

Connectivity of fish assemblages along the mangrove-seagrass-coral reef continuum in Wenchang, China

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Abstract

Understanding the connectivity of fish among different typical habitats is important for conducting ecosystem-based management, particularly when designing marine protected areas (MPA) or setting MPA networks. To clarify of connectivity among mangrove, seagrass beds, and coral reef habitats in Wenchang, Hainan Province, China, the fish community structure was studied in wet and dry seasons of 2018. Gill nets were placed across the three habitat types, and the number of species, individuals, and body size of individual fish were recorded. In total, 3 815 individuals belonging to 154 species of 57 families were collected. The highest number of individuals and species was documented in mangroves (117 species, 2 623 individuals), followed by coral reefs (61 species, 438 individuals) and seagrass beds (46 species, 754 individuals). The similarity tests revealed highly significant differences among the three habitats. Approximately 23.4% species used two habitats and 11.0% species used three habitats. A significant difference ($p < 0.05$) in habitat use among eight species (*Mugil cephalus*, *Gerres oblongus*, *Signanus fuscescens*, *Terapon jarbua*, *Sillago maculata*, *Upeneus tragula*, *Lutjanus russellii*, and *Monacanthus chinensis*) was detected, with a clear ontogenetic shift in habitat use from mangrove or seagrass beds to coral reefs. The similarity indices suggested that fish assemblages can be divided into three large groups namely coral, seagrass, and mangrove habitat types. This study demonstrated that connectivity exists between mangrove-seagrass-coral reef continuum in Wenchang area; therefore, we recommend that fish connectivity should be considered when designing MPAs or MPA network where possible.

Key words: connectivity, fish, mangrove, seagrass, coral reef, Wenchang, northern South China Sea

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1 Introduction

Mangroves, seagrass beds, and coral reefs are three typical marine ecosystems, which are often adjacent to one another, forming connections through chemical, biological, and physical interactions (Ogden, 1997). Examples of connections that exist across these habitats include the ontogeny of larval, juvenile, and adult fauna (Lowe and Falter, 2015) and exchange of carbon, nitrogen, and phosphorus among different habitats (Nagelkerken, 2009), leading to connectivity. Several studies have shown that the connectivity of different habitats provides abundant food resources and suitable habitats for the biodiversity of adjacent ecosystems, playing an important role in maintaining population structure and regulating ecological processes (Kindlmann and Burel, 2008; Bauer and Hoye, 2014). However, the above ecosystems are negatively affected by various anthropogenic activities and climate change in recent decades, resulting in habitat loss and fragmentation (Krosby et al., 2010; Brodie et al., 2012). Con-

sequently, the connectivity among these ecosystems is severely reduced (Hughes, 2003), leading to a decrease in the diversity of species and changes in community structures (Pandit et al., 2017). Therefore, it is necessary to increase our understanding about the connectivity across mangroves, seagrass beds, and coral reefs.

Studies on the mechanism of connectivity have mainly focused on the transfer of organisms and nutrients, especially on the fauna migration between ecosystems (Du et al., 2015). Commonly, juvenile and adult fish occupy different habitats to meet their own needs, and undeniably mobile organisms move between and within habitat patches. Furthermore, some species often migrate to nearshore habitats to avoid being preyed (Shulman, 1985; Nakamura et al., 2003) or for food (Nagelkerken et al., 2000a) and as a nursery (Nagelkerken, 2009; Weinstein and Heck, 1979; Dorenbosch et al., 2004; de la Morinière et al., 2002; Nagelkerken et al., 2000b), which increased connectivity among dif-

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ferent habitats. On the contrary, the biological connectivity enhances the productivity and biodiversity (Costanza et al., 1997). Therefore, it is important to maintain connectivity across different habitats to safeguard the structure and diversity of fish assemblages. However, the ontogenetic shifts and utilization patterns of fish from the typical marine ecosystems remain largely unknown, especially in China.

Wenchang, located on the east coast of Hainan Province, has the largest area of seagrass in China, and it supports one of the few mangrove–seagrass–reef continuums in China. However, the coverage of seagrass and hermatypic corals in this area is sharply declining (Chen et al., 2015; Wu et al., 2017). In this study, we aimed to analyze the fish assemblages and connectivity along mangroves, seagrass beds, and coral reefs in Wenchang. The results of this study are expected to improve our understanding of the connectivity of fish assemblages among habitats in Hainan Province, which could help improve the habitats protection strategies and fisheries management.

2 Materials and methods

2.1 Study area

Wenchang has tropical oceanic monsoon climate, sufficient light, high temperature, and abundant rainfall (Yang et al., 2017; Chen et al., 2015; Wu et al., 2011). The fish assemblages in the mangroves, seagrass beds, and coral reefs in Wenchang were studied, during the wet (March) and dry seasons (August) in 2018 (Fig. 1). Three sites passing through mangroves, seagrass beds,

and coral reefs were designed. The site in mangrove is situated in the mouth of a lagoon at a depth of 0.5 m; the sediment is mainly silt and sand and the dominant species in mangrove are *Bruguiera gymnorrhiza*, *Kandelia candel*, and *Aegiceras corniculatum*. The site in seagrass is approximately 1 km from the coastline at the depth of 1 m, the most dominant species in seagrass beds is *Enhalus acoroides*, and the sediment is mainly composed of coral chips, shell chips and gravels. In the recent years, the seagrass distribution in this area has become patchy or scattered (average cover 33.55%) (Chen et al., 2015). The site in coral reef fringe is approximately 3 km from the coastline at the depth of 3 m. The dominant species are *Platygyra daedalea* and *Lobophyllia corymbosa* (approximately 65% coverage, but with only 0.33% live coral remaining) (Wu et al., 2011).

2.2 Sample collection

Gill nets (height 1 m, width 150 m, and mesh size 0.5 cm) were used in all the three habitats, and were collected at 2–3 h during the day time (05:00 to 17:00), one net per day for five consecutive days. Gill nets provide a non-destructive method for sampling, and they are an effective method for sampling diurnal near-shore fish assemblages in seagrass and other typical habitats (Unsworth et al., 2007).

All fish were identified to the species level (Chen and Yang, 2013; Liu et al., 2013; <http://www.fishbase.org>), while it was not possible to identify six species beyond the genus level. The total length (TL) of each specimen was measured to 0.1 cm accuracy. The collection, treatment, and analysis of samples were in accordance with the relevant provisions of the Marine Survey Specifications (General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China and Standardization Administration of the People's Republic of China, 2007).

To determine how the fish utilized the habitat, the species were divided into the following seven habitat groups: (1) mangrove species, which were only present in mangrove; (2) seagrass species, which were only present in seagrass beds; (3) reef species, which were only present in coral reefs; (4) mangrove–seagrass species, which were present in both mangrove and seagrass beds; (5) seagrass–reef species, which were present in both seagrass beds and coral reefs; (6) mangrove–reef species, which were present in both mangrove and coral reefs; and (7) mangrove–seagrass–reef species, which occurred in all three habitats (Nakamura and Sano, 2004).

2.3 Statistical analysis

All specimens were collected from the three sites. The family composition of species and the number of individuals in each habitat were analyzed. A nonparametric Kruskal–Wallis H-test was used to determine the difference in individual numbers and species in each habitat, because assumptions of homogeneity of variance could not be met by some data, even after transformation (Shibuno et al., 2008). Differences in body length among mangroves, seagrass beds, and coral reefs were analyzed. The numbers of species and individuals were also compared using Mann–Whitney U test in different seasons among the three habitats.

The similarity of fish assemblages in the three habitats was calculated using data obtained from five consecutive days of sampling within each habitat for two seasons. The samples were ordinated based on Bray–Curtis dissimilarity matrices. The fish abundance results were visualized by nonmetric multidimensional scaling (NMDS). Fish community composition difference among habitat types were conducted using a nonparametric

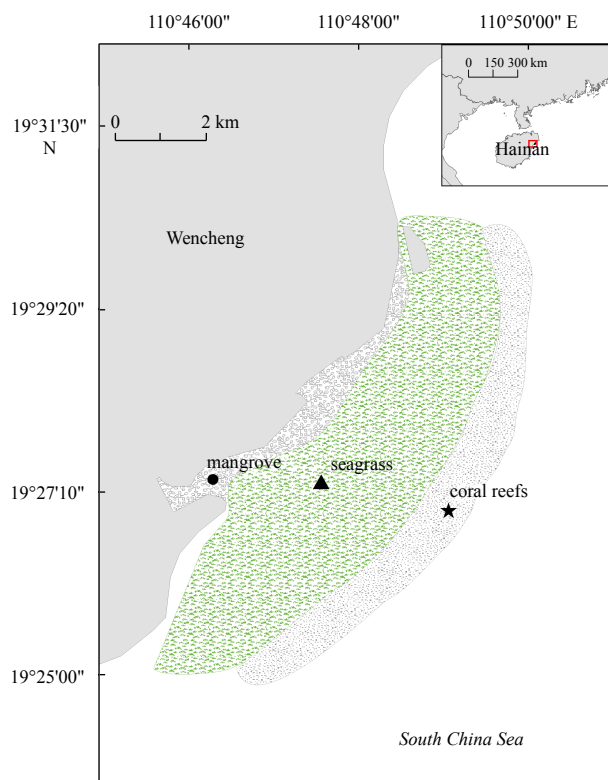


Fig. 1. Three study sites in the mangrove–seagrass–reef continuum in Wenchang, Hainan Province, China. The mangrove area was the closest to land (approximately 360 m) and the seagrass beds were in an intermediate location of mangroves and coral reefs, whereas the coral reefs were located along the edge of the continental shelf.

multivariate analysis of variance (NPMANOVA; $\alpha=0.05$). The analysis was performed using the “vegan” package of R ver. 3.5.2 (R development Core Team).

3 Results

3.1 Community structure

A total of 3 815 individuals were collected from the three habitats, comprising 154 species belonging to 57 families (Table A1). In the mangrove area, 2 623 individuals of 117 species belonging to 48 families were collected. In contrast, fewer fish were recorded in the seagrass beds (754 individuals belonging to 46 species of 28 families) and coral reefs (438 individuals belonging to 61 species of 35 families). More number of species and individuals were recorded in the mangroves than that in the seagrass beds and coral reef habitats (Table 1). The mean number of individuals in the samples collected for five consecutive days in mangrove area was significantly higher than that in seagrass beds and coral reefs in wet season ($p<0.05$) (Fig. 2a). The mean number of species in the samples collected for five consecutive days in mangrove was significantly higher than that in coral reefs in wet season and in seagrass in dry season ($p<0.05$) (Fig. 2b). In addition, there was no significant difference in the mean number of individuals and species between seagrass beds and coral reefs.

The most dominant families in the mangrove were Gobiidae (20 species, 17.1%, represented by *Oxyurichthys ophthalmonema*), followed by Labridae (5 species, 4.3%, represented by *Halichoeres nigrescens*), and Leiognathidae (5 species, 4.3%, represented by *Leiognathus equulus*) (Fig. 3a). In the seagrass beds, Gerreidae (4 species, 8.7%), Leiognathidae (3 species, 6.5%), and

Lutjanidae (2 species, 4.3%) were the dominant families, and the representative species included *Gerres oblongus*, *Leiognathus equulus*, and *Lutjanus russellii*. In the coral reef, the most dominant families were Labridae (8 species, 13.1%), Lethrinidae (4 species, 6.6%), and Lutjanidae (4 species, 6.6%), with *Lethrinus haematopterus* being the representative species.

In terms of individual numbers, Gobiidae was the dominant family in the mangrove area, accounting for 21.3% of all species, followed by Mugilidae and Siganidae, which together accounted for 22.4% of the species (Fig. 3b). Mugilidae was the most dominant species in the seagrass beds, representing approximately 47.7%, followed by Terapontidae (101 individuals, 13.4%) and Gerreidae (94 individuals, 12.5%). Siganidae (105 individuals, 24.0%), Mugilidae (89 individuals, 20.3%), and Terapontidae (39 individuals, 8.9%) were the three dominant species in the coral reef.

The similarity indices suggested that fish assemblages can be divided into three groups (coral, seagrass, and mangrove habitat type) (Figs 4a, b). The results of similarity tests using NPMANOVA revealed a highly significant difference among habitats ($F_{2, 27}=4.01, p=0.003$).

3.2 Fish utilized multiple habitats

Of the 154 species recorded, 101 species (accounting for approximately 65.6% of all species) occurred in a single habitat, whereas the individuals accounted for 23.7% of all species. However, only 36 species were recorded in two habitats and 17 species were recorded in three habitats; thus, 34.4% of all species were recorded in multiple habitats (Table 1). Specifically, 16 species were recorded in the mangrove–seagrass areas, 17 species

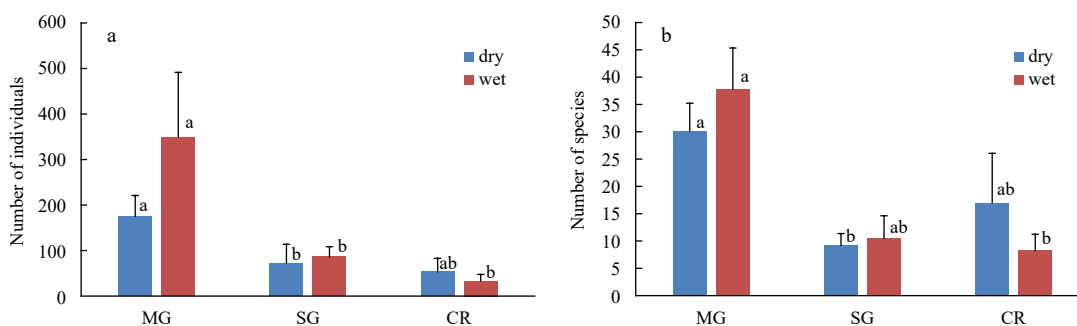


Fig. 2. Mean number of fish species (a) and individuals (b) during sampling months in each habitat. The error bars are standard deviations. MG, SG, and CR represent mangroves, seagrass, and coral reefs, respectively.

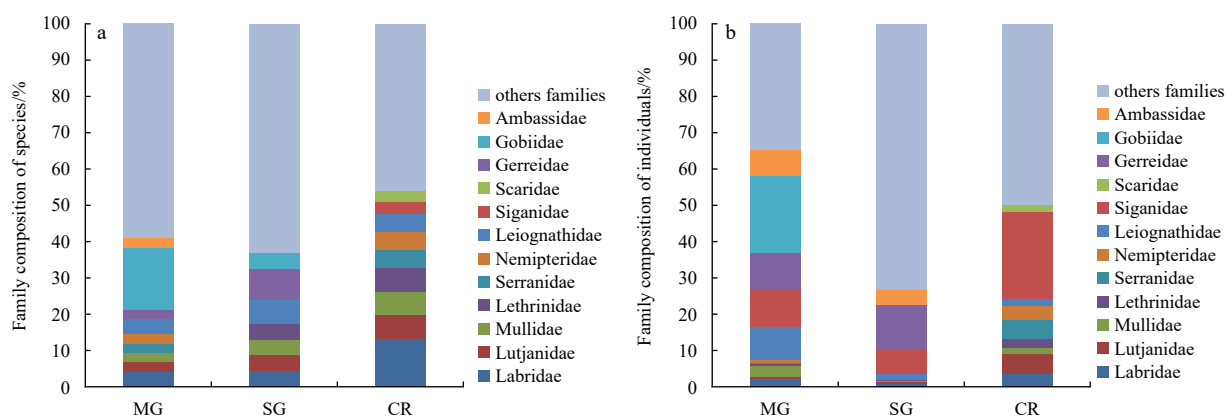


Fig. 3. Relative family composition of fish species (a) and the number of individuals (b) in the three habitats.

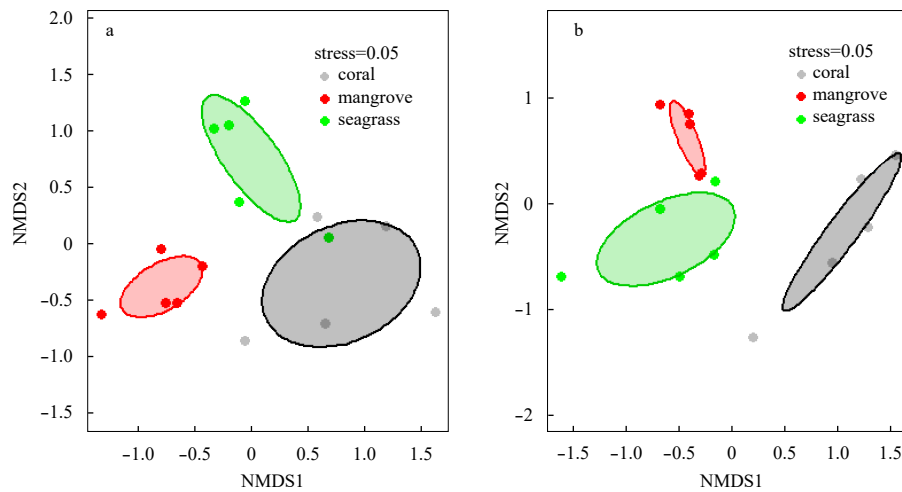


Fig. 4. Nonmetric multidimensional scaling (NMDS) of data from all five days in each habitat in March (a) and August (b).

Table 1. Percentage contribution by species and individuals for each habitat group

Habitat/habitat group	All species/% (n)	Individuals/%
Mangrove		
Mangrove species	57.3 (67)	31.3
Mangrove–seagrass species	13.7 (16)	17.9
Mangrove–reef species	14.5 (17)	2.9
Mangrove–seagrass–reef species	14.5 (17)	48.0
Seagrass bed		
Seagrass species	21.7 (10)	2.8
Mangrove–seagrass species	34.8 (16)	19.9
Seagrass–reef species	6.5 (3)	0.4
Mangrove–seagrass–reef species	37.0 (17)	76.9
Coral reef		
Reef species	39.3 (24)	16.1
Seagrass–reef species	4.9 (3)	3.0
Mangrove–reef species	27.9 (17)	10.1
Mangrove–seagrass–reef species	27.9 (17)	70.8

Note: Number of fish species is shown in parentheses.

were recorded in the mangrove–coral reef areas, 3 species were recorded in the seagrass–coral reef areas, and 17 species were recorded in the mangrove–seagrass–coral reef areas. In the mangrove and coral reef areas, the local species represented more than 35% of the total species. In comparison, in the seagrass area, species that used multiple habitats accounted for 78.3% of all species. In terms of individuals, more than 60% of all individuals used two or three habitats, especially seagrass and coral reef areas. The mangrove–seagrass–coral reef species contributed to approximately 70% of all individuals in seagrass and coral reef areas, although seagrass–coral reef species only represented 0.4% of individuals in the seagrass beds. Minimal differences were found in both fish species and individuals using the mangrove–seagrass–coral reef continuum (Table 1).

The length of eight species (*Mugil cephalus*, *G. oblongus*, *Siganus fuscescens*, *Terapon jarbua*, *Sillago maculata*, *Upeneus tragula*, *L. russellii*, and *Monacanthus chinensis*) was higher in coral reef than that in seagrass and mangrove areas, showing possible ontogenetic habitat shifts from mangrove or seagrass beds to coral reef (Fig. 5). This shift might explain the trend towards changing habitats by individuals and species. On the

whole, in their early stages of development, these fish mainly inhabited the mangrove and seagrass beds, which is consistent with the fact that mangrove and seagrass habitats serve as nurseries for fish (Beck et al., 2001).

4 Discussion

This study demonstrated that the structure of fish assemblages across mangroves, seagrass beds, and coral reefs differed with respect to the number of individuals and species (Fig. 3, Table 1). More number of individuals and species were present in mangroves than that in seagrass and coral reef areas. This result is different from that reported in Mindoro and Mindanao Islands in Philippines, where the fish species in coral reef (265) was much higher than that in mangroves (47) and seagrass beds (38) (Honda et al., 2013). This might be because the gill net was used to collect samples in this study, while the diving visual censuses was used in Philippines, which might miss several small fish, such as goby. Moreover, the fish diversity in mangrove is also high in other areas in China; for example, 115 species in Dongzhaigang National Nature Reserve for Mangroves (Shi, 2005) and 127 species in the Leizhou Peninsula (He et al., 2003). In addition, fewer individuals were present in coral reefs than those in seagrass; however, the diversity of species in coral reefs was higher than that in seagrass. The 117 fish species recorded in mangrove accounted for approximately 76.0% of all fish species recorded, whereas only 16 and 17 species exclusively utilized seagrass and coral reef habitats, respectively (Table 1). The fact that 67 species were found only in mangrove habitats emphasizes the need to protect multiple habitats even without considering connectivity.

In this study, 53 of the 154 species were detected in two to three of the surveyed habitats. The distribution of the eight species based on the body length was significantly different among the three habitats ($p < 0.05$; Fig. 5), which might reflect ontogenetic changes in habitat use among the three habitats. In recent years, several studies have focused on the ontogenetic changes in fish using the gut content and stable isotope ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) analyses (de la Morinière et al., 2003; Berkström et al., 2013). *Monacanthus chinensis* is omnivorous and seagrass is its minor food item (Bell et al., 1975). Most individuals of this species were detected in the mangrove area of this study and were in the early stage of development. Some adult individuals were also recor-

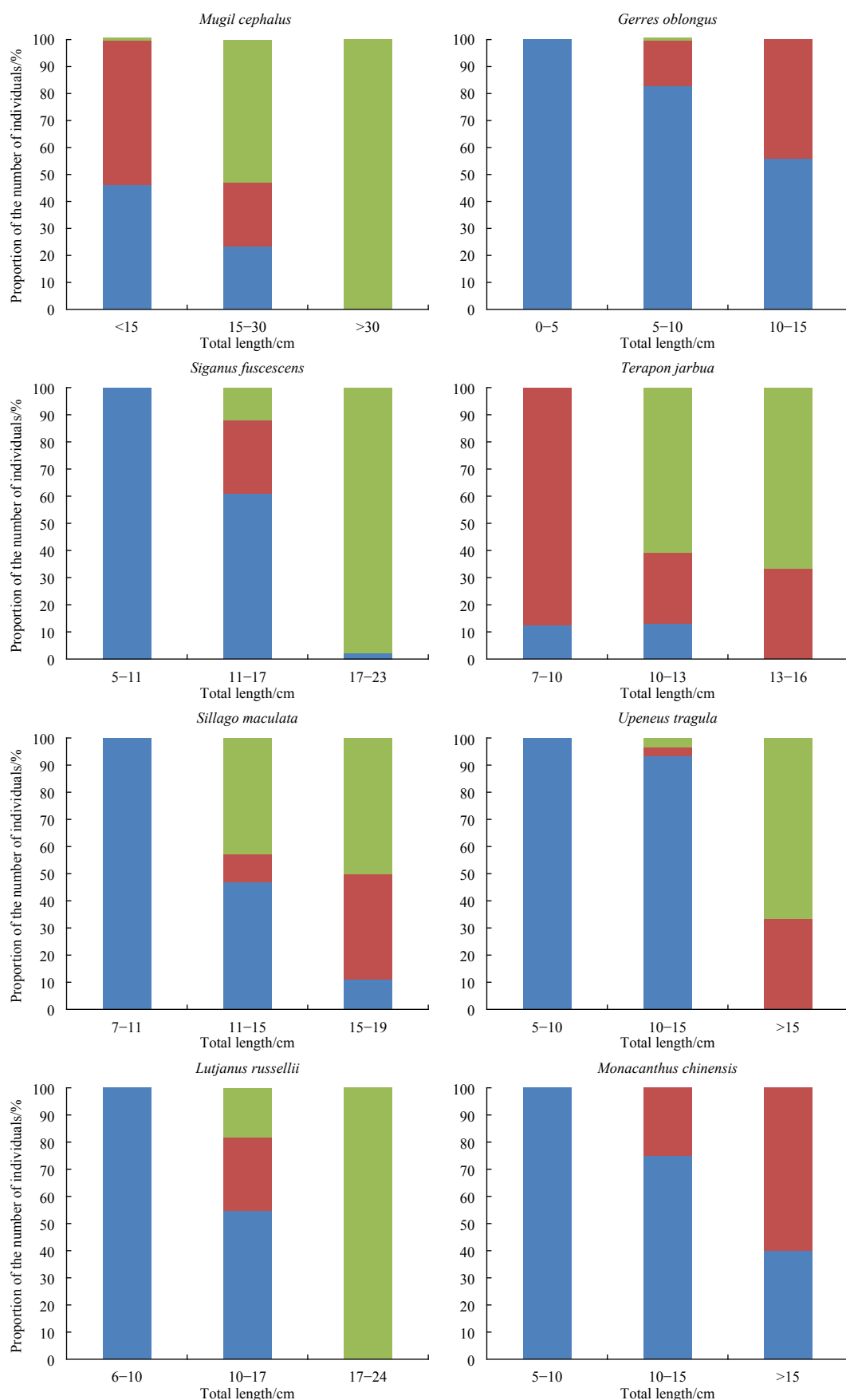


Fig. 5. Relative abundance of the eight fish species in the mangrove (blue), seagrass (red), and coral reefs (green) habitats according to the class size using pooled date.

ded in the seagrass beds. However, there was no record of this species in seagrass beds at Had Khanom Mu Ko Thale Tai National Park of Thailand (Sichum et al., 2003).

Most individuals of the species *L. russellii* were detected in the mangroves and coral reefs, and this multiple habitat use reflects a relaxed day–night shift, with individuals feeding in seagrass beds at night and shifting to sheltered areas (mangrove/coral reefs) by daytime (Nagelkerken et al., 2000a; Bond et al., 2018). *Upeneus tragula* and *Sillago maculata* utilized almost all habitats. *Gerres oblongus* is a common species in coastal areas, and it spawns from February to June in the Jaffna Lagoon, Sri Lanka (Sivashanthini and Abeyrami, 2003). Thus, the samples collected from the mangrove and seagrass beds were juveniles, which preferentially use mangroves as a nursery over seagrass beds. Most juveniles and a group of adults of *T. jarbua* were found occupying the seagrass beds. Other adult fish of this species were found in coral reefs. On the contrary, 77% of *Triacanthus biaculeatus* individuals were recorded in seagrass beds, and only a few in mangroves. Overall, there was an abundance of fish in the early stages of development in the mangrove and seagrass beds, with more number of individuals in the later stages of development in the coral reefs. This finding was similar to that detected for fish assemblages in the Indo–Pacific (Unsworth et al., 2009) and Caribbean islands (Nagelkerken et al., 2002).

Studies on connectivity among coastal habitats have mainly focused on the Indo–Pacific (Unsworth et al., 2007, 2008, 2009) and Caribbean (Weinstein and Heck, 1979; Nagelkerken et al., 2002; Kopp et al., 2007), particularly with respect to fish structure among different habitats. It is widely accepted that mangroves and seagrass beds serve as nurseries for reef fish species; however, empirical studies supporting this assumption remain limited. The structure, food resources, and shade provided by mangrove–seagrass beds strongly attract juvenile fish (Verweij et al., 2006). In addition, some studies have emphasized the importance of mangrove and seagrass beds for maintaining fish density in coral reefs (Nagelkerken et al., 2002). Furthermore, overlapping use of seagrass beds with adjacent coral by fish has been documented (Nakamura and Sano, 2004). Consequently, habitat degradation or loss in coastal areas could have significant negative effects on other fauna occupying these habitats.

The rich fishery resources and numerous fishing gears in the South China Sea have promoted the rapid development of the marine fishery. According to the characteristics of fish and the environment, the choice of suitable gear is an issue worth considering. Trawling is the most important fishing tool in the South China Sea, but it is also the most damaging to fisheries and the marine environment (Yang, 1997). More numbers of young fish can be caught using stow net than by trawling (Zhang, 2014). Diving or snorkeling represent a good approach to study fish assemblages (Honda et al., 2013); however, this method depends on the water visibility is good enough. Gill nets were used in this study considering the complex habitats and low visibility in March and August. In the future, different methods may be used to study the connectivity, such as underwater visual census in appropriate months (Verweij et al., 2006; Hylkema et al., 2015). If possible, combining with the skill of otolith (Lueders-Dumont et al., 2018) would be another choice.

Coverage of coastal habitats and fish diversity is declining, with multiple ecological habitats requiring protection for the comprehensive management of marine biodiversity. Relevant research is required for rapid recovery of population structures. This study contributes towards advancing our understanding of

fish ecology and connectivity among habitats. In particular, the connectivity of coastal habitats should be incorporated into management plans, as these habitats are already severely degraded. For example, there is *Euclidean* Nature Reserve of Hainan Province in Wenchang area, however, the key protected objects in this reserve is *Euclidean*, but not the habitats (Wu et al., 2017). Moreover, there are also other MPAs, such as Qinglangang Provincial Mangrove Nature Reserve and Tongguling National Nature Reserve in Wenchang area, while the former focuses on mangrove and the latter focuses on coral reef; both do not consider the connectivity between these habitats. Therefore, it is recommended that fish connectivity should be considered when designing MPAs or MPA network where possible.

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Appendix:

Table A1. The number of individuals of fish in mangrove, seagrass bed and coral reef in Wenchang, China

Species	Common name	Family	Number of individuals		
			Mangrove	Seagrass bed	Coral reef
<i>Cynoglossus macrolepidotus</i>	Tonguesole	Cynoglossidae	0	0	1
<i>Cynoglossus joyneri</i>	Red tonguesole	Cynoglossidae	2	0	0
<i>Brachirus orientalis</i>	Oriental sole	Soleidae	9	1	0
<i>Pardachirus pavoninus</i>	Peacock sole	Soleidae	1	0	0
<i>Sardinella zunasi</i>	Japanese sardinella	Clupeidae	5	9	1
<i>Konosirus punctatus</i>	Dotted gizzard shad	Clupeidae	0	4	0
<i>Thrissa setirostris</i>	Longjaw thryssa	Engraulidae	0	1	0
<i>Dasyatis akajei</i>	Whip stingray	Dasyatidae	1	0	1
<i>Siganus fuscescens</i>	Mottled spinefoot	Siganidae	260	48	104
<i>Siganus guttatus</i>	Orange-spotted spinefoot	Siganidae	14	0	1
<i>Leiognathus brevirostris</i>	Shortnose ponyfish	Leiognathidae	5	1	4
<i>Leiognathus equulus</i>	Common ponyfish	Leiognathidae	202	11	1
<i>Leiognathus berbis</i>	Berber ponyfish	Leiognathidae	1	0	0
<i>Nuclequula nuchalis</i>	Spotnape ponyfish	Leiognathidae	14	1	3
<i>Gazza minuta</i>	Toothpony	Leiognathidae	15	0	0
<i>Gerres oblongus</i>	Slender silver-biddy	Gerreidae	200	53	1
<i>Gerres filamentosus</i>	Whipfin silver-biddy	Gerreidae	48	34	0
<i>Gerres erythrourus</i>	Deep-bodied mojarra	Gerreidae	0	5	0
<i>Gerres limbatus</i>	Saddleback silver-biddy	Gerreidae	0	1	0
<i>Gerres macracanthus</i>	Longspine silverbiddy	Gerreidae	15	0	0
<i>Upeneus tragula</i>	Freckled goatfish	Mullidae	74	2	3
<i>Upeneus sulphureus</i>	Sulphur goatfish	Mullidae	1	0	0
<i>Parupeneus ciliatus</i>	Whitesaddle goatfish	Mullidae	2	0	1
<i>Parupeneus indicus</i>	Indian goatfish	Mullidae	0	1	2
<i>Parupeneus multifasciatus</i>	Manybar goatfish	Mullidae	0	0	1
<i>Terapon jarbua</i>	Jarbua terapon	Terapontidae	15	66	39
<i>Therapon oxyrhynchus</i>	Sharpbeak terapon	Terapontidae	2	0	0
<i>Therapon theraps</i>	Largescaled terapon	Terapontidae	2	0	0
<i>Pelates quadrilineatus</i>	Fourlined terapon	Terapontidae	218	35	0
<i>Scarus frenatus</i>	Bridled parrotfish	Scaridae	0	0	4
<i>Scarus ghobban</i>	Blue-barred parrotfish	Scaridae	6	0	5
<i>Leptoscarus vaigiensis</i>	Marbled parrotfish	Scaridae	1	0	0
<i>Sillago maculata</i>	Trumpeter whiting	Sillaginidae	98	12	30
<i>Sillago japonica</i>	Japanese sillago	Sillaginidae	38	1	0
<i>Lutjanus malabaricus</i>	Malabar blood snapper	Lutjanidae	0	0	1
<i>Lutjanus russellii</i>	Russell's snapper	Lutjanidae	12	3	6
<i>Lutjanus fulviflamma</i>	Dory snapper	Lutjanidae	2	1	17
<i>Lutjanus argentimaculatus</i>	Mangrove red snapper	Lutjanidae	1	0	1
<i>Lethrinus haematopterus</i>	Chinese emperor	Lethrinidae	0	1	8
<i>Lethrinus ornatus</i>	Ornate emperor	Lethrinidae	3	0	1
<i>Lethrinus nebulosus</i>	Spangled emperor	Lethrinidae	10	1	1
<i>Lethrinus harak</i>	Thumbprint emperor	Lethrinidae	0	0	1
<i>Scolopsis monogramma</i>	Monogrammed monocle bream	Nemipteridae	17	0	10
<i>Scolopsis vosmeri</i>	Whitecheek monocle bream	Nemipteridae	2	0	4
<i>Scolopsis lineata</i>	Striped monocle bream	Nemipteridae	0	0	3
<i>Scolopsis taenioptera</i>	Lattice monocle bream	Nemipteridae	3	0	0
<i>Pentapodus setosus</i>	Butterfly whiptail	Sparidae	1	0	0
<i>Acanthopagrus schlegelii</i>	Blackhead seabream	Sparidae	0	0	7
<i>Acanthopagrus chinshira</i>	Okinawan yellow-fin seabream	Sparidae	1	0	0
<i>Rhabdosargus sarba</i>	Goldlined seabream	Sparidae	0	1	0
<i>Labracinus cyclophthalmus</i>	Fire-tail devil	Pseudochromidae	0	0	1

to be continued

Continued from Table A1

Species	Common name	Family	Number of individuals		
			Mangrove	Seagrass bed	Coral reef
<i>Epinephelus quoyanus</i>	Longfin grouper	Serranidae	3	0	21
<i>Epinephelus fasciatus</i>	Rock grouper	Serranidae	2	0	1
<i>Epinephelus trimaculatus</i>	Threespot grouper	Serranidae	3	0	1
<i>Rachycentron canadum</i>	Cobia	Rachycentridae	0	0	2
<i>Sphyrna flavicauda</i>	Yellowtail barracuda	Sphyrnaeidae	1	0	3
<i>Sphyrna jello</i>	Pickhandle barracuda	Sphyrnaeidae	4	2	0
<i>Sphyrna barracuda</i>	Great barracuda	Sphyrnaeidae	17	1	0
<i>Monodactylus argenteus</i>	Silver moony	Monodactylidae	3	0	1
<i>Drepane punctata</i>	Spotted sicklefish	Drepaneidae	0	0	1
<i>Pennahia argentata</i>	Silver croaker	Sciaenidae	1	0	1
<i>Nibea albiflora</i>	Yellow drum	Sciaenidae	1	4	0
<i>Dendrophysa russelii</i>	Goatee croaker	Sciaenidae	0	2	0
<i>Trachinotus blochii</i>	Snubnose pompano	Carangidae	0	0	1
<i>Trachinotus bailloni</i>	Pompano	Carangidae	1	0	0
<i>Scomberoides commersonnianus</i>	Talang queenfish	Carangidae	0	0	1
<i>Scomberoides lysan</i>	Doublespotted queenfish	Carangidae	2	0	0
<i>Caranx papuensis</i>	Brassy trevally	Carangidae	0	0	1
<i>Caranx sexfasciatus</i>	Bigeye trevally	Carangidae	3	0	0
<i>Alectis ciliaris</i>	African pompano	Carangidae	1	0	0
<i>Selaroides leptolepis</i>	Yellowstripe scad	Carangidae	1	0	0
<i>Trachurus japonicus</i>	Japanese jack mackerel	Carangidae	0	2	0
<i>Eleutheronema tetradactylum</i>	Fourfinger threadfin	Polynemidae	0	0	2
<i>Halichoeres nigrescens</i>	Bubblefin wrasse	Labridae	34	5	3
<i>Halichoeres marginatus</i>	Dusky wrasse	Labridae	0	0	1
<i>Choerodon schoenleinii</i>	Blackspot tuskfish	Labridae	2	1	2
<i>Stethojulis strigiventer</i>	Three-ribbon wrasse	Labridae	14	0	1
<i>Stethojulis interrupta</i>	Cutribbon wrasse	Labridae	8	0	0
<i>Bodianus</i> sp. 1	hogfish	Labridae	0	0	1
<i>Bodianus</i> sp. 2	hogfish	Labridae	1	0	0
<i>Hemigymnus fasciatus</i>	Barred thicklip	Labridae	0	0	1
<i>Hemigymnus melapterus</i>	Blackeye thicklip	Labridae	0	0	3
<i>Cheilinus chlorourus</i>	Floral wrasse	Labridae	0	0	3
<i>Pempheris schwenkii</i>	Silver sweeper	Pempheridae	0	0	16
<i>Oreochromis</i> sp. 1	tilapia	Cichlidae	1	2	0
<i>Oreochromis</i> sp. 2	tilapia	Cichlidae	0	3	0
<i>Oreochromis</i> sp. 3	tilapia	Cichlidae	1	0	0
<i>Ambassis kopsii</i>	Singapore glassy perchlet	Ambassidae	8	33	0
<i>Ambassis urotaenia</i>	Banded-tail glassy perchlet	Ambassidae	173	0	0
<i>Ambassis interrupta</i>	Long-spined glass perchlet	Ambassidae	2	0	0
<i>Scatophagus argus</i>	Spotted scat	Scatophagidae	2	0	0
<i>Selenotoca multifasciata</i>	Spotbanded scat	Scatophagidae	3	0	0
<i>Glossogobius bicirrhosus</i>	Bearded flathead goby	Gobiidae	11	0	0
<i>Psammogobius biocellatus</i>	Sleepy goby	Gobiidae	44	0	0
<i>Glossogobius giuris</i>	Tank goby	Gobiidae	5	0	0
<i>Acentrogobius caninus</i>	Tropical sand goby	Gobiidae	9	0	0
<i>Oligolepis fasciatus</i>	Platband goby	Gobiidae	2	0	0
<i>Oligolepis acutipennis</i>	Sharptail goby	Gobiidae	14	0	0
<i>Amblygobius albimaculatus</i>	Butterfly goby	Gobiidae	1	0	0
<i>Amblygobius phalaena</i>	Whitebarred goby	Gobiidae	1	0	0
<i>Yongeichthys criniger</i>	Horny goby	Gobiidae	77	1	0
<i>Acentrogobius viridipunctatus</i>	Spotted green goby	Gobiidae	2	0	0
<i>Acentrogobius caninus</i>	Tropical sand goby	Gobiidae	3	0	0
<i>Synechogobius ommaturus</i>	Asian freshwater goby	Gobiidae	48	0	0
<i>Rhinogobius davidi</i>	Stream goby	Gobiidae	1	0	0

to be continued

Continued from Table A1

Species	Common name	Family	Number of individuals		
			Mangrove	Seagrass bed	Coral reef
<i>Chaenogobius annularis</i>	Forktongue goby	Gobiidae	3	0	0
<i>Exyrias puntang</i>	Puntang goby	Gobiidae	6	0	0
<i>Favonigobius reichei</i>	Indo-Pacific tropical sand goby	Gobiidae	15	0	0
<i>Oxyurichthys ophthalmonema</i>	Eye-brow goby	Gobiidae	200	0	0
<i>Oxyurichthys tentacularis</i>	Tentacle goby	Gobiidae	108	0	0
<i>Oxyurichthys cornutus</i>	Horned tentacle goby	Gobiidae	8	0	0
<i>Cryptocentroides insignis</i>	Insignia prawn-goby	Gobiidae	0	1	0
<i>Amblychaeturichthys hexanema</i>	Pinkgray goby	Gobiidae	2	0	0
<i>Taeniamia fucata</i>	Orangelined cardinalfish	Apogonidae	1	0	0
<i>Taeniamia lineolata</i>	Shimmering cardinal	Apogonidae	8	0	0
<i>Ostorhinchus cookii</i>	Cook's cardinalfish	Apogonidae	23	0	0
<i>Salarias fasciatus</i>	Jewelled blenny	Blenniidae	3	0	0
<i>Chaetodon auriga</i>	Threadfin butterflyfish	Chaetodontidae	1	0	0
<i>Chaetodon auripes</i>	Oriental butterflyfish	Chaetodontidae	0	0	6
<i>Eleotris fusca</i>	Dusky sleeper	Eleotridae	2	0	0
<i>Eleotris melanosoma</i>	Broadhead sleeper	Eleotridae	3	0	0
<i>Valenciennea</i> sp. 1	Sleeper	Eleotridae	1	0	0
<i>Ophiocara porocephala</i>	Northern mud gudgeon	Eleotridae	1	0	0
<i>Butis melanostigma</i>	Black-spotted gudgeon	Eleotridae	1	0	0
<i>Stegastes fasciolatus</i>	Pacific gregory	Pomacentridae	17	0	0
<i>Neoglyphidodon melas</i>	Bowtie damselfish	Pomacentridae	13	0	0
<i>Abudefduf vaigiensis</i>	Indo-Pacific sergeant	Pomacentridae	1	0	0
<i>Pomadasys maculatus</i>	Saddle grunt	Haemulidae	1	1	0
<i>Pomadasys kaakan</i>	Javelin grunter	Haemulidae	3	1	0
<i>Platax orbicularis</i>	Orbicular batfish	Ephippidae	1	0	0
<i>Rastrelliger kanagurta</i>	Indian mackerel	Scombridae	0	1	0
<i>Gymnothorax isingteena</i>	Spotted moray	Muraenidae	2	0	0
<i>Pisodonophis boro</i>	Rice-paddy eel	Ophichthidae	3	0	0
<i>Ophichthus macrochir</i>	Bigfin snake eel	Ophichthidae	1	0	0
<i>Muraenichthys gymnopterus</i>	Snake eel	Ophichthidae	1	0	0
<i>Plotosus lineatus</i>	Striped eel catfish	Plotosidae	4	5	1
<i>Diodon holocanthus</i>	Longspined porcupinefish	Diodontidae	0	0	1
<i>Monacanthus chinensis</i>	Fan-bellied leatherjacket	Monacanthidae	17	5	0
<i>Stephanolepis cirrhifer</i>	Threadsail filefish	Monacanthidae	0	1	2
<i>Triacanthus biaculeatus</i>	Short-nosed tripodfish	Triacanthidae	19	24	0
<i>Lactoria cornuta</i>	Longhorn cowfish	Ostraciidae	1	0	0
<i>Takifugu alboplumbeus</i>	Pufferfish	Tetraodontidae	3	0	0
<i>Synodus variegatus</i>	Variegated lizardfish	Synodontidae	2	0	1
<i>Trachinocephalus myops</i>	Snakefish	Synodontidae	2	0	0
<i>Minous trachycephalus</i>	Striped stingfish	Synanceiidae	1	0	3
<i>Onigocia macrolepis</i>	Notched flathead	Platycephalidae	1	0	0
<i>Scorpaenopsis neglecta</i>	Yellowfin scorpionfish	Scorpaenidae	1	0	0
<i>Scorpaenodes guamensis</i>	Guam scorpionfish	Scorpaenidae	0	0	3
<i>Mugil cephalus</i>	Flathead grey mullet	Mugilidae	314	360	89
<i>Megalops cyprinoides</i>	Indo-Pacific tarpon	Megalopidae	3	0	0
<i>Elops machnata</i>	Tenpounder	Elopidae	7	1	1
<i>Hyporhamphus dussumieri</i>	Dussumier's halfbeak	Hemiramphidae	6	1	0
<i>Hypoatherina tsurugae</i>	Silverside	Atherinidae	2	4	0
<i>Fistularia commersonii</i>	Bluespotted cornetfish	Fistulariidae	0	0	1