青岛近岸水域春、秋季鱼类群落结构

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摘要:根据 2004 年春、秋季渔业资源底拖网调查数据,应用单元和多元统计方法分析了青岛近岸水域春、秋季鱼类群落结构。春、秋季调查分别渔获 31、32 种鱼类,平均每网渔获量分别为 7.36 kg/h 和 2.99 kg/h,优势种类主要包括赤鼻棱鳀 *Thrissa chefuensis*、大泷六线鱼 *Hexagrammos otakii*、方氏云鳚 *Enedrias fangi*、黄鳍刺鰕虎鱼 *Acanthogobius flavimanus*、细纹狮子鱼 *Liparis tanakai* 和长条蛇鲻 *Saurida elongata* 等。聚类分析表明,春、秋季青岛近岸水域鱼类群落都可划分为 3 个站位组,分别对应于北部、中部和南部调查水域。不同站位组的优势种组成变化较大,不同站位组间种类组成差异显著。分析了造成站位组内种类组成相似的特征种和造成不同站位组间相异的分歧种。不同站位组的特征种不同。赤鼻棱鳀、大泷六线鱼、黄鳍刺鰕虎鱼、方氏云鳚、星康吉鳗 *Conger myriaster*、角木叶鲽 *Pleuronichthys cornutus* 和细纹狮子鱼是春季所有站位组间的分歧种;赤鼻棱鳀、白姑鱼 *Argyrosomus argentatus*、大泷六线鱼、带鱼 *Trichiurus lepturus*、短吻红舌鳎 *Cynoglossus joyneri*、方氏云鳚、细条天竺鱼 *Apogonichthys lineatus*、小黄鱼 *Pseudosciaena polyactis* 和矛尾鰕虎鱼 *Chaeturichthys stigmatias* 是秋季所有站位组间的分歧种。大多数特征种也是不同站位组间的分歧种,主要是由于这些种类的数量分布的空间变化造成的。青岛沿海鱼类群落结构存在明显的时空异质性。

关键词:鱼类群落;聚类分析;种类组成;种类多样性;青岛近岸水域

文章编号:1000-0933(2007)10-4224-09　**中图分类号**:Q145,Q178.1,Q958,Q959.4　**文献标识码**:A

Fish community structure in the coastal waters off Qingdao in spring and autumn

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***Acta Ecologica Sinica*, 2007, 27(10): 4224 ~ 4232.**

Abstract: Based on the data collected from the bottom otter trawl surveys in the coastal waters off Qingdao in spring and autumn 2004, the fish community structure was analyzed using univariate and multivariate methods. The results showed that 31 and 32 fish species were caught in spring and autumn surveys, respectively. The mean catches per haul were at 7.36 kg/h in spring and 2.99 kg/h in autumn. The dominant species mainly consisted of chefoo thryssa *Thrissa chefuensis*, fat greenling *Hexagrammos otakii*, blenny *Enedrias fangi*, yellowfin goby *Acanthogobius flavimanus*, snailfish *Liparis tanakai* and shortfin lizardfish *Saurida elongata* etc. Three station groups were identified for both spring and autumn, being located at the northern, central and southern part of the survey waters, respectively. The dominant species varied in different station groups in spring and autumn. There were significant differences in species compositions among different station

基金项目:国家重点基础研究发展规划(2005CB422306);青岛市海洋功能区划项目;中国海洋大学引进人才科研启动基金项目(813759)

收稿日期:2006-09-21;**修订日期**:2007-06-09

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致谢:We would like to thank Professor LIU Qun from Ocean University of China for invaluable comments on the manuscript; Thanks are also given to the faculty members and students from Department of Fisheries Science, College of Fisheries, Ocean University of China, and crew for their assistances in data collection during the surveys; We are grateful to the anonymous reviewers for their constructive comments on our manuscript

Foundation item: The project was financially supported by National Key Basic Research Program (No. 2005CB422306); Project of Division of Marine Functional Zonation of Qingdao; Start-up fund from Ocean University of China (No. 813759)

Received date: 2006-09-21; **Accepted date**: 2007-06-09

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groups. The typifying species within station groups and discriminating species most responsible for the dissimilarity between station groups were examined. The typifying species varied between station groups in spring and autumn. In spring, chefoo thryssa, fat greenling, yellowfin goby, blenny, whitespotted conger *Conger myriaster*, frog flounder *Pleuronichthys cornutus* and snailfish were discriminators for all between-groups. In autumn, chefoo thryssa, white croaker *Argyrosomus argentatus*, shortfin lizardfish, fat greenling, hairtail *Trichiurus lepturus*, red tongue sole *Cynoglossus joyneri*, blenny, cardinal fish *Apogonichthys lineatus*, small yellow croaker *Pseudosciaena polyactis* and finespot goby *Chaeturichthys stigmatias* were most responsible for the dissimilarities for all between-groups. Most typifying species also acted as the discriminator between station groups, which was mainly caused by the spatial changes in the abundance of these species. There existed distinct spatiotemporal heterogeneity for the fish community structure in the coastal waters off Qingdao.

Key Words: fish assemblages; hierarchical cluster analysis; species composition; species diversity; coastal waters off Qingdao

Coastal marine ecosystems were the interactive areas of ocean and land, and supported many important fisheries [1,2]. However, they were also among the most extensively affected and threatened aquatic environments, which were caused by both climate changes and human activities [3]. Fisheries were an integral part of human activities on the coast zones. Fishing activities in the nearshore environment had clear impacts on the structure and function of these ecosystems, although other, non-fishing issues also affected these ecosystems [3].

The coastal waters off Qingdao, located in the western Yellow Sea, was part of important spawning, feeding grounds for many economically important species in the waters off southern Shandong Peninsula, and it was also an important fishing ground [3,4]. In spring, the over-wintered fish species in the southern Yellow Sea migrated into the coastal waters off Qingdao for spawning, and the young of the year recruited in autumn. The fish species compositions included most migratory and resident ones in spring and autumn; while being relatively stable in summer and winter [4—6].

Due to overfishing and degraded environments, the abundance of many commercially important species had declined and the species compositions of fish communities had changed in the Yellow Sea [4—7]. These changes would have great impacts on the fisheries in the coastal waters. Considering the depletions of many fish species, stock enhancement programs for some species were important in rebuilding the stocks in the coastal waters off Qingdao. The understanding of spatial distribution of fish species and fish assemblages was fundamental for stock enhancement; it could be used for selecting suitable releasing species within different ecological niches, and it was important for fisheries management and stock enhancement of the coastal fisheries.

The aim of the present study was to describe species composition, community structure and species diversity of fish assemblages in the coastal waters off Qingdao in spring and autumn based on the data collected from the bottom otter trawl surveys.

1　Materials and methods

1.1　Data sources

The data were collected from the bottom trawl surveys conducted in spring (May) and autumn (October) 2004 in the coastal waters off Qingdao. The sampling area (35°25′—36°25′N, 119°55′—121°15′E) and the sampling stations are shown in Fig. 1. 13 stations in spring and 11 out of 13 stations in autumn (excluding stations 11, 13 in autumn) were successfully sampled, respectively. The trawl surveys were conducted in the daytime. The net was towed for 1 hour in duration and the hauling speed was around 3 knots in both surveys. The width and height of the sampling net was 11.5m and 1.6m respectively, with the 20mm stretched mesh size cod-end.

At each haul the fish were identified to species where possible, and the weight and the number of each species were recorded. The catch rates (kg/h) for the species in each haul were used in the data analysis.

1.2 Community structure analysis

The fish species composition was examined using hierarchical cluster analysis based on Bray-Curtis similarity matrices calculated on square-root transformed biomass (kg/h) data [8,9]. One-way analysis of similarity (ANOSIM) was used to examine differences between station groups [9].

Similarity of percentage analysis (SIMPER) was used to identify species that typified station groups, and to find out those species that were most responsible for the discrimination between groups [9,10].

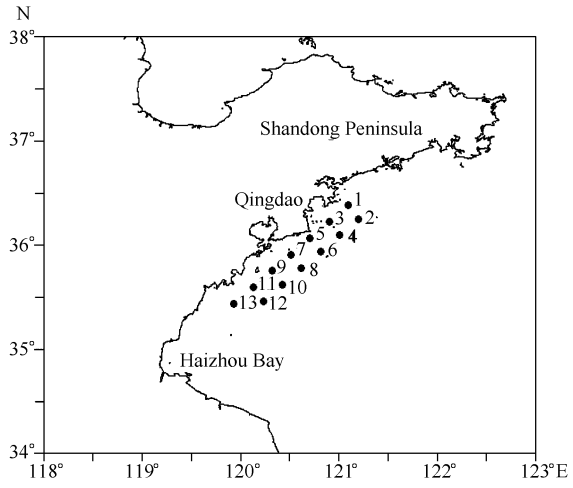

Fig. 1 Survey stations by bottom otter trawl in the coastal waters off Qingdao in spring and autumn

All the multivariate analyses were performed with PRIMER software package, including modules 'CLUSTER', 'SIMPER' and 'ANOSIM' [10,11].

1.3 Species diversity analysis

Since the individual size of fish species differed greatly, the species diversity indices for the fish assemblages in the coastal waters off Qingdao were expressed in terms of relative biomass (kg/h) rather than the number of individuals [2,13]. Species diversity, richness and evenness were calculated for each station group using the Shannon-Wiener diversity index (H'), Margalef's index of species richness and Pielou's evenness index (J') [4]. A *t*-tests proposed by Hutcheson was used to determine whether the diversity indices were significantly different between station groups [5].

2 Results

31 fish species were caught in spring, with mean relative biomass of 7.36 kg/h, including pelagic (2.62 kg/h) and demersal (4.74 kg/h) fishes. The dominant species were chefoo thryssa *Thrissa chefuensis*, accounting for 34.4% of the total biomass, followed by fat greenling *Hexagrammos otakii*, blenny *Enedrias fangi*, yellowfin goby *Acanthogobius flavimanus* and snailfish *Liparis tanakai*.

In autumn, 32 fish species were captured, with mean biomass of 2.99 kg/h, including pelagic fishes of 0.57 kg/h and demersal species of 2.42 kg/h. Chefoo thryssa dominated the catches, accounting for 15.1% of the total catch, followed by shortfin lizardfish *Saurida elongata*, great pipefish *Syngnathus acus*, white croaker *Argyrosomus argentatus* and blenny.

2.1 Fish assemblages

In spring, cluster analysis indicated that 12 of the 13 stations in the coastal waters off Qingdao could be classified to three station groups at the similarity level of 36.3%, with one outlying station (Fig. 2a). In autumn, three station groups were defined at the similarity level of 39.7% (Fig. 2b).

Table 1 listed the number of stations, number of species and top five fish species by biomass for each station group in the coastal waters off Qingdao in spring and autumn. It showed that species composition and dominant species varied in different station groups in spring and autumn.

SG1 mainly distributed in the northern waters, and pelagic fishes accounted for 72.3% of the total catch. SG2 was in the central survey area, with demersal fishes amounting to 91.6% of the total catch. SG3 occupied the

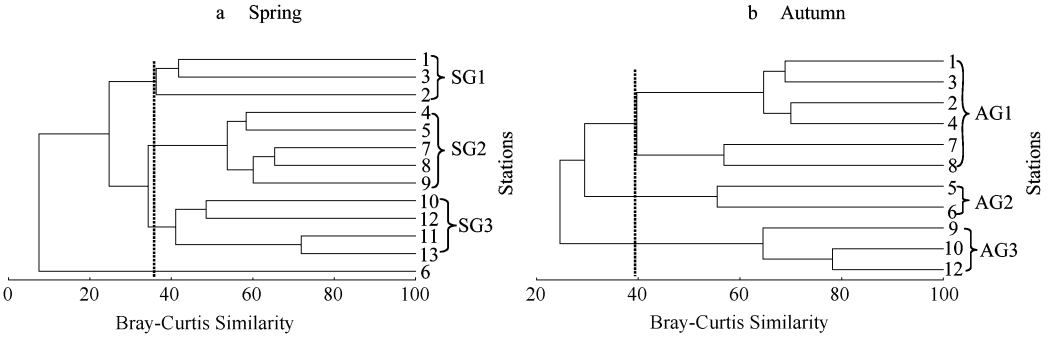

Fig. 2　Cluster analysis for the fish assemblages based on the Bray-Curtis similarity matrices in the coastal waters off Qingdao in spring (a) and autumn (b)

southern waters, and demersal fishes accounted for 91.0% of the total catch.

Table 1　Top five fish species by biomass for each station group in spring and autumn

Species	*W* (g/h)	*P* (%)	*F*
SG1 (6 stations, 19 species)			
Chefoo thryssa *Thryssa chefuensis*	9.82	71.8	3
Yellowfin goby *Acanthogobius flavimanus*	2.35	17.1	3
Snailfish *Liparis tanakai*	0.44	3.2	3
Blenny *Enedrias fangi*	0.38	2.7	3
Anglerfish *Lophius litulon*	0.24	1.8	1
SG2 (5 stations, 22 species)			
Fat greenling *Hexagrammos otakii*	2.40	29.6	5
Blenny *Enedrias fangi*	1.73	21.4	5
Yellowfin goby *Acanthogobius flavimanus*	0.69	8.5	3
Whitespotted conger *Conger myriaster*	0.67	8.3	5
Pricklebacks *Azuma emmnion*	0.54	6.7	5
SG3 (4 stations, 19 species)			
Fat greenling *Hexagrammos otakii*	0.88	33.0	4
Snailfish *Liparis tanakai*	0.70	26.4	3
Richardson's dragonet *Callionymus richardsoni*	0.25	9.4	3
Arrow dragonet *Callionymus sagitta*	0.23	8.6	4
Black caudal dragonet *Callionymus beniteguri*	0.18	6.9	4
AG1 (6 stations, 28 species)			
Chefoo thryssa *Thryssa chefuensis*	0.83	24.2	6
White croaker *Argyrosomus argentatus*	0.48	14.0	6
Small yellow croaker *Pseudosciaena polyactis*	0.31	9.1	5
Shortfin lizardfish *Saurida elongata*	0.25	7.3	6
Finespot goby *Chaeturichthys stigmatias*	0.30	8.8	5
AG2 (2 stations, 17 species)			
Fat greenling *Hexagrammos otakii*	0.15	29.7	2
Hairtail *Trichiurus lepturus*	0.06	11.3	1
Red tongue sole *Cynoglossus joyneri*	0.05	10.0	2
Small yellow croaker *Pseudosciaena polyactis*	0.05	9.2	2
Blenny *Enedrias fangi*	0.03	6.4	2
AG3 (3 stations, 18 species)			
Great pipefish *Syngnathus acus*	1.22	32.0	2
Shortfin lizardfish *Saurida elongata*	1.12	29.5	3
Bluefin searobin *Chelidonichthys kumu*	0.46	12.0	3
Blenny *Enedrias fangi*	0.28	7.5	3
Cardinal fish *Apogonichthys lineatus*	0.24	6.2	3

W, mean catch rate; *P*, percentage of total catch by biomass; *F*, number of stations where fish were caught in the respective station group

AG1, AG2 and AG3 largely distributed in the northern, central and southern waters respectively, and demersal fishes accounted for 71.9%, 94.7% and 95.6% of the total catch in the corresponding station groups.

One-way analysis of similarity (ANOSIM) indicated that there were significant differences in fish species compositions between different station groups in spring (Global $R = 0.854$, $P < 0.001$). Furthermore, all pair-wise comparisons between station groups were significant at the level of $P < 0.002$. There was also a significant difference in species composition between station groups in autumn (Global $R = 0.845$, $P < 0.002$). As for the pair-wise comparisons, there were significant differences between AG1 and AG2, AG1 and AG3 ($P < 0.05$), while there was no significant difference between AG2 and AG3 ($P > 0.05$).

2.2 Explaining the multivariate patterns

Table 2 and Table 3 listed those typifying species, which contributed more than 2% to the within-group similarities and their percentage contributions to the similarities in spring and autumn, respectively. It showed that the typifying species varied between station groups in spring and autumn.

Table 2 Typifying species of each station group in the coastal waters off Qingdao in spring

Species	SG1	SG2	SG3
Chefoo thryssa *Thryssa chefuensis*	15.9	2.9	
Fat greenling *Hexagrammos otakii*		26.8*	30.6*
Arrow dragonet *Callionymus sagitta*			17.7
Red tongue sole *Cynoglossus joyneri*	8.5*		
Blenny *Enedrias fangi*	12.3	18.1*	5.8
Black caudal dragonet *Callionymus beniteguri*			13.6*
Yellowfin goby *Acanthogobius flavimanus*	32.7*	5.6	
Frog flounder *Pleuronichthys cornutus*		3.5	6.8
Jewfish *Johnius belengeri*	9.6*		
Richardson's dragonet *Callionymus richardsoni*			4.9
Pricklebacks *Azuma emmnion*		13.7*	
Snailfish *Liparis tanakai*	13.6*		6.3
Whitespotted conger *Conger myriaster*		16.2*	5.7
Sebaste *Sebastes schlegelii*		3.8	
Average similarity	38.1	56.7	47.4

Asterisk indicated Sim./S. D. >2

Table 4 and Table 5 listed those discriminating species contributing more than 2% to the between-group dissimilarities and their percentage contributions in the coastal waters off Qingdao in spring and autumn, respectively.

In spring, chefoo thryssa, fat greenling, yellowfin goby, blenny, whitespotted conger *Conger myriaster*, frog flounder *Pleuronichthys cornutus* and snailfish, which contributed 54.2%—62.5% to the average dissimilarity, were discriminators for all between-groups (Table 4).

In autumn, chefoo thryssa, white croaker, shortfin lizardfish, fat greenling, hairtail *Trichiurus lepturus*, red tongue sole *Cynoglossus joyneri*, blenny, cardinal fish *Apogonichthys lineatus*, small yellow croaker *Pseudosciaena polyactis* and finespot goby *Chaeturichthys stigmatias*, which contributed 46.9% — 60.2% totally to the average dissimilarity, were discriminators for all between-groups (Table 5).

2.3 Diversity

The diversity indices for different station groups in spring and autumn were listed in Table 6. In spring, although the number of species caught in each station group was similar, the species richness was higher in SG2 and

SG3. The lowest diversity and evenness indices were found at SG1. The biomass distribution among species was very uneven in SG1, and a single species Chefoo thryssa dominated this station group. The other two station groups showed relatively higher species diversity and evenness (Table 6).

Table 3　Typifying species of each station group in the coastal waters off Qingdao in autumn

Species	AG1	AG2	AG3
White croaker *Argyrosomus argentatus*	13.3		
Shortfin lizardfish *Saurida elongata*	7.4		26.3*
Chefoo thryssa *Thryssa chefuensis*	19.4*		
Fat greenling *Hexagrammos otakii*		25.7	
Hairtail *Trichiurus lepturus*	4.8		
Red tongue sole *Cynoglossus joyneri*	3.3	17.4	
Sandwhiting *Sillago sihama*			2.7*
Blenny *Enedrias fangi*	7.1	12.4	11.6*
Scorpionfish *Sebastiscus marmoratus*		9.2	
Great pipefish *Syngnathus acus*			8.9
Jewfish *Johnius belengeri*	4.5		
Pinkgray goby *Chaeturichthys hexanema*	6.8		
Bluefin searobin *Chelidonichthys kumu*			15.5*
Finespot goby *Chaeturichthys stigmatias*	9.3		3.1*
Pricklebacks *Azuma emmnion*		12.7	
Cardinal fish *Apogonichthys lineatus*	3.2		11.2*
Small yellow croaker *Pseudosciaena polyactis*	6.4	17.3	
Whitespotted conger *Conger myriaster*	5.3		
Silver pomfret *Pampus argenteus*			6.2*
Brown barracuda *Sphyraena pinguis*			7.0*
Average similarity	51.5	55.5	69.1

Asterisk indicated Sim./S. D. >2

Table 4　Discriminating species between station groups in the coastal waters off Qingdao in spring

Species	SG1 & SG2	SG1 & SG3	SG2 & SG3
Chefoo thryssa *Thryssa chefuensis*	16.4	19.3	5.7
Fat greenling *Hexagrammos otakii*	13.9*	9.1*	8.9
Yellowfin goby *Acanthogobius flavimanus*	9.8	15.5	7.7
Blenny *Enedrias fangi*	7.2	4.2	11.6
Whitespotted conger *Conger myriaster*	6.8*	2.1	8.1*
Frog flounder *Pleuronichthys cornutus*	4.6	3.1	5.4
Snailfish *Liparis tanakai*	3.8	6.9	6.7
Pricklebacks *Azuma emmnion*	6.9*		7.6*
Sebaste *Sebastes schlegelii*	4.4		5.5
Half-fin anchovy *Setipinna taty*	2.6		3.5
Pored ray *Raja porosa*	2.4		
Eelpout *Enchelyopus elongatus*	2.2		2.7
Anglerfish *Lophius litulon*	3.0	3.7	
Red tongue sole *Cynoglossus joyneri*	2.7*	3.8*	
Small yellow croaker *Pseudosciaena polyactis*	2.4	2.7	
Arrow dragonet *Callionymus sagitta*		5.6*	4.4
Black caudal dragonet *Callionymus beniteguri*		5.1	4.5
Richardson's dragonet *Callionymus richardsoni*		4.0	4.2
Jewfish *Johnius belengeri*		3.4*	
Japanese anchovy *Engraulis japonicus*			2.5
Pored ray *Raja porosa*			3.1
Average dissimilarity	70.7	81.0	65.8

Asterisk indicated Diss./S. D. >2

Table 5 Discriminating species between station groups in the coastal waters off Qingdao in autumn

Species	AG1 & AG2	AG1 & AG3	AG2 & AG3
Chefoo thryssa *Thryssa chefuensis*	12.65*	10.1*	1.7*
White croaker *Argyrosomus argentatus*	9.5	6.0	1.7
Shortfin lizardfish *Saurida elongata*	6.5	8.1	16.1*
Fat greenling *Hexagrammos otakii*	4.7	2.1	4.3*
Hairtai *Trichiurus lepturus*	3.2	2.8*	2.6
Red tongue sole *Cynoglossus joyneri*	3.3*	2.8	3.6*
Blenny *Enedrias fangi*	3.9	3.3	5.3*
Cardinal fish *Apogonichthys lineatus*	3.4	3.7	6.0*
Small yellow croaker *Pseudosciaena polyactis*	5.2	5.0	3.4*
Finespot goby *Chaeturichthys stigmatias*	8.2	4.6	2.2*
Pinkgray goby *Chaeturichthys hexanema*	6.3	3.3	
Yellow drum *Nibea albiflora*	3.2	2.2	
Half-fin anchovy *Setipinna taty*	3.5	2.8	
Jewfish *Johnius belengeri*	4.2	2.9	
Whitespotted conger *Conger myriaster*	3.5	2.8	
Rubicundus eelgoby *Odontamblyopus rubicundus*	2.1		
Mi-iuy croaker *Miichthys miiuy*	2.1		
Pricklebacks *Azuma emmnion*	3.1*		2.8*
Scorpionfish *Sebastiscus marmoratus*	2.0*		2.0*
Great pipefish *Syngnathus acus*		10.4	13.1
Frog flounder *Pleuronichthys cornutus*		2.9	3.5
Bluefin searobin *Chelidonichthys kumu*		8.2*	10.7*
Silver pomfret *Pampus argenteus*		4.3	6.2
Brown barracuda *Sphyraena pinguis*		2.9*	4.5*
Arrow dragonet *Callionymus sagitta*			1.9
Average dissimilarity	70.5	72.8	83.1

Asterisk indicated Diss./S. D. >2

In autumn, the number of species caught differed greatly in different station groups with the highest value occurred in AG1; and the species richness was highest in AG1, followed by AG2 and AG3. The diversity indices also showed the same trend, while the highest evenness was found in AG2, followed by AG1 and AG3 (Table 6).

Table 6 Number of species (S), species richness (d), Shannon diversity (H') and evenness (J') indices by biomass in different station groups in spring and autumn

Groups	S	d	J'	H'
SG1	19	1.89	0.34	1.00
SG2	22	2.33	0.71	2.20
SG3	19	2.28	0.66	1.93
AG1	28	3.32	0.77	2.57
AG2	17	2.57	0.84	2.38
AG3	18	2.06	0.64	1.86

Highly significant differences in the species diversity indices between station groups were found by t-test in spring and autumn for all comparisons (all $P<0.01$).

3 Discussions

The coastal waters off Qingdao, located in the western Yellow Sea, were in the temperate region, and there were distinct seasonal variations in water temperature and salinity [4, 5, 16]. Many studies showed that fish community structure was highly related to the environmental factors in the Yellow Sea [7,18]. For example, the water temperature was the main factor that influenced fish assemblages in the Yellow Sea [7].

The marine environments in the coastal waters off Qingdao were mainly dominated by coastal currents and also

were affected by Qingdao cold water mass and Yellow Sea cold water mass [6]. Due to the influences of the cold water masses, there were temporally and spatially distributed regions which had low water temperature [4,5,16], and therefore the marine environments showed a distinct spatial heterogeneity in the coastal waters off Qingdao. The fish community structure also showed some spatial heterogeneity related to the marine environments in this study. Only two fish species were sampled in station 6 in spring, and therefore it had little similarity to other stations in fish species compositions, which was regarded as an outlying station in our analysis. The fish assemblages in spring and autumn were both classified into three station groups, corresponding to the northern, central and southern part of survey waters (Fig. 1, Fig. 2). However, the *in situ* environmental factors were not available in the surveys, and therefore the relationship between fish community structure and environmental factors were not explicitly examined in this study. A more comprehensive study of ecological processes was certainly needed to determine which physical or biological factors might be important in structuring the small-scale fish assemblages in the regional waters.

In spring, top five fish species in each station group were defined by biomass, accounting for 74.4%—96.7% of the total catches (Table 1). Except for the anglerfish, all the dominant species were also the typifying species in each station group, which contributed 74.4%, 80.5% and 73.1% in total to the average within-group similarities of SG1, SG2 and SG3, respectively (Table 1, Table 2), and these species were also identified as discriminators between station groups (Table 4). In autumn, top five fish species by biomass in each station group accounted for 63.5%—87.1% of the total catches (Table 1). All the dominant species were also the typifying species in each station group, which contributed 55.8%, 72.7% and 73.5% to the average within-group similarities of AG1, AG2 and AG3, respectively (Table 1, Table 2); and these species were also identified as discriminators between station groups (Table 4). Therefore, although the species compositions between station groups were significantly different, they were mainly caused by the spatial changes in the abundance of a few species and the randomicity of bottom trawl surveys. The fish distribution pattern indicated the high niche separation of fish species in the coastal waters off Qingdao, which guaranteed the full use of microhabitat including the space and food resources.

More than 100 fish species ever inhabited the Jiaozhou Bay and its adjacent waters, and the traditionally dominant species were mostly economically important fish species [9]。However, the biomass of those species was low and the dominant species had changed to largely the low-valued fish species such as chefoo thryssa, yellowfin goby, blenny, snailfish, fat greenling and shortfin lizardfish in both surveys. Niches left by some traditionally important fish species that declined in abundance were utilized by some small-sized, low-valued fish species in the coastal waters off Qingdao. In order to make full use of the niches left by economically important species and the spatial heterogeneity fish communities, it is important to carry out stock enhancement of fishery species with different ecological niches for the goal of increase in fishery resources.

In addition, the coastal waters off Qingdao were an important spawning and nursery ground for many commercially important fish species in the Yellow Sea [3,4]. The spatial dynamics in the coastal waters was only one stage for many fish species in their life cycles. Study on the fish community structure in the coastal waters would also promote the understanding of the connectivity between the coastal waters and other habitats for many fish species [2].

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