Bull. Inst. Zool., Academia Sinica 30(4): 261-272 (1991)

INITIAL ICHTHYOPLANKTON STUDIES IN THE KUROSHIO EDGE EXCHANGE AREA

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(Accepted March 1, 1991)

Tai-Sheng Chiu and Pei-Yi Lee (1991) Initial ichthyoplankton studies in the Kuroshio edge exchange area. *Bull. Inst. Zool., Academia Sinica* 30(4): 261-272. There are two major water masses in the north eastern waters of Taiwan, the mid-shelf and the oceanic. The Kuroshio current dominates the oceanic water and fluvial influence modifies the water property of the mid-shelf. In this study, a transect line across these two water masses was surveyed for realization of ichthyoplankton composition and for inference on the pattern of water exchange in the Kuroshio edge.

The findings included in this paper are: 1) the T-S diagram of water mass, 2) the densities of fish egg, ichthyoplankton and zooplankton, 3) the familial composition of ichthyoplankton, 4) the similarity of sampling stations, and 5) the representative ichthyoplankton species of sampling stations.

The T-S lines from six stations indicated two major groups of sea water, the mid-shelf and oceanic. The analysis of the densities of fish eggs, ichthyoplankton and zooplankton revealed that higher densities are located on the mid-shelf side. The densities in weight of ichthyoplankton and zooplankton are positively correlated. Both the station dendrogram of similarity and the station cladogram of representative species indicated a polarity on the transect line. Judging from these findings, the pattern of water mixing in the Kuroshio edge is discussed.

Key words: Ichthyoplankton composition, Kuroshio, Indicator species.

The northeastern waters of Taiwan are laying on a bottom with various depths which separate the sea into the continental shelf, continental slope and abyss. These waters come from at least two major origins; one from the mid-shelf side where water may ascribe to inland discharge and the other from the oceanic side where the Kuroshio dominates the properties of the sea water. Because the confrontation between these two major origins triggers the exchange of sea water (Liu, 1983), the Kuroshio edge exchange area has been defined for further studies.

To study water masses and their boundaries, several approaches are available which can lead to an understanding of the marine process. In the northeastern waters of Taiwan, most contributions have come from the disciplines of physics or chemistry. These included the analysis of temperature, salinity and nutrient distributions (Yin, 1973; Chu, 1976; Fan, 1980; Liu, 1983; Liu and Pai, 1987; Wong *et al.*, 1989). In contrast, much less biological information was available (Tzeng, 1970), although marine creatures are sometimes good indicators to make inferences of the marine process.

Ichthyoplankton are the larvae or juveniles of fishes which spend their daily life suspended in the water column with little active swimming. Owing to their limited horizontal movement, their presence in a specific water mass may identify the water mass itself. Therefore, an ichthyoplankton survey was conducted across the Kuroshio edge exchange area in order to understand the ichthyoplankton composition and to implicate the marine process.

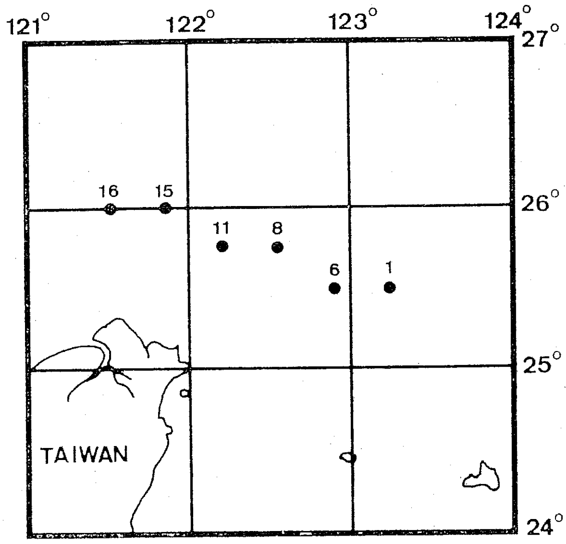

Fig. 1. The map showing sampling stations off the northeastern coast of Taiwan.

MATERIALS AND METHODS

Survey

The study area of the Kuroshio edge exchange process was pre-defined by the longitude 121°30′E–123°15′E and the latitude 25°30′N–26°N. The transect line chosen for the present study was made up of six sampling stations (Sts. 1, 6, 8, 11, 15 and 16; Fig. 1). The basic locality data, including latitude, longitude, sampling date and time, wind degree and speed, air temperature and sound depth, are shown in Table 1. All data used in this study were taken from the cruise ship coded CR-212 of R/V Ocean Research I.

The sampling gear was modified from a Maruchi (circle steel mouth) net with a mouth opening of 1.3 M in diameter (details described elsewhere, see Chiu and Liu, 1989). The mesh size of the conical net was 1.0 MM×1.0 MM. Upon sampling, the net was attached to a wire and was released at a rate of 40 M/min. Thereafter, the ship was kept at a speed of approximately 2.0 knots to maintain the wire angle at about 45°. When the net reached its final depth, the wire was retrieved at a rate of 20 M/min until the net surfaced. The next was towed obliquely. The final depth was set at 200 M or to a depth as close to the bottom as possible for bottom depths less than 200 M. A hydrologic flowmeter was mounted in the center of the mouth of the net to estimate total water volume filtered during the sampling. A CTD

Table 1
Information on ichthyoplankton sampling locations

Locations	Lat.	Long.	Date	Time	Wind Degree,	Wind Speed	Air Temp. (°C)	Sound Depth (M)
St. 1	25°30′N	123°15′E	06/05/89	1035	280,	8 M/S	27.6	847
St. 6	25°30′N	122°54′E	06/05/89	0823	160,	8 M/S	27.1	1,234
St. 8	25°45′N	122°33′E	06/05/89	2006	270,	6 M/S	24.0	111
St. 11	25°45′N	122°12′E	06/06/89	0048	170,	12 M/S	23.5	127
St. 15	26°00′N	121°50′E	06/06/89	0424	250,	8 M/S	25.3	109
St. 16	26°00′N	121°30′E	06/06/89	0620	270,	8 M/S	25.0	72

profiler was cast immediately after the net was hauled on board in order to collect hydrologic information on the water column.

Data analysis

Profile data of the water temperature and salinity obtained from a CTD instrument were processed into a standard format using the supplemented program of the profiler. The T-S diagram was adopted to describe the physical characteristics of the water mass.

The catches of the ichthyoplankton net were fixed with 10% formalin in sea water and brought back to the laboratory for later analysis. Fish eggs, fish larvae and juveniles, and incidental catches of invertebrate were separated. Fish larvae and juveniles were categorized as ichthyoplankton. Incidental catches of invertebrate were categorized as zooplankton. Fish eggs and ichthyoplankton were counted under stereo microscope and weighed with an electric balance. Only the weights of zooplankton were measured. The counts and weights were converted to densities based on the readings of the attached flowmeter. No attempts were made to identify fish eggs and zooplankton. Identification of ichthyoplankton was accomplished under stereo microscope. Identified ichthyoplankton was then cataloged into an inventory database, from which lists of ichthyoplankton composition were prepared for analysis on similar and representative species.

In order to draw a basic pattern among the stations across the Kuroshio exchange front, stations were grouped based on the specific familial composition of ichthyoplankton. The grouping of stations was based on the relative similarity index using a method of UPGMA (Sneath and Sokal, 1973). For selection of the exclusively occurring species at specific stations, a cladistic method (Wiley, 1981) was adopted.

RESULTS

Water masses

Ranges of water temperature and salinity from the six sampling stations are shown in Table 2, along with the depths of the samplings. Except at St. 11, the maximum temperature occurred on the surface and had a magnitude of greater than 25°C. The maximum temperature (23.53°C) of St. 11 is relatively low. The minimum temperatures varied among stations (16.36°C–22.23°C). The minimum water temperatures did not necessarily accord with the CTD depth. At Sts. 1, 6, 11 and 15, the minimum water temperatures stayed around 16°C, while at Sts. 8 and 16 the minimum water temperatures were above 20°C. The maximum salinities of these stations varied between 34.25‰ and 34.79‰ and

Table 2
The characteristics of water mass at the sampling stations

Stations	CTD Depth (M)	Temperature Range (°C)	Salinity Range (‰)
St. 1	200	27.78–16.41	34.76–34.17
St. 6	200	27.17–16.36	34.79–34.16
St. 8	120	26.69–20.83	34.71–34.20
St. 11	106	23.53–16.54	34.65–34.20
St. 15	100	25.41–16.42	34.59–33.98
St. 16	66	25.04–22.23	34.25–34.03

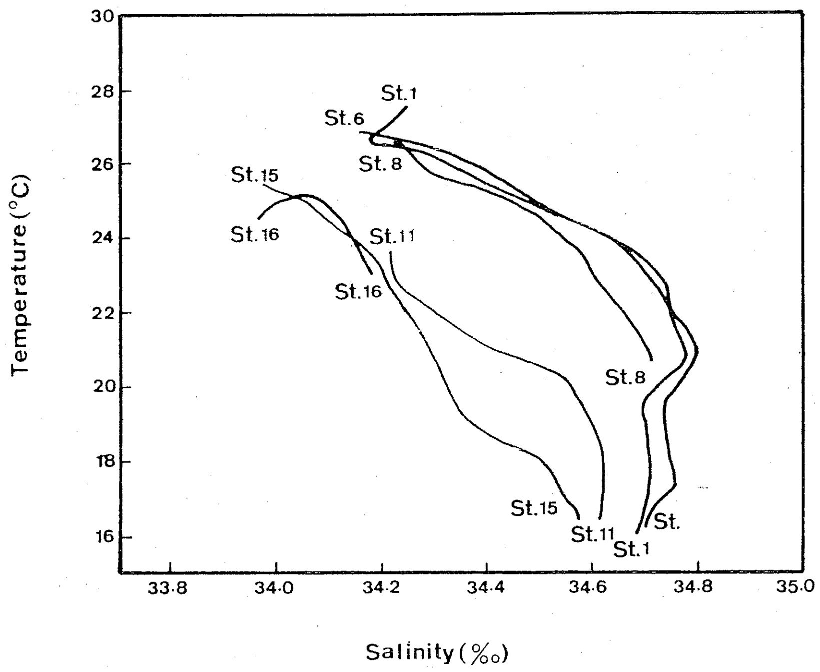

Fig. 2. The T-S diagram of 6 sampling stations.

the minimum salinities were between 33.98‰ and 34.20‰. Both the maximums and minimums of salinity did not significantly vary.

The plotting of temperature *vs* salinity (T-S diagram) of six stations is shown in Fig. 2. The water masses from these six stations can be discriminated into two primary and one intermediate groups when temperature and salinity are considered simultaneously. The T-S lines of Sts. 1, 6 and 8 are in one group (group 1) and those of Sts. 15 and 16 in the other group (group 2). In group 1, water temperature and salinity were higher than those of the same water depth in group 2. The leftover T-S line of St. 11 was recognized as the intermediate. The surface water of this station, being similar to group 2, had a relative low temperature and salinity. The bottom water of St. 11, being similar to group 1, had a relative high temperature and salinity. From the surface of the sea to the bottom of St. 11, the property of sea water detached first from those of group 2 by gaining a characteristic increase in salinity. The onset of the increase in salinity occurred at the water temperature of 21°C. The water salinity reached its equilibrium at a temperature of 19°C. When the water temperature was lower than 18°C, the water salinities of stations 1, 6, 11 and 15 all became similar.

Plankton densities

Station specific densities of fish eggs, ichthyoplankton and zooplankton in terms of number and weight are summarized in Table 3. The results are as follows:

Density in number: The densities in the number of fish eggs and ichthyoplankton ranged from 0 to 31,763/1,000 M^3 and from 242 to 19,649/1,000 M^3, respectively. Both fish eggs and ichthyoplankton were the most abundant at St. 15. In this survey, no fish eggs were found at St. 8. The minimum density in the

Table 3
Aquatic organism density at six sampling stations

Stations	Density in Number (No./1,000 M³)		Density in Weight (g/1,000 M³)		
	Egg	Ichthyoplankton	Egg	Ichthyoplankton	Zooplankton
St. 1	246	242	0.17	0.72	113.15
St. 6	2088	267	1.13	0.81	171.64
St. 8	0	1497	0	1.62	263.32
St. 11	309	521	0.17	1.06	144.69
St. 15	31765	19649	22.68	25.04	2126.92
St. 16	530	13182	1.16	18.98	1591.16

number of ichthyoplankton was 242/1,000 M^3, which was found at St. 1. No parallel trends were found between the densities in the number of fish eggs and ichthyoplankton based on an analysis using Spearman's rank correlation.

Density in weight: The densities in the weight of fish eggs, ichthyoplankton and zooplankton ranged 0-22.68 grams/1,000 M^3, 0.72-25.04 grams/1,000 M^3 and 113.15-2,126.92 grams/1,000 M^3, respectively. The minimum density in weight of fish eggs occurred at St. 8, while those of ichthyoplankton and zooplankton were at St. 1. The maximum densities in weight of fish eggs, ichthyoplankton and zooplankton occurred simultaneously at St. 15. No statistically significant relationships can be extracted from densities of fish eggs and ichthyoplankton. On the other hand, a positive correlation between densities of ichthyoplankton and zooplankton was found (Spearman's rank correlation, r_s= 0.9429, p=0.0350).

Table 4
The ten families and the percentage of ichthyoplankton at six sampling locations across the Kuroshio edge exchange area

Rank	St. 1	St. 6	St. 8	St. 11	St. 15	St. 16
1	My (14.6)*	My (16.8)	Ca (12.0)	My (23.6)	Ca (23.0)	Ca (12.6)
2	So (10.4)	Gn (7.1)	Sc (8.9)	Ca (21.8)	Sc (14.7)	Sc (12.4)
3	Lu (8.4)	Br (5.3)	My (7.0)	Sc (13.6)	Pr (13.4)	Pr (9.3)
4	Ca (5.2)	Pa (5.3)	Go (5.7)	En (5.5)	Br (5.5)	Br (8.7)
5	Br (4.2)	Bl (3.5)	En (5.7)	Po (4.6)	Cy (3.1)	Cy (4.1)
6	An (3.1)	St (2.7)	Gn (4.4)	Sy (3.6)	Sy (2.7)	Sy (3.5)
7	Co (3.1)	As (2.7)	Cy (2.5)	So (2.7)	My (2.2)	Go (2.6)
8	Gn (3.1)	Ge (2.7)	Pr (1.9)	Gn (2.7)	Ap (1.4)	Mu (2.4)
9	Pr (3.1)	Ml (2.7)	Pa (1.9)	Au (1.8)	Te (1.4)	Ap (2.2)
10	St (3.1)	Mn (2.7)	Sn (1.3)	Lu (1.8)	Tr (1.2)	Te (2.0)
Others	(44.8)	(48.5)	(48.7)	(18.3)	(31.4)	(40.2)

Remark: * Family code (Percentage within station).
Family code: An=Anguillidae; Ap=Apogonidae; As=Astronesthidae; Au=Aulopodidae; Bl=Blenniidae; Br=Bregmacerotidae; Ca=Carangidae; Co=Coryphaenidae; Cy=Cynoglossidae; En=Engraulidae; Ge=Gempylidae; Go=Gobiidae; Gn=Gonostmatidae; Lu=Lutjanidae; Me=Melanocetidae; Mn=Menidae; Mu=Mullidae; My=Myctophidae; Pa=Paralepididae; Po=Pomancentridae; Pr=Priacanthidae; Sc=Scombridae; So=Scorpaenidae; St=Stomiidae; Sy=Synanceiidae; Sn=Synodontidae; Te=Tetraodontidae; and Tr=Trichiuridae.

Familial composition of stations

The top ten abundant families were drawn from each station for further analysis and are shown in Table 4. A total of 28 families are listed in this table. Stations 1 and 6 have higher percentages of myctophid, bregmacerotid and gonostomatid fishes. At Sts. 15 and 16, scombrid, scorpaenid and priacanthid become the major components. The specific composition of each station is described below.

St. 1: The most abundant ichthyoplankton of this station are mesopelagic species of myctophid (mainly *Myctophum orientalis*), which total 14.6% of the total catch. Neritic water fishes, such as scorpaenid (10.4%), lutjanid (8.4%) and carangid (5.2%) ranked second to forth place. The fifth is bregmacerotid (4.2%). Families ranking sixth to the tenth place are anguillid, coryphaenid, gonostomatid, priacanthid and stomiid with equal percentages of 3.1%.

St. 6: Myctophid accounted for 16.8% of the total ichthyoplankton catch at this station. Myctophid is composed of at least nine taxa. Among them, *Benthosema pterotum* was the most abundant. Other mesopelagic species, such as gonostomatid, bregmacerotid and paralepidid accounted for 7.1%, 5.3% and 5.3% of the total catch, respectively. Offshore pelagic fishes, such as blenniid (3.5%), gempylid (2.7%) and menid (2.7%) were minor components.

St. 8: Fishes of neritic water with commercial value were the major component in this station. Among them carangid (12.0%) ranked the first and scombrid (8.9%) the second. Mesopelagic fish of myctophid (7.0%) were the third. It is worth noting that coastal fishes, such as gobiid (5.7%) and engraulid (5.7%) were also listed among the top ten families. The sixth to tenth places were gonostomatid (4.4%), cynoglossid (2.5%), priacanthid (1.9%), paralepidid (1.9%) and synodontid (1.3%).

St. 11: Myctophid accounted for 23.6% of the total catch in this station and was composed of at least 6 taxa. Among them, *Benthosema pterotum* was the most abundant. One of the neritic water fishes, carangid (21.8%), was the second most common and the most abundant in the neritic domain. Other neritic water fishes, such as scombrid (13.6%) and coastal water species, such as engraulid (5.5%) were also important in this familial composition.

St. 15: Neritic water fishes of carangid (23.0%) and scombrid (14.7%) were the major components of familial composition. Myctophid (2.2%) became comparatively less important in this station. The other families among the top ten were priacanthid (13.4%), bregmacerotid (5.5%), cynoglossid (3.1%), synanceiid (2.7%), apogonid (1.4%), tetraodontid (1.4%) and trichiurid (1.2%).

St. 16: Neritic water fishes of carangid (12.6%) and scombrid (12.4%) were the major components of familial composition. It is worth noting that myctophid (1.2%) was excluded from the top ten list. The third to tenth places were priacanthid (9.3%), bregmacerotid

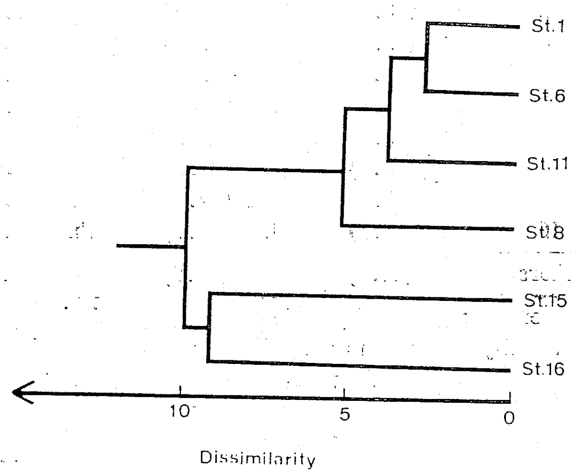

Fig. 3. Similarity dendrogram of sampling locations.

(8.7%), cynoglossid (4.1%), synanceiid (3.5%), gobiid (2.6%), mullid (2.4%), apogonid (2.2%) and tetraodontid (2.0%).

Regarding the familial composition, no correlations were found among all possible pairs of stations when the pairs were checked with the Spearman's rank test at a 95% significant level. Additional analysis, based on the clustering method of UPGMA, have created a dendrogram of stations (Fig. 3). Stations 1, 6, 11 and 8 are grouped into a primary cluster sequentially. The common characteristic of this group is having a high percentage of mesopelagic families. It is worth noting that St. 11 joined the group of Sts. 1 and 6 before St. 8 was added. Stations 15 and 16 linked and formed as the other groups did on a relative high level of dissimilarity. In contrast to the stations of the first group, the ichthyoplankton assemblages of these two stations shared the common characteristic of having a high percentage of carangid, scombrid and priacanthid.

Representative ichthyoplankton

A total of 95 taxa were arranged cladistically with 52 taxa indicating a significance on station reference (Table 5 and Fig. 4). Five species (coded 1–5; *Coryphaena hippurus, Lutjanus bohar, Seriola dumerili, Stomias nebulosus* and *Symbolophorus californiensis*) occurred exclusively at St. 1. Four species (coded 8–11; *Lestrolepis intermedia, Promethichthys prometheus, Ptroscirtes springeri* and *Stomias affinis*) exclusively occurred at St. 6. Fourteen species (coded 15–28; *Apogon kienis, Benthosema fibulatum, Cirrhilabrus temminckii, Coccorella atlantica, Decapterus macarellus, Decapterus maruadsi, Emmelichthys strubsakeri, Histrio histrio, Neocirrhites armatus, Protomyctophum thompsoni, Scomberomorus guttatus, Spectrunculus grandis, Stemonosudis miscella* and *Symphurus arientalis*) occurred exclusively at St. 8. Three species (coded 30–32; *Aulopus japonicus, Chromis notatus* and *Scomber australasicus*) occurred exclusively at St. 11. Six species (coded 38–43; *Leiognathus nuchalis, Parapercis pulchella, Pempheris xanthoptera, Serda orientalis, Synodus hoshinonis* and *Synodus variegatus*) occurred exclusively at St. 15. Nine species (coded 44–52; *Aluterus monoceros, Cerotoscopelus warmingi, Caranx bartholomaei, Inimicus japonicus, Nibea albiflora, Petroscirtes mitratus, Pseudorhombus pentophthalmus, Sphyraena pinguis* and *Upeneus*

Table 5

Selected taxa for water mass identification

Species		Station					
Code	Name	1	6	8	11	15	16
1.	*Coryphaena hippurus*	×					
2.	*Lutjanus bohar*	×					
3.	*Seriola dumerili*	×					
4.	*Stomias nebulosus*	×					
5.	*Symbolophorus californiensis*	×					
6.	*Repomucenus beniteguri*		×	×	×	×	×
7.	*Vinciguerria nimbaria*		×	×	×	×	×
8.	*Lestrolepis intermedia*		×				
9.	*Promethichthys prometheus*		×				
10.	*Ptroscirtes springeri*		×				
11.	*Stomias affinis*		×				

Table 5
Selected taxa for water mass identification (Continued)

Species		Station					
Code	Name	1	6	8	11	15	16
12.	*Elagatis bipinnulata*			×	×	×	×
13.	*Trachinocephalus myops*			×	×	×	×
14.	*Trichiurus lepturus*			×	×	×	×
15.	*Apogon kienis*			×			
16.	*Benthosema fibulatum*			×			
17.	*Cirrhilabrus temminckii*			×			
18.	*Coccorella atlantica*			×			
19.	*Decapterus macarellus*			×			
20.	*Decapterus maruadsi*			×			
21.	*Emmelichthys strubsakeri*			×			
22.	*Histrio histrio*			×			
23.	*Neocirrhites armatus*			×			
24.	*Protomyctophum thompsoni*			×			
25.	*Scomberomorus guttatus*			×			
26.	*Spectrunculus grandis*			×			
27.	*Stemonosudis miscella*			×			
28.	*Symphurus orientalis*			×			
29.	*Minous monodactylus*				×	×	×
30.	*Aulopus japonicus*				×		
31.	*Chromis notatus*				×		
32.	*Scomber australasicus*				×		
33.	*Apogon lineatus*					×	×
34.	*Aseraggodes kobensis*					×	×
35.	*Bregmaceros neonectabanus*					×	×
36.	*Cynoglossus joyneri*					×	×
37.	*Parastromateus niger*					×	×
38.	*Leiognathus nuchalis*					×	
39.	*Parapercis pulchella*					×	
40.	*Pempheris xanthoptera*					×	
41.	*Sarda orientalis*					×	
42.	*Synodus hoshinonis*					×	
43.	*Synodus variegatus*					×	
44.	*Aluterus monoceros*						×
45.	*Cerotoscopelus warmingi*						×
46.	*Caranx bartholomaei*						×
47.	*Inimicus japonicus*						×
48.	*Nibea albiflora*						×
49.	*Petroscirtes mitratus*						×
50.	*Pseudorhombus pentophthalmus*						×
51.	*Sphyraena pinguis*						×
52.	*Upeneus bensasi*						×

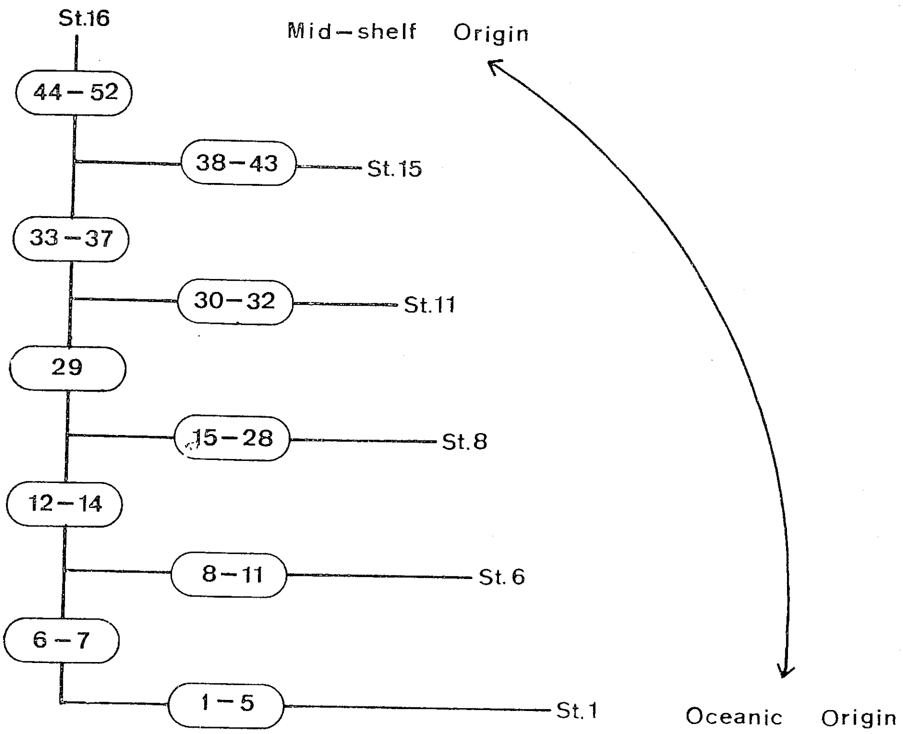

Fig. 4. Schematic dendrogram of water mass inferred by potential indicator species. Indicator species code (1-52) see Table 5.

bensasi) occurred exclusively at St. 16. *Repomucenus beniteguri* (coded 6) and *Vinciguerria nimbaria* (coded 7) were widely distributed at Sts. 6, 8, 11, 15 and 16. Three species (coded 12-14; *Elagatis bipinnulata*, *Trachinocephalus myops* and *Trichiurus lepturus*) were commonly observed at Sts. 8, 11, 15 and 16. *Minous monodactylus* (29) was the only species which occurred jointly at Sts. 11, 15 and 16. Five species (coded 33-37; *Apogon lineatus*, *Aseraggodes kobensis*, *Bregmaceros neoneclabanus*, *Cynoglossus joyneri* and *Parastromateus niger*) were found in the mid-shelf stations of Sts. 15 and 16.

DISCUSSION

Temperature and salinity of sea water are important factors in identifing a water mass. Generally, no drastic changes occurred in the offshore sea waters in this study, therefore it would be useless to treat temperature and salinity as independent variables. However, a T-S diagram is a useful tool to identify a water mass. In this study, water masses of a mid-shelf origin are readily distinguished from those of an oceanic origin by a T-S diagram. The water masses of Sts. 1, 6 and 8 are recognized and characterized as of the Kuroshio origin displaying properties of high temperature and high salinity, although the water mass of St. 8 differed slightly from Sts. 1 and 6 (Fig. 2). The Kuroshio water comes from the south containing higher levels of solar energy and meeting little inland interference. On the other hand, the water masses of Sts. 15 and 16, displaying relative low temperatures and low salinities, are generally considered to originate in the mid-shelf due to their lower solar energy levels and fluvial influences. The surface water of St. 11 was similar to that of the mid-shelf, but the sub-surface water indicated a mixing property of the mid-shelf and the oceanic waters. On the sea bottom, all the waters exhibited similar properties of low temperature and moderate salinity.

The three physical events of eddy, upwelling and meandering may be triggered when the Kuroshio water flows north and hits the continental margin of the East China Sea. At St. 11, the fact that the surface water had an extraordinary low temperature and median salinity possibly indicates the upward movement of sub-surface sea water. This suppositive upwelling event deserves further study.

Based on the water temperature and salinity of the waters of north eastern Taiwan, Fan (1980) proposed that an upwelling event takes place located in the area of 25°30′N to 25°50′N and 122°20′E to 123°00′E, He also pointed out that the surface upwelling was subtle, but a significant amount could be detected at a depth of about 100 M. The locations of Sts. 8 and 11 in this study are close to the upwelling area proposed by Fan (1980). Our evidence is demonstrated in the station dendrogram (Fig. 3) based on the similarities of ichthyoplankton composition. The ichthyoplankton composition of St. 11 shows a closer similarity to the oceanic stations, yet St. 11 is located along the shelf area. This tendency is more obvious at St. 11 than at St. 8, although St. 8 is located closer to the oceanic side. Because both mid-shelf and oceanic ichthyoplankton occurred jointly at St. 11, a convergent front built along the mid layer of this station is proposed as an initial hypothesis. In this study, we treat the water column as a whole and did not attempt to obtain multi-layer sampling data, therefore evidence that a strong upwelling at certain depths along the transect line could not be further substantiated. However, the supposition of water mixing occurring along the Kuroshio and mid-self can be inferred at least from the evidence demonstrated by the ichthyoplankton composition at Sts. 8 and 11.

Density of ichthyoolankton showed a polarity declining from the mid-shelf to the oceanic side (Table 3). This polarity rejects a supposition of an upwelling event (Fan, 1980; Wong *et al.*, 1989) occurring, since this would result in higher standing stocks instead of faunistic replacement as indicated at Sts. 8 and 11 of this study. In the intermediate stations (Sts. 8 and 11) along this surveying line, mid-shelf and oceanic ichthyoplankton occurring in both stations should point to the phenomenon of water mixing. Since the temperature of the surface water at St. 11 was relatively low and no significant Ekman transport was recorded before, the momentum that moves bottom water upward is probably driven by a sub-surface jet flow.

The most remarkable feature of ichthyoplankton assemblage originating from the oceanic side is its simplicity (Fig. 3). The complexity of familial composition found in the transitional stations 8 and 11 (Table 4) is due to the various strengths of convergence of the mid-shelf and oceanic waters. The richness of ichthyoplankton taxon found in this area could be accomplished by several mechanism. Hydrographic events, such as eddies (Fan, 1980), the jet flow (Fan, 1980 Liu, 1983), and meandering (Liu and Pai, 1987) may play important roles. But, other reasons, more than kinds of passive transport of ichthyoplankton, could also explain the transportation of faunistic elements. Therefore, the faunistic replacement should not be oversimplified and explained as a result of a pure hydraulic end-product.

The cladistic method used to explain the occurrence of species at specific stations can initially provide a representative species for the identification of water masses. A schematic cladogram showing the relationships of stations is proposed in Fig. 4. Along the transect line, St. 1 lays on the extreme of oceanic side and St. 16 on the extreme of the mid-shelf. The ichthyoplankton supporting this cladogram are shown in the rectangular boxes. Mesopelagic groups favor the oceanic water. On the other hand, coastal or demersal species prefer the mid-shelf or neritic water. To obtain a clearer picture of representative species of different water masses, further study on the planktonic organisms are necessary.

Acknowledgements: The author is grateful to Ms. M.H. Yang, Ms. K.Z. Chung, Ms. Y.H. Hsyu, and Mr. S.S. Yang of the Economic Fishes Laboratory, Department of Zoology, National Taiwan University. The author would also like to thank Drs. J. Kuo and R.Q. Jan for kindly reviewing this manuscript. Thanks are also extended to the National Science Council, the Republic of China for grants NSC79-0211-B002-31 and NSC79-0209-M002-01.

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黑潮交換區浮游魚類的初期研究

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臺灣東北部水域至少擁有兩個特性的水團，一個來自中陸棚區，另一個來自外洋區。這個研究第一步探討橫過兩個水團的穿越線上浮游魚類的組成及其特性，再由生物組成的特性檢視可能代表水團的特別種類。

從這些水團中所獲得的鹽溫圖顯示，有一冷水發生於 25°45′N，122°12′E，密度分佈顯示在陸棚區的浮游魚類較高。以科爲單位之組成顯示，在中陸棚水及外洋水的輻合區有較豐富的組成。燈籠魚類及鱷蜥鱚類的浮游魚類爲交換區外洋邊的主要種類。鰺科魚類及鰹鮪類爲中陸棚邊的主要浮游魚類。最後，並提出一個建議性的指標種類，以爲水團之代表。