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WINTER ABUNDANCE AND SPECIES COMPOSITION OF ANCHOVY LARVAE ASSOCIATED WITH HYDROLOGICAL CONDITIONS IN THE COASTAL WATERS OF TANSHUI, TAIWAN

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WINTER ABUNDANCE AND SPECIES COMPOSITION OF ANCHOVY LARVAE ASSOCIATED WITH HYDROLOGICAL CONDITIONS IN THE COASTAL WATERS OF TANSHUI, TAIWAN

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Key words: El Niño, anchovy larvae, *Engraulis japonicus*.

ABSTRACT

The present study investigated changes in the winter abundance and composition of anchovy larvae associated with hydrological conditions in the coastal waters of Tanshui, Taiwan. A survey during the period of 2008-2014 revealed that the abundance of larvae caught using fyke nets varied from 123.9 to 28,314 ind/1000 m^3, whereas the surface water temperature and salinity ranged from approximately 17°C to 18°C and 32.84 psu to 33.72 psu, respectively. *Engraulis japonicus* (Japanese anchovy), *Encrasicholina punctifer* (buccaneer anchovy), and *E. heteroloba* (shorthead anchovy) were the dominant species of anchovy larvae, accounting for 0.17%-93.56%. In the La Niña years 2008 and 2011, Japanese anchovy was dominant, with a relatively high abundance of approximately 128-25,432 ind/1000 m^3 when the current at 10-m depth moved southwestward. In the El Niño years 2010 and 2014, buccaneer anchovy and shorthead anchovy were the dominant species, with a relatively low abundance of approximately 0.21-8,334.38 ind/1000 m^3 when the current at 10 m depth moved northeastward. The change in the pattern of currents induced by El Niño-Southern Oscillation events may be crucial in determining the winter abundance and species composition of anchovy larvae in the coastal waters of Tanshui. Additionally, an elevated sea surface water temperature probably reduces the abundance of Japanese anchovy and increases that of buccaneer anchovy and shorthead anchovy in winter.

I. INTRODUCTION

The larval anchovy fishery is an important coastal fishery for Taiwan. Catches around Taiwan mainly comprise one northern species (*Engraulis japonicus*, Japanese anchovy) and two southern species (*Encrasicholina heteroloba*, shorthead anchovy; and *E. punctifer*, buccaneer anchovy) (Lee et al., 1990; 1994; Chiu et al., 1997; Tsai et al., 1997; Hsieh et al., 2009) of the family Engraulidae. The three main fishing grounds for these fishes are located in Kenfang, Yilan, northeastern Taiwan; Tanshui, New Taipei, northwestern Taiwan; and Fangliao, Pintung, southwestern Taiwan, respectively (Chiu et al., 1997). Two major fishing methods are used to capture anchovy larvae in Taiwan: large mesh trawling nets and fyke nets. In the trawling net method, a large-mesh wing net is used to actively herd larvae into a cod net (Lee et al., 1995a), whereas the fyke net method is passive and uses the change in current to collect larvae in a cod net (Tzeng and Wang, 1992). Typically, anchovy larvae are harvested throughout the year, with late spring and early autumn being the peak fishing seasons in the coastal waters of northeastern and southwestern Taiwan (Chiu et al., 1997). However, adult Japanese anchovies might migrate from the East China Sea to the coastal waters of Taiwan to spawn around late winter (Tu et al., 2012). Tzeng and Wang (1992; 1993) examined winter fishing of anchovy larvae after spawning, establishing that they constitute the most important species of the winter fishing ground in the Tanshui estuary, northwestern Taiwan.

Regarding the hydrological factors related to the formation of larval anchovy fishing grounds, Lee et al. (1995b) indicated that the primary factors in the coastal waters of southwestern Taiwan are surface water temperature, which is related to the occurrence of Japanese anchovy; surface water salinity, which affects the influx of offshore water and river discharge; and food

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availability, which is associated with plankton production. These factors are similar to those described in previous reports (Kim et al., 2005; Alemany et al., 2006; Harrison and Whitfield, 2006; Islam et al., 2006; Chen et al., 2014), indicating that sea temperature, salinity, and food availability are the major factors affecting the distribution and survival rate of estuarine fishes. The optimal temperature and salinity ranges for Japanese anchovy are narrower than those for buccaneer anchovy and shorthead anchovy, similar to the results of Wang and Tzeng (1997b, 1999). In spring, Japanese anchovy inhabits environments with relatively low temperature and salinity, whereas in the fall, buccaneer anchovy and shorthead anchovy inhabit the northern waters of Taiwan (Tzeng and Wang, 1997). Hsieh et al. (2009) investigated the correlations between the relative abundance (catch per unit effort) and environmental conditions for anchovy larvae and inferred that fluctuations in their abundance were due to the local sea surface temperature (SST) and were related to the Southern Oscillation Index for the spring and fall fishing seasons of the coastal waters of southwestern Taiwan (Tsai et al., 1997).

The current may be another crucial factor influencing the catch, composition, and distribution of anchovy larvae in Taiwan. Bishai (1960) suggested that larvae cannot swim effectively; consequently, the water current not only affects the distribution of fish larvae (carrying them to different areas) but also indirectly affects their survival (Chen et al., 2016). Chen and Chiu (2003) stated that coastal currents may affect the spawning migration of Japanese anchovy fishes, which are transported from offshore to the coastal waters of northeastern Taiwan from April to May. However, most studies have examined the spring and fall fishing seasons but not the winter fishing season.

Because the early life stage is the most critical period that determines the annual recruitment, distribution, growth, and survival of commercial fishes (Houde, 2008), understanding the effects of environmental conditions on the early life stage of fish populations is essential for ecosystem-based fishery management (Hsieh et al., 2009; Cheung et al., 2012). Therefore, this study evaluated changes in winter larval anchovy composition and abundance associated with hydrological conditions in the coastal waters of Tanshui, northwestern Taiwan.

II. MATERIALS AND METHODS

Biological samples were collected using the commercial fyke boat Jhih-Ping No. 1, which operated from two stations (A: 121°21.846′E, 25°12.598′N; depth, 40 m and B: 121°23.250′E, 25°10.800′N; depth, 15 m) in the coastal waters of Tanshui (Fig. 1) in January 2008, 2010, 2011, and 2014. The sampling net was 50-m long with a mouth diameter of 0.5 m, and the mesh size of the cod net was 2 mm (Tzeng and Wang, 1992). A flow meter was attached to the net mouth to measure the volume of filtered water. All samples were frozen and transported to the laboratory. In the laboratory, according to the external characteristics of larvae, the samples were sorted and identified to the species level (or to the lowest possible taxonomic level) by using a microscope (Wang and Tzeng, 1997a; Okiyama, 2014). For analysis

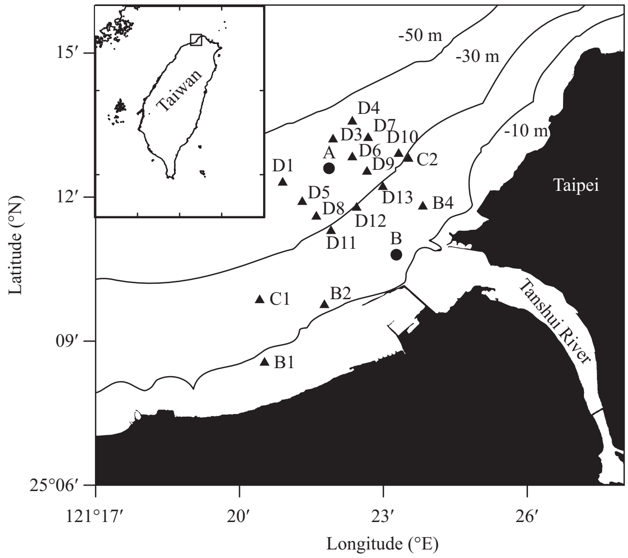

Fig. 1. Sampling stations in the coastal waters of the Tanshui River (triangle; stations with CTD data only, and circles; stations with both CTD and larval fish sampling data).

of anchovy, 100 samples were randomly selected from all anchovy larval samples. The number and percentage of these larvae identified as species of Japanese anchovy, buccaneer anchovy, and shorthead anchovy were calculated (Wang and Tzeng, 1997a; Okiyama, 2014). Finally, the species composition of larvae was estimated. An analysis of similarities (ANOSIM) test was used to determine similarities in species composition for the sampling stations or sampling year.

Measurements of larval abundance were transformed to the square root, and the Bray-Curtis similarity matrix was calculated according to the method of Clarke and Warwick (2001). Subsequently, the Bray-Curtis similarity matrix was used to calculate R (Clarke and Warwick, 2001):

$$R = \frac{\left(rB - rW\right)}{\frac{1}{2}M} \tag{1}$$

where $M = n\ (n\text{-}1)/2$, and n is the total number of samples being analyzed. rB is the average of rank similarities arising from all pairs of replicates among different sites. rW is defined as the average of all rank similarities among replicates within sites. The value of R ranges between 0 and 1. The species composition of fish larvae did not significantly differ when $R <$ 0.2 but demonstrated a slightly significant difference (not very clear but sufficient to discriminate differences between stations or years) when $0.2 < R < 0.7$. When $R > 0.7$, the factor groups of the larval composition differed significantly. The p value indicating statistically significant levels was calculated using the following equation:

$$p = \frac{t+1}{T+1} \tag{2}$$

Table 1. Summary of sampling stations coordinates, date, and depth of sampling.

Station	Longitude (°E)	Latitude (°N)	Data	Depth (m)
A	121°21.38’	25°12.73’	2008/1/3 2010/1/10	40
B	121°23.25’	25°10.88’	2011/1/1 2014/1/16	15
B1	121°20.5’	25°08.55’		12
B2	121°21.75’	25°09.75’		19
B4	121°23.8’	25°11.8’		18
C1	121°20.4’	25°09.85’		24
C2	121°23.5’	25°12.8’		31
D1	121°20.88’	25°12.3’		36
D3	121°21.93’	25°13.2’		40
D4	121°22.33’	25°13.57’	2008/1/2 2010/1/10 2011/1/1 2014/1/16	42
D5	121°21.29’	25°11.9’		34
D6	121°22.33’	25°12.83’		38
D7	121°22.66’	25°13.23’		38
D8	121°21.58’	25°11.59’		32
D9	121°22.64’	25°12.53’		33
D10	121°23.00’	25°12.9’		34
D11	121°21.89’	25°11.29’		27
D12	121°22.42’	25°11.78’		25
D13	121°22.97’	25°12.21’		26

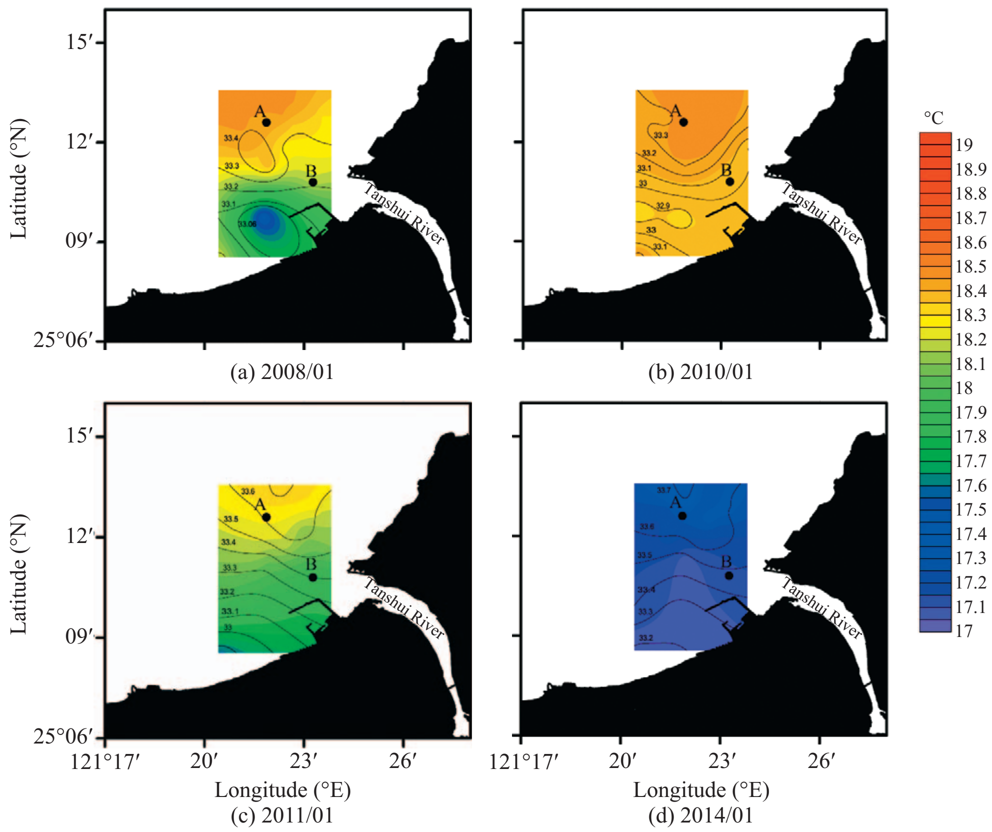

Fig. 2. Surface water temperature (°C; color scale) and salinity (black line; 5 m) of the coastal waters of the Tanshui River.

where *t* and *T* represent the numbers of permuted statistics exceeding or equal to Global *R* and the number of permutations, respectively. Additionally, hydrographic data were collected by the Ocean Research Vessel II from 19 stations by using a conductivity-temperature-depth (CTD) instrument at each station, which conducted measurements from the surface to 5 m above the bottom (Fig. 1 and Table 1).

The Hybrid Coordinate Ocean Model (HYCOM), which has

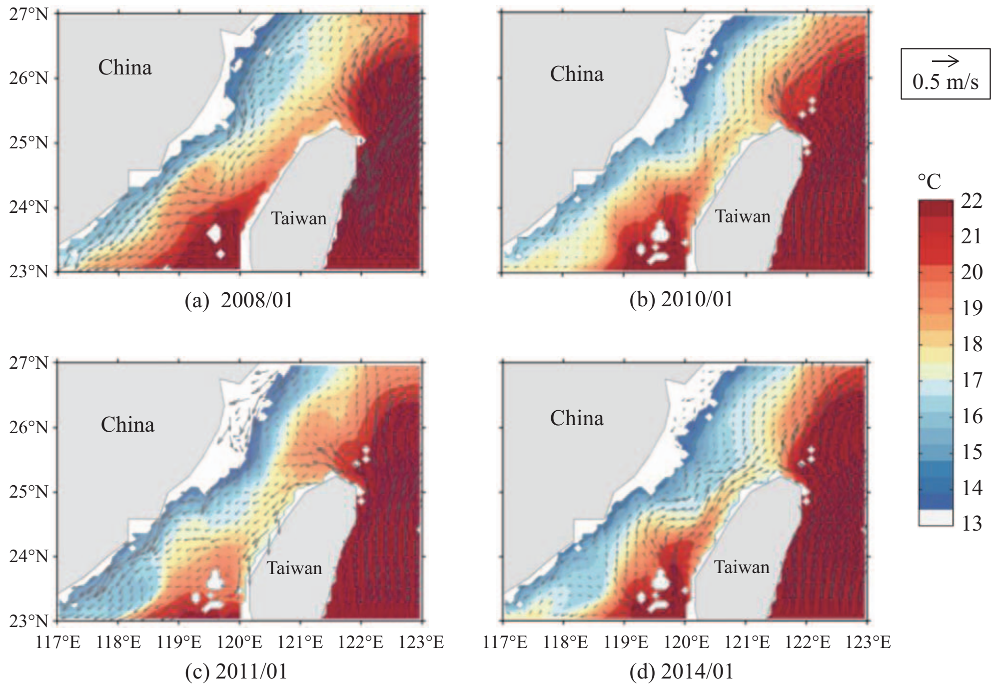

Fig. 3. Surface water temperature, current velocity, and current direction of the waters around Taiwan. The direction and length of the arrows symbolize the current direction and velocity, respectively.

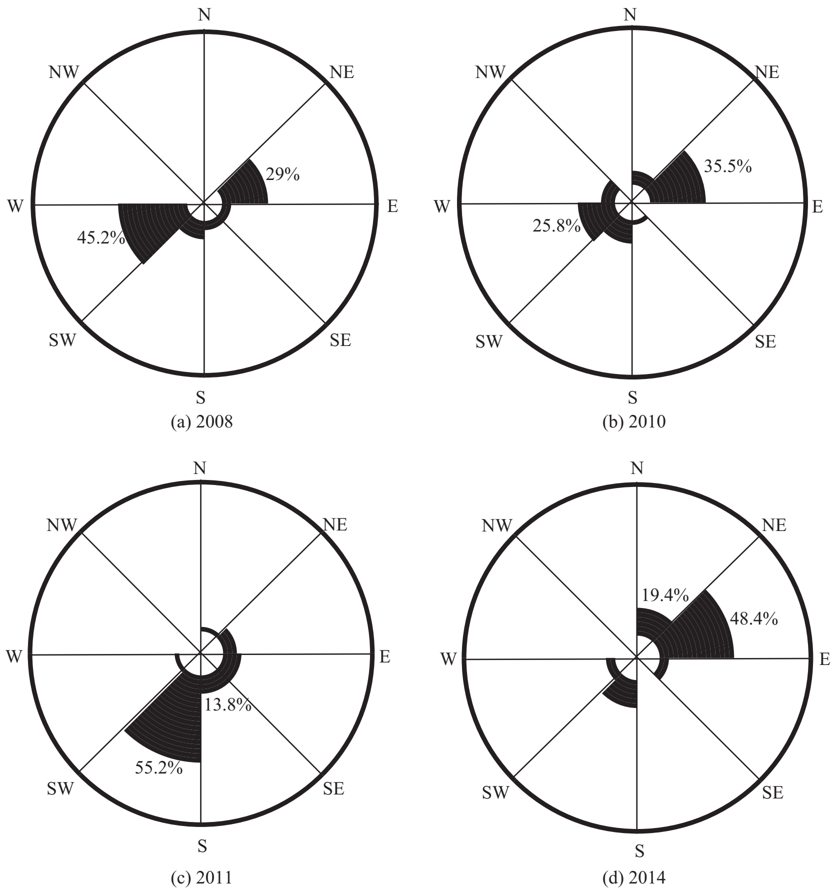

Fig. 4. Daily mean current direction of the coastal waters of Tanshui River in January 2008, 2010, 2011, and 2014. The current direction is represented by the eight quadrants.

Table 2. Results of the ANOSIM test for sampling stations for the composition of anchovy (a) and other fish species (b) in 2008, 2010, 2011, and 2014.

(a)

Factor group		R	p-value
Station	A B	0.167	0.999
Year	2008 2010 2011 2014	0.667	0.01
ENSO event	La Niña year El Niño year Normal year	0.85	0.005

(b)

Factor group		R	p-value
Station	A B	0.182	0.943
Year	2008 2010 2011 2014	0.604	0.01
ENSO event	La Niña year El Niño year Normal year	0.2	0.667

a 1/12° horizontal resolution at the equator (approximately 7 km at mid-latitudes), is the ocean model component of an eddy-resolving operational forecast system (Bleck, 2002). The HYCOM data set assimilates all operational sources of observation, including Advanced Very High Resolution Radiometer-Global Area Coverage and Geostationary Operational Environmental Satellite SST, in situ SST, altimeter sea surface height, temperature-salinity profile (Argo, CTD, and expendable bathythermograph), and Special Sensor Microwave Imager sea ice data. The HYCOM data set is a useful tool for simulating mean real-time oceanic conditions (Lee et al., 2014). In addition, data of the surface temperature and velocity and direction of currents in the waters around Taiwan were analyzed using the MATLAB software package from http://www.math.ethz.ch/. Moreover, we calculated the daily average current direction in the coastal waters of Tanshui (121°17-121°26′E, 25°09-25°16′N; Fig. 1).

III. RESULTS

1. Hydrographic Conditions

Fig. 2 presents the horizontal distributions of the SST and sea surface salinity (SSS) derived from the CTD data. The SST ranged from 17.07°C to 18.5°C, and the SSS ranged from 32.84 to 33.72 psu. To obtain comprehensive data on the surface water temperature and current, we examined the current and water temperature at a depth of 10 m, as simulated through the HYCOM (Fig. 3). In the La Niña years 2008 and 2011, the southward CCC strongly intruded into the Taiwan Strait. In the El Niño years 2010 and 2014, the CCC retreated southward, and the KBC simultaneously moved northward into the northern Taiwan Strait (Fig. 3). Figs. 4(a)-(d) represent the plots displaying the contribution of different daily mean flow angles, defined in octants, during January 2008. Due to the northeast (NE)-southwest (SW) direction of the Taiwan Strait, the flow primarily moved in the northwest (NW) or southwest (SW) direction. In 2008, the southwestward (W-SW) flow (45.2%) was more frequent than the northeastward (E-NE) flow (29%). The flow pattern was similar in 2011; the W-SW flow was dominant (55%), except that the flow direction in 2008 was biased to the west compared with that in 2011. Conversely, in the El Niño years 2010 and 2014, the northeastward flow was dominant.

2. Abundance and Species Composition of Ichthyoplankton

The ANOSIM test revealed no significant differences in species composition at the two stations (R = 0.167 and 0.182, respectively; Table 2). Therefore, the data from these stations were combined. In this study, an average abundance of 2421.32 g/1000 m^3 was obtained from four journeys (Table 3). The abundance of fish larvae was the highest (approximately 28,314 ind/1000 m^3) in 2011 and the lowest (approximately 123.9 ind/

Table 3. Species composition (percentage abundance) of the fish sampled in this study.

Taxon	Year			
	2008	2010	2011	2014
E. heteroloba		91.96	3.75	
E. punctifer				0.17
Eng. japonicus	38.92		89.82	
Apogonidae gen. spp.		0.86		0.73
Anguilla japonica				0.26
Blenniidae gen spp.				0.26
Bothidae gen. spp.	0.60			0.55
Bregmaceros japonicus				0.69
Bregmaceros spp.	0.60			
Callionymidae gen. spp.			0.83	0.67
Clupeidae gen. spp.				0.55
Chaunacidae gen. spp.				0.26
Congridae gen. spp.		0.86		4.99
Elops machnata	17.37	0.86	1.15	72.51
Gerres erythrourus				0.33
Gerres filamentosus				0.82
Gobiidae gen. spp.	0.60	0.86	0.75	4.60
Pomadasys kaakan				0.55
Leiognathidae gen. spp.	1.20			
Nuchequula nuchalis				0.26
Lethrinus ornatus				0.47
Mugilidae gen. spp.				0.41
Mullidae gen. spp.				0.12
Benthosema pterotum	0.60	0.24	0.41	0.22
Ophichthidae gen. spp.	0.60			3.27
Paralepididae gen. spp.			0.83	0.28
Sciaenidae gen. spp.		0.16		
Scorpaenidae gen. spp.	4.19	1.16		0.26
Sebastiscus marmoratus			0.25	
Sillago japonica			0.83	0.26
Sparidae gen. spp.			0.17	
Acanthopagrus latus				4.79
Harpadon microchir				0.55
Synodus fuscus		1.86	0.75	
Trachinocephalus myops			0.34	
Trichiurus sp.	35.33	1.16	0.13	0.55
SUM	100	100	100	100
Total abundance(ind/1000 m^3)	328.47	9063.050	28314	123.9
Total wet weight (g/1000 m^3)	41.945	1013.8	1226.6	138.97

1000 m^3) in 2014 (Table 3 and Fig. 5). A total of 37 fish species from 28 families were identified (Table 3). Among them, the proportion of anchovy larvae significantly fluctuated from 93.56% in 2011 to 0.17% in 2014. The dominant species was Japanese anchovy in 2008 (38.92%) and 2011 (89.82%), followed by *Trichiurus* sp. (35.33%) in 2008 and shorthead anchovy (3.74%) in 2011. In 2010, shorthead anchovy was the dominant species, accounting for 91.96% of the total abundance, followed by *Synodus fuscus* (1.86%), Scorpaenidae gen. spp. (1.16%), and *Trichiurus* sp. (1.16%). In 2014, *Elops machnata* (72.51%), Congridae gen. spp. (4.99%), and *Acanthopagrus latus* (4.79%) were the three most dominant species. The ANOSIM test revealed a slightly significant difference in fish compositions at the two stations over the 4 years (R = 0.667 and 0.604, respectively; Table 2).

Fig. 6 presents the percentage composition of anchovy larvae.

Table 4. The abundance (ind/1000m^3) and comparisons of the species composition of fish larvae with the current directions (%) in La Niña, El Niño, and normal years in the coastal waters of Tanshui.

Time (La Niña/El Niño/ Normal year)		Dominant species	Abundance	(%)	Current direction	Reference
1990/2	Normal	*Arius thalassinus*	-	61.64	-	Tzeng and Wand (1992, 1997)
		E. punctifer	-	19.63		
		Elops machnata	-	4.57		
1992/10-1993/1	El Niño	*E. punctifer*	-	64	-	Wang and Tzeng (1997b)
		E. heteroloba	-	24		
		Sardinella spp.	-	4		
2008/1	La Niña	*Eng. japonicus*	127.84	38.92	W-SW (45.2%)	This study
		Trichiurus sp.	116.05	32.33		
		Elops machnata	57.06	17.37		
2010/1	El Niño	*E. heteroloba*	8334.38	91.96	E-NE (35.5%)	
		Synodus fuscus	168.57	1.86		
2011/1	La Niña	*Eng. japonicus*	25431.63	89.82	S-SW (55.2%)	
		E. heteroloba	1058.94	3.74		
		Elops machnata	325.61	1.15		
2014/1	Normal	*Elops machnata*	89.84	72.51	E-NE (48.4%)	
		Congridae gen. spp.	6.18	4.99		
		Acanthopagrus latus	5.93	4.79		

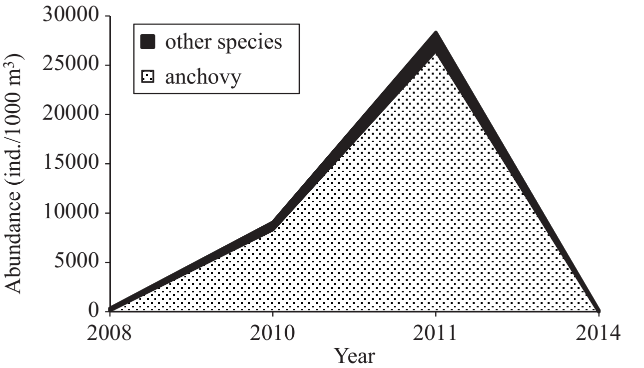

Fig. 5. Abundance of anchovy and other species in the coastal waters of the Tanshui River.

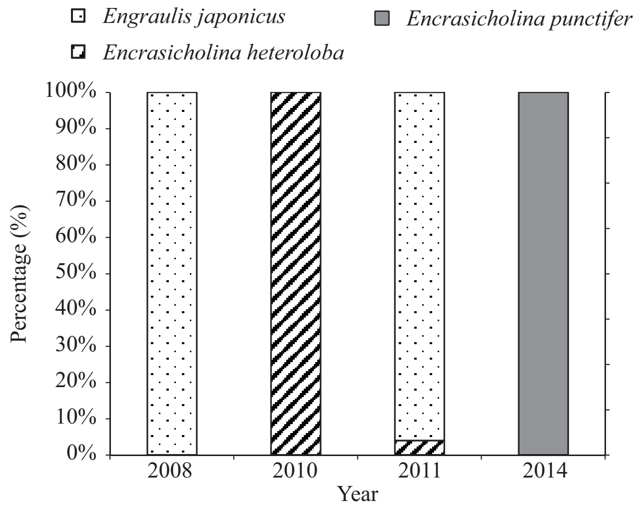

Fig. 6. Percentage composition of anchovy species in 2008, 2010, 2011, and 2014.

Japanese anchovy was dominant only in 2008 (100%) and 2011 (96%); shorthead anchovy and buccaneer anchovy were the dominant species in 2010 (100%) and 2014 (100%), respectively. Only few shorthead anchovy fishes were captured in 2011 (4%).

IV. DISCUSSION AND CONCLUSIONS

The findings of the present study suggest that annual variations in the winter abundance and species composition of anchovy larvae are affected by hydrological conditions. The abundance of fish larvae was the highest (approximately 28,314 ind/1000 m^3) in the winter of 2011, and it was 3, 86, and 228 times of the abundance in 2010, 2008, and 2014, respectively. Table 4 shows differences in the dominant species composition of ichthyoplankton in the Tansui estuary in winter. Japanese anchovy accounted for approximately 38%-89.8% of the total ichthyoplankton sampled in the winter of La Niña, whereas shorthead anchovy and buccaneer anchovy were the dominant species in the winters of El Niño and normal years. Wang and Tzeng (1997b) reported that the peak abundance of Japanese anchovy markedly decreased in the spring of 1992 (21%) and 1993 (17%). The magnitude of the anchovy catch may be mainly determined by the abundance of Japanese anchovy, which may be influenced by the SST anomaly (Lee el., 1990). Lee et al. (1995b) reported that the optimal survival temperature of Japanese anchovy is lower than that of shorthead anchovy and buccaneer anchovy. They also indicated that the anchovy catch increased when Japanese anchovy was the dominant species during a year with a low local SST. However, the catch declined by approximately 55% because of the anomaly of rising water temperature, resulting in the dominance of shorthead anchovy and buccaneer anchovy (Lee et al., 1990). Tsai et al. (1997) suggested an association between anchovy larvae and El Niño-Southern Oscillation (ENSO) events caused by oceanographic conditions affecting coastal upwelling. This correlation is transient and simply reflects ENSO events (Bradley et al., 1987; Hsieh et al., 2009). Taiwan is located in the extra-tropical region of the Western Pacific, outside ENSO's maximum effective zone; however, ENSO events have been indicated to affect Taiwan's coastal fish stocks and fisheries (i.e., anchovy and mullet larvae; Lee et al., 1995a; Lan et al., 2014). During a year with high SSTs and positive anomalies, the catches of the genus *Encrasicholina* are typically reduced. During a year with low water temperatures, Japanese anchovy is the dominant species, with increased catches (Lee et al., 1995b). Thus, we suggest that high SSTs reduce the abundance of Japanese anchovy but increase that of shorthead anchovy and buccaneer anchovy in winter.

The current strength may be another crucial factor influencing the abundance of anchovy larvae (Hsieh et al., 2009). Chang et al. (2009) suggested that continuous high winds result in the strong southward intrusion of the CCC into the Taiwan Strait during La Niña winters. By contrast, Kuo and Ho (2004) observed that a weaker northeasterly wind reduced the CCC intrusion into the Taiwan Strait and favored the flow of the northward KBC into the Taiwan Strait during more intense El Niño winters. These findings support that climate variability (ENSO events) results in anomalous wind patterns and significantly alters sea water temperatures and the flow of currents around Taiwan (Mora and Ospina, 2002; Xue et al., 2003; Beare et al., 2004; Murphy and Timbal, 2008). Japanese anchovy are typically transported to the northeastern Taiwan Strait by the CCC and spawn in the coastal zones from late winter to early spring (Chiu et al., 1997; Hsieh et al., 2009; Lo et al., 2010; Tu et al., 2012). Wang et al. (2013) suggested that after hatching, Japanese anchovy spawned off the Changjiang River are driven southward to the Taiwan Strait by the CCC. From 1981 to 2013, the spatial average of winter SST warming in the Taiwan Strait was 3°C (Kuo and Lee, 2013; Belkin and Lee, 2014). Long-term warming was strongly enhanced in winter, with a maximum warming of 0.07°C/year in February (Kuo et al., 2018). Nevertheless, the unusual cold CCC intrusion into the southern Taiwan Strait might result in the increased abundance of some migratory species, such as Japanese anchovy, during La Niña years (Lee et al., 2014).

Notably, the dominant anchovy species was observed to change with the current phase (Table 4 and Fig. 4). In January, the daily mean current direction along the coastal waters of the Tanshui River was predominantly west and southwest (Fig. 4). The CCC substantially intruded into the northern Taiwan Strait in the southwestward direction in the La Niña years and to a greater extent than it did in the El Niño years. The results of the present study revealed a low abundance of Japanese anchovy (128 ind/1000 m^3) corresponding to the westward current in January 2008 but a high abundance (25432 ind/1000 m^3) associated with the southwestward current in January 2011. Hsieh et al. (2009) emphasized that ENSO events reduce the strength of the Asian monsoon and thus weaken the flow of the CCC toward Taiwan. The reduced CCC may cause a decline in anchovy larval populations during the ENSO events, as the CCC is crucial in facilitating the spawning migration of Japanese anchovy. In January 2008, the intrusion of cold water into the waters of Western Taiwan was too weak to reduce the SST (Chang et al., 2009). Although Japanese anchovy was the dominant species, catch rates were not high. We infer that the high SSTs and weak CCC in January 2008 may have caused the low catch rates. In addition, the main direction of the flow changed to W-SW in 2008 and S-SW in 2011. Therefore, the westward-biased flow was identified as a possible crucial factor in the transportation of Japanese anchovy larvae away from the coastal waters, subsequently significantly reducing the abundance of anchovy larvae during the 2008 La Niña winter. However, the effects of the current and increasing sea temperature on the composition of the two species of buccaneer anchovy and shorthead anchovy were difficult to evaluate in this study because the habitat of buccaneer anchovy nearly overlaps with that of shorthead anchovy in the coastal waters of northern Taiwan (Hung et al., 2006; Kuo and Lee, 2013). Hung et al. (2006) assumed that the KC has slightly higher salinity than the South China Warm Current, explaining the predominance of the two aforementioned species during the South China Warm Current and KC. Thus, changes in the current pattern might affect the abundance of the aforementioned species that are caught in the coastal waters of the Tanshui River in winter. Thus, biophysical factors, such as seasonal monsoons, river discharge, speed and direction of oceanic currents, SST, and salinity, influence the species composition of anchovy larvae and fish assemblage. Although various descriptors and approaches are used, conducting comparison studies remains difficult.

In the present study, we examined the winter abundance and species composition of anchovy larvae, which may be influenced by environmental conditions in the coastal waters of Tanshui. The ANOSIM test revealed that ENSO events resulted in significant differences in the composition of anchovy larvae (R = 0.85) but not in that of other species (R = 0.2; Table 2). The strong CCC may have caused an increase in anchovy larvae during the La Niña years, as the CCC is crucial in facilitating the spawning migration of Japanese anchovy (Tu et al., 2012). When the current at 10-m depth moved southwestward in the La Niña years, Japanese anchovy was dominant, with a high abundance of approximately 128-25,432 ind/1000 m^3. In the El Niño years, buccaneer anchovy and shorthead anchovy were dominant, with a low abundance of approximately 0.21-8,334.38 ind/1000 m^3 when the northeastward current prevailed. Adult Japanese anchovy fishes were found to migrate from the East China Sea to the coastal waters of Taiwan for spawning around late winter and early spring (Tu et al., 2012). The recruitment rate of Japanese anchovy may decrease annually with increases in seawater temperature (Hsieh et al., 2009). The simultaneous collection of biophysical field data (i.e., SST and current direction and speed) is not feasible because of adverse maritime conditions during winter. Understanding the winter recruitment mechanism underlying the transport of larval anchovy to the fishing ground is the fundamental challenge, and gaining such an understanding can promote the management of larval anchovy fisheries in the coastal waters of the Tanshui River estuary.

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