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Factors Affecting the Wintering Habitat of Major Fishery Resources in Southwestern Korean Waters

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Abstract – We investigated the temperature and salinity effects on the major fish species in the wintering grounds based on trawl surveys and oceanographic observations in the southwestern waters of Korea during March-early April in 2002-2003. The influence area of warm Kuroshio water was limited to the southwestern area of Korea in 2003 with a range of 7.7-16.3°C, 32.54-34.70 of salinity, wider than that of 2002. The number of fish species and density of major fish species in 2003 were higher than in 2002. Geographical estimation showed high proportions of species number and catches in the areas around Jeju Islands, southwestern waters and the southeastern coast of Korea. Five species; silver pomfret (*Pampus echinogaster*), hairtail (*Trichiurus lepturus*), anchovy (*Engraulis japonicus*), small yellow croaker (*Larimichthys polyactis*) and yellow goosefish (*Lophius litulon*) were most abundant, composing above 60% of the total catch in 2002 and 2003. More than 50% of catch in the major fish species were mostly distributed in the range of 9.5-11.0°C of temperature and 33.1-33.9 of salinity. Non-parametric estimation for the major species showed the 1st mode around 10°C and the 2nd mode at 8-9°C in 2002 and 11-14°C in 2003. Among major fish species, hairtail was principally composed of juveniles, and larger individuals were caught in southeastern waters. These results are considered to be helpful for the area-based fishery management strategy for the wintering grounds of the Yellow Sea and coastal waters of Korea.

Key words – wintering habitat, temperature, salinity effect, trawl survey, Korean waters

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1. Introduction

The southwestern waters of Korea have been important wintering and spawning grounds of major commercial fishes in Korea (Wang and Zuo 2004; Kim *et al.* 1999b). Warm fish species start to migrate to the adjacent coastal waters in April-May. Fishing grounds were formed in the frontal area which varied seasonally in terms of physical and biological oceanographic conditions such as strength of warm Kuroshio Current and production of plankton in a limited area. Negative effect on fish stock could occur by overfishing in the wintering grounds (Park *et al.* 2000, Xu and Jin 2005).

Spatio-temporal distribution of commercially important fishes in the Korean waters has been studied relating to the biological factors using commercial catch statistics and port sampling (Kim *et al.* 1999a; Park *et al.* 2000). Recently, more detailed results of fisheries resources in the Korean waters were investigated through trawl and hydro-acoustic surveys (Kim *et al.* 1999; Choi *et al.* 2001; Choi *et al.* 2004; Yeon *et al.* 2004). However, information on major fishes in relation to environmental factors has not been sufficient for efficient fisheries management.

This study is to determine the fish species composition and the temperature and salinity effect on major fish species in the wintering ground based on trawl survey and oceanographic observation in the southwestern waters of Korea during March in 2002 and 2003.

2. Materials and Methods

Samples were collected in March 2002 and 2003 in the areas of 32.0-34.5°N and 123-129°E. This area has been known as a major wintering grounds of warm water fish species in Korean waters (Figure 1). Trawl survey and oceanographic observation were carried out aboard the NFRDI research vessel, Tamgu No.1 (2,180 G/T) during 9-25 March in 2002 and 21 March-9 April in 2003. Trawl fishing gear was composed of main net with 147.9 m in total length, 62.8 m in head rope, 85.5 m in ground rope and 50 mm in stretched mesh size at the cod-end.

Fish samples were identified by species and measured for the total length (TL), fork length (FL) and/or anal length (AL) to the nearest 1 mm and the wet weight to the nearest 1 g. Temperature and salinity were observed by the CTD (Conductivity Temperature Depth profiler, SBE-19). We estimated spatial temperature and salinity distribution of surface and bottom layer. The number and catch weight were estimated by 1 degree in longitude and latitude. Distribution pattern and modes for major species were also determined using non-parametric methods by Nadaraya-Watson estimator (Silverman 1986; Müller 1997; Wang 2006). Length frequency distribution was used to determine juvenile occurrence and the role of recruit in each area.

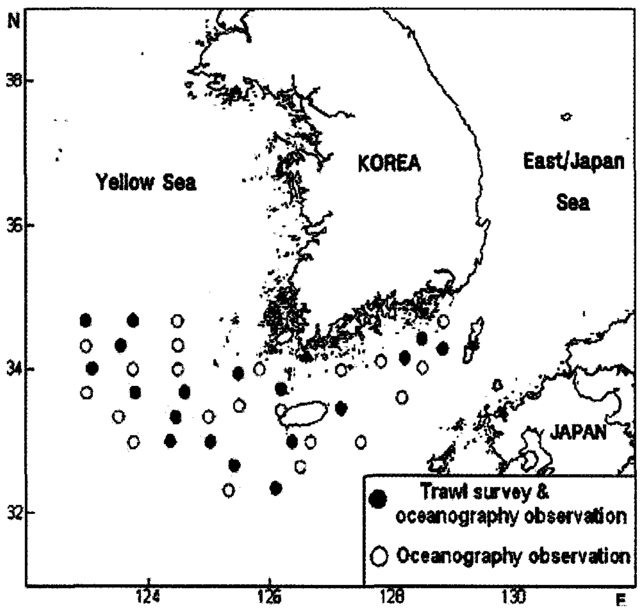

Fig. 1. Location of the sampling stations of trawl survey and oceanography observation in the southwestern area of Korean waters during March, 2002-2003.

3. Results

Oceanographic characteristics and occurrence of fish species

During March 2002, the temperature ranged from 8.0 to 16.3°C on the surface and from 7.7 to 15.5°C at the bottom and salinity ranged from 32.26 to 34.62 on the surface and from 32.72 to 34.60 at the bottom (Figure 2). In 2003, temperatures ranged from 7.9 to 16.5°C on the surface and 7.7-16.3°C at the bottom, and salinity ranged from 32.54 to 34.71 at the surface and from 32.54 to 34.70 at the bottom, which was wider than those in 2002. Mean values ranged from 11.45 to 12.18°C in temperature and from 33.76 to 33.98 in salinity. Observed mean in 2003 was 0.3-0.6°C higher in temperature of surface water and

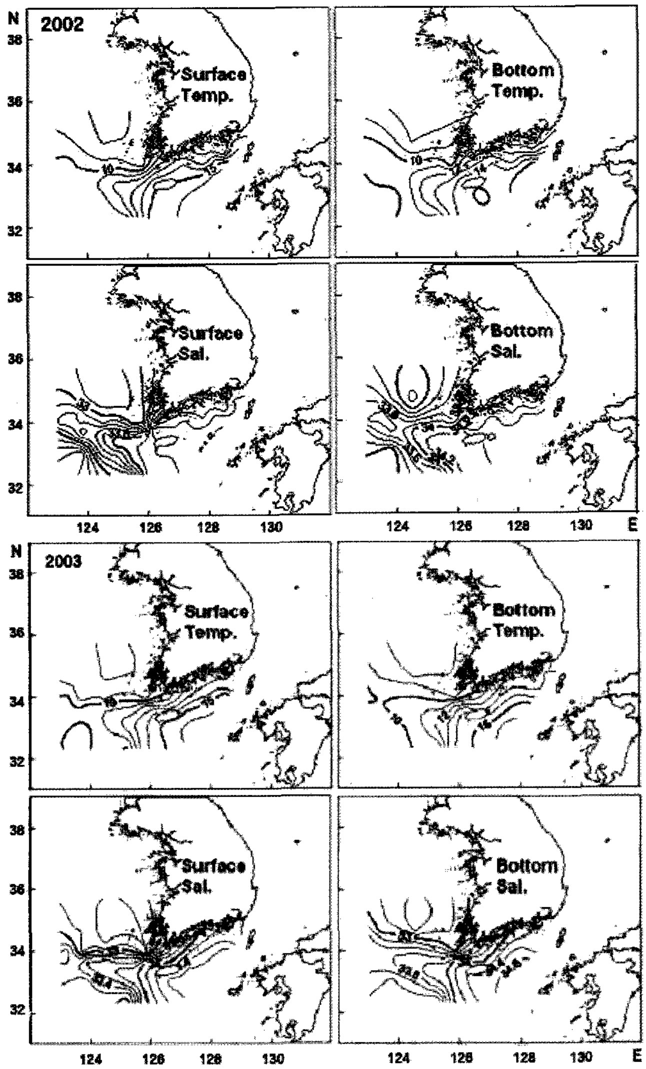

Fig. 2. Spatial distribution of temperature and salinity in the southwestern area of Korean waters during March, 2002-2003.

Table 1. Catch composition of fish by trawl survey during March, 2002 and 2003.

Scientific Name	2002		2003	
	Catch (g)	Ratio (%)	Catch (g)	Ratio (%)
Acropoma japonicus	2,203	0.77	146	0.03
Amblychaeturichthys hexanema	20	0.01	14	0.00
Ammodytes personatus	1			
Anguilla japonica			1,082	0.23
Apogon lineatus	1,117	0.39	1,177	0.25
Arctoscopus japonicus	20	0.01		
Argyrosomus argentatus	1,390	0.49	7,470	1.60
Ariosoma shiroanago shiroanago			711	0.15
Aulopus japonicus			638	0.14
Benthosema pterotum	620	0.22	35,034	7.51
Branchiostegus japonicus	315	0.11	291	0.06
Chaeturichthys stigmatias			6	0.00
Champsodon snyderi	99	0.03	475	0.10
Chelidonichthys kumu	455	0.16	846	0.18
Cleisthenes pinetorum			165	0.04
Clidoderma asperrimum	215	0.08	1153	0.25
Cociella crocodila	173	0.06	735	0.16
Coilia ectenes	203	0.07		
Coleorhynchus multispinulosus	23	0.01	53	0.01
Collichthys niveatus	643	0.23	64	0.01
Conger myriaster	1,163	0.41	6,922	1.48
Congridae			114	0.02
Cynoglussus robustus			423	0.09
Dentex tumifrons	2,075	0.73	588	0.13
Dipturus kwangtungensis			4,681	1.00
Doederleinia berycoides	1,561	0.55	2,027	0.43
Dysomma anguillare			64	0.01
Engraulis japonicus	33,734	11.85	59,060	12.66
Eopsetta grigorjewi			1,184	0.25
Erisphex pottii	8,695	3.05	490	0.11
Fistularia petimba			90	0.02
Genoproktopterus mylodon			192	0.04
Gnathagnus elongatus			591	0.13
Hapalogenys mucronatus			1,653	0.35
Harpadon nehereus	83	0.03	416	0.09
Helicolenus hilgendorfi	1,067	0.37	434	0.09
Hoplobrotula armata	4,107	1.44	5,834	1.25
Ilisha elongata	183	0.06	56	0.01
Johnius grypotus	35	0.01	213	0.05
Kaiwarinus equula			979	0.21
Konosirus punctatus	3,910	1.37	1,007	0.22
Larimichthys polyactis	30,920	10.86	32,114	6.89
Lateolabrax japonicus	3,372	1.18	203	0.04
Leiognathus nuchalis	2,031	0.71		
Lepidotrigla abyssalis			381	0.08
Lepidotrigla guentheri			79	0.02
Lepidotrigla kishinouyei			118	0.03
Lepidotrigla microptera	55	0.02	69	0.01

(**Table 1.** Continued)

Scientific Name	2002		2003	
	Catch (g)	Ratio (%)	Catch (g)	Ratio (%)
Lophiomus setigerus			29,705	6.37
Lophius litulon	16,575	5.82	38,675	8.29
Malakichthys wakiyai			4	0.00
Maurolicus japonicus	6,438	2.26	441	0.09
Michthys miiuy			5,631	1.21
Microcanthus strigatus	513	0.18		
Minous quincariantus			86	0.02
Narke japonicus			430	0.09
Nemipterus virgatus			16	0.00
Neobythites sivicola	59	0.02		
Okamejei kenojei	498	0.17	476	0.10
Ophisurus macrorhynchus			1,240	0.27
Pagrus major			356	0.08
Pampus echinogaster	64,160	22.54	88,967	19.07
Parapercis multifasciata			4	0.00
Pholis fangi			19	0.00
Pholis nebulosus			11	0.00
Platycephalus indicus	360	0.13	1,638	0.35
Pleuronichthys cornutus			340	0.07
Psenopsis anomala	3,707	1.30	332	0.07
Raja sp.			1,728	0.37
Sardinella zunasi			1,069	0.23
Saurida undosquamis			327	0.07
Scomber japonicus	8,724	3.06	6,483	1.39
Scomberomorus niphonius	16,467	5.79	22,978	4.93
Scorpaena onaria	879	0.31	734	0.16
Scyliorhinus torazame			6,383	1.37
Sebastes schlegeli	950	0.33	693	0.15
Sebastes thompsoni			79	0.02
Sebastiscus tertius			285	0.06
Setipinna tenuifilis	4,492	1.58	4,637	0.99
Sillago japonica	190	0.07		
Sphyraena pinguis	4,868	1.71	283	0.06
Stephanolepis cirrhifer			44	0.01
Synagrops japonicus	11	0.00		
Synagrops philippinensis	15	0.01		
Synodus macrops			18	0.00
Takifugu poecilonotus	760	0.27	75	0.02
Tanakius kitaharai			374	0.08
Thamnaconus modesutus	623	0.22	1,442	0.31
Thrysa chefuensis	1,296	0.46		
Trachurus japonicus	12,119	4.26	1,061	0.23
Triacanthodes anomalus			6	0.00
Trichiurus lepturus	39,890	14.01	76,203	16.34
Upeneus bensasi			129	0.03
Uranoscopus japonicus			1,073	0.23
Zebrias zebra			162	0.03
Zenoposis nebulosa			641	0.14
Zeus faber			1,095	0.23
Zoarces gilli	565	0.20		
Total	284,647	100	466,415	100
Number of species	53		87	

0.1 lower in salinity of surface layer than in 2002. The fronts were formed along the 12°C and 34 at the bottom, regardless of year, between warm Kuroshio Current water and cold Yellow Sea water. Influence area of warm water current in 2003 was weaker in the study area than in the northwestern direction in 2002 (Figure 2).

Total catch was 285 kg in 2002 and increased to 466 kg in 2003 (Table 1). In 2002, 53 species occurred with the dominant species being silver pomfret (*P. echinogaster*, 22.54%), hairtail (*T. lepturus*, 14.01%), anchovy (*E. japonicus*, 11.85%), small yellow croaker (*L. poliactis*, 10.86%) and yellow goosefish (*L. litulon*, 5.82%). Spanish mackerel (*S. niphonius*, 5.79%) and jack mackerel (*T. japonicus*, 4.26%) also showed as a high proportion of the catch in 2002. The numbers of fish species collected were 87 in 2003, higher than in 2002 with the dominant species being silver pomfret (19.07%), hairtail (16.34%), anchovy (12.66%), yellow goosefish (8.29%) and small yellow croaker (6.89%). Five species such as silver pomfret, hairtail, anchovy, small yellow croaker and yellow goosefish were most abundant, composing above 60% of total catch in 2002 and 2003.

Table 2 showed the number of occurring species and relative catch weight (%) in each area by 1 degree of latitude and longitude in the study area during March, 2002 and 2003. In 2002, 51 species and 32.67% of the total catch occurred around Jeju Island (33-34°N, 126-127°E), 35 species and 13.66% were in southwestern waters (34-35°N, 123-124°E), and 30 species and 10.88% were in the southeastern coastal waters (34-35°N, 128-129°E). In 2003, 51 species and 21.13% of the catch occurred in the southeastern coastal waters, and 47 species and 30.91% were around Jeju Island. In the southwestern waters, 36 species and below 10% of total catch occurred. Therefore, geographical distribution in the number of species showed high proportions of species numbers and catches in the areas around Jeju Island, southwestern waters close to the central Yellow Sea, and the southeastern coast of Korea.

Distribution patterns of major fish species are depicted in Figure 3. Silver pomfret, the most dominant species, was widely distributed in the study area in 2002 and 2003, showing high density at the southwestern waters in 2002 and at southeastern coastal waters in 2003. Hairtail was mainly distributed in the southwestern waters, western offshore area of Jeju Island, and southeastern coastal areas

Table 2. Number of species occurring and relative catch weight(%) in each area by 1 degree of latitude and longitude in the study area during March, 2002 and 2003.

Longitude (°N)		Latitude(°E)					
Year		123-	124-	125-	126-	127-	128-
Number of species							
2002							
	34-	35					30
	33-	16	30	21	51	7	
	32-		15	16	15		
2003							
	34-	36	3				51
	33-	13	12	31	47	25	
	32-				20		
Proportion of Catch(%)							
2002							
	34-	13.66					10.88
	33-	6.16	8.82	8.58	32.67	4.90	
	32-		5.50	4.05	4.78		
2003							
	34-	7.65	4.31				21.13
	33-	4.59	1.37	23.05	30.91	2.75	
	32-				4.25		

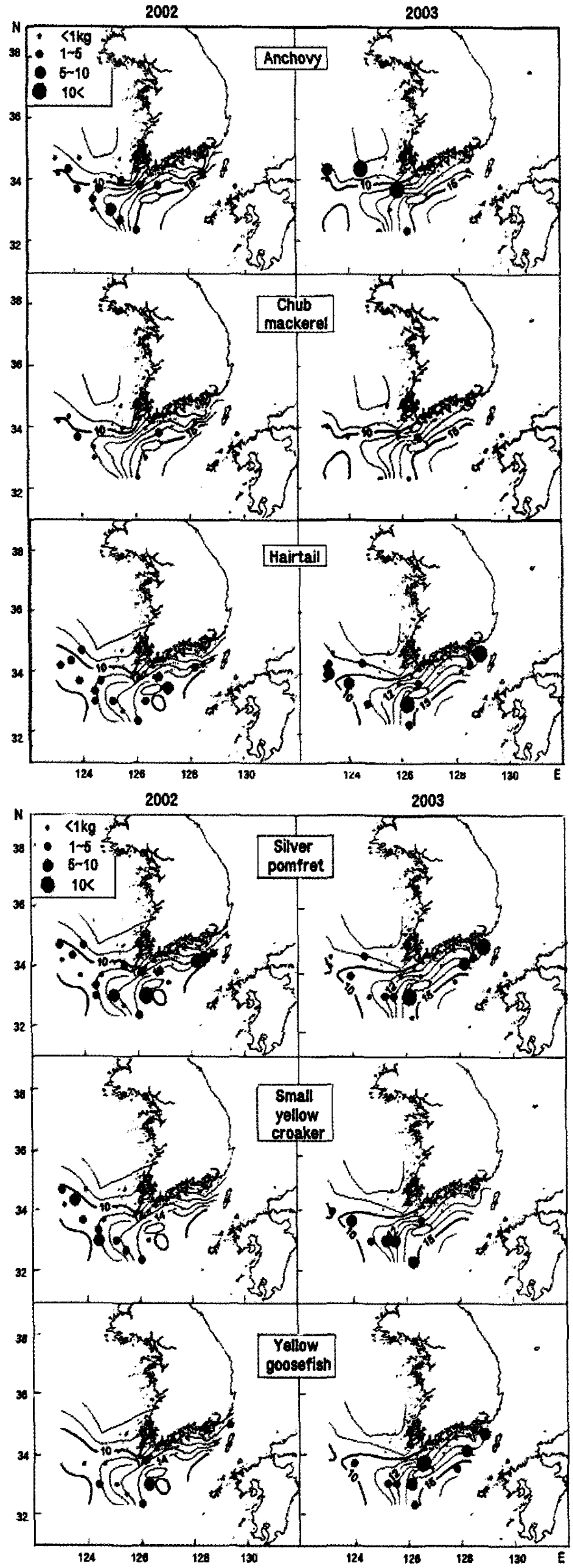

Fig. 3. Spatial distribution of major fish species by trawl survey and surface temperature in the southwestern area of Korean waters during March, 2002-2003.

in 2002 and 2003. Small yellow croaker was distributed west of Jeju Island in 2002 and 2003. High density area was moved southward around Jeju Island in 2003. Yellow Goosefish was scattered around western Jeju Island and southeastern coastal water in 2002 and showed low density in the Yellow Sea in 2003. Chub mackerel showed low density in the southwestern waters and northern Jeju Island in 2002 and in the western Jeju Island in 2003. Anchovy showed wide distribution in the southwestern waters near the central Yellow Sea and southern coastal waters in 2002, but more restricted occurrence in 2003.

Estimation of box plots and non-parametric results for major fish species

The ranges of bottom temperature and salinity where the fish were caught, were plotted (mean±25% and total range) in 2002 and 2003 (Figure 4). More than 50% of major fish species were collected in the range of 9-11°C of temperature and 33-34 of salinity, which appeared at the front area in the investigated area. Hairtail, silver pomfret, anchovy and small yellow croaker occurred even below 8°C. Occurrence of jack mackerel was skewed to the more warm temperature areas than was that of chub

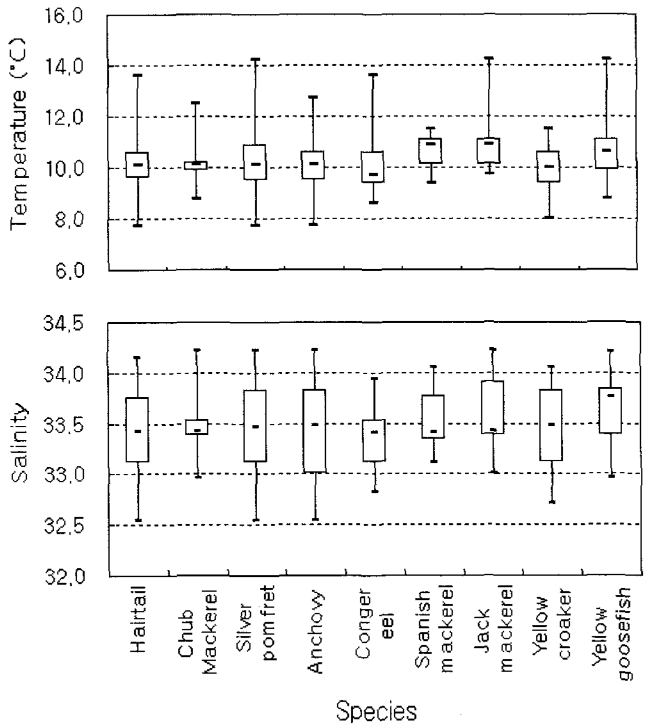

Fig. 4. Box plots of the range of temperature and salinity for major fish species.

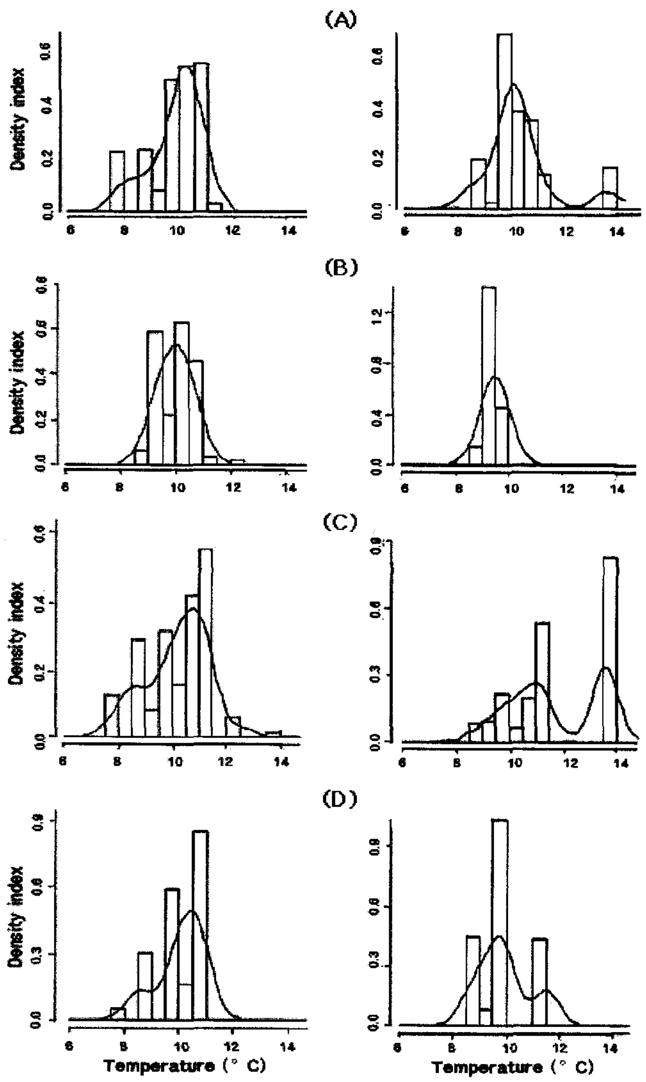

Fig. 5. Occurrence of hairtail (A), chub mackerel (B), silver pomfret (C), small yellow croaker (D) during March, 2002 (left) and 2003 (right) analyzed by non-parametric statistics.

mackerel. Spanish mackerel and small yellow croaker showed in the restricted range of 8-12°C. Occurrence of hairtail, silver pomfret and anchovy showed wide range of salinity with the minimum value below 33 and maximum value above 34 in salinity. Chub mackerel, spanish mackerel and yellow goosefish occurred above 33 in salinity. Conger eel, spanish mackerel and small yellow croaker were limited in their distribution below 34 in salinity. Proportion of catch for 4 major species, hairtail, chub mackerel, silver pomfret and small yellow croaker was compared for temperature distribution and estimated by the non-parametric method (Figure 5). Hairtail was distributed in the range of 7.5-11.5°C in 2002 and 7.5-14.0°C in 2003 with 2 modes in non-parametric estimation. Chub mackerel was distributed in 8.5-12.5°C in 2002 and 8.5-10.0°C in 2003 with 1 mode. Silver pomfret had distribution in the range of 7.5-14.0°C with 2 modes, small yellow croaker, 7.5-11.0°C in 2002 and 8.5-11.5°C in 2003 with 2 modes. Non-parametric estimation of 4 species showed mostly to be 1st mode around 10°C and 2nd modes were 8-9°C in 2002 and 11-14°C in 2003 respectively.

Occurrence of juveniles for major fish species

We compared length distribution of hairtail in the southwestern and southeastern waters of Korea (Figure 6). Length distribution of hairtail showed a range of 3-27 cm AL during 2002 and 3-43 cm AL during 2003 and divided in distribution area with small size group in the low temperature and low salinity area and large size in the frontal area between 9-11°C in temperature and 33.8-34.5 in salinity. When we compared them by the survey

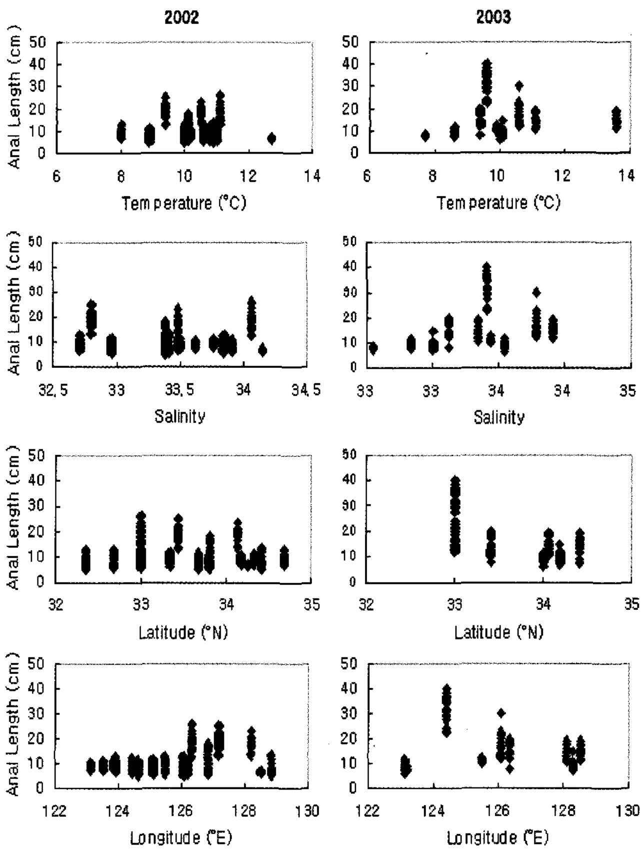

Fig. 6. Length distribution of hairtail in comparison with temperature, salinity, longitude and latitude of each station in 2002 and 2003.

area in the basis of the latitude and longitude, the small size group of hairtail was distributed in the southwestern Korean waters in 2002 and southeastern Korean coastal waters in 2003. Therefore we determined that most of the hairtails were juveniles, and larger individuals were distributed southwestern waters in 2003.

4. Discussion

Some information on the warm water fishes in the wintering grounds is available; this information is based on the commercial fisheries data in the Korean waters. However, detailed information for the fisheries management is limited due to the lack of scientific survey data. Therefore, we investigated temperature and salinity effects on the major fishes in the wintering grounds based on the trawl surveys and oceanographic observations in the southwestern waters of Korea during March in 2002 and 2003. When we compared the dominant species in this study to those of the previous study (Kim *et al.* 1970), dominant fishes were changed from demersal fish to semi-demersal and pelagic fish. Kim *et al.* (1970) showed that the most frequently occurring fishes were pleuronectids, representative bottom fish such as roundnose flounder (*Eopsetta grigorjewi*) and willowy flounder (*Tanakius kitakarai*). The present study shows that the 5 most abundant species (Table 1), silver pomfret, hairtail, anchovy, small yellow croaker and yellow goosefish, were semi-demersal and pelagic fish, which is similar to the results by Xu and Jin (2005). Dominant species from bottom otter trawl survey in the western area of the Yellow Sea during the summer of 1999 were anchovy, hairtail and mackerel and they principally consisted of juveniles (Yeon *et al.* 2004). In this study, hairtail were also composed of juveniles, and some larger individuals were only caught in the southwestern area in 2003 (Figure 6).

Most abundant water for major fish species was limited in the range of 9.5-11℃ in temperature and 33.1-33.9 in salinity where the thermal front appeared in the areas around Jeju Island, southwestern waters near the central Yellow Sea, and southeastern coast with the 1st mode around 10℃ and the 2nd mode of 8-9℃ in 2002 and 11-14℃ in 2003 (Figure 4 and 5). As for the strength of the warm water current in 2003, it was weaker in the southwestern waters and stronger in southern Korean waters than it was in 2002 (Figure 2). Despite the delay of survey periods in 2003, we detected that all major fish species except anchovy were distributed in southwestern waters with low density and in southeastern Korean waters with high density in 2003 (Figure 3). Those results indicate that temperature and salinity distribution and subsequent formation of thermal front in spring plays an important role in the distribution of major fish species and the recruitment of juveniles to the adjacent coastal growing habitats.

The main use of ecosystem indicators is to summarize trends in ecosystem structure or functioning that can be related to fishing and environmental variability (Erzini *et al.* 2005). To estimate habitat specific-density difference and variance of density differences, trawl surveys have a limited ability to sample all habitats representatively (Jagielo *et al.* 2003). Statistical analyses are available for the related problem of sampling large-scale commercial landings of fish at markets as well as trawling samples (Cotter 1998). Although we used non-parametric method and box plots to define limiting factor of occurrence of wintering grounds, statistical analyses must develop to handle trends, explanatory variables and missing values (Erzini *et al.* 2005).

Scientific survey may provide an ecosystem-level experimental framework to study the persistence and stability of communities, detect both direct and indirect effects of fishing, and devise a fisheries management strategy through constitution of useful management tool for protection of juveniles from overfishing (Sosa-Lopez *et al.* 2005). Therefore, the results of these scientific surveys are considered to be beneficial for the area-based management strategy for the wintering grounds of the Yellow Sea and coastal waters of Korea.

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