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DIVERSITY AND ASSEMBLAGE PATTERNS OF JUVENILE AND SMALL SIZED FISHES IN THE NEARSHORE HABITATS OF THE GULF OF THAILAND

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ABSTRACT. — Species richness, abundance, diversity and fish assemblage patterns in seagrass beds, mangroves, mudflats and sandy beaches were investigated at Had Khanom Mu Ko Thale Tai National Park, Thailand. Fish samples were collected using a beach seine during the day on alternate months between February and December 2009. The juvenile fishes and adults of small sized fishes accounted for 95.6% in total catch. In total, 131 species from 48 families were collected. Of these, 76, 74, 55 and 47 species were caught in seagrass beds, mangroves, mudflats and sandy beaches, respectively. Leiognathidae was the most diverse family present in seagrass beds, mudflats and sandy beaches, with seven species obtained at each habitat. The most diverse family (13 species) in mangroves was Gobiidae. The three most abundant species in each habitat represented more than 60% of the catches although they showed temporal variations in abundance. Abundance and diversity indices varied spatially with the highest values occurring in seagrass beds and mangroves. Significant temporal variation was only observed in the abundance data with the lowest value in February. Four general patterns of fish assemblages were identified (**G1** to **G4**) by cluster analysis, loosely based on habitat preference. Species such as *Siganus javus*, *Ambassis kopsii*, and *Leiognathus decorus* are considered generalists and commonly found in all habitat types sampled. *Ambassis nalua*, *Ambassis vachellii*, and *Scatophagus argus* were exclusively found in mangroves while *Siganus canaliculatus*, *Monacanthus chinensis*, and *Terapon puta* were only found in seagrass beds. Temperature, pH, dissolved oxygen, salinity and transparency of the water were monitored. While spatio-temporal variation was evident, they did not predict fish assemblage patterns. Only the fish assemblage patterns in the mangroves could be correlated to the parameters measured using linear discriminant analysis, with a prediction success of 83 %.

KEY WORDS. — habitat type, cluster analysis, water quality, prediction

INTRODUCTION

Nearshore coastal areas are among the most productive of marine habitats and serve as feeding and nursery grounds for many species of marine fishes (Blaber, 2000). Such areas are more suitable for the survival of fish eggs and larvae than the open sea because of the higher water mass stability and higher food availability (Álvarez et al., 2012). Assemblages of fishes and shellfishes in these habitats change continually in time and space, according to reproductive seasons of the species and to environmental fluctuations driven by meteorological and oceanographic seasonal features (Beck et al., 2003). Spatial differences are mostly attributed to size, shape, fragmentation, depth and distance to shore (Beck et al., 2003; Huang et al., 2006; Hajisamae & Yeemin, 2010). In tropical shallow waters, different nearshore habitats are often located adjacent to each other constituting a mosaic of interlinked patches (Berkström et al., 2012). Nevertheless, each habitat type has its own fish assemblage pattern according to the habitat preference of the juveniles and adults of species in the area (Nakamura & Sano, 2004; Lugendo et al., 2007a). Seagrass beds show a high fish diversity, particularly of small inconspicuous fishes and juveniles of larger fishes (Beck et al., 2001). They prefer this habitat as they can easily seek protection from predators (Hemminga & Duarte, 2000). Positive correlations between faunal richness and abundance to the aboveground biomass in seagrass beds have been observed (Kwak & Klumpp, 2004). Meanwhile, mangrove habitats are considered important nursery grounds (Nagelkerken & van der Velde, 2002; Sheridan & Hays, 2003), the abundance and diversity if which is related to the degree of structural habitat complexity (Nagelkerken & van der Velde, 2002; Ikejima et al., 2003). Salinity is another factor that governs the species diversity in mangroves. Larval fishes from families Sciaenidae, Blenniidae and Cynoglossidae, for example, spawn within the mangrove estuary, but are exported to offshore waters since they need consistent salinity for their development (Barletta et al., 2005; Ooi & Chong, 2011).

Little work has been done on the diversity of fishes utilising intertidal mudflats (Stevens et al., 2006). Fish abundance and species diversity in this habitat are lower than in the adjacent habitats, particularly for juveniles (Hosack et al., 2006; Stevens et al., 2006). Small semi-pelagic fish migrate to the mudflats for foraging purposes, possibly following hyperbenthic and pelagic prey species (e.g., mysids and copepods), which are passively transported by the currents on the mudflat (Speirs et al., 2002; Stevens et al., 2006). On sandy beaches, densities of smaller juvenile fishes are relatively low compared to larger juveniles (Suda et al., 2002) and few species can be considered true residents (Santos & Nash, 1995).

Anthropogenic reclamations of nearshore coastal habitats affect fishes and fisheries (Halpern et al., 2008; Barbier et al., 2011). Insights into habitat utilisation by fishes are needed to understand the processes that structure fish communities to evaluate management and utilisation regimes (Barbier et al., 2011). Few studies have simultaneously compared these habitats, and these studies are even less common in Southeast Asia (Fortes, 1994; Poovachiranon & Satapoomin, 1994; Hajisamae & Chou, 2003; Jaafar et al., 2004; Berkström et al., 2012). This study aims to provide baseline information of different shallow marine habitats in the Gulf of Thailand by (a) comparing the diversity and abundance of juveniles and small sized fishes and (b) determining if these fish assemblage patterns are related to water quality variables.

MATERIAL AND METHODS

Study area. — Had Khanom Mu Ko Thale Tai National Park (09°13'N, 99°51'E) is located in Nakhon Si Thammarat Province, in southern Thailand. It covers an area of 316 km^2 and includes within the protected area, the island Koh [=Island in Thai] Tharai. The climate is tropical and characterised by southwest monsoons in May to October and northeast monsoons in November to January. The weather is divided into two seasons; the rainy season starts in May and lasts until January, while the dry season is between February and April. Four different habitat types were studied along the northern end of the Park: seagrass beds, mangroves, intertidal mudflats and intertidal sandy substrates (Fig. 1). This area is a mixed tidal type with principally semidiurnal tides, with amplitudes ranging from 0.2 to 3.0 m during the neap and spring tides, respectively.

Sites of seagrass beds chosen for this study are found at the southern to eastern sides of Koh Tharai, covering an area of about 0.10 km^2. Their substrate consists of varying composition of silt and fine sand and the water is rather turbid. The mangrove swamps surround Thong Nian Bay, where the total area is about 1.42 km^2. Talet Noi Bay, approximately 0.34 km^2 in size, is an intertidal mudflat surrounded by a rocky shoreline and a small sandy beach. Mudflats in this bay are gently sloping and water depth varies from less than 0.5 m to 4.0 m near the mouth of the bay. The sandy beach is at Leam Thap with a shoreline length of 0.79 km. The eastern and western ends of the beach are bordered by rocky headlands. The substratum, of the beach per se, consists mainly of fine sand. Meanwhile, the sand is coarser and less sorted in the intertidal zone.

Data collection and sample processing. — Fishes were collected with beach seine, a suitable method to quantify fish in all habitats sampled (English et al., 1994). The beach seine used in the study was designed specifically for juvenile and small sized fishes. The net consisted of two wing ends, each measuring 12 m long and 1.2 m high, and 10 mm stretched mesh. The cod end of the net was 4.5 m with 5 mm stretched mesh. Each sample covered an area of 500 m^2, achieved by two persons at opposite ends of the 5 m opening of the net, hauling the net for a distance of 100 m to the shore. The distance between hauls was at least 100 m to avoid sampling artifacts. At each habitat type, three replicates were made and sampling was always carried out at the same depth, about 0.8–1.2 m. Although adults and fast swimming species are under-represented in beach seines (Lugendo et al., 2007b), the same procedure was used for all habitats and hence the samples were comparable across habitat types. Sampling was carried out every two months between February and December 2009 during daylight hours (between 0900–1700 hours). Sampling at different habitat types was carried out on consecutive days during the same tidal period. All samples were fixed in 10% formalin for later identification in the laboratory. All fish specimens were classified to the species level as well as identified as juvenile or adult. Each taxon was counted and individuals were measured for total length (TL) to nearest mm and weighed to the nearest 0.01 g. In this

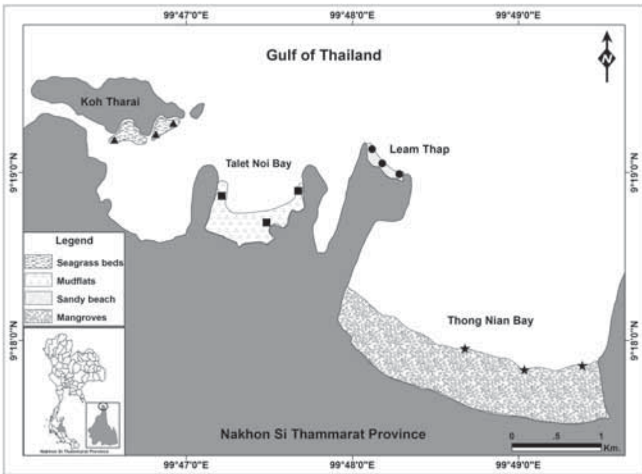

Fig. 1. Location of the sampling habitats at Had Khanom Mu Ko Thale Tai National Park, Thailand. Note: the sampling sites; ▲ seagrass beds; ■ mudflats; ● sandy beaches; ★ mangroves.

study, we designate "juveniles" as fish less than one-third of the maximum species length and "small fishes" as either (a) fish between one-third and two-thirds of the maximum species length or (b) species less than 10 cm maximum adult size. (Dalzell, 1993; Nagelkerken & van der Velde, 2002). After processing, all fish samples were deposited in the Walailak Zoological Reference Collection. Prior to seining, temperature, pH and dissolved oxygen were measured in situ at mid depth by YSI Model 85. Salinity was recorded at the water surface using a refractometer. Water transparency was assessed as Secchi disc depth.

Data analysis. — Analysis of variance (ANOVA) was used to examine the differences in fish abundance (individuals per 500 m^2) and the Shannon diversity index (H′ index: Magurran, 2004) of the sampling occasions, in each habitat. Fish abundance data was $\log_{10}(x+1)$ transformed to reduce non-normality. Duncan's post-test was used whenever significant differences were detected at a = 0.05. Hierarchical agglomerative clustering was performed for both Q-mode (i.e., sampling occasions) and R-mode (i.e., fish-species). Results were related to dendrogram of abundance ($\log_{10}$ transformed), which provided a near tri-dimensional space to interpret species-habitat relationships (Cunha et al., 2008). Analysis of similarity (ANOSIM) was used to test for significant differences among clusters. Linear discriminant analysis (LDA) was used to determine whether the clusters of sampling occasions discriminated according to selected environmental variables. The significance of the LDA result was tested by a Monte-Carlo method with 1,000 random permutations. Statistical analyses were performed in R (R development core team, 2012).

RESULTS

Fish abundance, composition and diversity. — A total of 45,158 fishes caught were from 131 species within 48 families. Juveniles and small sized fishes accounted for 95.7% of the total catch. The family Gobiidae were the most speciose (15 species), followed by Engraulidae and Leiognathidae (nine species each) and Ambassidae (seven species). Twenty-six families were represented by two to six species and 18 families were represented by only a single species (Table 1). Forty-six species were found to include both juveniles and adults while 68 species were found only as juveniles and 17 species only as adults (Table 1). The highest species richness was observed in seagrass beds (76), followed by mangroves (74). The proportion of juveniles was largest in mangroves at 63%, while the size spectrum of samples was largest in mangroves and followed by seagrass beds (Fig. 2).

In the seagrass beds, Leiognathidae was the most represented family (seven species), followed by Gobiidae (six species) and Engraulidae and Ambassidae (four species). The most abundant species were *Siganus javus* (45.9%), *Secutor ruconius* (21.8%), and *Leiognathus splendens* (12.8%). Abundance of these species varied markedly over the study period. *Siganus javus* was the most abundant in August and least so in June. The abundance of *Se. ruconius* was highest in April and lowest in October. Abundance of *L. splendens* was highest in June and lowest in the dry season.

Gobiidae (13 species) was the most diverse family in the mangroves, followed by Ambassidae (six species) and Leiognathidae (five species). The three most abundant species in the mangroves accounted for 66.0 % of the total abundance; *Ambassis vachellii*, *Ambassis kopsii* and *Scatophagus argus*. *Ambassis vachellii* was the most dominant during the northwest monsoons and least so in August. *Ambassis kopsii* was most abundant in October and least so in February. Meanwhile, abundance of *Sc. argus* was highest in December and lowest in the dry season.

Leiognathidae was most speciose (seven species) in intertidal mudflats, followed by Engraulidae (six species) and Ambassidae and Sciaenidae (four species). The three most abundant species were *L. splendens* (47.1%), *Se. ruconius* (26.9%) and *Leiognathus decorus* (8.6%). *Leiognathus splendens* was most abundant in April and October and least abundant in August.

The abundance of *Se. ruconius* was highest in October and lowest in April. The abundance of *L. decorus* peaked in April and decreased in February and December. Lastly, on the sandy beaches, Leiognathidae, Engraulidae and Carangidae were the three most diverse families, comprising seven, six and five species, respectively. The three most abundant species accounted for 89.1% of the total number of individuals collected in this habitat; *L. splendens*, *Se. ruconius* and *Stolephorus dubiosus*. *Leiognathus splendens* was the dominant species during southwest monsoons but was absent in the dry season. Abundance of *Se. ruconius* was highest in August and lowest in October, similar to the seagrass beds. Meanwhile, abundance of *St. dubiosus* peaked in April and declined in August.

Species richness of seagrass beds and mangroves was lowest (26 species) in December and February, respectively. Meanwhile, species richness in seagrass beds and mangroves was highest in June (42 species) and December (39 species), respectively. Species richness in intertidal mudflats fluctuated, ranging from 9 species in October to 30 species in April. Species richness on the sandy beaches fluctuated less, ranging from 14 species in June to 24 species in October (Fig. 3). Analysis of variance (ANOVA) performed on fish abundance ($\log_{10}$ transformed, Fig. 4a) revealed significant temporal differences in all habitats ($P < 0.05$), except intertidal mudflats. The highest H-index values were recorded in mangroves in August (2.33 ± 0.08). Meanwhile the average values of H-index of the remaining sampling occasions were less than two. ANOVA and Duncan's test (Fig. 4b) showed that significant differences in H-index in the mangroves were between August and October. The H' index of the sandy beaches was highest in December but differences with other months, except June, were not significant. Meanwhile, temporal differences in H' index within seagrass beds and mudflats were not significant.

Fish assemblage patterns. — Sixty-six fish species were excluded from the analysis of assemblage patterns because there were less than 10 individuals per species and the percentage of occurrences were less than 5%. Cluster analysis for the samples (Q-mode cluster analysis) separated the fish assemblages into four groups (Fig. 5). Group 1 (**G1**) was the fish assemblages found exclusively in mangroves and group 2 (**G2**) consisted of all samples from seagrass beds. The assemblage group 3 (**G3)** mainly consisted of samples from the sandy beaches. Meanwhile the assemblages from sandy beaches from June to August were grouped with the assemblages from intertidal mudflats of group 4 (**G4**). Analysis of similarity (ANOSIM) demonstrated a significant difference between clusters ($R = 0.80$, $P < 0.001$).

Species groups (R-mode cluster analysis) were statistically different from each other (ANOSIM; $R = 0.21$, $P = 0.002$). Four distinct fish groups were identified (Table 1, Fig. 5). Group **A** comprised of species which was collected from all habitat types. There were six species in this group *viz*., *Si. javus*, *A. kopsii*, *L. decorus*, *St. dubiosus*, *L. splendens*, and *Se. ruconius*. Group **B** were the fishes that were mainly found in mangroves. Examples of fishes in this group were *Ambassis interruptus*, *Ambassis macracanthus*, and *Neostethus lankesteri*. Other fishes in this group, such as *Ambassis nalua*, *Ambassis vachellii* and *Sc. argus* as well as juveniles of *Pomadasys kaakan* and *Liza subviridis*, were occasionally found in other habitats. Group **C** contained species that were found almost exclusively in seagrass beds. This group was comprised of *Siganus canaliculatus*, *Monacanthus chinensis*, *Terapon puta*, and *Lethrinus lentjan*. Group **D** represented the species only occasionally caught. This group was subclustered into three groups. Subcluster **D1** was the fishes from the seagrass beds. This group was comprised of *Archamia bleekeri*, *Syngnathoides biaculeatus*, *Apogon fasciatus*, *Bastrichthys grunniens*, *Hippocampus kuda*, *Pelates quadrilineatus*, *Stolephorus indicus*, *Psammogobius biocellatus*, and *Triacanthus biaculeatus*. Subcluster **D2** mainly consisted of the species from the mangroves. Examples of fishes in this group were *Thryssa hamiltonii*, *Ambassis interruptus*, and *Leiognathus equulus*. Subcluster **D3** represented species from the mudflats and sandy beaches. Examples of fishes in this group were *Alectis indicus*, *Acentrogobius caninus*, *Secutor insidiator*, and *Strongylura strongylura*.

Parameters and their relationship to fish assemblages. — Water temperature ranged between 27.6 and 32.4°C. In all habitats, the highest water temperatures were in April. The lowest water temperature was in October for mudflats but in August for the remaining habitats. (Fig. 6a). The pH at all areas ranged between 7.5 and 8.4, but trended to neutral, i.e., pH 7, in the mangrove area during the southwest monsoons (Fig. 6b). Dissolved oxygen (DO) ranged from 5 and 6 mg L^{-1} in all habitats except in the mangroves, where readings sharply declined at the start of the monsoon season and remained lower than 4 mg L^{-1} throughout the monsoon seasons (Fig. 6c). Salinity ranged between 25.1 and 33.9 psu. The difference between the highest and lowest salinity was ca. 6 psu in the seagrass beds and mangroves and ca. 3

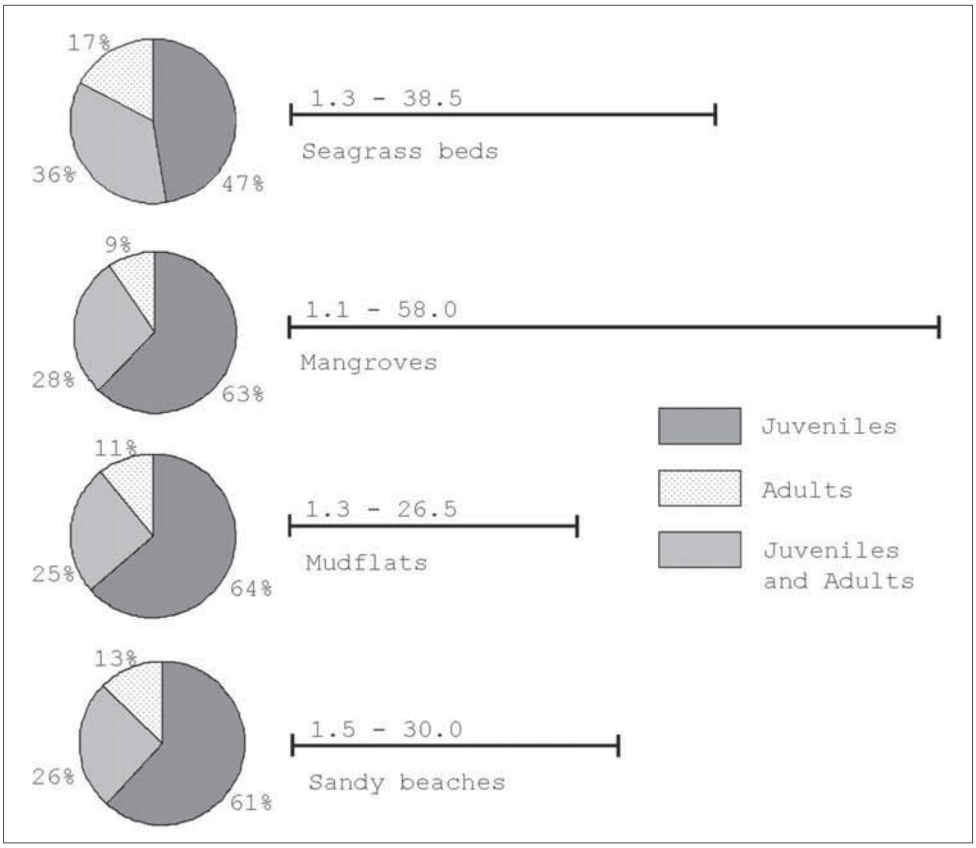

Fig. 2. Proportion of life stages and size spectra (cm) of the samples in each habitat.

Table 1. List of species, abbreviation (ABB), size ranges (TL), life history stages (J, juveniles; A, adults) and total number of fishes collected from seagrass beds (SG), mangroves (MG), mudflats (MF), and sandy beaches (SB), and its group in the R-mode classification.

Family	Species	ABB	SG	MG	MF	SB	Length range (cm)	Life history stages	Total number	Group in R-mode
Dasyatidae	*Himantura* sp.	His1			*		26.5	J	1	NA
Megalopidae	*Megalops cyprinoides*	Mecy		*			19.1	J	1	NA
Clupeidae	*Escualosa thoracata*	Esth		*	*	*	4.8–10.3	J,A	33	D3
	Herklotsichthys dispilonotus	Hedi	*				9.6–10.4	A	3	NA
	Sardinella albella	Saal	*			*	4.3–6.0	J	24	D3
Pristigasteridae	*Ilisha melastoma*	Ilme	*		*	*	3.8–8.0	J	26	D3
Engraulidae	*Coilia dussumieri*	Codu			*		7.0–15.3	J,A	3	NA
	Stolephorus chinensis	Stch	*		*		5.7–7.5	J,A	2	NA
	Stolephorus dubiosus	Stdu	*		*	*	2.5–8.2	J,A	607	A
	Stolephorus indicus	Stin	*		*	*	3.0–7.0	J	26	D1
	Stolephorus tri	Sttr		*		*	6.0–10.0	J,A	2	NA
	Stolephorus sp.	Sts1		*		*	5.3–6.8	J	2	NA
	Thryssa hamiltonii	Thha		*	*	*	2.4–8.7	J	93	D2
	Thryssa kammalensis	Thka	*		*	*	7.0–10.8	A	7	NA
	Thryssa sp.	Ths1		*			3.0–6.8	J	12	D2
Bagridae	*Mystus gulio*	Mygu		*			11.3–14.0	J	4	NA
Ariidae	*Hexanematichthys sagor*	Hesa		*			20.2	J	1	NA
Plotosidae	*Plotosus canius*	Plca	*	*	*		4.1–38.6	J,A	105	B
	Plotosus lineatus	Plli	*	*	*		8.5–24.7	J,A	40	D3
Synodontidae	*Saurida micropectoralis*	Sami			*		10.3	J	1	NA
	Saurida sp.	Sas1	*		*	*	7.0–12.7	J	4	NA
Batrachoididae	*Bastrichthys grunniens*	Algr	*	*			9.0–22.2	J,A	4	NA
	Batrachomoeus trispinosus	Batr	*	*			9.0–22.6	J,A	16	D1
Mugilidae	*Liza subviridis*	Lisu	*	*	*	*	3.0–17.8	J	550	B
	Mugil sp.	Mus1		*			9.0	J	1	NA
	Paramugil parmatus	Papa		*			10.1	J	1	NA
	Valamugil cunnesius	Vacu		*			5.8–16.3	J	10	D2
Atherinidae	*Atherinomorus duodecimalis*	Atdu	*		*		3.5–9.4	J,A	9	NA
	Hypoatherina valenciennei	Hyva				*	8.1–9.0	A	5	NA
Phallostethidae	*Neostethus lankesteri*	Nela		*			2.5–4.0	J,A	66	B
Belonidae	*Strongylura strongylura*	Stst	*	*	*	*	16.0–33.4	J,A	33	D3
Hemiramphidae	*Hyporhamphus limbatus*	Hyli	*	*		*	11.2–19.0	J,A	45	D3
Zenarchopteridae	*Zenarchopterus buffonis*	Zebu		*	*	*	5.0–19.7	J,A	188	B

Table 1. Cont'd.

Family	Species	ABB	SG	MG	MF	SB	Length range (cm)	Life history stages	Total number	Group in R-mode
Syngnathidae	*Hippichthys penicillus*	Hipe	*	*			14.8–15.8	A	2	NA
	Hippocampus kuda	Hiku	*				11.7–17.5	J,A	14	D1
	Syngnathoides biaculeatus	Sybi	*				19.8–25.9	A	19	D1
Platycephalidae	*Cociella punctata*	Copu		*			8.4–11.9	J	2	NA
	Sunagocia carbunculus	Suca	*				14.4–14.6	A	2	NA
Centropomidae	*Lates calcarifer*	Laca	*	*			9.2–58.0	J,A	15	D2
Ambassidae	*Ambassis gymnocephalus*	Amgy	*	*	*	*	2.6–6.7	J,A	162	D2
	Ambassis interruptus	Amin		*			3.2–11.6	J,A	106	B
	Ambassis kopsii	Amko	*	*	*	*	2.1–10.1	J,A	2019	A
	Ambassis macracanthus	Amma		*			4.1–11.7	J,A	106	B
	Ambassis nalua	Amna	*	*	*	*	3.0–11.8	J,A	244	B
	Ambassis vachellii	Amva	*	*		*	2.1–8.2	J,A	3682	B
	Ambassis sp.	Ams1			*		7.4–10.2	J,A	2	NA
Serranidae	*Epinephelus coioides*	Epco	*	*			2.4–23.5	J	5	NA
Apogonidae	*Apogon fasciatus*	Apfa	*				2.6–9.5	J,A	41	D1
	Archamia bleekeri	Arbl	*			*	4.3–8.2	J,A	79	D1
Sillaginidae	*Sillago sihama*	Sisi	*	*	*	*	2.2–8.8	J	13	D3
Carangidae	*Alectis indicus*	Alin				*	8.7–21.0	J	14	D3
	Carangoides armatus	Caar				*	10.0–10.7	J	6	NA
	Carangoides praeustus	Capr	*	*		*	3.0–9.0	J	9	NA
	Scomberoides sp.1	Scs1	*	*	*	*	2.4–4.2	J	6	NA
	Scomberoides sp.2	Scs2				*	5.0	J	2	NA
	Trachinotus mookalee	Trmo			*		3.6–5.3	J	2	NA
Leiognathidae	*Gazza minuta*	Gami	*		*	*	3.1–5.0	J	14	D3
	Gazza sp.	Gas1	*				3.2–3.6	J	31	D3
	Leiognathus decorus	Lede	*	*	*	*	1.6–8.4	J,A	2094	A
	Leiognathus equulus	Leeq	*	*	*		1.5–9.0	J	40	D2
	Leiognathus splendens	Lesp	*	*	*	*	1.6–9.5	J	7994	A
	Leiognathus sp.	Les1		*		*	2.4–9.5	J	20	D3
	Secutor hanedai	Seha	*		*	*	1.9–7.7	J,A	101	D3
	Secutor insidiator	Sein			*	*	2.5–8.0	J,A	16	D3
	Secutor ruconius	Seru	*	*	*	*	1.5–8.2	J,A	9533	A
Lutjanidae	*Lutjanus johnii*	Lujo	*	*	*		3.0–8.3	J	18	D2
	Lutjanus russelli	Luru	*	*			2.6–24.3	J	224	B

Table 1. Cont'd.

Family	Species	ABB	SG	MG	MF	SB	Length range (cm)	Life history stages	Total number	Group in R-mode
Gerreidae	*Gerres erythrourus*	Geer		*			2.3–6.6	J	23	D2
	Gerres oyena	Geoy		*			3.7–6.0	J	6	NA
	Gerres sp.	Ges1	*	*			2.4–4.8	J	3	NA
Haemulidae	*Diagramma pictum*	Dipi	*				8.3–15.5	J	5	NA
	Pomadasys kaakan	Poka	*	*	*	*	1.7–11.5	J	71	B
Lethrinidae	*Lethrinus lentjan*	Lele	*				2.7–12.0	J	226	C
Nemipteridae	*Scolopsis taeniopterus*	Scta	*				7.2	J	1	NA
Mullidae	*Upeneus sulphureus*	Upsu	*				4.9–5.3	J	3	NA
	Upeneus tragula	Uptr	*				4.1–12.0	J	9	NA
Sciaenidae	*Dendrophysa russelli*	Deru		*	*		2.4–13.6	J	20	D2
	Johnius belangerii	Jobe			*		5.5–6.0	J	19	D3
	Nibea soldado	Niso		*	*		3.5–14.2	J	6	NA
	Otolithes rubber	Otru			*		9.0–10.0	J	3	NA
Monodactylidae	*Monodactylus argenteus*	Moar		*			2.0–3.5	J	4	NA
Scatophagidae	*Scatophagus argus*	Scar	*	*	*	*	1.1–13.5	J,A	547	B
Siganidae	*Siganus canaliculatus*	Sica	*		*		2.2–14.2	J,A	1592	C
	Siganus guttatus	Sigu	*				3.6–6.5	J	9	NA
	Siganus javus	Sija	*	*	*	*	2.1–15.8	J,A	12884	A
Terapontidae	*Pelates quadrilineatus*	Pequ	*		*		2.2–9.5	J	25	D1
	Terapon jarbua	Teja		*	*		4.0–7.8	J	2	NA
	Terapon puta	Tepu	*				1.9–10.0	J,A	161	C
	Terapon theraps	Teth				*	6.0–6.2	J	6	NA
Callionymidae	*Callionymus schaapii*	Casc			*		7.9–8.0	A	2	NA
	Repomucenus sp.1	Res1		*	*		2.2–8.3	J,A	4	NA
	Repomucenus sp.2	Res2				*	2.2	J	1	NA
Blenniidae	*Petroscirtes breviceps*	Pebr	*				8.0–8.1	A	4	NA
	Petroscirtes variabilis	Peva	*				8.0	A	1	NA
	Petroscirtes sp.	Pes1	*				5.3–8.4	J,A	2	NA
Eleotridae	*Butis butis*	Bubu	*	*			2.5–13.5	J,A	208	B
	Butis humeralis	Buhu	*	*			9.0–15.1	A	14	D2
	Butis koilomatodon	Buko	*	*	*		2.0–5.6	J,A	42	D3
Gobiidae	*Glossogobius* sp.	Gls1		*			9.7–10.0	A	2	NA
	Glossogobius aureus	Glau		*			10.0–32.7	J,A	3	NA
	Oxyurichthys microlepis	Oxmi		*		*	6.0–8.0	A	4	NA

Table 1. Cont'd.

Family	Species	ABB	SG	MG	MF	SB	Length range (cm)	Life history stages	Total number	Group in R-mode
	Acentrogobius caninus	Acca	*	*	*		3.3–7.0	J	13	D3
	Acentrogobius malayanus	Acma	*	*			2.5–4.1	J,A	15	D2
	Acentrogobius viridipunctatus	Acvi		*			6.4–14.5	J,A	20	D2
	Boleophthalmus boddarti	Bobo		*			8.6–9.4	J	3	NA
	Periophthalmus gracilis	Pegr		*			7.1	A	1	NA
	Periophthalmus novemradiatus	Peno	*	*			5.1–7.0	J	3	NA
	Periophthalmodon schlosseri	Pesc		*			7.0–7.5	J	4	NA
	Psammogobius biocellatus	Psbi	*				8.5–9.0	J,A	12	D1
	Pseudapocryptes lanceolatus	Psla		*			10.7–15.8	J,A	11	D2
	Stigmatogobius sadanundio	Stsa		*			4.0–4.5	J	4	NA
	Trypauchen vagina	Trva	*	*			4.5–7.2	J,A	3	NA
	Unknown	Gobi	*	*			3.0–7.5	J,A	59	B
Sphyraenidae	*Sphyraena jello*	Spje	*	*	*	*	5.8–22.2	J	23	D3
	Sphyraena putnamae	Sppu	*			*	5.0–6.7	J	5	NA
	Sphyraena sp.1	Sps1				*	6.2–6.8	J	5	NA
	Sphyraena sp.2	Sps2				*	6.5–6.9	J	2	NA
Labridae	*Halichoeres bicolor*	Habi	*				10.4–13.3	A	5	NA
	Halichoeres nigrescens	Hani	*				13.0	A	1	NA
Trichiuridae	*Trichiurus lepturus*	Trle		*	*	*	17.2–21.1	J	12	D3
Paralichthyidae	*Pseudorhombus* sp.1	Pss1	*		*		5.0–10.0	J	3	NA
	Pseudorhombus sp.2	Pss2	*				7.0–12.2	J	8	NA
Cynoglossidae	*Cynoglossus bilineatus*	Cybi			*	*	20.3–26.5	A	2	NA
	Cynoglossus cynoglossus	Cycy		*			15.8	A	1	NA
	Cynoglossus sp.	Cys1			*		12.4	J	1	NA
Triacanthidae	*Triacanthus biaculeatus*	Trbi	*		*		5.6–12.9	J	15	D1
	Triacanthus nieuhofi	Trni	*		*		2.6–9.3	J	5	NA
Monacanthidae	*Monacanthus chinensis*	Moch	*				2.4–18.8	J,A	163	C
Tetraodontidae	*Lagocephalus lunaris*	Lalu	*	*	*	*	2.4–10.0	J	22	D3
	Takifugu oblongus	Taob		*	*		1.8–6.8	J	29	D3
	Tetraodon nigroviridis	Teni	*	*	*		1.9–14.0	J,A	234	B

Table 2. Confusing matrix showing cross validation of the linear discriminant model (LDA), using the water variables to predict assemblage patterns with a global performance of prediction = 45.8 %.

Observed	Predicted				% Success
	G1	G2	G3	G4	
G1	5*	0	0	1	83.3
G2	0	2*	1	3	33.3
G3	0	1	1*	2	25.0
G4	0	2	3	3*	37.5

Note: *indicates the number of surveys that showed good prediction.

psu in the mudflats and sandy beaches (Fig. 6d). The highest transparency was observed in seagrass beds (65.0 cm) during October and lowest at 23.3 in mangroves during April (Fig. 6e). All five environmental variables were used in LDA to predict the four clusters of fish assemblages. Two discriminant functions (F1 and F2) were generated, which accounted for 42.3% and 33.2% of the between-clusters variability, respectively. The assemblage pattern of **G1** separated to the other clusters, meanwhile **G2**, **G3** and **G4**, overlapped (Fig. 7). The random Monte-Carlo permutation test also indicated that the assemblages were poorly separated (P = 0.312). The first axis (F1) related to DO and pH, meanwhile the second axis (F2) related to salinity, water temperature and transparency. These five parameters were able to predict the assemblage patterns (i.e., global performance of prediction) at 45.8%. The prediction success was good for **G1** (83%) but poor in other groups which were less than 50% (Table 2).

DISCUSSION

This study documents fish species composition and assemblage patterns in different nearshore habitats in a national park in Thailand. We recorded 131 fish species of which 66 species were included in assessments of assemblage patterns. This provided a more complete picture of habitat utilisation of individual species compared to previous report where lower numbers (30) of fish were used in the analysis (Hajisamae et al., 2006).

The majority of fish were juveniles and small sized species (95.6%) from families such as Leiognathidae, Engraulidae, and Siganidae. This is typical of fish communities in shallow tropical coastal waters, and consistent with the role of these areas as important nursery grounds for several marine and estuarine fish species (Blaber, 2000; Ikejima et al., 2003; Hajisamae & Chou, 2003; Hajisamae et al., 2006). Catches (97.4%) in a semi-enclosed estuarine bay in southern Gulf of Thailand were dominated by juveniles and adults of small sized fish (Hajisamae et al., 2006). Ikejima et al. (2003) reported that 74 out of 89 fish species collected from mangroves in Trang Province, Thailand, were in juvenile stages. Juveniles and adults of small sized fishes also dominated the catch on impacted nearshore areas within the Johore Straits (90.1%) (Hajisamae & Chou, 2003), and at Pasir Ris Park (92.3%) in Singapore (Jaafar et al., 2004).

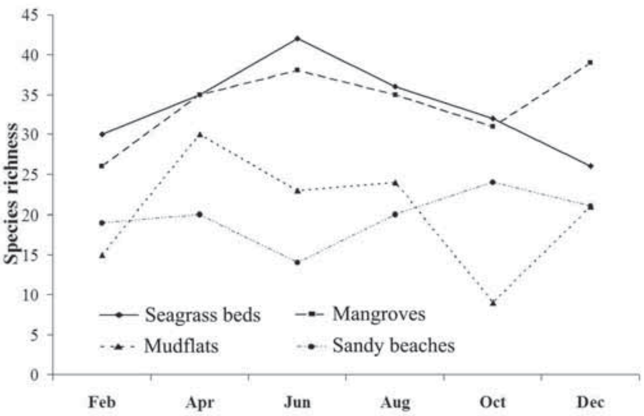

Fig. 3. Species richness of fish samples in each habitat during the study period.

The small sized pelagic species in families Leiognathidae, Engraulidae, and Ambassidae were diverse and abundant in the nearshore areas of this study. The findings of this study are similar to other nearshore areas in the Gulf of Thailand (Monkolprasit, 1994; Ikejima et al., 2003; Hajisamae et al., 2006). In contrast, Gobiidae, the most diverse family in mangroves, formed only a small proportion of abundance. This could be due to the large proportion of mangroves in this study on hard substrata, which are not suitable for gobiid fish (Blaber & Milton, 1990; Ikejima et al., 2003). Juveniles and adults of secondary freshwater fishes, such as *Anabas testudineus*, *Hemibagrus filamentus*, and *Oxyeleotris marmorata* were sometimes found in nearshore areas connected to the rivers (Hajisamae et al., 2006; Jutagate et al., 2011). No secondary freshwater fish were found in this study because there are no major rivers in the study area.

Abundance in all habitat types was dominated by relatively few species (>60% in abundance), as indicated by the low H′ index (<2) obtained in this study. These dominant species included *Leiognathus* spp., *Stolephorus* spp., and *Ambassis* spp., all *r*-selected life history species with protracted or year-round spawning (Avendaño-Ibarra et al., 2004; Ooi & Chong, 2011). Variations in abundance of fishes in nearshore areas may directly relate to their reproductive strategies, which peak during a certain period of the year (Álvarez et al., 2012). For example, recruits of fish species such as *Lates calcalifer* and *Epinephelus coioides* appeared during the southwest monsoons (Jeyaseelan, 1998) while the recruits of *Sillago sihama* were observed during northeast monsoons (Eadsui, 2011). Species richness, abundance, and H′-index values of this study fluctuated more in mudflats and sandy beaches than in seagrass beds and mangroves.

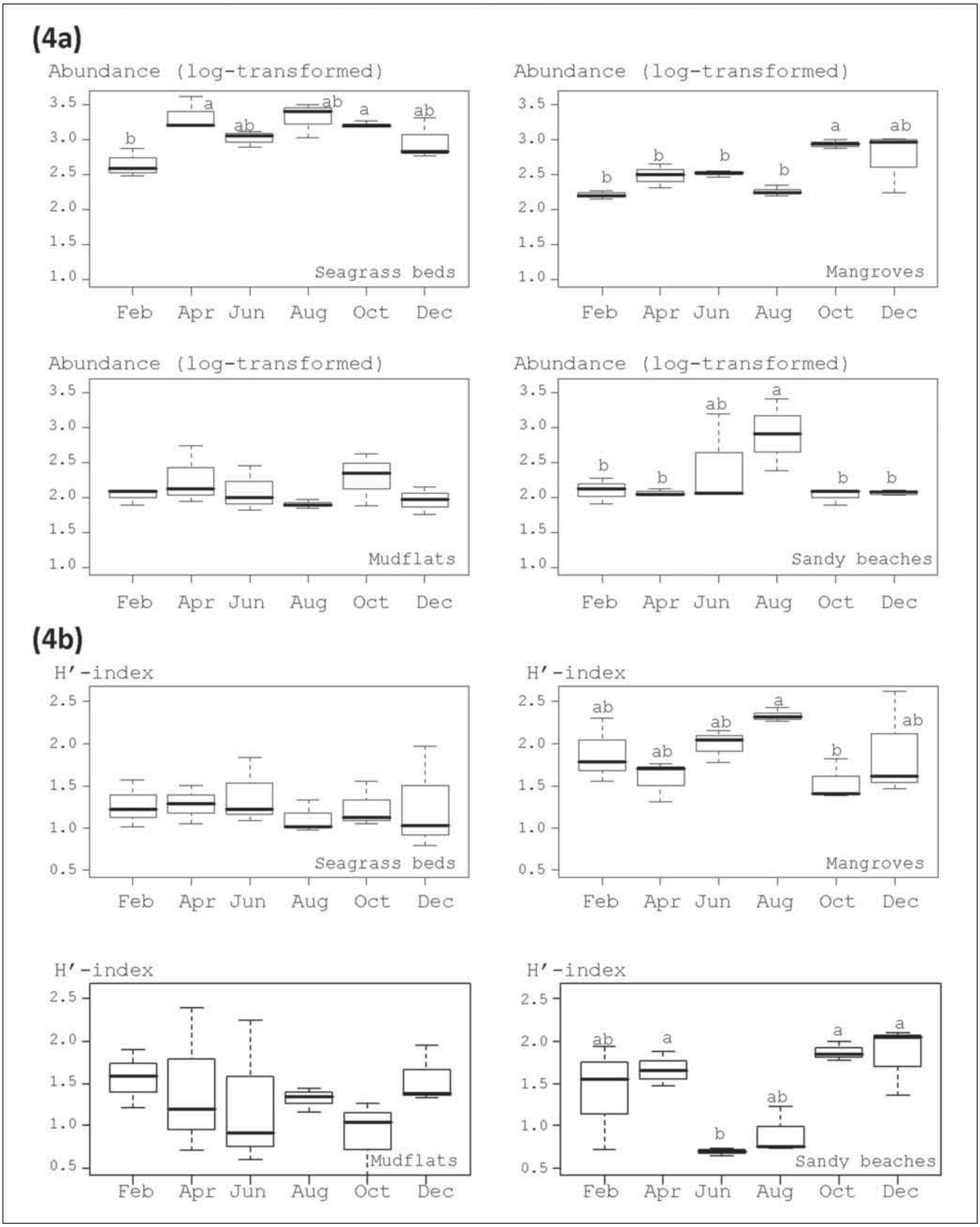

Fig. 4. Boxplots showing (a) abundance (log_{10}-transformed) and (b) diversity index (H′ index) of fish samples in each habitat. Note: The same letter(s) in each box indicates values that are not significantly different when applying the Duncan's post-test, p-value > 0.05.

This could result from the structural complexity of seagrass beds and mangroves habitats. However, besides providing shelters and increasing surface area for accumulation of food (Laegdsgaard & Johnson, 2001), structural complexity alone may not be greatly attractive to juveniles and small sized fishes. Diversity also varies within in a single habitat according to micro-habitat types (Ikejima et al., 2003; Inui et al., 2010) and distance from shoreline (Hajisamae & Yeemin, 2010; Inui et al., 2010). Low abundance in February could be linked to the reproductive strategies of many tropical fish species, which achieve maturity during the monsoon seasons (Jeyaseelan, 1998; Blaber, 2000). The abundance of *r*-selected species such as engraulids show clear seasonal differences in abundance, in which they are dominant during rainy season but relatively scarce in dry season (Ikejima et al., 2003).

Assemblages were separated according to habitat types: a, the small complex structure plant groups (macroalgae and seagrass); b, the larger complex plant structures (mangroves); and c, areas without complex structures or

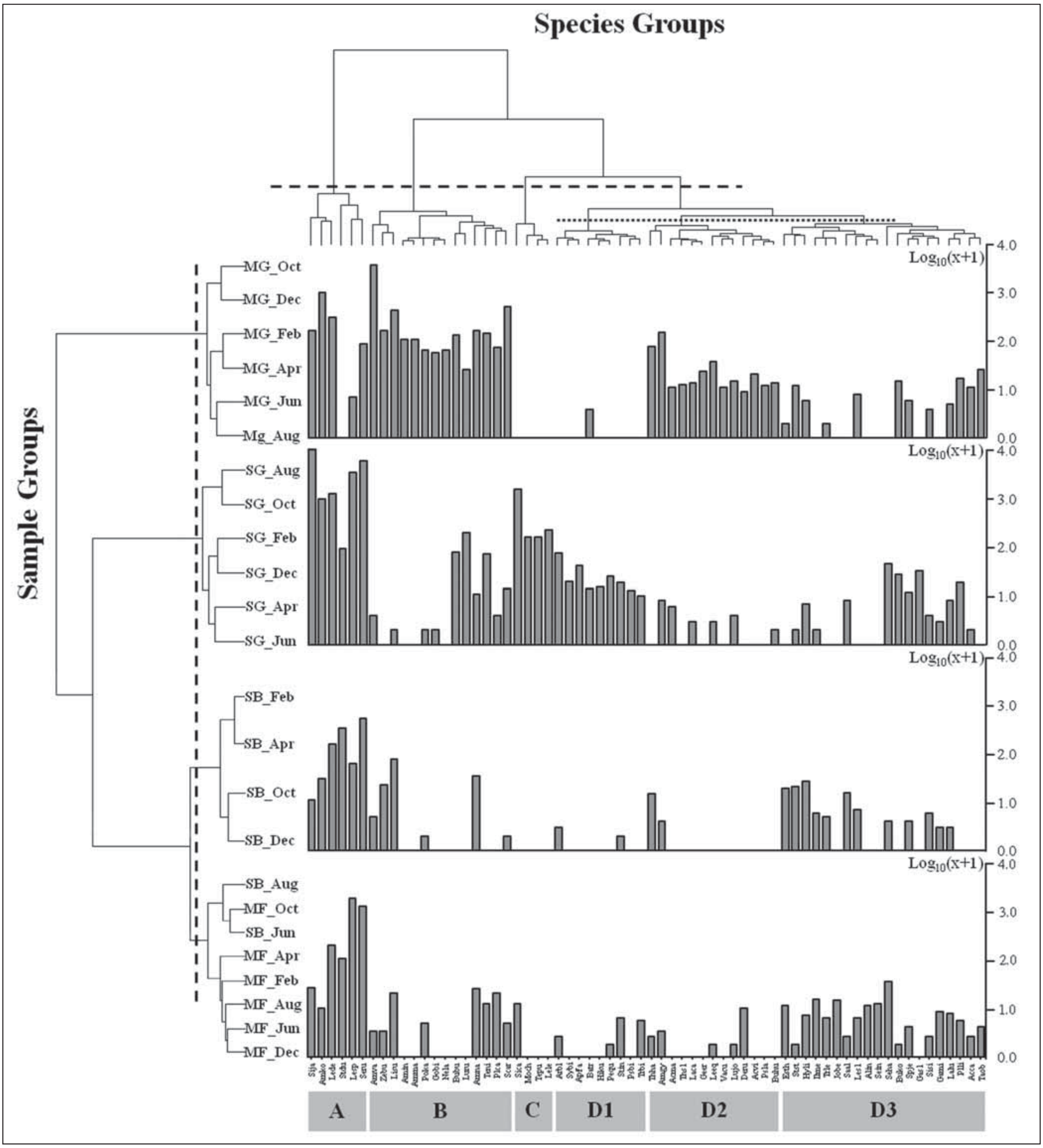

Fig. 5. Nodal diagram showing species and sample groups and abundance (log_{10}-transformed) of fish samples per cluster.

vegetation (mudflats and sandy beaches). Habitat complexity and spatial heterogeneity are thus both important factors to maintain healthy and productive nearshore environments (França et al., 2012). An overlap in species composition is common if the area of interest is limited (Magurran, 2004). Lugendo et al. (2007b) reported a high overlap in species composition (>50%) among adjoining habitats. In this study, six species in Group **A** were distributed across all types of habitats while some species showed a preference for specific habitat. Observed differences in habitat specificity among species agree with previous reports (Monkolprasit, 1994; Poovachiranon & Satapoomin, 1994; Ikejima et al., 2003; Hajisamae et al., 2006). *Siganus canaliculatus*, *T. puta*, and *H. kuda*, for instance, were generally associated with the seagrass beds, *Ac. caninus* and *Se. insidiator* were found predominantly over the mudflats, whereas species such as *Ambassis* spp., *Butis* spp., *L. equulus*, and *Liza subviridis* were dominant in the mangroves.

Attempts to employ water quality variables as predictors of assemblage patterns failed. Only the assemblage **G1** was clearly discriminated and described by the selected parameters. **G1** was the mangrove assemblage, and was associated with relatively low DO and pH. Degradation of organic matter, detritus and mangrove leaves are major causes in low DO and pH in mangroves (Singkran & Sudara, 2005). In the present study, salinity, transparency and temperature were along the F2 axis, indicating that they had lower power in discriminating the assemblage patterns than DO and pH, although a conspicuous change in these three

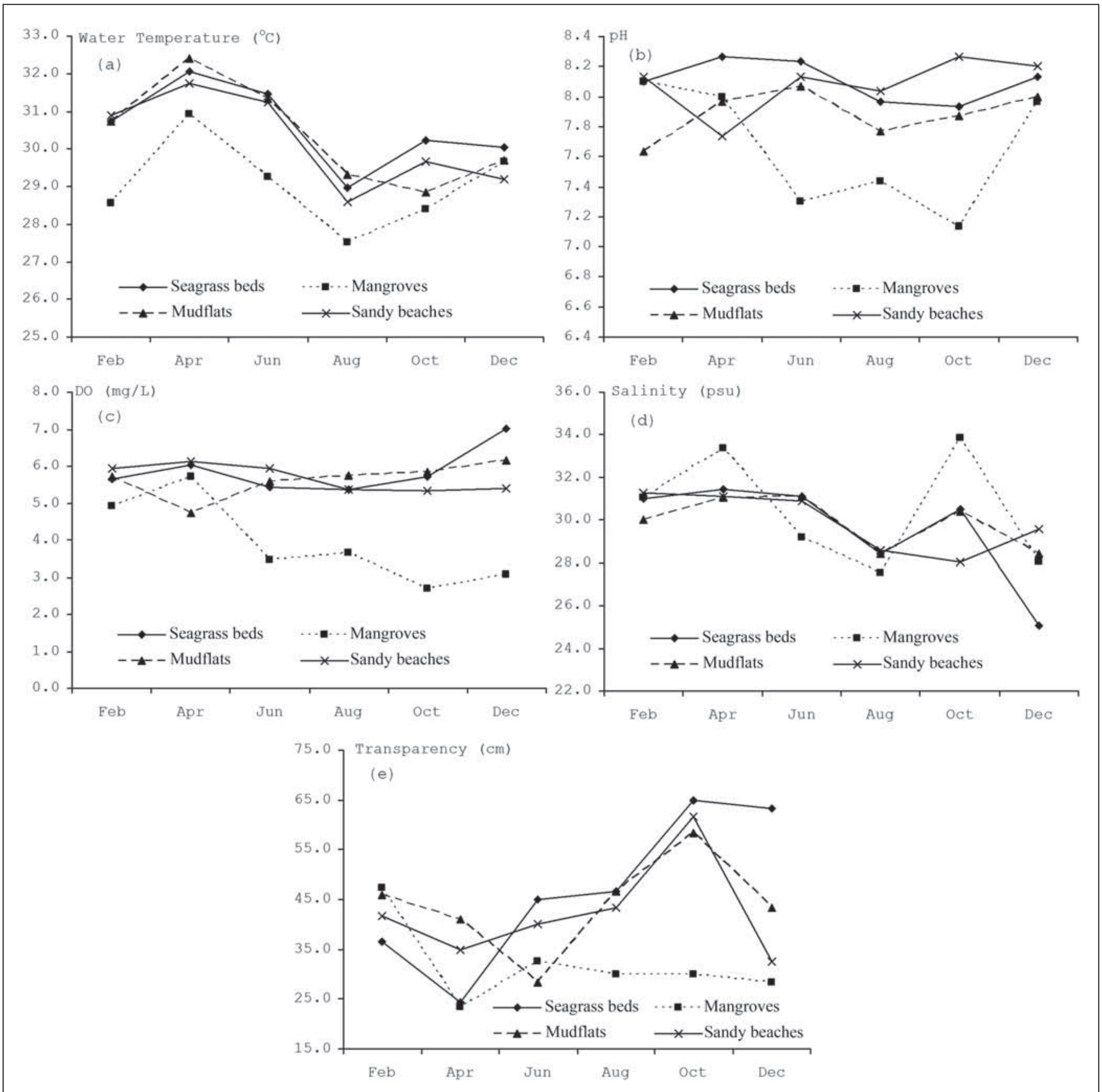

Fig. 6. Changes in (a) water temperature, (b) pH, (c) DO, (d) salinity and (e) transparency in each habitat during the study period.

parameters was observed during the study period. This also implies that most fish found in this limited nearshore area are euryhaline and have the capacity to cope with seasonal or even tidal fluctuations (Blaber, 2000; Singkran & Sudara, 2005; Lugendo et al., 2007a).

In conclusion, in the limited tropical nearshore area, which is comprised of a mosaic of habitats, fish assemblages differed among habitat types. The vegetated habitats such as mangroves and seagrass beds showed higher species richness, abundance and species diversity. Future work on feeding habits and resource utilization by inhabitants of tropical nearshore environments are necessary to prepare long-term conservation plans for these different habitats.

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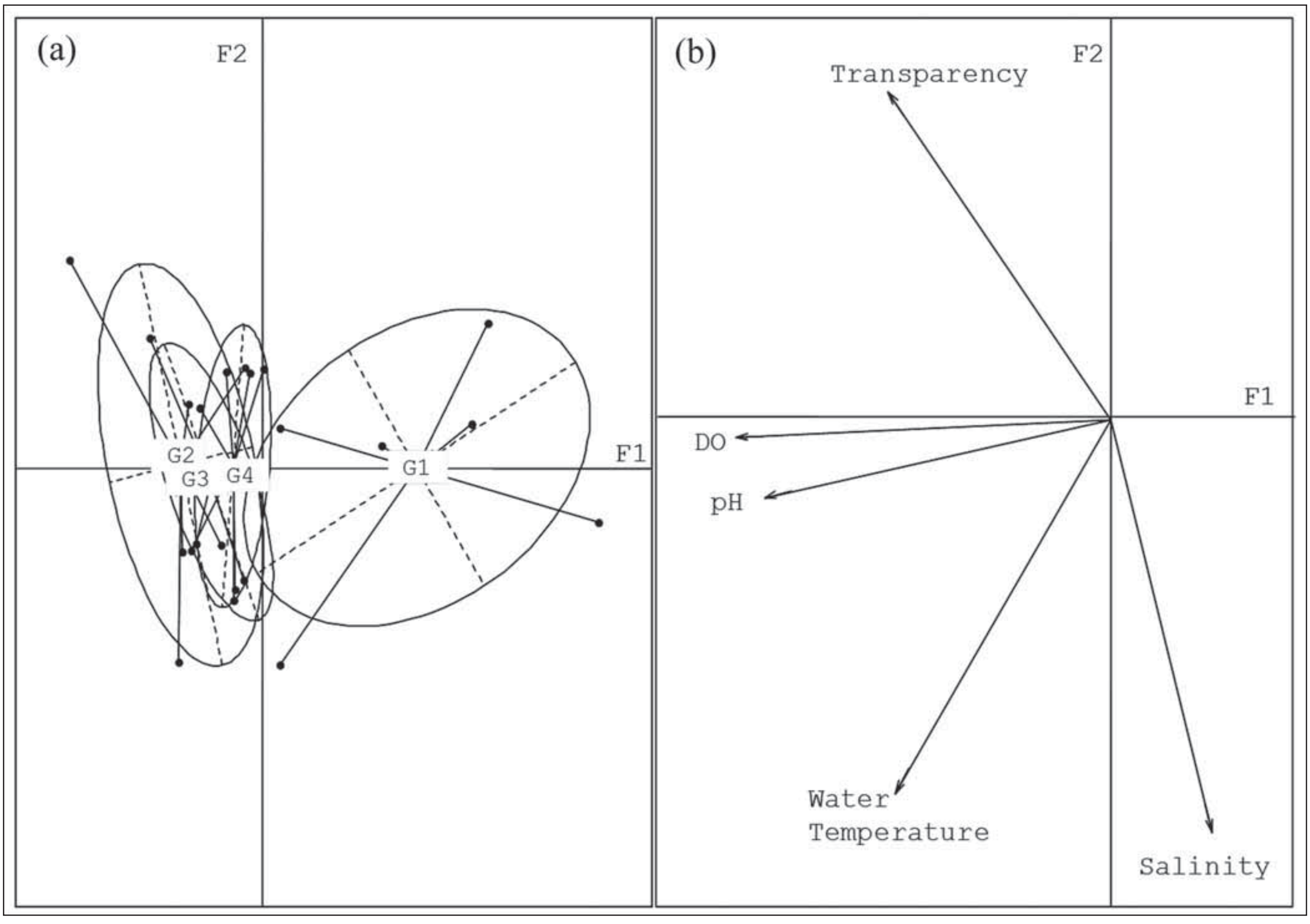

Fig. 7. Results from LDA analysis showing (a) the distribution and overlap of groups of clusters (ellipsoid) and (b) the contribution of parameters to F1 and F2.

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