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Comparison of Ichthyoplankton Guild in the Kuroshio Edge Exchange Area

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ABSTRACT

This study is part of research on the Kuroshio edge exchange process (KEEP). In this study, we studied the ichthyoplankton guilds in the KEEP area and compared the results with those from upstream, I-lan Bay and downstream, the shelf of the East China Sea.

Three sub-areas were recognized in the KEEP area based on the temperature-salinity (T-S) lines, and the sampling stations were grouped accordingly. These station groups are the Kuroshio, mixing zone and East China Sea shelf. Dominant species of ichthyoplankton and diversity indices within each station group are discussed. The similarity of station groups as revealed by guild characteristics is illustrated by Spearman's rank correlation and cluster analysis. Ichthyoplankton fauna of station groups indicated an indirect linkage from I-lan Bay to the shelf of the East China Sea. Since the Kuroshio water mixing zone was excluded from the direct linkage, dispersing of ichthyoplankton by Kuroshio current might be suggested. In other words, ichthyoplankton guild in the mixing water could not maintain a stable similarity with adjacent areas longitudinally.

1. INTRODUCTION

The waters off northeastern Taiwan are one of the major coastal fishing grounds for both demersal and pelagic fishes (Anon., 1990). High productivity and complex marine environment make this area interesting for various disciplines. At least two water masses reach this marine environment; the Kuroshio current from the south and the mid-shelf water from the north (the East China Sea). The water property of the Kuroshio is warm and saline, and that of the mid-shelf relatively cold and less saline. These two water masses mix in the offshore area of northeastern Taiwan (Chern and Wang, 1990). In the mixing area, the transported planktonic organisms converge to a front, which might lead to high productive fishing ground. From a practical point of view, the mechanism of fishing ground formation is knowledge basically needed for reasonable exploitation and conservation of fishing resources.

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In addition to biological studies initiated from the fishery point of view (Liu and Chiu, 1981; Liu and Kao, 1979; and Hwang and Chen, 1984), several oceanographic studies have also been carried out to understand the oceanic processes. For example, during the study period of the Kuroshio Edge Exchange Process (KEEP), regular surveys were carried out for two years. Some preliminary results were reported, such as physical oceanography (Fan, 1980; Liu, 1983; Chern and Wang, 1989, 1990a, b, c; and Liu and Pai, 1987); chemical oceanography (Wei, 1991 and Wong *et al.*, 1989); biological oceanography (Chiu, 1991a, b; and Chiu and Lee, 1991).

Ichthyoplankton is composed of organisms from early life stage of fishes. Realization of the trophic relationship of marine organisms and inference on the marine process are two major objectives of ichthyoplankton study. In KEEP, earlier studies indicated that the density distribution was relatively low at the southeastern corner of the KEEP area and relatively high in the north (Chiu, 1991a). Isopleth diagram of density indicated an extremely low desnity in the mixing site (Chiu, 1991a). Further studies showed that the influence of the Kuroshio on ichthyoplankton distribution decreased along a direction from southeast to northwest. Some representative species of different water constitutes were sorted out (Chiu and Lee, 1991). Since the similarity of ichthyoplankton guild within the KEEP area can not be figured out without referring to the upstream and downstream fauna, we borrowed data from the I-lan Bay and the shelf of the East China Sea. In the study, spatial pattern on the ichthyoplankton guilds from the KEEP area, the East China Sea and I-lan Bay are analyzed and similarities among guilds are compared.

2. MATERIALS AND METHODS

The Area The Kuroshio Edge Exchange Process (KEEP) area is designated by latitudes between 121°30′E and 123°15′E and longitudes between 25°30′N and 26°N. Three transect lines were selected to cover two types of topography, the continental shelf and the continental slope. Three subdivisions were chosen (Figure 1; A, B, and C) based on temperature and salinity of the waters. An offshore water off the I-lan Bay (Figure 1; D) referred to as the Kuroshio upstream zone and a shelf water (E) were selected as reference.

The Survey The present study was compiled from three cruises conducted by R/V *Ocean Research I* and R/V *Hai-Fu*. In the KEEP study area, the sampling stations were designed to represent an area of 15 latitudinal by 20 longitudinal minutes apart. The data from I-lan Bay and shelf areas was obtained from studies aiming at understanding of the recruit mechanism of major stocks of commercial fisheries. Those data from outside of the KEEP area were selected as reference. Although reference data were collected at different times, previous study indicated a consistency in average species composition of ichthyoplankton within the same water mass which makes this comparison possible.

Three station groups (SG) were categorized in KEEP area: SG-A was composed of sts. 1, 2, 3, 4, 5 and 6; SG-B of sts. 7 and 8; SG-C of sts. 9, 10, 11 and 12. Two other sampling sites were selected for comparison; SG-D of sts. 13, 14 and 15 from offshore water of I-lan Bay, and SG-E of 16, 17, 18 and 19 from the shelf of the East China Sea. Information on the locality, sampling date and time of day, and bottom depth for each station is shown in Table 1.

The sampling gear used in this study for collection of the fish eggs and ichthyoplankton was a RMI net with 4-m conical net and 1.3m mouth opening (details see Chiu and Liu, 1989).

Data-analysis Samples taken were fixed on board with 10% formalin in sea water, and then sorted upon return. All larval or early juvenile fishes were picked for further study. Those larvae and juveniles are termed ichthyoplankton.

Table 1. Basic background information of ichthyoplankton samples used in this study

Station group Station	Position Lan.;Long.	Date mm/dd/yy	Time hhmm	Depth (m)
A 1	26°00'N;122°33'E	05/01/90	2130	107
2	26°00'N;122°54'E	05/02/90	0015	106
3	25°45'N;122°54'E	05/02/90	0240	190
4	25°29'N;122°54'E	05/02/90	0510	1000
5	25°31'N;122°34'E	05/02/90	0825	400
6	25°47'N;122°34'E	05/02/90	1015	126
B 7	26°00'N;122°12'E	05/01/90	1930	103
8	25°44'N;122°12'E	05/02/90	1840	123
C 9	25°30'N;121°44'E	05/01/90	1315	116
10	25°44'N;121°48'E	05/01/90	1340	123
11	25°59'N;121°52'E	05/01/90	1730	106
12	25°30'N;122°14'E	05/02/90	2020	103
D 13	24°54'N;121°55'E	05/23/91	0720	50
14	24°54'N;121°58'E	05/23/91	0900	100
15	24°54'N;122°01'E	05/22/91	1600	200
E 16	26°41'N;122°18'E	07/07/89	0903	95
17	26°53'N;122°17'E	07/07/89	1300	93
18	26°57'N;122°29'E	07/07/89	1600	94
19	27°03'N;122°38'E	07/07/89	1921	92

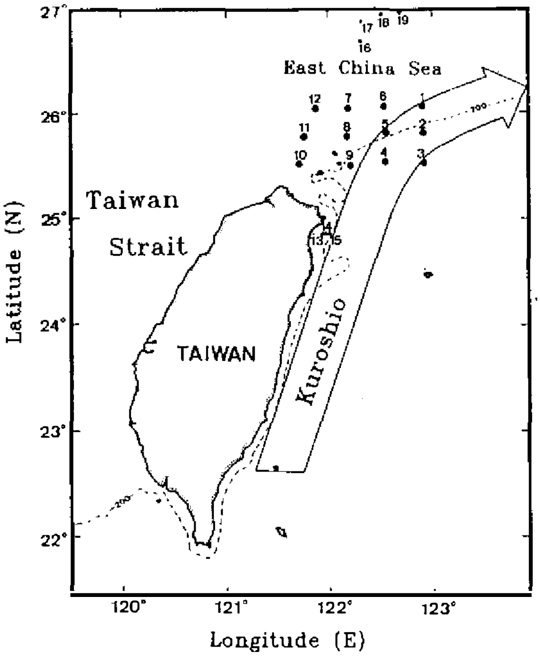

Fig. 1. Sampling stations and station groups in the ichthyoplankton study in the Kuroshio edge area and the adjacent waters.

Relative species composition was made by percentage of catch within each SG. Diversity indices and Spearman's rank correlation analysis were based on 10 based logarithmic data of catches. The relationship of SG was estimated from Euclidean distance by UPGMA method.

3. RESULTS

3.1 The T-S diagram and determination of station Group

Twelve T-S curves from sampling stations of the KEEP study area are shown in Figure 2. Based on the property of the T-S curve, three station groups can readily be distinguished in the KEEP study area. Station group (SG)-A is composed of sts. 1, 2, 3, 4, 5 and 6 (the Kuroshio water); SG-B (mixing water) of sts. 7 and 8; and SG-C (mid-shelf water) of sts. 9, 10, 11 and 12. The Kuroshio water is characterized by a property of higher temperature and lower salinity in the surface, rapid increase in salinity in the sub-surface water and salinity decrease at greater depths. The mid-shelf water is relative shallow, as indicated by the short T-S curves in this plot (Figure 2). The temperature and salinity of the surface mid-shelf water are low. Except at St. 7, all salinities are monotonically related to the temperature. The T-S curves from sts. 6, 7 and 8 are complicated. The upper layer of the water column from St. 6 indicates a similarity to the Kuroshio, but the bottom layer looks more like those of the mid-shelf. The properties of St. 7 indicated a tendency of offset of the Kuroshio. The upper water layer of st. 8 is closer to the mid-shelf; on the other hand, the lower water layer is similar to that of the Kuroshio. Since our ichthyoplankton samples were all from photic zone, we should tentatively treat data from St. 6 as part of the Kuroshio. Since in the T-S diagram, the sts. 7 and 8 are located between the Kuroshio and mid-shelf, the water from these two stations are grouped as the mixing zone.

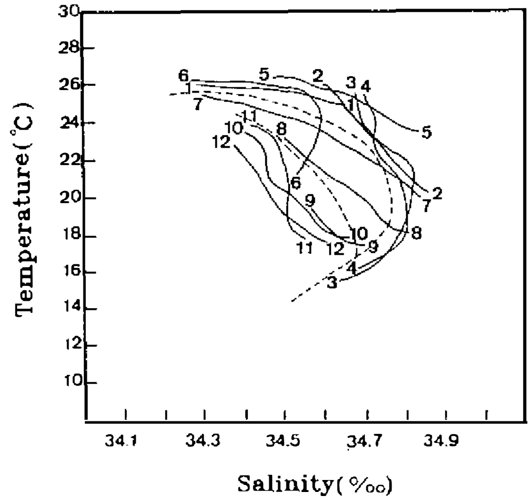

Fig. 2. The selected T-S lines from station groups of A, B, and C.

3.2 Guild characteristics

3.2.1 Species composition

Catches from ichthyoplankton sampler were converted to species composition in percentage for each station group. Those taxa having a cumulative percentage greater than 1% are selected to the checklist of ichthyoplankton species composition. The relative species composition for five station groups is shown in Table 2.

Table 2. Relative species composition of ichthyoplankton in different station groups

Family	Percentage within Station Group				
Species	A	B	C	D	E
Anguillidae					
Anguilla japonica					1.12
Apogonidae					
Apogon notatus		0.53	1.25	0.01	
Bothidae					
bothid				0.68	0.45
Bramidae					
Brama japonica	3.14	0.53			
Bregmacerotidae					
Bregmaceros atlanticus	1.78	1.07		0.01	0.45
Bregmaceros macclellandii	0.42	0.27	0.62		0.22
Bregmaceros nectabanus				0.02	3.35
Bregmaceros neonectabanus			0.42	0.93	0.22
Callionymidae					
Callionymus beniteguri				1.64	0.67
Callionymus sp.			0.83	0.51	1.79
Carangidae					
Decapterus macarellus	1.44	0.27	0.42	2.29	
Decapterus maruadsi	0.25	0.53	3.33		0.89
Decapterus sp.	0.25	1.33	0.42	35.06	1.34
Seriola dumerili	0.08	0.27			0.67
other carangid	1.44	2.13		0.35	
Champsodontidae					
Champsodon snyderi				0.03	2.01
Clupeidae					
Sardinops melanostictus			2.29	0.01	
Etrumeus teres	1.78	2.40			
Coryphaenidae					
Coryphaena hippurus	0.76	0.80		0.06	0.67
Cynoglossidae					
Cynoglossus joyneri			0.42	1.54	2.46
Gobiidae					
Pterogobius sp.				2.27	
other gobies			3.33	0.89	3.35
Gonostomatidae					
Cyclothone acclinidens		2.40			
Cyclothone alba	4.33	3.20		0.01	
Gonostoma gracile	4.41	1.60	1.25		
Vinciguerria nimbaria	11.54	1.33	0.42	0.09	0.89
Labridae					
Halichoeres poecilopterus	0.59	0.27			0.22
Thalassoma sp.		0.27	0.42	0.02	0.67
Lutjanidae					
Lutjanus vitta	0.42	1.07	1.25	0.14	
Menidae					
Mene maculata		0.80	0.21	1.61	
Mugilidae					
Liza carinata			2.08	0.21	
Liza haematocheila				3.43	
Mullidae					
Upeneus bensasi		0.53	1.46		
Mullid		1.33		8.92	1.34

Table 2. Continued

Family	Percentage within Station Group				
Species	A	B	C	D	E
Myctophidae					
Benthosema pterotum	12.22	8.80	43.24	0.71	13.17
Benthosema suborbitale	0.76		0.42		
Ceratoscopelus warmingi	1.27			0.25	
Hygophum proximum	1.36	0.53	0.21		9.15
Lampanyctus sp.	1.69	6.67	0.62		
Myctophum obtusirostre	0.42	0.53	0.62		
other myctophid	4.33	19.20		0.05	1.34
Nomeidae					
Cubiceps pauciradiatus	1.27	1.07	1.25		
Ophichthidae					
ophichthid			0.21	0.05	2.90
Paralepididae					
Lestrolepis intermedia	1.78	0.27	0.83		
Percichthyidae					
Synagrops philippinensis	0.08		0.42	0.03	6.47
Priacanthidae					
Priacanthus macracanthus	0.08	0.80	0.62	14.75	6.70
Salangidae					
Salangichthys sp.		1.07			
Scaridae					
Scarus sp.				0.56	0.67
Sciaenidae					
Argyrosomus argentatus	0.08	0.27	0.62		4.24
Nibea albiflora		1.07	1.46	0.01	
Scombridae					
Auxis sp.	0.17	2.40		0.93	1.34
Sarda orientalis	0.08	1.60		0.03	
Scomber japonicus		1.34	0.62	1.46	
Scomberomorus guttatus		0.27	1.04	4.23	10.04
Thunnus obesus	0.42	0.80		0.01	
Scopelarchidae					
scopelarchid	0.08	0.53	0.42		
Scorpaenidae					
scorpaenid	0.59		0.14	0.45	
Serranidae					
Sacura margaritacea	1.27	0.53	0.62		
Soleidae					
Aseraggodes kobensis				0.02	2.68
Sparidae					
Acanthopagrus sp.		1.07	2.91	0.03	
Sphyraenidae					
Sphyraena pinguis		1.33		0.02	
Synodontidae					
Trachinocephalus myops			1.46	0.49	2.46
other synodontid	1.61			0.01	
Theraponidae					
Rhyncopelates oxyrhynchus		0.80	0.38		
Trichiuridae					
Benthodesmus elongatus	0.76		0.62	0.01	
Trichiurus lepturus		1.33	1.66	0.19	0.45
Triglidae					
Lepidotrigla sp.				0.01	1.34
Other	37.05	24.79	19.71	14.90	13.82

In the SG-A, larvae of mesopelagic fishes constitute the major part of ichthyoplankton guild of the Kuroshio. Among them, lantern fish (*Benthosema pterotum*) counted for 12.22% of total catch. Another member of mesopelagic fish, *Vinciguerria nimbaria* was the second major species (11.54%). Primary mesopelagic fishes of the open ocean, families Gonostomatidae and Myctophidae, counted for 42.35% of total catch from SG-A. Some epiplagic-pelagic fish larvae, linked to the commercial species of coastal fishing, such as *Brama japonica* (3.14%) and carangid (3.46%), *Cubiceps pauciradiatus* (1.27%), *Sacura margaritace* (1.27%) and synodontid (1.61%), also took part in the Kuroshio ichthyoplankton guild.

In the SG-B, *B. pterotum* was still the dominant species in the ichthyoplankton guild, which made up to 8.8% of total catches. Another myctophid member, *Myctophum obtusirostre*, became the other major species in the guild. A fifth (19.2%) of catch from Myctophidae was difficult to assign a species name. More than a third (35.7%) of total catches were identified as species of Myctophidae. Gonostomid fishes became modest in the composition of SG-B guild. Four species, *Cyclothone acclinidens* (2.40%), *Gonostoma gracile* (1.60%), *C. alba* (3.20%) and *V. nimbaria* (1.30%) were collected. Epipelagic species of carangid (4.53%) and scombrid (6.41%) increased their abundance in this ichthyoplankton guild. Mackerel (*Auxis* sp., 2.40%) were the major scombrid fishes found in this guild. The taxon abundance in SG-B was significantly higher than the neighboring waters.

In the SG-C, *B. pterotum* was the most dominant species, which almost took half of total catches (43.24%). The rest of meso-pelagic species were insignificant in the guild composition. Among them, apogon (*Apogon japonica*, 1.25%), carangid (*Decapterus maruadsi*, 3.33%), clupeid (*Sadinops melanostictus*, 2.29%), gobies (3.33%), lutjanid (*Lutjanus vitta*, 1.25%), mugilid (*Liza carinata*, 2.08%), nomeid (*Cubiceps pauciradiatus*, 1.25%), sciaenid (*Nibea albiflora*, 1.46%) and sparid (*Acanthopagrus* sp., 1.33%) were the obvious species.

In the SG-D, larvae of epipelagic fishes from neritic water constitute the major part of ichthyoplankton guild. The species composition from this station group was related to the environment of the I-lan Bay. Carangid fish, most of them *Decapterus*, counted for 37.70% of the total catches. *Priacanthus macracanthus* (14.75%) was the next abundant larval fish in this offshore guild. The rest of members of coast-epipelagic fishes were mullid (8.92%), scombrid (*Scomberomorus guttatus*, 4.23%), mugilid (*L. haematocheila*, 3.43%) and gobies (*Pterogobies* sp., 2.27%). The dominance of meso-pelagic fishes, such as myctophid and gonostomid, was not significant.

In the SG-E, myctophid fishes, *B. pterotum* (13.17%) and *Hygophum proximum* (9.15%), were the dominant species which counted for 23.66% of total catches. On the other hand, gonostomid was not significant. The rest of the major components were shelf species. Major shelf species were scombrid (*S. guttatus*, 10.04%), priacanthid (*P. macracanthus*, 6.70%), percichthyid (*Synagrops philippinensis*, 6.47%), gobies (3.35%), soleid (*Aseraggodes kobensis*, 2.68%), and synodontid (*Trachinocephalus myops*, 2.46%).

3.2.2 Diversity and evenness indices

Simpson's diversity index and evenness were estimated from five station groups (Table 3). Highest diversity was found with highest evenness on the SG-E as representative of the shelf of the East China Sea. This pattern can also be re-examined at the species checklists, since no single species had taken large portion in the species composition pie (Table 2). Relative high magnitude of diversity indices and low evenness were found in SG-A and SG-B, which were influenced by the Kuroshio current. In areas closer to the Taiwan coast (SG-C and SG-D), the diversity indices were the lowest.

Table 3. Simpson diversity index

Station Group	Diversity Index	Evenness	No. of Species > 1%
A	0.8909	0.6848	17
B	0.8901	0.6841	22
C	0.8720	0.7087	15
D	0.8719	0.7607	11
E	0.8995	0.8075	12

3.2.3 Guild Similarity

Spearman's rank correlation analysis was used to test all possible relationships that might exist among station groups. The results are shown in Table 4. Five pairs of station group exhibited a high significance (P<1%) in guild composition. Those pairs were (A-B), (B-C), (C-D), (C-E), and (D-E). Two marginal correlation were found with (A-C) and (B-D). The schematic diagram for guild association is shown in Figure 3. It is worth noting that a network linkage among station group C, D, and E, that does not involve B group of the Kuroshio affected area.

Table 4. Spearman's rank correlation analysis based on the species composition of station groups

Station Groups	A	B	C	D	E
A	1*	0.8014	0.4695	0.2364	-0.212
	(20)	(20)	(20)	(20)	(20)
	1**	0.0005	0.0407	0.3028	0.9265
B		1	0.6956	0.4682	0.2074
		(20)	(20)	(20)	(20)
		1	0.0024	0.0413	0.3661
C			1	0.7744	0.5498
			(20)	(20)	(20)
			1	0.0007	0.0165
D				1	0.7591
				(20)	(20)
				1	0.0009

Remark:* - Coefficient of Spearman's rank correlation; ( ) - Sample size
** - P-value, significance.

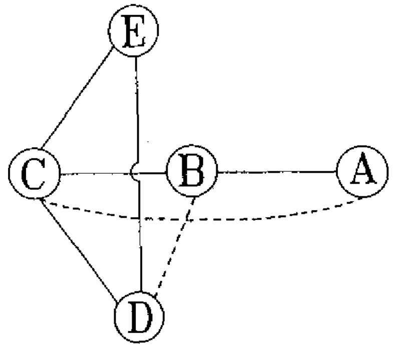

Fig. 3. Schmetic diagram indicating the guild association between station groups (A-E). (solid lines , close association ($P < 1\%$; dashed lines , marginal association, $1\% < P < 5\%$).

The dendrogram of station group, produced by UPGMA method on species composition data, is shown in Figure 4. Relative higher in-group similarity occurred in the station group of SG-A, SG-B, and SG-C. Relative low similarity occurred in the out-group of SG-D and SG-E. A relatively closer association found between stations further apart than the neighboring ones indicated a nonlinear linkage between station groups. In other words, the dispersal of ichthyoplankton fauna might take the route away from the Kuroshio flushing area, rather than going straight along the course of the Kuroshio.

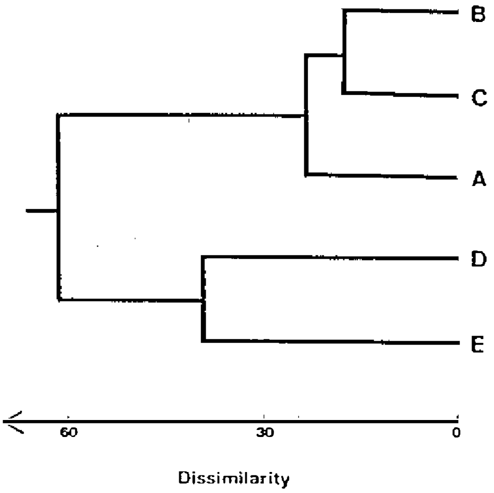

Fig. 4. The dendrogram of station groups (A-E).

4. DISCUSSION

Marine environment is a complex ecosystem composed of basic trophic hierarchy of biotic factors and current system of abiotic factors. In open ocean, this system keeps quite stable equilibrium. However, the cycle of marine process on the edge of a major current system has temporal and spatial variation. During its meroplanktonin stage, ichthyoplankton has little horizontal movement, which makes it a tracer for transport process.

In this study, we surveyed the species composition of ichthyoplankton in the KEEP area. A specific pattern of species composition was found between station groups, and thereafter, sub-regions of guild were defined. Some tendencies were found that the closer the station to the Kuroshio, the more abundant the mesopelagic species, such as *B. pterotum* and *V. nimbaria*, were. In the mixing zone, *V. nimbaria* was longer dominant, but *B. pterotum* increased its share in the oceanic ichthyoplankton guild. Carangid species and *P. macracanthus* were the major component in ichthyoplankton guild in the I-lan Bay area. With strong swimming ability, scombrid fish was the most dominant fish in the shelf of the East China Sea, but minor myctophid also played some role in the formation of oceanic guild.

The abundance of a planktonic species across sampling area or the distribution of species within a ichthyoplankton guild is the outcome of marine processes, such as current, nutrient and tropic level. However, the mechanism may be oversimplified to contribute to a marine process from an analysis of spatial pattern of ichthyoplankton. For instance, ecologists frequently used match-mismatch model to imitate the success of specific fish recruitment. Therefore, instead of using single key species (Chiu and Lee, 1991) and discussing specific species within the guild, we adopted spatial pattern analysis on the species data matrix to elucidate the nature. Using various statistical methods, this data matrix produced adequate indices in describing guild characteristics.

In this study, the Spearman's rank correlation also supported a ichthyoplankton linkage of I-lan Bay (SG-D), western of Kuroshio mixing zone (SG-C) and the shelf of the East China Sea (SG-E). This relationship suggests two facts: 1) dispersion of ichthyoplankton in mixing zone (Chiu, 1991a), and 2) indirect route of faunal transport might be taken by larval drift to avoid the Kuroshio mixing zone (Figure 3). Choosing this stable route for larval drift might be the basic mechanism to maintain a stable recruitment in the shelf fish population.

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黑潮邊緣交換區和鄰近水團的
浮游魚類群集之比較

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摘要

本研究爲黑潮邊緣交換過程(KEEP)大型計劃之部分。在本篇報告中，我們分析了黑潮邊緣交換區浮游魚類相的結構，並將此結果與交換區上游---宜蘭灣和交換區下游---東海中陸棚區之結果互相比較。

依據水文資料中溫鹽曲線圖，可以將黑潮交換區之測站分成三組：A組爲黑潮本體區，B組爲混合交換區，C組爲東海陸棚區。我們分別討論了各組間的優勢魚種和歧異度情形。利用魚種組成資料，進行Spearman氏順位相關及聚類分析，結果可以看出組間的相似程度。由組間的浮游魚類相指出，在宜蘭灣到東海陸棚處有一間接關連存在。而黑潮本體和交換區並不在這關連上，這可能暗示了黑潮交換區對仔稚魚有擴散的效應；也就是說，仔稚魚在擴散區內不能與南北鄰接區的仔稚魚相保持較穩定的相似。