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Diurnal Cycling in Vertical Distribution of Ichthyoplankton at a Fixed Station off Northwestern Taiwan

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Tai-Sheng Chiu and Kwang-Zong Chang (1995) Diurnal cycling in vertical distribution of ichthyoplankton at a fixed station off northwestern Taiwan. *Zoological Studies* **34**(3): 183-192. The diurnal vertical variation of ichthyoplanktonic abundance was investigated on May 21-22, 1994, at a 65 m deep fixed station (25°12'N, 121°20'E) situated 7 km offshore from the mouth of the Tanshui River, Taiwan. Temperature was stratified at noon but was homogeneously distributed during the remainder of the day. A similar distribution pattern was found also in salinity profiles. The density of ichthyoplankton ranged from 126 to 3167 ind/1000 m^3. The highest density occurred in bottom water at 0100 and a fairly even distribution occurred in mid-water. A total of 5,860 ichthyoplankton specimens was collected and 222 species, or species groups belonging to 82 families, were identified. *Sardinops melanostictus* was the most abundant, making up 7.2% of the total catch. The next four most abundant species were *Callionymus huguenini* (5.1%), *Mene maculata* (4.7%), *Auxis* spp. (4.3%) and *Therapon jarbua* (3.8%). The dendrogram from the clustering method of unweighted pair-group method using arithmetic averages (UPGMA) exhibited three assemblages: mid-night (0100), after-dark (1900) and daytime (0700 and 1300). The former two assemblages were grouped as the nighttime assemblage because they were similar, and the dominant species were *Leiognathus rivulatus, Setipinna tenuifilis, Ctenotrypauchen microcephalus*, gobiid and ophichthid. The daytime assemblage was primarily composed of *Scomberoides lysan, Therapon jarbua, Sardinops melanostictus, Upeneus bensasi*, and *Holocentrus* sp.

Key words: Larval fish, Diversity, Length frequency.

The ichthyoplanktonic fauna has previously been surveyed in the offshore waters of northwestern Taiwan. Samples were collected from the photic zone at depths of less than 200 m (Chiu and Chang 1994). Also, several surveys of fish larvae and early juveniles have been conducted in estuaries and coastal waters of northern Taiwan (Chan et al. 1985, Tzeng et al. 1985, Tzeng and Wang 1992). The samplings were conducted at specific times of day or at specific stages of the tidal cycle.

Movement of younger stages of fish in coastal waters is affected by illumination and by tidal cycle. Most ichthyoplanktonic species exhibit diurnal vertical migration (Williams and Hart 1974) in which larval fish move between bottom and upper water layers. They are also carried in and out by water movement in the tidal range. The combined effect of illumination and tidal cycle may result in a complex pattern of ichthyoplanktonic distribution. Thus, comprehensive data are needed on diurnal vertical distribution of ichthyoplankton to characterize the temporal and spatial variations in its abundance and distribution.

This study sought to determine variations in the vertical distribution patterns of ichthyoplankton in the offshore waters of northwestern Taiwan.

MATERIALS AND METHODS

After a reconnaissance survey, a fixed station was selected for the study at 25°12'N and 121°20'E with a depth of 65 m (Fig. 1). This station was located 7 km outside the mouth of the Tanshui River, which is the largest river in northern Taiwan;

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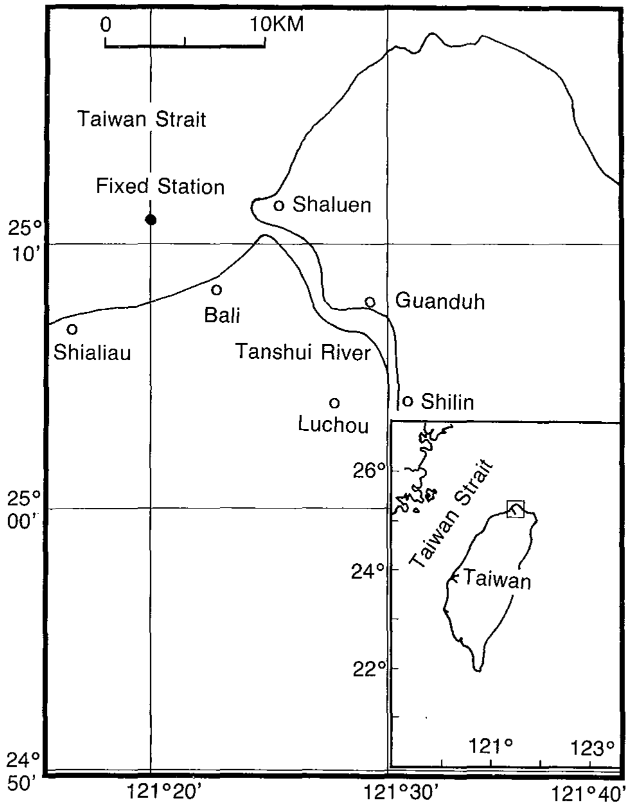

Fig. 1. Location of the fixed station for the study of diurnal vertical distribution of ichthyoplankton.

it drains the Taipei metropolitan area.

Ichthyoplankton was sampled at six-hour intervals for 24 hours starting at 0700 May 21, 1994. A 4-m stretched conical net with 1.0 mm mesh and an opening of 130 cm diameter was used for sampling. A Hydro-Bios flowmeter was set in the center of the opening to estimate the water volume straining through the net. During each time period, three samples were taken: one sample each at the depths of 0 m (surface water), 30 m (mid-water) and 60 m (bottom water). The sampling period was 15 min. No gauge was used for opening and closing the ichthyoplankton net, so during the mid-water and bottom trawls, a wire was laid out under the vessel to maintain a minimal headway. Once the net reached the desired depth, the vessel speed was increased to 3 knots. At the end of the sample period, the vessel was set adrift and the net was quickly hauled up. The catches were preserved in a 10% formalin sea water solution, and brought back to the laboratory for identification. Each individual specimen was identified to species or species group, and its total length was measured.

For each sampling, the water volume filtered through the net was estimated from the reading of the flowmeter, and the density of ichthyoplankton was calculated accordingly. The abundance of each species or species group of ichthyoplankton in the sample was converted to a percentage value. The latter was compared among the three depths of a sampling period, and also among the four sampling periods at a given sampling depth. Spearman's rank correlation analysis, a measure of resemblance, was conducted for selected dominant species. A clustering algorithm of unweighted pair-group method using arithmetic averages (UPGMA) was used to categorize temporal spatial variations into similar groups. Hydrographic conditions were measured by a conductivity-temperature-depth (CTD) sensor (SBE 19 SEACAT Profiler, SEA-BIRD ELECTRONIC, INC.).

RESULTS

Hydrographic conditions

The vertical profiles of average temperatures and salinities at the fixed station are plotted in Fig. 2. The temperature profiles indicated a homogeneous distribution through the water column at 0100 (26.75-26.77 °C), 0700 (26.80-26.82 °C) and 1900 (27.00-27.01 °C), and temperature stratification at 1300. A thermocline was located at just above 7 m (27.06-27.23 °C), a slight reversed temperature gradient existed between 7 and 15 m (27.06-27.14 °C) and a lower thermocline existed between 15 and 20 m (26.85-27.14 °C). The temperature of the deeper water remained unchanged (26.85-26.77 °C). A similar pattern in the salinity profile was also found at the fixed station (Fig. 2). Except at 0700 and 1300, the salinity profiles of sea water indicated a homogeneous distribution through the water column. The highest salinity was found at 0100 (ca. 34.60 ppt), the next highest at 1900 (ca. 34.58 ppt) and the lowest at 0700 (34.46-34.54 ppt). At 1300 salinity varied from the surface to 15 m depth (34.58-34.54 ppt), but became homogeneous in the lower layers (34.56-34.60 ppt).

Ichthyoplanktonic density

Ichthyoplankton in the samples consisted of fish eggs, larvae and early juvenile stages. Zooplankton was also present. The temporal variations in the densities of fish eggs, ichthyoplankton and zooplankton at the three water depths are shown in Fig. 3. The highest density of fish eggs (1774 ind/1000 m^3 and 0.53 g/1000 m^3) was located in mid-water at 0100, while at 0700, a comparatively high density occurred in bottom water (1078 ind/1000 m^3 and 0.65 g/1000 m^3). This suggests a settling downward of the eggs into the bottom water.

The densities of ichthyoplankton ranged between 126 ind/1000 m^3 and 3167 ind/1000 m^3. The highest density occurred in bottom water at 0100. The second highest density was 1787 ind/1000 m^3 in surface water at 1900. In mid-water the densities at three time periods were almost equal: 1148 (0100), 1288 (0700) and 1311 (1900) ind/1000 m^3. A similar pattern was found for the densities as measured by weight (g/1000 m^3). The highest weight density recorded at each of the three depths was 12.6 g/1000 m^3 (surface at 1900), 5.1 g/1000 m^3 (mid-water at 1900) and 11.8 g/1000 m^3 (bottom at 0100). A relatively even distribution of ichthyoplankton was found in mid-water, except at 1300 when the densities were low at all three depths.

An exceptionally high density (500 g/1000 m^3) of zooplankton was found in bottom water at 0100, followed by 229 g/1000 m^3 in mid-water at 0100 and 1900 (Fig. 3).

Composition and dominant species

In total, 5,860 individual ichthyoplanktonic specimens were caught and 222 species or species groups in 82 families were identified. The major species that occurred at least once with number greater than 1% of the sample are shown in Table 1. *Sardinops melanostictus*, accounting for 7.2% of the total catch, was the most abundant species. The remaining ten major species in terms of abundance were *Callionymus huguenini* (5.1%), *Mene maculata* (4.7%), *Auxis* spp. (4.3%), *Therapon jarbua* (3.8%), *Konosirus punctatus* (3.5%), *Scomberoides lysan* (2.9%), *Leiognathus rivulatus* (2.8%), *Setipinna tenuifilis* (2.6%) and *Priacanthus macracanthus* (2.5%). Of the 222 species or species groups examined, twenty-six species were each found to account for more than 1% of the total catch. Most of these species are important fishery species except a few mesopelagic species of Myctophidae and Paralepididae.

Diurnal and vertical patterns

The estimated densities of 222 species or species groups at the three water depths and the four sampling periods were rearranged semi-arbitrarily into 135 categories for handling con-

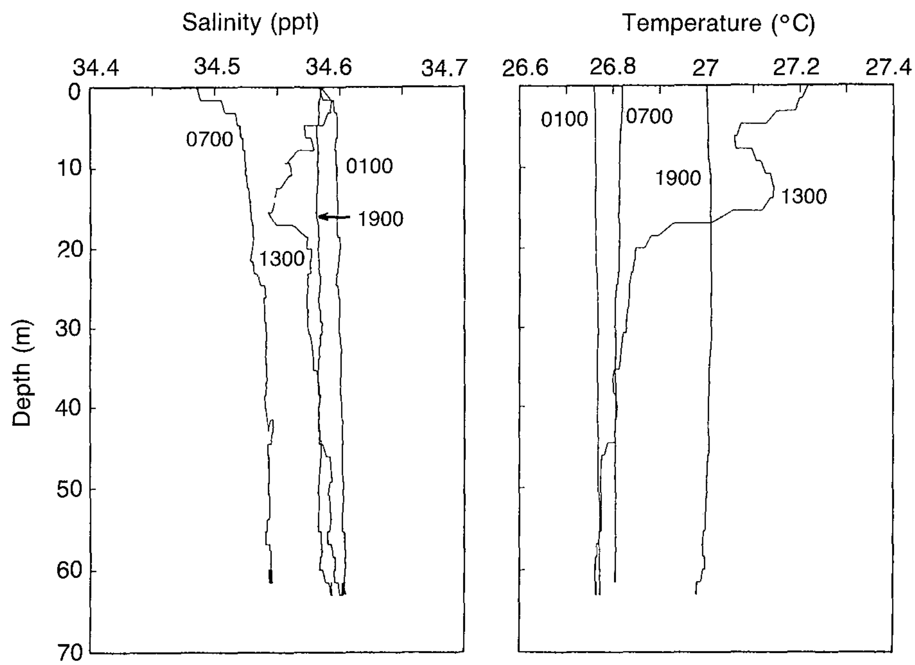

Fig. 2. Temperature and salinity profiles at the fixed station during the diurnal vertical distribution study of ichthyoplankton.

venience. For each family, besides the dominant species, the minor species were combined as "others", but sometimes all species were lumped together when their numbers were small.

The cluster analysis was applied to those categories having a density greater than 10 ind/1000 m^3. Dendrogram and subsequent nodal analysis, depicting the temporal and spatial similarities among species or species groups of ichthyoplankton, are shown in Fig. 4. There were marked temporal variations in the densities of ichthyoplankton. Three distinctive assemblages at three sampling periods were identified as mid-night (0100), after-dark (1900) and daytime (0700 and 1300). The ichthyoplankton assemblages in surface and mid-water at 0700 were similar to those at 1300, and less similar to the bottom assemblage at 0700 (Fig. 4).

The mid-night and after-dark assemblages, which were fairly similar to each other and different from the daytime assemblage, were combined as the nighttime assemblage. The nighttime species were *Leiognathus rivulatus, Setipinna tenuifilis, Ctenotrypauchen microcephalus*, gobiid, ophichthid,

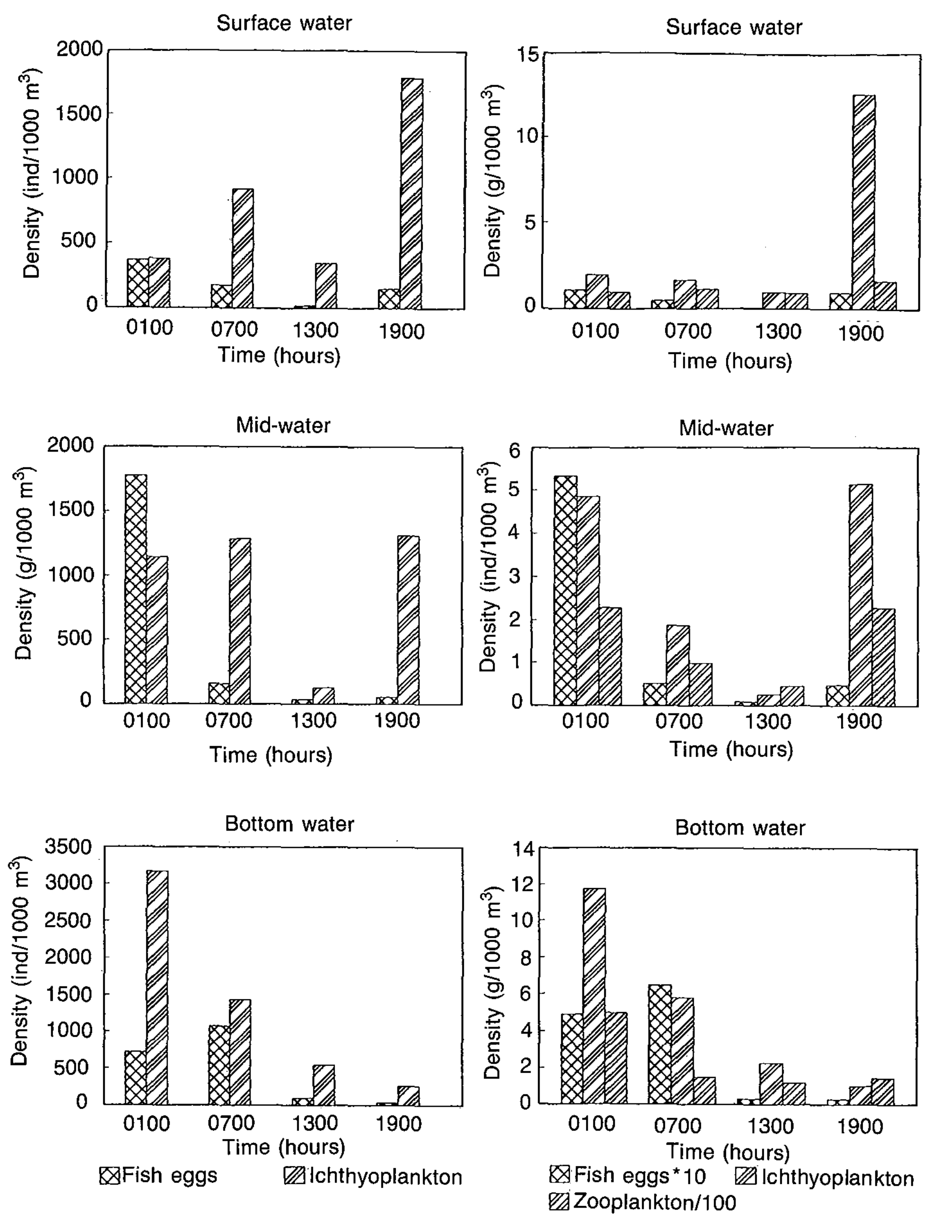

Fig. 3. Density variation of fish eggs, ichthyoplankton and zooplankton at three water depths and four sampling periods.

Table 1. A list of major species of ichthyoplankton which occurred at fixed station in waters off NW Taiwan, May 21-22, 1994

Family	Occurrence (%)			
Species	Bottom water	Mid-water	Surface water	Total
Clupeidae				10.92
Konosirus punctatus	0.59	9.18	0.17	3.53
Sardinops melanostictus	8.25	10.28	2.21	7.20
Gobiidae				10.60
Boleophthalmus pectinirostris	1.56	0.86	0.06	0.87
Ctenotrypauchen microcephalus	1.56	1.77	0.35	1.28
others	10.98	8.08	4.19	7.95
Myctophidae				5.68
Ceratoscopelus warmingi	0.88	1.20	1.40	1.14
Diaphus pacificus	0.59	0.96	1.57	1.01
Lampanyctus spp.	0.34	0.14	2.33	0.85
Carangidae				5.39
Decapterus spp.	0.83	0.81	1.51	1.02
Scomberoides lysan	2.44	2.06	4.30	2.85
Leiognathidae				5.24
Leiognathus nuchalis	0.15	1.24	0.12	0.53
Leiognathus rivulatus	4.10	2.34	1.75	2.78
Leiognathus spp.	1.12	0.00	1.80	0.92
Callionymidae				5.07
Callionymus huguenini	8.88	2.01	4.19	5.05
Menidae				4.68
Mene maculata	4.29	1.96	8.44	4.68
Scombridae				4.57
Auxis spp.	1.95	4.92	6.69	4.41
Theraponidae				3.89
Therapon jarbua	3.47	3.44	4.60	3.79
Engraulidae				2.90
Setipinna tenuifilis	2.24	4.06	1.34	2.63
Paralepididae				2.87
Lestidiops spp.	1.22	3.68	2.79	2.56
Bothidae				2.83
Engyprosopon multisquama	2.20	1.20	2.39	1.89
Priacanthidae				2.73
Priacanthus macracanthus	2.54	2.53	2.44	2.51
Mugilidae				2.47
Liza haematocheila	0.73	1.39	0.58	0.92
Liza macrolepis	1.22	0.33	0.06	0.56
Apogonidae				2.27
Apogon spp.	0.88	1.62	2.27	1.55
Synodontidae				2.13
Trachinocephalus myops	1.02	1.82	2.56	1.76
Cynoglossidae				2.13
Cynoglossus joyneri	0.93	1.24	1.28	1.14
Paraplagusia japonica	1.07	0.38	1.11	0.84
Holocentridae				2.12
Holocentrus sp.	2.10	1.24	3.20	2.12
Gerreidae				2.12
Gerres japonicus	2.24	1.34	2.21	1.91
Sillaginidae				1.88
Sillago japonica	1.42	1.43	0.35	1.11
Sillago sihama	0.34	0.67	1.11	0.68
Mullidae				1.40
Upeneus bensasi	1.42	1.39	1.40	1.40
Ophichthidae				1.04
Ophichthid	1.46	0.53	0.64	0.89
Ambassidae				1.01
Ambassis spp.	0.83	0.53	1.45	0.90
Tetraodontidae				0.87
Tetraodontid	0.00	0.00	1.11	0.32

Engyprosopon multisquama and labrid (Fig. 4).

The daytime assemblage was composed of six species: *Scomberoides lysan, Therapon jarbua, Sardinops melanostictus, Upeneus bensasi, Holocentrus* sp., and *Konosirus punctatus*. There was no significant difference in the assemblage between 0700 and 1300. With the exception of *S. melanostictus* and *K. punctatus*, the densities of daytime species were comparatively low.

Little diurnal difference was found in densities of *Decapterus* spp., *Apogon* spp., *Mene maculata, Cynoglossus joyneri, Priacanthus macracanthus, Trachinocephalus myops*, and *Diaphus pacificus* (Fig. 4).

Correlation and diversity of assemblages

Spearman's rank correlation analysis was applied to the ichthyoplanktonic assemblages at the three water depths and the four sampling periods (Table 2). Most of the assemblages were not correlated at the 5% significant level, except four

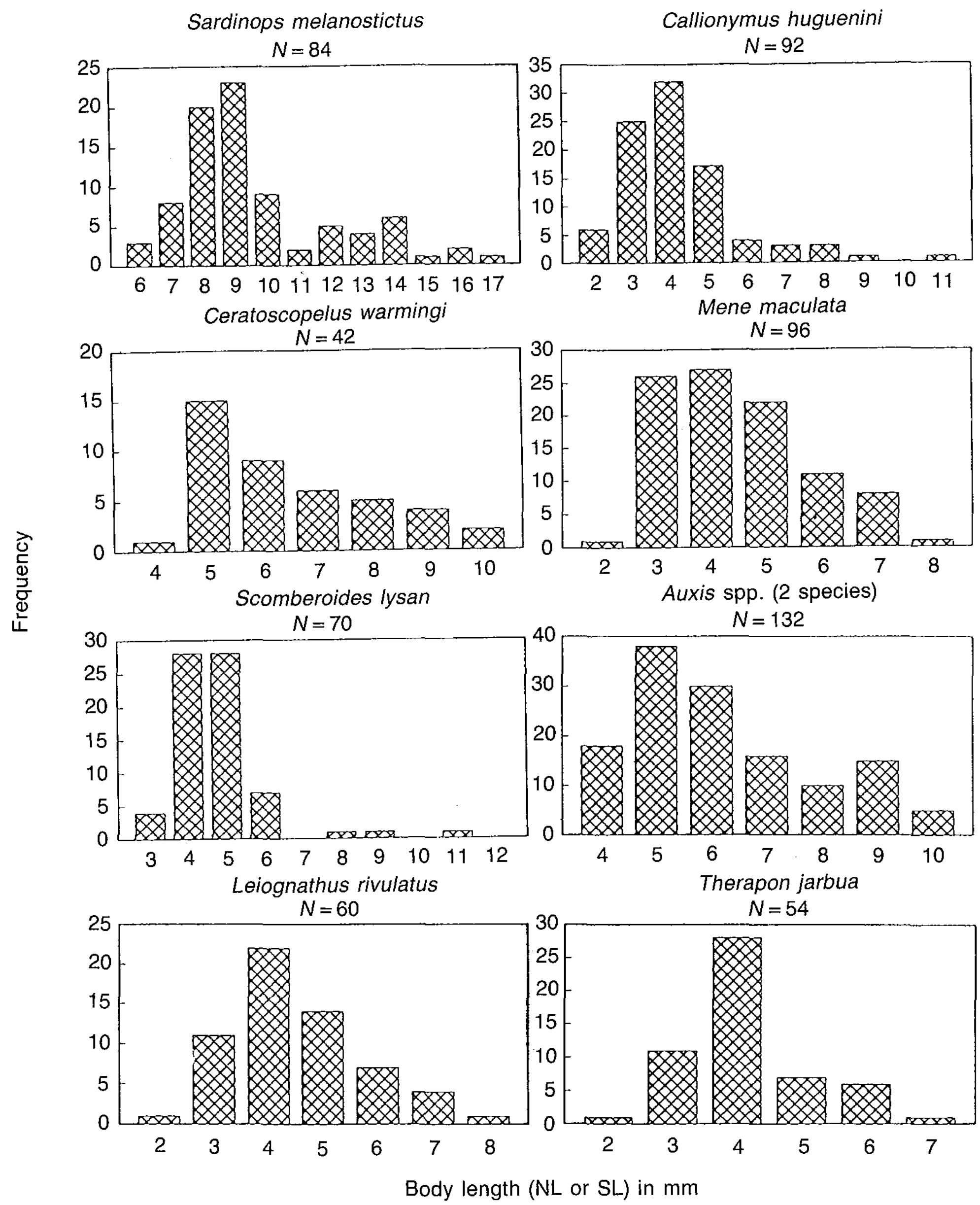

Fig. 4. Dendrograms depicting the similarities of sampling periods and ichthyoplankton species during the diurnal vertical distribution study (number in parentheses indicates average density, ind/1000 m^3).

Table 2. Result of Spearman's rank correlation analysis on ichthyoplankton assemblages

	Water depth			Time of day			
	Surface	Mid	Bottom	0100	0700	1300	1900
Surface		.5068	.3082	.3516	.0449	.5872	.4873
Mid	.0055		.1563	.2481	.0564	.1308	.4462
Bottom	.0914	.3921		.2712	.3469	.2311	.1073
0100	.0541	.1742	.1374		−.2875	−.0823	.1216
0700	.8056	.7572	.0574	.1153		.3105	−.3276
1300	.0013	.4738	.2057	.6522	.0890		.1567
1900	.0076	.0145	.5566	.5054	.0728	.3906	

Upper triangle: Spearman's rank correlation coefficient.
Lower triangle: significance level.

Table 3. Simpson's diversity index of ichthyoplankton assemblages which occurred during diurnal depth study at the fixed station in the waters off northwestern Taiwan (log*e* base)

Sample	Index	Evenness	No. of species (No.>1%)
0100			
Surface	0.9273	0.3046	56 (21)
Mid-water	0.9004	0.2913	74 (22)
Bottom	0.9215	0.2939	75 (23)
0700			
Surface	0.8970	0.3166	69 (17)
Mid-water	0.8227	0.3038	73 (15)
Bottom	0.8860	0.3127	66 (17)
1300			
Surface	0.7636	0.2820	57 (15)
Mid-water	0.8197	0.3299	30 (12)
Bottom	0.8523	0.3008	52 (17)
1900			
Surface	0.8673	0.2945	73 (19)
Mid-water	0.8172	0.2827	54 (18)
Bottom	0.8223	0.3954	33 (8)

pairs — surface vs. mid-water (r_s = 0.51, p = 0.01), surface vs. 1300 (r_s = 0.59, p = 0.00), surface vs. 1900 (r_s = 0.49, p = 0.01), and mid-water vs. 1900 (r_s = 0.45, p = 0.01). The low correlation suggests the occurrence of both vertical and horizontal movements of ichthyoplankton.

Simpson's diversity indices of ichthyoplankton assemblages are shown in Table 3. Apparently, the highest diversity index occurred at 0100 and the lowest at 1300. The highest evenness index occurred at 0700 and the lowest at 1900 (excluding the bottom assemblage). The exceptionally high evenness of the bottom assemblage at 1900 resulted from the few number and low density of species.

Length frequency and growth stages

The length frequency distributions of the eight species with the highest densities are shown in Fig. 5. The sizes of *Sardinops melanostictus* specimens ranged from 6 to 17 mm SL and included flexion larvae (6-7 mm), post-flexion larvae (8-15 mm), and early juveniles (> 16 mm). The size ranges and growth stages of the remaining seven species were: *Ceratoscopelus warmingi*, 4-10 mm SL, flexion (4-5 mm), post-flexion (6-7 mm) and early juvenile (≥ 8 mm); *Scomberoides lysan*, 3-11 mm SL, pre-flexion (< 4 mm), flexion (4-5 mm), post-flexion (6-9 mm) and early juvenile (≥ 10 mm); *Leiognathus rivulatus*, 2-8 mm SL, pre-flexion (< 3 mm), flexion (3-5 mm) and post-flexion (≥ 6 mm); *Callionymus huguenini*, 2-11 mm SL, pre-flexion (< 4 mm), flexion (4-5 mm), post-flexion (6-8 mm) and early juvenile (≥ 8 mm); *Mene maculata*, 2-8 mm SL, pre-flexion (< 3 mm), flexion (3-5 mm) and post-flexion (≥ 6 mm); *Auxis* spp., 4-10 mm SL, pre-flexion (< 5 mm), flexion (5-7 mm) and post-flexion (≥ 8 mm); and *Therapon jarbua*, 2-7 mm SL, pre-flexion (< 4 mm), flexion (4-6 mm) and post-flexion (> 6 mm).

DISCUSSION

Analyses of hydrographic data collected at the study station indicate that there was a temporal stratification in the water column. At 1300 the surface water was heated by solar radiation and the water temperature increased about 0.4 °C, above temperature at 0700 and 0100 (Fig. 2). The homogeneous distribution of water temperatures during the remaining of sampling periods indicated cooling of the water. Since planktonic fish are a feeble swimmers and positioning of ichthyoplankton in the waters off northwestern Taiwan varies diurnally, the ichthyoplanktonic samples obtained at different sampling times and stations should be standardized at the same sampling time before comparison. The comparison of physical locality data from several water depths should also be correlated. Cumulative knowledge of the vertical distributions of larval fishes is therefore important for understanding the results of ichthyoplanktonic surveys (Ahlstrom 1959).

Diurnal vertical variation of ichthyoplankton was also observed in two other fixed stations in waters around Taiwan in two previous studies (Chiu 1991, Chiu and Chang 1993). Stratification feature of the water column was found at a site in the I-Lan Bay area, northeastern Taiwan in June 1992 (Chiu and Chang 1993). However at

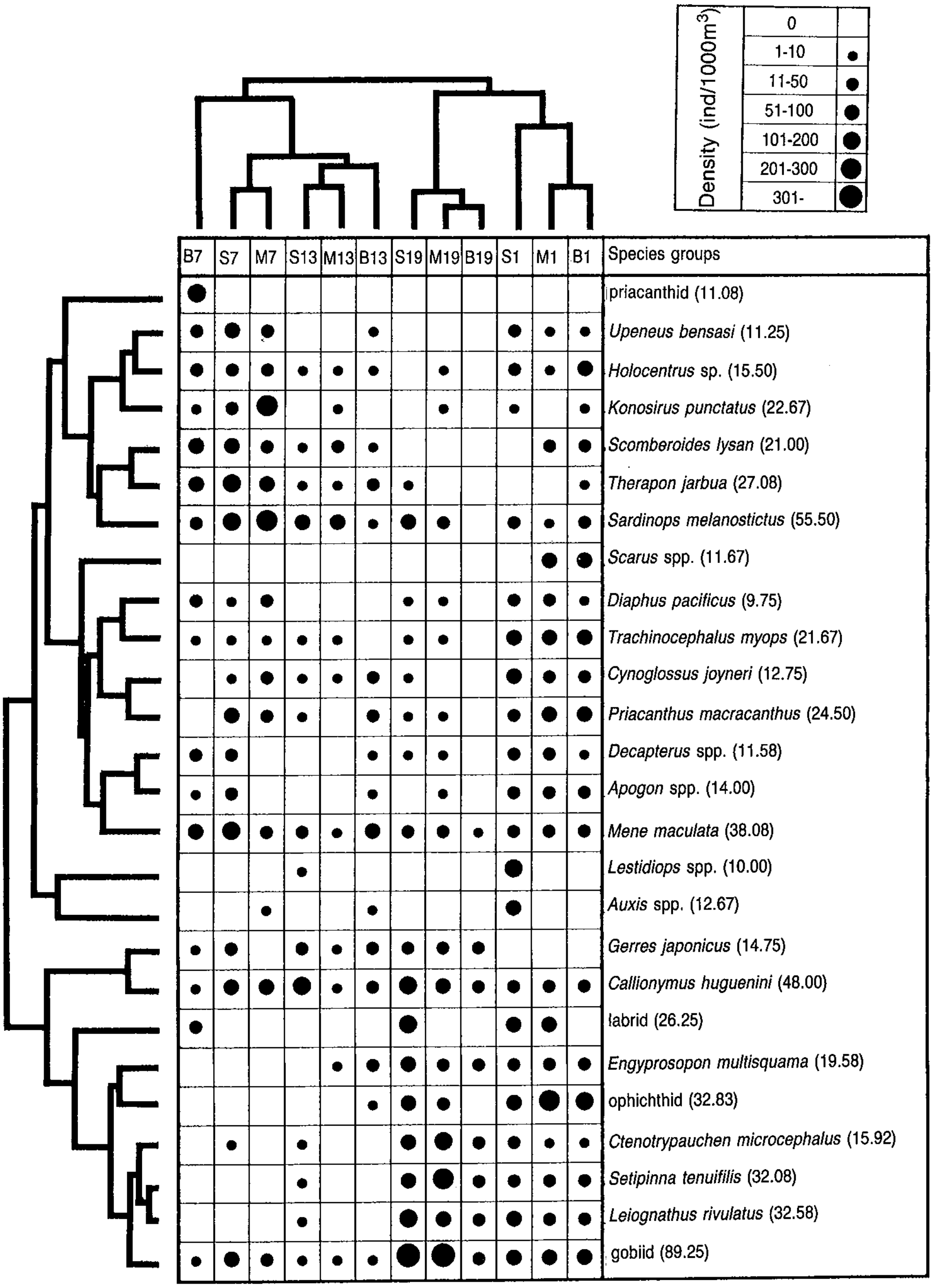

Fig. 5. Body length frequency distribution of eight major species caught during the diurnal vertical distribution study.

a station undergoing a vigorous Kuroshio edge exchange process, the maintenance of a stable ichthyoplankton assemblage was not found (Chiu 1991). Similar conditions were found at the fixed station of the present study.

Two methods can be used to study diurnal variations of ichthyoplankton: using a drogue to tag a water parcel (Kendall and Naplin 1981, Leis 1991, Smith et al. 1978) or setting a fixed point (Chiu 1991, Eldridge et al. 1978, Leis 1991). In this study, we selected the fixed-point strategy because of operation convenience. Leis (1991) indicated that using a drogue was not superior to the fixed-point method. In the waters around Taiwan, the drogue should be used in highly stratified water, such as in the I-Lan Bay area, but it is not appropriate for areas with vigorous water mixing, such as the neritic waters of northwestern and northeastern Taiwan.

The highest density of ichthyoplankton was found in surface water at 1900; relatively high densities in mid-water at 0100, 0700 and 1900; the highest density in bottom water occurred at 0100 (Fig. 3). Differential vertical density distribution of ichthyoplankton throughout the day is a widespread phenomenon (Eldridge et al. 1978, Smith et al. 1978, Kendall and Naplin 1981, Boehlert et al. 1985, Chiu 1991, Leis 1991, Chiu and Chang 1993). McLaren (1974) proposed some explanation for vertical migration of zooplankton. Light modified by other physical and biological factors seems to be important in initiating and controlling vertical migration. In a detailed examination of the vertical stratification of three near-shore larval fishes (*Engraulis mordex, Genyonemus lineatus*, and *Seriphus politus*), Schlotterbeck and Connally (1982) suggested that vertical distribution of larval fishes appears to be related to mode of feeding, development stage, and availability of food in the area. In this study, except in surface water, the densities of zooplankton were highly correlated with the densities of ichthyoplankton (Fig. 3). However, a different view was proposed by Leis (1991) who argued that day/night changes in vertical distributions of fish larvae were due to randomization or spread rather than active migration.

The species composition of ichthyoplankton obtained from several surveys in the waters off northern Taiwan were hardly consensus (Tzeng and Wang 1992, Chiu and Chang 1993, this study), even though the water mass is small. Tzeng and Wang (1992) reported that in May 1990 the larval community in the inner estuary of the Tanshui River was mainly composed of *Stolephorus buccaneeri, Gerres abbreviatus*, sparids, leiognathids, *Thryssa kammalensis*, and *Sillago maculata*. With the exceptions of leiognathid, these species were not found to be the major species of ichthyoplankton in the present study (Table 1), although our study station was located in the outer plume of the Tanshui River. The species common to this study and a similar study (Chiu and Chang 1993) were carangids (*Scomberoides lysan* and *Decapterus* spp.), *Callionymus* spp., *Auxis* spp., and *Priacanthus macracanthus*. These two studies were both conducted at the same time of year (May and June), but the localities of the stations were different (inner shelf vs. marginal Kuroshio).

Based on the nodes exhibited on the dendrogram, three apparent ichthyoplanktonic assemblages were identified: mid-night, after-dark and daytime (Fig. 4). The mid-night and after-dark assemblages were significantly distinct from the daytime. However, because knowledge of life stages, behavior and feeding patterns of most of these ichthyoplankton species is still lacking, the grouping of species into assemblages is more or less arbitrary, although it can be utilized for handling convenience.

The length-frequency distributions indicated that the modal length group of major species, with the exception of *Sardinops melanosticus*, were composed of flexion larvae (Fig. 5). The caudal fin of flexion larva is considered to be incompletely developed, resulting in poor swimming ability. In the water plume of the Tanshui River, the thermocline is ephemeral (Fig. 2), and the ability of ichthyoplankton to maintain a certain position at a specific water depth is not considered possible (Table 2).

Sampling in a general survey of ichthyoplankton should cover the entire water column in order to average out depth variations. Neuston samples (Tzeng et al. 1985, Chan et al. 1985, Tzeng and Wang 1992) would underestimate the abundance and richness of ichthyoplankton species. Although ichthyoplankton samples taken from the entire water column (Chiu and Chang 1994) might compensate for an unevenly distributed ichthyoplankton density at a specific water depth, the effect of behavioral avoidance by the ichthyoplankton during daytime should also be taken into consideration. Standardization of collecting times is therefore necessary before comparisons can be made among samples.

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REFERENCES

Ahlstrom EH. 1959. Vertical distribution of pelagic fish eggs and larvae off California and Baja California. Fish. Bull. **60:** 107-146.

Boehlert GW, DM Gadomski, BC Mundy. 1985. Vertical distribution of ichthyoplankton off the Oregon coast in spring and summer months. Fisher. Bull. **83:** 611-621.

Chan SL, CF Huang, HC Tang. 1985. Survey of fish larvae and juveniles inn the coastal waters off the north-western coast of Taiwan. *In* Report on fish larvae research, eds. SC Chen, CC Huang. Taipei: COA Fish. Ser. **2:** 111-144.

Chiu TS. 1991. Diurnal depth change of ichthyoplankton in the Kuroshio edge exchange front. Acta Oceanogr. Taiwanica **26:** 53-65.

Chiu TS, KZ Chang. 1993. Diurnal vertical distribution of ichthyoplankton in I-Lan Bay, NE Taiwan. J. Fish. Soc. Taiwan **20**(3): 191-205.

Chiu TS, KZ Chang. 1994. Comparison of ichthyoplankton fauna in northern Taiwan Strait during winter and spring. Acta Zoologica Taiwanica **5**(1): 23-31.

Eldridge PJ, FH Berry, MC Miller. 1978. Diurnal variations in catches of selected species of ichthyoplankton by the Boothbay neuston net off Charleston, South Carolina. Fisher. Bull. **76**(1): 295-297.

Kendall AW, NA Naplin. 1981. Diel-depth distribution of summer ichthyoplankton in the middle Atlantic Bight. Fish. Bull. **79:** 705-726.

Leis JM. 1991. Vertical distribution of fish larvae in the Great Barrier Reef lagoon, Australia. Mar. Biol. **109:** 157-166.

McLaren IA. 1974. Demographic strategy of vertical migration by a marine copepod. Am. Nat. **108:** 91-102.

Schlotterbeck RE, DW Connally. 1982. Vertical stratification of three nearshore southern California larval fishes (*Engraulis mordax, Genyonemus lineatus*, and *Seriphus politus*). Fish. Bull. **80:** 895-902.

Smith WG, JD Sibunka, A Wells. 1978. Diel movements of larval yellowtail flounder, *Limanda ferruginea*, determined from discrete depth sampling. Fish. Bull. **76:** 167-178.

Tzeng WN, YT Wang. 1992. Structure, composition and seasonal dynamics of the larval and juvenile fish community in the mangrove estuary of Tanshui River, Taiwan. Mar. Biol. **113:** 481-490.

Tzeng WN, YT Wang, TT Chen, SY Yu. 1985. Investigation of fish larvae and juveniles in the estuaries of northern Taiwan (1982-1983). *In* Report on fish larvae research, eds. SC Chen, CC Huang. Taipei: COA Fish. Ser. **2:** 17-34.

Williams R, PJB Hart. 1974. Vertical and seasonal variability of fish eggs and larvae at ocean weather station "India". *In* The early history of fish, ed. JHS Blaxter. New York: Springer-Verlag, pp. 233-243.

臺灣西北外海一固定測站浮游魚類之日週垂直變異

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1994年的五月21-22日，我們在25° 12'N，121° 20'E以固定測站的方式，進行浮游魚類的日週垂直變異之研究。這個固定測站約在淡水河口外的7公里處。現場的溫度和鹽度剖面變化顯示，此處中午時分有水溫分層之現象，且形成躍溫層；其餘時間則分布較均勻。

浮游魚類之密度範圍爲126至3,167個體/1000立方米。最大密度發生在0100時之底層水，次大者爲1,787個體/1000立方米(1900的表層海)。中層水裏三個時段中，浮游魚類之密度約略相等，分別爲1,148(0100)，1,288(0700)及1,311(1900)個體/1000立方米。

本次實驗共採得5,860個標本，分別屬於82科222個種類。*Sardinops melanostictus*，佔7.28%爲數目最多者。其餘主要爲：*Callionymus huguenini* (5.1%), *Mene maculata* (4.7%), *Auxis* spp. (4.3%), 及 *Therapon jarbua* (3.8%)。聚類分析的結果顯示：浮游魚類群集在三個時間上有區別。此三個時間區別爲：午夜(0100)、入夜(1900)及日間(0700及1300)。午夜及入夜有若干程度上的相似，可再歸併，合稱夜間群集。此群集的主要種類爲：*Leiognathus rivulatus, Setipinna tenuifilis, Ctenotrypauchen microcephalus,* gobiid, ophichthid。日間群集則爲*Scomberoides lysan, Therapon jarbua, Sardinops melanostictus, Upeneus nensasi, Holocentrus* sp., *Konosirus punctatus*。大部分浮游魚類群集之組成在不同時間上用統計測驗其相關性，結果顯示其間並不相關。

關鍵字：仔稚魚, 歧異度, 體長組成。

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