Journal of Marine Science and Technology

Volume 21
Issue 7 *Vol 22, Supplemental*

Article 7

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Ming-An Lee
Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, Keelung, Taiwan, R.O.C. Center of Excellence for Oceans, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.

Yi-Chen Wang
Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.

Yu-Kai Chen
Taiwan Fishery Research Institute, Keelung, Taiwan, R.O.C.

Wen-Yu Chen
d97310001@mail.ntou.edu.tw

Long-Jing Wu
Coastal and Offshore Resources Research Center, Taiwan Fishery Research Institute, Kaohsiung, Taiwan, R.O.C.

See next page for additional authors

Recommended Citation

Lee, Ming-An; Wang, Yi-Chen; Chen, Yu-Kai; Chen, Wen-Yu; Wu, Long-Jing; Liu, Don-Chung; Wu, Ji-Lun; and Teng, Sheng-Yuan (2013) "SUMMER ASSEMBLAGES OF ICHTHYOPLANKTON IN THE WATERS OF THE EAST CHINA SEA SHELF AND AROUND TAIWAN IN 2007," *Journal of Marine Science and Technology*: Vol. 21: Iss. 7, Article 7.
DOI: 10.6119/JMST-013-1219-5
Available at: https://jmstt.ntou.edu.tw/journal/vol21/iss7/7

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Acknowledgements

This study was financially supported by the National Science Council, Taiwan, (99-2611-M-019-013; 100-2611-M019-005) and Fisheries Research Institute, Council of Agriculture (96AS-15.1.1-AI-A3). The authors expressed their deepest respect and gratitude to the LORECS Research Team and Taiwan Fishery Research Institute for providing information and assisting with the research experiment.

Authors

Ming-An Lee, Yi-Chen Wang, Yu-Kai Chen, Wen-Yu Chen, Long-Jing Wu, Don-Chung Liu, Ji-Lun Wu, and Sheng-Yuan Teng

Journal of Marine Science and Technology, Vol. 21, Suppl., pp. 41-51 (2013)
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SUMMER ASSEMBLAGES OF ICHTHYOPLANKTON IN THE WATERS OF THE EAST CHINA SEA SHELF AND AROUND TAIWAN IN 2007

Ming-An Lee[1, 2], Yi-Chen Wang[1], Yu-Kai Chen[3], Wen-Yu Chen[4], Long-Jing Wu[4], Don-Chung Liu[3], Ji-Lun Wu[3], and Sheng-Yuan Teng[1]

Key words: larval fish, Kuroshio water, Changjiang diluted water (CDW), TaiCOFI.

ABSTRACT

This study investigated the relationships between assemblages of larval fish and hydrographic features in the East China Sea (ECS) and seas surrounding Taiwan during the summer of 2007. A survey was conducted from 2007 July 1 to 2007 July 11 in the ECS and from 2007 July 4 to 2007 July 16 in the waters surrounding Taiwan. A total of 12,670 larval fishes belonging to 95 families, 163 genes, and 189 species were identified. *Engraulis japonicus and Sillago japonica* were the 2 dominant species, accounting for 56.15% and 6.66% of the fish larvae samples. The cluster analysis results showed that the fish larval distribution patterns corresponded to hydrographic conditions. The results were also used to identify the following larval assemblages: the Kuroshio assemblage, coastal assemblage, Changjiang diluted water (CDW)/Yellow Sea mixed water assemblage, and Taiwan Strait water assemblage. The spatial distribution results showed a clear association between high abundances of larval fishes and shallow water areas near the ECS coast, and between low abundances and offshore Kuroshio water. The canonical correlation analysis results indicated that abundances of *E. japonicus* and *S. japonica* were strongly and positively correlated with chlorophyll a, but negatively correlated with salinity. These associations suggest that food sources and CDW might be crucial factors that determine the abundance and distribution of larval fishes during the summer.

I. INTRODUCTION

The East China Sea (ECS) is one of the largest marginal seas and bordered by Mainland China, the northern coast of Taiwan, the Japanese archipelago, and the southern coast of the Korean Peninsula. The ECS has a surface area of approximately 1,249,000 km2 and is greatly affected by ocean currents, including the Kuroshio Current (KC), Taiwan Strait Water (TSW), and China Coastal Current (CCC) [21, 22, 28, 33]. As well as freshwater discharge from the Changjiang River, the largest river runoff in the world. The freshwater discharge from the Changjiang River varies annually and mixes with offshore seawater [9]. Changjiang diluted water (CDW), with a salinity of ≤ 31, extends into the surrounding ocean regions during the summer [5]. In addition to CDW, Yellow Sea Cold Water (YSCW) of low temperature, low salinity, and high turbidity also invades the ECS. Because the YSCW in the southern ECS mixes with other shelf waters, it was renamed as Yellow Sea Mixed Water (YSMW) [8].

Physical and chemical oceanographic features, such as currents, upwelling, temperature, salinity, and nutrients [11], extreme ocean conditions such as those caused by typhoons [2], and current conditions such as transport and circulation [16, 29], have been thoroughly investigated in the ECS and waters surrounding Taiwan. The TSW, which flows northeastward along the coast of China and causes coastal upwelling, and the KC, which flows northward along the eastern coast of Taiwan and forms anticyclonic eddies northeast of Taiwan, supply a considerable amount of nutrients to the ECS [3]. Excluding the river discharge, increased nutrients resulting from upwelling appear to enhance primary production in the ECS, thereby improving fishery resources [7, 9, 11].

Paper submitted 10/30/13; revised 12/09/13; accepted 12/19/13. Author for correspondence: Wen-Yu Chen (e-mail: d97310001@mail.ntou.edu.tw).
[1] Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.
[2] Center of Excellence for Oceans, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.
[3] Taiwan Fishery Research Institute, Keelung, Taiwan, R.O.C.
[4] Coastal and Offshore Resources Research Center, Taiwan Fishery Research Institute, Kaohsiung, Taiwan, R.O.C.

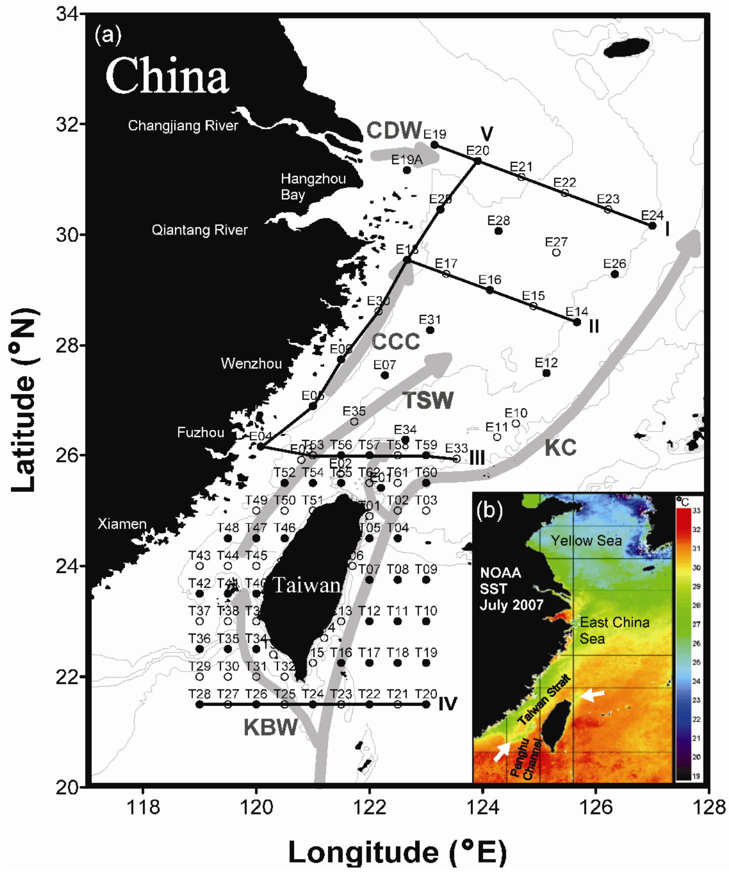

Fig. 1 . (a) Sampling stations in the southern ECS surveyed from 2007 July 1 to 2007 July 11(Stations E-) and in waters surrounding Taiwan surveyed from 2007 July 4 to 2007 July 16 (Stations T-). In this chart, grey arrows denote currents. KC, Kuroshio Current; TSW, Taiwan Strait water; KBW, Kuroshio Branch Water; CCC, China Coastal Current, which flows southward in the winter; CDW, Changjiang diluted water. (open circles denote stations with CTD data only, and solid circles denote stations with both CTD data and fish larval samples); (b) Satellite images of sea surface temperatures for July 2007.

Accordingly, the ECS is considered a crucial fishing ground and major spawning and nursery ground for commercially valuable species, such as *Trachurus japonicus*, *Scomber japonicus*, *Scomber australasicus*, and *E. japonicus* [14, 35].

The survival of larval fishes is closely associated with environmental systems because fish larvae are passively transported by currents [35]. Recent studies have indicated that environmental variability is a major factor in determining the survival of fishes at early life stages [13] and potentially influences the recruitment of larval fish [14, 15]. Changes in environmental factors, such as sea temperatures, salinities, prey and predator densities, and current transport, are considered the primary factors that affect the survival and distribution of the early stages of fishes [27, 31].

Numerous studies on physical and chemical oceanography [1, 19] and zooplankton compositions [24, 32] have been conducted on the shelf of the ECS and TS; however, information regarding larval fish assemblage in both areas is minimal. The purpose of this study was to investigate the assemblage structure of larval fishes, distribution of dominant species, and composition and abundance of ichthyoplankton in relation to the hydrological environment, including the discharge of the Changjiang River into the continental shelf of the ECS and waters surrounding Taiwan.

II. MATERIALS AND METHODS

The samples obtained for this study were collected on 2 cruises. Specifically, 31 stations (Stations E-) in the southern ECS were surveyed from 2007 July 1 to 2007 July 11 on board the *Ocean Research I*, and 62 stations (Stations T-) in the waters surrounding Taiwan were surveyed from 2007 July 4 to 2007 July 16 on board the *Fishery Researcher I* as shown in Fig. 1(a). In addition, 4 latitudinal and one meridional transect were used to represent the vertical hydrographic conditions. For convenience, the latitudinal transects along 21.5°N, 26°N, 29°-30°N, and 31°-32°N, as well as the meridional transect along the 50 m isobaths, were named Transects I, II, III, IV, and V, respectively as shown in Fig. 1(a). Temperatures and salinities were recorded from the water surface to a depth of 200 m (when permitting), or the sea floor when the water depth was less than 200 m, using a

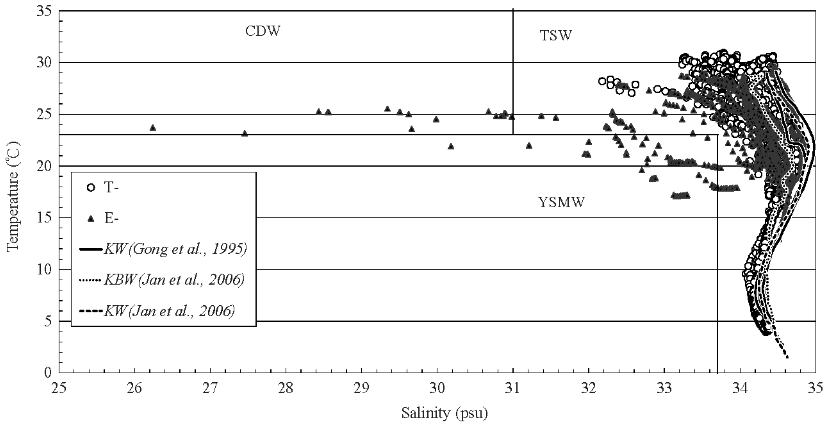

Fig. 2. At temperature-salinity (T-S) diagram for the survey area water (including E- and T-). The area between the solid lines represents the Kuroshio axis water (Gong *et al.*, 1995), and the dashed line denotes the Kuroshio axis water (Jan *et al.*, 2006). The dotted line denotes the Kuroshio branch water (Jan *et al.*, 2006).

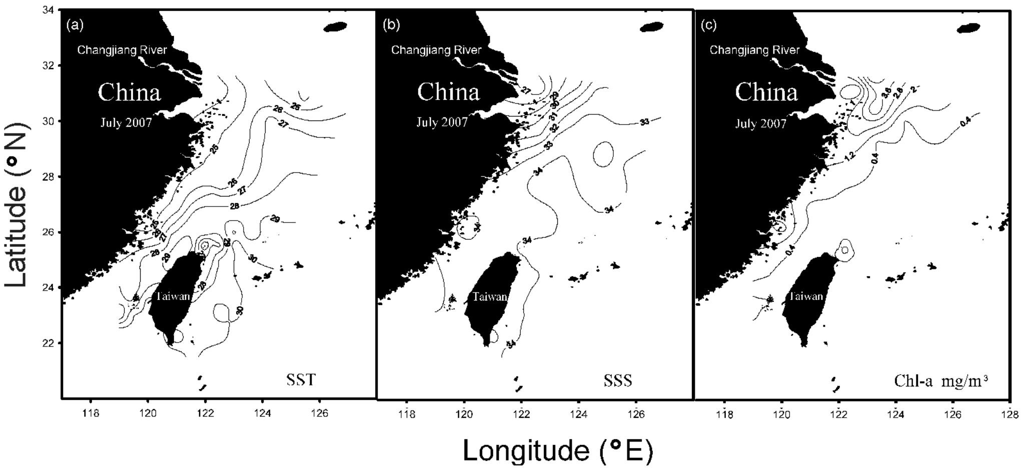

Fig. 3. The temperature (°C) and salinity (psu) contours in the surface *in situ* and chlorophyll-*a* during the survey period.

conductivity temperature depth (CTD) profiler. Satellite-derived sea surface temperatures (SSTs) were also collected for this study [25].

A rosette (GO-1015) mounted on the CTD profiler frame was sequentially closed at specific target depths as the CTD profiler was raised. One liter of seawater was filtered through Whatman GF/F filter papers and stored in a refrigerator at -70°C. In the laboratory, pigments were extracted in cold acetone (90%) for 24-48 h. Acetone extracts were acidified and centrifuged at 3,000 rpm and 4°C for 15 s. Chlorophyll and phaeopigments were independently measured using a fluorescence spectrophotometer. The euphotic zone-integrated Chlorophyll (Chl)-*a* concentration was expressed as milligrams per cubic meter (mg/m^3). The hydrographical features of the study area were analyzed using T-S diagrams of the sea surface to near the sea floor.

An ORI net, with a mouth diameter of 160 cm, length of 6 m, mesh size of 330 μm, and flow meter mounted at the center of the net mouth, was towed obliquely from a depth of 200 m to the sea surface at ca. 1 m/s at the 51 selected stations as shown in Fig. 1(a) (the stations are marked with a solid circle). The samples obtained were immediately fixed in seawater with 5% formalin. In the laboratory, larval fishes were sorted from the samples and identified to the lowest taxonomic level possible.

Cluster analysis with normalized Euclidean distances was used to measure the level of similarity in species compositions among the sampling stations, and the Ward method was employed to illustrate their relationships in a dendrogram. The cluster analysis results were processed using the STATISTICA 8 statistical software package. Abundances of fish larvae were expressed as the number of individuals (ind.)/1000 m^3 and then transformed using a logarithmic function [ln(x+1)] for cluster analysis. In addition, canonical correlation analysis (CCA) was conducted to determine the relationship between dominant species and oceanographic conditions (ter Braak, 1994). Moreover, 6 hydrographic variables were used to examine the relationships among larvae of the 11 most dominant taxa, with an average abundance of > 1% in total number.

III. RESULTS

1. Hydrographic Conditions

Hydrographic data were obtained from satellite images and CTD records. From a satellite image (Fig. 1(b)), the spatial distribution of monthly mean SST showed warm KC in the waters east of Taiwan and the Kuroshio Branch Water (KBW) intruding into the Taiwan Strait along the Penghu Channel in July 2007. A temperature-salinity diagram was used to determine variations in water mass and to conduct comparisons with results reported by previous studies (Fig. 2). Based on the results reported by Gong *et al.* [10] and Jan *et al.* [21], typical T-S curves of the KW, KBW, TSW, CDW, and YSMW are plotted in Fig. 2. The data in Fig. 2 show that the temperature and salinity varied from 4.47 to 30.01°C and 26.24 to 34.91, respectively. By contrast, the T-S curves of the stations were similar to the T-S curves of the KW, KBW, and YSMW in the southern ECS and waters surrounding Taiwan.

The CTD data show that SST ranged from 23.7 to 30.9°C, and the sea surface salinity (SSS) ranged from 26.2 to 34.5 in July 2007 (Figs. 3(a) and 3(b)). Chl-*a* concentrations in the surface layer varied from 0.05 to 5.30 mg/m^3 as shown in Fig. 3(c). Along the China coast, temperature gradients were nearly parallel to the coastline at 50-m depths from the mouth of the Changjiang River to the Taiwan Strait. In the northeast of Taiwan, temperature gradients formed circular isotherms as shown in Fig. 3(a). The surface salinity gradient observably accompanied the periphery of the CDW with low salinities of < 31 as shown in Fig. 3(b). Chl-*a* values peaked at the mouth of the Changjiang River, decreasing from the coast to further offshore as shown in Fig. 3(c). In addition, increased Chl-*a* concentrations were observed in the water northeast of Taiwan.

Vertical profiles of temperature and salinity along 5 transects from north to south depict the vertical structure of the water column as shown in Fig. 4. Stratification of the CDW (< 31) was clearly observed in Transects I and II as shown in Figs. 4(b) and 4(d). The strongest stratification occurred in the Changjiang River plume region at stations E19-E21. The YSMW of < 20°C at the bottom of Transect I resulted in a severely steep temperature gradient for YSMW, according to the dense isotherms and isohalines (Fig. 4(a)). The CDW was characterized by extremely low salinities and high temperatures in water depths of less than 15 m, whereas the YSMW had comparatively lower temperatures and higher salinities at depths greater than 20 m. The temperature and salinity structures in Transect II indicated that diluted water was located close to shore (Figs. 4(c) and 4(d)), and that the 31 isohaline was a boundary for diluted water. The temperatures and salinities of Transects III and IV were nearly stable, ranging between 16 and 23°C and 34.1 and 34.7, respectively. Unlike that in the latitudinal Transects II–IV, the temperatures in Transect V exhibited dome-shaped vertical isotherms over the coastal area, with water stratification at depths greater than 10 m (Figs. 4(i) and 4(j)). A strong saline front separating the CDW from the shelf water along the coast extended to Station E18 (Fig. 4(j)), although the thermal front was on the bottom and more southerly in Transect V (Fig. 4(i)). Vertical distributions of temperature and salinity increased from north to south, possibly due to TSW and KW intrusion.

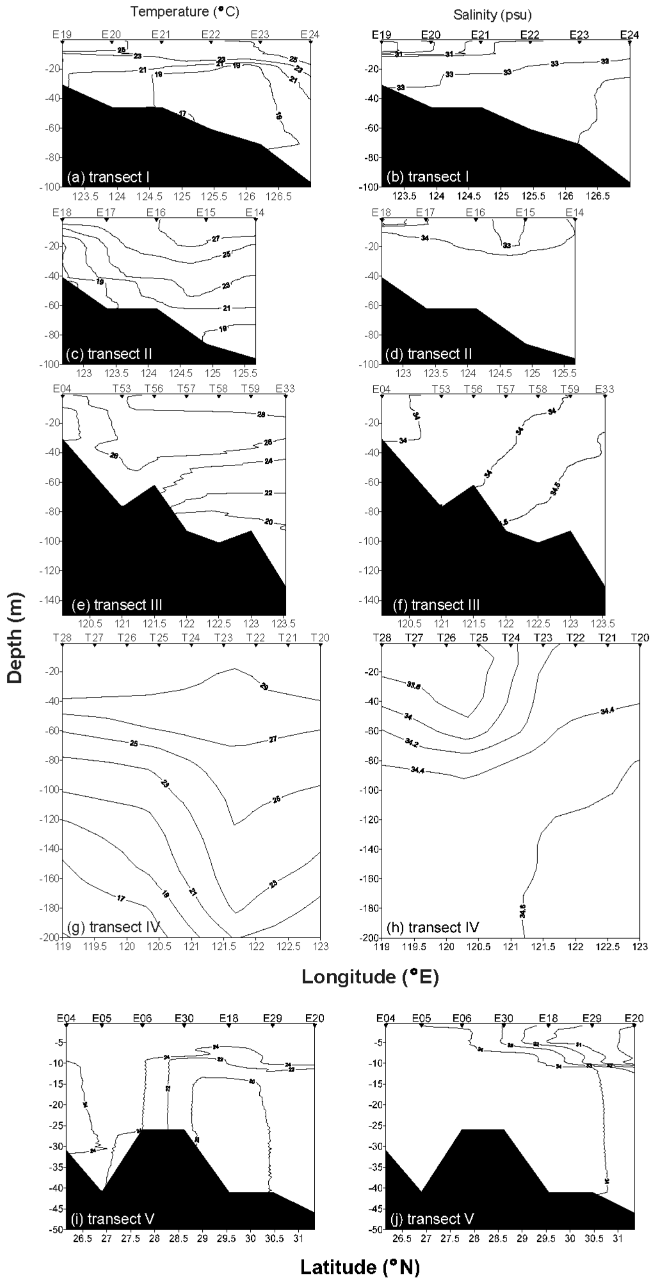

Fig. 4. The 5 vertical transects of temperature and salinity.

During the survey, most stations in the shelf region were identified as KW and TSW with high salinities. The stations adjacent to the Changjiang River mouth were considered the CDW and YSMW with lower salinities. Stations E19, 19A, 20, and 29, all of which are adjacent to the Changjiang River mouth, were characterized by low salinities and strongly

Table 1. The larval abundances (ind./1000 m^3) of dominant families (which comprising > 1% in numbers).

Family		Abundance ind./1000m^3	Sum	%
ENGRAULIDIDAE	*Engraulis japonicus*	34000.01	34404.89	56.82
ENGRAULIDIDAE	*Encrasicholina heteroloba*	308.36		
ENGRAULIDIDAE	*Encrasicholina punctifer*	69.93		
ENGRAULIDIDAE	Gen. spp.	14.69		
ENGRAULIDIDAE	*Stolephorus indicus*	6.94		
ENGRAULIDIDAE	*Thrissa* sp.	4.97		
GOBIIDAE	type 2	3217.32	5593.53	9.24
GOBIIDAE	type 1	1505.57		
GOBIIDAE	Gen. spp.	849.26		
GOBIIDAE	*Bathybobius* sp.	21.38		
SILLAGINIDAE	*Sillago japonica*	4032.41	4039.17	6.67
SILLAGINIDAE	*Sillago sihama*	6.76		
SCIAENIDAE	Gen. spp.	2095.06	2095.06	3.46
MYCTOPHIDAE	*Benthosema pterotum*	1447.21	2061.27	3.40
MYCTOPHIDAE	*Diaphus B*	295.10		
MYCTOPHIDAE	*Diaphus A*	63.21		
MYCTOPHIDAE	*Myctophum orientale*	54.34		
MYCTOPHIDAE	*Lampanyctus* sp.	37.44		
MYCTOPHIDAE	*Hygophum proximum*	29.93		
MYCTOPHIDAE	*Ceratoscopelus warmingi*	24.73		
MYCTOPHIDAE	Gen. spp.	23.91		
MYCTOPHIDAE	*Benthosema suborbitale*	13.50		
MYCTOPHIDAE	*Lampanyctus* sp.	8.23		
MYCTOPHIDAE	*Myctophum asperum*	8.11		
MYCTOPHIDAE	*Myctophum spinosum*	7.63		
MYCTOPHIDAE	*Symbolophorus* sp.	6.48		
MYCTOPHIDAE	*Lampadena* sp.	6.13		
MYCTOPHIDAE	*Diogemichthys atlanticus*	6.08		
MYCTOPHIDAE	*Hygophum reinhardtii*	4.84		
MYCTOPHIDAE	*Bolinichthys* sp.	4.48		
MYCTOPHIDAE	*Myctophum selenops*	3.77		
MYCTOPHIDAE	*Symbolophorus evermanni*	3.50		
MYCTOPHIDAE	*Lampanyctus* sp.	2.70		
MYCTOPHIDAE	*Lampadena lumonisa*	2.64		
MYCTOPHIDAE	*Myctophum obtusirostre*	2.56		
MYCTOPHIDAE	*Triphoturus* sp.	2.44		
MYCTOPHIDAE	*Myctophum nitidulum*	1.31		
MYCTOPHIDAE	*Notolychnus valdiviae*	1.02		
CYNOGLOSSIDAE	*Cynoglossus* spp.	1940.22	1940.22	3.20
BREGMACEROTIDAE	*Bregmaceros* spp.	1724.31	1724.31	2.85
SYNODONTIDAE	*Saurida* sp.	1273.80	1444.78	2.39
SYNODONTIDAE	*Trachinocephalus myops*	107.42		
SYNODONTIDAE	*Synodus macrops*	62.54		
SYNODONTIDAE	*Synodus* sp.	1.02		
SCOMBRIDAE	*Auxis* sp.	1038.38	1127.53	1.86
SCOMBRIDAE	*Katsuwonus pelamis*	17.95		
SCOMBRIDAE	*Thunnus albacares*	13.84		
SCOMBRIDAE	*Euthynnus affinis*	13.38		
SCOMBRIDAE	*Thunnus obesus*	12.79		
SCOMBRIDAE	*Thunnus alalunga*	9.97		
SCOMBRIDAE	*Thunnus thynnus*	7.53		
SCOMBRIDAE	*Sarda orientalis*	7.07		
SCOMBRIDAE	*Scomber japonicus*	4.25		
SCOMBRIDAE	*Acanthocybium solandri*	2.37		
other fish larvae (135 species)		6117.99		10.10
Sum		60548.75		100.00

Table 2. The larval abundances (ind./1000 m^3) of dominant species (which comprising > 1% in numbers).

family		abundanceind./1000m^3	%
ENGRAULIDIDAE	*Engraulis japonicus*	34000.01	56.15
SILLAGINIDAE	*Sillago japonica*	4032.41	6.66
GOBIIDAE	type 2	3217.32	5.31
SCIAENIDAE	Gen. spp.	2095.06	3.46
CYNOGLOSSIDAE	*Cynoglossus* spp.	1940.22	3.20
BREGMACEROTIDAE	*Bregmaceros* spp.	1724.31	2.85
GOBIIDAE	type 1	1505.57	2.49
MYCTOPHIDAE	*Benthosema pterotum*	1447.21	2.39
SYNODONTIDAE	*Saurida* sp.	1273.80	2.10
SCOMBRIDAE	*Auxis* sp.	1038.38	1.71
GOBIIDAE	Gen. spp.	849.26	1.40
other species		7425.21	12.26
sum		60548.75	100.00

Table 3. Chi-squared tests with successive roots removed and variance extracted (* indicate the value < 0.001).

root	R	R^2	x^2	df	p	Bio-variance		Hydr-variance	
						Extracted	Reddncy.	Extracted	Reddncy.
1	0.95	0.91	239.09	66.00	0.00	0.19	0.17	0.53	0.48
2	0.86	0.74	141.84	50.00	0.00	0.21	0.15	0.15	0.11
3	0.84	0.70	86.89	36.00	0.00	0.06	0.04	0.06	0.04
4	0.67	0.45	37.65	24.00	0.04	0.05	0.02	0.08	0.04
5	0.46	0.21	13.32	14.00	0.50	0.11	0.02	0.09	0.02
6	0.30	0.09	3.75	6.00	0.71	0.04	0.00	0.08	0.01

influenced by the CDW (Fig. 3(b)); however, the influence of the CDW and YSMW decreased at more southerly latitudes (Figs. 4(i) and 4(j)).

2. Composition and Abundance of Ichthyoplankton

In this study, 12,670 larval fishes belonging to 95 families, 163 genes, and 189 species were identified. The engraulid, gobiid, and sillaginid were the 3 most abundant families, accounting for 56.82%, 9.24%, and 6.67% of the total sample number, respectively (Table 1). Some larvae could not be identified because of their mutilated conditions. The most dominant larval fish species are shown in Table 2. *E. japonicus* was the most dominant species (34,000.01 ind./1000 m^3) and numerically accounted for 56.15% of all specimens. *S. japonica* was the second most dominant species (4,032.41 ind./1000m^3) and accounted for 6.66% of all specimens. The other dominant species were gobiid type 2 (5.31%), *sciaenid gen.* spp. (3.46%), and *Cynoglossus* spp. (3.20%).

3. The CCA of Ichthyoplankton

The CCA diagram derived from the abundances of the 11 predominant larval fish taxa correlations between the environmental variables and larval fish distributions (Table 2). The environmental variables included the temperature and salinity at depths of 5 m and 50 m (or the sea floor at shallower stations with depths of less than 50 m), sea bottom depth, and Chl-*a*. This result yielded 2 types of canonical variable that accounted for 65.97% of the total variation. The first 4 roots showed significant relationships between larval fish and hydrographic variance ($P < 0.05$) are shown in Table 3, and explained 51% of larval variance and 82% of hydrographic variance.

Biplots of the multiaxis CCA diagram were further employed to evaluate the relationship between larval fish abundances and environmental factors (Fig. 5). *E. japonicus*, *S. japonica*, and *Cynoglossus* spp. were positively associated with Chl-a and negatively associated with salinity (Fig. 5(a)); specifically, with salinity at bottom depths (Figs. 5(b)-(f)). Other species such as gobiid types 1 and 2, sciaenid, *Bregmaceros* spp., *Benthosema pterotum*, *Saurida* sp., *Auxis* sp., and other gobiids were negatively correlated with temperature (Fig. 5(a)). In particular, gobiid types 1 and 2, other gobiids, and Saurida sp. were associated with low temperatures at 5-m depths (Figs. 5(c)-(f)). However, the factors that influence the distribution of certain species in the sea are too complex to classify according to simple hydrographic variances. Thus, examining the relationship between temperature and salinity was challenging for certain species, such as the sciaenid, *Bregmaceros* spp., *B. pterotum*, and *Auxis* sp.

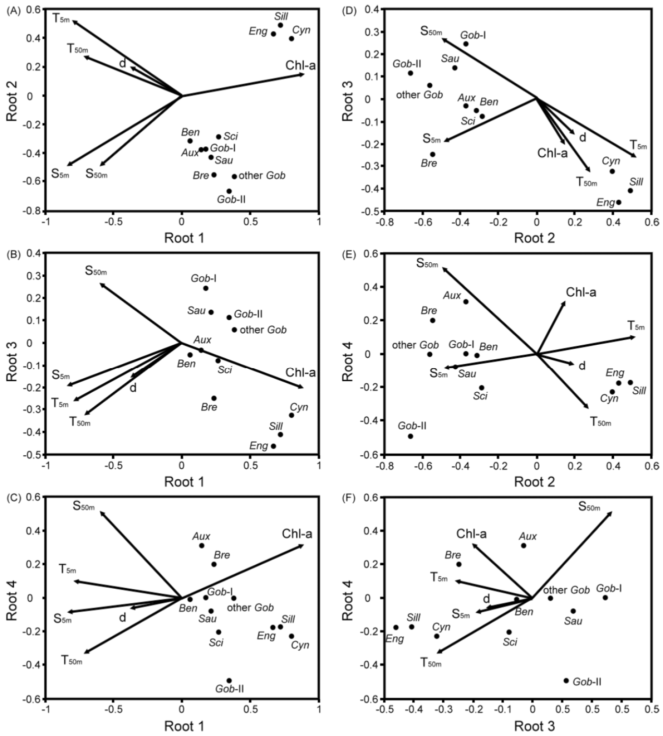

Fig. 5. **Canonical correlation analysis biplots for 11 taxa of larval fish abundances (symbols) in relation to environmental factors (arrows). T_{5m} and T_{50m} represent temperatures at depths of 5m and 50 m; S_{5m} and S_{50m} represent salinities at depths of 5m and 50 m; Chl-*a* denotes chlorophyll a; d denotes depth; Aux denotes *Auxis* spp.; Ben denotes *Benthosema pterotum*; Bre denotes *Bregmaceros* spp.; Cyn denotes *Cynoglossus* spp.; Eng denotes *Engraulis japonicus*; Gob-I, II denotes Gobiid type 1 and type 2; other Gob denotes other Gobiid; Sau denotes *Saurida* sp.; Sci denotes Sciaenid; Sill denotes *Sillago japonica*.**

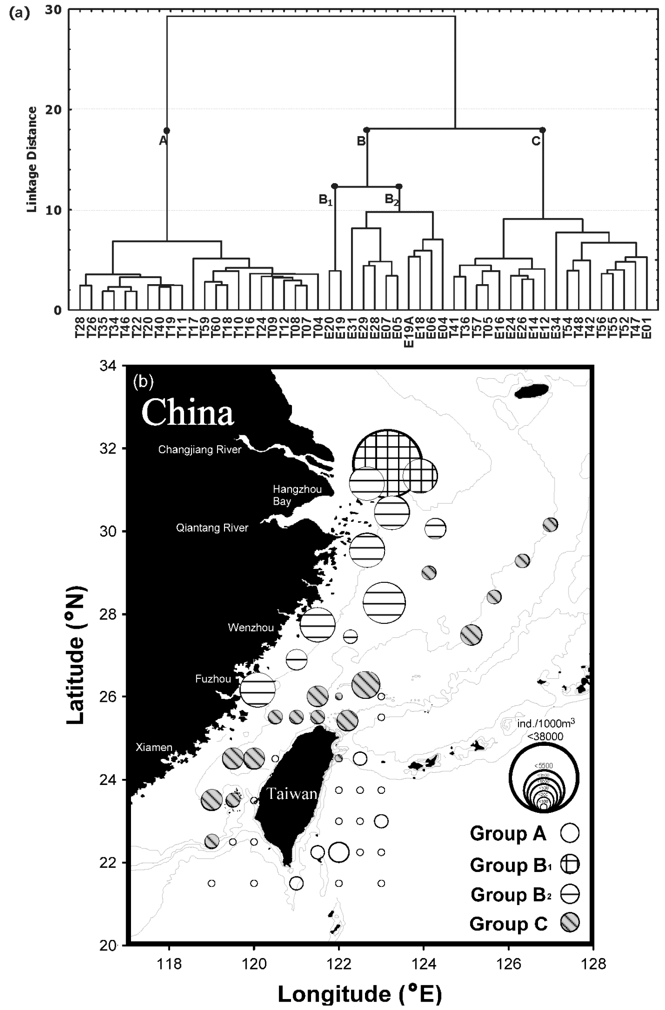

Fig. 6. **(a) The larval assemblage distributions in the survey area for July 2007 determined using Ward linkage cluster analysis; (b) open circles denote larval abundances (ind./1000 m^3).**

4. Species Compositions of Assemblages

According to the dendrogram derived from cluster analysis, larval fish of the 51 sampling stations were divided into 3 groups (A, B, and C) at linkage distances of Level 18, and 2 subgroups (B_1 and B_2) at a linkage distance of Level 12 (Fig. 6(a)). Group A was composed of 22 stations located in the eastern TS and to the east of Taiwan and characterized by relatively low abundances (Fig. 6(b)). Group B_1 was composed of 2 stations (E19 and E20) located near the mouth of the Changjiang River. Group B_2 comprised 9 stations located in the coastal region of the ECS. Both Groups B_1 and B_2 were characterized by a high abundance of fish larvae are shown in Fig. 6(b). Group C comprised 18 stations located at the middle of the TS to the central ECS.

The total abundances of fish larvae were 1,605.78 ind./1000 m^3 in Group A, 39,387.02 ind./1000 m^3 in Group B_1, 15,103.53 ind./1000 m^3 in Group B_2, and 4,452.42 ind./1000 m^3 in Group C (Table 4). The dominant species were *Diaphus* B group, *Bregmaceros* spp., and lutjanid in Group A. In addition, certain mesopelagic fishes, including the myctophid (such as *Diaphus* spp., *Myctophum orientale*, and *Hygophum proximum*), gonostomatid (such as *Cyclothone alba* and *Sigmops gracilis*), and *Vinciguerria nimbaria* of the phosichthyid were abundant in Group A. Group B_1 was characterized by high abundances of *E. japonicus* (31,791.94 ind./1000 m^3 and 80.72% of the total larval fishes of Group B_1) and *S. japonica* (4,021.65 ind./1000 m^3 and 10.21% of the total larval fishes of Group B_1). In addition, benthic fishes, including cynoglossids, were abundant in Group B_1. In Group B_2, the dominant species were gobiid type 2 species, *E. japonicus*, and *Bregmaceros* spp. *E. jponicus* was dominant in Group B_1, and extremely abundant in Group B_2 (Table 4). Group C was mainly dominated by commercial fish species that live in epipelagic, neritic, and oceanic waters, such as *Auxis* sp.; in coral and coastal waters such as the sciaenid and gobiid; and in shallow waters such as *B. pterotum*, the *Diaphus* B group, and *Bregmaceros* spp. Certain reef-associated and benthic fish species, such as the bothid, cynoglossid, and *Trachinocephalus myops* were common in Group C (Table 4).

Table 4. The dominant species (comprising > 1% in numbers) of each group based on a cluster analysis of larval fish referring to Fig. 7.

A group		inds/1000m^3	%
MYCTOPHIDAE	*Diaphus* B	150.77	9.39
BREGMACEROTIDAE	*Bregmaceros* spp.	58.46	3.64
LUTJANIDAE		57.22	3.56
LABRIDAE		57.12	3.56
MYCTOPHIDAE	*Diaphus* A	56.90	3.54
MYCTOPHIDAE	*Myctophum orientale*	53.04	3.30
GONOSTOMATIDAE	*Cyclothone alba*	48.07	2.99
ACANTHURIDAE		46.61	2.90
PHOSICHTHYIDAE	*Vinciguerria nimbaria*	42.05	2.62
ENGRAULIDIDAE	*Encrasicholina punctifer*	41.30	2.57
SERRANIDAE	type 1	36.71	2.29
MYCTOPHIDAE	*Lampanyctus* spp.	34.03	2.12
CARANGIDAE	*Decapterus* sp.	32.47	2.02
PARALEPIDIDAE	*Lestrolepis* sp.	32.23	2.01
MYCTOPHIDAE	*Hygophum proximum*	29.93	1.86
NOMEIDAE	*Cubiceps pauciradiatus*	28.04	1.75
GONOSTOMATIDAE	*Sigmops gracilis*	26.48	1.65
HOPLICHTHYIDAE		23.45	1.46
SCORPAENIDAE		19.76	1.23
MYCTOPHIDAE		19.29	1.20
CARANGIDAE		18.97	1.18
SCARIDAE		18.55	1.16
GONOSTOMATIDAE	*Cyclothone pseudopallida*	18.36	1.14
TETRAODONTIDAE	*Takifugu* sp.	17.75	1.11
NOTOSUDIDDAE	*Scopelaurus* sp.	17.43	1.09
MYCTOPHIDAE	*Ceratoscopelus warmingi*	17.21	1.07
GOBIIDAE		17.13	1.07
BRAMIDAE		16.72	1.04
other fishes		569.73	35.48
SUM		1605.78	100

B1 group		inds/1000m^3	%
ENGRAULIDIDAE	*Engraulis japonicus*	31791.94	80.72
SILLAGINIDAE	*Sillago japonica*	4021.65	10.21
CYNOGLOSSIDAE	*Cynoglossus* spp.	1340.07	3.40
other fishes		2233.36	5.67
SUM		39387.02	100

B2 group		inds/1000m^3	%
GOBIIDAE	type 2	3217.32	21.30
ENGRAULIDIDAE	*Engraulis japonicus*	2173.43	14.39
BREGMACEROTIDAE	*Bregmaceros* spp.	1529.92	10.13
SCIAENIDAE		1331.32	8.81
MYCTOPHIDAE	*Benthosema pterotum*	1287.67	8.53
SYNODONTIDAE	*Saurida* spp.	1258.30	8.33
GOBIIDAE	type 1	1000.73	6.63
GOBIIDAE		636.51	4.21
CYNOGLOSSIDAE	*Cynoglossus* spp.	464.58	3.08
SCOMBRIDAE	*Auxis* spp.	351.15	2.32
ENGRAULIDIDAE	*Encrasicholina heteroloba*	298.42	1.98
SCARIDAE		216.46	1.43
OPHICHTHIDAE		153.73	1.02
other fishes		1183.99	7.84
SUM		15103.53	100

C group		inds/1000m^3	%
SCOMBRIDAE	*Auxis* spp.	679.08	15.25
SCIAENIDAE		518.34	11.64
GOBIIDAE	type 1	479.13	10.76
BOTHIDAE		210.48	4.73
GOBIIDAE		195.62	4.39
MYCTOPHIDAE	*Benthosema pterotum*	150.79	3.39
CARANGIDAE		146.18	3.28
MYCTOPHIDAE	*Diaphus* B	144.34	3.24
BREGMACEROTIDAE	*Bregmaceros* spp.	135.93	3.05
CYNOGLOSSIDAE	*Cynoglossus* spp.	128.26	2.88
SYNODONTIDAE	*Trachinocephalus myops*	104.84	2.35
LABRIDAE		85.38	1.92
AMMODYTIDAE		77.88	1.75
OPHICHTHIDAE		73.50	1.65
SYNODONTIDAE	*Synodus macrops*	62.54	1.40
MONACANTHIDAE		61.03	1.37
APOGONTIDAE		59.68	1.34
CALLIONYMIDAE		59.07	1.33
PERCICHTHYIDAE	*Synagrops* spp.	53.17	1.19
CARANGIDAE	*Caranx* sp.	46.73	1.05
MULLIDAE		44.55	1.00
other fishes		935.90	21.02
SUM		4452.42	100

III. DISCUSSION

In this survey, the results of cluster analysis enabled the 3 main larval assemblages to be identified and separated in a group of coastal stations, where most larvae belonged to neritic species, a group of shallow stations and shelf stations dominated by mesopelagic species, and a group of further offshore stations occupied by Kuroshio species. This situation was comparable to that of the third group described in the TSW [15]. Moreover, species components revealed substantial differences among the groups; detailed comparisons are presented below.

1. Group A: Kuroshio Assemblage

All stations of Group A were located in Kuroshio Water (KW) on the eastern portion and over the Penghu Channel of Taiwan of our study area. The KW enters the ECS along the eastern coast of Taiwan, then flows northeasterly along the ECS shelf slope, and diverges over the continental shelf near 28°N northwest of Okinawa [23]. In addition, the KBW enters the eastern TS through the Penghu Channel [22], and its warmer and saltier waters may reach 24-26°N [16]. Based on the T-S definition of water masses described by Gong *et al*. [10] and Jan *et al*. [21], Group A occupied both the KW and KBW regions. Consequently, Group A was regarded as the Kuroshio assemblage. This might explain the abundance of Kuroshio species larvae that appear at these stations. Even the occurrence of oceanic spawning species, such as myctophids, gonostomatids, and *Vinciguerria nimbaria* of the phosichthyid in the Penghu Channel, is a satisfactory indication of oceanic waters [4, 33, 34, 36].

In the Kuroshio assemblage, myctophids, gonostomatids, and phosichthyids comprised 27.84%, 6.68%, and 3.00% of the total larval fishes in this group. Certain dominant species of myctophid and gonostomatid larvae were used as indicator species for the KW region [6, 36, 39]. Among these, myctophid larvae are the most abundant species group of oceanic larval fish assemblages; for example, the *Diaphus* B group was the most abundant in KW and offshore oceanic waters [36]. In this study, typical oceanic and mesopelagic or bathypelagic species, such as the myctophids (e.g., *Diaphus* spp., *Myctophum orientale*, *Lampanyctus* spp., *Hygophum proximum*, *Ceratoscopelus warmingi*, and other unidentified myctophids), gonostomatids (e.g., *Cyclothone alba* and *Sigmops gracilis*), and *Vinciguerria nimbaria* of the phosichthyid, were abundant in the KW area.

The results obtained in this study are consistent with those of previous observations [30, 32]. Therefore, the intrusion of the KBW into the TS might transport Myctophid larvae from Kuroshio to the TS. However, because of the complex hydrodynamic situation and topographic features in the study area, reef and coastal species, such as lutjanids, labrids, and serranids, were observed less frequently in the KW area. The presence of neritic species larvae in mesopelagic regions, where spawners are not present, was observed in the KW, as transported by oceanographic events. This finding indicates that both the coastal region of Taiwan and water masses substantially affected the distribution of larval fish.

2. Group B: The Coastal and CDW/YSMW Assemblage

As expected, larvae of coastal species were relatively more abundant but not homogenously distributed at the Group B stations. These species were primarily concentrated in the area of coastal water, which was heavily affected by river discharge and YSMW stations located at the Changjiang River mouth. Coastal water mixed with freshwater discharge from the Changjiang River flows southward along the coast of China to the TS [12]. The complexity of the coastal water resulting from the mixing of oceanic currents and river runoffs stimulated our interest. Less saline, low-temperature water extending from China's coastal region toward the shelf area suggests that a frontal current of coastal water had formed. The minimum salinity coincided with the maximum Chl-*a* because of the strong flow of the Changjiang River runoff on the shelf bifurcating near the river mouth.

According to Ichikawa and Beardsley [19], the southward flowing water transports Changjiang River freshwater and low-saline shelf water from the estuary to the Chinese coast of the ECS. Therefore, in the coastal waters of the research area, cluster analysis enabled identifying 2 larval subassemblages (Groups B_1 and B_2) separated according to water type. The Changjiang River and YSMW Group B_1 from the northern ECS and without coastal influences was associated with the dominance of *E. japonicus*, *S. japonica*, and *Cynoglossus* spp. This larval assemblage was characterized by a high abundance of certain mesopelagic species, which were extremely abundant at stations located at the Changjiang River mouth, rather than abundances of neritic and coastal fish species.

E. japonicas, which is widely known to be a major species in inshore waters of the continental shelf area from Japan to the south of China, congregates in large near-surface schools primarily in coastal waters. Spatial patterns of *E. japonicus* egg distribution and abundance were examined in areas of the Changjiang River where large spawning grounds exist [20]. Takasuka *et al*. [38] determined that 22.0°C was the optimal temperature for larval growth. *E. japonicus* larvae generally move and aggregate to feed in estuaries with water temperatures ranging between 22.6 and 30°C [26]. In addition, the distribution of *E. japonicas* was closely associated with salinity at 50-m depths. As shown in Fig. 4, YSMW forms the bottom water of the Changjiang River mouth. Because salinity substantially affects larval fish distributions, hydrodynamics rather than water depth limits larval distributions. Therefore, we infer that the southerly flowing YSMW may play a crucial role in transporting *E. japonicus* throughout the research area. Fig. 5 is coherent with the observed hydrodynamic conditions, because the research area was influenced by successive inflows of CDW and YSMW from the north, thereby promoting the transport of *E. japonicus* larvae to shelf stations. Considering the distributions of fish larvae and hydrographic features obtained in this study, *E. japonicus* appears to spawn offshore of the Changjiang River area. After hatching, the eggs may be carried southerly toward the shelf by the CDW and YSMW. However, the association between their spawning mechanism and hydrological conditions, such as interaction with the CDW and YSMW, remained unclear, necessitating additional field investigations for further examination.

In Group B_2, in addition to a high abundance of *E. japonicus*, certain neritic and coastal fish species, such as gobiid, *Saurida* sp., and sciaenid larvae, were also abundant in coastal areas. The presence of these taxa was a satisfactory indicator of TSW intrusion to the ECS [30]. In addition, coastal distributions of *Auxis* sp. were abundant at Group B_2 stations during the summer. These results suggest that some larval fish may be transported and mixed because of complex hydrographic conditions. Thus, Group B_1 was considered a coastal group, and Group B_2 was considered a CDW and YSMW group.

3. Group C: TSW Assemblage

This assemblage comprised all stations in the TS and southern ECS shelf. In addition, group C covered the TSW region, according to the definition of water masses provided by Gong *et al*. [10]. A previous report indicated that TSW exists only in the summer and flows to the north through the TS [28]. Thus, the numerous water masses that mix here contribute to the complexity of fish larvae in Group C. In this study, Group C was regarded as the TSW group. This assemblage was characterized by an abundance of *Auxis* spp. distributed in the shelf region (E12, E14, E16, E24, and E26) and the southern ECS shelf waters (E01, E34, T52, T54, T55, T56, and T57). Comparatively higher densities of *Auxis* have been reported in the same region [17] with saltier surface waters that were more mixed with shelf waters. *Auxis* is a prominent and common commercial fish genus in Taiwan. Huang and Chiu [17] found that *Auxis* spp. were the second most abundant taxa in the Kuroshio edge exchange area (KEEP program of Taiwan) off northeastern Taiwan in the spring and summer, and suggested that they should have evolved a mechanism that matched the larval hatching with the seasonal plankton bloom. In this assemblage, certain other species were also abundant and distributed throughout the shelf area, such as sciaenids, gobiids, and bothids. Gobiid species typically inhabit waters above sandy bottoms and seaward reefs and are extremely common in waters west of Taiwan [15].

In conclusion, the results of this study showed that horizontal distributions of larval fishes in the ECS and TS region were highly influenced by the dynamics of the KW and KBW, TSW, and CDW. These observations indicate that the main larval fish groups corresponded well with the hydrographic conditions of the research area. Additional long-term research involving transection surveys that cover the Changjiang River and continental shelf of the ECS can contribute to clarifying the biogeochemical dynamics of YSMW and CDW larval associations to specific hydrographic features. The distribution of fish larvae showed a clear relationship to water masses, with high abundances of larval fishes occurring in shallow areas near to the coastal areas of the ECS, whereas low abundances were observed offshore in the KW area. Through cluster analysis, 3 larval assemblages were distinguished. The resulting fish larval distribution patterns corresponded to the hydrographic conditions. The spatial larval distributions observed can be explained according to salinity gradients, indicating that CDW may be a crucial factor in determining the abundance and distribution of larval fishes during the summer.

ACKNOWLEDGMENTS

This study was financially supported by the National Science Council, Taiwan, (99-2611-M-019-013; 100-2611-M-019-005) and Fisheries Research Institute, Council of Agriculture (96AS-15.1.1-AI-A3). The authors expressed their deepest respect and gratitude to the LORECS Research Team and Taiwan Fishery Research Institute for providing information and assisting with the research experiment.

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