Asian Fisheries Science 8 (1995): 177-190.
Asian Fisheries Society, Manila, Philippines

https://doi.org/10.33997/j.afs.1995.8.3-4.001

Seasonal Changes of the Demersal Fish Community of the Yellow Sea

X. JIN

Yellow Sea Fisheries Research Institute
106 Nanjing Road
Qingdao 266071, China

Abstract

Seasonal changes in structure of demersal fish assemblages of the Yellow Sea are studied by means of cluster analysis based on bottom trawl surveys from March 1985 to January 1986. Simple discriminate analysis is used to test for significant differences in environmental character-istics among sampling station groups which show that species composition and biomass in each group and season are associated with bottom water temperature. The cold water mass in the central Yellow Sea plays an important role in distribution of fish. One to three absolutely dominant species in each group usually characterize the grouping area, accounting for more than 40% of the total catch. The similarity values of species composition between seasons are relatively low, all less than 50%.

Introduction

Demersal fish assemblages or associations and their relationship with environmental parameters in the continental shelves have been investigated in many parts of the world (Day and Pearcy 1968; Fager and Longhurst 1968; Colvocoresses and Musick 1984; Overholtz and Tyler 1985; Bianchi 1991, 1992). Spatial and temporal changes in the demersal fish community have been examined by Iglesias (1981) in the Ria de Arosa (NW Spain) and by Tyler (1971) in the Passamaquoddy Bay, Atlantic.

Since 1985, a seasonal bottom trawl survey of the Yellow Sea has been conducted by the Yellow Sea Fisheries Research Institute. The survey area varied seasonally, but covered a major part of fish distribution in the Yellow Sea. This study investigates the structure of demersal fish assemblages and discusses how they vary geographically, thermally and seasonally. There is no previous similar study in this area.

Materials and Methods

Sampling

Data were collected by bottom trawl from March 1985 to January 1986. The four seasons are defined in this study as spring (March-April), summer

(June-July), autumn (September-October) and winter (December-January). The surveys, except in winter, were conducted in two cruises each season. The survey area covered most parts of the Yellow Sea as shown in Fig. 1. The pair-trawlers "Yellow Sea" 103 and 104 used a net of 550 mesh X 30 cm and a stretched 5.1-cm mesh size codend in the spring surveys, and the R/V "Bei Dou" applied a net of 450 mesh X 17 cm, a 10-cm mesh size codend, and a 2.0-cm mesh size codend liner for other seasons. A parallel survey was carried out in September to compare the two types of vessels/gear, and results from the spring survey were standardized into other seasons. The number of sampling stations used were 69 (spring), 93 (summer), 91 (autumn) and 43 (winter). Those stations have included the seasonal distribution of most fishes in the Yellow Sea. The trawl period was 1.5 h which was standardized into 1 h.

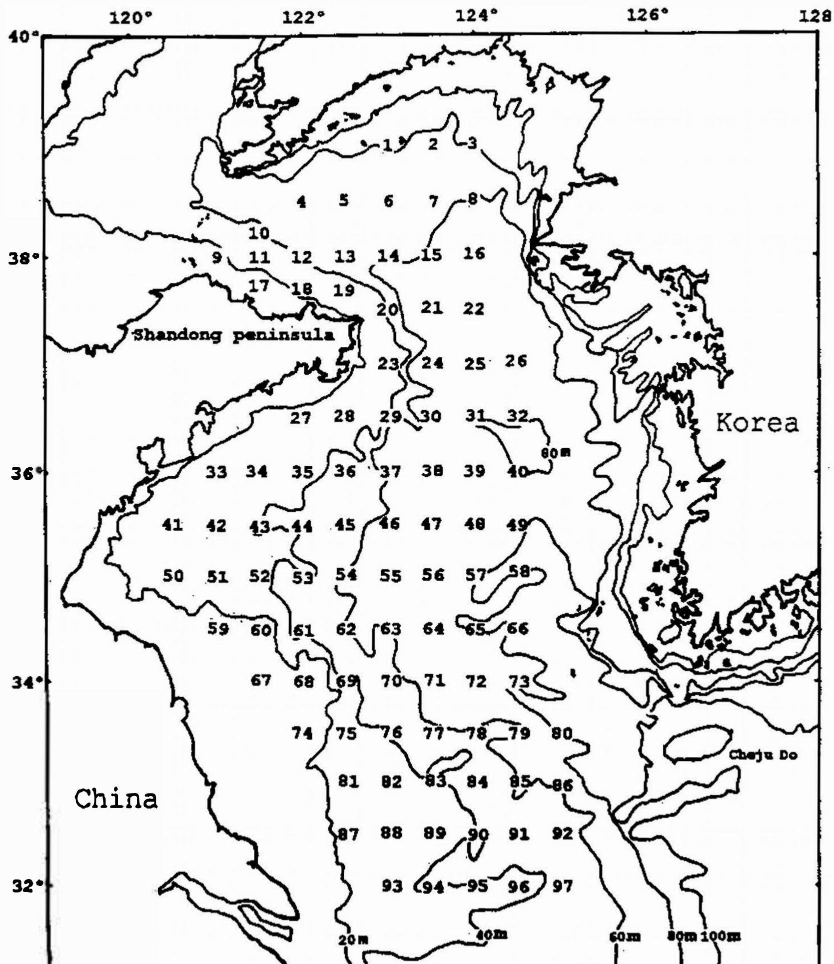

Fig. 1. Station number and bathymetric contours of the Yellow Sea.

Analysis

The standardized catch data are first analyzed by cluster analysis, a method traditionally used in fish community studies to sort samples into groups, and to produce a classification dendrogram by season which presents the hierarchical relationships between sampling stations. A total of 128 fish species were sampled during the surveys, of which 77 species, grouped into 42 species (or families) comprising more than 98% of the total catch of fish, were selected as variables in the cluster analysis. The following description is confined to the 42 species (or families). The Bray and Curtis (1957) percent dissimilarity index was used to measure the Q-mode resemblance between sampling stations. The flexible strategy (b=-0.25) was applied in the clustering (Colvocoresses and Musick 1984).

For the assemblage of species in the different groups by season, simple discriminate analysis (SDA) was used to test for significant differences in environmental characteristics among sampling station groups delimited by cluster analysis (Ludwig and Reynolds 1988). Three abiotic factors: depth, bottom water temperature and salinity were considered. In each season, based on the results of SDA, when the F-statistic test is greater than the critical F value with (p, n_1+n_2-p-1) degree of freedom, it is believed that there is a significant difference between two groups at a probability of less than 0.025, where p is the number of environmental factors, $p=3$, and n_1 and n_2 denote the number of sampling stations in each group.

Results

Thermal Regime

The Yellow Sea is a semi-enclosed continental shelf sea with an average depth of 44 m and smooth topography. The magnitude of the seasonal variation of bottom water temperature ranges from 2 to 24°C. It is large (>20°C) along the coastal waters and small (around 2°C) in the central part (Chen et al. 1991). The isotherms in the survey areas for four seasons of 1985 are shown in Fig. 2. Temperature was 3.4-12.1°C during the spring surveys with the high value in the south and low in the north without obvious gradient. But there was an area in the central part of the Yellow Sea with even temperature distribution that developed a cold water mass as seen in the summer isotherms (Fig. 2). These are the remains of the cold winter water system. Bottom water temperature increased sharply in summer, especially along the Chinese shallow coastal waters, while in the central part, a strong cold water mass formed with a distribution similar to those surveyed in spring. A strong thermal gradient was present between the coastal waters and the cold water mass. The distribution pattern in autumn was similar to the summer pattern with a reduced cold water mass and a large area with high temperature (>20°C). The increased turnover of the water system in winter resulted in isotherms approximately parallel to the latitude with the highest value in the southeastern part of the Yellow Sea.

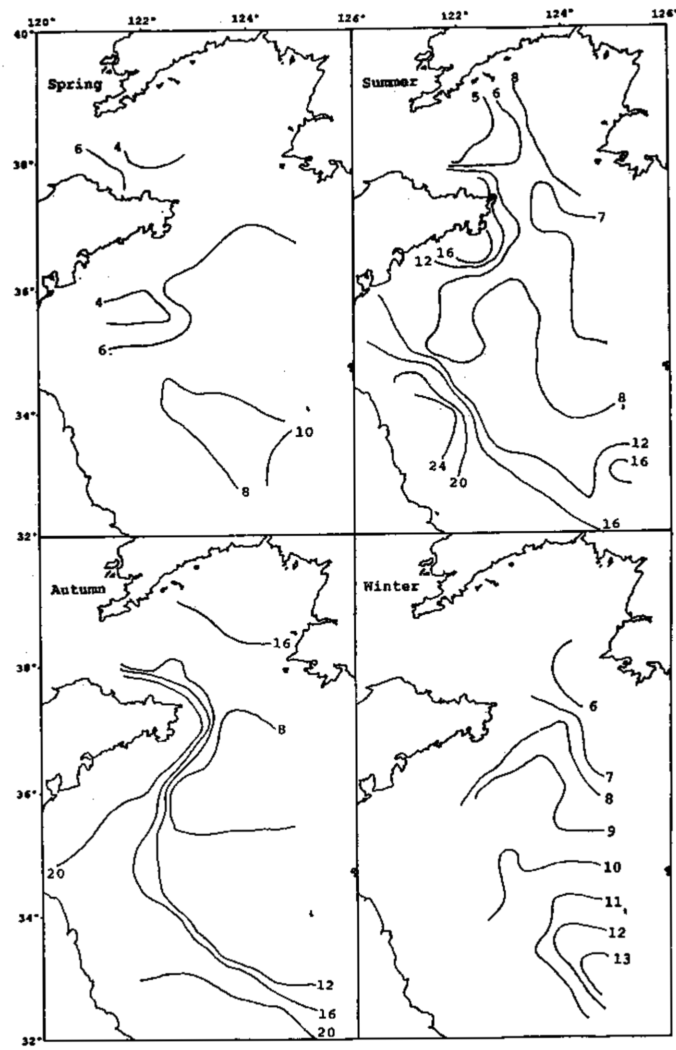

Fig. 2. Isotherms of bottom water temperature (°C) by season during the 1985 surveys.

Clustering and Species Assemblages

Groupings by season (Fig. 3a-d) show the results of cluster analyses based on species composition at each station. They represent the relationship between the various sampling stations. The groups identified are different between seasons.

Table 1. shows the results of SDA, including mean values of the three environmental factors with standard deviation, the total multivariate distance (relative importance) of environmental factors expressed as a relative percentage contribution. The groups are separated for each season with a probability of significant difference of $P<0.025$.

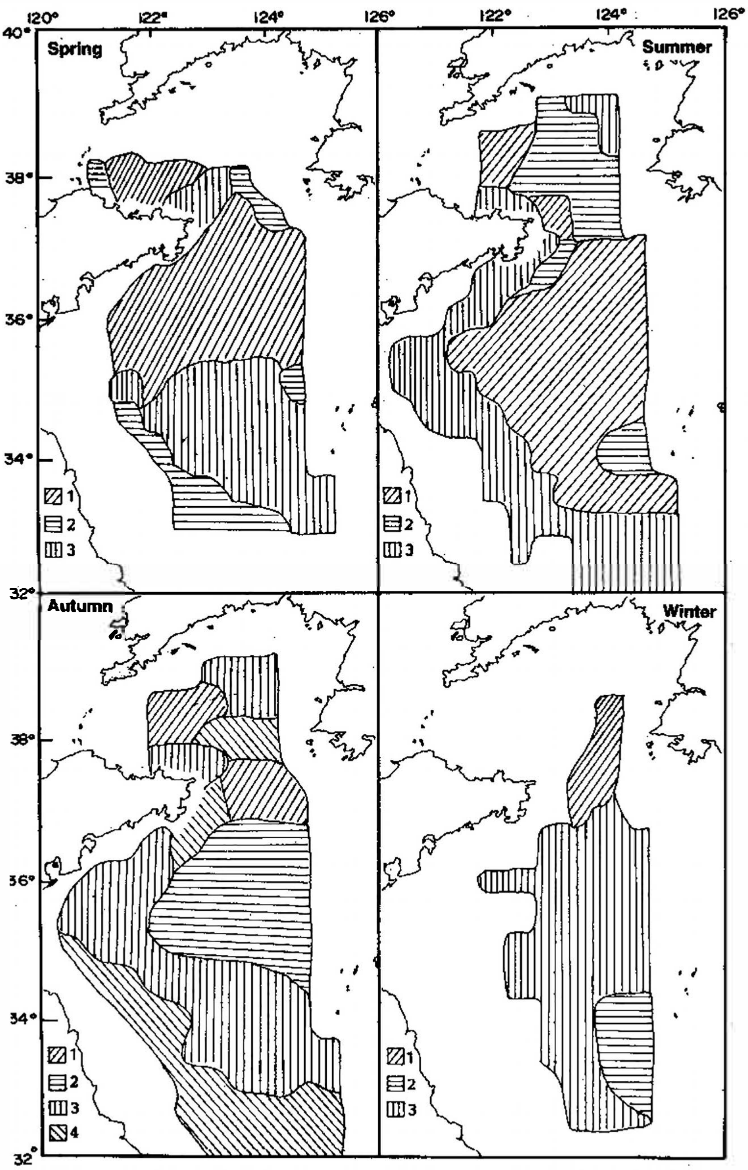

Fig. 3. Station groups derived from cluster analysis in spring (a), summer (b), autumn (c) and winter (d).

Table 2 presents the results of catch by weight and frequency of occurrence of main species for each group by season. Results of the percent similarity (Bray and Curtis 1957) between seasons based on the selected 42 species showed relatively low values, all below 50% (Table 3). The neighboring seasons had higher similarity index than the rest.

Table 4 shows the Pearson's product-moment correlations between groups. The plot of mean catch per haul per hour by bottom water temperature stratum in four seasons is shown in Fig. 4.

The different groups identified are described by season as follows:

Table 1. The results of SDA show mean temperature (°C), depth (m), salinity (‰) and their standard deviation (in parentheses). The percentage indicates the relative importance, and the probability of significant level is indicated by P.

	Group	Mean temperature (°C)	Mean depth (m)	Mean salinity (‰)	P
Spring	1	5.6 (1.3)	54 (22.9)	32.4 (0.3)	
	2	7.1 (0.9)	42 (24.2)	32.3 (0.8)	
	3	8.0 (1.7)	68 (16.8)	32.9 (0.5)	
	1-2	81.4	18.3	0.3	0.005
%	1-3	77.2	-3.0	25.8	0.001
	2-3	12.3	80.7	7.0	0.005
Summer	1	6.0 (1.1)	63 (12.4)	31.2 (0.5)	
	2	7.5 (1.1)	72 (11.8)	31.5 (0.4)	
	3	10.1 (2.6)	54 (19.0)	31.4 (0.8)	
	4	16.2 (5.1)	40 (16.6)	30.9 (0.7)	
	1-2	66.3	13.5	20.3	0.005
	1-3	91.1	1.3	7.6	0.001
%	1-4	101.8	3.2	-5.0	0.001
	2-3	60.0	42.3	-2.4	0.001
	2-4	53.5	45.4	1.1	0.001
	3-4	100.5	-3.8	3.3	0.001
Autumn	1	9.2 (2.3)	73 (12.1)	33.0 (1.2)	
	2	12.6 (5.1)	63 (15.8)	32.9 (1.1)	
	3	19.6 (2.7)	42 (13.1)	32.8 (1.1)	
	1-2	99.6	0.3	0.2	0.025
%	1-3	111.7	-11.0	-0.8	0.001
	2-3	87.7	12.7	-0.4	0.001
Winter	1	11.8 (1.8)	71 (17.4)	32.5 (1.2)	
	2	6.6 (0.8)	72 (4.3)	33.6 (0.3)	
	3	9.6 (1.1)	68 (14.6)	31.8 (1.6)	
	1-2	87.0	0.3	12.6	0.005
%	1-3	97.3	1.6	1.1	0.005
	2-3	83.1	-0.9	17.7	0.001

SPRING

A total of 69 stations was sampled and 38 of the selected 42 species were caught. Three groups are defined based on the cluster analysis (Fig. 3a).

Group 1 comprises 31 stations in the central Yellow Sea and north of Shandong Peninsula, including 32 species with an average depth of 54 m and bottom water salinity of 32.4 ‰. A very low bottom water temperature (5.6°C) characterizes this area. The mean biomass of total species is 24.4 $kg \cdot h^{-1}$. The dominant species are boreal and temperate water fishes whose primary distribution and seasonal migration are mainly within the Yellow Sea. They include Pacific herring *Clupea pallasi*, the flatfishes *Paralichthys olivaceus* and *Cleisthenes herzensteini*, eel-pout *Zoarces elongatus* and cod *Gadus macrocephalus* with the highest biomass in this group as shown in Table 2. Pacific herring and cod are typical endemic stocks, which are distributed only in the Yellow Sea, especially in this area characterized by the Yellow Sea cold water mass.

Table 2. Total weight and frequency (no. of stations where found in the respective groups) of main fish species from station groups by season. P indicates pelagic fish, the rest are demersal fish. Species 1= boreal, 2=temperate, 3=warmwater.

	Specific name	Total weight (kg)	%	Frequency	Species	
SPRING						
Group 1 (31 stations, 32 species, 756.9 kg)						
	Clupea pallasi	192.2	25.4	19	1	P
	Paralichthys olivaceus	77.6	10.3	18	2	
	Zoarces elongatus	66.7	8.8	28	1	
	Gadus macrocephalus	58.5	7.7	20	1	
	Pseudosciaena polyactis	52.2	6.9	24	2	
	Lophius litulon	40.0	5.3	14	2	
	Cleisthenes herzensteini	37.8	5.0	24	1	
Total		525.0	69.4			
Group 2 (12 stations, 32 species, 427.2 kg)						
	Rajiforms	217.2	50.8	11	2	
	Collichthys	76.6	17.9	10	2	
	Coilia	31.8	7.4	9	2	P
	Setipinna taty	19.0	4.5	10	3	P
Total		344.6	80.6			
Group 3 (26 stations, 37 species, 1,445.0 kg)						
	Engraulis japonicus	564.8	39.1	24	2	P
	Pseudosciaena polyactis	240.4	16.6	26	2	
	Setipinna taty	182.3	12.6	25	3	P
	Rajiforms	54.7	3.8	14	2	
	Zoarces elongatus	48.9	3.4	24	1	
Total		1,091.1	75.5			
SUMMER						
Group 1 (10 stations, 13 species, 71.9 kg)						
	Clupea pallasi	25.8	35.9	4	1	P
	Gadus macrocephalus	16.2	22.5	10	1	
	Cleisthenes herzensteini	12.4	17.2	9	1	
	Hemitripterus villosus	6.2	8.6	8	1	
	Zoarces elongatus	4.1	5.7	10	1	
	Hexagrammos otakii	4.0	5.6	7	1	
Total		68.7	95.5			
Group 2 (20 stations, 15 species, 56.1 kg)						
	Cleisthenes herzensteini	30.7	54.7	20	1	
	Engraulis japonicus	12.4	22.0	5	2	P
	Zoarces elongatus	4.8	8.5	13	1	
	Liparis tanakae	2.8	5.0	14	1	
Total		50.7	90.2			
Group 3 (38 stations, 30 species, 144.2 kg)						
	Lophius litulon	44.9	31.1	20	2	
	Liparis tanakae	33.0	22.9	34	1	
	Zoarces elongatus	14.2	9.8	29	1	
	Platichthys bicoloratus	10.9	7.6	6	1	
	Engraulis japonicus	8.2	5.7	24	2	P
	Pseudosciaena polyactis	7.7	5.4	8	2	
Total		118.9	82.6			
Group 4 (25 stations, 36 species, 1,054.5 kg)						
	Engraulis japonicus	384.4	36.5	11	2	P
	Scomber japonicus	378.6	35.9	7	3	P
	Sardinella zunasi	93.0	8.8	5	3	P
Total		856.0	81.2			

continued

Table 2. continuation

Specific name	Total weight	%	Frequency	Species	
AUTUMN					
Group 1 (39 stations, 31 species, 684.6 kg)					
Liparis tanakae	316.3	46.2	37	1	
Lophius litulon	127.7	18.7	25	2	
Cleisthenes herzensteini	53.0	7.7	27	1	
Engraulis japonicus	50.2	7.3	27	2	P
Total	547.2	79.9			
Group 2 (14 stations, 35 species, 879.4 kg)					
Engraulis japonicus	421.8	48.0	9	2	P
Liparis tanakae	191.5	21.8	12	1	
Rajiforms	144.4	16.4	10	2	
Total	757.7	86.2			
Group 3 (38 stations, 37 species, 2,831.2 kg)					
Trachurus japonicus	745.3	26.3	5	3	P
Stromateoides argentus	564.5	19.9	34	3	P
Scomber japonicus	332.3	11.7	7	3	P
Scomberomorus niphonius	258.9	9.1	25	2	P
Pseudosciaena polyactis	244.6	8.6	26	2	
Sardinella zunasi	230.5	8.1	15	3	P
Total	2,376.1	83.7			
WINTER					
Group 1 (5 stations, 22 species, 95.8 kg)					
Rajiforms	69.6	72.6	5	2	
Paralichthys olivaceus	14.4	15.1	5	2	
Zoarces elongatus	2.3	2.4	3	1	
Total	86.3	90.2			
Group 1 (6 stations, 25 species, 173.3 kg)					
Scomber japonicus	89.1	51.4	4	3	P
Pseudosciaena polyactis	46.0	26.5	5	2	
Lophius litulon	7.1	4.1	4	2	
Total	142.2	82.0			
Group 3 (32 stations, 39 species, 703.9 kg)					
Liparis tanakae	305.3	43.4	32	1	
Cleisthenes herzensteini	85.4	12.1	25	1	
Lophius litulon	60.6	8.6	29	2	
Engraulis japonicus	33.9	4.8	25	2	P
Paralichthys olivaceus	33.0	4.7	14	2	
Total	518.2	73.6			

Group 2 is found along the shallow coastal waters at an average depth of 42 m and bottom water salinity of 32.3‰. This group includes 12 stations with 32 species, and the biomass averaged 35.6 $kg \cdot h^{-1}$. The mean bottom water temperature (7.1°C) is medium among the three groups. Therefore, species composition is mixed, dominated by temperate water species. Rays (mainly *Raja porosa* and *R. pulchra*) and croakers (mainly *Collichthys niveatus*) are abundant in this area (Table 2).

Group 3 includes 26 stations and 37 species, mainly in the southern part of the Yellow Sea with an average bottom water salinity of 32.9 ‰. High bottom

Table 3. Bray and Curtis (1957) percent similarity between seasons.

	Spring	Summer	Autumn	Winter
Spring	100			
Summer	47	100		
Autumn	35	49	100	
Winter	43	39	45	100

water temperature (8.0°C) and deep water (68 m) characterize this area. The mean biomass of 55.6 kg·h^{-1} was greater than in the above two groups. Pelagic fish, typically anchovy *Engraulis japonicus* and half-fin anchovy *Setpinna taty*, account for very high proportions in the catch. Small yellow croaker *Pseudosciaena polyactis* is also abundant (Table 2).

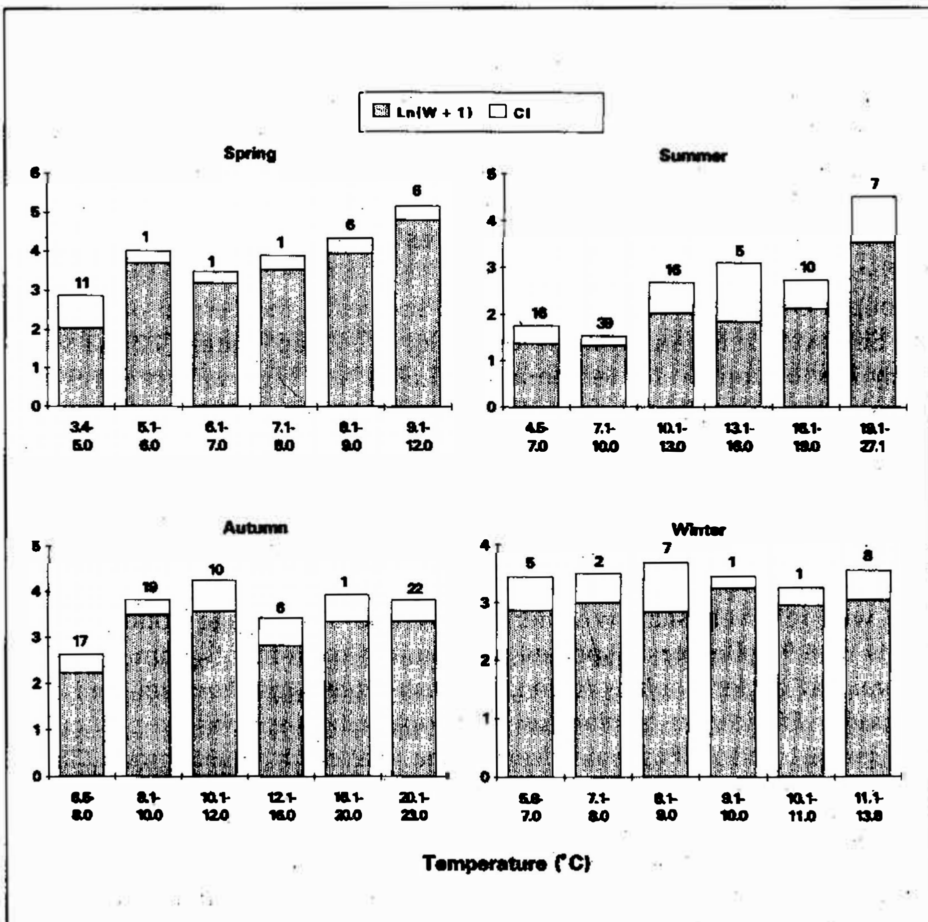

Fig. 4. Variation of mean Ln (catch+1) when present with bottom water temperatures (°C) at four seasons. A 95% confidence interval (CI) is indicated by the blank bars and the number of hauls is on top of the bars.

Table 4. Pearson's product-moment correlation coefficient between groups. Values with asterisks indicate significant correlation ($P<0.001$, df=40)

	Spring			Summer				Autumn			Winter		
	1	2	3	1	2	3	4	1	2	3	1	2	3
1	1	0.05	0.10	0.77*	0.14	0.09	-0.10	0.01	-0.04	-0.09	0.13	0.00	0.01
2		1	0.13	-0.07	-0.03	0.01	0.06	-0.01	0.31	-0.07	0.91*	-0.03	0.05
3			1	-0.08	0.31	0.14	0.58*	0.09	0.77*	-0.01	0.04	0.12	0.05
1				1	0.34	-0.05	-0.01	0.04	-0.06	-0.15	-0.03	-0.09	0.07
2					1	0.14	0.20	0.24	0.34	-0.11	-0.02	-0.06	0.32
3						1	0.01	0.79*	0.30	-0.05	0.03	0.05	0.66*
4							1	0.06	0.61*	0.20	0.03	0.59*	0.00
1								1	0.45*	-0.08	-0.01	0.04	0.96*
2									1	-0.09	0.27	0.04	0.44*
3										1	-0.06	0.33	-0.11
1											1	-0.04	0.06
2												1	-0.02
3													1

SUMMER

A total of 93 stations was sampled, and all 42 selected species were caught. Four groups are defined according to the cluster analysis (Fig. 3b).

Group 1 includes 10 stations in the northern part of the survey area. There are only 13 species with a mean biomass of 7.2 $kg \cdot h^{-1}$ in this group. Because of the area's low bottom water temperature (6.0°C) and relatively deep water (63 m), it is dominated by boreal species, such as Pacific herring, cod and plaice *Cleisthenes herzensteini* (Table 2).

Group 2 consists of 20 stations with 15 species in the central part of the Yellow Sea with a mean biomass of 2.8 $kg \cdot h^{-1}$. Deep water (72 m) with relatively low bottom water temperature (7.5°C) and high salinity (31.5 ‰) characterize this area. This group is dominated by boreal and temperate water species, such as plaice and anchovy, which show high proportions by weight (Table 2).

Group 3 is related to a larger area, distributed in the central, south and edges of the survey area. This group includes 38 stations with 30 species, and a mean biomass of 3.8 $kg \cdot h^{-1}$. The bottom water temperature is relatively high (10.1°C) with relatively shallow water (54 m), and the average bottom water salinity is 31.4 ‰. Demersal species with limited movements dominate this group, typically angler *Lophius litulon*, grassfish *Liparis tanakae*, eel-pout and stone flouder *Platichthys bicoloratus*. The former two species, in particular, account for 31.1 and 22.9%, respectively, of the total catch for this group (Table 2).

Group 4 consists of 25 stations with 36 species, mainly in the southwestern part of the Yellow Sea. A small area in the eastern part of Shandong Peninsula is also included in this group. The mean biomass is 42.2 $kg \cdot h^{-1}$. A very high bottom water temperature (16.2°C), low salinity (30.9 ‰) and shallow water (40 m) characterize this area. Consequently, temperate and warmwater pelagic species with dense schools and low frequency of occurrence dominate this group (Table 2). Anchovy is abundant in some stations in the southern part and off Shandong Peninsula, while chub mackerel *Scomber japonicus* is abundant only in the southern part. The small pelagic fish, scaled sardine *Sardinella zunasi*, is distributed mainly in the southwestern part of the Yellow Sea.

AUTUMN

Autumn is the main feeding season for most fish species in the Yellow Sea. Many fish which have finished spawning start feeding in schools. Of the selected 42 species, 41 were caught during the surveys. Three groups are defined based on the cluster analysis (Fig. 3c).

Group 1 covers 39 stations in the central part of the Yellow Sea, at a mean depth of 72 m and bottom water salinity of 33.0 ‰. This group includes 31 species with an average biomass of 17.6 $kg{\cdot}h^{-1}$ which is the lowest among the three groups during autumn surveys. Low bottom water temperature (9.2°C), high salinity and deep water characterize this area. As a result, boreal and temperate water species, mostly demersal fish, dominate this group. Grassfish represent a high proportion, accounting for 46.2% of the total catch for this group (Table 2).

Group 2 is dispersed mainly in the northern part of the Yellow Sea. This group includes 14 stations with 35 species, with an average biomass of 62.8 $kg{\cdot}h^{-1}$. The three environmental factors considered are in between the other two groups (Table 1). Species composition includes mainly anchovy, grassfish and rays, with anchovy accounting for 48.0% of the total catch (Table 2).

Group 3 covers a long range at the edges of the survey area. This group consists of 38 stations and 37 species with an average biomass of 74.5 $kg{\cdot}h^{-1}$. Due to the high bottom water temperature (19.6°C) and shallow water (42 m), warmwater pelagic fish abound. Typically, horse mackerel *Trachurus japonicus* and chub mackerel show high biomass with low frequency of occurrence (Table 2), which correspond to the distribution in very dense schools for the two species at a few stations in the southern part of the Yellow Sea. Silver pomfret *Stromateoides argenteus* shows a similar picture.

WINTER

This season is the wintering period for most fish in the Yellow Sea. The survey area is confined to deep water, focusing on fish in the wintering grounds. Of the selected 42 species, 40 were found during the survey. Three groups are defined on the basis of cluster analysis with a small variation of mean depth (Fig. 3d).

Group 1 covers the northern part of the survey area, including five stations and 22 species with an average biomass of 19.2 $kg{\cdot}h^{-1}$. Low bottom water temperature (6.6°C) and high salinity (33.6 ‰) characterize this area. Species composition is dominated by demersal fish (rays) which have limited movement year round (Table 2).

Group 2 is in the southern part of the Yellow Sea, including six stations and 25 species with an average biomass of 28.9 kg·h^{-1}. A high bottom water temperature (11.8°C) makes this area an important wintering ground for warm and temperate water species of fish, such as chub mackerel and small yellow croaker, which account for 51.4 and 26.5%, respectively, of the total catch for this group (Table 2).

Group 3 includes most (32) of the stations sampled during the winter survey, comprising 39 species with an average biomass of 22.0 kg·h^{-1}. The bottom water temperature is intermediate among the three groups. Demersal fish are abundant, grassfish and plaice account for 43.4 and 12.1%, respectively, of the total catch for this group (Table 2).

Discussion

Migratory fishes in the Yellow Sea are very sensitive to changes in water temperature. The coastal currents, Kuroshio current and cold water mass affect the Yellow Sea and distribution of fish. Overholtz and Tyler (1985) pointed out that cluster analysis proved to be a useful statistical method for delineating assemblage boundaries and associated species. In the Yellow Sea, the groupings from the cluster analysis were primarily consistent with the bottom water temperature. Boreal fish with seasonal migration of limited extension were distributed mainly in the central part, while most temperate and warmwater species undertake seasonal long distance migrations with temperature changes. In contrast, depth and salinity were not as important as temperature in influencing the distribution and biomass of fish. Information on latitude, longitude, sediment type, and oxygen was not available in this study, although they might be useful parameters of species distribution (Fager and Longhurst 1968; Pimentel 1979; Qiu 1988; Bianchi 1991, 1992).

In the spring surveys, the difference in bottom water salinity between the three groups was small, while the bottom water temperature of group 1 differed largely from groups 2 and 3. Temperature changes are very important for fishes with spawning migration in the spring. Many species which winter in the southern part of the Yellow Sea migrate northwestwards to the coastal spawning area with the increasing temperature during spring time (Zhao et al. 1990). Therefore, the high biomass is found in the high temperature area (group 3). The results of SDA in spring show a high percent contribution for the bottom water temperature in the relative importance of the environmental factors between groups 1 and 2, and between groups 1 and 3. However, the difference in bottom water temperature between groups 2 and 3 is small, but it is large in depth. As a result, depth is responsible for 80.7% of the difference between groups 2 and 3 (Table 1).

The results of SDA in summer show a significant difference in the environmental factors ($P<0.005$) between groups. The relative importance of bottom water temperature is 60.0-101.8%, while depth and salinity show less importance in the analysis, even weaken the analysis in theory (Ludwig and Reynolds 1988, negative percent contribution, Table 1). From the point of view of the analysis of the relative percentage contribution to the multivariate distance, the results can be meaningful and useful. During surveys in autumn and winter, the relative importance of bottom water temperature from SDA are 87.7-111.7% and 83.1-97.3%, respectively.

Colvocoresses and Musick (1984) examined the distributional patterns, and concluded that continental shelf demersal fish communities in the Middle Atlantic Bight are largely structured by temperature on the inner- and mid-shelf and by depth on the outer shelf and shelf break. Gabriel and Tyler (1980) demonstrated that most assemblages were associated with specific depth strata with a relatively large depth gradient (20-500 m) in the northern Pacific off the coast of Oregon.

After investigating the latitudinal variation in the regular and seasonal components of several nearshore Atlantic marine fish communities, Tyler (1971) concluded that the proportion of seasonal and occasional components to regular components varied directly with annual variation in water temperature, and that the temporal species composition is largely related to temperature regime in temperate regions.

Many studies on the tropical water assemblages of shelf and upper slope indicated that changes in species composition are depth related (e.g., McManus 1985; Roel 1987; Qiu 1988; Bianchi, 1991, 1992). Iglesias (1981) studied the demersal fish community of the Ria de Arosa by season, and concluded that there were no important seasonal changes in abundance, with high similarity between samples from two different sampling periods, and groupings of species and samples were related to water depth and the nature of the bottom. The magnitude of seasonal changes in the temperature of tropical waters is usually smaller than in temperate. Therefore, temperature has less effect on fish distribution than depth.

In the present study, the areas surveyed in each season were divided into several groups (Fig. 3a-d) based on cluster analysis according to the selected 42 species (or families). Since the seasonal bottom water temperature showed great variation, the biomass in each season, also in each group, showed positive relations with bottom water temperature (Fig. 4, Table 2). The similarity values of species composition between seasons are relatively low (Table 3), this might be caused by the seasonal migration with changes of water temperature. The species composition in each group is temperature-related (Tables 1 and 2). Generally, each group has one to three dominant species (accounting for more than 40% of the total catch) which characterize the areas (Table 2). Those species were highly associated with bottom temperature, boreal fish dominated the low temperature area and warmwater species dominated the high temperature area, while temperate species dominated the intermediate area.

In the temperate area, when depth gradient is small and water temperatures usually vary greatly, changes in species composition between seasons and groups may be associated with temperature. However, when the depth gradient is large, even the temperature gradients exist, species assemblage might be depth related.

Acknowledgments

I am grateful to Dr. Qisheng Tang, Yellow Sea Fisheries Research Institute, China; and two anonymous referees for their valuable comments on the manuscript; and to my colleagues for their assistance during the surveys.

References

Bianchi, G. 1991. Demersal assemblages of the continental shelf and slope edge between the Gulf of Tehuantepec (Mexico) and the Gulf of Papagayo (Costa Rica). Marine Ecology Progress Series 73: 121-140.

Bianchi, G. 1992. Demersal assemblages of the continental shelf and upper slope of Angola. Marine Ecology Progress Series 81: 101-120.

Bray, T.R. and J.T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs 27: 325-349.

Chen, G., X. Gu, H. Gao and G. Yang, Editors. 1991. Marine fishery environment in China. Zhejiang Science and Technology Press, Zhejiang. 233 pp.

Colvocoresses, J.A. and J.A. Musick. 1984. Species assemblages and community composition of Middle Atlantic Bight continental shelf demersal fishes. Fishery Bulletin 82(2): 295-313.

Day, D.S. and W.G. Pearcy. 1968. Species associations of benthic fishes on the continental shelf and slope off Oregon. Journal of the Fisheries Research Board of Canada 25: 2665-2675.

Fager, E.W. and A.R. Longhurst. 1968. Recurrent group analysis of species assemblages of demersal fish in the Gulf of Guinea. Journal of the Fisheries Research Board of Canada 25: 1405-1421.

Gabriel, W.L. and A.V. Tyler. 1980. Preliminary analysis of Pacific coast demersal fish assemblages. Marine Fisheries Review (March-April): 83-88.

Iglesias, J. 1981. Spatial and temporal changes in the demersal fish community of the Ria de Arosa (NW Spain). Marine Biology 65: 199-208.

Ludwig, J.A. and J.F. Reynolds. 1988. Statistical ecology. John Wiley & Sons, Inc., New York. 337 pp.

McManus, J.W. 1985. Descriptive community dynamics: background and an application to tropical fisheries management. University of Rhode Island, Providence. Ph.D. thesis. 192 pp.

Overholtz, W.J. and A.V. Tyler. 1985. Long-term responses of the demersal fish assemblages of Georges Bank. Fishery Bulletin 83(4): 507-520.

Pimentel, R.A. 1979. Morphometrics: the multivariate analysis of biological data. Kendal/Hunt Publ. Co., Dubuque, Iowa.

Qiu, Y. 1988. The regional changes of fish community on the northern continental shelf of South China Sea. Journal of Fisheries of China 12(4): 303-313.

Roel, B.A. 1987. Demersal communities off the west coast of South Africa. South African Journal of Marine Science 5: 575-584.

Tyler, A.V. 1971. Periodic and resident components in communities of Atlantic fishes. Journal of the Fisheries Research Board of Canada 28: 935-946.

Zhao, C., X. Liu, B. Zeng and Y. Yu, Editors. 1990. Marine fishery resources of China. Zhejiang Science and Technology Press, Zhejiang. 178 pp.

Manuscript received 16 March 1995; accepted 4 September 1995.