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Distributions and assemblages of larval fish in the East China Sea in the northeasterly and southwesterly monsoon seasons 2008

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Abstract

A total of 8459 larval fish were collected in the southern East China Sea during the winter northeasterly monsoon season and the summer southwesterly monsoon seasons in 2008. They were composed of 184 species belonging to 105 families and 162 genera. The abundance in terms of CPUE (number of individuals/1000 m^3) of the larvae was about six times higher in the southwesterly monsoon season than that in the northeasterly monsoon season. The primary environmental factors affecting the larval abundance were found to be water temperature in the northeasterly monsoon season but food availability in the southwesterly monsoon season. Three larval fish assemblages were recognized; the inshore assemblage, the offshore assemblage, and the summer coastal assemblage. The distribution and species composition of the larvae in the assemblages reflected the hydrographic conditions and water currents resulted from the seasonal monsoons.

1 Introduction

The East China Sea (ECS) is one of the largest marginal seas in the world. It is bordered by China Mainland, Taiwan Island, Japanese Archipelago, and Korean Peninsula. The hydrographic systems in the continental shelf of ECS have been known to be influenced by the southward China Coastal Current and Yellow Sea water in the northeasterly monsoon season, but by the northward Kuroshio Current and Taiwan Strait Current in the southwesterly monsoon season (Katoh et al., 2000; Gong et al., 2003; Yang et al., 2011, 2012). Fresh water discharges from the Changjiang River also affect the hydrographic system of ECS in the summer (Gong et al., 1996).

Ichthyoplankton are meroplankton, a planktonic stage that is very sensitive to environmental changes. Their spatial distribution and assemblages are closely related to oceanic hydrographic features (Okazaki et al., 2002; Okazaki and Nakata, 2007; Lo et al., 2010). These features act as the mechanisms of enrichment, concentration and

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retention for larval fish, affecting their survival and production (Okazaki et al., 2002; Hsieh et al., 2011). This biological–physical relation has been observed in estuarine system (Queiroga et al., 1997; DiBacco et al., 2001), shelf break front (Hsieh et al., 2007; Chen et al., 2012) and upwelling area (Vargas and Castro, 2001; Yannicelli et al., 2006).

Many studies have been conducted on the changes in the structure of larval fish assemblages in relation to the hydrographic conditions, such as current transportation (Sassa et al., 2006), seasonal changes (Hsieh et al., 2011), and food availability and competition (Sassa et al., 2008). For ECS such studies have been made on a shelf break area (Okazaki and Nakata, 2007) and the waters around Taiwan (Hsieh et al., 2010). Recently, more attentions have been made on effects of monsoon systems on marine environments, particularly on the circulation pattern (Lo et al., 2010; Hsieh et al., 2010, 2011, 2012). With these there were the studies on the spatio-temporal difference in larval fish assemblages in relation to local hydrographic features between different monsoon seasons in the northwest Pacific Ocean (Hsieh et al., 2011, 2012).

We have been conducting the Longterm Observation and Research of East China Sea (LORECS) since 1997 to determine the biogeochemical cycle and main plankton loop to assess the impacts of the reduction in Changjiang River discharges on marine environments caused by the construction of Three Gorges Dam in 2003 (Gong et al., 2007). This study was a part of the LORECES to investigate the species composition, assemblages and abundances of larval fish in the ECS and compared them between the two distinct monsoon seasons in 2008 as a part of the evaluation of the food web dynamics in ECS.

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2 Materials and methods

2.1 Data collection

Larval fish were collected at 16 stations on board the Ocean Research I in January and July 2008 (Fig. 1), using an Ocean Research Institute (ORI) net with a mouth diameter of 1.6 m and stretch mesh size of 0.33 mm. At each of the station, the net was towed obliquely from the depth at 200 m to the surface at deep stations (depths > 200 m) or from 10 m above the bottom to the surface at shallower stations (< 200 m). The volume of water filtered was calculated using a flow meter attached at the center of the net. Biological samples collected were fixed immediately in 5 % formalin-seawater solution. In the laboratory, ichthyoplankton were picked up from the collections and identified to the lowest taxonomic level as possible, according to the atlas of Okiyam (1988), and Leis and Carson-Ewart (2000). Larval fish abundance was calculated and standardized as CPUE (number of individuals/1000 m^3). Sea water temperature and salinity were recorded by a conductivity temperature depth (CTD) profiler (SBE 9/11, Sea-Bird Electronics Inc. Washington DC, USA). Environmental features including nutrients and chlorophyll *a* were obtained from the LORECS reports (Chen et al., 2009).

Meso-scale oceanographic conditions of ECS were collected from the satellite images and HYCOM model data. The sea surface temperature images were obtained from the National Oceanic and Atmospheric Administration/Advanced Very High Resolution Radiometer (NOAA/AVHRR) sensors (Lee et al., 2005). The HYCOM ocean surface currents with 1/12° spatial resolution were download from the OPeNDAP ocean database (http://opendap.org/ml-toolbox) (Cornillon et al., 2009).

2.2 Data analysis

Mann–Whitney U-test was used to determine the significant level in difference of CPUEs between the two monsoon seasons. The CPUEs were normalized by a logarithmic function [$\ln(x+1)$] transformation. Cluster analysis with normalized Euclidean

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distances was used to measure levels of similarity in species composition among the sampling stations. Ward's method was used to illustrate their relations in a dendrogram. The cluster analysis was processed using the STATISTICA 8 statistical software package.

Pearson's correlation analyses were used to determine the relationship between CPUEs and each of sea surface temperature (SST), primary production and zooplankton wet weight. Non-linear relationships between dominant taxa and environmental variables were analyzed with the canonical correlation analysis (CCA), a statistical visualization method (ter Braak, 1994).

3 Results

3.1 Hydrographic conditions

Maps of satellite temperatures and current directions in January and July 2008 showed the meso-scale environmental features in ECS (Figs. 2 and 3). In January the cold China Coastal Current flowed southward (Fig. 2a, blue color) and Kuroshio Branch Current occurred on the southeastern shelf (Fig. 2a, green color). In July the warm waters ($> 25\,^{\circ}$C) were widely distributed in the continental shelf (Fig. 2b). The current directions displayed that Kuroshio Current was a strong current flowing along the 200 m isobaths in both seasons (Fig. 3). In northeasterly monsoon season, the southward current at a depth of 10 m intruded along the coast of China into the southern ECS around latitude 26° N (Fig. 3a). In the southwesterly monsoon season, this current move northeasterly from the Taiwan Strait to the shelf of ECS with the flow rate of ca. $0.5\,\mathrm{m\,s^{-1}}$ (Fig. 3b). The current directions at the depths of 10 m and 50 m changed from northeast direction to east direction around the latitudes of 30° N and 28° N, respectively (Fig. 3b, d).

The distributions of sea surface temperature and salinity at the depth of 10 m in January and July 2008 are shown in Fig. 4. In general, the temperature and salinity at the stations adjacent to the coast of China were lower. In the winter northeasterly monsoon season, the sea surface temperatures ranged between 12.1 and 24.3 °C and salinities between 30.8 and 34.6 psu. In the southwesterly monsoon season, the temperatures were between 19.6 and 29.6 °C that were higher than those in the northeasterly monsoon season. The salinities varied between 28.0 and 34.2 psu. The salinities less than 31 psu (Gong et al., 1996) were found only at the Changjiang River estuary in the southwesterly monsoon season.

3.2 Abundance and composition of larval fish in relation to environments

A total of 8459 fish larvae were collected. They were comprised of 184 species belonging to 105 families and 162 genera with a total CPUE of 15 534 ind./1000 m^3. The spatial distribution of larval abundance expressed as CPUE is showed in Fig. 5. The average CPUE was 143 ind./1000 m^3 in the northeasterly monsoon season that was about 6 times less than 828 ind./1000 m^3 in the southwesterly monsoon season. The maximum CPUE was 502 ind./1000 m^3 at Station E8 in the northeasterly monsoon season and 4061./1000 m^3 at Station E19 in the southwesterly monsoon season (Fig. 5). The CPUEs showed a significant difference between northeasterly and southwesterly monsoon seasons (Mann–Whitney U-test, $p < 0.05$) but not between day and night in each of the two seasons (Tables 1 and 2).

Figure 6 shows the relationships between CPUEs and the environmental variables: sea surface temperature, primary production and zooplankton wet weight. In the northeasterly monsoon season, CPUE were significantly, positively correlated ($r = 0.61$, $p < 0.05$) with sea surface temperature but not with primary production. A positive correlation was also found between CPUE and zooplankton wet weights, when Station E20 where a shrimp bloom occurred was excluded ($r = 0.57$, $p < 0.05$) (Fig. 6c). In the southwesterly monsoon season, a significant, positive correlation was found only between CPUE and primary production ($r = 0.59$, $p < 0.05$).

The dominant species of larval fish (> 1 %) are showed in Table 2. In the northeasterly monsoon season, the dominant species were *Valamugil* sp., *Sigmops gracilis*, and

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scorpaenid larvae. When their numbers were combined, the combined average CPUE was 795 ind./1000 m^3, occupying 34.48 % of the total larval fish sample. In the southwesterly monsoon season, gobiid type 2, *Saurida* spp. and *Engraulis japonicus* were the dominant taxa accounted for 6084 ind./1000 m^3, occupying 45.92 % of the total sample.

The ordination diagrams of canonical correlation analysis (CCA) of CPUEs of dominant larval fish taxa and environment variables are shown in Fig. 7. In the northeasterly monsoon period, CPUE of each of *Sigmops gracilis*, *Diaphus* A and B, and callionymid larvae was positively related with sea surface temperature, sea surface salinity and primary production, but negatively with DO and opposite to CPUE of scorpaenid larvae (Fig. 7a). In the southwesterly monsoon season, the CPUE of *Engraulis japonicus* was positively related with primary production and zooplankton wet weight, but negatively with sea surface salinity and opposite to CPUE of gobiid type 2 (Fig. 7b). The CPUE of *Bregmaceros* spp. was negatively correlated with DO.

3.3 Assemblages and biodiversity of larval fish

The dendrogram and geographic locations of the larval fish communities analyzed with the cluster analysis for the two monsoons are shown in Fig. 8. In the dendrogram, based on the station association and spatial distribution pattern of the species, three assemblages were recognized; they were the inshore assemblage, the offshore assemblage, and the summer coastal assemblage. The latter one occurred only in the southwesterly monsoon season. The dominant species of each of the assemblages with ecological information of species at adult stage in the two monsoon seasons are shown in Table 3.

The inshore assemblage was observed at 11 stations in the northeasterly monsoon season and 3 stations in the southwesterly monsoon season (Fig. 8). It was located in the area with lower sea surface temperature and sea surface salinity (Fig. 4) with average CPUE of 68 ind./1000 m^3 in the northeasterly monsoon season and 168 ind./1000 m^3 in the southwesterly monsoon season (Table 3). Its abundance was the

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lowest for the three assemblages. The most dominant species of the larvae in the inshore assemblage was scorpaenid larvae that accounted for 26.45 % in the northeasterly monsoon season and 20.18 % in the southwesterly monsoon season (Table 3). The offshore assemblage was observed at 5 stations in the northeasterly monsoon season and 8 stations in the southwesterly monsoon season in the offshore region (Fig. 8) with higher sea surface temperature and sea surface salinity (Fig. 4). The average CPUE of the assemblage was 286 ind./1000 m^3in the northeasterly monsoon season and 289 ind./1000 m^3 in the southwesterly monsoon season. They were, respectively, 2 to 4 times higher than those of the inshore assemblages in both seasons (Table 3). The most dominant species were *Valamugil* sp. in the northeasterly monsoon season and *Trachinocephalus myops* in the southwesterly monsoon season. The former had CPUE of 323 ind./1000 m^3occupying 22.61 % of the total offshore assemblage sample, while the latter had 295 ins./1000 m^3accounted for 12.79 %.

The summer coastal assemblage occurred only at 5 stations at the 50 m isopleths along the China coast south and out the mouth of the Changjiang River in the southwesterly monsoon season (Fig. 8b). Its abundance was 10 304 ind./1000 m^3 that was comparatively higher than those of the other two assemblages (Table 3). Three dominant species were gobiid type 2 (2344 ind./1000 m^3), *Saurida* larvae (2234 ind./1000 m^3) and *Engraulis japonicas* (1,378 ind./1000 m^3) (Table 3). *E. japonicas* larvae were highly aggregated at Stations E19 (446 ind./1000 m^3) and E27 (897 ind./1000 m^3) located at or near the Changjiang River estuary.

4 Discussion

4.1 Seasonal difference in oceanic currents

The hydrography in ECS was strongly influenced by the seasonal changes in China Coastal Current, Taiwan Strait Current and Kuroshio Branch Current, even the boundary of the Kuroshio Current with high temperature and salinity was along the shelf break of ECS in the two monsoon seasons (Figs. 2 and 3). In the northeasterly monsoon season, water temperature is low with an obvious intensive thermal front, when the monsoon wind turns northeasterly direction and brings the China Coastal Current flows southwardly. It has been revealed that the cold China Coastal Curent expands southward over the mid-shelf of ECS and interacts with the Kuroshio Branch Current to form thermal fronts along the 50 m isopleths (Fig. 2a) (Chang et al., 2008). The extension of southward China Coastal Current along the China coast disappeared in the southwesterly monsoon season (Fig. 2b).

The Kuroshio Branch Current and Taiwan Strait Current concurrently intrude to the East China Sea carrying with warm water from the south in the southwesterly monsoon (Isobe, 2008). They may block the southward flow of the China Coastal Current with cold water from the north at the south of Changjiang River (Figs. 3b and 4). Intrusion of the lower salinity water into the East China Sea has been described by Chang and Isobe (2003) and Gong et al. (2011) suspecting that the discharges of the Changjiang River in the seas extends farther northeastward but constrained by the Taiwan Strait Current in the southwesterly monsoon season.

4.2 Abundance of larval fish in relation to environmental variables

In this study the abundance of larval fish in the northeasterly monsoon season was found to be much lower than that in the southwesterly monsoon season in the ECS (Table 2), a fairly similar result obtained by Hernandez et al. (2010). It has been known that larval fish are significantly abundant in the warm season (Meekan et al., 2003) and the low temperature ($< 20\,^{\circ}$C) in general is not suitable for larval fish to live. Batty and Blaxter (1992) and Stoll and Beeck (2012) indicate that growth and swimming ability of larval fish was impeded by the low temperature. Okazaki and Nakata (2007) suggest that the abundance of larval fish and species number are less so at lower temperature and increased with the warm temperature.

It was found that sea surface temperature was significantly positively correlated with zooplankton wet weight (Chen et al., 2012) and abundance of larval fish was

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positively related to zooplankton wet weight and presumed to related to availability of food sources in summer (Hsieh et al., 2010). Zooplankton are also known to be the primary prey for larval fish and their mouth widths must match with the prey sizes in predation (Cunha and Planas, 1999). Fifty percent of the larvae are able to capture prey when the size of the prey was equal to 85 % of the width of the mouth. When the prey size is less than 57 % of the width of the mouth, more than 95 % larvae were able to capture them (Hunter and Kimbrell, 1980).

Development stages of the larval fish collected with the ORI net with a mesh size of 330 um mesh was dominated by the pre-flexion and flexion stages. The mouth development at these stages was not completely established to enable the larvae to capture most of mature zooplankton. Therefore, it was difficult for this study to examine whether zooplankton wet weight was a causal factor for the fish larval abundance, even they were significantly, positively correlated in the northeasterly monsoon season (Fig. 6). The suitable warm temperature is considered to an important factor affecting the survival and production of larval fish in the northeasterly monsoon season (Zenitani et al., 2009).

It is interesting that the larval increased with primary production but not SST and zooplankton wet weight in the southwesterly monsoon season (Fig. 6). This suggested that the influence of SST on survival and production of larval fish decreased as the environment became warmer (> 25 °C). The primary production is the biomass index of food availability for fish (Chen et al., 2004), suggesting that the production and survival of larval fish were influenced by food availability in the southwesterly monsoon season.

4.3 Larval fish assemblages in relation to oceanic currents

There were three larval fish assemblages, inshore assemblage, offshore assemblage and summer coastal assemblage in ECS. Many biological features, such as trophic level, life style and migration, are not obviously different among larval stages and species. Fish larvae are pelagic plankton in the early life stages of fishes whose ecological features differ from their adults (Leis, 2006). Therefore, ecological features were not the main reason for group structures. Even then, our result still showed that the abundance of the larvae differed significantly at each of the assemblages between the two monsoon seasons. The summer coastal assemblage had the highest average CPUE, about 2061 ind./1000 m^3, that was about 12 times higher that of the inshore assemblage and 7 times higher than that of offshore assemblage. Moreover, spatial distribution and species composition among the three assemblages were also differed significantly. As paragraph of the previously discussion, we suggest that it depends on food supply.

In the northeasterly monsoon season, the offshore assemblage occupied a few shelf areas at the latitudes from 26° N to 28° N, while the inshore assemblage occupied the southern area of ECS. This inshore assemblage receded toward the Changjiang River estuary and bank in the southwesterly monsoon season. Scorpaenid larvae were dominant in both monsoon seasons. Wu (2000) indicating their optimal temperature ranged between $10 \sim 14\,^{\circ}$C that fairly well corresponded to the temperature $< 19\,^{\circ}$C, salinity < 33 psu) of the southward China Coastal Current (Jan et al., 1998; Chen and Wang, 2006). In addition, Adult scorpaenid preferred to live the shallow near-shore waters with rocky bottom and belong to settled habitat type (Okiyama, 1988), so the place of adult scorpaenid life was its spawning ground.

The spatial distributions of the offshore assemblage stations were found to be fairly stable in the shelf waters. However, the two most dominant species were *Valamugil* spp. and *Sigmops gracilis* in the northeasterly monsoon season but changed to *Trachinocephalus myops* and *Auxis* larvae in the southwesterly monsoon season. Among them *Valamugil* larvae was widely distributed in the ECS and Taiwan Strait, but their taxonomy and ecology are still not clear (Durand et al., 2012). *T. myops* and *Auxis* larvae were abundant taxa important to the warm Taiwan Strait Current (Hsieh et al., 2012); while *Sigmops gracilis* have been recorded as the dominant species in the Kuroshio water (Hsieh et al., 2011). As shown in Fig. 7a, *Sigmops gracilis* was well related to the warm and saline water. Nakabo (2002) indicates that this adult species mainly inhabit the deeper oceanic waters and its larvae are pelagic life and abundant in

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the Kuroshio Current and offshore waters. In general, the larvae are pelagic plankton, sensitive to environmental changes (Ohshimo et al., 2012), and their survival depends on availability of food supply and suitable temperature. Moreover, Parmesan and Yohe (2003) also point out the current context of marked environmental changes may affect species distributions, natural resources and biodiversity. The above suggested that the change in the dominant species in the ECS between the two monsoon seasons might be due to the northward intrusion of Taiwan Strait Current and Kuroshio Current in the southwesterly monsoon season.

The summer coastal assemblage was biggest among the three assemblages. It was found in the coastal waters and the Changjiang River estuary and along its bank. *E. japonicus* was the 3rd dominant species in this assemblage. It was distributed mainly at the Changjiang River estuary and south side of the river bank, similar to that reported by Iseki and Kiyomoto (1997), who also states that the estuary is its major spawning ground. Gobiid type 2 and *Saurida* larvae were the two most dominant species of the assemblage. Although the gobiid type 2 occur widely in the coastal waters of ECS, the larvae taxonomy and phylogeny of gobiidae are not well established and morphological characters useful for species diagnosis of the larvae are insufficient, resulting in the constraint in the species identification. It is not easy to identify larval fish to species level (Thacker and Roje, 2011; Ko et al., 2013). In order to solve the above problems, it has been suggested to employ bio-technique methodology (Spies et al., 2006; Ko et al., 2013).

5 Conclusions

Our results provide evidence that the distribution of the larval fish assemblage in the continental shelf of ECS linked to the hydrographic conditions. It may be concluded that the abundance and spatial-temporal distribution of the larval fish assemblage were related to SST in the northeasterly monsoon season but food availability in the southwesterly monsoon season. There were three larval fish assemblages, the inshore, offshore

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and summer coastal assemblages. The species composition and distribution of the assemblages differed between the two monsoon seasons, resulted from changes in oceanic currents and hydrographic conditions of the two seasons.

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Table 1. Results of Mann–Whitney U-test for seasonal and diurnal differences in larval fish abundance (CPUE) in ECS, 2008.

Periods		Number of station	p value
northeasterly monsoon		16	0.0008
southwesterly monsoon		16	
northeasterly	day	8	0.9164
	night	8	
southwesterly	day	7	0.1248
	night	9	

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Table 2. Abundance (CPUE, number of individuals/1000 m^3) of dominant species of larval fish in the northeasterly and southwesterly monsoon seasons in ECS, 2008.

Northeasterly monsoon			Southwesterly monsoon		
Species	CPUE (ind./1000 m^3)	%	Species	CPUE (ind./1000 m^3)	%
Valamugil sp.	326	14.23	Gobiidae type 2	2344	17.69
Sigmops gracilis	239	10.46	*Saurida* spp.	2274	17.16
Scorpaenidae	230	10.06	*Engraulis japonicus*	1466	11.07
Diaphus A group	145	6.33	Gobiidae type 1	1064	8.03
Diaphus B group	113	4.95	*Bregmaceros* spp.	902	6.81
Callionymidae	111	4.85	Sciaenidae	763	5.76
Gobiidae type 2	71	3.09	*Cynoglossus* spp.	714	5.39
Trachurus japonicus	67	2.93	other Gobiidae species	359	2.71
other Gobiidae species	62	2.71	Apogontidae	352	2.66
Bregmaceros spp.	60	2.61	*Benthosema pterotum*	304	2.29
Myctophum asperum	40	1.77	*Trachinocephalus myops*	295	2.23
Triglidae	39	1.72	Callionymidae	235	1.77
Champsodon sp.	35	1.51	Leiognathidae	170	1.29
Ceratoscopelus warmingi	34	1.47	Scorpaenidae	146	1.1
Trichiurus lepturus	33	1.43	*Auxis* sp.	136	1.03
Vinciguerria nimbaria	29	1.25	others (< 1 %, 170 species)	1722	13
Scomber japonicus	29	1.25	Total	13 246	100
Teraponidae	25	1.09	Average	828	
Scomber australasicus	23	1.02			
others (< 1 %, 165 species)	578	25.27			
Total	2288	100			
Average	143				

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Table 3. The abundance (CPUE, ind./1000 m^3) and percentage contribution of dominant larval fish (> 80 %) of three larval fish assemblages in ECS, 2008 (NE, the northeasterly monsoon season; SW, the southwesterly monsoon season).

Inshore assemblage

Species	NE (11) Abu. (%)	SW (3) Abu. (%)
Scorpaenidae[n,b]	223 (26.45)	112 (20.18)
Gobiidae[n,b]	58 (6.89)	54 (9.64)
Gobiidae type 1[n,b]		88 (15.76)
Benthosema pterotum[n,b,o,p]	18 (2.09)	67 (12.09)
Trachurus japonicus[n]	66 (7.83)	
Gobiidae type 2[n,b]	64 (7.66)	
Engraulis japonicus[n,p]		64 (11.57)
Apogontidae[n]		60 (10.72)
Scomber spp.[n,p]	52 (6.16)	
Saurida sp.[n,b]	17 (1.98)	34 (6.07)
Callionymidae[n,b]	33 (3.87)	
Triglidae[n,b]	31 (3.74)	
Trichiurus lepturus[o]	28 (3.38)	
Bregmaceros spp.[o]	26 (3.04)	
Teraponidae[n]	24 (2.84)	
Terapon jarbua[n]	22 (2.62)	
Gadidae[o]	22 (2.60)	
Other species	66 (18.85)	26 (13.97)
Total	750 (100)	505 (100)
Average	68	168

Offshore assemblage

Species	NE (5) Abu. (%)	SW (8) Abu. (%)
Valamugil sp.[n,b]	323 (22.61)	
Trachinocephalus myops[n,b]		295 (12.79)
Sigmops gracilis[o]	230 (16.13)	
Auxis spp.[o,p]		204 (8.83)
Gobiidae type 1[n,b]		172 (7.45)
Champsodon spp.[n,b]	32 (2.25)	121 (5.24)
Bregmaceros spp.[o]	34 (2.38)	118 (5.13)
Diaphus B group[o,p]	102 (7.15)	39 (1.68)
Sciaenidae[n,b]		139 (6.03)
Diaphus A group[o,p]	131 (9.18)	
Callionymidae[n,b]	78 (5.50)	36 (1.57)
Ophichthidae[n,b]		98 (4.22)
Bothidae[n,b]	13 (0.89)	75 (3.26)
Apogontidae[n]		83 (3.58)
Cynoglossus sp.[n,b]		63 (2.72)
Vinciguerria nimbaria[o,b]	29 (2.01)	23 (1.01)
Ostraciidae[n]		47 (2.02)
Gobiidae[n,b]		43 (1.84)
Serranidae type 1[b]	13 (0.92)	26 (1.13)
Myctophum asperum[o,p]	37 (2.61)	
Benthosema pterotum[n,b,o,p]		35 (1.51)
Ceratoscopelus warmingi[o,b]	33 (2.30)	
Lophiidae[b]		31 (1.36)
Ophidiidae[b]		31 (1.35)
Percophidae[b]		31 (1.34)
Engraulis japonicus[n,p]		24 (1.02)
Pleuronectidae[n,b]		22 (0.94)
Decapterus maruadsi[n]		22 (0.94)
Mullidae[n]		21 (0.92)
Maurolicus sp.[o]	21 (1.48)	
Myctophum orientale[o,p]		21 (0.90)
Leiognathidae[n]		20 (0.87)
Decapterus sp.[n]		19 (0.82)
Lampanyctus spp.[o,p]	17 (1.19)	
Synagrops spp.[n,b]	15 (1.03)	
Gempylidae[n,b,o,p]	15 (1.02)	
Notoscopelus spp.[o,p]	14 (0.99)	
Dentex tumifrons[n]	11 (0.80)	
Other species	280 (19.56)	451 (19.53)
Total	1428 (100)	2310 (100)
Average	286	289

Summer coastal assemblage

Species	SW (5) Abu. (%)
Gobiidae type 2[n,b]	2344 (22.75)
Saurida spp.[n,b]	2234 (21.68)
Engraulis japonicus[n,p]	1378 (13.38)
Gobiidae type 1[n,b]	804 (7.80)
Bregmaceros spp.[o]	768 (7.45)
Cynoglossus sp.[n,b]	645 (6.26)
Sciaenidae[n,b]	619 (6.01)
Other species	1513 (14.68)
Total	10304 (100)
Average	2061

The ecological information of species at adult stage was remarked: [n] neritic; [o] oceanic; [b] benthic; [p] pelagic.

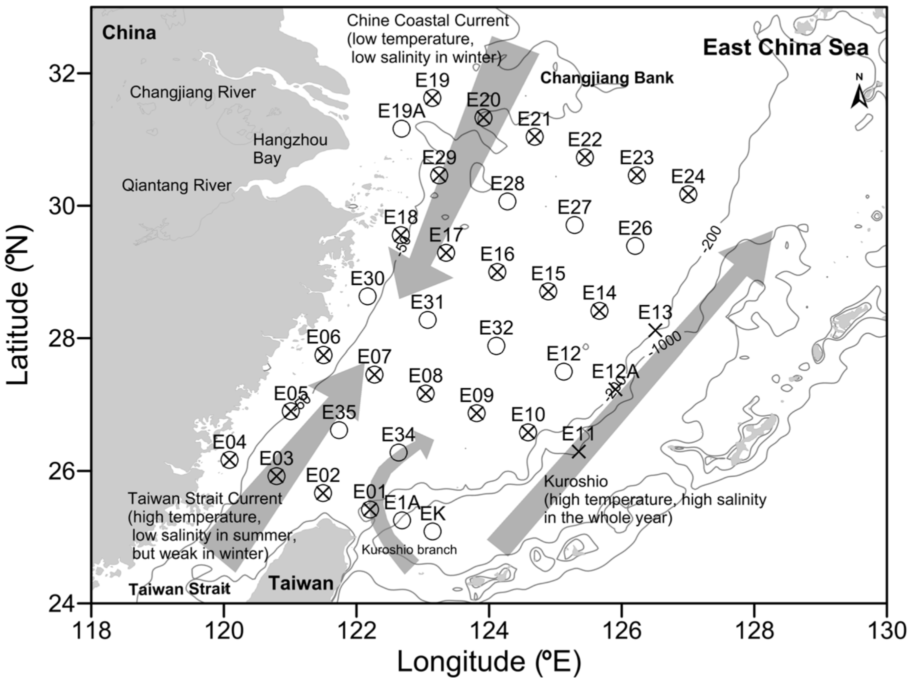

Fig. 1. Locations of the larval fish sampling stations in the northeasterly monsoon season (crosses), the southwesterly monsoon season (open circles) and both seasons (open circles with cross) in ECS, 2008.

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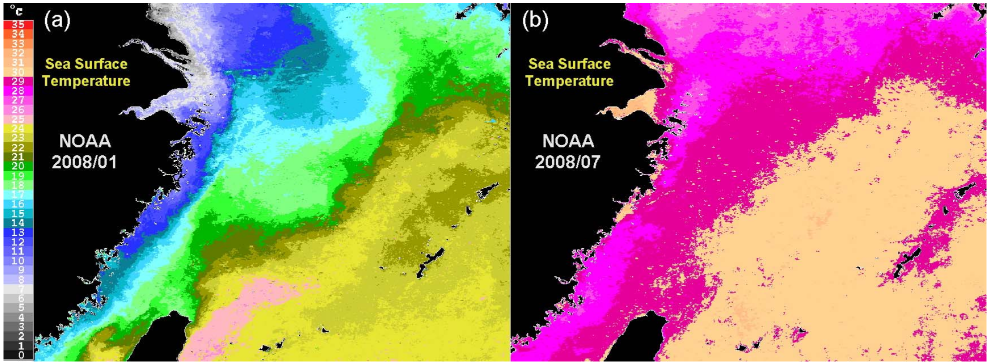

Fig. 2. Satellite images of monthly mean sea surface temperature in ECS in the months of January and July 2008.

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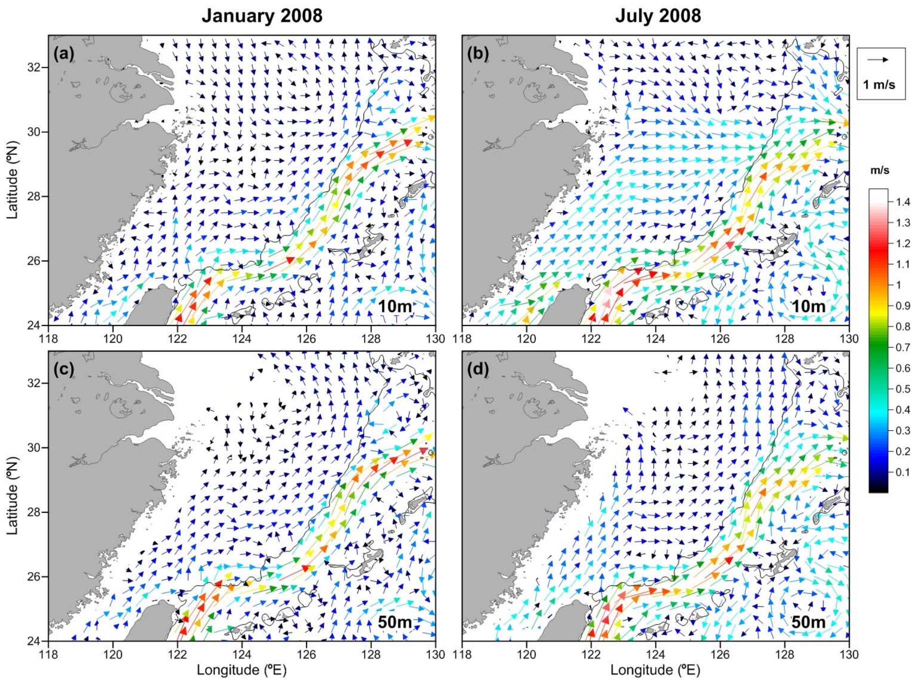

Fig. 3. Current conditions (length of arrow, current speed with a scale of 1 m s^{-1}; arrow direction, current direction) at the depths of 10 m **(a,b)** and 50 m **(c,d)** in ECS derived from the OPeNDAP ocean database, January and July 2008.

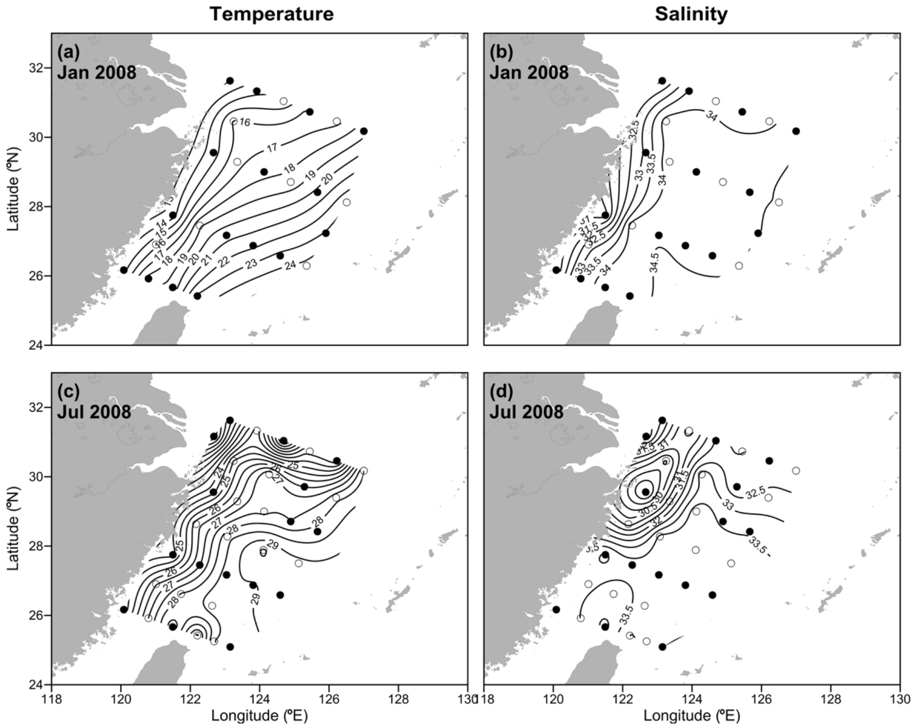

Fig. 4. Spatial distributions of temperature and salinity isopleths at the depths of 10 m in ECS, 2008 (open circles, stations with CTD data only; solid circles, stations with both CTD data and the data from the fish larval sampling).

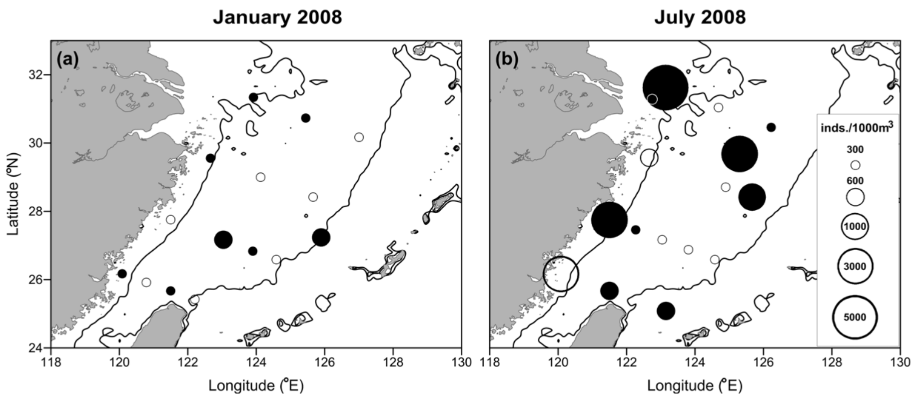

Fig. 5. CPUEs (ind./1000 m^3) of larval fish in the northeasterly monsoon season **(a)** and the southwesterly monsoon season **(b)** (open circles, daytime sampling; solid circles, nighttime sampling).

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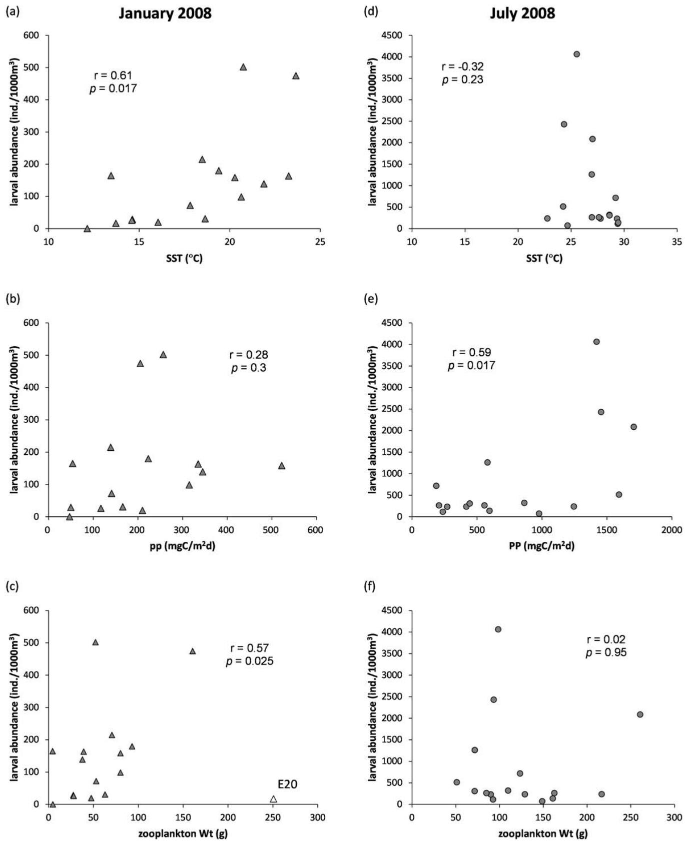

Fig. 6. Relationships between CPUE of larval fish and each of the environmental variables, sea surface temperature, primary production, and zooplankton wet weight.

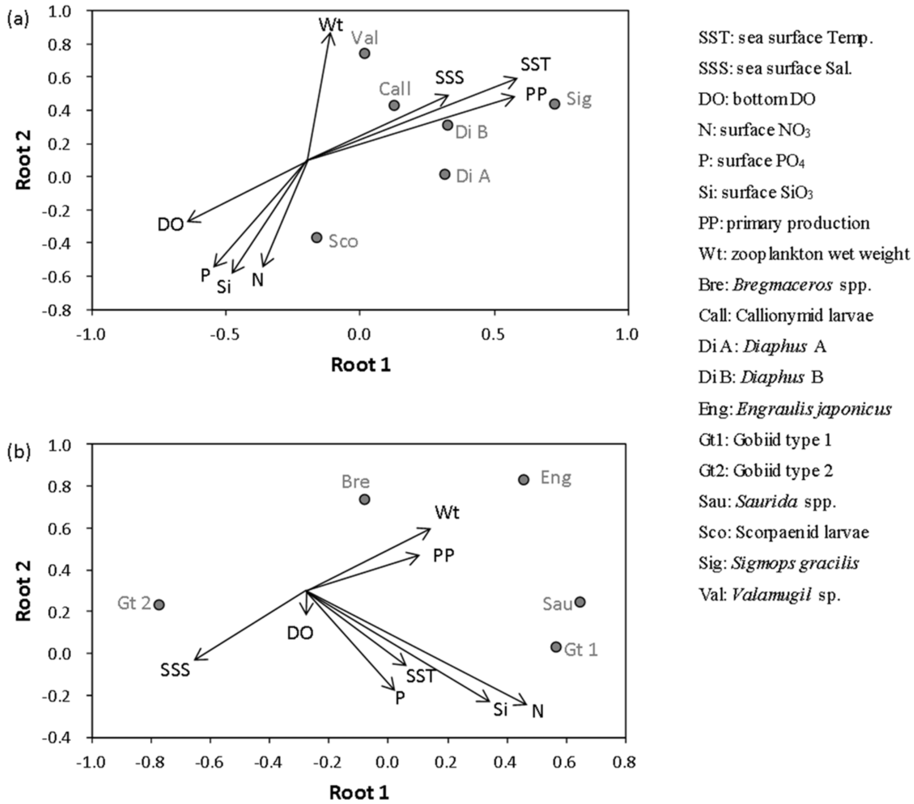

Fig. 7. Ordination diagram of canonical correlation analysis (CCA) showing the relationships between hydrographic factors and abundance of dominant larval fish taxa in the northeasterly monsoon season **(a)** and the southwesterly monsoon season **(b)**.

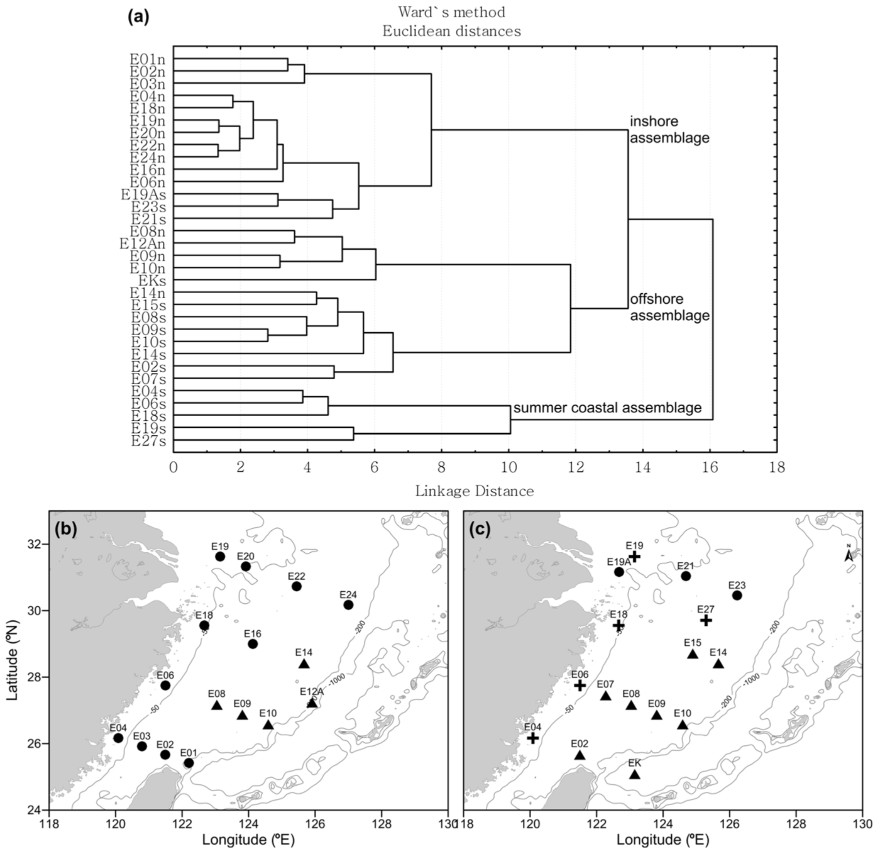

Fig. 8. The dendrogram of species composition similarity among stations in the northeasterly monsoon season; s, in the southwesterly monsoon season) by Ward's linkage cluster analysis **(a)** and its geographic locations of the larval fish assemblages in the northeasterly monsoon season **(b)** and the southwesterly monsoon season **(c)** (solids circles, inshore assemblage; solid triangles, offshore assemblage; crosses, summer coastal assemblage).