國立台灣大學動物學研究所

碩士論文

Institute of Zoology

College of Life Science

National Taiwan University

Master Thesis

鯷魚豐度及群集組成與ENSO事件之關聯

Anchovy abundance and assemblage composition in relation with ENSO events

張又元

Yu-Yuan Chang

指導教授：丘臺生 博士

Advisor: Tai-Sheng Chiu, Ph.D.

中華民國101年7月

July 2012

謝辭

終於能夠邁向畢業了。在台灣大學動物所研究生的這兩年，對我而言是相當豐碩的。總括而言，能夠進台大這所學校對我的人生有相當大的衝擊和影響。一路走來從得知能入學，又興奮又緊張的心情，到開始找指導老師的時間太晚，導致不斷受到拒絕而以致不知道怎麼辦的慌張。最後蒙丘臺生老師接受我，能夠讓我在這邊學習和完成研究。這樣兩年下來，更是歷經了許多的波折，現在回首來看可說是五味雜陳，感慨萬千！

兩年下來，想要感謝的人有太多太多。以前曾在書本上念過所謂得之於人者太多而出之於己者太少，此刻很確實的有了體會。兩年下來從幾乎是零到現在這種程度，真的是得到太多幫助了。首先丘臺生老師，除了接收我在這邊學習和完成研究之外，在這兩年下來也不吝給予指導，讓我能夠在學問方面有所拓展。張光榕和成家貞小姐從進實驗室起便不斷指導我稚仔魚分類方面的知識。研究室的夥伴裡，曾志翔學長和可婷都是需要感謝的對象，以及可揚學長和學妹信璇。他們給了我很多的幫助和指教，不論是研究上或是平常生活方面。還有在平常定期進行討論的海洋所的同學也都是不能不提到的。要是缺少了上述任何一個人，不知道我是否還能如此順利完成？

除了台大這邊的老師和夥伴外，還要感謝口試委員的楊樹森老師、黃文彬老師、陳志炘老師、以及王慧瑜老師。要感謝諸位委員對於研究的指教和意見。

最後，家人們也是我要感謝的對象。正所謂家是永遠的避風港，在這段時間內我也曾不知所措。但無論如何至少有個宜人而可以放鬆的家，讓我在喪氣的時候能夠很快的重新振作。這段時間的走走停停，家人們的關切和鼓勵對我而言一直有相當的激勵和鞭策作用。

感謝這段路上陪我走過的每一個人。謝謝！

摘要

ENSO (El Niño-Southern Oscillation) 是半週期性的大氣海洋作用，通常發生在熱帶太平洋，其包含 El Niño 和 La Niña 兩種事件，伴隨 ENSO 事件的發生週期，太平洋之東部及西部發生氣壓以及海表面溫度的明顯變化。 若干研究顯示，此變化對於海洋生態以及漁業有廣泛及深遠的影響。 在本論文中，我企圖探究台灣周遭重要近海漁業—魩鱙漁業之漁獲組成與 ENSO 現象變化之間的關聯。

魩鱙漁業的主要漁獲目標為大洋性表層洄游的鯷科和鯡科魚類；在台灣周遭以日本鯷、異葉公鯷以及刺公鯷為主要物種組成。 此三物種之繁殖及洄游路徑各自對應不同洋流，因此三物種之相對組成變化，在探討海洋事件方面可能可以反應其所棲息之洋流改變之情形。 除主要對象外，混獲魚類亦為我的探討目標，尤其在混獲魚類當中有許多魚類其習性不同於鯷科魚類，棲習於不同水層，與洋流之相依程度不一，藉由分析這些混獲魚種，也可以幫助我們釐清 ENSO 事件發生時其影響是否侷限於海水表層。

本研究 ENSO 事件方面依據海洋聖嬰指數(Ocean Niño Index)，取 2008 年春天為 La Niña 事件，2009 年春天為中性狀況，2010 年為 El Niño 事件。 根據台灣魩鱙漁業的漁場分為東北、西北、以及西南三處，取此三地上述時段之漁獲樣本以氣候資料。 在漁獲樣本中，將每一尾魚盡可能鑑定到種的階級。 將魚種分為目標魚種組和混獲魚種組，混獲魚種組中又依其生態習性分為大洋表層魚類與非大洋表層性魚類。 比較不同魚種之豐度變化，以 Spearman’s rank correlation analysis 檢驗在同一氣候條件下不同地區間魚種組成的相關性。 並藉由群集分析法檢視各地區在各氣候狀態下魚種組成的相似程度。 最後計算各漁獲樣本之物種多樣性。

研究結果顯示，在西北和西南區域，目標魚種皆有與 ENSO 相應之變化。 在

混獲魚種方面，表層魚類之差異性歸因於 ENSO 事件的可能性較低；非表層魚類面其物種組成較平均，顯示 ENSO 現象帶來的影響較小。 在地區間的差異方面，主要反應在目標物種上，中性狀況時東北和西南水域其物種組成有正相關，然而在 El Niño 時東北和西北組成有正相關，反之在 La Niña 時西北和西南有正相關，這可能反映了在不同 ENSO 條件下海流狀況的不同。 群集分析法的結果中，亦只有在表層魚類有較明顯的分群關係。 因此，可以推測 ENSO 事件對於台灣周遭魚類群集組成的影響主要透過表層海流的變化所影響。 又，許多魚類的相對組成變化，其極端值反而發生在中性條件下，由此點來看，在探討台灣周遭魚類群集組成時，El Niño 和 La Niña 事件可能不完全代表相反的氣候相(meteorological phases)。

關鍵字: ENSO 現象、魩鱙漁業、鯷科魚類、魚種組成、黑潮

Abstract

ENSO (El Niño-Southern Oscillation) is a quasi-periodic climate pattern, which includes two large-scale meteorological events of the El Niño and La Niña. ENSO variations can be seen significantly in the alterations of atmosphere and surface water temperature in the tropical Pacific. The effects from ENSO events on ocean ecology and fisheries have long been noticeable with pretty studied. In this study, I try to estimate the relationship between ENSO and the catch composition of Taiwanese larval fisheries, which are important economic practices in the inshore waters.

The main targets of Taiwanese larval fishery are anchovies and herrings, which all live to pelagic life in coastal waters. Japanese anchovy (*Engraulis japonica*), shorthead anchovy (*Encrasicholina heteroloba*) and Buccaneer anchovy (*Encrasicholina punctifer*) are the most commonly species. The migration of these three species are by-and-large associated with 3 different prevailing currents around Taiwan, thus their composition patterns may correspond to the shifts of the prevailing currents. Besides, by-catch is also inevitably interested to illustrate non-pelagic species in response to ENSO variations.

In my study, the ENSO event is determined following the Ocean Niño Index (ONI).

According to the ONI, I took the spring sample of 2008 stands for La Niña, 2009 as neutral and 2010 as El Niño. My research sites include the northeastern (NE), northwestern (NW) and southwestern (SW) waters of Taiwan. Identified of fish samples were grouped into 3 categories of target, by-catch pelagic and by-catch non-pelagic. I compared the composition of the abundance of the species, using spearman's rank correlation to test the areal difference in each climatic condition. Cluster analysis was used to the similarity of the categories. The diversity of the samples was also calculated. It turns out that in the ENSO condition, the target species composition reflected a similarity between NW and SW, but the pattern did not reflect the by-catch species. The compositions of non-pelagic species were vague, in response to the ENSO shifts, partly due to the later took place primarily in surface water. The compositions of target species of NE and SW were positively correlated in the neutral condition; but situations shift to NE and NW in the El Niño condition, and NW and SW in the La Niña condition. The explainable reasons for the composition shift may ascribe to the changing pattern of the surface currents. Clustering analyses indicated that the target species presented a clear grouping following prevailing currents, but not non-pelagic species, supports that the ENSO effect took placed in marine surface fish species. Finally, owing to substantial amounts of extreme measurements were taken in the neutral condition, the fish assemblages around Taiwan in these two extreme meteorological conditions may not be simply mirrored to the opposite conditions.

Key word: ENSO, larval fishery, anchovy, species composition, Kuroshio

Contents

1. Introduction

1.1 ENSO

1.2 The hydrography around Taiwan

1.3 Larval fisheries of Taiwan

1.4. Larval recruitment

1.5 Aim of this study

2. Material and method

2.1 Definition of ENSO events

2.2 Meteorological Data

2.3 Sampling of larvae fishes

3. Results

3.1 Meteorological variables

3.2 Species compositions of larval fishes

3.2-1 Northeastern Taiwan

3.2-2 Northwestern Taiwan

3.2-3 Southwestern Taiwan

4. Discussion

4.1 Characteristics of meteorological conditions

4.2 Patterns of larval composition

1. Introduction

1.1 ENSO (El Niño and Southern Oscillation)

1.1-1 El Niño and southern oscillation

El Niño is a large-scale meteorological event. It takes place in tropical Pacific and occurs at a cycle of 3 to 7 years. Southern Oscillation (SO) refers to the fluctuation of sea surface temperature in the southern Pacific, in which the variation may give an indication of the intensity of El Niño. Practically, the SO index (SOI) is calculated based on the sea-level pressure differences between Tahiti and Darwin (Trenberth, 1983; Ropelewski and Jones, 1987). The word ENSO is thus used commonly to denote the coupling of the two climatic phenomena to facilitate the studies on their effects in agriculture and fishing in particular. Two typical events can be identified during SOI variations; i.e., higher SOI values refer to El Niño event, and reversely lower SOI values point to La Niña.

Since ENSO events take place in ocean, their effects on ocean ecology and fisheries were significant, and the resulting abnormality can be widely found in inshore and open ocean areas. For instance, the change of equatorial currents and position of warm pool during El Niño might cause the change of tropical tuna catch rates (Howell and Kobayashi, 2006). In addition, due to the change of atmospheric modes during extreme ENSO (i.e., strong El Niño or La Niña events), heavy rainfalls might episodically happen to raise river outflows, and the ensuing lower salinity can influence the recruitment strength and spatial distribution of tropical coastal species (Blanco *et al*., 2007; Vieira *et al*., 2008). Its variations also linked to the changes of tropical benthic community structure and the mortality rates of organisms at their early ontogenetic stages (Gaymer, *et al*., 2010).

1.1-2 ENSO effects on Asia

Although the phenomena of extreme ENSO events are mainly found in the eastern tropical Pacific, their influences can also be traced in the western Pacific because the ENSO events are known to be large-scale affective meteorologically and oceanographically. The influences of ENSO variability in Asia can be observed and categorized into two effects. First one is the volume and path changes of major marine currents in the western North Pacific, among which the Kuroshio originated from the Northern Equatorial Current (NEC) was the most significant. For instance, the temperature of Kuroshio front lowered than neutral years was observed associated with 1982 ENSO event (He, 1987). Observing from eel larval transport in the North Pacific, we can estimate the shift of NEC when the ENSO events occurred varied the bifurcation position and flow-volume of the Kuroshio (Kim *et al*., 2007), and the shift make the

Kuroshio colder when El Niño was taking place. The second effect on Asia is the change of atmospheric pattern that causes the variations of meso-scale monsoon system. During El Niño, the monsoons of west Pacific would decline, both for Northeastern and Southwestern monsoons (Chao, 1996), and also the weaker of monsoons affects the ocean flow patterns and subsequent rainfalls. The relationship of Asia rainfall and ENSO had been called Pacific-East Asian teleconnection with various connections (Jiang *et al*., 2003). Heavy spring rainfall events could occur in strong ENSO and Non-ENSO years with different large-scale air circulation patterns. The ocean flow pattern changes ascribed to the ENSO may bring up by monsoon. For instance, the water mass distribution in Taiwan Strait (TS) is determined by the monsoon system (Jan *et al*., 1994; Jan *et al*., 1998), so it had been found that the pattern changed when ENSO events were taking place; i.e., the sea surface wind was much weaker during El Niño than La Niña, and the SST in the TS is colder in the northwestern part and warmer around the southeastern region. Specifically, the 1997~1999's data showed that after 1997/1998 El Niño event, it was colder in subsequent summer temperature, and also warmer in winter temperature during the 1998/1999 La Niña event (Kuo and Ho, 2004).

1.2 The hydrography around Taiwan

1.2-1 Ocean currents

The Taiwan Island is located in the margin of the Northwest Pacific continental shelf, and tucked between tropical and subtropical marine provinces. Three major currents reach Taiwan Island with various strength seasonally; i.e., the Kuroshio Current (KC), China Coast Current (CCC), and South China Sea Current (SCSC) (Jan, 2002; Hu, 2000). The KC is a strong north-bound current that passes eastern Taiwan with limited water nutrients (Shang *et al.*, 2005). The west-bound NEC turns northward at the place where northward KC starts. In the vicinity of Taiwan, the KC makes two branches from its mainstream: the first branch goes through the Bashi channel in the southern tip of Taiwan where the branched water intrudes to northern South China Sea forming a cyclic eddy during winter, and the other branch occurs at northeastern Taiwan where the subsurface KC water flushes onto the shelf resulting an all-season upwelling (Wang and Chern, 1988). The CCC and SCSC are two seasonal currents driven by monsoons; the former originates from the East China Sea flowing south-westward driven by the Northeast Monsoon in winter, and the latter is bought up by Southwest monsoon from the South China Sea (Jan, 2002).

1.2-2 Variations of the currents

Seasonal and intra-seasonal variations of the KC in the eastern Taiwan could be found with various forcing mechanisms (Hsin *et al.*, 2010). The flow pattern in western Taiwan, including Taiwan Strait and South China Sea, is even more complicated. During winter when the Northeast monsoon is prevailing, the cold water from CCC goes southward and spread widely in the Taiwan Strait. As the Northeast monsoon wanes in early spring, the current in the Taiwan Strait turns to the north-east direction, and thus the water from KC branch becomes dominant in the eastern Strait reaching to the western coast of Taiwan, while the CCC dominate in the western Strait stretching to the eastern coast of China Mainland (Jan *et al*., 2002). During early summer, the SCSC starts to invade to the Taiwan Strait, and its water replaces the waters from KC branch in part. Getting to summer, the SCSC goes further northeast and the current becomes much stronger to cover the whole Taiwan Strait eventually (Jan *et al*., 2002; Jan *et al*., 2006). The dominance of SCSC in the Taiwan Strait lasts to autumn until the Southwest monsoon wanes.

1.2-3 Ocean current variations in relation to ENSO

The ENSO variations may have influenced the flow patterns around Taiwan Island, because the ENSO events are meso- to large-scale with rampant effect almost the whole planet, and also the ENSO-related tropical warm pool is right located upstream of the Kuroshio. In eastern Taiwan, the Kuroshio strength (flow-volume) and its water temperature changes with ENSO were observed (He and White, 1987; Kim *et al*., 2007).

In the western Taiwan, both CCC and SCSC are driven by the major monsoon systems, therefore the components of water mass in the Strait could have changed due to ENSO (Wu *et al*., 2007). For instance, the water of Taiwan Strait became warmer in winter and cooler in summer when El Niño took place (Kuo and Ho, 2004). In the meanwhile, the distribution of eutrophic water was estimated to reduce to smaller area (Shang *et al*., 2005), in which condition the ecosystem in the Taiwan Strait changed accordingly.

1.3 Larval fisheries of Taiwan

1.3-1 The practices of larval fisheries

The practice of larval fisheries in Taiwan is not significant until 1977 when trawlers geared with large-sized wing-net were introduced from Japan (Chiu *et al*., 1997). The trawler's net is equipped with 2 mm meshed cod-end that can catch tiny larvae in fairly shallow long-shore water as much as 5-30 m depths (Tasi *et al*., 1997; Chiu *et al*., 1997). Ascribing to geomorphological and hydrographical characteristics, three major fishing grounds are formed, and they are located in the northeastern (related to KC), northwestern (CCC) and southwestern (SCSC) Taiwan. The fisheries facilities are based on three major ports of Kengfong (Ilan County), Dansui (New Taipei City) and Fongliao (Pingtung County), respectively (Wang and Tzeng, 1999; Lee *et al*., 1990;

Hsieh *et al*., 2009). Monitoring system is established to check fisheries' landing and estimate catch rates for better and reasonable management.

1.3-2 Catch compositions

The fishing season of Taiwanese larval fisheries starts when annual massive anchovy recruits to the coastal area with relatively predictable months. The main interests for local fishermen focused on anchovies and sardines, which are members of the families Engraulidae and Clupeidae, respectively (Chiu *et al.*, 1997). Three most distinctive species of anchovies were found in catches; i.e. Japanese anchovy(*E. japonicas)*, Buccaneer anchovy (*En. punctifer)* and shorthead anchovy (*En. heteroloba)* (Young *et al.*, 1992). They are all small- to median-sized pelagic fishes found commonly in the western North Pacific. These fishes comes to Taiwan area with ocean currents mainly for the nursery ground inshore of Taiwan and their nursing periods of the fishes are similarity (Tasi *et al.*, 1997). Owing to relative non-selection of the fishing gear and fishing method, many larvae belonging to economically important species with less reproductive values as anchovy or herring were also by-caught in the practices (Chiu *et al.*, 1997). The seasonal variations of the catch-composition and the relative abundance are considered linking to environmental factors and meso-scale decadal events.

1.3-3 Variation in abundance and composition

Two consecutive harvesting seasons in spring and autumn could be identified in the past. Spring season lasts from March to May, and the autumn season is from August to October around (Chiu *et al.*, 1997). The spring production is larger than autumn one in general, and the fishing season opens in all three fishing grounds. Comparing with spring, the catches of larvae changed drastically in the autumn because extreme weather conditions appeared frequently, for instance no fishing in the southwestern fishing ground during 2009 and 2010, when typhoons Morakot and Fanapi impacted southern Taiwan. Apart from anchovies and herrings, the compositions of by-catch are even more urgent to understand, because serious concerns are raised due to their high diversity and the involved species are of low reproduction. Chiu *et al*. (1997) found that the percentage of by-catch composition peaked in July and June. For conservative reasons, current management plan has incorporated a three-months banning season for the practices including June and July.

1.4. Larval recruitment

1.4-1 Anchovies

Generally, the three major anchovy species that take turns to show up in the waters around Taiwan are related to the strength of major currents; Japanese anchovy from the north pertaining to the CCC, and the other two southern species, *Enc. heteroloba,* and *Enc. punctifer*, might linked to the Kuroshio branches and the SCSC. Two cohorts of Japanese anchovy were found around Taiwan, one at spring (March to May) and the other at late summer (August to September) (Chiu and Chen, 2001). During spring, two geographic populations of Japanese anchovy could be separated: one found in Taiwan Strait originated from the coastal East China Sea (ECS), and the other in the eastern side come from the oceanic ECS closed to the shelf margin (Chen and Chiu, 2003; Chen *et al*., 2010). For the two southern species, the sources of recruitment are different; *En. heteroloba* might come with SCSC and *En. punctifer* come with Kuroshio, and both originate from south heading to the north. The arrived time and quantity of *En. heteroloba* and *En. punctifer* to the fishing grounds varied, and the variations might relate to the shifts of the major currents.

1.4-2 By-catch species

In addition to massive productive species of anchovy and herring, other larvae or juvenile of fish species with less reproductive capacity were also caught at the same time as by-catch species. For example, estuarine inhabitants such as pony fish (Leiognathidae) and coastal spawners such as scomber (Scombridae) are fairly frequent swept out by huge larval nets (Chiu *et al*., 1997). Benthic fishes like threadfin breams

(Nemipteridae), deep sea fishes like lantern fishes (Myctophidae), and even catadromous fresh water fishes (Gobiidae) were not uncommonly found in the by-catch lists (Chiu *et al.*, 1997). The co-occurrence of target and non-target species in the larval nets indicated larval fishes shared a similar behavior and ecological place. Although the amount of by-catch species was a few as compared to target species, their appearance may reflect specific recruitment conditions that could be highly related to environmental changes. For instance, Huang *et al.* (1985) suggested the seasonal variations of fish larval abundance in Yen Liao (New Taipei city) were related with production cycle of plankton.

1.5 Aim of this study

1.5-1 Larvae recruitment as environmental change proxy

Annual abundance of specific larvae and its geographic distribution pattern can shed lights of fish ecology, like spawning successes of adult fish, behavior and mortality of larvae, and oceanographic process (Hsieh *et al.*, 2010). Most fish species at their larval stages live in pelagic waters, and thus become vulnerable to larval fisheries with surface fishing gears. Changes that take place in the sea surface may promptly reflect to fisheries' catch rate and fish composition. By using historical fisheries data, we may follow ecological shifts in the fishing grounds. Taking advantages of large quantity and extensive area of commercial fishing data, the fingerprints of the ENSO variation may be identified after stringent data analyses.

1.5-2 Research goal

In this study, I would like to estimate the variations of larval abundance and species composition in relation to the typical ENSO events, such as El Niño and La Niña. Three principal areas of NE, NW and SW in corresponding to three major current systems of the KC, CCC and SCSC are attempted to display spatial variability. The outcome of this study may comprehend current knowledge of larval ecology and assist to improve extant fisheries management plan.

2. Material and method

2.1 Definition of ENSO events

2.1-1 ENSO events

It has been a long time since ENSO events were first recorded by researchers. Subsequently, the periodicity of ENSO events is found in relation to ocean and atmospheric dynamics. There are many ways to describe the fluctuation of weather in the Pacific where the ENSO variations were found the most significant; to name a few important, such as Southern Ocean Index (SOI) recorded the atmosphere difference of east and west side Pacific, and North Pacific Index (NPI) recorded the sea surface temperature anomaly of 30°N ~ 65°N, 160°E ~ 140°W). However, none of these were used in this study due to remoteness of the geographic localities.

2.1-2 Ocean Niño Index

Ocean Niño Index (ONI) is used to feature significant ENSO events that have happened in this study period. The reason that I choose ONI is that the area of Niño-3.4 locates close to the North Equatorial Current and upstream to the Kuroshio Current. The index is published by Climate Prediction Center (CPC), USA, in which the index is calculated by using monthly sea surface temperature anomaly at 5°N ~ 5°S, 170°E ~ 120°W (i.e., Niño-3.4 area; Fig. 1). This index indicates that at the El Niño condition the values of anomaly are observed larger than 0.5 for 3 months or more, while at La Niña condition the values are less than -0.5 for more than 3 months (NOAA). Apart from the two extreme, the neutral condition shows a value ranges between -0.5 and 0.5. Figure 2 illustrated the time series of ONI from 2007 to 2010 of the studying period; when one La Niña event (October 2007 ~ May 2008) and one El Niño events (June 2009 ~ May 2010) were identified.

2.2 Meteorological Data

2.2-1 Sea surface temperature

The data of sea surface temperature (SST) is interpreted from the satellite images downloaded from Aqua MODIS (Moderate Resolution Imaging Spectroradiometer). Monthly averaged images of March, April, and May from 2008 to 2010 were obtained to match to the biological data of this study. For surface water temperature, I used the data from buoys deployed by Central Weather Bureau, Taiwan. The buoy stations at SuAo (YiLan County), JhuWei (TaoYuan County) and HsiaoLiuChiu (PingTung County) were adopted to represent the 3 major fishing grounds NE, NW and SW waters, respectively.

2.2-2 Rainfall and wind speed

For rainfall and wind flow, I used the data from Central Weather Bureau. The data from station SuAo, DanShui (New Taipei County) and KaoHsiung (KaoHsiung City) were used to represent NE, NW and SW areas respectively.

2.2-3 Statistical treatments of meteorological data

All meteorological data were grouped by 3 climatic conditions and descriptive and Student's t-test were used to quantify inter-category's differences.

2.3 Samples of larvae fish

2.3-1 Study area and samples

The data used in this study are subsampled from the data deposited in the Economic Fish Lab., Institute of Zoology, National Taiwan University. The catches from 3 larval fishing grounds of NE, NW and SW were subsampled for monitoring the status of fishing practices (Fig. 3). The sampling dates, water (localities) and specimens used were tabulated in Table 1, and the data are categorized into 3 meteorological conditions of neutral (June 2008 ~ May 2009), El Niño (June 2009 ~ May 2010) and La Niña (October 2007 ~ May 2008). Only data from spring fishing were interested because no autumn data from SW waters were available due to unable to undertake larval fishing practices in the aftermaths of devastated typhoon Morakot (2009) and Fanapi (2010).

2.3-2 Sample treatment and morphological classification

The obtained samples were preserved in 70% alcohol. Morphological identification was exerted on each larval specimen down to species level as much as possible. The references for larval fish identification including Okiyama (1987), Chiu (1999), Shen (1993), and Taiwan Fish Database (Shao, 2009).

The key features for checking each specimen are described as followed:

Body shape: pertaining to contrast of individual's measurements in general, several type can be identified, such as elongated, streamline, compressed, flatted, chubby, etc. Basically, most of the specimen can be assigned to the family level based on the characteristics of body shape. For example, fishes of bothid can be easily identified due to their flatted body shape.

Proportion of length and height: pertaining to the ratio of major measurement axes. Taking precise measurements of length and height can be very useful in identifying significant groups within a family. This feature may play a decisive role to identify individual specimen down to species level; such as larvae of anguillid in their leptocephalus phase.

Organ placement: pertaining to relative position of organs. For instance, the position of dorsal fin and anal fin is an important key to identify *Enc. heteroloba* and *Enc. punctifer*, i.e., origin of anal fin overlapping the end of dorsal fin to identify *Enc. heteroloba*, otherwise it would be *Enc. punctifer*.

Number of fins: pertaining to medial fins, largely dorsal fin. Some species have one dorsal fin, and the others have more than one departed fins, for example, most of fish have one dorsal fin, however, apogonid have two dorsal fins, and some gadid have three dorsal fins.

Number of fin spines and rays: pertaining to number counted. This characteristic can be used for identification of late larvae and juveniles, because at these stages the fin development almost has reached its mature stages.

Spine and bone plate prominence: pertaining to intermediate stage of full-bone formation. Often time, this structure can be found in a developing operculum, and the characteristic of spine or bony plates could be helpful in recognition of siganid (many saw-teeth in the posterior margin of operculum).

Chromatophore: pertaining to distribution of pigments. Number of chromatophors and their position probably are the most important key for larval fishes in lizardfishes (Synodontidae and Harpadantidae). In addition, chromatophore could also be found in gut's lining and between muscles. For instance, herrings show specific variations on the position of chromatophores bearing on guts.

Number of vertebral: pertaining to vertebra counts. Similar species might have different number of vertebra due to ecological factors, such as dwelling different temperature conditions of warm or cold environments. For instance, the vertebral number of genus *Engraulis* which is in the northern water is larger than genus *Encrasicholina* live in southern waters. We can count the number of myotomes to reflect the number of vertebral.

Luminous organ: pertaining to light production. This is especially important for some deep sea fishes, such as lantern fishes (Myctophidae) which can be identified by the number and position of photophore.

Unique organ: pertaining to highly specialized structure. Such as larvae of Lophifomes have membrane outside their body, and that of Gobiidae have sucking disk on their ventral side.

2.3-3 Sample preparations and statistical treatments

All examined and identified specimens were separated into two groups of target species and by-catch species. The former is composed of fishes commonly named anchovy (Engraulidae) and herring (Clupeidae). All other non-anchovy and non-herring species are treated as by-catch species. The by-catch species are further grouped as pelagic and non-pelagic according to their frequent appearance in the water column. The 3 climatic conditions and 3 marine waters make 9 categories, and the number of specimens in each category was converted into relative abundance (RA), as shown by 10,000 individuals. Documented data are used to assign by-catch species either pelagic dweller or not (Shen, 1993; Shao, 2009).

Areal differences on species composition, both target and by-catch species, were examined by descriptive statistics. For quantifying similarity among areas, Spearman's rank correlation analysis was used to test if there are any areal link due to physical climatic conditions. Because I organized my data into three areas with three climatic periods, the similarities between nine categories were exhibited by cluster analyses based on Euclidian distances.

2.3-4 Diversity and eveness

For each category, I calculated the diversity and the evenness to display its community structure. Shannon's diversity index were used.

Shannon's Diversity Index

$$H' = -\boldsymbol{\Sigma}^{s}_{i=1} P_i \mathrm{Log} P_i \qquad (P_i = n_i/N)$$

N: total number of individuals

n_i: number of species i found in this sample

s: total number of species found in this sample

3. Results

3.1 Meteorological conditions

3.1-1 Temperature variations in the Northwest Pacific

The monthly average diagrams of sea surface temperature (SST) in the Northwest Pacific from 2008 to 2010 are exhibited in Fig. 4. Three meteorological categories were identified according to climatic conditions reflected by ONI: 1) La Niña occurred in the period of March-May of 2008 (Fig. 4a-c); 2) neutral in March-May of 2009 (Fig. 4d-f); and El Niño in March-May of 2010 (Fig. 4g-i). Compare La Niña to neutral condition, apparent higher temperature was found on the flow-path of the Kuroshio in the whole spring season. Compare El Niño to neutral condition, a cooler water was found in the flow-path of the Kuroshio before April, however, I also found that the water turned warmer in the May of 2010 when El Niño was taking place. In the East China Sea, it can also found that the continental waters became cooler as compared to the neutral condition. And, reversed pattern was found with the occurrence of El Niño, especially in the May of 2009 and 2010. In the seas south to Taiwan, the data for most of area were not available due to cloudy sky, however the data also presented a status that during 2010's El Niño event, the SST was relatively high in the South China and Philippine Seas. It is also worth to note that the SST goes to high from April to May drastically in 2010.

The water temperatures of NE area are estimated 22.47 ± 1.13 °C, 23.05 ± 1.16 °C and 22.62 ± 0.93 °C, for neutral, El Niño and La Niña respectively (Table 2). Student’s t-test indicated that difference were found in El Niño condition, in which a raise of 0.58 ^{o}C was measured. However, no difference was detected in La Niña condition. A raise in NE water temperature in El Niño parallels to the ONI.

Similarly, the water temperature in the NW waters was measured to 20.08 ± 1.70 °C (neutral) , 20.48 ± 1.53 °C (El Niño) and 20.46 ± 3.73 °C (La Niña). No significant differences were found in this area across three climatic conditions.

In SW waters, comparing to the other two areas apparently higher temperature were measured, with 26.71 ± 0.80 °C for neutral conditions, and 26.92 ± 0.72 °C and 27.25 ± 1.26 °C for El Niño and La Niña respectively. Singular water pattern was found in the SW waters that indicated a warm marine climate when La Niña was taking place.

3.1-2 Rainfalls of each area each period

Time series plot for monthly rainfalls was followed from January 2008 to

December 2010 (Fig. 5). Apart from climatic condition might affect local rainfall, seasonality can also be observed at least in the NE and SW areas. Owing to my comparison was focus on spring fishing season, the data from March to May in each year were separated for further treatment. The average rainfalls at different climatic conditions are shown in Table 3. In the NE area, highest rainfall was occurred in La Niña, while lowest in El Niño. In the NW area, elevated rainfalls were found with extreme climatic condition, especially in the La Niña. In general, the SW is an area with apparent fewer rainfall compared to the previous two areas. In SW area, El Niño rainfalls doubled neutral condition, and La Niña rainfall was intermediate.

By and large, the rainfall was the most abundant in the NE area. Seasonal variations are obvious, with most rainfalls occurred in mid-autumn. The rainfalls in northwestern area are general lower than northeastern area. The lowest NW spring rainfall took place in 2009, and highest in 2008. The highest monthly rainfall record was in 2008's September, whose 1084 mm at least 3 times more than the average. Significant seasonal variations were also found in SW area; the rainfalls imploded only in summer and early autumn with little in spring. The onset of raining season is June in general, however, an early start of 2010 was also noticeable.

3.2 Species composition of larval fish

3.2-1 Northeastern Taiwan

3.2-1-1 Anchovy

The relative abundance of three major anchovy species, including Japanese anchovy (*Engraulis japonicus*), shorthead anchovy (*Encrasicholina heteroloba*) and Buccaneer anchovy (*Encrasicholina punctifer*) found in NE are shown in Fig. 6. In neutral condition, fewer south-bound Japanese anchovy was exhibited, that only counted to 7.06%. Anchovies came from the south dominated neutral condition, with shorthead anchovy (24.55%) and Buccaneer anchovy (62.41%). In El Niño and La Niña conditions, the Japanese anchovy became dominant over a half, with 52.78% and 59.78%, respectively. It is also noticeable that shorthead anchovy outnumbered Buccaneer anchovy (21.21% vs. 8.60%) in El Niño, while the place reversed in La Niña (4.56% vs. 33.26%). In total, 5 clupeid and 6 engraulid species were found in the studying period (Table 4). Two clupeid species were found significant (> 1%) in the neutral list; i.e., *Sardinella zunasi* (1.83%) and *Sardinops melanostictus* (1.72%). Excluded 3 major anchovies, no other engraulid became significant.

In El Niño, 4 clupeid became significant; i.e., *Sardinella zunasi* (7.82%), *Nematalasa japonica* (3.25%), *Sardinops melanostictus* (3.06%) and *Konosirus punctatus* (1.05%). *Thryssa chefuensis* (1.97%) was the only engraulid species put to the significant group joining with the major anchovies.

In La Niña, the three major anchovies overwhelmingly occupied the significant group that pulled a huge gap off other species (< 1%).

3.2-1-2 By-catch species

The species incidentally caught with targeted anchovies are separated into two groups of pelagic and non-pelagic species. The relative abundance of pelagic by-catch species is summarized in Table 5. For the pelagic fishes, *Elops hawaiensis* had the highest abundance in neutral and El Niño conditions; in which its percentages counted to 95.96% and 65.79% respectively. However, is dominance faded a bit in La Niña condition, only counted to 23.81%. During La Niña, substantial amount of blue mackerel (*Scomber australasicus*) (38.1%) presented in the NE waters, and its significance replaced *E. hawaiensis*.

By climatic conditions and excluding the most significant species in the list, only two significant species were found in neutral, including *Megalops cyprinoides* (2.22%), and *Valamugil seheli* (2.22%); three species in El Niño, *Scomber ausrtralasicus* (13.16%), *Liza macrolepis* (18.42%), and *Liza affinis* (2.63%); and 7 species in La Niña, *E. hawaiensis* (23.81%), *Liza affinis* (9.52%), *Scomber japonicas* (9.52%), *Selar crumenophthalmus* (4.76%), *Megalops cyprinoides* (4.76%), *Oedalechilus labiosus* (4.76%), and *Bolinichthys pyrsobolus* (4.76%).

At least 53 non-pelagic species were found in the NE waters of Taiwan during studying periods (Table 6) In neutral condition, I found 11 significant species, and named the top five as: *Leiognathus* spp. (25.56%), *Harpadon nephereus* (22.01%), *Leiognathus lineolatus* (19.22%), *Rhinogobius brunneus* (8.58%) and Leiognathus nuchalis (4.29%). Similarly, 10 and 12 significant species were found in the El Niño and La Niña conditions; and the top five were *Leiognathus* spp. (19.09%), an unidentified gobius (19.29%), Leiognathus nuchalis (16.51%), Rhinogobius brunneus (10.58%) and *Lateolabrax japonicas* (6.12%) for the El Niño, and *Chromis notatus* (26.61%), *Leiognathus* spp. (19.09%), *Harpadon nehereus* (9.14%), *Leiognathus elongatus* (8.06%) and *Leiognathus lineolatus* (4.03%) for the La Niña.

3.2-2 Northwestern Taiwan

3.2-2-1 Anchovy

For the 3 major anchovies, their relative significance is illustrated in Fig. 7. We could also found that major anchovies took less proportion in NW area’s target species in general. In neutral condition, Japanese anchovy was the fewest one (1.33%), that even less than some clupeids. Shorthead anchovy took the front in the proportion list, and it counted to 29.25%. Buccaneer anchovy showed behind the shorthead (19.16%). In El Niño condition, percentage of Japanese anchovy was moderately up to 16.63% ranked the second place. However, shorthead anchovy was less abundant, only count to 3.73%. Buccaneer anchovy held the most significant amount of 30.09%. Pattern of major anchovies in La Niña was similar to neutral condition (shorthead anchovy (50.222%) > Buccaneer anchovy (22.17%) > Japanese anchovy (0.26%)).

Target species composition in the NW waters of Taiwan is tabulated in Table 7. We found 6 clupid and 7 engraulid species in the studying waters. There were 5 clupids and 2 engraulids significantly found in neutral condition; i.e., *Sardinella zunas* (14.94%), *Thryssa chefuensis* (12.12%), *Sardinops melanostictus* (9.24%), *Dussumieria elopsoides* (6.05%), *Thryssa dussumieri* (3.01%), *Nematalosa japonica* (2.67%) and *Konosirus punctatus* (1.69%). The dominate species of El Niño condition were similar to the neutral condition, with 5 clupeids and 2 engraulids showed up significantly; i.e. *Sardinops melanostictus* (20.31%), *Sardinella zunas* (15.43%), *Thryssa dussumieri* (3.68%), *Konosirus punctatus* (3.35%), *Nematalosa japonica* (2.99%), *Dussumieria elopsoides* (2.35%) and *Thryssa chefuensis* (1.31%). In La Niña condition, four clupeids and one engraulid were found significantly: *Sardinella zunasi* (15.41%), *Thryssa dussumieri* (5.16%), *Dussumieria elopsoides* (2.71%), *Nematalosa japonica* (1.77%),and *Sardinops melanostictus* (1.43%).

3.2-2-2 bycatch

The by-caught species of NW area are tabulated in Table 8 and Table 9. In pelagic fishes, carangid was a speciose group with significant abundance in neutral condition; six species were identified, five of them were significant; i.e., *Decapterus maruadsi* (36.32%), *Decapterus macrosoma* (4.48%), *Atule mate* (3.14%), *Decapterus macarellus* (2.69%) and *Decapterus russellii* (2.24%). In El Niño condition, the most percentages were taken by *Elops hawaiensis* (43.48%) and *Trichiurus lepturu* (39.13%). Many fishes occurred in other two conditions did not appear in El Niño condition. In La Niña, the most abundant fishes are *Elops hawaiensis* (39.80%)*, Benthosema pterotum* (27.55%), and *Trichiurus lepturus* (8.16%). Many fish occurred uniquely in this condition; i.e. *Megalops cyprinoides (8.16%), Vinciguerria nimbaria* (2.04%), *Liza macrolepis* (1.02%).

For the non-pelagicfishes, the most abundant fishes in neutral are *Saurida elongata* (30.28%), *Leiognathus* spp. (29.89%) and *Saurida wanieso* (10.64%). In El Niño condition, *Saurida elongata* (44.54%) and *Saurida wanieso* (41.27%) were the most significant species. However, the percentages of la Niña condition were more evenly. Many species only significant in La Niña, for instance *Engyprosopon multisquama* (1.29%), *Gerres abbreviatus* (1.45%), *Harpadon nehereus* (2.75%) and *Lestrolepis japonica* (3.23%).

3.2-3 Southwestern Taiwan

3.2-3-1 Anchovy

The major anchovy in SW waters were composed of Buccaneer and shorthead anchovies almost without a share of Japanese anchovy (Fig. 8). In neutral condition, shorthead anchovy was counted to 79.07%, while Buccaneer anchovy held only 7.95%. Similarly, in El Niño, the proportion of shorthead anchovy got further to 94.14% and that of buccaneer anchovy dropped a bit to 4.26%. Conversely, in La Niña, condition is quite different: the portion of Buccaneer anchovy increased quite big, up to 32.6%, and that of shorthead anchovy decreased to 49.16%.

Except the major anchovy, there are 5 clupids found in neutral condition, four of them were significant; including *Nematalosa japonica* (4.10%), *Sardinops melanostictus* (3.37%), *Sardinella zunas* (3.26%) and *Konosirus punctatus* (2.21%).

In El Niño, only one clupeid could be significantly seen, *Nematalosa japonica* (1.20%). In La Niña, 4 of 6 clupids were significantly found, including *Sardinella zunas* (8.17%), *Nematalosa japonica* (3.31%), *Sardinops melanostictus* (2.47%) and *Dussumieria elopsoides* (1.45%).

3.2-3-2 bycatch

The by-caught species of NW waters are tabulated in Table 11 and 12 for pelagic and non-pelagic species respectively. Due to rarity of pelagic species incidentally caught, all by-catch pelagic fishes were calculated more than 1% (level of significant by-catch proportion). There are many economically important species only or predominately occurred in neutral condition; for instance, *Scomber australasicus* (15.52%), *Auxis rochei* (6.90%), *Selar crumenophthalmus* (1.72%), *Decapterus maruadsi* (1.72%) and *Euthynnus pelamis* (1.72%).

For non-pelagic fishes, the top 5 species or group in neutral condition were *Leiognathus* spp. (41.56%), *Leiognathus nuchalis* (27.60%), *Harpadon nehereus* (8.44%), *Nemipterus bathybus* (2.44%) and *Acanthopagrus latus* (2.11%). In El Niño condition, those commonly found were *Leiognathus* spp. (27.96%), *Leiognathus nuchalis* (17.02%), *Leiognathus lineolatus* (12.77%), *Leiognathus lineolatus* (6.69%)

and *Archamia goni* (6.99%). In La Niña condition, *Harpadon nehereus* counted 45.08% taking the first place, and followed by *Secutor ruconius* (17.01%), *Lestrolepis japonica* (14.55%), *Saurida elongate* (6.97%) and *Archamia goni* (4.92%).

3.2-4 Areal association

Within each climatic condition, the degree of association between areal species compositions was assessed by Spearman's rank correlation. In neutral condition, significant association between target-species' assemblages of NE and SW was confirmed statistically. No any pair of comparisons between by-catch pelagic species was found with significant association. Significant associations were found in NE-NW and NE-SW as comparisons were made based on non-pelagic species.

Similarly, the result under El Niño condition indicated that only one significant positive correlation in NE-NW for target species (Table 14). All other pair-comparisons exhibited no significant association. In the analyses of SW samples, two significant correlations are found; one in NW-SW for target species, and the other NE-SW for the by-catch non-pelagic species (Table 15).

3.2-5 Similarity between area-climatic conditions

The similarity of species compositions is visualized by the dendrogram (Fig. 9), resulted from a cluster analysis based on assemblages of target species. The cluster analysis based on Euclidian distances indicated that the closeness was found in SW waters where the neutral and El Niño assemblages were quite similar. The next joined group was NW and SW during La Niña period. By and large, all NW and SW assemblages were clustered together at moderate similarity levels, however NE assemblages were relatively unrelated.

For assemblages formed by by-catch pelagic species, cluster analysis turned out a disproportional tree shape (Fig. 10); with SW-La Niña, NW-El Niño, NE-La Niña and NE-neutral formed immediate group, and subsequently joined by NE-El Niño and SW El Niño. The rest categories were from somewhat singular assemblages.

The results of cluster analysis based on by-catch non-pelagic fishes were shown in Fig. 11. One group formed by SW-neutral and SW-El Niño exhibited a very-closed similarity. Apart from this group, all other groups were rather remote, indicating a contrasting assemblage composition.

3.2-6 Diversity and evenness

The species diversity of climate-categorized assemblages are shown in Table 16.

For target species, it apparently that NW had the highest amount of anchovy-and-herring’s diversity (0.613 ~ 0.852), followed by NE (0.397 ~ 0.455) and SW (0.117 ~ 0.571). Similar patterns were also found with By-catch pelagic fish and By-catch non-pelagic fish.

4. Discussion

4.1 Characteristics of meteorological conditions

4.1-1 Neutral

The term neutral should describe a condition that a situated in between two extremes in common sense. However, the water temperatures of NW and SW had experienced lowest values in neutral area, this may refer to that neutral condition is not actually a “neutral” condition in the areal meteorological situations (Table 2). Similar situation was found with the pattern of rainfall. In NW and SW area, neutral condition had the fewest rainfalls in spring (Table 3), rendering a cool-and-dry spring during neutral “years”.

A typical pattern was found in the NE waters, with the levels of rainfalls and water temperature all sat in the middle of three conditions. This may reflect that for the meteorological factors, the neutral condition is a really common average in the West Pacific proper (contrasting to its marginal seas). The aberrant patterns that happened in the area close to the marginal seas may have different driving forces or the pattern may have having modified due to time-lag effects.

4.1-2 El Niño

In the El Niño condition of 2010's spring, I found that the Kuroshio proper waters exhibited a cooler temperature before April but got warmer in May (Fig. 4). The warm Kuroshio waters in May may become the heat source in the western North Pacific. The onset of Southwestern monsoon is generally in May, thus the SW wind might have blown the warmer water northward, in which the SST around Taiwan (especially southern area) were first found getting warmer after May. This proposal explain that the water temperature in NE it was significant increased due directly to the Kuroshio, that of SW was secondarily related to the Kuroshio, and water temperature in NW was less influence by the Kuroshio. The patterns of water temperature strongly suggested that the Kuroshio it had its the most effect in NE waters when El Niño takes place, the effect in other two waters were minor or even insignificant.

Increases of rainfalls in El Niño condition was found in the SW waters (Table 3), while this pattern were not observable in the NE and NW waters. Jiang *et al.* (2003) suggested the heavy spring rain events in Taiwan during ENSO year was related to the anticyclones formed on Philippine Sea. In SW, experience says a common dry spring season, and thus the raised rainfalls estimated in this study might fit to the model that ENSO signals the Philippine Sea to result in the SW's increased rainfall.

4.1-3 La Niña

The water temperature in the Kuroshio proper showed apparent higher temperature with extended warm water ranges reaching almost to the southern Japan in La Niña condition, and the boundary of the flow path was distinctively warm in northeast Taiwan. This may suggest that the Kuroshio is powered by warmer and larger volume in its low latitude origination. Water temperature measurement in the SW waters also reflected similar conditions, that significant differences to the neutral and El Niño were obvious (Table 2). I also found significant water temperature differences found between El Niño and La Niña in NE area, but the difference of La Niña and neutral area were insignificant.

Overall, I see that El Niño event increases NE water temperature, and conversely La Niña event increases SW water temperature. Since SW waters is not connected to the Pacific Kuroshio, the degree of water temperature shifting may be influenced via the strength of Kuroshio branch.

4.2 Patterns of larval fish composition

4.2-1 Variation of Japanese anchovy

In early researches back to 1990's, we can see substantial amounts of Japanese anchovy occurred in southwestern area (Chiu, 1997), however, the appearance of Japanese anchovy is quite unlikely in southwestern area no matter what meteorological conditions. Unpublished data provided by Lee (2001) suggested the absence of Japanese anchovy in the SW waters may be a consequence of global warming. During the reign of warm-regime, the southern limit of Japanese anchovy spawning area may move north to fit its cold-water life. In the Taiwan Strait, the Chang-Yun Ridge might be an insurmountable barrier for south-bound spawner. Regime shift may also affect the recruitment of the NE waters, in which shift also resulted in the decreased abundance of Japanese anchovy. However, taking three major anchovy species relatively, regime shift did not leave finger-print effectively in my dataset, i.e., Japanese still reigned the NE local assemblages during El Niño and La Niña periods (Fig. 6). It would be intriguing for further studies to realize that the appearing / disappearing of Japanese anchovy is coupled to 3-5-years (ENSO) or 10-20-years (regime shift) cycle's events.

In NW waters, higher proportion of Japanese anchovy was observed in El Niño, and low in the La Niña (Fig. 7). While Japanese anchovy was abundantly found in both El Niño and La Niña conditions. Chen *et al.* (2010) reported that the stocks in the NW and NE belonged to different spawning groups; and this implied different migration routes. The changing of Kuroshio and northeastern monsoon may influence the Japanese in the two waters at different ways. The highest proportion of Japanese anchovy in NW during El Niño might relate to China Coastal Current via remote linkage of the El Niño. Since my larval samples were taken in spring, their abundance effects were apparently paralleled to progenitor's migration strength. On the other hand, the changing of Kuroshio may play a more direct role. We can see that the Kuroshio was more stronger in 2008 when La Niña took place, and the Kuroshio brought more southern species to the NW, ensuing a dilution effect for Japanese anchovy in the SW assemblages.

4.2-2 Variation of the two southern species

The pattern of two southern species is appetent in SW area: *Enc. heteroloba* dominates and *Enc. punctifer* increases when La Niña takes place, with Kuroshio front warmer. Similar pattern is found in NE area if we only focus on the two southern species. However, the situation is quite different in NW area, where is most distant to the origin of Kuroshio. Comparing to the other two areas, NW station is less affected by Kuroshio, and this may be the reason why the pattern is not similar to NE and SW area. Hsieh *et al*. (2010) suggest that the water around Taiwan can be group as KC-associate and South China Sea-associate; this opinion can support the difference of NW area with other two areas in my study.

Overall, for the result of two southern species' proportion in this study, the abundance variation of *Enc. punctifer* is highly relate with ENSO events due to the effects on Kuroshio. This situation happens when we only focus on the two southern species. If we consider all target species, the pattern between the two southern species is different. For instance, in NE area the pattern is not clear if we consider all major anchovies. It seems that the two species can be seemed as one in north areas (for in SW area, northern species (Japanese anchovy) seldom appears).

4.2-3 Variation of the By-catch species

Elopid and scomberid species are frequently observed by-catch pelagic fishes, with variable abundance in areas and meteorological conditions. For instance, the relative abundance of *Elops hawaiensis* in NE area exhibited highest in neutral, and followed by El Niño and La Niña. However, the pattern reversed in NW and SW waters, where the lowest abundance was found in neutral condition. Carangid fishes, like *Selar crumenphthalmus*, in NE showed low relative abundance in neutral condition, but in NW and SW waters their relative abundance went highest in the same condition. These mosaic situations may indicate that the effects from ENSO events may not be universal but depends on complexity of local environment.

The responses of non-pelagic fishes to the ENSO shift were found less significant as compared to the other two categories (Table 6, 9 & 12). However, Gaymer *et al*. (2010) recognized significant differences for benthic creatures between neutral and La Niña conditions in northern Chile. Geographic location is the first point to explain the different outcomes; because Taiwanese waters are all far more removed from the warm pool, as suggested by Howell and Kobayashi (2006). On the other hand, Chile coast is the location that sends typical El Niño signal globally. Gaymer *et al*. (2010) also suggested that the effect on benthic organisms were unlikely direct, but due to the amplification of predator-prey interplays. However, my study is focused on fish larvae, whose recruitments can be more directly and promptly response to environmental changes without amplifying effects. Foggy results in corresponding to the ENSO events might due to analytical artifact. More detailed studies with sophisticated statistical tools to sort out wide-ranged species-specific responses are apparently future works.

4.3 Larval recruitment in ENSO events

During neutral period, the relative abundances of the target species in the NE and

SW waters were correlated positively with statistical significance (Table 13). Taken prevailing water circulation in Taiwan into consideration, we may argue that was influenced by the major current of the Kuroshio and its Branch. When the El Niño taking place, positive correlation is only found between NE and NW, this may indicate that the effect from Kuroshio on the waters in the northern Taiwan declined, and that make the two northern areas of NE and NW became uniformed in environmental conditions. However, in La Niña condition, the positive correlation is found between NW and SW areas. This pattern may in agreement to that the northward flow of Surface South China Sea water reaching to the northern Taiwan Strait, making the SW and NW waters as a communicating unit.

Observing from non-pelagic by-catch species, positive correlations are found between NE and the other waters of NW and SW during neutral and La Niña conditions, indicting a scenario of areal linkage with rather few influenced by meteorological changes (Table 13 & 15). Larvae of non-pelagic species are born with limited dispersal abilities, and also larvae may manipulate their air bladder so that they are somewhat able to adjust their gravity to retain their vertical position during tidal and current reverses. Shifting on food-chain relationship driven by meteorological change might secondarily affect non-pelagic species composition, however most local non-pelagic species are sedentary with little consequence to the waters at upper levels.

In evaluating similarity among categories, clustering analysis revealed that spatial factor generally explained the most information upon variations of species composition, indicating a fixed range effect. For instance in the NE waters, using neutral as baseline, we found that the compositions in El Niño and La Niña still resemblance together higher than any other two groups (Fig. 9). The only exception with less geographic factors is found in La Niña condition that NW and SW went higher similarity. Fixed range effect mentions a local assemblage may modify their composition (structure) annually due to climatic shift, but the magnitude is limited not being able to change from A site to B site. However, for non-target species, area and climatic condition played almost equal amount of influences on the assemblage's composition change (Fig. 10 & 11). Moreover, the clusters of non-target species, both pelagic and non-pelagic, qualified categorical heteroscedasticity, in which high dissimilarity values exhibited singular tree topology, and neither geographic factor nor climatic condition could be a comprehensive reason for clusters.

In conclusion, areal larval fish assemblages in the waters of the NE, NW and SW Taiwan are quasi-stationary with areal distinctiveness. However, meteorological changes shaped climatic conditions, such as the El Niño and La Niña events also impacted on assemblage structure, as revealed by catch compositions of Taiwanese larval fisheries. Generally, we may consider the El Niño and La Niña are two extreme phases of water anomaly. However, the simplicity of reversed phases did not observed in examined species compositions. For instance, strong year classes of Japanese anchovy are recruiting to the NE waters when the El Niño and La Niña are taking place but not in neutral condition. During neutral condition, the number of species is fairly high, however the number is reduced due to extreme climatic conditions of the El Niño and La Niña.

5. References

Blanco JA, Barandica JCN, Viloria EA (2007) ENSO and the rise and fall of a tilapia fishery in northern Colombia. Fish Res 88: 100-108.

Chao SY, Shaw PT, Wu SY (1996) El Niño modulation of the South China Sea circulation. Prog Oceanog 38: 51-93.

Chen CS, Tzeng CH, Chiu TS (2010) Morphological and molecular analyses reveal separations among spatiotemporal populations of anchovy (*Engraulis japonicus*) in the Southern East China Sea. Zool Stud 49: 270-282.

Chen CS, Chiu TS (2003) Early life history traits of Japanese anchovy in the northeastern waters of Taiwan, with reference to larval transport. Zool Stud 42: 248-257.

Chiu TS, Chen CS (2001) Growth and temporal variation of two Japanese anchovy cohorts during their recruitment to East China Sea. Fish Res 53: 1-15.

Chiu TS, Young SS, Chen CS (1997) Monthly variation of larval anchovy fishery in I-lan Bay NE Taiwan with an evaluation for optimal fishing season. J Fish Soc Taiwan 24: 273-282.

Gaymer CF, Palma AT, Vega JMA, Monaco CJ, Henriquez LA (2010) Effects of La Niña on recruitment and abundance of juveniles and adults of benthic community-structuring sepecies in northern Chile. Mar Freshwater Res 61: 1185-1196

He Y, White WB (1987) Interannual variability of Kuroshio frontal structure along its western boundary in north Pacific ocean associated with 1982 ENSO event. J Phys Oceanogr 17: 1494-1506.

Howell EA, Kobayashi DR (2006) El Niño effects in Palmyra Atoll region oceanographic changes and bigeye tuna catch rate variability. Fish Oceanogr 15:

477-489.

Hsieh CH, Chen CS, Chiu TS, Lee KT, Shien FJ, *et al.* (2009) Time series analyses reveal transient relationships between abundance of larval anchovy and environmental variables in the coastal waters southwest of Taiwan. Fish Oceanogr 18: 102-177.

Hsieh HY, Lo WT, Liu DC, Su WC (2010) Influence of hydrographic features on larval fish distribution during south-westerly monsoon in waters of Taiwan, west North Pacific Ocean. J Fish Biol 76: 2521-2539.

Hsin YC, Qu T, Wu CR (2010) Intra-seasonal variation of the Kuroshio southeast of Taiwan and its possible forcing mechanism. Ocean Dynam 60: 1293–1306

Hu J, Kawamura H, Hong H, Qi Y (2000) A review on currents in South China Sea: Seasonal curculation, South China Sea Warm Current and Kuroshio intrusion. J Oceangr 56: 607-624.

Huang CC, Tzeng WN (1985) Preliminary survey on larval fishes of Yen-Liao bay, northeastern Taiwan. Bull Inst Zool 24: 147-154

Jan S, Chern CS, Wang J (1994) A numerical study on currents in Taiwan Strait during Summertime. La mer 32: 225-234.

Jan S, Chern CS, Wang J (1998) A numerical study on currents in Taiwan Strait during Winter. TAO 9: 615-632.

Jan S, Sheu DD, Kuo HM (2006) Water mass and throughflow transport variability in the Taiwan Strait. J Geophys Res 111: C12012, doi:10.1029/2006JC003656.

Jan S, Wang J, Chern CS, Chao SY (2002) Seasonal variation of circulation in Taiwan Strait. J Marine Syst 35: 249-268.

Jiang Z, Chen TJ, Wu MC (2003) Large-scale circulation patterns associated with heavy spring rain events over Taiwan in strong ENSO and Non-ENSO years. Mon Wea Rev 131: 1769-1782.

Kim H, Kimura S, Shinoda A, Kitagawa T, Sasai Y, *et al*. (2007) Effect of El Niño on migration and larval transport of Japanese Eel(*Anguilla japonica*) J Marine Sci 64: 1387-1395.

Kuo NJ, Ho CR (2004) ENSO effect on the sea surface wind and sea surface temperature in the Taiwan Strait. Geophys Res Lett 31: L13309, doi:10.1029/2004GL020303, 2004.

Lee MA, Lee KT, Ou HC (1990) The larval anchovy fishing ground formation in relation to osmotic presure changes of the coastal waters along southern Taiwan. J Fish Soc Taiwan 17: 233-245.

Ropellewski CF, Jones PD (1987) An extension of Tahiti-Darwin southern oscillation index. Mon Wea Rev 115: 2161-2165. 32: L11601

Shang S, Zhang C, Hong H, Liu Q, Wong GTF, *et al*. (2005) Hydrographic and biological changes in the Taiwan Strait during the 1997–1998 El Niño winter. Geophys Res Lett 32: L11601, doi:10.1029/2005GL022578.

Trenberth KE (1983) Signal versus noise in the southern oscillation. Mon Wea Rev 112: 326-332

Tsai CF, Chen PY, Chen CP, Lee MA, Shiah GY, *et al*. (1997) Fluctuation in abundance of larval anchovy and environmental conditions in coastal waters off south-western Taiwan as associated with the El Niño-Southern Oscillation. Fish Oceanogr 6: 238-249.

Vieira JP, Garcia AM, Grimm AM (2008) Evidences of El Niño effects on the mullet fishery of the Patos Lagoon estuary. Braz J Biol 51: 433-440.

Wang J, Chern CS (1988) On the Kuroshio branch in Taiwan Strait during wintertime. Prog Oceanogr 21: 469-491.

Wang YT, Tzeng WN (1999) Differences in growth rates among cohorts of *Encrasicholina punctifer* and *Engraulis japonicus* larvae in the coastal waters off

Tanshui River Estuary, Taiwan, as indicated by otolith microstructure analysis. J Fish Biol 54: 1002-1016.

Wu CR, Chao SY, Hsu C (2007) Transient, seasonal and interannual variability of the Taiwan Strait current. J Oceanogr 63: 821-833.

Young SS, Chen CC, Chiu TS (1992) Resource characteristics of young herring-like fish in the I-lan Bay area-Fishing season, major species and size variation. J Fish Soc Taiwan 19: 273-281.

Table 1. Basic data for larval fish assemblage analyses - sampling dates, localities, number of specimen used categorized by climatic conditions

Climatic conditions	Waters (localities)	Sampling date	Number of specimens used
La Niña	NE (SuAo)	25 Apr., 6 & 20 May, 2008	12451
	NW (PaLi)	28 Mar., 22 May, 2008	7720
	SW (FongLiao)	11 Apr., 13 & 18 May, 2008	8701
neutral	NE (SuAo)	6, 16 & 30 May, 2009	15148
	NW (PaLi)	27 Mar., 6 Apr. , 28 May , 2009	15181
	SW (FongLiao)	17 & 27 Mar., 23 Apr., 2009	11276
El Niño	NE (SuAo)	25 & 27 Apr., 26 May, 2010	12135
	NW (PaLi)	29 Mar., 6 & 28 Apr., 2010	4991
	SW (FongLiao)	8 Mar.,6 & 18 Apr., 2010	5123
Total			

Table 2. The average and standard deviation (S.D.) of water temperature and areal differences among climatic conditions in NE, NW and SW waters

Waters / Climate patterns	Mean ± S.D.	Neutral, 2009	El Niño, 2010	La Niña, 2008
NE waters				
Neutral	22.47 ± 1.13 (70)	-	0.000	0.196
El Niño	23.05 ± 1.16 (70)	0.58*	-	0.013
La Niña	22.62 ± 0.93 (70)	0.15	-0.43*	-
NW waters				
Neutral	20.08 ± 1.70 (70)	-	0.967	0.137
El Niño	20.48 ± 1.53 (70)	0.40	-	0.967
La Niña	20.46 ± 3.73 (70)	0.38	-0.02	-
SW waters				
Neutral	26.71 ± 0.80 (70)	-	0.098	0.000
El Niño	26.92 ± 0.72 (70)	0.21	-	0.014
La Niña	27.25 ± 1.26 (70)	0.54*	0.33*	-

*, $p < 0.05$ as revealed by Student’s t-test, lower triangle denotes differences, upper triangle p-values.

Table 3. Average of rainfalls (in mm) and differences between climatic conditions in NE, NW and SW areas

Area / Climatic condition	Mean (months)	Neutral, 2009	El Niño, 2010	La Niña, 2008
NE				
Neutral	130.1 (3)	-		
El Niño	98.9 (3)	-31.2	-	
La Niña	165.0 (3)	34.9	66.1	-
NW				
Neutral	94.0 (3)	-		
El Niño	135.3 (3)	41.3	-	
La Niña	172.9 (3)	78.9	37.6	-
SW				
Neutral	38.9 (3)	-		
El Niño	79.0 (3)	40.1	-	
La Niña	51.4 (3)	12.4	27.6	-

Table 4. Target species composition of larval fisheries in the NE waters of Taiwan categorized by 3 climatic patterns

Family	Species	Relative abundance		
		Neutral	El Niño	La Niña
Clupeidae				
	Dussumieria elopsoides	26 (0.27%)	11 (0.11%)	2 (0.03%)
	Sardinella zunasi	176 (1.83%)	744 (7.82%)	51 (0.68%)
	Sardinops melanostictus	165 (1.72%)	291 (3.06%)	10 (0.14%)
	Konosirus punctatus	42 (0.43%)	100 (1.05%)	20 (0.27%)
	Nematalosa japonica	77 (0.8%)	309 (3.25%)	64 (0.85%)
Engraulidae				
	Thryssa dussumieri	20 (0.21%)	14 (0.15%)	15 (0.2%)
	Thryssa chefuensis	69 (0.71%)	188 (1.97%)	18 (0.23%)
	Stolephorus insularis	-	-	1 (0.01%)
	Engraulis japonicus	679 (7.06%)	5023 (52.78%)	4529 (59.78%)
	Encrasicholina heteroloba	2361 (24.55%)	2019 (21.21%)	345 (4.56%)
	Encrasicholina punctifer	6001 (62.41%)	818 (8.6%)	2519 (33.26%)
Total		14566	11549	9433

Table 5. By-catch pelagic species composition of larval fisheries in NE waters of Taiwan categorized by 3 climatic patterns

Family	Species	Relative abundance		
		Neutral	El Niño	LaNiña
Carangidae				
	Selar crumenophthalmus	-	-	1 (4.76%)
Elopidae				
	Megalops cyprinoides	1 (2.22%)	-	1 (4.76%)
	Elops hawaiensis	28 (95.56%)	21 (65.79%)	4 (23.81%)
Mugilidae				
	Liza affinis	-	1 (2.63%)	2 (9.52%)
	Liza macrolepis	-	6 (18.42%)	-
	Valamugil seheli	1 (2.22%)	-	-
	Oedalechilus labiosus	-	-	1 (4.76%)
Myctophidae				
	Bolinichthys pyrsobolus	-	-	1 (4.76%)
Scombridae				
	Scomber australasicus	-	4 (13.16%)	6 (38.1%)
	Scomber japonicus	-	-	2 (9.52%)
Total		46	38	24

Table 6. By-catch non-pelagic species composition of larval fisheries in the NE waters of Taiwan categorized by 3 climatic patterns

Family	Species	Relative abundance		
		neutral	El Niño	LaNiña
Albulidae				
	Albula vulpes	1 (0.19%)	-	-
Ammodytidae				
	Embolichthys mitsukurii	-	-	2 (0.54%)
Apogonidae				
	Archamia goni	1 (0.19%)	6 (1.3%)	2 (0.54%)
	Apogon endekataenia	-	2 (0.37%)	-
	Apogon notatus	-	2 (0.37%)	2 (0.54%)
Blenniidae				
	Scartella cristata	2 (0.56%)	1 (0.19%)	-
Centropomidae				
	Ambassis urotaenia	1 (0.19%)	-	-
	Psenopsis anomala	-	-	1 (0.27%)
Gerreidae				
	Gerres abbreviatus	3 (0.93%)	-	1 (0.27%)
	Gerres filamentosus	3 (0.75%)	-	1 (0.27%)
	Gerres oyena	1 (0.19%)	-	-
Gobiidae				
	Amblychaeturichthys hexanema	-	2 (0.37%)	-

	Boleophthalmus pectinirostris	-	1 (0.19%)	1 (0.27%)
	Rhinogobius flumineus	5 (1.49%)	-	-
	Rhinogobius brunneus	30 (8.58%)	47 (10.58%)	-
	Cryptocentrus filifer	1 (0.19%)	-	-
	unidentified	2 (0.56%)	86 (19.29%)	2 (0.81%)
	Sagamia geneionema	1 (0.19%)	-	2 (0.81%)
	Oxyurichthys sp.	1 (0.37%)	-	1 (0.27%)
	Luciogobius sp.	-	1 (0.19%)	-
	Parachaeturichthys polynema	1 (0.37%)	-	-
	Sicyopterus micrurus	3 (0.75%)	-	-
Haemulidae				
	Parapristipoma trilineatum	-	2 (0.56%)	-
	Pomadasys maculatus	1 (0.19%)	-	2 (0.54%)
	Pomadasys quadrilineatus	-	-	1 (0.27%)
Harpadontidae				
	Harpadon nehereus	78 (22.01%)	-	27 (9.14%)
Labridae				
	Unidentified	1 (0.19%)	-	-
Labrisomidae				
	Neoclinus sp.	-	1 (0.19%)	-
Leiognathidae				
	Gazza minuta	7 (1.87%)	1 (0.19%)	-
	Secutor ruconius	9 (2.43%)	9 (2.04%)	10 (3.23%)

	Leiognathus lineolatus	68 (19.22%)	2 (0.37%)	12 (4.03%)
	Leiognathus nuchalis	15 (4.29%)	73 (16.51%)	3 (1.08%)
	Leiognathus elongatus	-	-	24 (8.06%)
	Leiognathus spp.	90 (25.56%)	143 (32.28%)	57 (19.09%)
Nemipteridae				
	Nemipterus bathybius	-	1 (0.19%)	3 (1.08%)
Ophichthidae				
	Muraenichthys sp.	-	-	1 (0.27%)
Percichthyidae				
	Lateolabrax japonicus	-	27 (6.12%)	-
Pomacentridae				
	Chromis notatus	-	2 (0.37%)	80 (26.61%)
	Chromis sp.	-	-	1 (0.27%)
	Pomacentrus coelestis	-	-	1 (0.27%)
Sciaenidae				
	Nibea sp.	-	-	1 (0.27%)
Scorpaenidae				
	Unidentified	-	-	1 (0.27%)
Sillaginidae				
	Sillago japonica	14 (3.92%)	2 (0.37%)	2 (0.81%)
	Sillago sihama	5 (1.49%)	2 (0.37%)	2 (0.54%)
	Sillago maculata	-	-	1 (0.27%)
Synodontidae				

	Synodus fuscus	-	-	1 (0.27%)
	Trachinocephalus myops	1 (0.19%)	-	3 (1.08%)
	Saurida elongata	7 (1.87%)	6 (1.3%)	23 (7.8%)
	Saurida wanieso	-	-	21 (6.99%)
Teraponidae				
	Pelates quadrilineatus	2 (0.56%)	-	2 (0.54%)
	Rhyncopelates oxyrhynchus	1 (0.19%)	-	-
Tripterygiidae				
	Enneapterygius etheostomus	1 (0.19%)	7 (1.48%)	7 (2.42%)
	Tripterygion inclinatus	1 (0.37%)	21 (4.82%)	1 (0.27%)
Total		536	539	372

Table 7. Target species composition of larval fisheries in the NW waters of Taiwan categorized by 3 climatic patterns

Family	Species	Relative abundance		
		neutral	El Niño	La Niña
Clupidae				
	Etrumeus teres	2 (0.02%)	10 (0.11%)	-
	Dussumieria elopsoides	545 (6.05%)	212 (2.35%)	246 (2.71%)
	Sardinops melanostictus	832 (9.24%)	1835 (20.31%)	130 (1.43%)
	Konosirus punctatus	152 (1.69%)	303 (3.35%)	73 (0.8%)
	Nematalosa japonica	240 (2.67%)	270 (2.99%)	161 (1.77%)
	Sardinella zunasi	1345 (14.94%)	1395 (15.43%)	1398 (15.41%)
Engraulidae				
	Stolephorus insularis	46 (0.51%)	2 (0.02%)	4 (0.04%)
	Stolephorus indicus	1 (0.01%)	-	-
	Thryssa dussumieri	271 (3.01%)	333 (3.68%)	468 (5.16%)
	Thryssa chefuensis	1092 (12.12%)	118 (1.31%)	3 (0.03%)
	Engraulis japonicus	120 (1.33%)	1503 (16.63%)	23 (0.26%)
	Encrasicholina heteroloba	2634 (29.25%)	337 (3.73%)	4554 (50.22%)
	Encrasicholina punctifer	1725 (19.16%)	2719 (30.09%)	2010 (22.17%)
Total		13669	4510	7001

Table 8. By-catch pelagic species composition of larval fisheries in NW waters of Taiwan categorized by 3 climatic patterns

Family	Species	Relative abundance		
		neutral	El Niño	La Niña
Bregmacerotidae				
	Bregmaceros nectabanus	2 (1.35%)	-	-
Carangidae				
	Atule mate	5 (3.14%)	-	4 (3.06%)
	Decapterus macarellus	4 (2.69%)	-	-
	Decapterus macrosoma	7 (4.48%)	-	-
	Decapterus russellii	3 (2.24%)	-	1 (1.02%)
	Decapterus maruadsi	53 (36.32%)	-	1 (1.02%)
	Selar crumenophthalmus	1 (0.45%)	-	-
Elopidae				
	Megalops cyprinoides	-	-	10 (8.16%)
	Elops hawaiensis	1 (0.9%)	20 (43.48%)	51 (39.8%)
Gonostomatidae				
	Vinciguerria nimbaria	-	-	3 (2.04%)
Mugilidae				
	Liza macrolepis	-	-	1 (1.02%)
Myctophidae				
	Benthosema pterotum	48 (32.74%)	6 (13.04%)	35 (27.55%)
	Diaphus pacificus	1 (0.9%)	-	-

	Idiolychnus urolampus	1 (0.45%)	-	-
	Lampanyctus parvicauda	1 (0.9%)	-	-
	Lampanyctus crocodilus	-	-	1 (1.02%)
	Lobianchia gemellarii	-	-	1 (1.02%)
	Myctophum obtusirostre	1 (0.45%)	-	-
	Unidentified	-	-	1 (1.02%)
Percichthyidae				
	Lateolabrax japonicus	-	-	1 (1.02%)
Scombridae				
	Scomber japonicus	1 (0.9%)	2 (4.35%)	3 (2.04%)
	Scomber australasicus	1 (0.45%)	-	-
	Auxis thazard	-	-	1 (1.02%)
	Auxis rochei	-	-	1 (1.02%)
Trichiuridae				
	Trichiurus lepturus	17 (11.66%)	18 (39.13%)	10 (8.16%)
Total		223	23	98

Table 9. By-catch non-pelagic species composition of larval fisheries in the NW waters of Taiwan categorized by 3 climatic patterns.

Family	*Species*	Relative abundance		
		neutral	El Niño	La Niña
Apogonidae				
	Archamia goni	1 (0.08%)	-	-
	Apogon kiensis	1 (0.08%)	-	-
	Apogon notatus	-	-	1 (0.16%)
Ammodytidae				
	Embolichthys mitsukurii	-	-	1 (0.16%)
Blenniidae				
	Scartella cristata	1 (0.16%)	2 (0.22%)	3 (0.32%)
	Omobranchus elegans	-	-	1 (0.16%)
Bothidae				
	Engyprosopon multisquama	1 (0.16%)	-	10 (1.29%)
	Engyprosopon grandisquama	1 (0.08%)	-	-
Cynoglossidae				
	Cynoglossus joyneri	1 (0.16%)	-	-
Gerreidae				
	Gerres abbreviatus	2 (0.23%)	-	12 (1.45%)
	Gerres filamentosus	9 (1.01%)	-	8 (0.97%)
	Gerres oyena	3 (0.39%)	-	4 (0.48%)
Gobiidae				

	Amblychaeturichthys hexanema	1 (0.16%)	-	-
	Apocryptodon madurensis	-	-	4 (0.48%)
	Boleophthalmus pectinirostris	3 (0.39%)	-	9 (1.13%)
	Cryptocentrus filifer	1 (0.16%)	-	1 (0.16%)
	Ctenotrypauchen microcephalus	1 (0.08%)	-	3 (0.32%)
	Oxyurichthys sp.	-	-	1 (0.16%)
	Parachaeturichthys polynema	1 (0.16%)	-	8 (0.97%)
	Rhinogobius brunneus	-	-	1 (0.16%)
	Sagamia geneionema	1 (0.16%)	-	-
	Taenioides cirratus	-	-	1 (0.16%)
	Tridentiger trigonocephalus	-	2 (0.22%)	-
	Unidentified	11 (1.32%)	-	6 (0.81%)
Haemulidae				
	Hapalogenys nitens	1 (0.08%)	-	-
	Hapalogenys mucronatus	-	-	1 (0.16%)
	Pomadasys maculatus	40 (4.74%)	-	5 (0.65%)
Harpadontidae				
	Harpadon nehereus	2 (0.23%)	18 (1.97%)	22 (2.75%)
Labridae				
	Halichoeres tenuispinnis	1 (0.16%)	12 (1.31%)	8 (0.97%)
	Choerodon azurio	-	2 (0.22%)	-
	Halichoeres poecilopterus	-	-	1 (0.16%)
Leiognathidae				

	Gazza minuta	9 (1.09%)	-	118 (14.7%)
	Secutor insidiator	2 (0.23%)	-	-
	Secutor ruconius	80 (9.47%)	6 (0.66%)	39 (4.85%)
	Leiognathus lineolatus	9 (1.09%)	-	-
	Leiognathus nuchalis	3 (0.31%)	2 (0.22%)	1 (0.16%)
	Leiognathus elongatus	-	-	4 (0.48%)
	Leiognathus bindus	-	-	4 (0.48%)
	Leiognathus spp.	254 (29.89%)	48 (5.24%)	9 (1.13%)
	Unidentified	-	-	3 (0.32%)
Lutjanidae				
	Lutjanus sp.	1 (0.08%)	-	-
Monacanthidae				
	Rudarius ercodes	1 (0.08%)	-	-
Mugiloididae				
	Parapercis snyderi	-	-	1 (0.16%)
Nemipteridae				
	Scolopsis sp.	-	-	3 (0.32%)
Ophichthidae				
	Muraenichthys sp.	1 (0.08%)	-	-
	Ophichthus sp.	-	-	1 (0.16%)
Paralepididae				
	Lestrolepis japonica	1 (0.16%)	6 (0.66%)	26 (3.23%)
	Lestrolepis intermedia	-	8 (0.87%)	19 (2.42%)

	Lestidium prolixum	-	2 (0.22%)	3 (0.32%)
Paralichthyidae				
	Pseudorhombus arsius	1 (0.08%)	-	-
	Pseudorhombus pentophthalmus	1 (0.08%)	-	-
Percophidae				
	Unidentified	3 (0.39%)	-	1 (0.16%)
Platycephalidae				
	Platycephalus indicus	5 (0.62%)	-	6 (0.81%)
Pomacentridae				
	Chromis notatus	-	-	1 (0.16%)
Sciaenidae				
	Nibea japonica	1 (0.08%)	-	1 (0.16%)
	Nibea mitsukurii	3 (0.39%)	-	5 (0.65%)
	Larimichthys crocea	-	-	1 (0.16%)
	Johnius sp.	-	-	1 (0.16%)
Serranidae				
	Selenanthias analis	1 (0.08%)	-	-
	Epinephelus akaara	-	-	1 (0.16%)
	Unidentified.	-	-	3 (0.32%)
Siganidae				
	Siganus fuscescens	1 (0.16%)	-	18 (2.26%)
Sillaginidae				
	Sillago japonica	20 (2.41%)	6 (0.66%)	14 (1.78%)

	Sillago maculata	3 (0.39%)	-	9 (1.13%)
	Sillago sihama	8 (0.93%)	6 (0.66%)	16 (1.94%)
Soleidae				
	Heteromycteris japonica	1 (0.08%)	-	-
Sparidae				
	Pagrus major	-	-	1 (0.16%)
	Acanthopagrus schlegeli	2 (0.23%)	4 (0.44%)	27 (3.39%)
	Acanthopagrus latus	-	2 (0.22%)	4 (0.48%)
Synodontidae				
	Synodus fuscus	-	2 (0.22%)	-
	Saurida wanieso	90 (10.64%)	379 (41.27%)	192 (23.91%)
	Saurida elongata	257 (30.28%)	409 (44.54%)	148 (18.42%)
	Trachinocephalus myops	3 (0.39%)	2 (0.22%)	1 (0.16%)
	Saurida undosquamis	-	-	1 (0.16%)
Teraponidae				
	Terapon jarbua	1 (0.08%)	-	-
	Pelates quadrilineatus	2 (0.23%)	-	4 (0.48%)
Tetraodontidae				
	Takifugu poecilonotus	1 (0.08%)	-	-
	Takifugu radiatus	-	-	1 (0.16%)
Total		1288	458	619

Table. 10. Target species composition of larval fisheries in the SW waters of Taiwan categorized by 3 climatic patterns

Family	*Species*	Relative abundance		
		neutral	El Niño	La Niña
Clupeidae				
	Sardinella zunasi	341 (3.26%)	14 (0.09%)	919 (8.17%)
	Konosirus punctatus	231 (2.21%)	10 (0.06%)	52 (0.46%)
	Sardinops melanostictus	353 (3.37%)	41 (0.26%)	278 (2.47%)
	Nematalosa japonica	429 (4.1%)	191 (1.2%)	372 (3.31%)
	Dussumieria elopsoides	3 (0.03%)	-	163 (1.45%)
	Etrumeus teres	-	-	94 (0.84%)
Engraulidae				
	Encrasicholina punctifer	832 (7.95%)	679 (4.26%)	3667 (32.6%)
	Encrasicholina heteroloba	8272 (79.07%)	15028 (94.14%)	5530 (49.16%)
	Engraulis japonicus	-	-	172 (1.53%)
	Stolephorus indicus	1 (0.01%)	-	-
Total		11797	8178	9788

Table 11. By-catch pelagic species composition of larval fisheries in SW waters of Taiwan categorized by 3 climatic patterns

Family	Species	neutral	El Niño	La Niña
Carangidae				
	Selar crumenophthalmus	1 (1.72%)	-	-
	Decapterus maruadsi	1 (1.72%)	-	-
Caesionidae				
	Caesio caerulaurea	-	4 (33.33%)	-
Elopidae				
	Elops hawaiensis	2 (3.45%)	4 (33.33%)	13 (44%)
	Megalops cyprinoides	-	-	1 (4%)
Myctophidae				
	Benthosema pterotum	13 (25.86%)	-	1 (4%)
	Benthosema fibulatum	1 (1.72%)	-	-
	Ceratoscopelus warmingi	3 (5.17%)	-	-
	Lampanyctus crocodilus	2 (3.45%)	2 (16.67%)	-
	Lampanyctus parvicauda	9 (17.24%)	-	-
	Lampanyctus pusillus	1 (1.72%)	-	-
	Taaningichthys minimus	1 (1.72%)	-	-
	Lobianchia gemellarii	3 (5.17%)	-	-
	Diaphus theta	1 (1.72%)	-	-
	Diaphus pacificus	1 (1.72%)	2 (16.67%)	-
	Lampanyctus ritteri	1 (1.72%)	-	-

	Lampanyctus achirus	1 (1.72%)	-	-
Mugilidae				
	Mugil cephalus	-	-	1 (4%)
	Liza affinis	-	-	1 (4%)
Scombridae				
	Scomber japonicus	-	-	3 (12%)
	Scomber australasicus	8 (15.52%)	-	2 (8%)
	Auxis rochei	4 (6.9%)	-	1 (4%)
	Euthynnus pelamis	1 (1.72%)	-	-
Sphyraenidae				
	Sphyraena barracuda	-	-	1 (4%)
	Sphyraena pinguis	-	-	1 (4%)
Trichiuridae				
	Trichiurus lepturus	-	-	2 (8%)
Total		58	6	25

Table 12. By-catch non-pelagic species composition of larval fisheries in the SW waters of Taiwan categorized by 3 climatic patterns.

Family	Species	Relative abundance		
		neutral	El Niño	La Niña
Apogonidae				
	Archamia goni	4 (0.65%)	45 (6.99%)	28 (4.92%)
	Apogon kiensis	9 (1.62%)	4 (0.61%)	-
	Rhabdamia gracilis	-	-	1 (0.2%)
	Apogon endekataenia	-	-	1 (0.2%)
	Gymnapogon sp.	2 (0.32%)	12 (1.82%)	-
	Apogon sp.	-	10 (1.52%)	-
Blenniidae				
	Scartella cristata	-	4 (0.61%)	-
Bothidae				
	Engyprosopon multisquama	6 (1.14%)	4 (0.61%)	2 (0.41%)
	Psettina gigantea	1 (0.16%)	-	-
	Crossorhombus kobensis	1 (0.16%)	-	-
	Engyprosopon grandisquama	-	2 (0.3%)	-
	Engyprosopon sp.	-	4 (0.61%)	-
Bregmacerotidae				
	Bregmaceros nectabanus	-	-	1 (0.2%)
Gerreidae				
	Gerres abbreviatus	1 (0.16%)	-	-

Gobiidae				
	Acentrogobius pflaumi	-	8 (1.22%)	-
	Cryptocentrus filifer	-	-	1 (0.2%)
	Unidentified.	1 (0.16%)	6 (0.91%)	-
Gonostomatidae				
	Vinciguerria nimbaria	2 (0.32%)	-	-
Harpadontidae				
	Harpadon nehereus	46 (8.44%)	2 (0.3%)	253 (45.08%)
Haemulidae				
	Pomadasys maculatus	1 (0.16%)	12 (1.82%)	-
	Hapalogenys nitens	-	2 (0.3%)	-
Labridae				
	Cheilinus sp.	1 (0.16%)	-	-
	Thalassoma bifasciatum	-	-	1 (0.2%)
Leiognathidae				
	Gazza minuta	6 (1.14%)	14 (2.13%)	-
	Secutor insidiator	4 (0.65%)	21 (3.34%)	-
	Secutor ruconius	9 (1.62%)	43 (6.69%)	95 (17.01%)
	Leiognathus lineolatus	6 (1.14%)	82 (12.77%)	11 (2.05%)
	Leiognathus nuchalis	151 (27.6%)	109 (17.02%)	6 (1.02%)
	Leiognathus spp.	227 (41.56%)	180 (27.96%)	5 (0.82%)
	Leiognathus elongatus	-	2 (0.3%)	-
Lethrinidae				

	Lethrinus nematacanthus	-	2 (0.3%)	-
Lutjanidae				
	Lutjanus bohar	-	-	1 (0.2%)
	Lutjanus argentimaculatus	-	-	2 (0.41%)
	Lutjanus spp.	-	4 (0.61%)	-
Nemipteridae				
	Nemipterus bathybius	13 (2.44%)	8 (1.22%)	-
Paralichthyidae				
	Pseudorhombus arsius	1 (0.16%)	-	-
Paralepididae				
	Lestrolepis intermedia	4 (0.65%)	-	-
	Lestrolepis japonica	-	-	82 (14.55%)
Pomacentridae				
	Chromis notatus	1 (0.16%)	-	-
	Chromis flavomaculata	2 (0.32%)	-	-
	Pomacentrus nagasakiensis	1 (0.16%)	2 (0.3%)	-
	Pomacentrus coelestis	1 (0.16%)	-	-
Platycephalidae				
	Platycephalus indicus	-	-	5 (0.82%)
Siganidae				
	Siganus fuscescens	1 (0.16%)	10 (1.52%)	7 (1.23%)
Sillaginidae				
	Sillago japonica	9 (1.62%)	10 (1.52%)	3 (0.61%)

	Sillago maculata	3 (0.49%)	-	-
	Sillago sihama	1 (0.16%)	-	1 (0.2%)
Serranidae				
	Chelidoperca hirundinacea	1 (0.16%)	-	-
	Plectranthias japonicus	-	-	1 (0.2%)
	Epinephelus moara	-	-	1 (0.2%)
Scorpaenidae				
	Sebastiscus marmoratus	-	-	1 (0.2%)
Sparidae				
	Acanthopagrus latus	12 (2.11%)	-	2 (0.41%)
	Pagrus major	3 (0.49%)	-	-
Sphyraenidae				
	Sphyraena barracuda	-	-	1 (0.2%)
	Sphyraena pinguis	-	-	1 (0.2%)
Synodontidae				
	Saurida wanieso	4 (0.81%)	18 (2.74%)	-
	Saurida elongata	9 (1.62%)	20 (3.04%)	39 (6.97%)
	Trachinocephalus myops	1 (0.16%)	-	-
Teraponidae				
	Pelates quadrilineatus	1 (0.16%)	-	-
	Terapon theraps	-	4 (0.61%)	-
Tetraodontidae				
	Takifugu pardalis	-	2 (0.3%)	-

Tripterygiidae				
	Enneapterygius etheostomus	3 (0.49%)	-	6 (1.02%)
	Tripterygion inclinatus	2 (0.32%)	-	1 (0.2%)
Total		616	329	488

Table. 13. Areal associations tested by Spearman's rank correlation during neutral period.

	NE	NW	SW
Target species			
NE	—		
NW	0.49	—	
SW	0.66*	0.59	—
By-catch pelagic fishes			
	NE	NW	SW
NE	—		
NW	0.01	—	
SW	-0.19	-0.30	—
By-catch non-pelagic fishes			
	NE	NW	SW
NE	—		
NW	0.37*	—	
SW	0.30*	0.16	—

* $P < 0.05$

Table. 14. Areal associations tested by Spearman’s rank correlation during El Niño period.

Target species			
	NE	NW	SW
NE	–		
NW	0.71*	–	
SW	0.58	0.49	–
By-catch pelagic fishes			
	NE	NW	SW
NE	–		
NW	0.24	–	
SW	-0.39	-0.46	–
By-catch non-pelagic fishes			
	NE	NW	SW
NE	–		
NW	0.03	–	
SW	0.16	0.08	–

* - $P < 0.05$

Table. 15. Areal associations tested by Spearman’s rank correlation during La Niña period.

Target species			
	NE	NW	SW
NE	–		
NW	0.37	–	
SW	0.60	0.83*	–
By-catch pelagic fishes			
	NE	NW	SW
NE	–		
NW	0.14	–	
SW	0.22	0.06	–
By-catch non-pelagic fishes			
	NE	NW	SW
NE	–		
NW	0.12	–	
SW	0.22*	0.02	–

* - $P < 0.05$

Table 16. Shannon's diversity of the samples from (a) NE (b) NW (c) SW waters

NE area

	neutral	El Niño	La Niña
Target fish	0.455	0.589	0.397
By-catch pelagic fish	0.451	0.551	0.999
By-catch non-pelagic fish	1.226	1.146	1.233

(b)

NW area

	neutral	El Niño	La Niña
Target fish	0.852	0.818	0.613
By-catch pelagic fish	1.022	0.457	0.721
By-catch non-pelagic fish	1.422	0.942	1.489

(c)

SW area

	neutral	El Niño	La Niña
Target fish	0.361	0.117	0.571
By-catch pelagic fish	0.854	0.301	1.032
By-catch non-pelagic fish	1.286	1.291	1.089

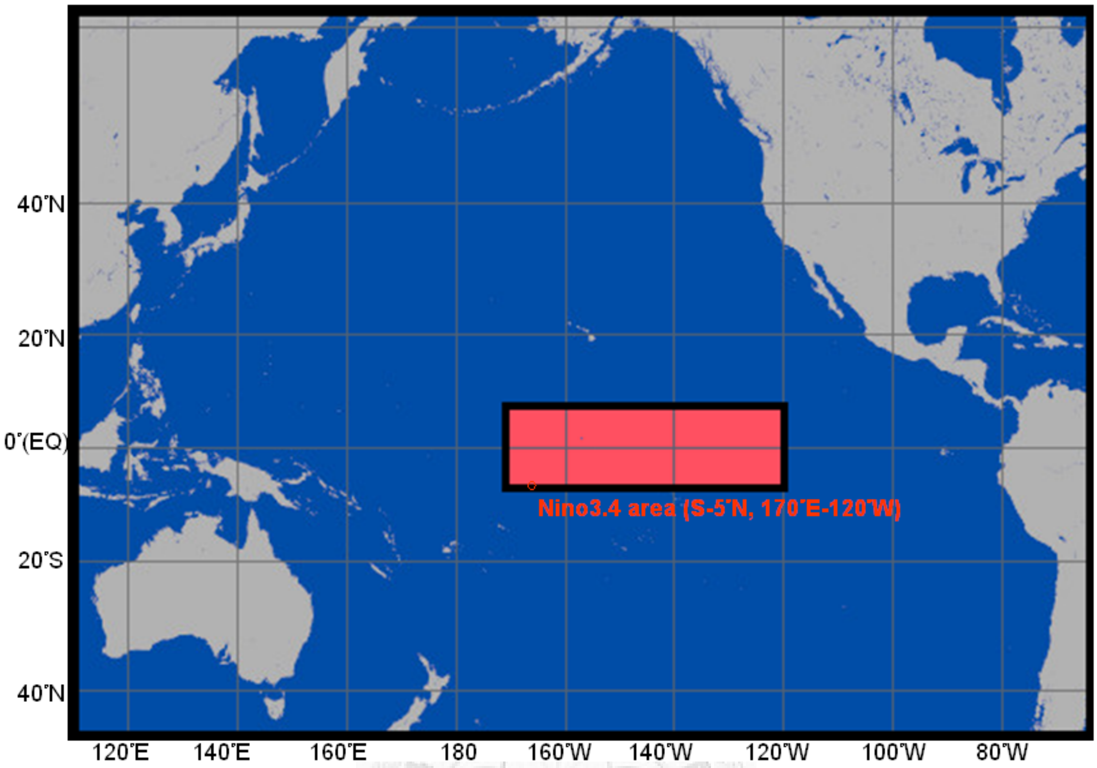

Fig. 1. Map showing the area of Niño 3.4, where the sea surface temperature anomaly (SSTA) are used for ONI definition (defined by Climate Predict Center (CPC), US)

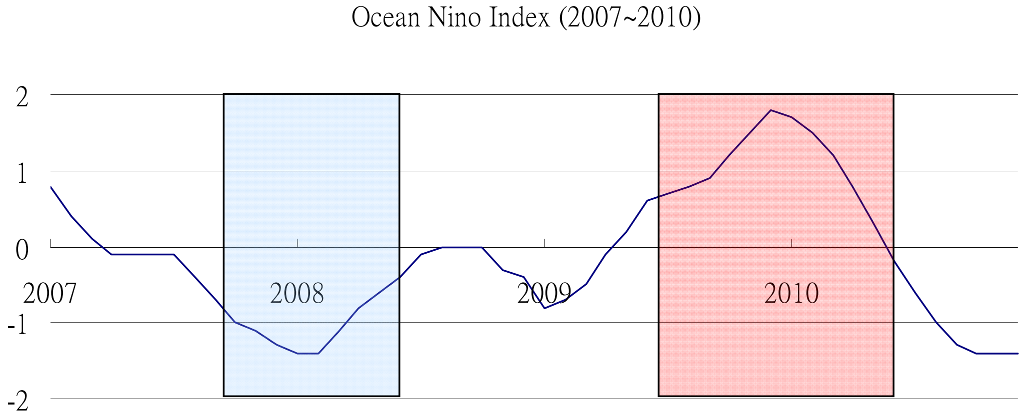

Fig. 2. Illustration of Ocean Niño Index (blue line, 2007 ~ 2010). El Niño starts from the third month when the value is higher than 0.5 (red period), and La Niña starts from the third month when the value is less than -0.5 (blue period).

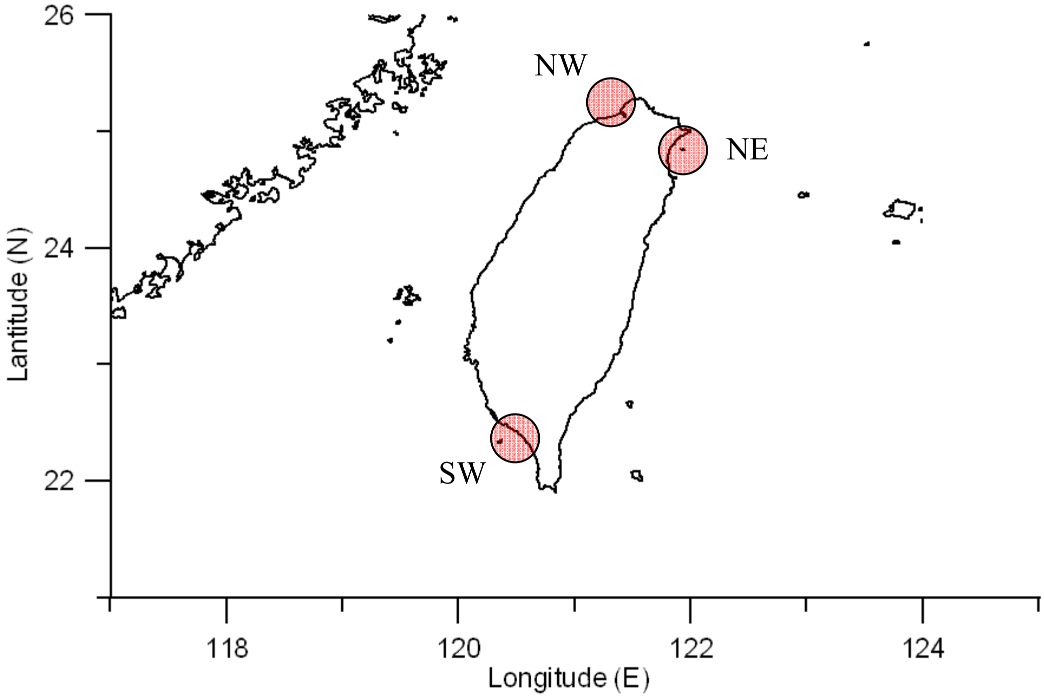

Fig. 3. Map showing location samples used in this study, including three major larval fishing grounds in the waters of Taiwan – Northeastern (NE), Northwestern (NW) and Southwestern (SW).

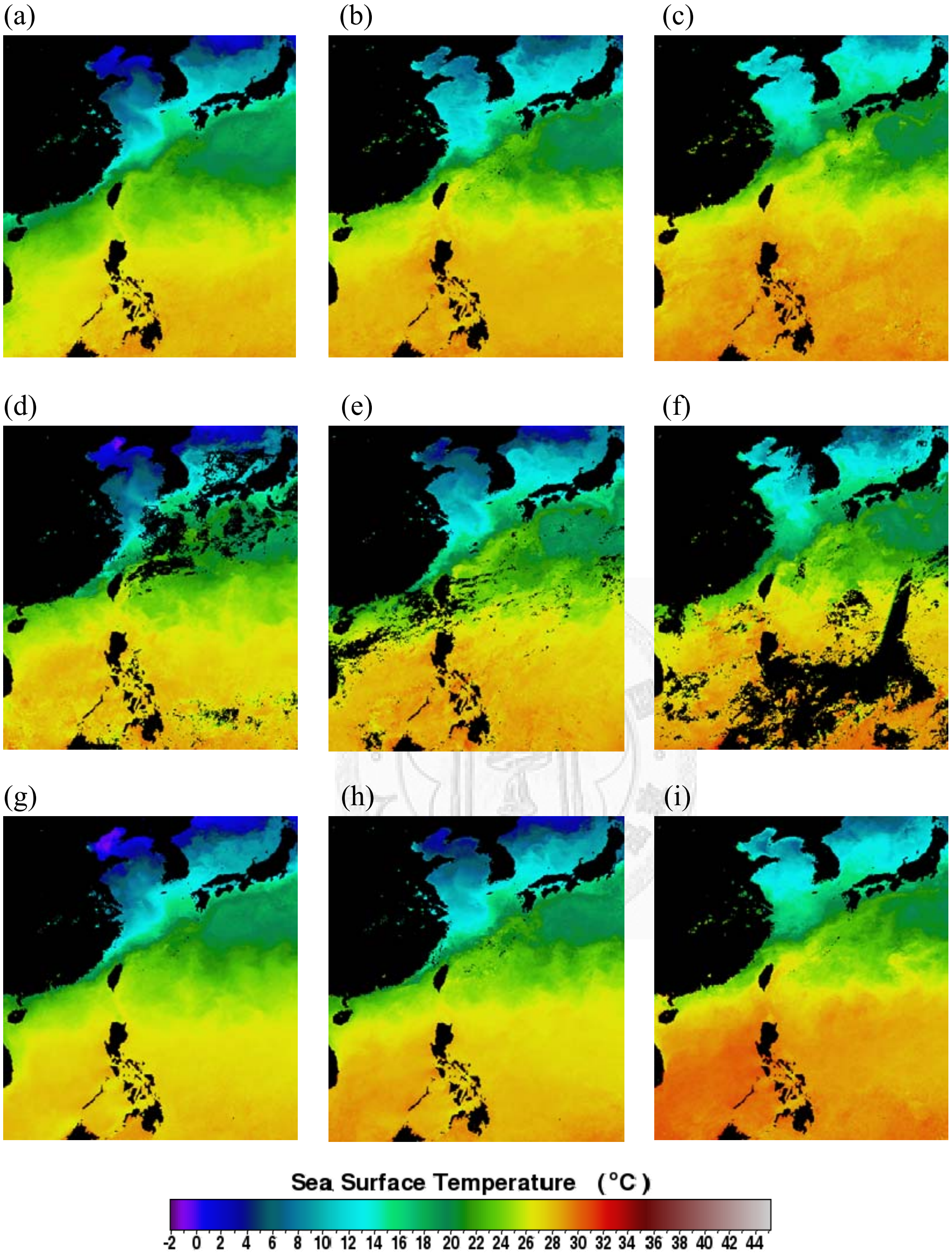

Fig. 4. The Aqua MODIS (or Moderate Resolution Imaging Spectroradiometer) sea surface temperature images, showing on the months of March, April & May 2008 (a-c), March, April & May, 2009 (d-f), and March, April & May, 2010 (g-i)

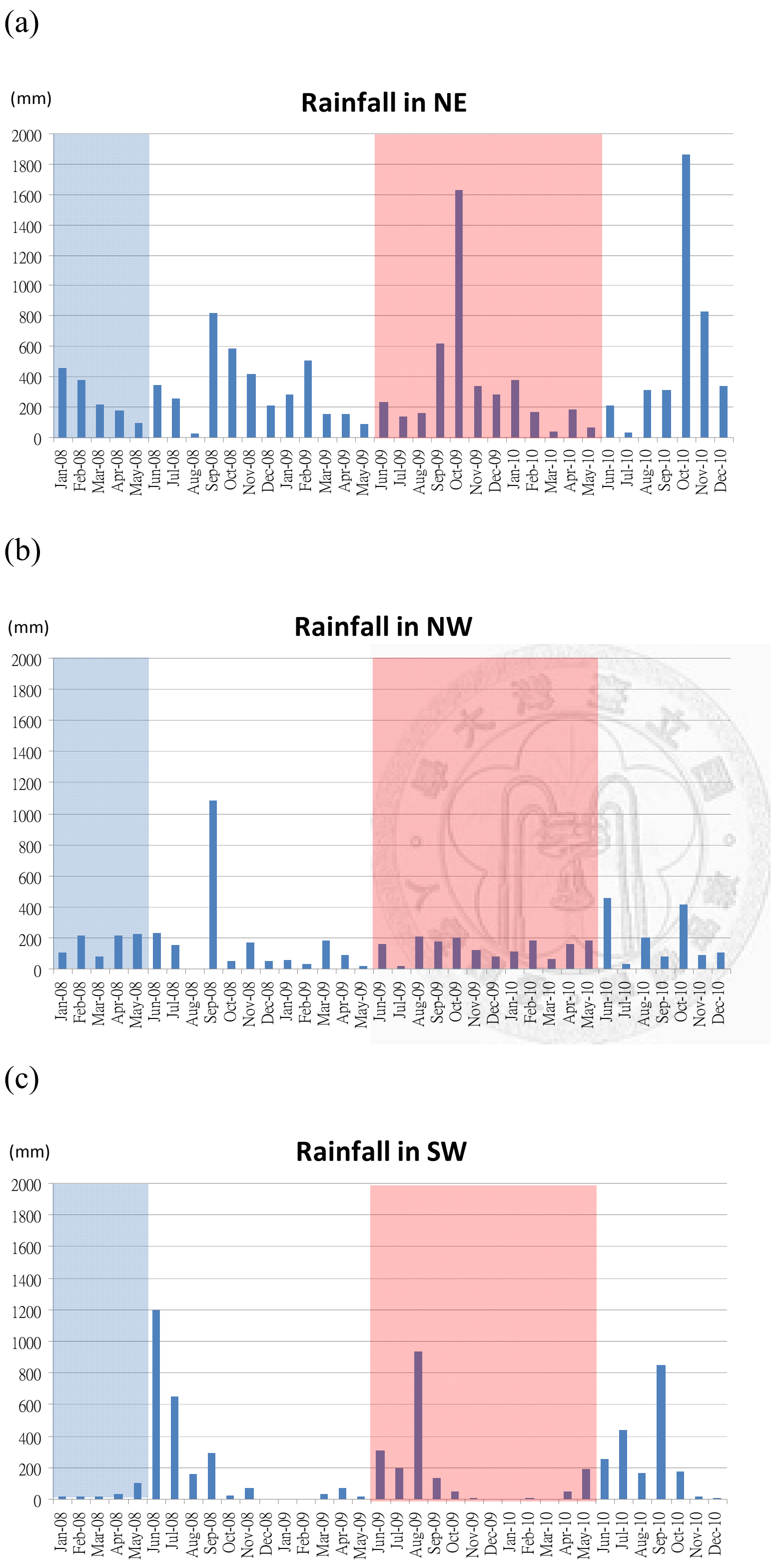

Fig. 5. Monthly rainfalls in three study areas; (a) NE, (b) NW and (c) SW. The first shade period denotes La Niña condition, and that of second denotes El Niño condition.

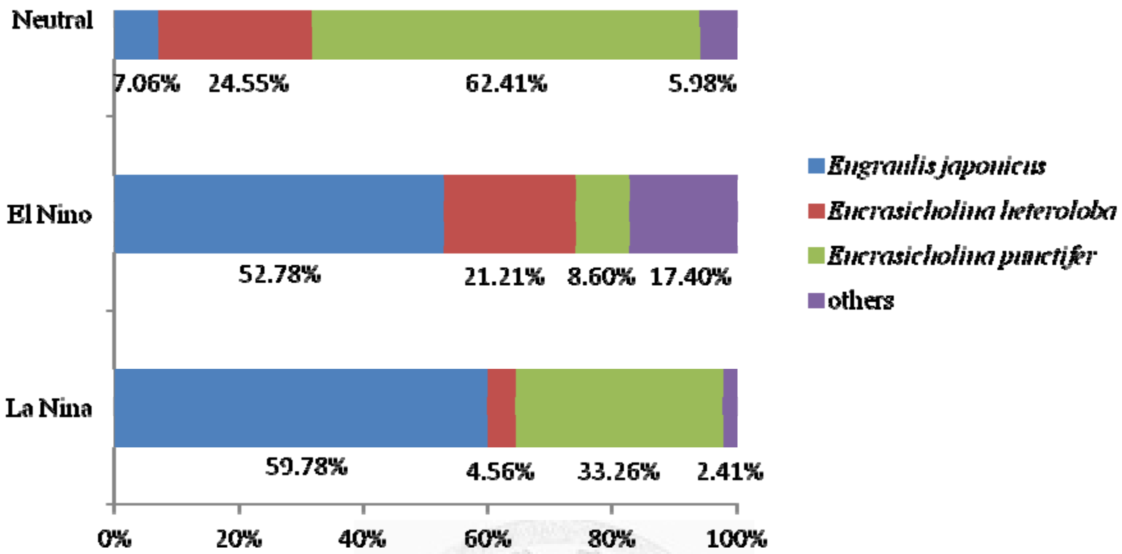

Fig. 6. Comparisons of anchovy species composition in the NE waters of Taiwan, showing by
composition shifts in two extreme climatic conditions of El Niño and La Niña.

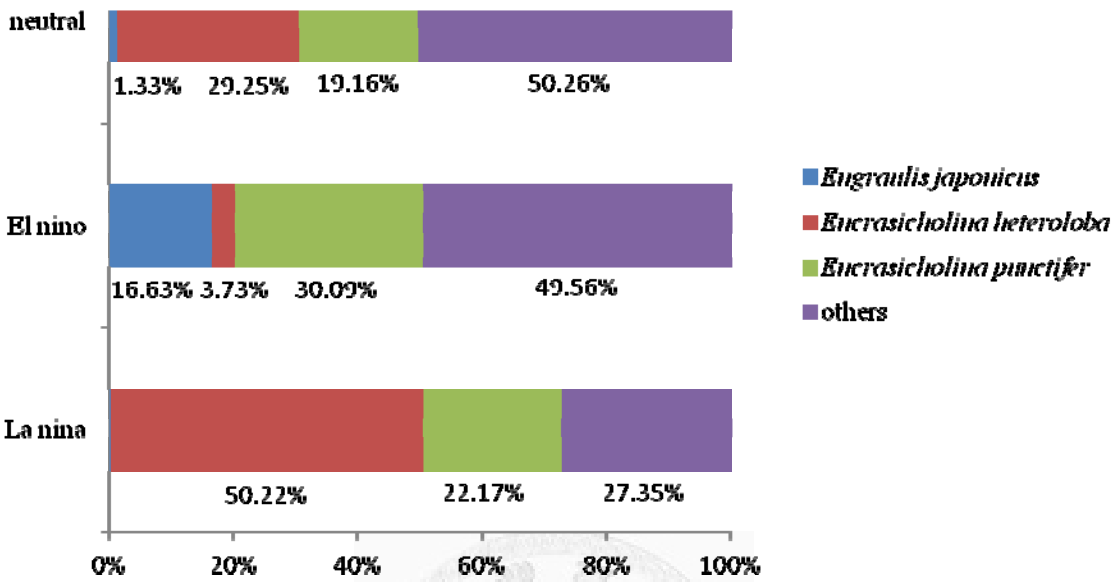

Fig. 7. Comparisons of anchovy species composition in the NW waters of Taiwan, showing by composition shifts in two extreme climatic conditions of El Niño and La Niña.

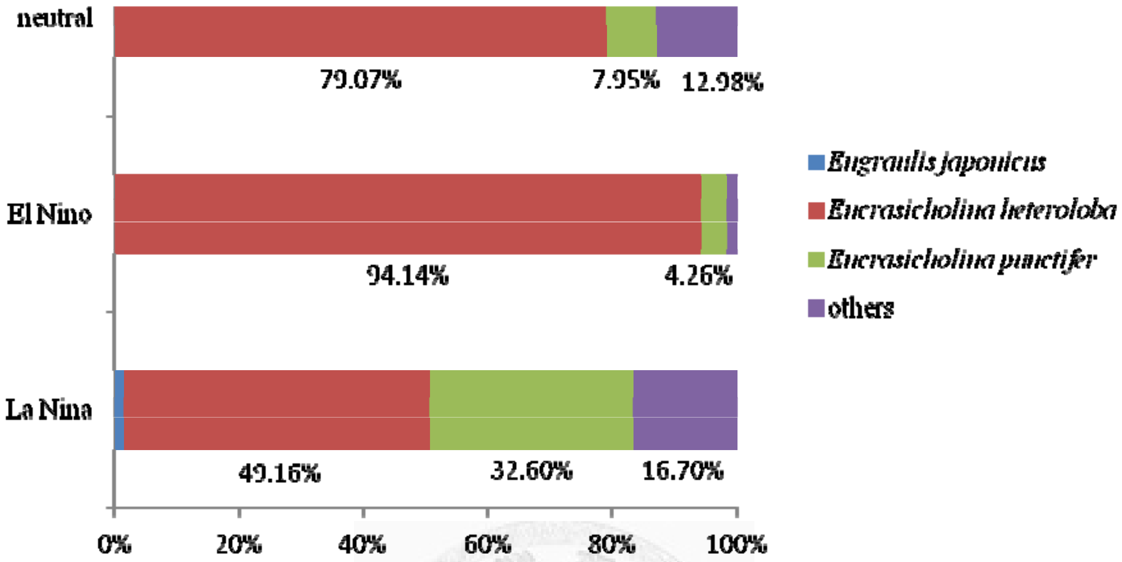

Fig. 8. Comparisons of anchovy species composition in the SW waters of Taiwan, showing by composition shifts in two extreme climatic conditions of El Niño and La Niña.

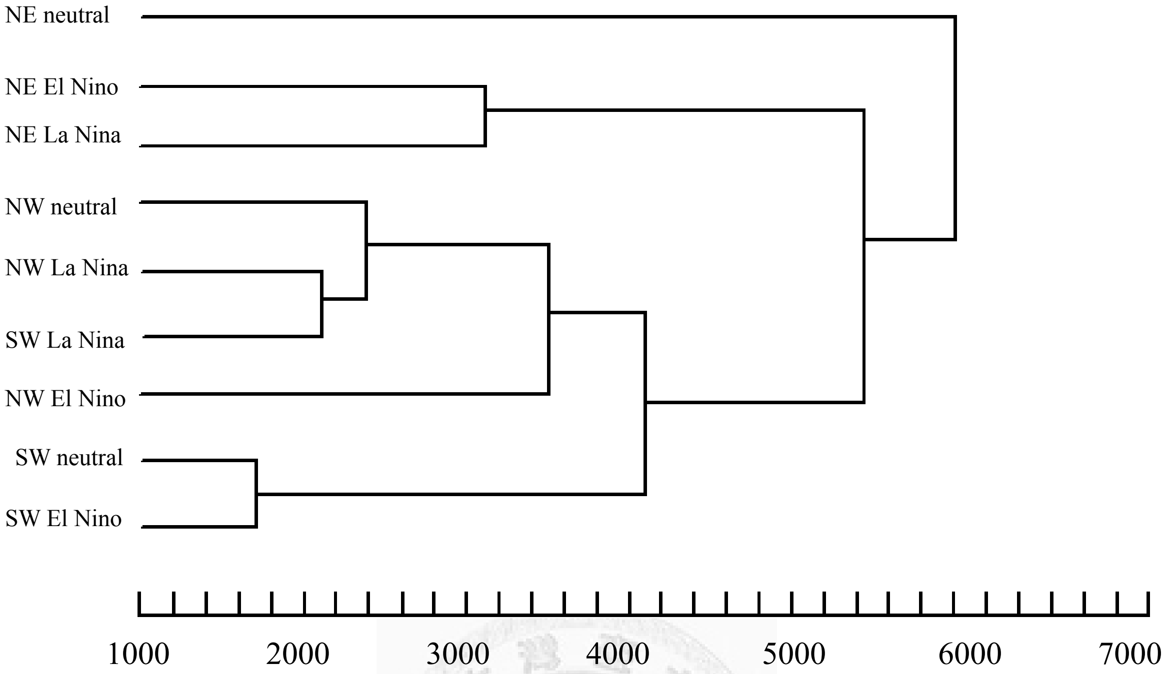

Fig. 9. Similarity analysis of target species composition, indicated by clustering based on Euclidian distances for 3 geographic waters and 3 climatic patterns.

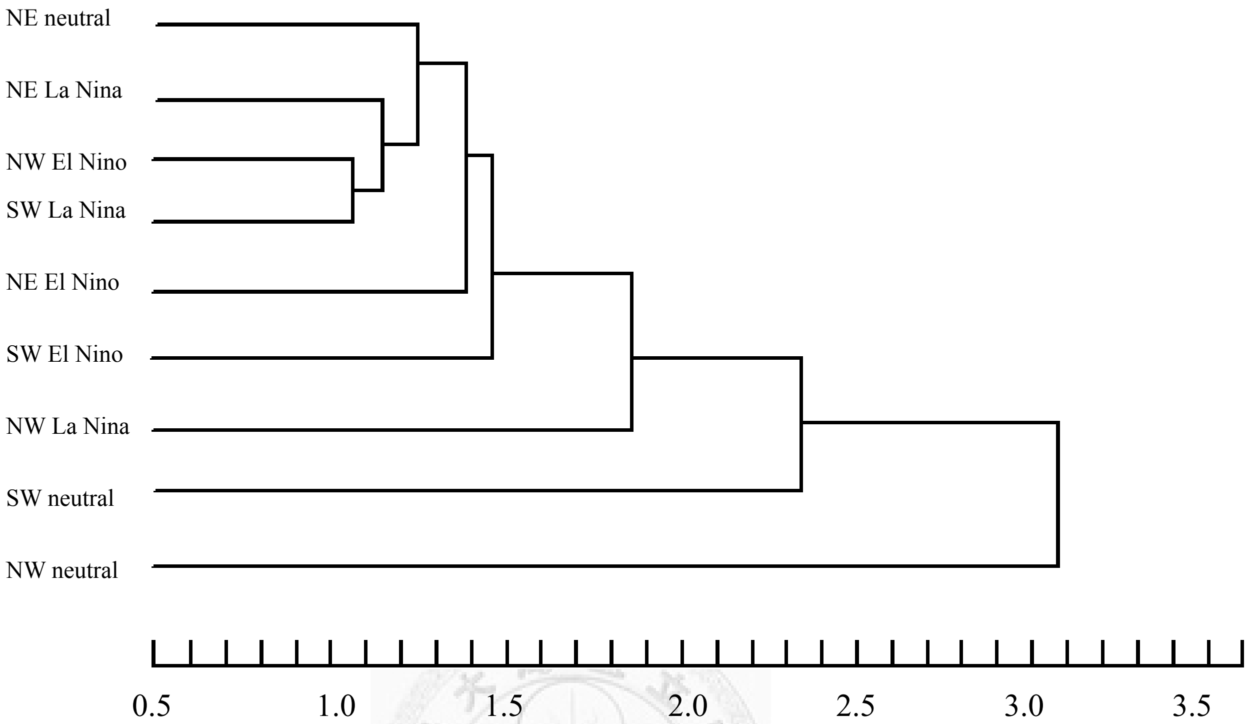

Fig. 10. Similarity analysis of by-catch pelagic species composition, indicated by clustering based on Euclidian distances for 3 geographic waters and 3 climatic patterns.

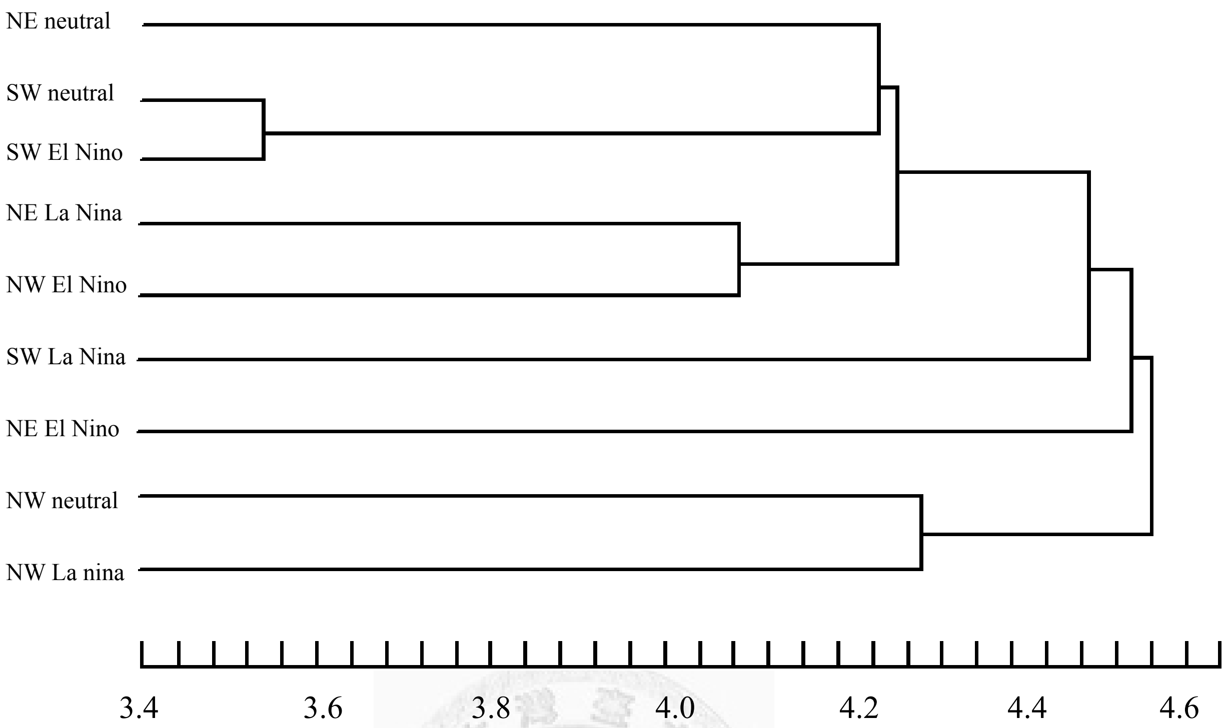

Fig. 11. Similarity analysis of by-catch non-pelagic species composition, indicated by clustering based on Euclidian distances for 3 geographic waters and 3 climatic patterns.