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PRELIMINARY STUDIES ON SPECIES COMPOSITION OF FISH LARVAE AND JUVENILES IN THE KUROSHIO WATERS ADJACENT TO TAIWAN WITH REFERENCE TO WATER MASS AND DIURNAL VARIATION

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ABSTRACT

Fish larvae and juveniles in the surface waters of six selected stations in the Kuroshio proper and its neighboring waters in the eastern Taiwan were investigated during the period from September 10 to 12, 1986. A total of 243 fish larvae and juveniles representing 35 families and 58 species was collected in this survey. The data indicated that the larvae and juveniles could be grouped into oceanic epipelagic, mesopelagic and coastal species categories. Among them, the mesopelagic fishes especially Myctophids and Gonostomatids were found to be the most dominant, constituting up to approximately 60% of the total catch. The occurrence of larvae and juveniles was found more abundant in nighttime than in daytime, probably due to the ascending migration of the mesopelagic fish. According to the T-S diagram the water masses in these six surveyed stations were categoried into three types: Kuroshio water, coastal water and intermediate mixed water where epipelagic, coastal and mesopelagic fishes were dominant, respectively. Species diversity was greater at the stations which were influenced by the coastal water than those at warm Kuroshio water.

INTRODUCTION

The studies of species composition, distribution and abundance of fish larvae and juveniles are very important for understanding the recruitment and fluctuation of fish population. Many investigations on the species composition of fish larvae and juveniles have been conducted in the coastal waters and estuaries of Taiwan (Chen, 1985; Huang, 1985; Huang *et al.*, 1985; Tseng, 1985; Tzeng *et al.*, 1985). However, studies on the species composition of fish larvae and juveniles in the offshore waters of Taiwan were very few. Species composition and abundance of fish larvae and juveniles were known to be dependent on current system. The surrounding waters of Taiwan was known to be influenced by the Kuroshio and China coast currents (Chu, 1963). The relationship between the distribution and abundance of fish larvae and juveniles and the oceanographic condition in the waters adjacent to Taiwan has also not been attempted yet.

This paper is to describe the occurrence of fish larvae and juveniles in the Kuroshio waters adjacent to Taiwan, and their variations in relations to oceanographic condition.

MATERIALS AND METHODS

Temperature and salinity were measured by CTD casting from surface to 1000 meter depth from the six selected stations (Fig. 1) in the Kuroshio area

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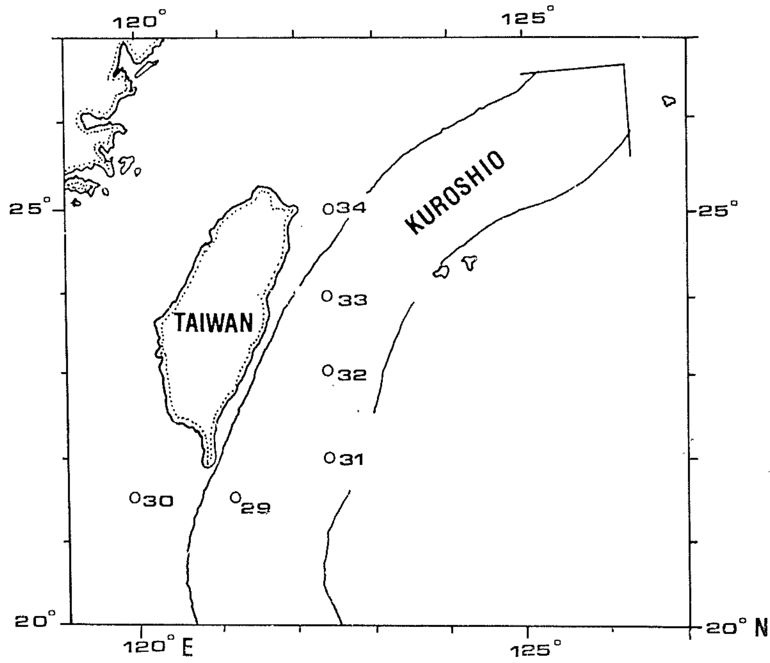
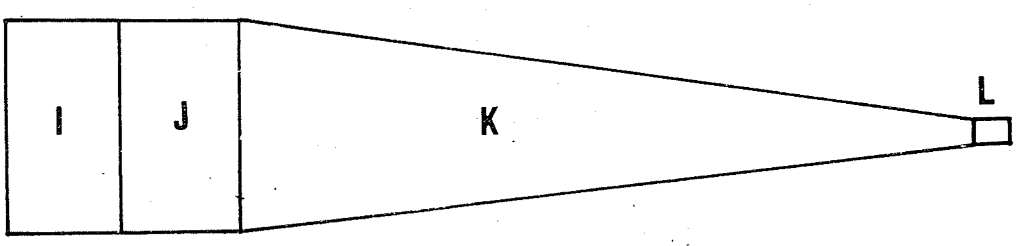


Fig. 1. Map showing the presumed path of Kuroshio along eastern coast of Taiwan in summer and the six surveyed stations (Sts 29-34) for larval netting and CTD casting.



SECTION	LENGTH (cm)	DIAMETER (cm)	MATERIAL	MESH APERTURES (mm x mm)
I	75	160	VINYLON NETTING	0.680 X 0.680
J	75	160	VINYLON SAIL CLOTH	--------
K	600	160-10	VINYLON NETTING	0.680 X 0.680
L	10	10	VINYLON SAIL CLOTH	--------

Fig. 2. Dimension and construction details of the ORI larval net.

eastern Taiwan during the period from September 10 to 12, 1986. Then temperature-salinity diagram was plotted to understand the characteristic of water mass of the station. Fish larvae and juveniles were collected with ORI (Ocean Research Institute, University of Tokyo) larval net (Fig. 2). The net was towed horizontally near the surface water at a speed of about 3 knots. The duration of net tow was preset for about 20 minutes for each stations. The flow-meter data were also recorded and used to compute the density of the fish. The samples were preserved with 10% formalin solution in the field. The larvae and juveniles were identified to the species level if possible. Their total lengths were measured to the nearest 0.1 mm. The development stages of larvae were determined following Kendall (1984). To understand the relationship between species composition of fish larvae and juveniles and water mass, the fish was grouped into oceanic epipelagic, mesopelagic and coastal species according to the habit of their adult stage. To understand the vertical migration of the fish, mesopelagic fishes were further divided into surface migrants, midwater migrants and non-migrants (Kawaguchi, 1974).

The community structures of fish larvae and juveniles in each stations were analyzed by using four species diversity indices, namely, Simpson's index of concentration (Peet, 1974), Margalef's index of species richness (Margalef, 1969), Shannon-Weaver's index of species diversity and Pielou's index of evenness (Pielou, 1966). The similarity of species composition of fish larvae and juveniles between stations was calculated by Kimoto's index of degree of overlap (Kimoto, 1976) and clustered by average-linkage method (Mountford, 1962).

RESULTS

1. Water Mass of the Surveyed Stations

The water mass of the six investigated stations, as shown by temperature-salinity diagram (Fig. 3), could be categoried into three types: (1) Stations 30 and 34 which located near to the coastal waters were found to be lower in temperature and salinity in surface layer, (2) Stations 29, 31 and 32 which located in Kuroshio waters were found to be higher in temperature and salinity in surface layer, and (3) Station 33 belonged to intermediate mixed type, water temperature and salinity were similar to those of former stations in surface layer, but similar to those of latter stations in deep layer.

The oceanographic condition in the surrounding waters of Taiwan was mainly influenced by the Kuroshio and China coast currents (Chu, 1963). Kuroshio, originated from north Equatorial current, was a warm and high saline water. In contrary, China coast current a cold and low saline water came from the north along the coast of China. The T-S diagram shown in Fig. 3 indicated that the water of higher temperature and salinity in stations 29, 31 and 32 might belong to Kuroshio water and the cold and low saline in the surface water at the stations 30 and 34 was resulted from the influences of the coastal water. Station 33 was also influenced by the coastal water, but very limited only in the surface layer.

2. Occurrence of Fish Larvae and its Relation to Water Mass

A total of 243 individuals representing 35 families and 58 species was collected in this survey (Table 1). Most of the larval and juvenile fish belonged to postlarvae, including preflexion, flexion and postflexion stages. The body lengths of most fish were less than 10 mm, except the surface migrant myctophids which belonged to young stage and were able to migrate. The length frequency

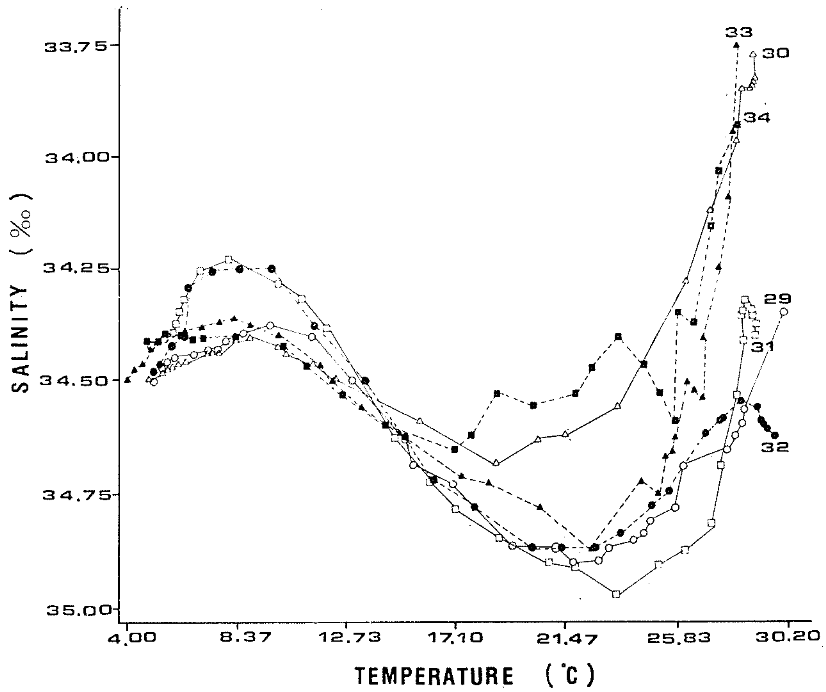


Fig. 3. Comparison of T-S curves of the six surveyed stations (Sts 29-34).

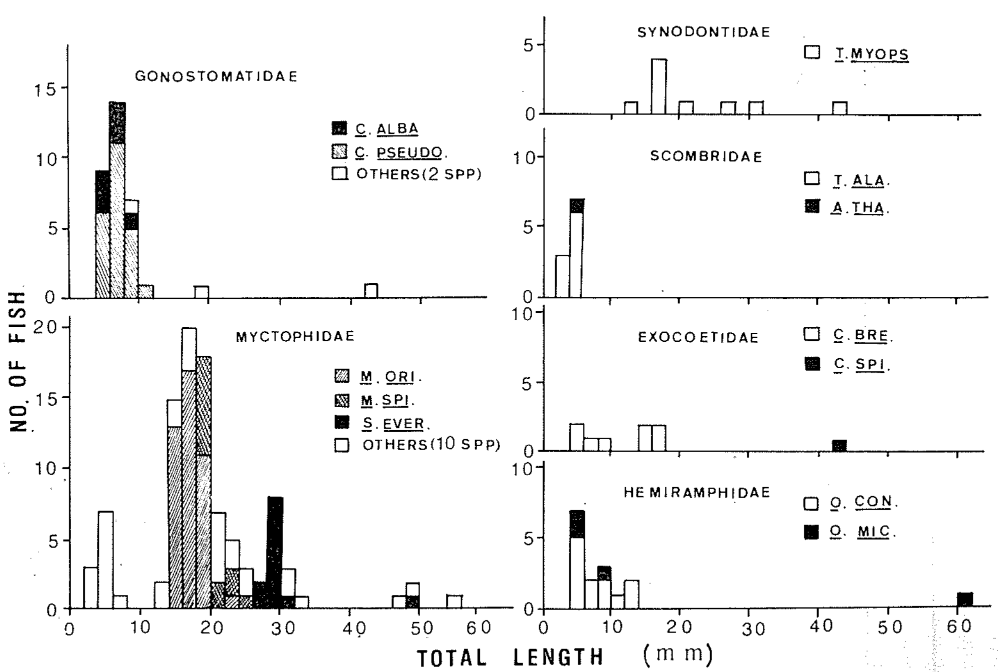


Fig. 4. Length frequency distribution of the dominant fish larvae and juveniles collected by the ORI larval net with surface tow in the adjacent waters of Taiwan, Sept. 10-12, 1986. Abbreviations of species name refer to Table 1.

Table 1. Development stage, occurrence, number and total length of fish larvae and juvenile collected by ORI larval net with surface tow from six surveyed stations in the adjacent waters of Taiwan, Sept. 10-12, 1986. Species are categoried by ecotype

Species	Development stages*	No. of individuals							Total length (mm)	
		St. 29	30	31	32	33	34	Total	Range	Mean
I. Oceanic epipelagic fishes										
Hemiramphidae										
Oxyporhamphus convexes convexes	Po.	11			1			12	4.7-12.2	7.67
Oxyporhamphus micropterus	Po.		1	2				3	3.5- 8.8	6.07
	Ju.			1				1	60.5	60.5
Exocoetidae										
Cypselurus (Prognichthys) brevipinnis	Po.	1						1	5.0	5.0
	Ju.			2	1			3	5.4- 8.5	6.97
	Yo.			4				4	14.5-16.8	15.88
Cypselurus spilopterus	Yo.		1					1	43.5	43.5
Coryphaenidae										
Coryphaena hippurus	Pr.		1	2				3	3.7- 4.1	3.93
	Fl.						2	2	4.1- 4.4	4.25
Istiophoridae										
Gen. sp.	Pr.	1		1	1			3	3.1- 3.7	3.40
Scombridae										
Thunnus alalunga	Fl.	1		8				9	3.7- 5.0	4.28
Auxis thazard	Fl.						1	1	4.1	4.1
II. Mesopelagic fishes										
(1) Surface migrants										
Mycophidae										
Myctophum orientale	Yo.		15	1		30	1	47	14.5-22.3	17.58
	Ad.		3					3	48.0-93.0	63.67
Myctophum nitidulum	Yo.		2					2	23.9-24.4	24.15
Myctophum spinosum	Yo.		5			5	2	12	18.5-24.6	20.44
Hygophum proximum	Yo.					2		2	16.0-16.6	16.3
Hygophum reinhardti	Yo.					4		4	14.0-16.8	15.22
Symbolophorus evermanni	Yo.		11	1				12	18.5-30.8	28.21
Centrobranchus choerocephalus	Yo.			5				5	22.5-34.0	28.80
Centrobranchus brevirostris	Yo.					1		1	17.0	17.0

Table 1. (continued)

Species	Development stages*	No. of individuals St. 29	30	31	32	33	34	Total	Total length (mm) Range	Mean
(2) Midwater migrants										
Myctophidae										
Benthosema pterotum	Fl.		1					1	4.3	4.3
Benthosema sp. 1	Fl.						2	2	3.7– 4.6	4.15
Benthosema sp. 2	Fl.						1	1	3.7	3.7
Ceratoscopelus warmingi	Pr.			1				1	3.4	3.4
Lampadana sp.	Fl.		2	3			1	6	4.1– 6.4	5.05
Gonostomatidae										
Diplophos taenia	Fl.						1	1	19.0	19.0
	Yo.			1				1	43.0	43.0
Melanostomiidae										
Gen. sp.	Pr.						2	2	4.4– 6.7	5.55
(3) Non-migrants										
Gonostomatidae										
Cyclothone alba	Fl.			2				2	4.8– 5.0	4.9
	Po.	1		2			2	5	6.0– 9.9	7.30
Cyclothone pseudopallida	Po.			4			19	23	4.7–10.8	7.24
Cyclothone atraria	Po.						1	1	9.9	9.9
III. Coastal fishes										
Elopidae										
Elops hawaiensis	Le.						1	1	24.3	24.3
Congridae										
Ariosoma sp.	Le.		1			1		2	30.5–103.8	67.15
Ophichthidae										
Gen. sp.	Le.		1					1	77.7	77.7
Clupeidae										
Sardinella zunasi	Po.						2	2	13.1–14.5	13.8
Engraulidae										
Stolephorus sp.	Po.						2	2	7.0– 7.8	7.4

Table 1. (continued)

Species	Development stages*	No. of individuals							Total length (mm)	
		St. 29	30	31	32	33	34	Total	Range	Mean
Synodontidae										
Trachinocephalus myops	Po.		6				4	10	13.3–42.9	22.95
Serranidae										
Epinephelus sp.	Fl.						1	1	3.3	3.3
Apogonidae										
Archamia sp.	Po.		1					1	7.7	7.7
Gen. sp.	Po.						1	1	9.2	9.2
Priacanthidae										
Gen. sp.	Pr.						1	1	3.2	3.2
Sillaginidae										
Sillago japonica	Fl.						2	2	3.5– 3.8	3.65
	Po.						1	1	6.4	6.4
Carangidae										
Decapterus macarellus	Fl.				1		2	3	3.1– 4.9	4.17
Decapterus sp.	Ju.						1	1	39.53	39.5
Gen. sp.	Pr.				1			1	3.1	3.1
Leiognathidae										
Gen. sp.	Pr.						2	2	2.3– 2.4	2.35
	Po.	1						1	4.0	4.0
Lutjanidae										
Gen. sp. 1	Fl.						2	2	4.3– 4.4	4.35
	Po.						1	1	7.3	7.3
Gen. sp. 2	Fl.						1	1	3.9	3.9
Gen. sp. 3	Pr.						1	1	3.4	3.4
Nemipteridae										
Gen. sp.	Fl.						1	1	3.4	3.4
Sparidae										
Gen. sp.	Fl.						1	1	4.5	4.5
Sciaenidae										
Gen. sp.	Fl.						3	3	3.7– 4.0	3.87

Table 1. (continued)

Species	Development stages*	No. of individuals St. 29	30	31	32	33	34	Total	Total length (mm) Range	Mean
Mullidae										
Gen. sp. 1	Po.	1					1	2	4.9- 7.0	5.95
Gen. sp. 2	Fl.				1			1	4.8	4.8
	Po.				1			1	8.4	8.4
Pomacentrida										
Gen. sp.	Fl.	2				1	1	4	3.2- 4.3	3.75
Labridae										
Xyrichthys sp.	Fl.						1	1	5.0	5.0
	Po.						2	2	11.0-13.4	12.20
Scaridae										
Gen. sp.	Po.						2	2	7.3- 8.0	7.65
Blenniidae										
Omobranchus sp.	Po.				1			1	14.4	14.4
Scorpaenidae										
Gen. sp.	Po.						1	1	8.2	8.2
Bothidae										
Bothus pantherinus	Po.					2		2	16.1-20.0	18.15
Balistidae										
Canthidermis maculatus	Pr.		2					2	2.7- 3.3	3.0
	Fl.			1				1	5.9	5.9
	Yo.			1				1	31.0	31.0
Diodontidae										
Diodon eydouxii	Yo.			1				1	16.5	16.5
Unidentified sp.	Fl.			1				1	5.1	5.1
No. of species		8	14	16	7	8	34	58		
No. of individual		19	53	44	8	46	73	243		
Density (Ind./1000 m^3 sea water)		5.85	18.96	12.76	2.83	13.83	24.42	13.14		

* Pr.: Preflexion larva, Fl.: Flexion larva, Po.: Postflexion larva, Le.: Leptocephalus, Ju.: Juvenile, Yo.: Young, Ad.: Adult.

distributions of six dominant families were shown in Fig. 4.

The occurrence of fish larvae and juveniles was obviously correlated with water masses of the stations (Table 2). Oceanic epipelagic fishes were dominant in the Kuroshio water, contributing 52.1% of the total catch of the stations 29, 31 and 32. Among them, *Oxyporhamphus* spp., *Thunnus alalunga* and *Cypselurus* spp. which undoubtedly belonged to oceanic species were abundant in Kuroshio water, but very few in coastal water and not found in intermediate mixed water. Mesopelagic fishes, especially *Myctophum orientale, M. spinosum, Cyclothone pseudopallida* and *S. evermanni,* were dominant in both coastal water (sts 30 and 34) and intermediate mixed water (st 33), contributing 56.3% and 91.3%, respectively. Coastal species was more abundant in the cold coastal waters (sts 30 and 34), especially *Trachinocephalus myops* only found in the coastal water and not found in Kuroshio water.

In addition, the abundance of fish larvae and juveniles was also correlated with the water mass of the station, the density of fish larvae and juveniles was higher in the coastal water station than in the Kuroshio water station (Tables 1, 2).

3. Diurnal Variation of Larval Abundance

The occurrence of fish larvae and juveniles was more abundant in the nighttime than in the day time (Fig. 5). The difference was probably due to the diurnal vertical migration of the surface migrant myctophids because the surface migrant myctophids occurred abundantly around midnight, declined in the earlier morning, and finally disappeared during daytime (Fig. 5, dashed line). This suggested that the

Table 2. Comparison of species composition of fish larvae and juvenile collected with the ORI larval net from six surveyed stations in three different water masses in the Kuroshio waters off Taiwan, Sept. 10-12, 1986

Species and family	Occurrence percentage in number of fish: Kuroshio water (st 29, 31, 32)	Coastal water (st 30, 34)	Mixed water (st 33)
1. Oceanic epipelagic species	52.1	4.8	0
Hemiramphidae			
Oxyporhamphus spp.	21.1	0	0
Scombridae			
Thunnus alalunga	12.7	0	0
Exocoetidae			
Cypselurus spp.	9.9	0.8	0
Istiophoridae			
Gen. sp.	4.2	0	0
2. Mesopelagic species	29.6	56.3	91.3
Myctophidae			
Myctophum orientale	1.4	15.1	65.2
M. spinosum	0	5.6	10.9
Symbolophorus evermanni	1.4	8.7	0
Gonostomatidae			
Cyclothone pseudopallida	5.6	15.1	0
3. Coastal species	18.3	38.9	8.7
Synodontidae			
Trachinocephalus myops	0	7.9	0
Total: Species	7-16	14-34	8
Total: Individual	71	126	46
Density (No./1000 m^3)	2.8-12.8	19.0-24.4	13.8

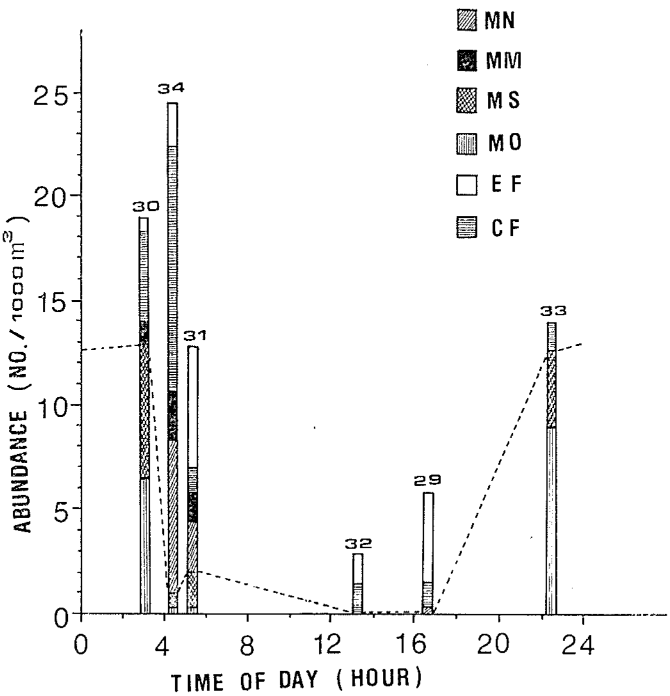


Fig. 5. Diurnal variation of species composition and abundance of fish larvae and juvenile collected by the ORI larval net with surface tow in the adjacent waters of Taiwan, Sept. 10-12, 1986. Numerals indicate the stations (Sts 29-34). CF=Coastal fish; EF=Epipelagic fish; MS, MM and MN=Surface migrating, midwater migrating and non-migrating mesopelagic fishes; MO=*Myctophum orientale.*

difference of larval abundance between daytime and nighttime in the surface waters was closely correlated with the vertical migration of surface migrant myctophids.

4. Species Diversity and Similarity

The community structure of fish larvae and juveniles was shown in Fig. 6. The value of concentration index ($\Sigma\pi^2$) was higher and index of eveness (J') was lower in the stations 29, 30 and 33 indicating that there were dominant species in these three stations. The dominant species occurred in the station 29 was *Oxyporhamphus convexes convexes*, and that in the stations 30 and 33 was *Myctophum orientale* (Table 1). The other stations seemed no dominant species. Both indices of species richness (d') and species diversity (H') were higher in the station 34 than in the other stations, indicating that the community structure was more complicated in this station. The reasons is probably due to many coastal species occurred in the station 34 (Table 1).

The similarity of species composition among stations increased as the sampling time of the day was closer (Fig. 7-(A)). In the other hands, when the diurnal vertical migrating myctophids which were dominant in nighttime collection (Fig. 5) were disregarded, the similarity of species composition among stations could be clustered into three groups which seemed to be corresponding to the different types of water masses except station 31 (Fig. 7-(B)). It indicated that species

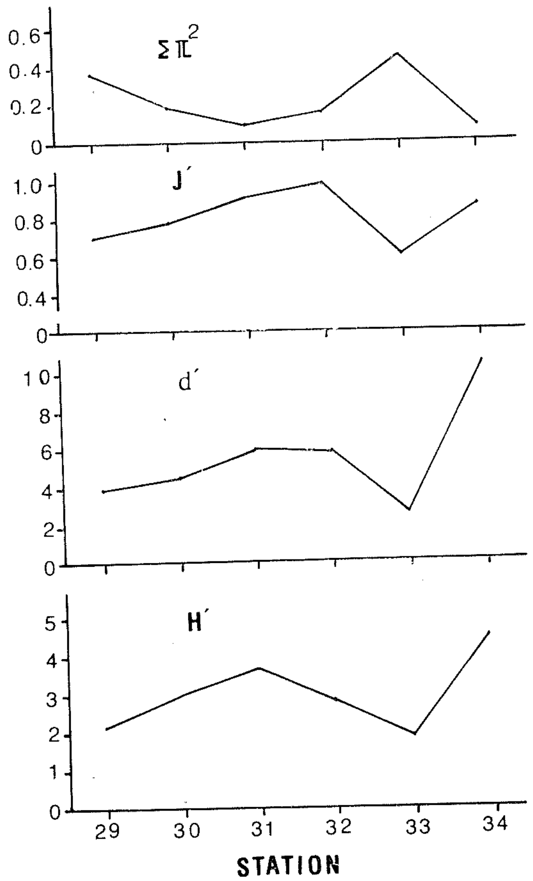


Fig. 6. Comparison of species diversity indices among stations. $\sum\pi^2$: Simpson's index of concentration, J': Pielou's index of evenness, d': Margalef's index of species richness and H': Shannon-Weaver's index of species diversity.

composition of fish larvae and juveniles seemed to be a good indicator of water mass.

DISCUSSION AND CONCLUSION

Mesopelagic fishes constituted most of the total catch of fish larvae and juveniles in this investigation (Table 1). The mesopelagic fishes were classified into surface migrants, midwater migrants and non-migrants according to their migration depth (Kawaguchi, 1974). The surface migrant myctophids distributed in 200–400 m depth during daytime and ascending to 0–10 m during nighttime. Therefore, surface migrant myctophids were possibly collected in the surface layer. In the other hand, the midwater migrant and the non-migrant myctophids were also found in the surface collection. The midwater migrants inhabited in 400–700 m in daytime and only ascended to 20–200 m in nighttime. They might appear in the surface layer where deeper water was upwelled or intrused into shallow coastal water (Kawaguchi *et al.*, 1972). The midwater migrant myctophids occurred in the coastal water (stations 30 and 34) and Kuroshio

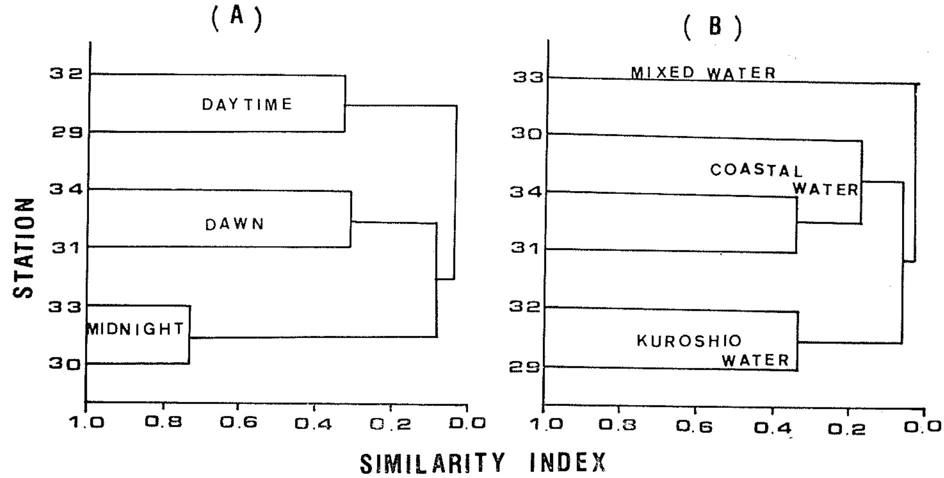


Fig. 7. Similarity of species composition of fish larvae and juvenile among stations 29–34, by the time of day (A) and the type of water mass (B). Similarity index was calculated using Kimoto's index of degree of overlap and clustered by Mountford's average linkage method. In diagram (B), the data of surface migrant myctophids were disregarded because their occurrence varied with the time of day.

water (station 31), probably indicated that the surface water in these stations were exchanged.

Diurnal migration of myctophids was studied in the waters adjacent to Japan, e. g. *Myctophum affine*, *Tarletonbeania taylori*. These two species ascended to sea surface layer during 20:00–04:00 and redescended to deep layer after sunrise (Hattori, 1964). The surface migrant myctophids collected in this study seemed to show the similar migration (Fig. 5).

Fish larvae and juveniles were more abundant in coastal water than in Kuroshio water (Table 2). The station which was influenced by coastal water revealed that the species composition of fish larvae and juveniles constituted the majority of coastal species (Table 1; e. g. station 34). Meanwhile, the occurrence of fish larvae and juveniles in the surface water was significantly different between day- and night-time collection (Fig. 5). These phenomena indicated that the abundance and species composition of fish larvae and juveniles were correlated both with the water mass and the sampling time of day. However, the larval communities in tropical areas were well known for their high species diversity. Before drawn a more concrete conclusions on species composition of larvae and juveniles in relation to oceanographic conditions in the surrounding waters of Taiwan, a many sampling cruises would be required for further investigation.

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臺灣東部黑潮水域仔稚魚出現特性之初步研究

曾 萬 年

摘 要

為了瞭解臺灣東部黑潮鄰近水域仔稚魚的種類組成與水塊之關係，以及仔稚魚出現的日夜性差異。1986 年 9 月於臺灣南部及東部海域，以 ORI 型稚魚網（口徑 160 cm，網身長 750 cm，網目 $0.68 \times 0.68\ mm^2$）表層拖曳方式，分六個測站採集仔稚魚。

結果，共發現仔稚魚 35 科、58 種、243 尾。這些仔稚魚依生態習性不同，可分為三大類別；即 (1)外洋表層性，(2)中層性及 (3)沿岸性。其中，以中層性的燈籠魚科（Myctophidae）及櫛口魚科（Gonostomatidae）魚類數量最多，佔總採獲量的60%。夜間仔稚魚的出現量比白天多，其原因可能與中層性仔稚魚的晝夜垂直運動有關。溫鹽曲線顯示，六個測站的海水性質有顯著差異；其中受沿岸水影響比較明顯的測站，仔稚魚出現量較多，種類組成也比較複雜。