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RESEARCH PAPER

Temporal Variation of Fish Diversity and Assemblages and their Associations to Environmental Variables in the Mangrove of Qinzhou Harbor, Guangxi Province, China

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Abstract

The composition and temporal variation of fish assemblages were investigated in the mangrove of Qinzhou Harbor, Guangxi Province, China from October 2011 to September 2012. A total of 67 fish species belonging to 57 genera, 32 families and 12 orders were collected. The Gobiidae (23.9%) were the most species-rich families, and the dominant species were *Acentrogobius viridipunctatus* and *Bostrychus sinensis*. Species richness, total abundance, total biomass and individual species abundance or biomass for the numerically abundant fish species were significantly different seasonally, such as abundance and biomass for *A. viridipunctatus*, *B. sinensis*, *Glossogobius giuris*, *Acanthogobius hasta*, *Gerres limbatus*, *Sillago sihama*, *Lateolabrax japonicas*, *Moolgarda cunnesius* and *Leiognathus brevirostris*. The Non-metric Multidimensional Scalings (NMDS) ordination showed a clear separation of fish samples with an anticlockwise direction for different sampling months, which indicated a gradual change in fish assemblages over the months. Results of two-way ANOVA showed fish species richness, total abundance and total biomass were significantly affected by tidal type in the mangrove of Qinzhou Harbor. However, NMDS ordination showed an unclear separation of fish samples between spring tide and neap tide. One-way ANOSIM further revealed no significant effects of tidal type.

Keywords: fish assemblage,temporal variation, mangrove, Qinzhou Harbor.

Introduction

Mangroves are one of the most productive features of coastal ecosystems across tropical and subtropical regions of the world (Baban, 1997). Because of its important role in terms of aquaculture, coastal fishery, carbon fixation, nutrient assimilation, and sediment acceleration (Fan *et al.*, 2013; Nagelkerken *et al.*, 2008; Dale *et al.*, 2014), mangroves are fertile habitats for foraging, breeding, and sheltering of various kinds of animal such as fish, crustaceans, birds, reptiles, and mammals (Alongi, 2002) . In China, mangroves naturally occur along the southeast Chinese coast and traverse the provinces of Hainan, Guangdong, Guangxi, Fujian, and Taiwan, intermittently extending from 18°N to 27°N, which includes 37 mangrove tree species (Li and Lee, 1997), and approximately 260 fish species have been recorded in Chinese mangroves waters (He *et al.*, 2007). However, anthropogenic activities such as overfishing and water pollution in recent years caused fish species decreased dramatically (Fan *et al.*, 1996; He *et al.*, 2001; He, 2004). In the past, mangroves were abundant and widely distributed in South China, nevertheless they were experiencing a drastic damage by human activities in mangrove areas (He, 2004; Duan and Xu, 2004; Lan and Chen, 2007; Peng *et al.*, 2008; Wu and Liang, 2008). To preserve coastal mangrove habitats for aquatic organisms, many surveys have been conducted in mangroves areas of China (He *et al.*, 2001; He and Fan, 2002; Chen *et al.*, 2013; Nong *et al.*, 2011; Chen *et al.*, 2012).

Mangrove areas are disappearing at the rate of approximately 1% per year globally (FAO, 2007), while the rates of mangrove loss in South China was 1.67% per year during the period 1980-1990, and which have declined to a rate of 1.04% per year between 1990 and 2000 (UNEP, 2008). The majority of this loss resulted from conversion to paddy fields, shrimp ponds and the construction of coastal infrastructure, including ports, harbours and urban infrastrusture, and turist resorts (Fan *et al.*, 2013), which resulted in decrease of habitat for organisms, including fish, mollusk, crabs, shrimp, birds, etc. In China, the remaining mangrove area was about 22000 ha by 2001, where 258 fish species inhabitated (He *et al.*, 2007). For instance, about 76 fish species were in the mangrove of Yingluo Bay, Guangxi Province, and

75 fish species were in the Gaoqiao mangrove Zone, Guangdong Province, and 127 fish species were in the mangroves of Leizhou Peninsula, Guangdong Province and 115 fish species were in the mangrove of Dongzhaigang Bay, Hainan Province (He *et al.*, 2001; Han *et al.*, 2003; Wang *et al.*, 2009; Ye *et al.*, 2007).

Mangroves distribute intermittently along the whole coast line in the Guangxi Province (Li, 2004). Most studies of biodiversity in the mangroves of Guangxi Province focused on mangrove tree species, macrobenthos, fouling fauna and birds (Li, 2004; Lai and He, 1998; Qing and Lin, 2004; Xu *et al.*, 2012), while little information on fish diversity in the mangroves of Guangxi Province is well documented (He and Fan, 2002; He *et al.*, 2001). Qinzhou Harbor is the second largest habor in South China, which supported 56.22 million tons of goods transported in 2012 which increased in an average of 36% in the last five years (Chen, 2014). Continually terminal operation and navigation would impact natural fish composition (Kano *et al.*, 2013; Rosso *et al.*, 2010). Moreover, the largest aquaculture for *Ostrea rivularis* in China is located in the mangrove of Qinzhou Harbor resulted in eutrophication and water acidification (Qiu, 2014), which caused decrease in fish diversity. The mangroves in the Qinzhou Harbor distribute around 1680 hm^2 areas in the coastal zone (He *et al.*, 2013), while the fish diversity in the mangroves of Qinzhou Harbor remains unknown. The objectives in this study are: (1) to describe fish species composition and temporal variation of fish diversity and fish assemblages in the mangrove of Qinzhou Harbor, Guangxi Province, and (2) to clarify patterns of association between fish assemblages and environmental variables, especially for tidal type.

Materials and Methods

Study Area

Mangroves of Qinzhou Harbor are located in the north of Beibu Gulf in southern China (Figure 1), and a mangrove forest of about 342.5 ha belongs to one part of the Maowei Gulf Mangrove Nature Reserve, which was designated as a National Marine park of China in 2011. *Acrostichum aureum*, *Aegiceras corniculatum* and *Kandelia obovata* are the dominant mangrove trees, which distribute around the main channel and numerous intertidal creeks. In addition, three endangered mangrove trees distribute inside the mangrove forest sporadically, such as *Bruguiera gymnorhiza*, *Acanthus ilicifolius*, *Rhizophora stylosa* (Liu *et al.*, 2009). The flooded mangrove forest is subject to diurnal tidal cycles which range from -2.39 m to 3.3 m (Li *et al.*, 2001). Mangroves of Qinzhou Harbor belong to a tropical marine climate, with significantly higher temperatures in summer and autumn than in winter. The annual mean temperatures are from 21 to 23℃, annual precipitation ranges from 150 mm to 1800 mm.

Sampling Methods

Fish were collected monthly from October 2011 to September 2012 at seven sites in this study (Figure 1), which were highly influenced by freshwater input from creeks and drainages. Seines (mesh 5~10 mm; high 4 m; length about 400 m) and traps (mesh 8.5 mm; 35 cm^2×10 m for one unit) were used for sampling in this study. Two seines and two traps were placed at the edge of the mangrove and three traps in

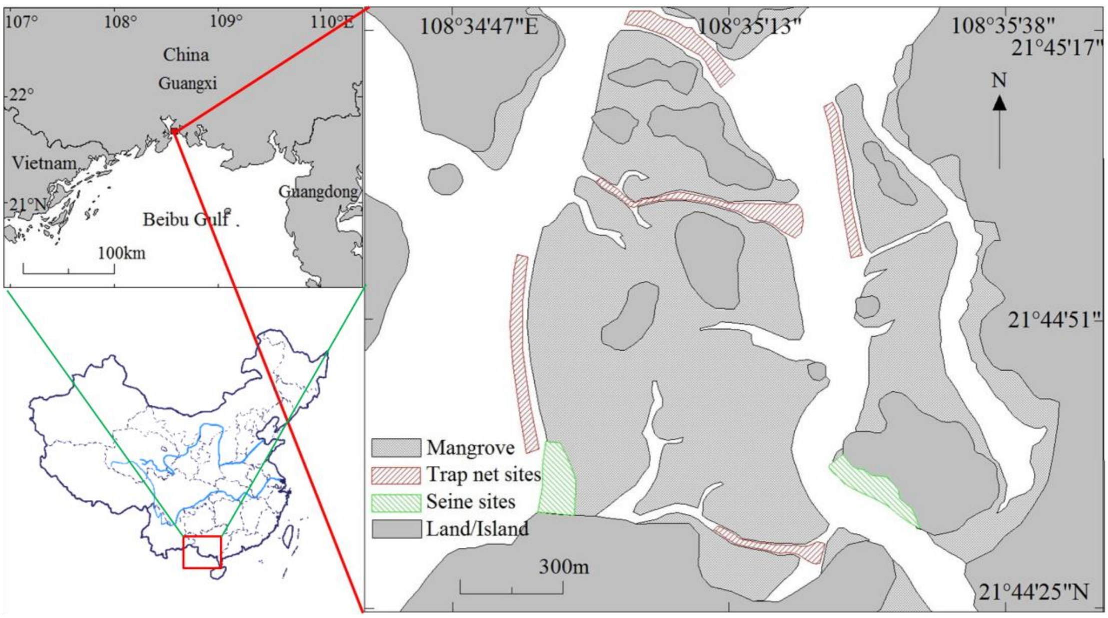

Figure 1. Location and sampling sites in the Mangrove of Qinzhou Harbor, Guangxi Province, South China.

creeks (Figure 1). Traps, conbined with 34 units each site, were sampled daily in a complete spring-neap tide cycle and a seine conducted once in spring tide each month. All traps were placed before flood tide and seines were placed at flood tide, and all fish in seine and traps were collected at ebb tide. All fish were removed from the nets and preserved in 10% formalin solution immediately after anesthesia by eugenol solution (Huang *et al.*, 2013). All specimens were sorted, identified according to reference books for fish indentification (Cheng and Zheng, 1987; Zhu *et al.*, 1962), counted and weighted, and then were subsequently stored in 5% formalin solution. Scientific nomenclature followed Nelson (2006) and Catalog of Fishes of California Academy of Science (http://www.calacademy.org/scientists/projects/catalog-of-fishes).

During sampling, environmental variables such as temperature and salinity were measured with conductivity-measuring instrument (AZ8371, Hengxin Taiwan) and pH was measured with a pH meter (Sartorius PB-10, China) under surface waters for 0.5 m at the mouth of the creek or near the creek. Tidal level data was obtained from State Oceanic Administration People's Republic of China (http://ocean.cnss.com.cn/).

Data Analyses

The relative abundance of each species at each sampling site was estimated. The Margalef index (D_{ma}), Simpson index (λ), Shannon-Wiener index (H') and Pielou index (J_e) were used to calculate diversity of the fish. $D_{ma} = (S-1)/\ln N$; $\lambda = \sum P_i^2$; $H' = -\sum P_i \log P_i$; $J_e = H'/\log S$, where S represent species richness, N represents total abundance; $P_i = N_i/N$, where N_i represents abundance of Species i (Magurran, 2004; Peet, 1974). The index of relative importance (IRI) was used to characterize the relative importance of species. IRI was calculated based on abundance, biomass and frequency of occurrence as follows: IRI= $(\%N + \%W) \times \%F$, where $\%N$, $\%W$ and $\%F$ are percentage contribution of abundance, contribution of biomass, and frequency of occurrence (Pinkas *et al.*, 1971). To assess how the four surveyed habitat variables [tide range, water temperature, salinity, pH] and fish biodiversity indices were interrelated, a correlation matrix using the Spearman rank correlation coefficient (r_s) was applied (Li *et al.*, 2012). All data was transformed by log (x+1), and the analyses were performed with STATISTICA 7.0 (StatSoft Inc., Tulsa OK 74104, USA).

A randomized design with two factors was used. The first factor was tidal type (spring tide and neap tide), and the second factor was season (spring, summer, autumn and winter). In order to minimize the issue of pseudo-replications, all of the fish captured on a given ebb tide at the three locations with the creek and four locations at the edge of the mangrove were pooled into a single composite sample, which was expressed as the catch per unit effort (CPUE). So, a total of 157 observations were used in the data analysis. The effect of tidal type and season on fish assemblages were analyzed by two-way analysis of variance (ANOVA). Multiple comparisons were performed using Least Square Difference (LSD) test. Differences were regarded as significant when $P < 0.05$. To meet assumptions of ANOVA, the numeric data were log (x + 1) transformed prior to statistical analyses when necessary (Li *et al.*, 2012). All analyses were performed with STATISTICA 7.0 (StatSoft Inc., Tulsa OK 74104, USA).

A dataset including all the species collected in mangrove was constructed. Similarities among fish communities collected in different months were estimated using a Bray-Curtis similarity coefficient, which was conducted basing on the presence (1) or absence (0) of each species in each sampling. The agglomerative method, using an un-weighted pairgroup average, was used to do a clustering analysis of the matrix (Li *et al.*, 2012; Clarke *et al.*, 2006), and an ordination plot of nonmetric multidimensional scaling (NMDS) was constructed to separate the fish fauna in time and in different tidal type. One way analysis of similarities (ANOSIM) was used to determine whether the fish assemblage separted by NMDS ordination differed significantly. All multivariate analyses were performed with the Plymouth Routines in Multivariate Ecological Research (PRIMER v5.0) software. Initially, a global R statistic is calculated to determine whether significant differences exist between all groups (analogous to the global F test in ANOVA). If differences are significant at a global level, then pairwise comparisons between sample groups are conducted to test for differences between pairs. In global test, the null hypothesis was rejected at a significance level of $P<0.05$ (Smith, 2003). All multivariate analyses were performed with the PRIMER 5.0 computer package. No species was removed from the analysis with PRIMER because all species, including uncommon or rare species are responding to environmental conditions and are thus important in revealing environmental changes (Cao *et al.*, 1998).

Results

Habitat Environment

Temperature and salinity differed among months. Water temperature ranged from 11 to 31.9℃. The highest value occurred in August, and the lowest in Febuary. The salinity ranged 8.1 to 26.5, which was highest in March and lowest in June, and the pH ranged from 6.6 to 8.9, which did not differ significantly in months (Table 1). The tidal range ranged from 63 to 457 cm, which occurred in December and November, respectively (Table 1).

Table 1. Monthly variation of environmental variables in the mangrove of Qinzhou Harbor

Month	Tidal range (cm)		Temperature (°C)		Salinity (mg/L)		pH	
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
Jan.	91-394	290±95	12.3-16.2	14.3±1.1	20.9-25.2	23.3±1.0	7.7-8.2	8.0±0.1
Feb.	113-353	259±72	11.0-18.7	14.3±3.0	23.9-25.9	24.8±0.5	7.5-8.2	8.0±0.2
Mar.	149-340	263±62	15.8-23.8	20.9±2.5	24.2-26.5	25.4±0.7	7.8-8.4	8.2±0.2
Apr.	136-341	281±71	26.1-29.3	28.2±1.0	23.9-25.1	24.9±0.4	6.6-8.6	8.1±0.5
May	89-446	292±116	27.5-29.0	28.3±0.4	22.8-25.2	24.3±0.8	7.5-8.9	8.2±0.4
Jun.	82-374	293±86	28.4-31.2	30.2±0.8	8.1-15.8	11.1±2.1	7.2-8.7	8.1±0.4
Jul.	96-370	275±87	30.2-31.5	31.1±0.4	15.4-20.3	17.6±1.3	7.0-8.8	8.0±0.3
Aug.	133-354	272±77	28.6-31.9	30.5±0.9	11.2-18.9	14.5±2.6	7.2-8.5	8.0±0.3
Sep.	115-378	282±80	26.9-29.6	28.4±1.2	19.3-23.1	21.3±1.1	7.8-8.3	8.0±0.1
Oct.	123-365	297±70	23.8-25.2	24.5±0.4	12.3-14.8	13.9±0.8	6.8-7.9	7.5±0.4
Nov.	94-457	303±124	25.2-27.0	25.9±0.5	14.9-18.6	16.5±1.1	7.1-8.0	7.7±0.3
Dec.	63-405	310±101	16.2-19.8	16.9±1.0	18.6-20.9	19.5±0.8	7.0-8.0	7.7±0.3

Tidal range varied significantly between days within one tidal cycle while did not differ significantly in months.

Fish Composition

A total of 67 fish species (35,673 fish individuals weighing 498.6 kg) were caught in this study, which belonged to 12 orders, 32 families and 57 genera (Table 2). Among the 12 orders, 32 families and 57 genera of fishes, the most species-rich order was Perciformes (15 families, 32 genera and 40 species), followed by Clupeiformes (2 families, 5 genera and 5 species), Mugiliformes (1 family, 3 genera and 4 species), Pleuronectiformes (2 families, 2 genera and 3 species), Scorpaeniformes (3 families, 3 genera and 3 species), Tetraodontiformes (1 family, 3 genera and 3 species). The most abundant species order in abundance was Perciformes, followed by Mugiliformes, Clupeiformes, Tetraodontiformes, and Scorpaeniformes, while the most abundant species order in biomass was Perciformes, followed by Anguilliformes, Mugiliformes, Scorpaeniformes and Tetraodontiformes (Table 3). Among all species, there were one introduced species (*Sciaenops ocellatus*) and two freshwater species (*Carassius autatus* and *Hemiculter leucisculus*) in this study.

The family Gobiidae, Mugilidae, Clupeidae, Carangidae, Eleotridae, Sciaenidae, Sparidae and Tetraodontidae were the most species-rich families, which comprised most of the fish compostion in the Mangrove of Qinzhou Harbor, accounting for 23.9%, 6.0%, 4.5%, 4.5%,4.5%, 4.5%, 4.5% and 4.5% of the total fish species , respectively (Figure 2). Fifteen dominant fish species were identified based on the IRI (IRI >100), accounting for 86.1% of the total fish abundance and 86.8% of the total biomass (Table 2). Spotted green goby *Acentrogobius viridipunctatus* and Four-eyed sleeper *Bostrychus sinensis* were the most important species in number and mass (Table 2). The most fish species in abundance were *A. viridipunctatus* (36.5%), *B. sinensis* (9.6%), *Acanthogobius hasta* (5.6%), *Glossogobius giuris* (4.9%), *Gerres limbatus* (4.2%), *Sillago sihama* (4.2%), *Lateolabrax japonicus* (4.0%), *Ambassis gymnocephala* (3.5%), *Moolgarda cunnesius* (3.3%) and *Acanthopagrus latus* (3.1%), whereas the most fish species in biomass were *A. viridipunctatus* (29.8%), *B. sinensis* (26.6%), *Pisodonophis boro* (4.0%), *L. japonicus* (4.0%), *G. giuris* (3.9%), *A. hasta* (3.7%), *A. latus* (3.5%), *S. sihama* (2.3%), *Platycephalus indicus* (2.1%), *Gastrophysus niphobles* (2.1%) and *Moolgarda cunnesius* (2.0%) (Figure 3a,3b).

Rice-paddy eel *P. boro* showed the largest mean standard length (L) (60.9 cm) while the lowest one (3.8 cm) was red seabream *Pagrus major*. And the rice-paddy eel showed the largest mean biomass (175.6 g) and the lowest one (1.1 g) was Chinese anchovy *Stolephorus chinensis*.

Temporal Variation of Fish Assemblages

The highest fish species richness in a month (44 fish species) occurred in August and October, while the lowest one (26 fish species) occurred in January and Febuary. However, the highest fish species richness per day (19±2 (M±SD) fish species) occurred in Spetember while the lowest (9±1 fish species) was also in Febuary (Table 4). The largest fish abundance (274±119 fish individual) and fish biomass (3.89±1.0 kg) per day occurred in September and in July, and the lowest fish abundance (24±10 fish individual) and biomass (0.27±0.07 kg) per day was in Febuary and in January, respectively (Table 4). In addition, the fish species diversity indices differed monthly in the mangroves of Qinzhou Harbor. For example, the highest Margalef index (D_{ma}) (3.31±0.22) observed in June and the lowest one (2.44±0.24) was in Febuary. The highest Shannon-Wiener index (H') (3.19±0.32), Pielou index (J_e) (0.95±0.02) and the lowest Simpson index (λ) (0.08±0.01) occurred in January, while the lowest Shannon-Wiener index (H') (2.14±0.1), Pielou index (J_e) (0.51±0.09) and the highest Simpson index (λ) (0.43±0.01) were all in August (Table 4).

Table 2. List of Species captured in the Mangroves of Qinzhou Harbor, Guangxi Province, showing total number of individuals (*N*), total biomass (*W*), index of relative importance (IRI), mean standard length (*L*) with range size in parentheses, mean biomass with range size in parentheses, ecological habit (P: pelagic fish; D: demersal fish; A: amphibious fish), season encountered (1:Spring, 2: Summer, 3: Fall, 4: Winter)

Order/Family	Fish species	*N*	*W* (g)	IRI	*L*(mm)	Biomass (g)	Ecolgical Habitat	Seasons
Anguilliformes								
Muraenesocidae	*Muraenesox cinereus* (Forsskål, 1775)	43	2443.1	9.37	380.1 (294.9-473.3)	56.8 (27.9-112.8)	D	1, 2, 3, 4
Ophichthidae	*Pisodonophis boro* (Hamilton, 1822)	144	20021.1	173.01	608.7 (335.8-855.9)	175.6 (25.2-276.0)	D	1, 2, 3, 4
Atheriniformes								
Atherinidae	*Hypoatherina valenciennei* (Bleeker, 1854)	2	3.0	0.00	51.8 (50.4-53.2)	1.5 (1.4-1.6)	P	3
Beloniformes								
Belonidae	*Strongylura strongylura* (van Hasselt, 1823)	8	149.6	0.22	211.0 (166.1-255.8)	18.7(12.1-55.0)	P	2
Clupeiformes								
Clupeidae	*Clupanodon thrissa* (Linnaeus, 1758)	14	100.5	0.13	70.1 (34.5-91.7)	7.2 (0.7-12.7)	P	2, 3
	Herklotsichthys quadrimaculatus (Rüppell, 1837)	17	317.3	0.47	87.1 (50.1-106.4)	18.7 (12.3-23.8)	P	1, 2, 3
	Konosirus punctatus (Temmick and Schlegel, 1846)	128	3085.0	15.51	125.0 (44.9-186.25)	24.1 (1.2-96.0)	P	1, 2, 3
Engraulidae	*Stolephorus chinensis* (Günther, 1880)	406	388.4	9.00	41.4 (14.7-74.0)	1.0 (0.2-3.9)	P	2, 3
	Thryssa hamiltonii Gray, 1835	269	1449.5	23.76	71.5 (47.0-109.4)	5.4 (1.5-15.5)	P	1, 2, 3, 4
Cypriniformes								
Cyprinidae	*Carassius auratus* (Linnaeus, 1758)	1	27.6	0.00	94.9	27.6	P	2
	Hemiculter leucisculus (Basilewsky, 1855)	1	5.6	0.00	67.3	6.0	P	2
Mugiliformes								
Mugilidae	*Liza carinata* (Valenciennes, 1836)	128	4214.5	22.93	120.1 (101.9-169.0)	32.9 (18.6-68.8)	D	1, 2, 3, 4
	Moolgarda cunnesius (Valenciennes, 1836)	1192	10084.6	277.99	40.2 (14.1-157.8)	8.5 (0.1-58.2)	P	1, 2, 3, 4
	Moolgarda seheli (Forsskål, 1775)	38	427.8	0.10	86.9 (62.2-137.2)	11.3 (4.5-30.9)	P	3
	Mugil cephalus Linnaeus, 1758	311	5201.0	25.32	97.7 (33.7-181.7)	16.7 (0.7-90.2)	D	1, 2, 3, 4
Pleuronectiformes								
Cynoglossidae	*Cynoglossus arel* (Bloch and Schneider, 1801)	11	117.3	0.14	124.2 (117.3-132.7)	10.7 (7.0-11.9)	D	1, 4
	Cynoglossus puncticeps (Richardson, 1846)	3	22.6	0.02	91.5 (91.0-95.5)	7.5 (7.2-7.5)	D	4
Soleidae	*Brachirus orientalis* (Bloch and Schneider, 1801)	29	220.7	1.20	72.2 (60.3-83.5)	7.6 (6.4-9.1)	D	1, 2, 3, 4
Perciformes								
Ambassidae	*Ambassis gymnocephala* (Lacepède, 1802)	1262	1640.3	132.88	39.1 (14.5-59.1)	1.3 (0.1-5.1)	D	1, 2, 3, 4
Blenniidae	*Istiblennius dussumieri* (Valenciennes, 1836)	4	24.6	0.03	42.1 (36.1-82.3)	6.2 (4.4-8.2)	D	1, 2
Carangidae	*Alepes djedaba* (Forsskål, 1775)	25	320.7	0.07	83.2 (42.6-121.0)	12.8 (1.5-35.3)	P	2
	Selaroides leptolepis (Cuvier, 1833)	7	117.8	0.09	116.2 (83.2-128.0)	16.8 (12.8-41.5)	P	4
	Trachinotus ovatus (Linnaeus ,1758)	41	762.7	0.43	76.1 (52.9-125.3)	18.7 (5.9-61.2)	P	2
Eleotridae	*Bostrychus sinensis* Lacepède, 1801	3414	132506.2	2256.2	97.2 (68.3-144.2)	38.8 (5.0-45.7)	D	1, 2, 3, 4
	Butis koilomatodon (Bleeker, 1849)	72	315.7	3.65	58.6 (38.5-75.6)	4.4 (1.5-10.7)	D	1, 2, 3, 4
	Butis butis (Hamilton, 1822)	38	168.8	1.34	47.1 (28.4-95.4)	4.4 (0.6-19.0)	D	1, 2, 3, 4
Gerreidae	*Gerres decacanthus* (Bleeker, 1864)	108	418.5	1.23	58.8 (37.4-69.3)	3.9 (1.3-10.0)	D	2, 3

	Gerres limbatus Cuvier, 1830	1496	7022.8	417.67	53.7 (17.0-85.7)	4.7 (0.1-15.4)	D	1, 2, 3, 4
Gobiidae	*Acanthogobius hasta* (Temminck and Schlegel, 1845)	2000	18190.8	636.25	89.3 (57.1-151.7)	9.1 (2.1-44.1)	D	1, 2, 3, 4
	Acentrogobius caninus (Valenciennes, 1837)	197	1268.5	21.75	73.2 (52.6-89.4)	6.4 (2.4-13.1)	D	1, 2, 3, 4
	Acentrogobius viridipunctatus (Valenciennes, 1837)	13033	148340.0	4101.5	80.8 (52.5-116.2)	11.4 (2.6-32.4)	D	1, 2, 3, 4
	Aulopareia atripinnatus (Smith, 1931)	328	3155.4	66.49	74.6 (34.0-110.4)	9.6 (0.7-29.5)	D	1, 2, 3, 4
	Boleophthalmus pectinirostris (Linnaeus, 1758)	115	1023.0	11.72	101.7 (55.2-202.8)	8.9 (2.8-25.7)	A	1, 2, 3, 4
	Cryptocentrus yatsui Tomiyama, 1936	10	28.5	0.11	89.8 (58.0-197.5)	2.9 (3.2-11.0)	D	1, 3, 4
	Glossogobius giuris (Hamilton, 1822)	1751	19413.2	637.72	83.4 (44.1-120.0)	11.1 (1.2-38.0)	D	1, 2, 3, 4
	Glossogobius olivaceus (Temmick & Schlegel 1845)	133	1285.9	2.33	81.8 (47.8-125.5)	9.7 (2.6-41.3)	D	2, 3
	Myersina filifer (Valenciennes, 1837)	4	29.5	0.04	101.9 (97.9-104.4)	7.3 (8.5-13.9)	D	1
	Oxyurichthys microlepis (Bleeker, 1849)	707	2942.1	123.75	65.9 (31.6-80.7)	4.2 (0.5-7.5)	D	1, 2, 3, 4
	Periophthalmus modestus Cantor, 1842	8	43.3	0.08	87.4(16.6-178.8)	5.4 (0.5-35.1)	A	1, 2, 3
	Psammogobius biocellatus (Valenciennes, 1837)	566	5562.2	35.73	79.5 (14.7-117.9)	9.8 (0.5-40.0)	D	1, 2, 3
	Tridentiger barbatus (Günther, 1861)	299	3270.0	41.88	69.5 (47.2-104.3)	10.9 (2.3-25.6)	D	1, 4
	Tridentiger obscurus (Temmick and Schlegel, 1845)	36	264.3	1.14	66.7 (56.7-81.8)	7.3 (3.2-12.3)	D	1, 4
	Tridentiger trigonocephalus (Gill, 1859)	169	1518.6	22.64	64.8 (40.8-89.2)	9.0 (3.4-16.2)	D	1, 3, 4
	Trypauchen vagina (Bloch and Schneider, 1801)	8	53.4	0.14	106.0 (99.7-117.9)	6.7 (4.6-8.9)	D	1, 3
Lateolabracidae	*Lateolabrax japonicus* (Cuvier, 1828)	1432	19785.8	477.05	66.0 (16.6-274.9)	13.8 (0.5-340.4)	D	1, 2, 3, 4
Leiognathidae	*Leiognathus brevirostris* (Valenciennes, 1835)	977	2913.2	188.00	48.0 (20.3-79.8)	3.0 (0.2-13.3)	D	1, 2, 3, 4
Scatophagidae	*Scatophagus argus* (Linnaeus, 1766)	25	1263.8	0.68	62.0 (46.7-96.1)	50.6 (41.2-87.3)	D	3
Sciaenidae	*Dendrophysa russelii* (Cuvier, 1829)	15	280.8	0.57	88.1 (63.7-113.4)	18.7 (5.2-32.3)	D	2, 3, 4
	Nibea albiflora (Richardson, 1846)	11	330.0	0.41	49.8 (41.6-58.0)	30.0 (22.1-35.2)	D	1, 2, 3, 4
	Sciaenops ocellatus (Linnaeus, 1766)	76	5026.8	14.86	145.0 (73.7-185.0)	66.2 (11.8-110.3)	D	1, 2, 3, 4
Siganidae	*Siganus canaliculatus* (Park, 1797)	96	1054.8	3.30	78.0 (65.5-108.8)	11.0 (6.1-30.8)	P	2, 3, 4
	Siganus fuscescens (Houttuyn, 1782)	37	425.6	1.10	85.4 (70.8-130.2)	11.5 (6.9-56.0)	P	2, 3, 4
Sillaginidae	*Sillago sihama* (Forsskål, 1775)	1479	11404.7	326.59	96.2 (36.4-121.4)	7.7 (0.5-18.5)	D	1, 2, 3, 4
Sparidae	*Acanthopagrus berda* (Forsskål, 1775)	110	2115.0	22.86	83.2 (59.3-118.5)	19.2 (5.5-44.5)	D	1, 2, 3, 4
	Acanthopagrus latus (Houttuyn, 1782)	1098	17657.6	332.59	68.9 (20.9-145.2)	16.1 (0.8-86.6)	D	1, 2, 3, 4
	Pagrus major (Temminck and Schlegel, 1843)	6	22.6	0.03	37.9 (26.8-60.9)	3.8 (2.1-5.9)	D	1
Stromateidae	*Pampus chinensis* (Euphrasen, 1788)	1	41.3	0.01	89.2	41.3	D	2
Terapontidae	*Terapon jarbua* (Forsskål 1775)	43	344.9	0.40	76.4 (53.9-96.1)	8.0 (2.9-14.8)	D	2, 3
Scorpaeniformes								
Platycephalidea	*Platycephalus indicus* (Linnaeus, 1758)	217	10493.6	113.37	160.4 (32.9-210.6)	48.4 (1.1-82.9)	D	1, 2, 3, 4
Sebastidae	*Sebastiscus marmoratus* (Cuvier, 1829)	397	2651.0	74.79	58.5 (27.7-94.2)	6.7 (1.0-24.0)	D	1, 2, 3, 4
Synanceiidae	*Inimicus japonicus* (Cuvier, 1829)	108	2388.7	21.50	77.2 (49.4-159.4)	22.1 (4.1-48.1)	D	1, 2, 3, 4
Siluriformes								
Ariidae	*Netuma thalassina* (Rüppell, 1837)	27	654.4	1.53	110.0 (82.4-131.8)	24.2 (16.1-29.8)	D	1, 4
Plotosidae	*Plotosus lineatus* (Thunberg, 1787)	204	7530.9	19.83	161.8 (116.7-194.4)	36.9 (15.2-60.8)	D	3, 4
Syngathiformes								

Syngnathidae	*Hippichthys cyanospilos* (Bleeker, 1854)	12	37.4	0.22	142.2 (129.2-158.0)	3.1 (2.7-3.2)	D	3
Tetraodontiformes								
Tetraodontidae	*Gastrophysus niphobles* (Jordan and Snyder, 1901)	539	10319.4	189.38	78.6 (29.4-108.8)	19.1 (1.0-48.4)	D	1, 2, 3, 4
	Lagocephalus lunaris (Bloch and Schneider, 1801)	85	1250.8	1.03	63.6 (60.4-66.2)	14.7 (14.5-18.5)	D	2, 3
	Takifugu niphobles (Jordan and Snyder, 1901)	132	2651.6	28.62	76.2 (57.4-96.3)	20.1 (7.9-31.1)	D	1, 2, 3, 4

Table 3. Orders of fish composition in the Mangrove of Qinzhou Harbor

	Family	Genus	Species	Abundance	Biomass (g)
Perciformes	15	32	40	31237	412353.7
Clupeiformes	2	5	5	834	5304.6
Mugiliformes	1	3	4	1669	19927.9
Pleuronectiformes	2	2	3	43	360.6
Scorpaeniformes	3	3	3	722	15533.3
Tetraodontiformes	1	3	3	756	14221.7
Anguilliformes	2	2	2	157	22464.2
Cypriniformes	1	2	2	2	33.6
Siluriformes	2	2	2	231	8185.3
Atheriniformes	1	1	1	2	3.0
Beloniformes	1	1	1	8	149.6
Syngnathiformes	1	1	1	12	37.4
Total	32	57	67	35673	498574.8

Table 4. Monthly variation of fish richness, abundance, biomass and fish diversity indices in the mangrove of Qinzhou Harbor

	Species richness	Fish abundance	Biomass (kg)	D_{ma}	λ	H'	J_e
Jan.	10.57±2.59	23.86±10.11	0.31±0.14	3.08±0.48	0.08±0.01	3.19±0.32	0.95±0.02
Feb.	8.86±1.10	25.71±7.19	0.27±0.07	2.44±0.24	0.11±0.02	2.94±0.15	0.94±0.02
Mar.	11.64±1.60	65.29±23.28	2.02±0.82	2.58±0.28	0.24±0.10	2.68±0.37	0.76±0.11
Apr.	15.42±1.31	171.58±38.24	3.45±0.80	2.79±0.27	0.22±0.05	2.74±0.31	0.70±0.07
May	15.08±1.75	156.15±20.51	3.78±0.40	2.79±0.30	0.24±0.03	2.79±0.18	0.71±0.03
Jun.	17.67±1.50	155.92±33.48	3.18±0.41	3.31±0.22	0.19±0.04	3.03±0.21	0.73±0.05
Jul.	15.86±1.35	257.50±66.54	3.89±1.00	2.70±0.23	0.33±0.11	2.46±0.42	0.62±0.10
Aug.	16.80±2.15	270.90±96.59	3.71±1.49	2.82±0.23	0.43±0.10	2.04±0.33	0.51±0.09
Sep.	19.00±1.91	273.50±118.57	3.79±1.51	3.26±0.20	0.37±0.12	2.35±0.44	0.56±0.11
Oct.	18.14±1.96	233.29±56.71	2.97±0.95	3.17±0.36	0.24±0.08	2.81±0.30	0.68±0.07
Nov.	16.29±1.07	222.93±90.68	2.35±1.04	2.88±0.29	0.35±0.20	2.40±0.75	0.60±0.19
Dec.	12.93±1.64	43.14±13.73	0.64±0.24	3.20±0.34	0.14±0.06	3.13±0.23	0.85±0.07

D_{ma}: Margalef index; λ: Simpson index; H': Shannon-Wiener index; J_e: Pielou index

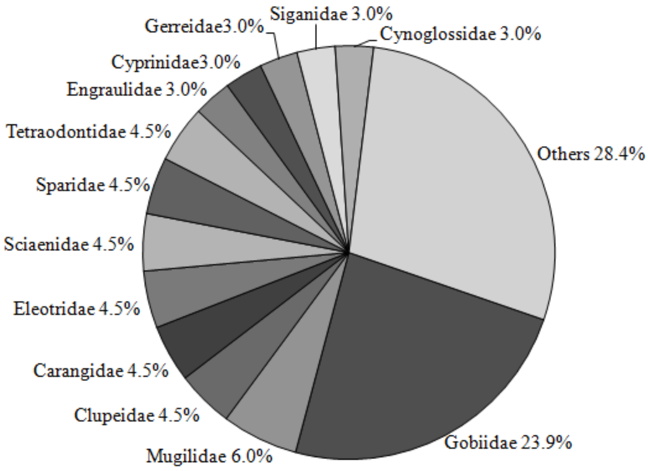

Figure 2. Percentage of fish species in the most species-rich families to the total species in the Mangrove of Qinzhou Harbor, Guangxi Province, South China.

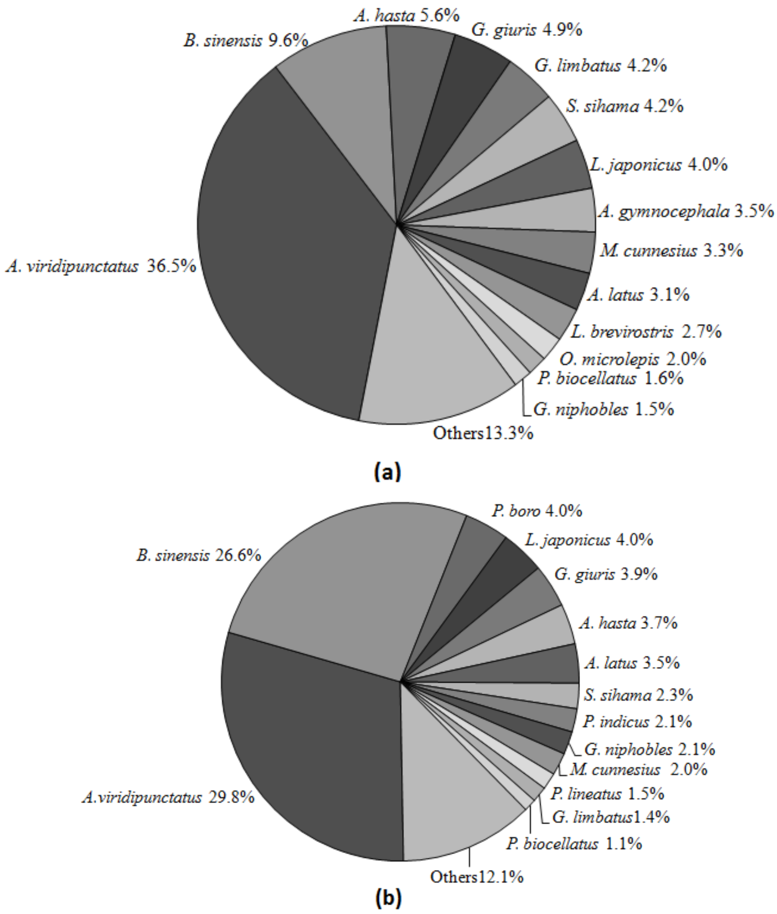

Figure 3. Percent of dominant species in abundance and biomass in the Mangrove of Qinzhou Harbor (a: dominant species in abundance; b: dominant species in biomass).

Species richness, total abundance, total biomass and individual species abundance or biomass for the numerically abundant fish species were significantly different seasonally (Table 5). For instance, time of year significantly affected fish species both in abundance and in biomass such as *A. viridipunctatus*, *B. sinensis*, *G. giuris*, *A. hasta*, *G. limbatus*, *S. sihama*, *L. japonicas*, *M. cunnesius* and *L. brevirostris*. And the *P. boro* and *P. indicus* differed significantly in biomass and in abundance in month, respectively. The Non-metric multidimensional scaling ordination showed a clear separation of fish samples with an anticlockwise direction for different sampling months (Figure 4), which indicated a gradual change in fish assemblages over the months. One-way ANOSIM further revealed a highly

Table 5. Summary of two-way ANOVA for testing the effects of season and tidal type on the species richness, total abundance and total biomass, and individual species abundance or biomass for the most 15 most numerically abundant fish species. Shown are *F*-values with significance levels in parentheses (significant differences P <0.05 are indicated in bold)

Variables	error df	Seasons(3df)	Tide type (1df)	Seasons×Tide type(3df)
Species richness	94	68.75 (<0.01)	50.46 (<0.01)	2.38 (0.08)
Total abundance	94	189.69 (<0.01)	80.00 (<0.01)	0.52 (0.67)
Total biomass	94	268.01 (<0.01)	127.25 (<0.01)	1.93 (0.13)
Individual species abundance				
Acentrogobius viridipunctatus	94	60.03 (<0.01)	52.03 (<0.01)	5.33 (<0.01)
Bostrychus sinensis	94	53.46 (<0.01)	25.85(<0.01)	1.20 (0.32)
Glossogobius giuris	94	29.47 (<0.01)	4.27(0.04)	0.29 (0.83)
Acanthogobius hasta	94	17.41 (<0.01)	2.35 (0.13)	0.39 (0.68)
Gerres limbatus	94	11.59 (<0.01)	2.45 (0.12)	0.76 (0.52)
Sillago sihama	94	42.96 (<0.01)	0.28 (0.60)	1.93 (0.14)
Lateolabrax japonicus	94	9.49 (<0.01)	0.74 (0.39)	0.30 (0.83)
Gastrophysus niphobles	94	2.19 (0.10)	0.78 (0.38)	4.49 (<0.01)
Pisodonophis boro	94	2.53 (0.08)	1.05 (0.31)	0.09 (0.96)
Moolgarda cunnesius	94	3.54 (0.02)	1.30 (0.26)	0.36 (0.79)
Leiognathus brevirostris	94	5.58 (<0.01)	3.82 (0.06)	4.96 (<0.01)
Oxyurichthys microlepis	94	0.30 (0.82)	0.53 (0.47)	0.34 (0.80)
Platycephalus indicus	94	3.88 (0.02)	7.12 (0.01)	0.70 (0.50)
Ambassis gymnocephala	94	6.00 (0.02)	24.07 (<0.01)	1.36 (0.26)
Acanthopagrus latus	94	2.13 (0.11)	0.06 (0.81)	1.06 (0.36)
Individual species biomass				
Acentrogobius viridipunctatus	94	56.63 (<0.01)	50.33 (<0.01)	4.25 (<0.01)
Bostrychus sinensis	94	44.50 (<0.01)	20.50 (<0.01)	1.05 (0.39)
Glossogobius giuris	94	15.29 (<0.01)	2.54 (0.12)	0.59 (0.62)
Acanthogobius hasta		8.08 (<0.01)	3.53 (0.07)	0.47 (0.63)
Gerres limbatus	94	10.59 (<0.01)	0.22 (0.64)	0.60 (0.62)
Sillago sihama	94	36.08 (<0.01)	0.20 (0.66)	1.05 (0.38)
Lateolabrax japonicus	94	5.53 (<0.01)	0.71 (0.41)	0.64 (0.60)
Gastrophysus niphobles	94	0.45 (0.72)	2.68 (0.11)	4.65 (0.01)
Pisodonophis boro	94	4.29 (0.01)	0.62 (0.44)	0.46 (0.71)
Moolgarda cunnesius	94	6.72 (<0.01)	1.22 (0.28)	0.83 (0.48)
Leiognathus brevirostris	94	3.99 (0.01)	1.63 (0.21)	2.14 (0.11)
Oxyurichthys microlepis	94	0.28 (0.84)	0.24 (0.63)	0.22 (0.88)
Platycephalus indicus	94	1.81 (0.17)	1.95 (0.17)	0.54 (0.59)
Ambassis gymnocephala	94	9.59 (<0.01)	0.77 (0.39)	3.38 (0.03)
Acanthopagrus latus	94	1.71 (0.18)	0.01 (0.91)	0.25 (0.78)

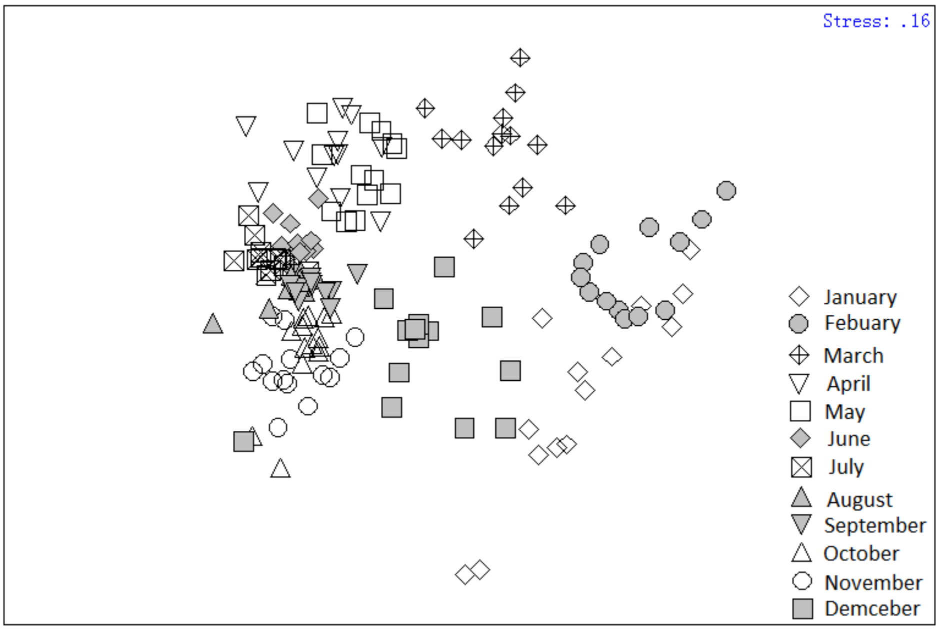

Figure 4. Non-metric multidimensional scaling (NMDS) ordination of fish assemblages for months base on abundance data in the Mangrove of Qinzhou Harbor.

significant effect of time of year (Global test R = 0.388, P = 0.001) on fish assemblages based on fish abundance data (Table 6).

Effect of tidal Type on Fish Assemblages

Fish species richness, total abundance and total biomass were significantly affected by tidal type in the mangrove of Qinzhou Harbor, and so did five fish species in abundance and two fish species in biomass (Table 5). For instance, tidal type significantly affected fish species both in abundance and in biomass such as *A. viridipunctatus* and *B. sinensis*, and other three species in abundance including *G. giuris*, *P. indicus* and *A. gymnocephala*. However, there were no significant difference between neap tide and spring tide at each season for species richness, total abundance and total biomass (Table 5). The total abundance and biomass of *A. viridipunctatus* and *G. niphobles* were significantly affected by tidal type at each season, as well as *L. brevirostris* in abundance and *A. gymnocephala* in biomass. The non-metric multidimensional scaling analysis showed an unclear separation of fish samples between spring tide and neap tide. One-way ANOSIM further revealed no significant effects of tidal type (Global R = 0.011, P = 0.171) on fish assemblages based on abundance data.

Relationship between Fish Assemblage Indices and Environmental Variables

The correlation coefficients of four environmental variables and seven assemblage indices derived from the samples taken monthly from the seven locations were shown in Table 7. There are three groups of pairs of variables that showed significant correlations. The first group included three environmental variables, such as salinity, water temperature and pH. For instance, salinity was significantly positively related to pH, while it was negatively related to water temperature significantly (Table 7). The second group significantly correlated

Table 6. One-way ANOSIM test for temporal variation of fish assemblage in the Mangrove of Qinzhou Harbor. Shown are R values and significance P value in parentheses (significant difference P < 0.05 are indicated in bold)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
Feb.	0.22 (0.05)										
Mar.	0.67 (0.001)	0.72 (0.001)									
Apr.	0.91 (0.001)	0.99 (0.001)	0.80 (0.001)								
May	0.87 (0.001)	0.98 (0.001)	0.77 (0.001)	0.79 (0.001)							
Jun.	0.90 (0.001)	0.998 (0.001)	0.93 (0.001)	0.79 (0.001)	0.91 (0.001)						
Jul.	0.93 (0.001)	0.999 (0.001)	0.96 (0.001)	0.92 (0.001)	0.93 (0.001)	0.75 (0.001)					
Aug.	0.85 (0.001)	0.998 (0.001)	0.95 (0.001)	0.86 (0.001)	0.91 (0.001)	0.69 (0.001)	0.42 (0.001)				
Sep.	0.81 (0.001)	0.996 (0.001)	0.94 (0.001)	0.90 (0.001)	0.93 (0.001)	0.70 (0.001)	0.43 (0.001)	0.08 (0.1)			
Oct.	0.82 (0.001)	0.998 (0.001)	0.98 (0.001)	0.89 (0.001)	0.92 (0.001)	0.69 (0.001)	0.64 (0.001)	0.36 (0.002)	0.29 (0.001)		
Nov.	0.84 (0.001)	0.997 (0.001)	0.99 (0.001)	0.98 (0.001)	0.98 (0.001)	0.80 (0.001)	0.82 (0.001)	0.42 (0.001)	0.43 (0.001)	0.15 (0.012)	
Dec.	0.49 (0.001)	0.83 (0.001)	0.84 (0.001)	0.87 (0.001)	0.87 (0.001)	0.77 (0.001)	0.85 (0.001)	0.63 (0.001)	0.64 (0.001)	0.70 (0.001)	0.70 (0.001)

Table 7. Matrix of Spearman r_s correlation coefficients of variables measured in the Mangrove of Qinzhou Harbor (Species richness (S), total abundance (N), total biomass (W), Margalef index (D_{ma}), Simpson index (λ), Shannon-Wiener index (H') and Pielou index (Je), Tidal range (Tid.), Water temperature (T) and Salinity (Sal.); ** shown P< 0 .01, * shown P< 0.05)

	S	N	W	D_{ma}	λ	H'	J_e	Tid.	T	Sal.	pH
S	1.00										
N	0.80**	1.00									
W	0.73**	0.87**	1.00								
D_{ma}	0.63**	0.12	0.21	1.00							
λ	0.53**	0.78**	0.71**	-0.09	1.00						
H'	-0.21**	-0.57**	-0.49**	0.39**	-0.88**	1.00					
J_e	-0.66**	-0.86**	-0.77**	-0.04	-0.97**	0.82**	1.00				
Tid.	0.31**	0.36**	0.43**	0.22	0.20*	-0.06	-0.24**	1.00			
T	0.65**	0.74**	0.77**	0.09	0.64**	-0.44**	-0.70**	0.02	1.00		
Sal.	-0.56**	-0.48**	-0.23**	-0.37**	-0.29**	0.10	0.38**	-0.02	-0.46**	1.00	
pH	-0.23**	-0.21**	0.05	-0.14	-0.17*	0.14	0.20*	0.11	-0.12	0.59**	1.00

between habitat variables and fish assemblage metrics. For example, fish richness, total abundance, total biomass, Simpson index were positively related to tidal range and water temperature significantly, whereas was negatively related to salinity and pH except total biomass (Table 7). The last group of significantly interrelated variables referred to high correlations among fish assemblage indices. For example, species richness was positively significantly correlated to total abundance, total biomass, Margalef index and Simpson index, while it was negatively related to Shannon-Wiener index and Pielou index significantly (Table 7).

Discussion

Mangals (mangrove trees and shurbs and their associated faunal communities) are often cited as providing important habitat for species utilise due to two hypotheses, such as predator refuge hypothesis and feeding hypothesis (Barbier *et al.*, 2011; Huxham *et al.*, 2004). This study found 67 fish species ultilizing creek and complex structures in the Mangroves of Qinzhou Harbor, South China. Among these, the most representative families were Gobiidae, Eleotridae, Gerreidae, Mugilidea, Lateolabracidae and Sparidae when species richness, total abundance and total biomass were taken into consideration (Figure 2; Figure 5a, 5b). Gobiidae or Mugilidae has also been reported as numerically dominant families in Asian, Oceania and South America (Halliday and Young, 1996; Hindell and Jenkin, 2004; Islam and Ikejima, 2010; Lin and Shao, 1999; Nanjo *et al.*, 2008; Shervette *et al.*, 2007;Tongnunui *et al.*, 2002). And Gerreidae and Sparidae were the principal families appeared in South African,Oceanian mangroves (Halliday and Young, 1996; Huxham *et al.*, 2004; Kimani *et al.*, 1996), and Eleotridae was one of the dominant families occurred in South American Mangroves (Braletta-Bergan *et al.*, 2002).

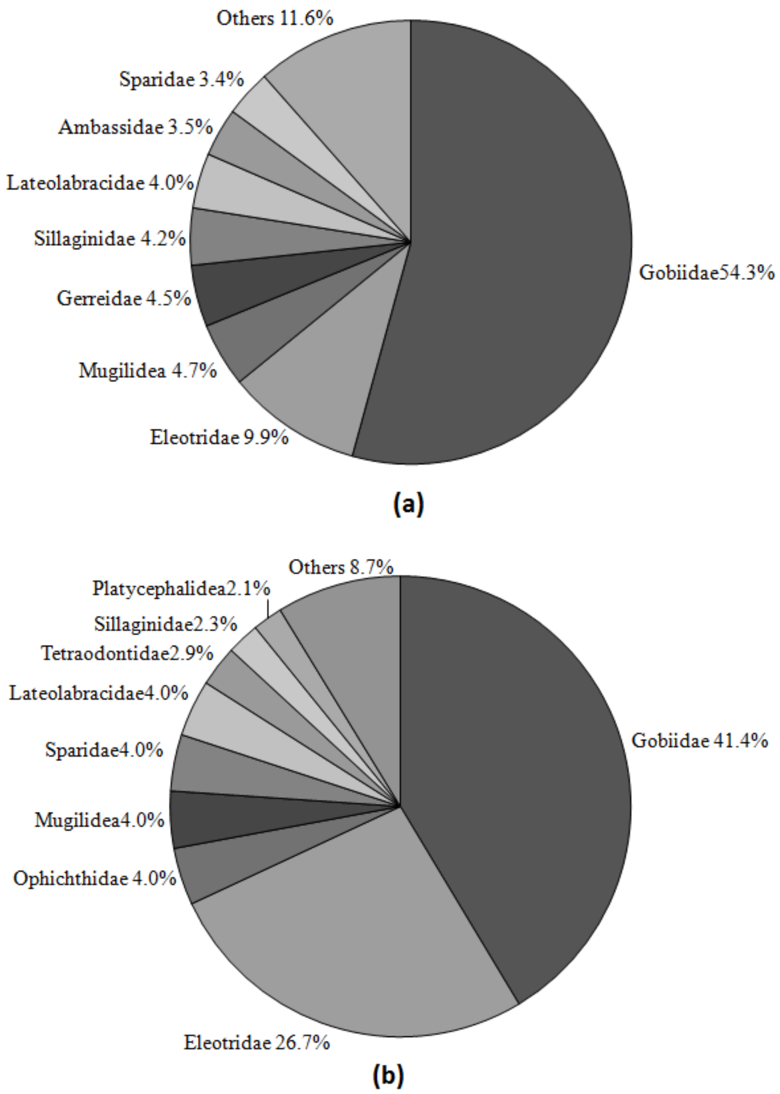

Figure 5. Percent of total abundance and total biomass in the dominant families in the Mangrove of Qinzhou Harbor (a: total abundance ; b: total biomass).

A. viridipunctatus, *B. sitnensis*, *A. hasta*, *G. giuris*, and *L. japonicus* were the most important fishery species in the Qinzhou Harbor, south China. All these fish were demersal fish, which indicated that benthic structrure in the mangroves played an important role as shelter and feeding habiat for demersal fauna (Nagelkerken *et al.*, 2010). About 51 fish species (including two amphibious fish) were demersal fish in the mangroves of Qinzhou Harbor, accounting for 76.1% of total fish species. In addition, two freshwater fishes (e.g. *Hemiculter leucisculus* and *Carassius auratus*) occured in the mangrove of Qinzhou Harbor in summer. This might be those freshwater fish were pushed to the mangrove by flood resulted in the decrease in salinity of water in the mangrove, which made these fish survive in the mangrove temporarily.

The structure of fish assemblage in the Mangroves of Qinzhou Harbor differed sinificantly seasonally. Marked seasonal changes in fish assembalge structures have also been detected in previous studies from mangrove ecosystems (Hindell and Jenkin, 2004; Lin and Shao, 1999; Newman *et al.*, 2007; Tommaso and Krumme, 2009). The species richness and total abundance increased from spring, and reached peak in summer and in fall (Table 4), which might be productive traits of fish caused.

Water temperature and salinity were the main factors influencing fish communities in estuarine ecosystems (Barletta *et al.*, 2005; Harrison and Whitfield, 2006; Morrison *et al.*, 2002). A total of 31 fish species occurred throughtout the year, while there are six species in summer and four species in fall only , and two fish species occurred in spring and winter only (Table 2). And the fish species richness, total abundance, total biomass and total abundance and total biomass dominant fish species were significantly changed in seasons in this study (Table 5), which might be caused by different water temperature and salinity in the mangroves of Qinzhou Harbor (Table 7).

Krumme *et al*. have already documented that fish abundance, stomach fullness and food consumption were significantly higher in spring tide than the one in neap tide (Krumme and Saint-Paul, 2008). Species richness, total abundance and total biomass of fishes differed significantly between spring tide and neap tide in this study (Table 5), But the fish assemblage structures did not differ significantly between spring tide and neap tide. The effect of tidal type on fish assemblages is complicated, so more studies are needed to make further generalizations in effects of these cycle on fish assemblages in mangroves and other estuarine ecosystems.

Acknowledgements

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