Scientific Research Publishing

Open Journal of Marine Science, 2019, 9, 49-63
http://www.scirp.org/journal/ojms
ISSN Online: 2161-7392
ISSN Print: 2161-7384

Characteristics of the Fish Assemblage in the Intertidal Salt Marsh and Mudflat of the Yangtze Estuary

Heng Zhang[1,2,3,4], Jingyu Ye[1,2,3], Xuehui Wang[2], Shenglong Yang[1]

[1]East China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Shanghai, China
[2]Key Laboratory of Open-Sea Fishery Development, Ministry of Agriculture, Guangzhou, China
[3]College of Marine Sciences, Shanghai Ocean University, Shanghai, China
[4]State Key Laboratory of Estuarine and Coastal Research, Shanghai, China
Email: zhangziqian0601@163.com

How to cite this paper: Zhang, H., Ye, J.Y., Wang, X.H. and Yang, S.L. (2019) Characteristics of the Fish Assemblage in the Intertidal Salt Marsh and Mudflat of the Yangtze Estuary. *Open Journal of Marine Science*, **9**, 49-63.
https://doi.org/10.4236/ojms.2019.91004

Received: January 2, 2019
Accepted: January 22, 2019
Published: January 25, 2019

Abstract

During July 2015 to June 2016, two permanent sampling sites were established in *Scirpus mariqueter* salt marsh and its adjacent mudflat on the intertidal zone of Chongming-Dongtan in the Yangtze Estuary. Based on monthly trap net surveys of fishes, the characteristics of the fish assemblages in the different subhabitats, including the salt marsh and mudflat, and the monthly variations were analyzed. A total of 19 species of fishes were found belong to 12 Families. The characteristics including the dominant fish species were different in these two subhabitats. 18 species of fish were recorded in the mudflat, of which the dominant species were the *Coilia ectenes*, *Pelteobagrus nitidus* and *Lateolabrax maculatus*. Ten species of fish were recorded in the salt marsh of which the dominant species were the *Coilia ectenes*, *Saurogobio dumerili*, *Liza haematocheila*, *Lateolabrax maculatus* and *Acanthogobius ommaturus*. *Pelteobagrus nitidus* prefers to use the mudflat, while *Lateolabrax maculatus* and *Liza haematocheila* prefer to use the salt marsh. There was a significant difference in the monthly variation of fish abundance between the fish abundance of salt marsh and mudflat, while there was no significant difference in fish biomass. The Simpson index of the fish of the mudflat was significantly higher than that of the salt marsh, while the Margalef index and the Pielou index were lower than the salt marsh. The community can be divided into two groups: winter-spring (A) and summer-autumn (B). The abundance of fish in the mudflat and the salt marsh show a very significant correlation with the water temperature (r = 0.773, 0.830, respectively) and a significant correlation with the water salinity(r = 0.654, 0.648, respectively). The abundance of fish in mudflat and salt marsh are both significantly correlated with water temperature and salinity. The abundance of fish of the mudflat (r = 0.470, P > 0.05) is more related to the highest submerged depth than of the salt marsh (r = 0.087, P > 0.05).

Keywords

Yangtze Estuary, Intertidal Zone, Subhabitat, Fish Assemblage, Species Richness

1. Introduction

The intertidal wetland in the estuary is the area where the river runoff flows into the ocean; it has both freshwater and saltwater habitats, which results in its diversification of topographical features and differences of habitat [1]. The different subhabitats of the intertidal wetlands in the estuary provide diverse habitat types for living organisms (such as fish, benthos and plants), the most typical of which are the mudflat, creek and salt marsh [2] [3]. Many studies have shown that increasing habitat heterogeneity can enhance diversity and key functions, yet research is limited on how different subhabitats affect higher trophic levels [4] [5] [6] [7].

The intertidal wetland in the estuary is an important habitat for fish, and the fishery productivity of the estuary is supported by the detrital food chain under the action of salt marshes [7] [8]. Most of the important coastal economic fish have dependence of estuary, and some of their life history is completed in the shallow water area of estuary [8] [9]. The intertidal wetland in the estuary provides many food organisms and prey refuges for fish, and it is also a necessary passage for anadromous migration and seaward migration of fish [10]. In the past ten years, humans have gradually realized that the estuary intertidal wetland is the area where fish are fed as food, avoid predator and breeding offspring, and have powerful supporting function for the estuary and coastal fishery.

The Yangtze River estuary is a very large silt estuary with typical salt marsh wetlands in the world [11]. Domestic scholars' research on the use of intertidal zone in the Yangtze River estuary mainly focuses on its species distribution, fauna composition, biodiversity, spatial and temporal distribution [9] [12] [13] [14]. Zhang and Zhu [15] studied the intertidal wetland in the Yangtze River estuary and found that the abundance of spring fish assemblages in the intertidal zone was different from other seasons, but the difference between summer and autumn was not significant. Yang *et al.* [10] found that the abundance of ecological groups in the intertidal waters of the Yangtze River estuary has significant differences. The summer fish assemblages is affected by marine migratory fish far more than the estuary settled fish, but the opposite is true in autumn fish assemblages. Very few scholars have studied the effects of different subhabitats on fish. For example, Tong, 2012 [11] studied with seasonal differences in the composition of fish assemblages in the different subhabitats of intertidal zone of the Chongming-Dongtan wetland, and found out the fish species, abundance and biomass of the fish assemblage in the mudflat were all higher than those in the salt marsh. Based on monthly survey, authors analyzed the species composition and biodiversity of fish species in intertidal salt marsh zone and mudflat of the Chongming-Dongtan wetland in the Yangtze River estuary, and discussed the value of different subhabitats for fish, thus providing a theoretical basis for protecting and scientific using of the Yangtze River estuary intertidal wetland.

2. Materials and Methods

2.1. Study Area

Study area was located at the southwest area of Chongming-Dongtan wetland that is one of the largest salt marshes in the Yangtze Estuary (namely Tuanjiesha, 31˚27'N - 31˚28'N, 121˚54'E - 121˚55'E). This area is the northern subtropical monsoon climate with an average annual temperature of 15.7˚C, the average annual precipitation is 1123.7 mm, the plant growth season is from April to November. The regional tide is irregular half-day tides, and the average tidal range is 2.5 m, up to 3.5 m. The highest astronomical tide tidal range is 5.2 m. The average tidal salinity is 1 - 3 [16] [17].

2.2. Fish Sampling

Scirpus mariqueter salt marsh (numbered H) and its adjacent mudflat (numbered G) on the intertidal zone of Chongming-Dongtan was surveyed monthly from July 2015 to June 2016. It was sampling twice a day, which sampling time is 12 hours. The sampling net is a long-bag ground bamboo cage net (semi-section in section), the length is 15 m, the width is 0.5 m, the height is 0.4 m, the cod-end mesh size is 8 mm, and the representative water area collected by the net is about 200 m^2. The structure is particularly beneficial for the sampling of the demersal fish (such as Gobioidei) and other swimming organisms in the intertidal subhabitats, which are not easily broken by surf or wind waves in the intertidal zone [18]. All the fish samples were taken back to the laboratory for analysis. The excess water of the body surface was absorbed by absorbent paper, the body mass was weighed (accurate to 0.1 g), and the standard body length of each fish was recorded (the standard length, SL) is taken as the body length of the fish (accurate to 0.1 mm). The species of the fish samplings were identified by reference to the literature [19] [20]. The salinity (accurate to 0.1‰) and the water temperature (accurate to 0.1˚C and the water depth of the monitoring station (accurate to 0.1 m) were measured during the day and night tide floods.

2.3. Date Analyze

We used Simpson index (D), Shannon-Wiener index (H') and Pielou index (J') [21] [22] to analyze the biodiversity of fish assemblages. The Berger-parker index (Y) is used as a characterization of species dominance (Xu & Chen, 1989;

Tang *et al.* 2016). SPSS 17.0 was used for variance analysis and Pearson correlation coefficient. One-way ANOVA was used to analyze the differences in diversity and biomass of fish in different subhabitats. From December to February of the next year, it is winter, March to May is spring, June to August is summer, and September to November is autumn. Pearson correlation coefficient was used to analyze the correlation between monthly fish abundance and environmental factors. The correlation of fish composition in different habitats in different habitats was analyzed by Bray-Curtis and non-Metric Multidimensional Scaling (nMDS) with Primer V5.0. All cluster analysis is based on the distance between the samples. The Bray-Curtis distance is the most commonly used indicator for the difference between the two communities. Most ecologists like to use this indicator to characterize the differences between the two communities. After the four-square root transformation of the abundance data of the corresponding species, the Bray-Curtis similarity coefficient is calculated, and then the similarity matrix is constructed. On this basis, hierarchical clustering and nMDS analysis are performed. The advantages and disadvantages of the nMDS results are measured by Stress. It is generally considered that when St << 0.2, it can be represented by the two-dimensional dot diagram of nMDS, and the graph has a certain explanatory meaning; when Stress < 0.1, it can be considered as a good arrangement, Stress < 0.05, is considered to be very representative [23]. Because of the natural complementarity of these two methods, they can be an effective tool for analyzing biotic community data, and verify the correctness of each other. We also use Primer V5.0 for Similarity percentages-species contribution (SIMPER) to analyze the average contribution rate of the species to Average similarity within group and Average dissimilarity between groups.

3. Result

3.1. Survey Environment

During the investigation, the water temperature showed a seasonal change (**Figure 1**). The water temperature gradually increased from March to August. The highest recorded temperature in August was 33.1˚C. The temperature in September-February was gradually decreased. The lowest temperature in February was only 3.4˚C. The annual fluctuation of salinity is relatively small, and the salinity is lower than 1 in May to September, and the salinity is gradually increased from autumn to winter (**Figure 1**). The highest value in January is 4.5. There was no significant difference in the maximum of submerged depth between the mudflat and the salt marsh (T test, $P > 0.05$). The maximum of submerged depth of the two habitats was the lowest in July, and it was relatively high from August to November.

3.2. Species Composition and Diversity

A total of 19 species of fish were recorded in this survey, belonging to 12 families, as shown in **Table 1**. Among them, the species of Cyprinidae (4 species) and

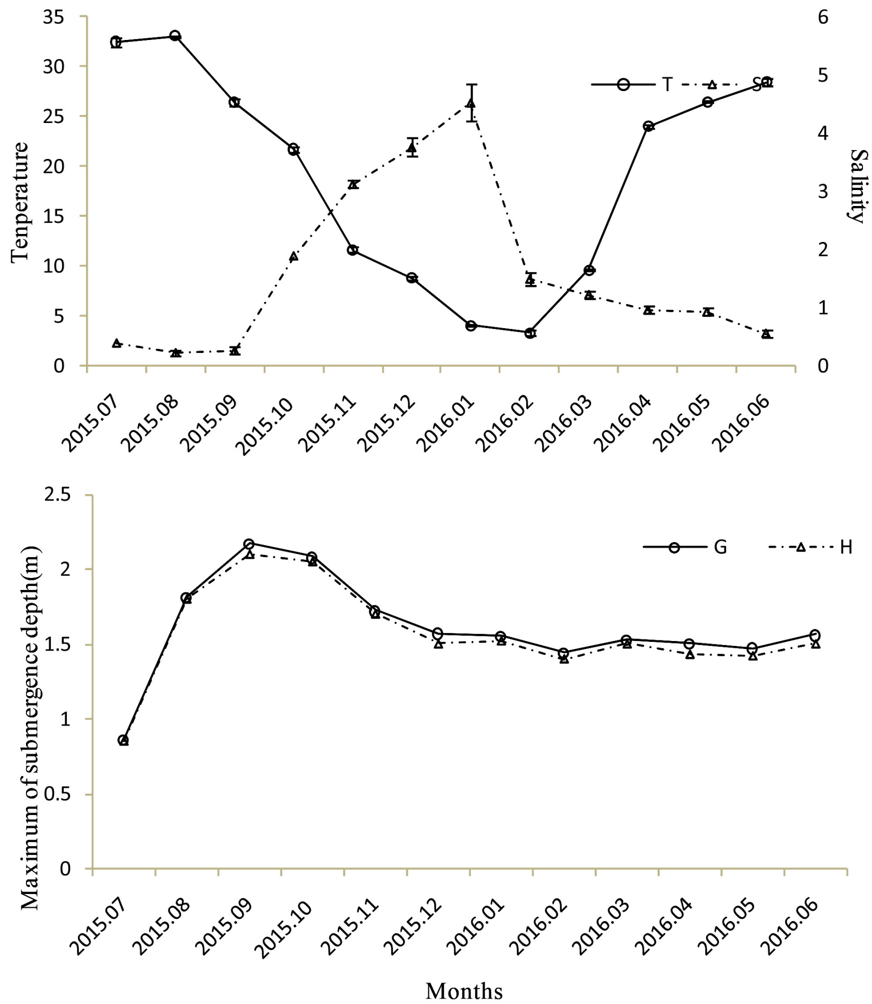

Figure 1. Monthly changes of the water temperature, salinity and maximum of submergence depth in 2 subhabitats (T, Temperature; S, Salinity; G, the Mudflat; H, the Salt marsh).

Gobiidae (4 species) were the most, Mugilidae (2 species) came second, and the other families have only one species. There are significant differences in fish assemblages and dominant species in the intertidal salt marsh zone and adjacent mudflat. A total of 18 species of fish were recorded in the mudflat, belonging to 12 families. The dominant species were *Pelteobagrus nitidus*, *Lateolabrax maculatus* and *Coilia ectenes*. A total of 10 species of fish were recorded in the salt marsh zone, belonging to 6 families. The dominant species were *Lateolabrax maculatus*, *Liza haematocheila*, *Acanthogobius ommaturus*, *Coilia ectenes* and *Saurogobio dumerili*. The proportion of fish species in the mudflat and salt marsh is 9:5. Except for *Periophthalmus magnuspinnatus*, all fish species in the salt marsh are recorded in the mudflat.

From the seasons, the species of fish in the two subhabitats were the least in winter, with only two species. In the summer and autumn, the fish species of the mudflat were the most, reaching 12 species, while the salt marsh were recorded

Table 1. Season changes of abundance and species of fish (G, the Mudflat; H, the Salt marsh, Y, Berger-parker index).

Species	Spring		Summer		Autumn		Winter		Y	
	G	H	G	H	G	H	G	H	G	H
Fish										
Engraulidae										
Coilia ectenes	1	1	73	13	2	1			0.021	0.027
Anguillidae										
Anguilla japonica				1	1				<0.001	<0.001
Cyprinidae										
Hemiculter bleeleri	1								<0.001	
Pseudolaubuca engraulis			1	5					<0.001	0.011
Saurogobio dumerili	1	7	17	9	5				0.017	0.021
Carassius auratus	1	1		1	2	2			0.001	0.007
Bagridae										
Pelteobagrus nitidus	86		7					7	0.085	
Mugilidae										
Liza haematocheila	1	10	5	7	3	3	1	2	0.007	0.107
Liza affinis			1	4		1		1	<0.001	0.011
Polynemidae										
Eleutheronema tetradactylum					1				<0.001	
Serranidae										
Lateolabrax maculatus	2	10	29	32	2	2	1		0.034	0.137
Gobiidae										
Acanthogobius ommaturus			14	12	4	7			0.013	0.051
Periophthalmus magnuspinnatus	3									0.002
Boleophthalmus pectinirostris		2		1	1	1			<0.001	
Scartelaos histophorus					2				<0.001	
Cynoglossidae										
Cynoglossus gracilis	1		1		3				0.004	
Tetraodontidae										
Takifugu obscurus			2						<0.001	
Hemiramphidae										
Hyporhamphus intermedius			1						<0.001	
Salangidae										
Salanx ariakensis			1						<0.001	
Total species abundance	9	6	12	10	12	7	2	2		

10 species in summer and 7 species in autumn. Generally speaking, the Simpson index (Figure 2) of the fish assemblage the mudflat was significantly higher than that in the salt marsh, while the Margalef index and the Pielou index of the fish assemblage in the salt marsh were higher than those in the mudflat. There are significant inter-monthly changes in fish assemblage biodiversity index in two subhabitats. As we can see from Figure 3, the Shannon-Wiener index and Simpson index of the fish assemblage in the mudflat are higher than that of the salt marsh, but there is no corresponding relation.

3.3. Abundance and Biomass Monthly Variation

In terms of monthly changes in fish abundance, from December to March, the fish abundance in the mudflat and the salt marsh was less than 5 (Figure 4). The highest abundance of fish in the mudflat was in September, at 224. The highest abundance of fish in the salt marsh occurred in August, at 47, which is about 1/5 of the abundance of fish in the mudflat. There was significant difference in fish abundance between the two sub-habitats (ANOVA, $P < 0.05$). In terms of fish biomass, the biomass of the fish in the mudflat is small fluctuation, while the fluctuation of the salt marsh is larger (Figure 5). From December to March, fish biomass in the mudflat and the salt marsh were lower continuously. The highest abundance of fish in the mudflat was in May, which was 605.2 g. The highest abundance of fish in the salt marsh was in April, which was 638.6 g. There was no significant difference in fish biomass between the two sub-habitats (ANOVA, $P > 0.05$).

There are some differences between the Bray-Curtis similarity cluster (Figure 6) and the nMDS (Figure 7) (Stress = 0.14, with certain reference value) of monthly fish abundance in different subhabitats. Because there is no fish was recorded in the mudflat in January, so we have to remove the date of it when performing nMDS. Can be seen from Bray-Curtis similarity cluster, in addition to the fish of the salt marsh in October and the fish of the mudflat in March, the

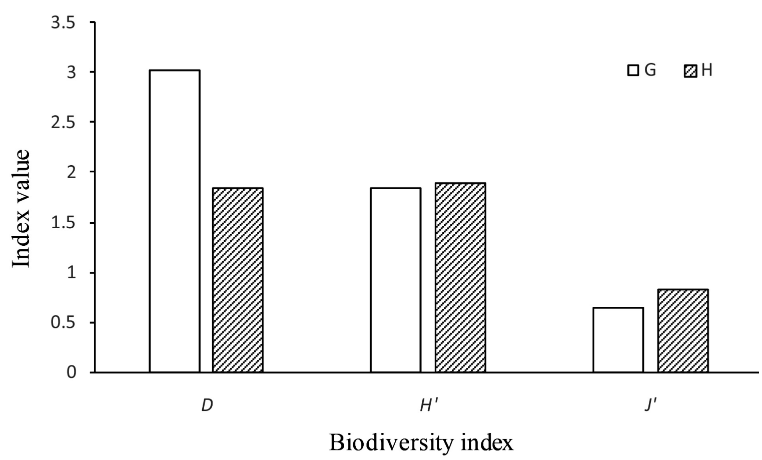

Figure 2. Biodiversity of fish in two subhabitats (G, the Mudflat; H, the Salt marsh).

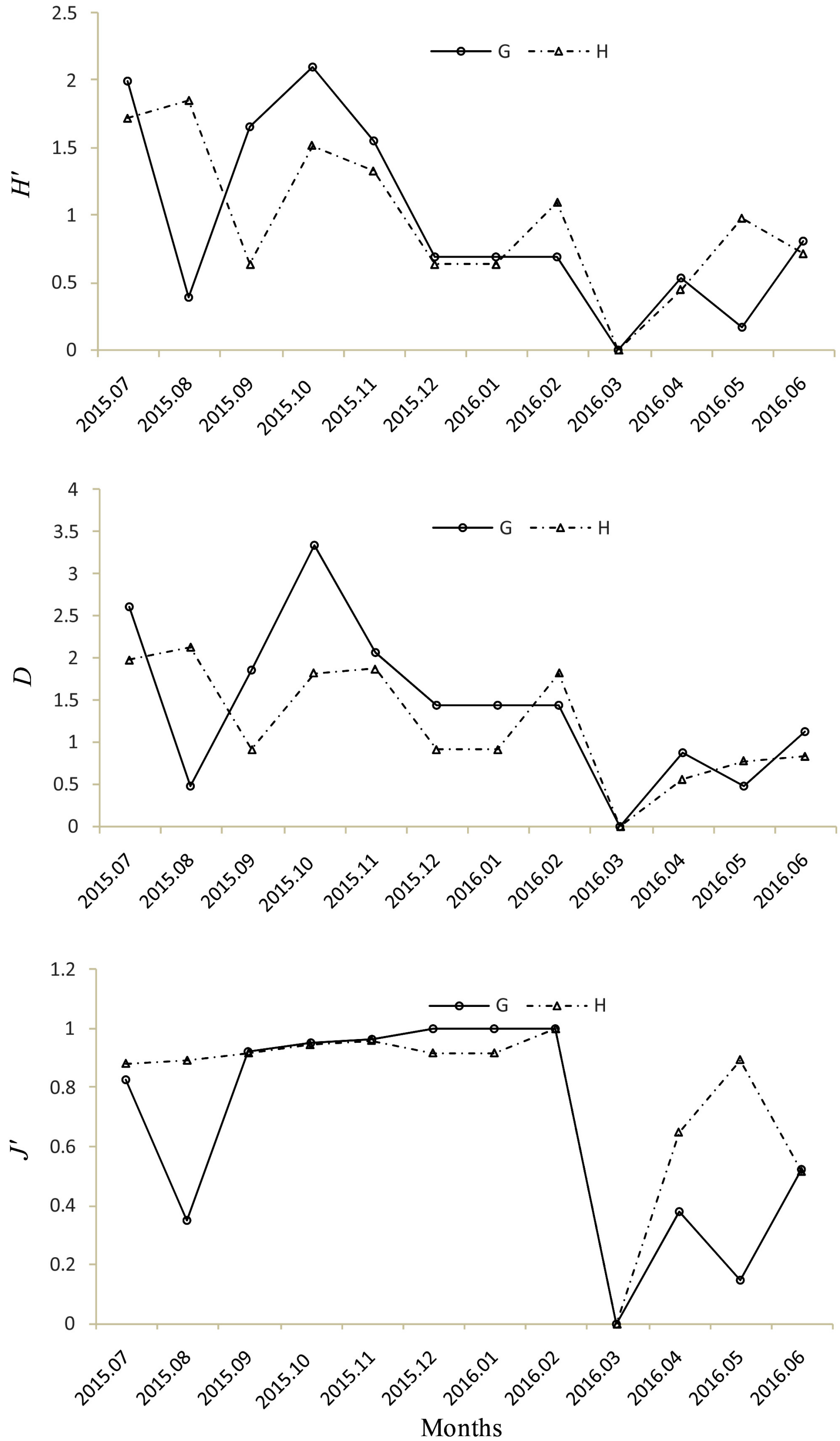

Figure 3. Biodiversity monthly change of fish assemblage in two subhabitats.

monthly fish abundance in different subhabitats can be roughly divided into summer-autumn (fish abundance in November-February of the mudflat and fish abundance in October-May of the salt marsh, group A) and winter-spring (fish

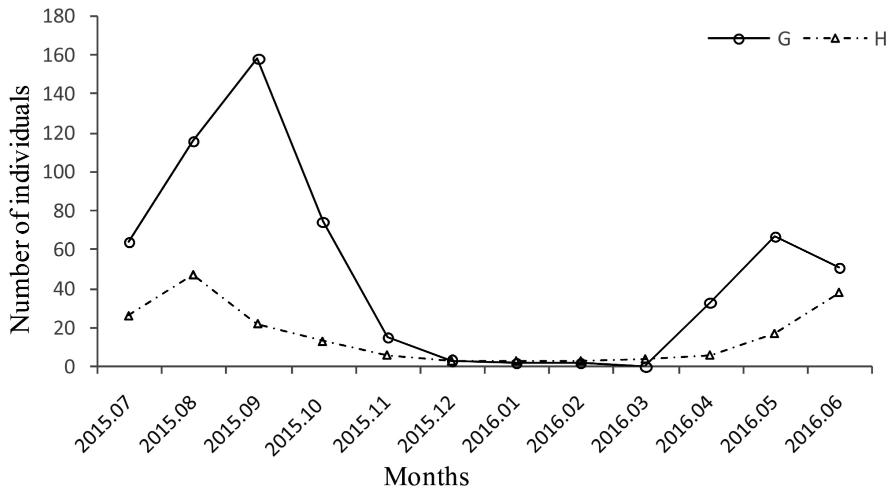

Figure 4. Monthly changes of fish abundance in two subhabitats (G, the Mudflat; H, the Salt marsh).

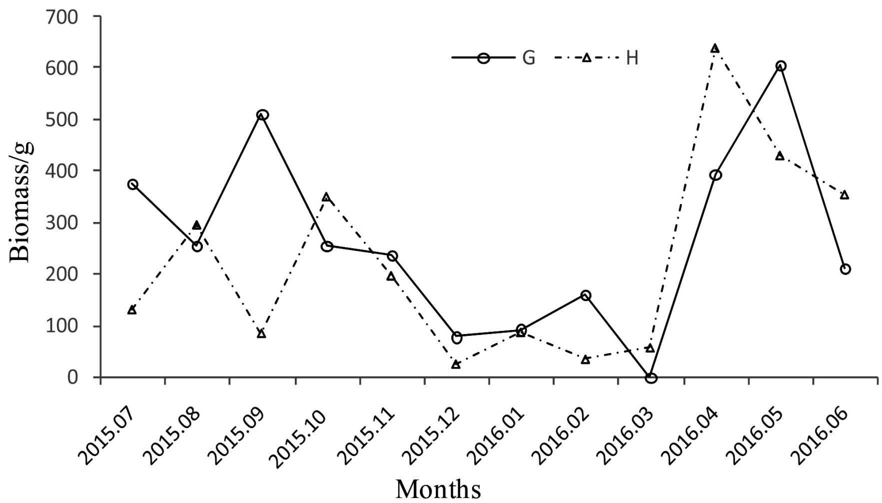

Figure 5. Monthly changes of fish biomass in two subhabitats (G, the Mudflat; H, the Salt marsh).

abundance in April-October of the mudflat and fish abundance in July-August of the salt marsh, group B) two groups. The nMDS shows that the similarity of fish in the salt marsh is higher in each month, while that in the mudflat is lower.

The average dissimilarity of fish species composition between groups A and B was 30.95%, and the cumulative contribution rate of 9 fish species to average dissimilarity was >90% (**Table 2**). The main contribution rate was from *Pelteobagrus nitidus*, *Coilia ectenes*, *Lateolabrax maculatus*, etc. The average similarity within group A was 33.09, and the contribution rate of *Liza haematocheila*, *Lateolabrax maculatus* and *Carassius auratus* to the average similarity of group A was over 90%. The average similarity within group A was 22.13, and the cumulative contribution rate of the six species of fish, such as *Pelteobagrus nitidus*, *Saurogobio dumerili* and *Coilia ectenes*, to the average similarity was over 90%.

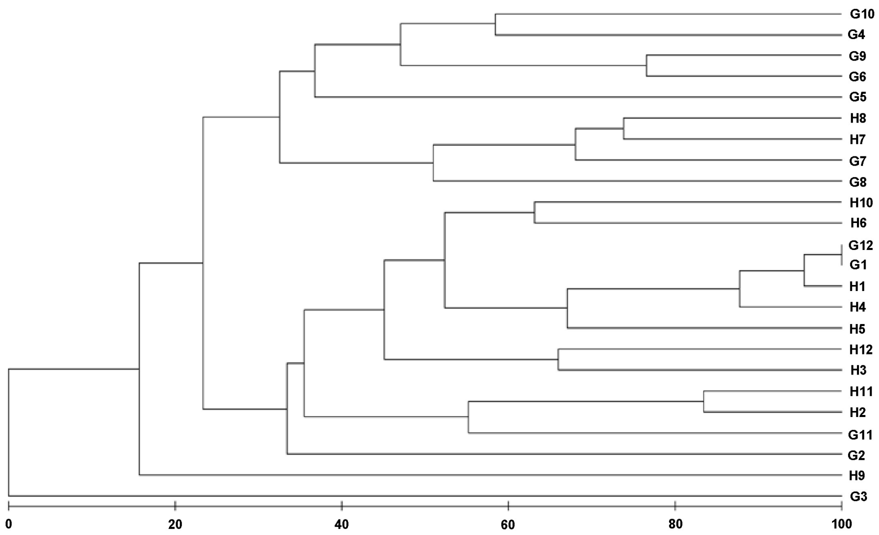

Figure 6. Bray-Curtis similarity cluster on abundance of fish in two subhabitats (G1-G12, Monthly fish abundance of the mudflat; H1-H12, Monthly fish abundance of the salt marsh).

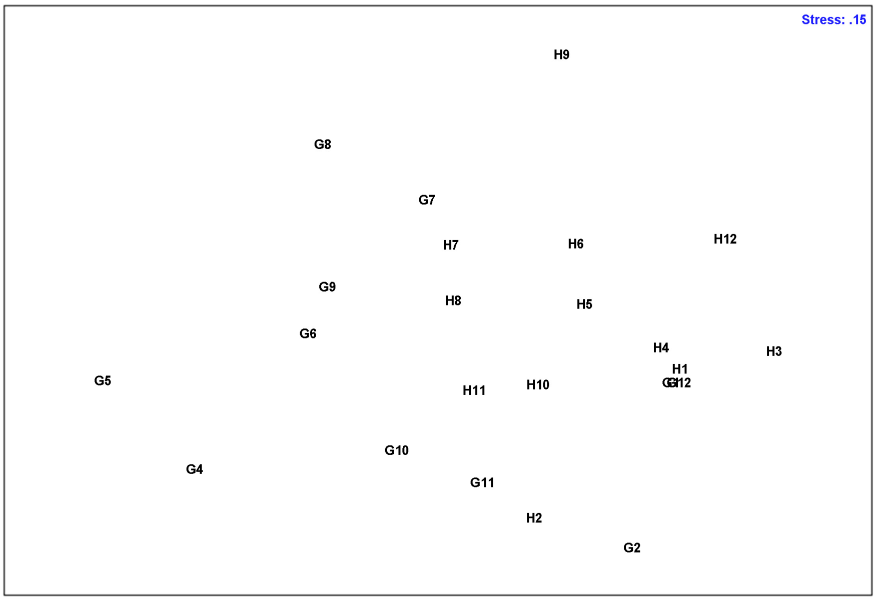

Figure 7. nMDS on abundance of fish in two subhabitats (G1-2 and G4-G12, Monthly fish abundance of the mudflat; H1-H12, Monthly fish abundance of the salt marsh).

3.4. Analysis of the Factors Affecting

It can be seen from Table 3 that the densities of fish species in the two subhabitats show a very significant correlation with the water temperature and a significant correlation with the water salinity. The abundance of fish in 2 subhabitats are both closely correlation with the maximum of submerged depth. The abundance of fish in the mudflat is highly correlated with the maximum of submerged depth, with an r value of 0.470 ($P > 0.05$) and an r value of only 0.087 ($P > 0.05$) in the salt marsh.

Table 2. Fish species which contributed >90% accumulative similarity within a group and dissimilarity between group A and B.

Species	A (33.09)		B (22.13)		A-B (86.64)	
	AS	C%	AS	C%	AD	C%
Pelteobagrus nitidus			5.7	25.74	23.86	27.54
Coilia ectenes			4.59	20.75	17.28	19.95
Lateolabrax maculatus	8.28	25.04	2.16	9.78	12.59	14.54
Saurogobio dumerili			4.66	21.08	9.71	11.21
Acanthogobius ommaturus			2.30	10.40	7.06	8.14
Liza haematocheila	20.43	62.41	1.04	4.68	4.33	5.00
Pseudolaubuca engraulis					2.29	2.64
Cynoglossus gracilis					1.78	2.05
Carassius auratus	2.74	8.30				

AS: Average similarity within group; AD: Average dissimilarity between groups; C: Contribution of similarity within group and dissimilarity between groups by fish species.

Table 3. Pearson Correlation Coefficient between abundance and environment factor.

Species	Environmental factor		
	T	S	MH
G	0.773**	0.654*	0.470
H	0.830**	0.648*	0.087

T: Temperature; S: Salinity; MH: Maximum of submergence depth; *P < 0.05; **P < 0.01

4. Discussion

Many studies have shown that fish species and their abundance are generally declining from the mudflat to the salt marsh [9] [11]. Tong, 2012 [11] found in northeast area of Chongming-Dongtan, that the fish species, abundance, biomass and biodiversity index (Simpson index, Shannon-Wiener index and Pielou index) of the fish assemblage in the mudflat were higher than those in the salt marsh. The study found that the species, abundance and biomass of the fish in the mudflat were higher than those in the salt marsh, which is similar to the research results of Tong 2012 [11]. However, the fish assemblage in the mudflat has a higher Shannon-Wiener index, the richness index and evenness index are lower than the salt marsh. This may be due to that the southern part of Yangtze river has low salinity, while the northern part affected by seawater intrusion and high salinity [24]. França and Cabral, 2009 [25] have also found that the species of fish in the coastal intertidal mudflat of Portugal are higher than those in the salt marsh, but the abundance of fish is lower than that of the salt marsh. This may because some of the fish species were particularly associated with certain habitat types, which might indicate that each estuarine habitat may be related with specific fish assemblages regardless the estuary. Carles *et al.*, 2008 [26] found that the abundance of commercial fish of *Aphanius iberus* in salt marshes on the Mediterranean coast was higher in the distribution of salt marsh than in other habitats, but the abundance of juvenile fish was similar in different habitats. This study also found that the dominance (Y) of *Pelteobagrus nitidus* in the mudflat reached 0.085, but it was not recorded in the salt marsh; the dominance of *Lateolabrax maculatus* in the salt marsh reached 0.137, and that in the mudflats was 0.034.

In terms of monthly changes in fish assemblages, some studies have shown that fish abundance in the Yangtze River estuary has obvious seasonal variation characteristics, and the species and abundance of fish in winter are the lowest, with the increase of spring water temperature and fish abundance, and those are higher in Summer [27] [28]. Studies have shown that seasonal changes in intertidal fish assemblages can be divided into three community types in winter, spring-summer and autumn [27]. Another study showed the intertidal fish community can be divided into three community types in spring-summer-autumn and winter [29]. The study found that the densities of fish in these two subhabitats were extremely low during the end of winter to the beginning of spring, and then increased with the water temperature. The abundance of fish in these two subhabitats reached the highest in August and September respectively. The community can be divided into two groups: winter-spring (A) and summer-autumn (B). The species that cause differences in fish communities between groups A and B are mainly *Coilia ectenes*, *Lateolabrax maculatus*, *Acanthogobius ommaturus*, *Saurogobio dumerili*, *Liza haematocheila*, *Pelteobagrus nitidus* and *Carassius auratus*. These fish are mainly ecological groups such as estuarine brackish water species, estuarine transitional species and marine fish. Juveniles of most species enter the estuarine intertidal wetlands seasonally or temporarily for feeding or hiding [27] [30]. This suggests that seasonal changes of fish assemblages are related to the composition.

Studies have shown that there are significant monthly changes of the corresponding ratios of fish in the mudflats and the salt marsh, but the relevance and difference between the two subhabitats are not significant [11]. The research results in this paper are different from the existing research. The study found that the abundance of fish in the mudflats from April to October was significantly higher than that in the salt marsh, and there was a significant difference in fish abundance between the two subhabitats. This probably demonstrates the effects of abiotic factors such as water temperature and salinity and biological factors such as vegetation and zoobenthos in different waters of estuary intertidal wetlands cause differences in fish assemblage composition. From the Bray-Curtis and the nMDS, the similarity of fish in the salt marsh is higher in each month, while the similarity between fish in the mudflat is lower. It may be because the mudflat environment is greatly affected by environmental factors such as temperature and tide, and the salt marsh can provide better protection for the fish assemblage. The Pearson correlation coefficient shows the correlation between the fish abundance of the mudflats and the maximum of submerged depth (r =

0.470) is higher than that of the salt marsh (r = 0.087), which may indicate that when the water depth of the mudflat is higher, it can provide better condition for feeding and hiding, then increasing the abundance of fish.

Acknowledgements

We thank the World Wide Fund for Nature for permission to do research work in protected areas under their jurisdiction. This study was financially supported by the Open Fund of the State Key Laboratory of Estuarine and Coastal Research (SKLEC-KF201805), the National Natural Science Foundation of Shanghai (18ZR1449800), the Fundamental Research Funds for the Central Universities (2015M07) and Open Fund of the Key Laboratory of Offshore Fisheries Development, Ministry of Agriculture (LOF 2018-01). And we would not have been done without the help from many people.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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