Zoological Studies **49**(6): 760-778 (2010)

Zoological Studies

Juvenile Fish Assemblages in Mangrove and Non-Mangrove Soft-Shore Habitats in Eastern Hong Kong

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(Accepted July 2, 2010)

Tony H. M. Nip and Chong Kim Wong (2010) Juvenile fish assemblages in mangrove and non-mangrove soft-shore habitats in eastern Hong Kong. *Zoological Studies* **49**(6): 760-778. Conducted in subtropical coastal waters of eastern Hong Kong, this study provides information on species compositions of juvenile fish communities in several mangrove and non-mangrove habitats, and evaluated the influences of water temperature, salinity, turbidity, sediment organic matter (SOM), water depth, and sediment grain size on fish assemblages. In total, 85,427 fish belonging to 76 species from more than 29 families were collected. Fish densities were higher in mangrove mudflats than in non-mangrove habitats, but only a few of the dominant species were significantly more abundant in mangrove than in non-mangrove habitats. Fish assemblages in mangrove and non-mangrove mudflats were quite similar. Fish compositions were influenced by environmental factors including the SOM and water depth, but not by the presence of mangroves. The present study suggests that the nursery function of mangroves is both site- and species-specific. Compared to shallow mudflats with and without mangroves, deep-water sandy beaches may be less suitable for juvenile fish because of their low SOM content and high piscivorous fish abundances. More studies need to be conducted before definitive conclusions can be made on the nursery function of mangroves in Hong Kong and subtropical Asia.
http://zoolstud.sinica.edu.tw/Journals/49.6/760.pdf

Key words: Mangroves, Juvenile fishes, Nursery habitats, Environmental factors, Subtropical Asia.

Mangroves are considered important nursery habitats for fish (Laegdsgaard and Johnson 1995, Kuo et al. 1999, Ikejima et al. 2003, Mumby et al. 2004). In addition to numerous reports of higher fish densities in mangrove than in non-mangrove soft-shore habitats (Thayer et al. 1987, Chong et al. 1990, Nagelkerken and van der Velde 2002), many studies noted the benefits provided to fish by mangroves. For example, structurally complex habitats created by the roots and branches of mangroves may provide refuge for juvenile fish (Thayer et al. 1987, Blaber 2000, MacDonald et al. 2009). Juveniles of some species of fish depend on mangroves as feeding grounds (Chong et al. 1990, Blaber 2000). Juvenile fish living in mangroves were shown to have higher survival rates and gut fullness than those living in non-mangrove habitats (Laegdsgaard and Johnson 2001).

While many investigators have argued that mangrove habitats may serve as important fish nurseries, most of their claims are not based on comparative studies (Louis et al. 1995, Kuo et al. 1999, Ikejima et al. 2003). Among studies that compared fish communities between mangrove and non-mangrove habitats, few are based on the use of the same sampling method in different habitats (Nagelkerken and van der Velde 2002, Mumby et al. 2004, Wang et al. 2009). Some investigators actually reported lower fish densities in mangrove than in non-mangrove habitats (Weerts and Cyrus 2002, Huxham et al. 2004, Wang et al.

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2009). In reality, the nursery value of mangroves may vary within and among regions (Baran and Hambrey 1998, Hindell and Jenkins 2004, Chittaro et al. 2005). Environmental factors such as salinity and turbidity can influence the structure of juvenile fish assemblages (Whitfield 1994, Blaber 2000), but their importance is often ignored in studies of mangrove fish communities (Beck et al. 2001).

In subtropical Asia, fish communities in mangrove habitats were studied in Taiwan (Kuo et al. 1999) and in Guangxi, China (He and Fan 2002), but few studies have actually compared juvenile fish assemblages between mangroves and other potential nursery habitats. As a result, the relative importance of habitats with potential nursery value to fish is poorly known. In subtropical southern China, fish populations in coastal seas are depleted by overfishing and destructive fishing practices (Fan et al. 1996, Sadovy 1998), and coastal habitats including mangroves have been destroyed by urban development and degraded by pollution (Tam and Wong 2000, Wang et al. 2008). Thus, there is an urgent need to evaluate the potential nursery functions of different habitats, especially mangroves, in the region.

In this study, juvenile fish were collected from 3 mangrove mudflats, a non-mangrove mudflat, and a non-mangrove sandflat using the same sampling methods. The objectives were: (1) to describe seasonal variations in density and species composition of juvenile fish communities in mangrove mudflats and other soft-shore habitats, (2) to examine the relationship between the community compositions of juvenile fish and environmental parameters such as temperature, salinity, turbidity, sediment organic matter (SOM), sediment particle size, and water depth, and (3) to assess the nursery values of mangrove and non-mangrove habitats. Data from this study can contribute to our knowledge of habitat requirements of juvenile fish and the nursery functions of various soft-shore habitats in subtropical Asia.

MATERIALS AND METHODS

Study sites, sampling methods, and laboratory analyses

The study was carried out in Tolo Harbour and Port Shelter (Fig. 1). Formerly a bay with extensive mangroves, Tolo Harbour has lost 42% of its original mangrove cover due to urban development (Tam and Wong 2000). Port Shelter is one of the few remaining areas in Hong Kong with rich coral coverage (McCorry 2002), but the total area covered by mangroves is smaller than that in Tolo Harbour (Tam and Wong 2000).

Five study sites were chosen for this study (Fig. 1). Kei Ling Hai Lo Wai (KL), Nam Wai (NW), and Wong Chuk Wan (WC) are mangrove mudflats. Starfish Bay (SB) is a non-mangrove mudflat and Sha Hai (SH) is a non-mangrove sandy beach. *Kandelia obovata* was the dominant mangrove species at all mangrove sites. Sites in Port Shelter (NW, WC and SH) contain small patches of seagrass beds formed mainly of *Halophila ovata*. All study sites receive freshwater input from small creeks and drainages. There is an unequal semi-diurnal tidal pattern in Hong Kong, and the mean tidal range is ~1.4 m.

Fish were sampled monthly in Tolo Harbour and seasonally in Port Shelter from Mar. 2002 to Feb. 2003. Seasonal samples were taken in Mar. (spring), July and Aug. (summer), Oct. (autumn), and Dec. and Jan. (winter). At each site, triplicate samples were collected with a beach seine (35 m long and 2 m deep, with a 1 mm mesh). The seine net was deployed in shallow water (0.2-1.3 m) in an upright position in the form of a semicircle with an area of ~200 m^2 and was slowly pulled towards the shore with the bottom edge lying firmly against the bottom. Captured fish were immediately preserved in a 10% formalin-seawater solution and returned to the laboratory for analysis. Species of conservation concern, such as the seahorse *Hippocampus kuda*, were released after analysis. All fish were collected at low tide during the daytime.

In the laboratory, all fish were sorted, identified, counted, and weighed. Wet weights of the fish were determined using an electronic balance. Fish were identified to the lowest taxon possible according to Shen et al. (1993), Leis and Carson-Ewart (2000), and Nakabo (2000). Mullet and halfbeak were identified with the assistance of Dr. Ian Harrison (American Museum of Natural History, New York, NY, USA) and Dr. Bruce Collette (National Museum of Natural History, Washington, DC, USA).

Piscivory in these fish was determined by a stomach analysis. Some of the results were published in Tse et al. (2008). Additional information was obtained from the literature (Fishbase 2009).

Physical parameters

Temperature, salinity, and turbidity of the seawater at each site were measured *in situ* with a Hydrolab® H20 multiprobe (Austin, TX, USA) at the time of fish sampling. Organic matter at each site was measured seasonally. Surface sediment samples were collected near the center of the area swept by the net and were taken to the laboratory in an icebox. In the laboratory, ~15 g of wet sediment was oven-dried to a constant weight at 105°C. Dried sediments were weighed and then combusted in a furnace at 500°C for 18 h. Weight loss due to combustion was regarded as the weight of the organic content of the sediment. The weight of the SOM was expressed as a percentage of the weight of the dry sediment. Sediment particle size was determined using sediment samples collected in Mar. A sample (~10 g) of oven-dried sediment was passed through a series of sieves and the fraction remaining on each sieve was weighed to the nearest 0.1 mg. The weights of gravel (> 2 mm), coarse sand (0.5-2 mm), fine sand (63 μm-0.5 mm), and silt-clay (< 63 μm) were expressed as a percentage of the weight of the original dry sediment sample. Water depth at the deepest point in the area swept by the seine net at each sampling site was recorded.

Data analysis

The maximum and maturation sizes of various fish species were obtained from FishBase (Fishbase 2009) and from the literature (Shen et al. 1993, Sadovy 1998). The method of Nagelkerken and van der Velde (2002) was used to determine the developmental stages of fish species with an unknown maturation size. Individuals with body lengths shorter than 1/3 of the maximum length reported for the species were regarded as juveniles. Unidentified gobiids were not included in the examination.

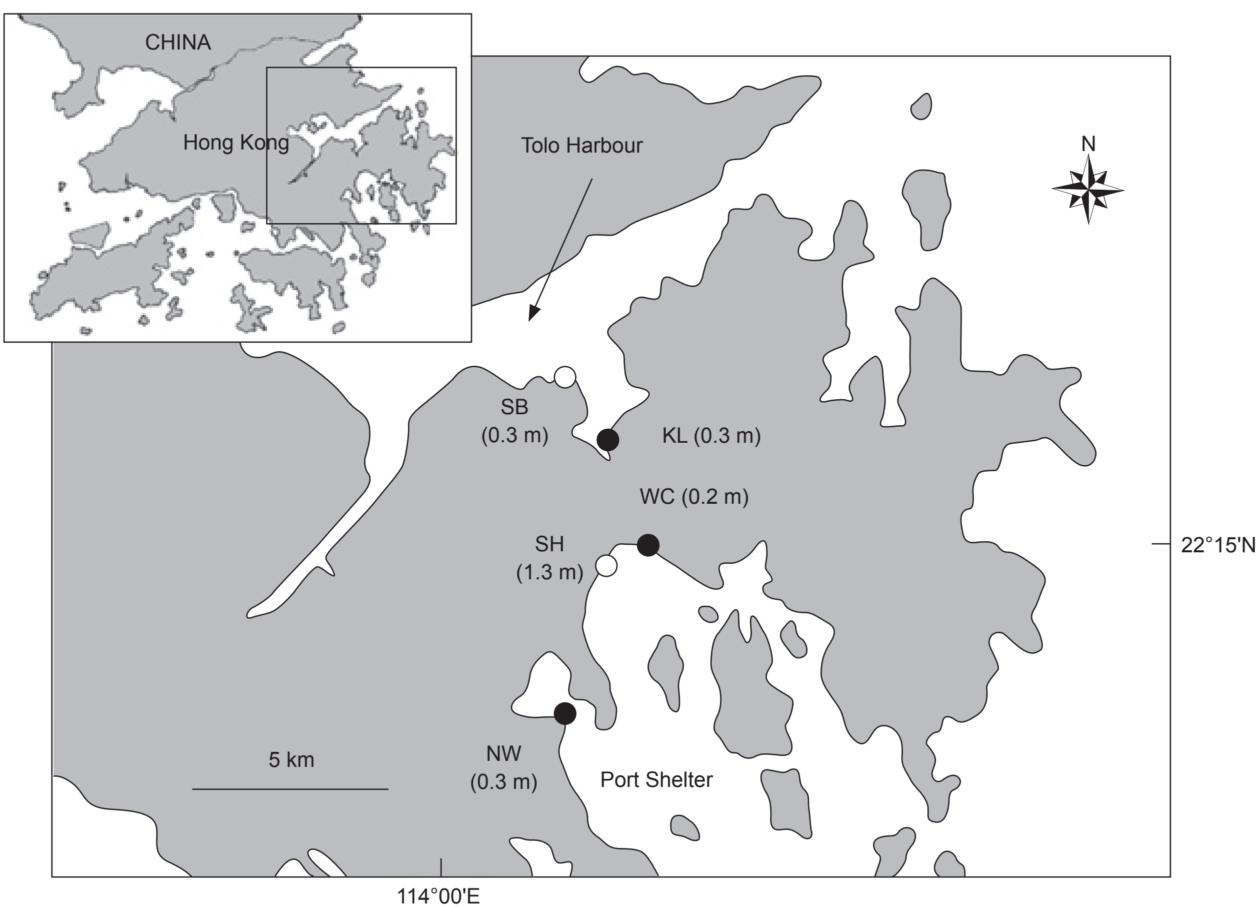

Fig. 1. Map of Hong Kong showing the location of the study sites. Mangrove and non-mangrove habitats are marked by closed and open circles, respectively. The maximum water depth recorded at each site is given in parenthesis.

Two-factor analysis of variance (ANOVA) was used to detect spatial and temporal variations in fish density, fish biomass, species richness, and physical parameters, such as temperature, salinity, turbidity, and SOM. Data from Tolo Harbour and Port Shelter were analyzed separately because of differences in sampling efforts. Two-factor ANOVA was also used to examine spatial and temporal variations in the densities of each of the 20 most abundant species in Tolo Harbour and the 11 most abundant species in Port Shelter. Tukey-Kramer tests were performed to compare the means when significant differences were detected. Data were log-transformed using log(n) or log(n+1) when the assumptions of normality and homogeneity of variance were not met (Zar 1999).

Similarities among fish communities collected from different sites in different seasons were estimated using the Bray-Curtis similarity coefficient. Log-transformed (log(n+1)) fish abundance data were used for calculations to minimize the effect of large values (Clark and Warwick 1994). A cluster analysis (group average cluster mode) was performed to group fish assemblages of different study sites and seasons based on the Bray-Curtis similarity coefficient. A similarity of percentage analysis (SIMPER) was used to identify species which contributed the most to the grouping of samples defined by the cluster analysis. The PRIMER computer program (Clark and Warwick 1994) was used to conduct the clustering and SIMPER analyses.

Pearson correlation analyses were used to examine relationships between the fish community and abiotic factors. The mean and total values of fish abundance, fish biomass, and number of fish species collected were correlated against temperature, salinity, turbidity, and SOM. Since fish data were collected monthly, but SOM was only measured seasonally, the correlation analysis between fish communities and SOM was conducted with fish data from months with SOM data only. Data collected from Tolo Harbour and Port Shelter were analyzed separately. The mean fish abundance, mean fish biomass, and average fish weight were correlated against the maximum sampling depth and sediment particle size. Data were log-transformed when necessary. ANOVA and correlation analyses were performed using the SigmaStat computer package (Systat Software Inc., Point Richmond, CA, USA).

RESULTS

Physical parameters

Data on temperature, salinity, turbidity, and SOM are presented in table 1 and figure 2. Temperature and salinity in Tolo Harbour did not significantly differ between the 2 study sites. Turbidity was significantly higher at SB than at

Table 1. Summary of two-factor ANOVA results for spatial and temporal variations in temperature, salinity, turbidity, and sediment organic matter (SOM) at 2 sites in Tolo Harbour and 3 sites in Port Shelter. Tukey-Kramer tests were performed as the posteriori tests with a significance level of $p < 0.05$

	Month/season	Site	Interaction	
Tolo Harbour				
Temperature	***	NS	***	5, 6, 7, and 8 > 1, 2, 3, 4, 11, and 12; 9 and 10 > 1, 2, 3, 11, and 12; 4 and 12 > 2, 3, and 11 > 1
Salinity	***	NS	NS	1 > 8 = 9 = 10; 2, 3, 4, 5, 6, 7, 10, 11, and 12 > 8 > 9
Turbidity	**	**	**	6 > 1 and 8; SB > KL
SOM	*	***	NS	Au and Wn > Sp; KL > SB
Port Shelter				
Temperature	***	NS	NS	Su > Au > Sp and Wn
Salinity	***	*	NS	Wn and Sp > Su; SH > NW
Turbidity	*	***	*	Su > Sp; NW and WC > SH
SOM	NS	***	NS	NW > WC > SH

1 to 12 refer to Jan. to Dec.; Sp, spring; Su, summer; Au, autumn; Wn, winter. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

KL, but the reverse was true for SOM. In Port Shelter, water temperature did not differ among the study sites. Salinity was significantly higher at SH than at NW. Turbidity was significantly higher at WC and NW than at SH. SOM values were significantly higher at NW than at WC and SH.

Temperature, salinity, turbidity, and SOM in Tolo Harbour and Port Shelter varied seasonally (Table 1, Fig. 2). In general, the variations reflect Hong Kong's climate, with hot, rainy summers and cool, dry winters. The maximum sampling depth of 1.3 m at SH was much greater than the 0.2-0.3 m recorded at the other sites (Fig. 1). Sediments on the mangrove mudflats at KL, WC,

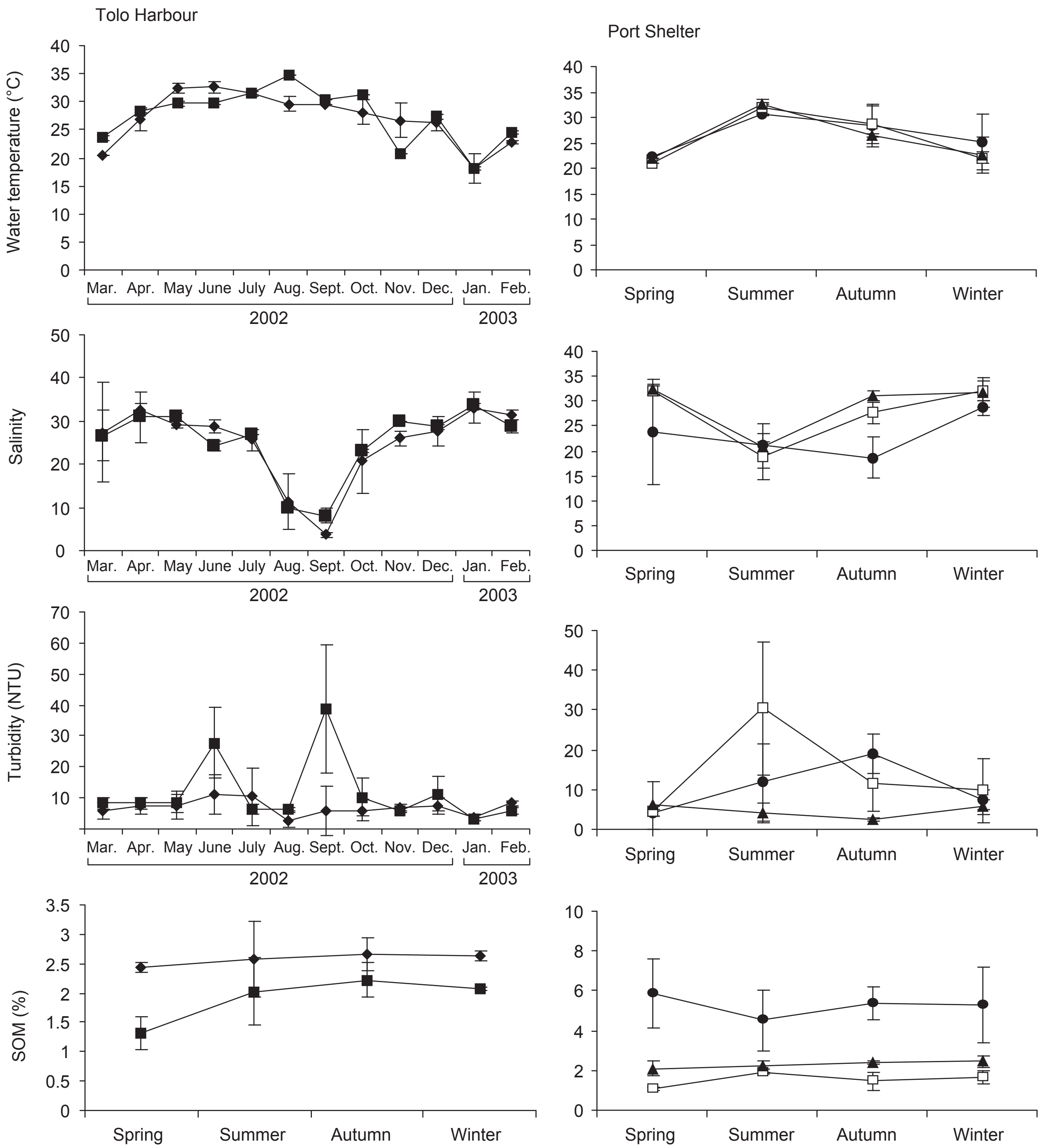

Fig. 2. Seasonal patterns of physical parameters at the 5 study sites. ■, KL; ◆, SB; ●, NW; □, WC; ▲, SH. Error bars are ± 1 S.D.

and NW consisted mainly of fine particles (Table 2). The non-mangrove mudflat at SB consisted of a mixture of coarse and fine sand. Coarse sand dominated the sandy beach at SH.

Community compositions

In total, 85,427 fish belonging to 76 species and at least 29 families were collected in this study (Table 3). The most abundant species in Tolo Harbor included *Ambassis gymnocephalus*, *Sillago*

Table 2. Particle size distribution (% w/w) in sediments at 2 sites in Tolo Harbour and 3 sites in Port Shelter

	Tolo Harbour		Port Shelter		
	KL	SB	NW	WC	SH
Gravel (> 2 mm)	3	16	1	0	6
Coarse sand (0.5-2 mm)	30	48	9	24	82
Fine sand (63 μm-0.5 mm)	54	26	23	67	10
Silt-clay (< 63 μm)	13	10	67	9	2

Table 3. Summary of fish species collected at 2 sites in Tolo Harbour and 3 sites in Port Shelter. Percentage contribution of each species to the fish community at each study site is expressed in terms of numerical abundance (%N) and biomass (%W). The rank of each species in Tolo Harbour and Port Shelter is based on the total number of individuals collected. L, life stage; J, juvenile; A, adult; N, not determined; *, new record for Hong Kong

		Tolo Harbour						
		KL			SB			
Family	Species	%N	%W	L	%N	%W	L	Rank
Clupeidae	*Konosirus punctatus*	11.55	4.34	J	11.43	9.20	J	3
	Nematalosa nasus	0.01	0.12	J,A				34
	Sardinella sp.	< 0.01	0.02	A				36
Engraulidae	Engraulidae	0.01	< 0.01	J				33
Synodontidae	*Trachinocephalus myops*							
Hemiramphidae	*Zenarchopterus striga* *	0.84	6.40	J,A	0.58	1.60	J,A	10
	Hyporhamphus sp. 1	0.01	0.20	J,A	0.11	0.62	J,A	25
	Hyporhamphus sp. 2							
Atherinidae	*Hypoatherina valenciennei*	0.01	< 0.01	J	0.16	0.02	J	24
Syngnathidae	*Hippocampus kuda*	< 0.01	0.06	A				36
Scorpaenidae	*Paracentropogon longispinus*							
Platycephalidae	Platycephalidae	0.01	< 0.01	J	0.01	< 0.01	J	32
Ambassidae	*Ambassis gymnocephalus*	67.74	66.27	J,A	0.30	0.05	J	1
Percichthyidae	*Lateolabrax japonicus*	< 0.01	0.03	J	0.02	0.01	J	33
Serranidae	*Epinephelus coioides*							
Teraponidae	*Terapon jarbua*	0.02	0.95	J,A	0.29	5.40	J,A	20
	Pelates quadrilineatus	< 0.01	<0.01	J	0.01	< 0.01	J	33
	Teraponidae				0.04	< 0.01	J	32
	Rhynchopelates oxyrhynchus							
Sillaginidae	*Sillago sihama*	6.35	2.13	J	45.68	12.95	J	2
	Sillago aeolus	0.01	< 0.01	J	2.77	1.05	J	12
Carangidae	*Scomberoides lysan*	< 0.01	< 0.01	J	0.02	0.08	J	33
	Caranx ignobilis	< 0.01	0.03	J	0.01	0.14	J	34
	Carangoides praeustus							
	Uraspis helvola							
Leiognathidae	*Leiognathus brevirostris*	0.40	2.16	J,A	0.03	0.03	J	15
	Leiognathus equulus				0.01	< 0.01	J	36
Lutjanidae	*Lutjanus argentimaculatus*							
	Lutjanus russellii							
Gerreidae	*Gerres oyena*	1.23	1.59	J	9.68	4.98	J	5
	Gerres oblongus	0.06	0.03	J	2.75	1.30	J	11
	Gerres filamentosus	0.45	0.14	J	3.19	0.62	J	9

Table 3. (continued)

		Tolo Harbour						
		KL			SB			
Family	Species	%N	%W	L	%N	%W	L	Rank
Sparidae	*Acanthopagrus schlegeli*	1.21	1.52	J	4.24	3.10	J	7
	Acanthopagrus latus	0.13	0.04	J	0.09	0.02	J	19
	Rhabdosargus sarba	0.01	0.01	J	0.34	0.92	J	21
Mullidae	*Upeneus tragula*							
Drepaneidae	*Drepane punctata*				0.01	0.04	J	35
Scatophagidae	*Scatophagus argus*							
Cichlidae	*Oreochromis mossambicus*							
	Vieja sp.				0.01	0.89	J,A	35
Mugilidae	*Liza affinis*	4.02	6.35	J	10.72	22.71	J	4
	*Liza parmata**	3.29	1.66	J	2.08	0.66	J	6
	*Valamugil persuii**	0.18	3.28	J	1.47	24.61	J,A	13
	*Valamugil speigleri**	< 0.01	0.03	J	0.24	1.85	J,A	22
	*Liza vaigiensis**							
	Liza macrolepis				0.24	0.88	J	23
	Mugil cephalus	0.03	0.05	J	1.05	4.28	J	17
Sphyraenidae	*Sphyraena jello*				0.01	0.04	J	35
	Sphyraena barracuda	< 0.01	0.04	J	0.01	0.12	J	35
Blennidae	Blennidae				0.01	< 0.01	J	36
Callionymidae	Callionymidae	< 0.01	<0.01	J	0.01	< 0.01	J	35
Gobiidae	*Pseudogobius javanicus*	1.84	0.98	J,A				8
	Favonigobius reichei	0.17	0.06	J,A	0.98	0.31	J,A	14
	Goby 1	0.31	0.02	N	0.15	0.01	N	16
	Tridentiger trigonocephalus	0.03	0.03	J,A	0.01	< 0.01	J	26
	Glossogobius biocellatus	0.01	0.01	J,A				30
	Oxyurichthys ophthalmonema	< 0.01	0.36	A				35
	Goby 2	< 0.01	< 0.01	N	0.01	0.01	N	34
	Goby 3	0.01	< 0.01	N	0.01	< 0.01	N	33
	Periophthalmus modestus	< 0.01	0.01	A				35
	Goby 4	< 0.01	< 0.01	N				36
	Goby 5	< 0.01	< 0.01	N				36
	Goby 6	0.01	< 0.01	N	0.01	< 0.01	N	29
	Istigobius sp.	0.01	0.02	A	0.06	0.10	J,A	27
	Goby 7	0.01	< 0.01	N				34
	Goby 8				0.04	0.03	N	31
	Goby 9				0.04	< 0.01	N	32
	Goby 10				0.02	< 0.01	N	33
	Mugilogobius abei				0.01	0.01	A	35
	Taenioides sp.				0.01	< 0.01	J	36
	Goby 11							
Bothidae	*Pseudorhombus arsius*							
Tetraodontidae	*Chelonodon patoca*	< 0.01	< 0.01	J	0.02	0.07	J	33
	Takifugu niphobles	0.02	1.03	J,A	0.93	1.23	J	18
Elopiformes	Elopiformes larvae 1				0.08	0.03	J	28
	Elopiformes larvae 2				0.04	0.01	J	32
	Total number of fish examined		55,421			17,090		
	Total biomass (g)		10,437			3310		
	Total number of species		47			50		
	Average individual fish weight per site (g)		0.19			0.19		
	Number of piscivorous fish		32			61		
	Percent (%) of species consisting of juveniles only		51			68		

sihama, *Konosirus punctatus*, and *Liza affinis*. At Port Shelter, *L. parmata* was the most abundant species, followed by *S. sihama*, *Valamugil persuii*, *Pseudogobius javanicus*, and *Gerres oyena*.

More than 1/2 of the species collected at KL, SB, NW, and WC were only represented by juveniles (Table 3). On average, fish captured at SH were much bigger in terms of weight than those captured at other sites (Table 3). In Tolo Harbour, more piscivorous fish were captured at SB than at KL. In Port Shelter, more piscivorous fish were captured at SH than at NW and WC. Overall, the abundance of piscivorous fish was much higher at SH than at other sites (Table 3).

Density, biomass, and species richness

Seasonal patterns in fish density and biomass at different sites are presented in figure 3. Fish density, biomass, and species richness showed significant spatial and temporal variations (Table 4). In Tolo Harbour, both fish density and biomass were significantly higher at KL than at SB, but differences between the 2 sites disappeared when *A. gymnocephalus*, which accounted for > 65% of the catch at KL, was excluded. Significant temporal variations in fish densities were observed, with the highest densities in July and Oct. and the lowest densities in Apr. and June. No significant

Table 3. (continued)

		Port Shelter									
		NW			WC			SH			
Family	Species	%N	%W	L	%N	%W	L	%N	%W	L	Rank
Clupeidae	*Konosirus punctatus*	0.04	< 0.01	J	0.12	0.03	J				21
	Nematalosa nasus										
	Sardinella sp.										
Engraulidae	Engraulidae	0.34	0.05	J							16
Synodontidae	*Trachinocephalus myops*							0.05	0.05	J	27
Hemiramphidae	*Zenarchopterus striga* *	0.03	0.19	A	0.05	0.16	J				24
	Hyporhamphus sp. 1							0.05	< 0.01	J	27
	Hyporhamphus sp. 2							0.11	0.12	A	26
Atherinidae	*Hypoatherina valenciennei*				1.30	1.61	J,A	0.16	< 0.01	J	15
Syngnathidae	*Hippocampus kuda*							0.21	0.92	A	24
Scorpaenidae	*Paracentropogon longispinus*							0.32	3.20	A	22
Platycephalidae	Platycephalidae	0.01	< 0.01	J							27
Ambassidae	*Ambassis gymnocephalus*	0.73	1.03	J,A	0.27	0.18	J				14
Percichthyidae	*Lateolabrax japonicus*										
Serranidae	*Epinephelus coioides*							0.05	0.28	J	27
Teraponidae	*Terapon jarbua*	0.32	1.41	J	1.55	1.15	J	20.29	7.02	J,A	6
	Pelates quadrilineatus										
	Teraponidae										
	Rhynchopelates oxyrhynchus	0.01	0.01	J							27
Sillaginidae	*Sillago sihama*	3.10	3.38	J	76.47	14.28	J	17.35	4.31	J,A	2
	Sillago aeolus				0.02	0.11	J	9.77	3.78	J,A	9
Carangidae	*Scomberoides lysan*							0.11	0.05	J	26
	Caranx ignobilis	0.07	0.63	J							23
	Carangoides praeustus							0.91	0.31	J	19
	Uraspis helvola							0.16	0.06	J	25
Leiognathidae	*Leiognathus brevirostris*	0.20	0.36	J,A	0.02	0.02	J	0.11	0.66	A	19
	Leiognathus equulus										
Lutjanidae	*Lutjanus argentimaculatus*	0.03	0.08	J							26
	Lutjanus russellii							0.16	0.75	J	25
Gerreidae	*Gerres oyena*				0.56	1.29	J	34.76	25.66	J,A	5
	Gerres oblongus										
	Gerres filamentosus	0.80	3.51	J,A	0.71	0.23	J	1.01	0.04	J	11

Table 3. (continued)

		Port Shelter									
		NW			WC			SH			
Family	Species	%N	%W	L	%N	%W	L	%N	%W	L	Rank
Sparidae	*Acanthopagrus schlegeli*	0.57	0.19	J	0.42	0.08	J	2.14	1.06	J	13
	Acanthopagrus latus	0.89	0.14	J	0.76	0.13	J	0.32	0.01	J	12
	Rhabdosargus sarba	0.01	< 0.01	J							27
Mullidae	*Upeneus tragula*							0.16	1.51	A	25
Drepaneidae	*Drepane punctata*										
Scatophagidae	*Scatophagus argus*	0.01	0.01	J							27
Cichlidae	*Oreochromis mossambicus*	0.33	1.32	J							17
	Vieja sp.										
Mugilidae	*Liza affinis*	4.36	1.72	J	3.24	13.69	J	0.21	4.32	J,A	7
	*Liza parmata**	57.63	40.32	J	1.67	4.05	J	0.64	8.03	A	1
	*Valamugil persuii**	16.92	36.24	J	8.07	58.25	J	1.55	6.01	A	3
	*Valamugil speigleri**	0.01	0.05	J	0.02	0.67	J	0.69	3.96	A	20
	*Liza vaigiensis**							0.11	0.10	J	26
	Liza macrolepis				0.10	2.70	J				24
	Mugil cephalus	2.21	1.40	J				0.53	15.87	J	10
Sphyraenidae	*Sphyraena jello*										
	Sphyraena barracuda	0.01	0.04	J				0.11	7.48	J	25
Blennidae	Blennidae										
Callionymidae	Callionymidae				0.10	0.09	J	0.05	< 0.01	J	23
Gobiidae	*Pseudogobius javanicus*	10.05	5.88	J,A	0.02	0.01	A				4
	Favonigobius reichei	0.60	0.54	J,A	4.22	1.22	J,A	7.53	0.61	J,A	8
	Goby 1				0.15	0.01	N				22
	Tridentiger trigonocephalus	0.01	0.08	A							27
	Glossogobius biocellatus	0.23	0.30	J,A				0.05	0.03	A	19
	Oxyurichthys ophthalmonema	0.11	1.04	A							21
	Goby 2	0.01	0.02	N	0.02	< 0.01	N				26
	Goby 3										
	Periophthalmus modestus										
	Goby 4										
	Goby 5										
	Goby 6										
	Istigobius sp.										
	Goby 7	0.27	0.01	N							18
	Goby 8										
	Goby 9				0.02	< 0.01	N				27
	Goby 10										
	Mugilogobius abei										
	Taenioides sp.										
	Goby 11				0.05	< 0.01	N				26
Bothidae	*Pseudorhombus arsius*							0.21	1.23	J	24
Tetraodontidae	*Chelonodon patoca*	0.01	0.05	J				0.05	0.86	A	26
	Takifugu niphobles	0.01	< 0.01	J	0.05	0.03	J	0.05	1.69	A	24
Elopiformes	Elopiformes larvae 1										
	Elopiformes larvae 2										
Total number of fish examined			6968			4075			1873		
Total biomass (g)			3243			749			2694		
Total number of species			32			25			33		
Average individual fish weight per site (g)			0.47			0.18			1.44		
Number of piscivorous fish			55			63			417		
Percent (%) of species consisting of juveniles only			66			72			48		

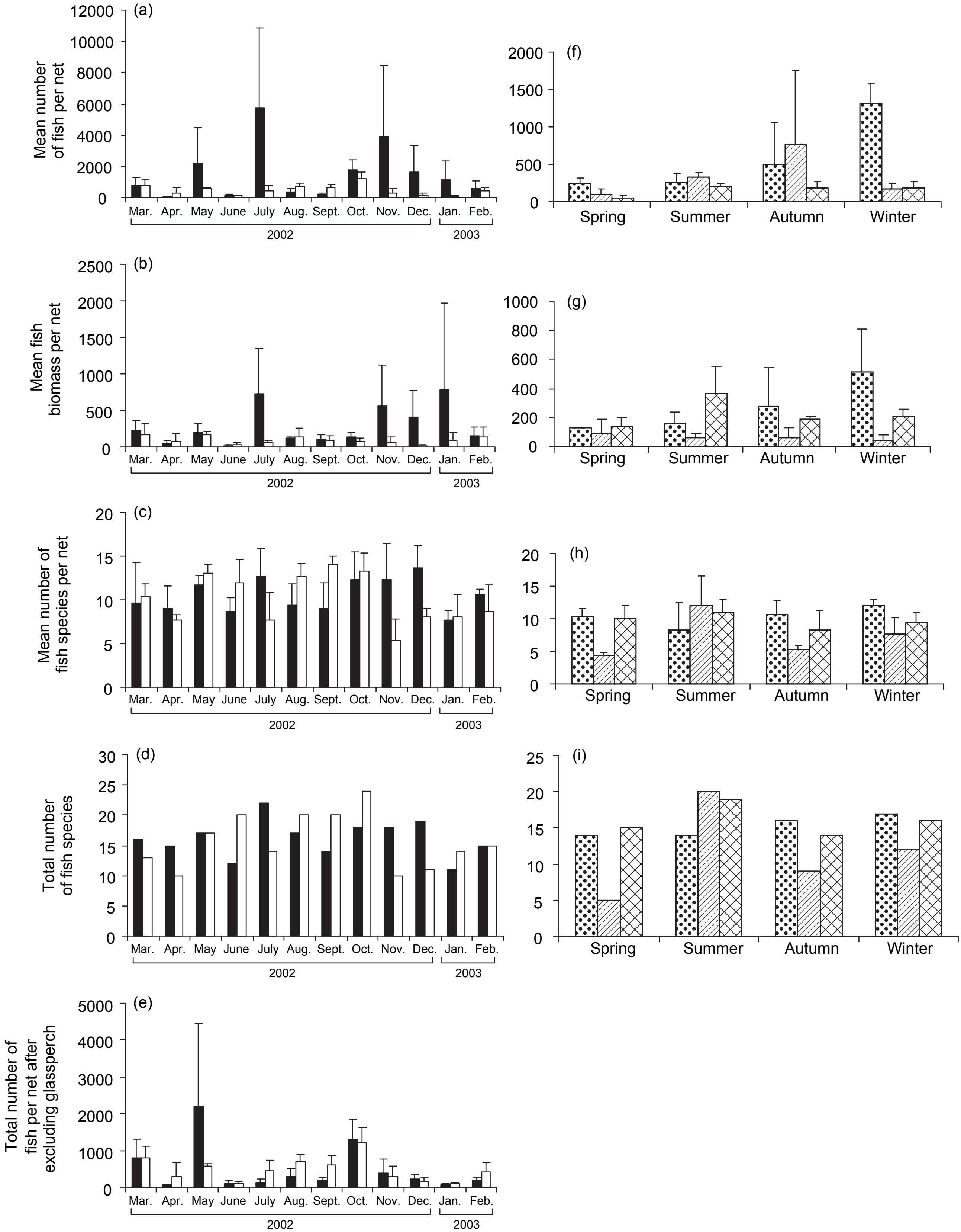

Fig. 3. Seasonal changes in the mean number of fish per net (a and f), mean fish biomass per net (b and g), mean number of fish species per net (c and h), total number of fish species (d and i), and total number of fish per net after excluding glassperch (e). ■, KL; □, SB; ⚃, NW; ▨, WC; ⊠, SH. Error bars are ± 1 S.D.

Table 4. Summary of two-factor ANOVA results for spatial and temporal variations in fish communities at 2 sites in Tolo Harbour and 3 sites in Port Shelter. Tukey-Kramer tests were performed as the posteriori tests with a significance level of $p < 0.05$

	Month/season	Site	Interaction	
Tolo Harbour				
Fish density	***	*	*	7 = 10 > 4 = 6; 3 = 5 > 4; KL > SB
Fish biomass	NS	**	NS	KL > SB
Species richness	*	NS	***	10 > 1
Ambassis gymnocephalus	***	***	***	7 > 3 = 4 = 5 = 9; 12 > 3 = 4 = 9; 1 = 10 = 11 > 4; KL > SB
Sillago sihama	***	***	*	10 > 1 = 2 = 3 = 4 = 5 = 6 = 7 = 12; 9 > 1 = 2 = 3 = 4 = 5 = 6 = 7; 11 > 1 = 2 = 3 = 4 = 5 = 7; 8 > 1 = 3 = 4 = 5 = 7; 12 > 1 = 3 = 4 = 5; 2 = 6 > 4; SB > KL
Konosirus punctatus	***	NS	***	5 > 1 = 2 = 6 = 7 = 8 = 9 = 10 = 11 = 12; 3 > 2 = 8 = 9
Liza affinis	***	*	NS	3 > 1 = 2 = 4 = 5 = 6 = 7 = 8 = 9 = 10 = 11 = 12; 5 > 1 = 7 = 8 = 9 = 10 = 11 = 12; 2 = 4 > 12; SB > KL
Gerres oyena	***	***	***	7 = 8 > 6 = 9 = 10 > 1 = 2 = 3 = 4 = 11 = 12; 5 > 1 = 2 = 3 = 11 = 12; KL > SB
Liza parmata	***	***	*	10 > 1 = 2 = 3 = 4 = 5 = 6 = 7 = 8 = 11; 12 > 1 = 2 = 3 = 4 = 5 = 6 = 7; 9 > 1 = 3 = 4 = 5 = 6 = 7; 11 > 1 = 5; KL > SB
Acanthopagrus schlegeli	***	NS	***	2 > 3 > 1 > 4 > 12 > 5 = 6 = 7 = 8 = 9 = 10 = 11
Gerres filamentosus	***	NS	***	7 > 1 = 2 = 3 = 4 = 5 = 6 = 12;8 > 1 = 2 = 3 = 4 = 5 = 6 = 7 = 10 = 11 = 12; 9 = 10 > 1 = 2 = 3 = 4 = 5 = 6 = 11 = 12
Sillago aeolus	***	*	***	5 > 1 = 2 = 3 = 4 = 6 = 7 = 8 = 9 = 10 = 11 = 12; SB > KL
Zenarchopterus striga	NS	NS	NS	
Gerres oblongus	***	***	***	5 > 6 > 1 = 2 = 3 = 4 = 7 = 8 = 9 = 10 = 11 = 12; 8 > 1 = 2 = 3 = 4 = 9 = 10 = 11 = 12; SB > KL
Valamugil persuii	NS	NS	NS	
Favonigobius reichei	NS	NS	*	
Leiognathus brevirostris	NS	*	NS	KL > SB
Goby 1	NS	***	*	KL > SB
Mugil cephalus	**	**	NS	2 > 5 = 10 = 11; SB > KL
Takifugu niphobles	***	***	***	12 > 1 = 2 = 3 = 4 = 5 = 6 = 7 = 8 = 9 = 10 = 11 = 12; 4 > 1 = 2 = 5 = 6 = 7 = 8 = 9 = 10; SB > KL
Acanthopagrus latus	***	*	*	12 > 1 = 2 = 3 = 4 = 5 = 6 = 7 = 8 = 9 = 10 = 11; KL > SB
Terapon jarbua	**	*	NS	8 = 9 > 3 = 11; SB > KL
Rhabdosargus sarba	***	**	***	2 > 1 = 3 = 4 = 5 = 6 = 7 = 8 = 9 = 10 = 11 = 12; SB > KL
Port Shelter				
Fish density	**	**	NS	Su = Au = Wn > Sp; NW > SH
Fish biomass	NS	***	NS	NW = SH > WC
Species richness	NS	*	*	NW > WC
Liza parmata	NS	***	*	NW > WC = SH
Sillago sihama	***	***	***	Su = Au = Wn > Sp; WC > NW = SH
Valamugil persuii	**	**	NS	Sp = Wn > Su; NW = WC > SH
Gerres oyena	***	***	*	Su = Au = Wn > Sp; SH > WC > NW
Terapon jarbua	***	***	*	Su = Au = Wn > Sp; SH > NW = WC
Liza affinis	***	***	***	Sp > Su = Au = Wn; NW = WC > SH
Favonigobius reichei	**	NS	*	Au = Wn > Su
Mugil cephalus	NS	NS	NS	
Gerres filamentosus	***	**	*	Su > Au > Wn = Sp; NW > WC = SH
Acanthopagrus latus	***	NS	NS	Wn > Sp = Su = Au
Acanthopagrus schlegeli	***	NS	NS	Sp > Su = Au = Wn

1 to 12 refer to Jan. to Dec., respectively; Sp, spring; Su, summer; Au, autumn; Wn, winter. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

temporal variations in fish biomass were found. Fish species richness did not differ between KL and SB, but significantly more species were found in Oct. than in Jan. Fish densities at Port Shelter exhibited significant spatial and seasonal variations. In general, densities were higher at NW than at SH and were lower in spring than in other seasons. Fish biomass and fish species richness did not vary seasonally, but tended to be lower at WC than at the other 2 sites. Overall, fish densities were higher at the 3 mangrove mudflats (KL, NW, and WC) than at the 2 non-mangrove sites (SB and SH).

Community structure

Fish assemblages were separated into several groups (Fig. 4). Group I consisted mainly of samples collected in Tolo Harbour between Jan. and May, but also included the June sample from SB and the spring sample from WC. Group II was comprised of all samples from SH. Group IVa was made up of samples obtained from SB between July and Oct. and summer samples from WC. Group IVb consisted of KL samples collected in June to Dec., and summer samples from NW. Group V contained NW samples from autumn, winter, and spring, WC samples from autumn and winter, and SB samples from Nov. and Dec.

The SIMPER analysis was used to identify the main species responsible for the similarity within each group (Table 5). *Liza affinis*, *A. schlegeli*, *S. sihama*, and *V. persuii* contributed substantially to the similarity within group I. *Gerres oyena*, *S. aeolus*, *S. sihama*, *Favonigobius reichei*, and *Terapon jarbua* contributed most to the similarity within group II. *Sillago sihama*, *G. filamentosus*, and several other species accounted for most of the similarity within group IVa. Similarity within group IVb was mainly due to *A. gymnocephalus*, *S. sihama*, *P. javanicus*, and *L. parmata*. *Sillago sihama*, *V. persuii*, *L. parmata*, and *F. reichei* contributed most to the similarity within group V. A dissimilarity analysis by SIMPER showed that in general, species that contributed most to similarities within groups also strongly contributed to differences between groups (Table 6).

Spatial and seasonal distributions of dominant species

Of the 61 species captured in Tolo Harbour,

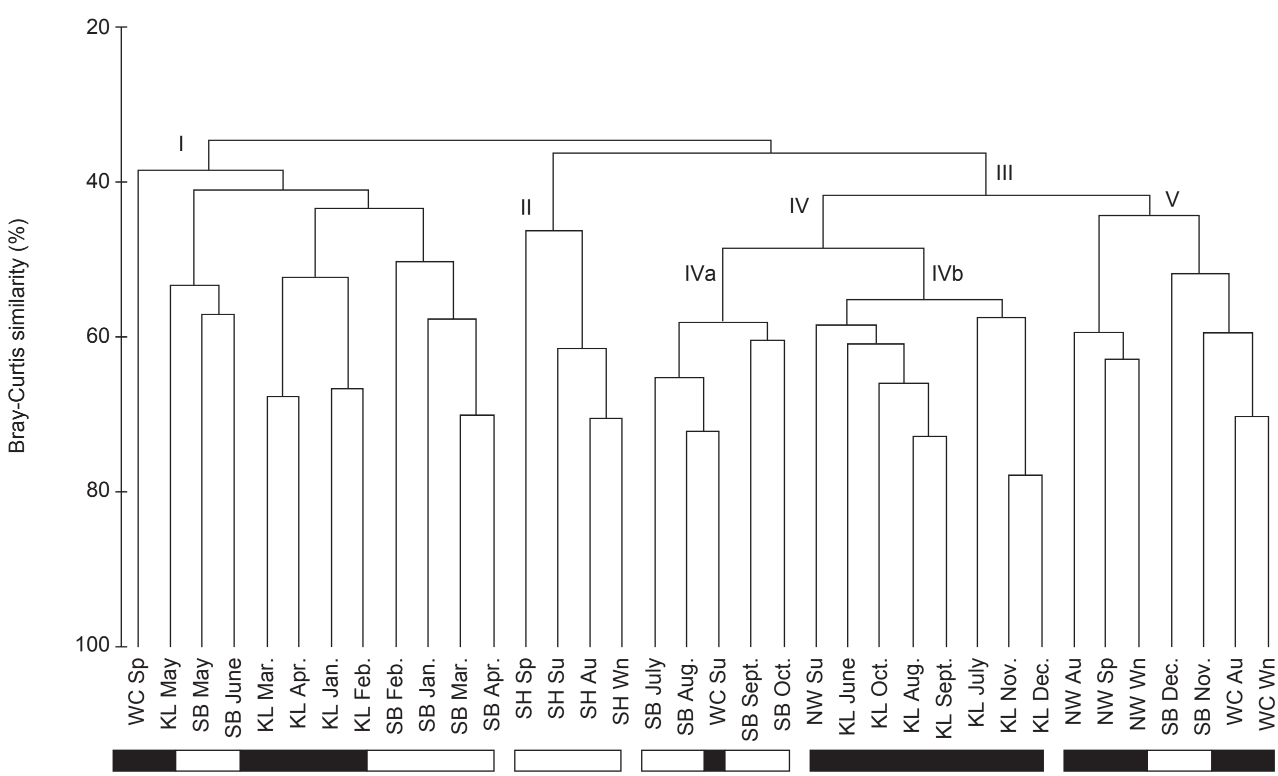

Fig. 4. Cluster dendrogram based on log-transformed fish abundance data. Black bars represent mangrove habitats and open bars represent non-mangrove habitats. Sp, spring; Su, summer; Au, autumn; Wn, winter.

36 species were found at both KL and SB, 11 species were found only at KL, and 14 species were found only at SB. Except for *P. javanicus*, which accounted for 1.84% of the fish captured at KL, species that occurred at only 1 site tended to be rare species. The 20 most abundant species that occurred at both KL and SB accounted for > 98% of the total catch. Two-factor ANOVA revealed that abundances of most of these species varied spatially and temporally (Table 4). Six species were significantly more abundant at KL than at SB, while 7 species were significantly more abundant at SB than at KL. Abundances of the remaining 7 species did not significantly differ between KL and SB.

Of the 53 species recorded at Port Shelter, 11 were exclusive to NW, 13 were exclusive to SH, and 4 were exclusive to WC. While only 11 species were found at all 3 sites, 19 species appeared in both mangrove mudflats (NW and WC) and the non-mangrove sandy beach (SH). The distribution of the 11 most abundant species that occurred in both mangrove mudflats and the non-mangrove sandy beach were analyzed by two-factor ANOVA with sites and seasons as fixed factors (Table 4). Two species were significantly

Table 5. Results of the SIMPER analysis showing the percentage contribution of species to the average similarity within groups identified using a clustering analysis. Only species contributing > 5% are shown

Similarity	I	II	IVa	IVb	V
Ambassis gymnocephalus			5.9	17.0	
Konosirus punctatus	6.5				
Sillago sihama	14.0	15.7	24.6	16.7	26.9
Sillago aeolus		15.8			
Liza affinis	20.5		6.5		
Liza parmata			8.7	10.7	14.8
Valamugil persuii	11.8				20.4
Acanthopagrus schlegeli	14.8				
Gerres oyena		22.3	9.1	8.5	
Gerres filamentosus			11.1	5.6	
Zenarchopterus striga	7.8			5.4	
Pseudogobius javanicus				14.4	
Favonigobius reichei	7.4	15.2	9.8	6.6	10.7
Terapon jarbua		12.5	5.2		6.0

Table 6. Results of the SIMPER analysis showing the percentage contribution of species to the average dissimilarity between groups identified using clustering and MDS analyses. Only species contributing > 5% are shown

Dissimilarity	I and II	I and IVa	I and IVb	I and V	II and IVa	II and IVb	II and V	IVa and IVb	IVa and V
Ambassis gymnocephalus			9.5			11.7		9.6	
Konosirus punctatus	5.8	5.4	5.3	6.5					
Sillago sihama		7.5	5.1	6.2	7.3		5.1		
Sillago aeolus	7.0				6.8	6.6	8.5		
Liza affinis	8.3	5.1	6.8	9.3					5.1
Liza parmata		5.4	6.7	8.8	5.6	5.9	8.0		6.1
Valamugil persuii				5.5			7.0		6.7
Acanthopagrus schlegeli	5.4	6.8	6.4	6.2					
Gerres oyena	8.4	6.9	5.8		5.6		10.5	5.9	8.5
Gerres filamentosus		7.4			7.6				7.5
Pseudogobius javanicus			6.5			8.7		9.8	
Terapon jarbua	6.5					5.5	5.5		

more abundant in the mangrove mudflats (NW and WC) than in the non-mangrove (SH) sandy beach, and 2 species were significantly more abundant in the non-mangrove sandy beach (SH) than in the mangrove mudflats (NW and WC).

Several species were abundant in both Tolo Harbour and Port Shelter and showed specific habitat preferences. *Pseudogobius javanicus* was found in mangrove mudflats only. *Liza parmata*, *A. gymnocephalus*, *A. latus*, and *Zenarchopterus striga* were more abundant in mangrove mudflats than in non-mangrove habitats. Small juveniles of *L. affinis*, *M. cephalus*, and *V. persuii* were most abundant on the non-mangrove mudflats. *Terapon jarbua* was most abundant at the non-mangrove sandy beach.

Most of the dominant species exhibited distinct seasonal variations in terms of abundances. *Mugil cephalus*, *A. schlegeli*, *R. sarba*, and *L. affinis* were most abundant in spring. *Konosirus punctatus* and *Gerres oblongus* were most abundant in early summer. *Sillago aeolus* reached a peak abundance in May in Tolo Harbour. In Port Shelter, however, this species was most abundant in winter. Juveniles of *T. jarbua* and *G. filamentosus* were most abundant in summer. *Ambassis gymnocephalus* and *G. oyena* were most abundant in summer in Tolo Harbour and in summer, autumn, and winter in Port Shelter. *Favonigobius reichei*, *L. parmata*, and *V. persuii* were most abundant in autumn and winter, but adult *F. reichei* appeared in both Tolo Harbour and Port Shelter year round. Peak abundances of *S. sihama* and *L. brevirostris* occurred in autumn, but juveniles of *S. sihama* could be found in both bays throughout the year. *Acanthopagrus latus* and *T. niphobles* were most abundant in winter.

Relationships between abiotic and biotic factors

In Tolo Harbour, mean and total species richness values were positively and significantly correlated with water temperature (Table 7). A significant positive correlation was also found between mean species richness and turbidity. In Port Shelter, fish abundances were positively and significantly correlated with SOM. A strong positive correlation was found between the average weight of fish and water depth (Table 8).

DISCUSSION

Sampling method

According to Beck et al. (2001), comparison of the nursery value of different habitats should be conducted using the same sampling method, and thus in this study, a beach seine was used to sample fishes in both mangrove mudflats and non-mangrove habitats. Because beach seines

Table 7. Pearson correlation coefficients between fish community characteristics and abiotic factors in Tolo Harbour and Port Shelter

	Temperature		Salinity		Turbidity		SOM	
Tolo Harbour	*r*	*n*	*r*	*n*	*r*	*n*	*r*	*n*
Mean abundance	0.133	24	0.038	24	-0.037	24	0.474	8
Total abundance	0.133	24	0.038	24	-0.037	24	0.474	8
Mean biomass	-0.267	24	0.054	24	-0.335	24	0.294	8
Total biomass	-0.267	24	0.054	24	-0.335	24	0.294	8
Mean species richness.	0.482*	24	-0.223	24	0.463*	24	0.242	8
Total species richness	0.488*	24	-0.257	24	0.343	24	0.321	8
Port Shelter	*r*	*n*	*r*	*n*	*r*	*n*	*r*	*n*
Mean abundance	0.434	12	-0.405	12	0.334	12	0.656*	12
Total abundance	0.434	12	-0.405	12	0.334	12	0.656*	12
Mean biomass	0.205	12	-0.176	12	-0.220	12	0.306	12
Total biomass	0.205	12	-0.176	12	-0.220	12	0.306	12
Mean species richness	0.329	12	-0.500	12	0.320	12	0.250	12
Total species richness	0.512	12	-0.537	12	0.371	12	0.072	12

*$p < 0.05$; r, correlation coefficient; n, number of samples.

could not be deployed in mangrove forests, fish at mangrove sites were sampled by pulling a beach seine on mudflats in front of the mangroves during low tide when receding water had forced the fish out of the mangroves. Some investigators (Beck et al. 2001, Sheridan and Hays 2003) cautioned that fish samples collected in areas adjacent to mangroves instead of inside mangrove forests do not provide reliable information for assessing the nursery value of mangroves because fish that stay on the mudflats but seldom enter the mangrove will also be included. However, other investigators argued that adjacent shallow waters can serve as temporary habitats for mangrove fish during low tide when the mangrove stands are not inundated (Laegdsgaard and Johnson 1995, Johnston and Sheaves 2007, Saintilan et al. 2007). Many studies on mangrove fish were actually based on samples taken in open habitats adjacent to mangrove forests (Little et al. 1988, Ikejima et al. 2003, Mwandya et al. 2009).

Monthly and seasonal variations

Some investigators reported higher fish abundances (Laegdsgaard and Johnson 1995, Laroche et al. 1997, Suda et al. 2002) and fish species richness (Laegdsgaard and Johnson 1995, Laroche et al. 1997, Suda et al. 2002) in shallow soft-shore habitats during the wet and/or warm seasons. Other investigators reported either no significant seasonal patterns in fish abundances and species richness or entirely different seasonal patterns for fish abundances and species richness (Little et al. 1988, Harris and Cyrus 1996, Lin and Shao 1999). Seasonal variations in the recruitment of difference species can influence the composition of fish communities in shallow coastal habitats (Little et al. 1988, Harris and Cyrus 1996, Lin and Shao 1999). Successive bouts of recruitment by different species can mask seasonal patterns in fish abundances and species richness (Little et al. 1988, Lin and Shao 1999). In Tolo Harbour, recruitment of *A. gymnocephalus* and *G. oyena* caused fish abundances to increase in July (summer), while recruitment of *S. sihama* and *L. parmata* accounted for the high fish abundances in Oct. Seasonal fluctuations in fish abundances in Port Shelter also reflected recruitment events such as those of *S. sihama* in summer and autumn, and that of mullet species in winter. Species richness in Tolo Harbour was significantly higher in Oct. than in Jan. Other than that, however, species richness in Tolo Harbour and Port Shelter did not show clear seasonal patterns. The absence of seasonal patterns in species richness suggests that species differ in their recruitment patterns and may only utilize mangroves and other shallow areas as transitional habitats.

Inter-site variations

Mangroves are widely considered to provide shelter and act as important nursery for fish (Laegdsgaard and Johnson 1995, Louis et al. 1995, Kuo et al. 1999, Nagelkerken and van der Velde 2002, Ikejima et al. 2003, Mumby et al. 2004). The most commonly used argument is that the density of juvenile fish is higher in mangroves than in other soft-shore habitats. Few studies have directly compared the nursery function between mangroves and other soft-shore habitats. Some investigators only sampled fish in mangrove habitats (Kuo et al. 1999, Ikejima et al. 2003), while others used different sampling gear to collect fish from different habitats (Thayer et al. 1987, Morton 1990). Only a few investigators used the same sampling device to compare fish assemblages between mangrove and non-mangrove habitats (Clynick and Chapman 2002, Hindell and Jenkins

Table 8. Pearson correlation coefficients between fish community characteristics and water depth and sediment particle size at 2 study sites in Tolo Harbour and 3 study sites in Port Shelter

	Water depth		Gravel (> 2 mm)		Coarse sand (0.5-2 mm)		Fine sand (63 μm-0.5 mm)		Silt-clay (< 63 μm)	
	r	*n*	*r*	*n*	*r*	*n*	*r*	*n*	*r*	*n*
Mean fish abundance	-0.362	5	-0.162	5	-0.399	5	0.420	5	0.356	5
Mean fish biomass	0.347	5	-0.348	5	-0.072	5	-0.321	5	0.283	5
Mean fish weight	0.965*	5	< 0.001	5	0.755	5	-0.703	5	-0.587	5

*$p < 0.05$. r, correlation coefficient; n, number of samples.

2004, Mumby et al. 2004, Wang et al. 2009). Most of the fish collected in this study were juveniles, and fish densities were higher in mangrove than in non-mangrove habitats in both Tolo Harbour and Port Shelter. While these results are consistent with the view that mangroves are important nursery habitats for fish, very few of the abundant species were restricted to mangroves. One goby species was restricted to mangroves, but the presence of both adults and juveniles in mangrove mudflats suggests that it is a mangrove resident rather than a temporary transient. Among the most abundant species, 6 species in Tolo Harbour and 2 species in Port Shelter were significantly more abundant in mangrove mudflats than in non-mangrove habitats. In contrast, 7 species in Tolo Harbour and 2 species in Port Shelter showed a reverse pattern. In fact, the abundance of many species did not significantly differ between mangrove and non-mangrove habitats. Numerous studies revealed that the dependence of fish on mangrove is species-specific (Nagelkerken et al. 2000, Hindell and Jenkins 2004, Chittaro et al. 2005). Results presented in this study suggest that the dependence of some species on mangrove habitats is also site-specific. For example, *L. affinis* was more abundant at mangrove sites at Port Shelter and at the non-mangrove site in Tolo Harbour. Similarly, *L. parmata* occurred in large numbers at NW, but was uncommon at WC. Obviously, different mangrove habitats have different nursery values (Hindell and Jenkins 2004, Chittaro et al. 2005).

Clustering analyses separated the fish assemblages collected from different sites at different times into 5 groups. In general, the composition of the groups (i.e. I, IVa, and V) tended to reflect seasonal variations rather than habitat differences. Therefore, the presence of mangroves is not the only factor affecting fish assemblages.

Relationships between abiotic and biotic parameters

At Port Shelter, the level of SOM was much higher at WC and NW, where fine sand and silt-clay formed the major substrata, than at SH, which was mostly covered by coarse sand. The meiobenthos, one of the major food items for juvenile fishes (Coull 1999), prefer organic-rich sediments (Coull 1999). Many benthic invertebrates also prefer muddy bottom habitats to sandy bottom habitats, where they can burrow deeper and be less vulnerable to predators (Coull 1999). Therefore, differences in food availability could partially explain why fish densities were higher at NW and WC than at SH. Fish in coastal zones were shown to associate with organic-rich areas (Whitfield et al. 1994, Laegdsgaard and Johnson 1995, Kuo et al. 1999). Mullet, the most abundant fish at Port Shelter, are iliophagous (Chong 1977, Blaber 2000) and prefer shallow, organic-rich environments (Blaber 2000). This fish group contributed to the significant positive correlation between fish abundance and SOM at Port Shelter.

Zooplankton are an important food for *A. gymnocephalus* and many juvenile fish (Martin and Blaber 1983, Tse et al. 2008), but there is no evidence to indicate that the abundance of zooplankton is higher in mangrove than in non-mangrove habitats (Robertson et al. 1988). The substrata in the mangrove and non-mangrove sites in Tolo Harbour were relatively similar, although the level of SOM was always slightly higher at KL than at SB. Therefore, food availability might not explain the higher abundances of fish at KL. An isotopic analysis conducted in Hong Kong mangroves revealed that mangrove fish obtained most of their energy from organic matter that originated from local streams, instead of mangroves (Lee 2000). A gut content analysis revealed that juvenile fish from KL and SB had comparable gut fullness levels (Tse et al. 2008). These results suggest that mangroves are not necessarily more important feeding grounds for juvenile fish than non-mangrove habitats.

Small creeks discharge large amounts of fresh water into all study sites during the rainy season. At Port Shelter, salinity was usually lower at NW and WC than at SH, and fish abundances and biomass levels were negatively correlated with salinity. Freshwater flows can enhance fish abundances in nearshore areas by increasing nutrient inputs (Whitfield et al. 1994, Grange et al. 2000). Fresh water may also provide olfactory cues which attract fish larvae in offshore areas and influence recruitment into coastal nursery habitats (Harris and Cyrus 1996, Whitfield 1999, Strydom 2003). However, salinity did not significantly differ between KL and SB, indicating that freshwater inputs were not responsible for differences in fish assemblages between these 2 sites.

Ambassids accounted for nearly 70% of the fishes captured at KL, the mangrove mudflat at Tolo Harbour, but they were either absent or rare in non-mangrove habitats in both Tolo Harbour and Port Shelter. Ambassids prefer sheltered and structurally complex habitats (Blaber 2000, Laegdsgaard and Johnson 2001, Shao and Chen 2003) which are provided by pneumatophores, prop roots, tree trunks, and fallen branches of mangroves at KL.

Water depth can influence fish distributions. Large piscivorous fish prefer to stay in deeper areas where they can feed more efficiently (Ruiz et al. 1993, Paterson and Whitfield 2000). Larger fish are less vulnerable to piscivorous fish (Ruiz et al. 1993, Laegdsgaard and Johnson 2001) and are more likely to stay in deeper areas (Ruiz et al. 1993). SH, the deepest site, contained high abundances of piscivorous fish and low abundances of small fishes. Some investigators pointed out that juveniles that retreat into shallow waters to avoid predators can feed on even-smaller fish (Baker and Sheaves 2005 2006), but stomach content analyses revealed that small fish constituted only a very small portion of the diet of juvenile fish captured at shallow study sites (Tse et al. 2008).

Water temperature plays an important role in structuring fish communities in mangroves, estuaries, and coastal areas (Whitfield 1999, Blaber 2000). Fish species richness was positively correlated with water temperature in Tolo Harbour, suggesting that more species were recruited into the study area during spring and summer. Blaber (2000) suggested that turbidity has a positive effect on fish abundances, but no correlation was found between turbidity and fish abundances in this study. This is in accordance with the view that turbidity is not always a deciding factor for fish abundances (Whitfield 1994, Laroche et al. 1997, Strydom 2003).

CONCLUSIONS

Fish densities were higher in mangrove mudflats than in non-mangrove habitats, but whether mangroves in Hong Kong are more important nursery grounds for fish than other non-mangrove habitats is inconclusive. While some species were significantly more abundant in mangrove mudflats than in non-mangrove habitats, the fish assemblages in mangrove and non-mangrove mudflats were generally quite similar. Only *A. gymnocephalus* showed a strong preference for the heterogeneous and structurally complex environment provided by mangroves. Environmental factors, including the SOM level and water depth, could influence fish communities, but there was no evidence to show that the presence of mangroves was the ultimate factor that determined the distribution of most species. In fact, the nursery value of a mangrove habitat seemed to depend on its location and the kind of habitat it was compared to. Results of this study confirm that the nursery value of mangroves is site- and species-specific. Compared to shallow mangrove and non-mangrove mudflats, sandy beaches with deeper water were less suitable for small juvenile fishes because of their low SOM levels and high piscivorous fish abundances.

Acknowledgments: This project was supported by a Direct Grant for Research provided to C.K. Wong by The Chinese University of Hong Kong. The authors thank K.C. Cheung, P. Tse, A. Lie, and H.S. Lai for assisting in the laboratory and with field sampling.

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