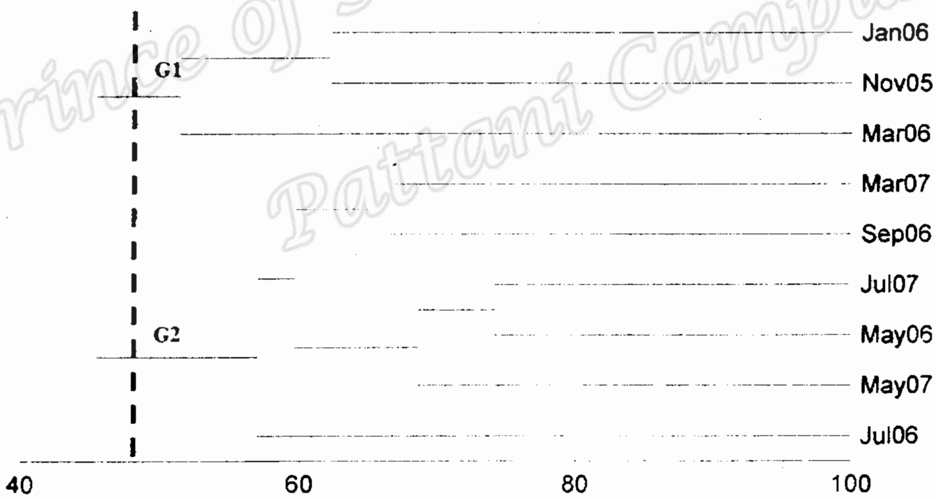


Figure 3 Cluster dendogram of abundance data for each samples collected bimonthly (a) at four different zones and (b) in different months off Pattani and Narathiwas coasts between November 2005 and July 2000

Preference over sites of dominant fish species

Fishes formed five different clusters on the dendogram **(Figure 4a)**. Analysis of similarity (ANOSIM) significantly divided 30 dominant species into five separated groups (Global R = 0.696, $P<0.01$). With the exception of G3 and G5, significant differences were demonstrated for all pairs on pair-wise tests.

Seven species formed the first cluster, such as *Apogon niger*, *Caesio cuning*, *Trachinocephalus myops* and *Upeneus tragula*. A similarity percentage (SIMPER) indicated that they were found mainly at deeper stations such as A3, D4, A4 and B3. The species such as *Saurida micropectoralis*, *Liachirus melanospiles*, *Scolopsis taeniopterus* and *Leiognathus stercorarius* created the largest cluster (Group 2). SIMPER identified that these species distributed in almost all areas. The third group consisting of *Lutjanus biguttatus*, *Plotosus anguilaris* and *Aeroliscus strigatus* were found specifically at A1 and C4. The forth cluster, consisting of all leiognathid species such as *Leiognathus decorus*, *Leiognathus splendens* and *Gazza minuta*, was identified by SIMPER that they were found almost entirely at the shallow stations including D2, D1, A1 and C1. *Arius venosus* and *Callionymus planus* formed the fifth cluster and was indicated by SIMPER that their preferred site was the shallowest waters especially at C1, B1 and A1.

(a)

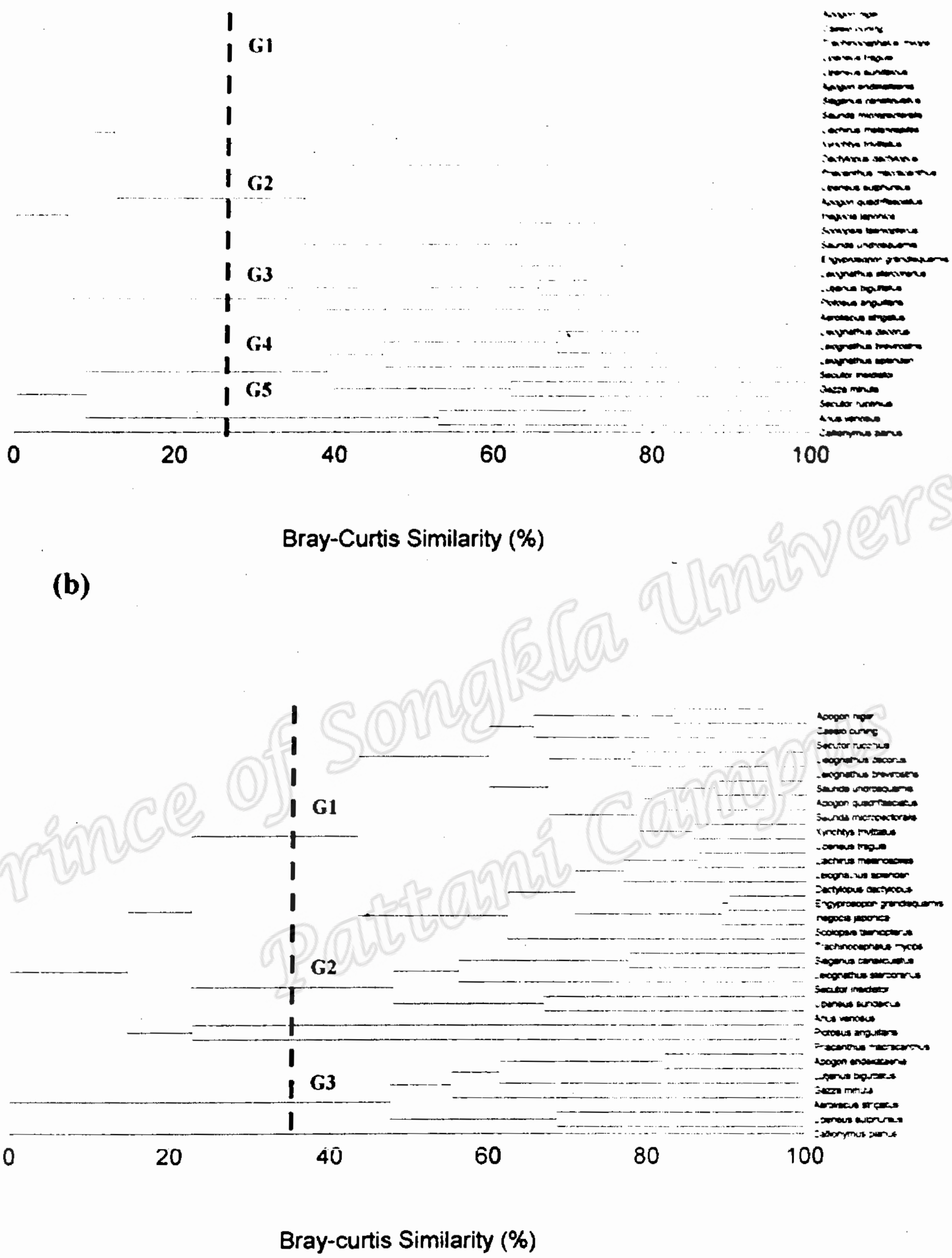


Figure 4 Cluster dendogram of abundance data for preference of 30 dominant fishes collected bimonthly (a) at different study sites and (b) in different months off Pattani and Narathiwas coasts between November 2005 and July 2007.

Effect of months

Analysis of variance (ANOVA) showed a highly significant difference in monthly fish species richness (*df* = 8, F = 4.146, *P* = *0.0002*) and a significant difference in monthly fish biomass (*df* = 8, F = 2.516, *P* = *0.014*). The highest diversity was in November 2005 and lowest in March 2007. The greatest average fish biomass was in May 2006 and lowest in January 2006. No monthly significant difference on fish density was examined (*df* = 8, F = 1.501, *P* = *0.162*).

Cluster dendogram separated fish composition into two main groups (**Figure 3b**). Analysis of similarity (ANOSIM) demonstrated a significant difference between each cluster groups (Global R-statistic value = 0.71, *P* = *0.012*). The first group consisted of November 2005, January 2006 and March 2006, representing northeast monsoon season. A combination of five species including *Leiognathus splendens*, *Leiognathus brevirostris*, *Scolopsis taeniopterus*, *Callionymus planus* and *Upeneus tragula*, contributed >50% to the formation of the group. The months of May 2006, July 2006, September 2006, March 2007, May 2007 and July 2007 constructed another group on the ordination. A combination, with >50% contribution, of *Leiognathus splendens*, *Leiognathus brevirostris*, *Upeneus tragula* and *Secutor ruconius* was responsible for this grouping.

Preference over months of dominant fish species

Analysis of similarity (ANOSIM) significantly divided 30 dominant fish species into three separated groups and two individual species (Global R = 0.814, *P=0.001*) (**Figure 4b**). Seventeen species formed the largest cluster, such as *Apogon niger*, *Caesio cuning*, *Secutor ruconius*, *Leiognathus splendens* and *Scolopsis taeniopterus*. Similarity Percentage (SIMPER) indicated that they were found the whole year round. *Siganus canaliculatus*, *Leiognathus stercorarius*, *Secutor insidiator*, *Upeneus sundaicus* and *Arius venosus* created the second cluster. They occurred mainly in May 2006, September 2006, July 2006 and July 2007, representing southwest monsoon season. The third group consisted of six species, such as *Lutjanus biguttatus*, *Gazza minuta* and *Upeneus sulphareus*. They were found specifically in November 2005, March 2006, March 2007 and January 2006, coinciding with a wet season of northeast monsoon.

Relationship between water parameters and fish attributes

Relationships between water parameters and fish community attributes including biomass, species richness and density are presented in **Table 6**. Highly significant positive correlations (P<0.001) were found between water temperature vs. species richness and fish density. A significant correlation was found between dissolved oxygen and fish biomass (P<0.05). Apart from these, no significant difference between fish attributes and other water parameters was recorded.

Table 6 **Results of regression analysis between water parameters and fish biomass, species richness and density caught waters of Pattani and Narathiwas provinces between November 2005 and July 2007 (n = 128).**

		Water parameters			
		Temperature	**pH**	**DO**	**Salinity**
Biomass	r^2	0.029	0.013	0.034	0.021
	F value	3.79	1.62	4.50	2.73
	P value	0.054	0.205	*0.036*	0.100
Species richness	r^2	0.112	0.003	0.007	0.260
	F value	15.88	0.41	0.87	3.40
	P value	*0.0001*	0.524	0.351	0.067
Density	r^2	0.121	0.026	0.006	0.002
	F value	17.41	3.38	0.74	0.21
	P value	*0.001*	0.068	0.391	0.648

Pattern of macro-invertebrates

Altogether, 5,574 individuals accounting for 493.7kg of macro-invertebrates were collected. Mollusks and crabs were the largest groups together with some contribution of shrimps, echinoderms, sea pens, sponges, sea squirts and jelly fishes. Details of abundance and distribution at each depth zone of these organisms are presented in **Table 7**. Analysis of variance indicated site differences for macro-invertebrate density (df = 7, F = 3.72, P=0.013) and biomass (df = 7, F = 6.03, P=0.001) and no difference for species number (df = 7, F = 1.39, P=0.247). ANOVA also demonstrated monthly difference for species number (df = 7, F = 6.39, P=0.0001) and no differences for density (df = 7, F = 1.04, P=0.41) and biomass (df = 7, F = 1.59, P=0.15).

Macro-invertebrates could be classified according to depth zone into two different clusters. The cluster A consisted of community at zones 1 and 2, whilst the cluster B included zones 3 and 4 **(Figure 5)**. Similarity analysis (SIMPER) indicated that organisms mainly contributing to the formation of cluster A were *Loligo spp.*, *Sepia spp.*, *Dromidopsis sp.*, *Charybdis spp.*, *Oratosquilla spp.* and *Pteroeides sp.* with contribution values of 64.4%, 5.6%, 5.1%, 3.3%, 2.9% and 2.2%, respectively. For cluster B, organisms responsible for the formation of this cluster included *Holotharia spp.*, *Minnivola pyxidata*, *Loligo spp.*, *Polycrapa sp.*, *Amusium pleuronectes* and *Pinna bicolor* with the contributions of 25.9%, 15.4%, 13.3%, 12.1%, 5.1% and 3.3%, respectively.

Table 7 Benthic organisms collected off coastal waters of Pattani and Narathiwas provinces between November 2005 and July 2007

Scientific name	Common name	Total
DECAPODA		
Penaeus merguiensis	white prawn	20
Penaeus monodon	tiger prawn	10
Penaeus semisulcatus	green tiger prawn	8
Metapenaeopsis stridulans	fiddler shrimp	96
Metapenaeopsis barbata	velvet shrimp	15
Trachypenaeus sp.	rough shrimp	2
Metapenaeus lysianassa	bird shrimp	5
Thenus orientalis	flathead lobster	111
Oratosquilla spp.	mantis shrimp	133
Charybdis sp.1	crab	27
Hyastenus sp.	spider crab	14
Eriphia sp.	rock crab	26
Leucosia sp.	button crab	5
Charybdis spp.	swimming crab	88
Portunus sanguinolentus	three spotted swimming crab	27
Podophthalmus vigil	sentinel crab	11
Dromidiopsis sp.	sponge crab	138
Portunus pelagicus	blue swimming crab	33
Charybdis cruciata	musk crab	22
Charybdis sp.2	swimming crab	11
Calappa sp.	box crab	84
Calappa philargius	brick-red box crab	3
Charybdis miles	swimming crab	29
Matuta sp.	moon crab	6
Paguroidae	hermit crab	69
MOLLUSCA		
Minnivola pyxidata	scallop	423
Amusium pleuronectes	scallop	319
Annachlamus macassarensis	macassa scallop	43
Oliva sp.	cowrie	1
Malleus spp.	hammer oyster	107
Placumen sp.	venus	8
Melo melo	melon shell	14
Cymbiota nobilis	noble volte	16
Pinna bicolor	pen shell	140
Pteria penquin	wing oyster	43
Paphia sp.	surf clam	1
Nassarius spp.	nussa mud snail	19
Babylonia areolata	spotted babylon	6
Sepia spp.	cuttle fish	214
Loligo spp.	squid	1648
Octopus spp.	octopus	20
Sepioteuthis lessoniana	soft cuttle fish	54
Euprymna sp.	squid	4
Dentaliidae	-	1
ECHINODERMATA		
Diadema sp.	sea urchin	93
Echinodiscus truncatus	sand dollar	18
Astropecten sp.	sand sea star	136
Holotharia spp.	sea cucumber	787
OTHERS		
Pteroeides sp.	sea pen	61
Polycarpa sp.	sea squirt	260
Cnidaria	jelly fish	119
Porifera	sponges	25
Total number		**5574**
Total weight (kg)		**493.7**

Discussion and conclusion

Fish within shallow-nearshore waters of the southern Gulf of Thailand forms a species-rich assemblage that is numerically dominated by a few taxa, especially *Leiognathus splendens*, *Leiognathus brevirostris* and *Priacanthus macracanthus*. This reflects a typical pattern of estuaries throughout the world such as those in New Caledonia (Wantiez et al., 1996); Western Yellow Sea, People Republic of China (Rhodes, 1998), Alligator creek, tropical Australia (Robertson and Duke, 1990), Gulf of Carpentaria, Australia (Blaber et al., 1995), and Johor strait, Singapore (Hajisamae and Chou, 2003). However, a great domination by Leiognathidae or pony fish causes different community structure compared to that of sheltered area of the same region. Hajisamae et al. (2006) found that from 48 families and 108 species of fishes collected in Pattani Bay, Thailand, and only 43.3% of Leiognathidae dominated the catch compared to 78.1% of this study. Most species reported in the bay were found in this study, in exception of some pelagic and/or brackish water species. Similarly, the most dominant fish species for these both areas is *Leiognathus splendens*. However, the ten most dominant species in the bay habitat was more evenly distributed. The family Centropomidae, especially *Ambassis kopsii*, the third most dominant species in the bay was absolutely absent from this study. Although not directly tested, a strong connection of fish use of these both habitats is observed and, as shown by the results, the more distance from the bay the more difference in fish community structure.

Community structure of fish in this area involved both depths and seasons. This indicates that, in general, there is a co-vary of the seasonality and the spatial assemblage. Though there are no differences in species richness and fish biomass at each depths, the greatest density is at the shallowest zone and reduces substantially towards deeper zone. A partitioning is due largely to difference in fish community structure between zones. Leiognathids are highly responsible for this pattern as they are found predominantly or restrictedly in the shallow water areas. Different depth occupancy apparently occurred for some fish species such as *Apogon niger*, *Trachinocephalus myops* and *Caesio cuning*, associated with the deeper zones, and *Leiognathus splendens*, *Leiognathus decorus* and *Gazza minuta*, associated with the shallowest zones. Factors controlling variation of community based on water depth are probably linked to physical condition; water current and bottom sediment, and biological processes related to life history; predation and competition (de Azevedo et al., 2007). Depth also plays a great role for changes in other macro-invertebrate. Two distinct communities based on water depth were classified. Shrimps, squid (*Loligo spp.*), and cuttle fish (*Sepia spp.)* distributed largely within the shallow zones, whilst echinoderms occupied the deeper. It is likely to indicate that a changing point of community structure for both fishes and macro-invertebrates in nearshore habitats of this region is between zones 2 and 3 at the depth of 16-20m. Fishes demonstrated seasonal and annual patterns of community structure in this study. On the other hand, monthly factor affects only change in species number for macro-invertebrates. In general, most of the dominant fish species found the whole year round, but preference over month or season for some species are slightly different. An important observation relevant to change of fish community structure is a strong grouping of the community between years. This pattern of change can be explained with the potential impact of unstable weather condition especially the obvious change and fluctuation of waves and winds between 2005, 2006 and 2007, when the sea condition and weather, as noted by fishermen, had changed unexpectedly during the sampling periods.

Significant correlations between water temperature vs. species richness and fish density and dissolved oxygen vs. fish biomass confirmed the influences of these factors on fish community. It is believed that if food is not a limiting factor, temperature is the most important controlling recruitment-related process such as growth and mortality (Gibson, 1994). A strong influence of temperature on both species richness and fish density is rarely reported in the tropics where temperature is less fluctuated compared to the temperate counterparts (Blaber, 2000). Variation of fish density and species richness between months is likely a reflection of monthly variation in water temperature. Water salinity, the most important factors controlling distribution of fish and in attraction of fish larvae, post-larvae and juveniles into many estuaries throughout the world (Costa et al., 2002), has no influence on fish community in this study area. Generally, in almost all open estuaries, fishes are subject to change in water salinity and such changes are usually diel and depend on tidal reflection (Blaber, 2000). However, almost constant water salinity at all zones during this sampling period paves a way to no influence of water salinity on fish abundance and distribution. This differs greatly with fish community in Pattani Bay where salinity plays a great role on fish distribution (Hajisamae, 2006). With this regards, it is possible to conclude that salinity will play a greater role in a very shallow coastal waters especially semi-enclosed coastal habitats, whilst less or no influence will be encountered as the sites shifting deeper, since no or less fluctuation of salinity recorded.

References

Blaber, S.J.M., 2000. *Tropical Estuarine Fishes: Ecology, Exploitation and Conservation.* Blackwell Science, 372pp.

Blaber, S.J.M., D.T. Brewer & J.P. Salini, 1995. Fish communities and the nursery role of a tropical bay in the Gulf of Carpentaria, Australia. *Estuarine, Coastal and Shelf Science* **40**: 177-193.

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

Cladridge, P.N., I.C. Potter & M.W. Hardisty, 1986. Seasonal changes in movements, abundance, size composition and diversity of the fish fauna of the Severn Estuary. *Marine Biological Association of United Kingdom* **66**: 229-258.

Clark, K.R. & R.N. Gorley, 2001. *Primer v5. User Manual/Tutorial PRIMER-E*, Plymouth.

Costa, M.J., H.N Cabral, P. Drake, A.N. Economou, C. Fernandez-Delgado, L. Gordo, J. Marchand, & R. Thiel 2002. Recruitment and production of commercial species in estuaries. In: Elliott, M. & K.L. Hemingway, (eds.), *Fishes in estuaries*, Blackwell Science Ltd. Pp. 54-123.

de Azevedo, M.C.C., F.G. Arau'jo, A.G. da Cruz-Filho, A.L.M. Pessanha, M. de Arau'jo Silva & A.P.P. Guedes, 2007. Demersal fishes in a tropical bay in southeastern Brazil: Partitioning the spatial, temporal and environmental components of ecological variation. *Estuarine, Coastal and Shelf Science* **75**: 468-480.

Gelwick. F. P., S. Akin, B.A. Arrington, & K.O. Winemiller, 2001. Fish assemblage structure in relation to environmental variation in a Taxas Gulf Coastal Wetlands. *Estuaries* **24**: 285–296.

Gibson, R.N., 1994. Impact of habitat quality and quantity on the recruitment of juvenile flatfishes. *Netherlands Journal of Sea Research* **32**: 191-206.

Griffiths, S. P., 2001. Factors influencing fish composition in an Australian intermittently open estuary. Is stability salinity-dependent? *Estuarine, Coastal and Shelf Science* **52**: 739–751.

Hajisamae S., P. Yeesin & S. Chaymongkol, 2006. Habitat utilization by fishes in a shallow, semi-enclosed estuarine bay in southern Gulf of Thailand. *Estuarine, Coastal and Shelf Science* **68**: 647-655

Hajisamae, S., & L.M. Chou, 2003. Do shallow water habitats of an impacted coastal strait serve as nursery ground for fish? *Estuarine, Coastal and Shelf Science* **56**: 281-290.

Harris, S.A., D. Cyrus, L.E. Beckley, 2001. Horizontal trends in larval fish diversity and abundance along an ocean-estuarine gradient on the northern KwaZulu-Natal coast, South Africa. *Estuarine, Coastal and Shelf Science* **53**: 221-235.

Howell, P. & D. Simpson, 1994. Abundance of marine resources in relation to dissolved oxygen in Long Island Sound. *Estuaries* **17**: 394–402.

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

Jaureguizar, A.J., R. Menni, R. Guerrero, & C. Lasta, 2004. Environmental factors structuring fish communities of the Rio de la Plata estuary. *Fisheries Research* **66**: 195-211.

Maes, T., A. Taillieu, K. Correnie, K. & F. Ollevier, 1998. Seasonal patterns in the fish and crustacean community of a turbid temperature estuary (Zeeschelde Estaury, Belgium). *Estuarine, Coastal and Shelf Science* **47**: 143-151.

Peterson, A.W. & A.K. Whitfield, 2000. Do shallow water habitats function as refugia for juvenile fishes? *Estuarine, Coastal and Shelf Science* **51**: 359-364.

Pinto, L., 1988. Population dynamics and community structure of fish in the mangroves of Pagbilao, Philippines. *Journal of Fish Biology* **33**: 35-43.

Rhodes, K.L., 1998. Seasonal trends in epibenthic fish assemblages in the near-shore waters of the Western Yellow Sea, Qingdao, People Republic of China. *Estuarine, Coastal and Shelf Science* **46**: 629-643.

Robertson, A.I. & N.C. Duke, 1990. Mangrove fish communities in tropical Australia: spatial and temporal patterns in densities, biomass and community structure. *Marine Biology* **104**: 369-379.

Sasekumar, A., V.C. Chong, M.U. Leh, & R.D. D'Cruz, 1992. Mangroves as a habitat for fish and prawns. *Hydrobiologia* **247**, 195-207.

Wantiez, L., M. Hermelin-Vivien & M. Kulbicki, 1996. Spatial and temporal variation in a soft-bottom fish assemblage in St Vincent Bay, New Caledonia. *Marine Biology* **125**: 801-812.