Composition, Abundance and Distribution of Ichthyoplankton in the South China Sea, Area III: Western Philippines

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ABSTRACT

Composition, abundance and distribution of ichthyoplankton were investigated in the South China Sea, western Philippines. Larval fish samples were collected at 31 stations by surface and double oblique tows in April/May 1998. A total of 7371.67 fish larvae, representing 85 families, were collected in the samples. Abundance of fish larvae were dominated by the Myctophidae followed by the Gonostomatidae. The ten most abundant families of fish larvae found in this study were separated into three broad categories: (1) inshore fishes, represented mainly by the Bregmacerotidae, Gobiidae, Apogonidae, and Carangidae; (2) mid zone fishes represented mainly by the Hemiramphidae, Labridae and Engraulidae; (3) offshore fishes represented mainly by the Myctophidae and Gonostomatidae. Depth and time of day appeared to affect the abundance of fish larvae and fish eggs. Fish larvae were found mainly in double oblique tows while fish eggs were found mostly in surface tows. The larvae caught at night were more abundant than larvae caught during the day. Abundance and distribution of tuna larvae are also discussed.

Keywords: Composition; abundance; distribution; ichthyoplankton; fish larvae; fish eggs; South China Sea; western Philippines.

Introduction

The SEAFDEC Interdepartmental Collaborative Research Program has aimed to collect and analyse the data and information necessary for the management of fishery resources and the protection of the environment through collaborative research among member countries and organisations concerned. The first two areas in the Southern part of South China Sea and the Gulf of Thailand (Area I&Area II) characterised as a coastal water condition were surveyed from 1995 to 1997. In 1998, the collaborative research program continued the next survey (Area III) in the northern part of South China Seas (off the west coast of Philippines) with the aim of assessing the fisheries resources in relation to oceanographic conditions.

Research on ichthyoplankton which has been very limited in this area was one of the major surveys, with even basic information on distribution and abundance sparse. The presence of fish larvae is an indicator of the fertility of the waters. Field investigation of the eggs and larvae of marine fin fish is, therefore, a practical check of the fisheries status as well as the survey on adult fishes. The survey on ichthyoplankton could also clarify the spawning grounds and spawning seasons of fishes.

In this paper, a 23-day study of ichthyoplankton in South China Sea is reported. Plankton samples were collected with the aim of obtaining information on composition, abundance, and distribution of ichthyoplankton. Tuna stock assessment was another major objective on this cruise and data on the distribution, abundance and length-frequency of tuna larvae are also presented in this paper.

Materials and Methods

Study site

Area in the South China Sea off the west coast of the Philippines (Area III), covers approximately 579,578 km^2 (latitude 11^{0}N to 20^{0}N and longitude 117^{0}E to 121^{0}E). The study site is oceanic with 95% of the area exceeding depths of 1000 metres. 31 survey sites, each separated by a 155.40 km interval, were set out in this area (Fig. 1).

Field work.

Ichthyoplankton was sampled on M.V. SEAFDEC from 17 April to 9 May 1998. Stations were trawled on arrival, regardless of the time of the day. Surface and double oblique plankton tows were simultaneously taken at each station with a 500 µm mesh net attached to 1 m ring and a pair of bongo nets (60 cm dia, 500 µm and 330 µm mesh respectively). Double oblique tows

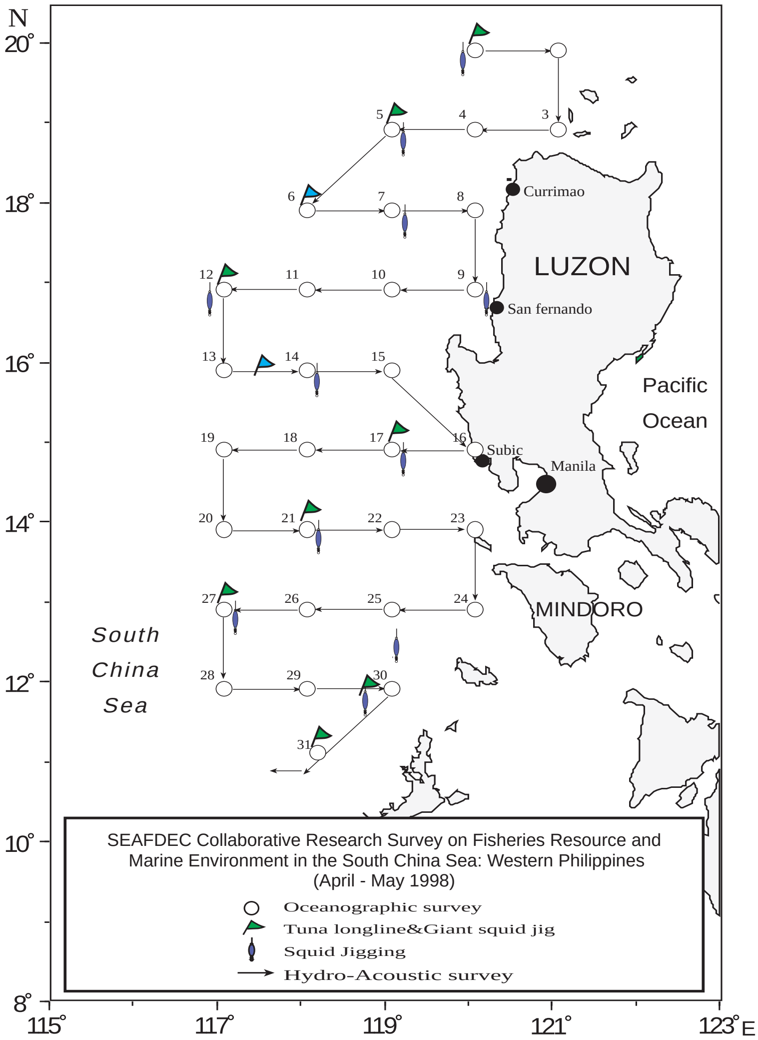

Fig. 1. Sampling stations in the South China Sea, Area III, Western Philippines

Table 1. Zone (inshore, middle, offshore) by region [northern (N), central (C) and southern (S)] in South China Sea (west coast of Philippines).

Region	Zone inshore	middle	offshore
N	St. 3, 8	St. 2, 4, 7	St. 1, 5, 6
C	St. 9, 15, 16	St. 10, 14, 17	St. 11, 12, 13, 18, 19
S	St. 23, 24, 30A, 31A	St. 22, 25, 29	St 20, 21, 26, 27, 28

were taken to a depth of approximately 60 m. Depth and tow profiles were monitored using a depth sensing unit. Each tow was of about 30 min duration at a speed of approximately 2-3 knots. Volume filtered was calculated for each net using a calibrated flow meter. All ichthyoplankton samples were then immediately preserved with 95% ethanol and were brought to a laboratory at Bangkok Marine Fisheries Development Center for processing.

Laboratory work

Fish larvae and fish eggs were sorted from the samples using a rotatable sorting ring under a dissecting microscope and, when necessary, eggs were subsampled. Ichthyoplankton were counted and identified to the lowest possible taxon with information currently available. The term larva used in this paper included the preflexion, flexion and postflexion stages as described by Leis and Rennis (1983). Larvae that could not be identified at either the species, genus or family level (including damaged specimens) were placed in the unidentified category. Tuna larvae were separated from the ichthyoplankton and the standard length (SL: tip of the snout to tip of the notochord or the hypural crease in postflexion larvae) was measured to the nearest 0.1 mm under a dissecting microscope with an ocular micrometer.

Statistical analysis

Individual stations were assigned to one of 3 regions (northern, central, and southern) and each region was subdivided into 3 zones: inshore (innermost station), mid zone (station between outermost and innermost station), offshore (outside station). Each region and zone combination is presented in Table 1.

The total number of larvae and the numbers of each species caught at each station were summed and converted to a concentration, i.e., numbers per 1000 m^3 volume filtered.

Two-factor analysis of variance (ANOVA) was used to determine differences in the mean numbers of larvae among regions, zones, tow types (surface and oblique), and towing time of the day (day and night). Homogeneity of variance was tested using Bartlett's Test. The numeric data were ln (x+0.001) or third root (x+0.0001) transformed prior to ensure normality and to remove heterogeneity of variance. Data distribution was then tested for normality using Shapiro-Wilk W Tests. The results were considered to be statistically significant if $P < 0.05$. Kruskal-Wallis's Test was used to test the difference between two or more factors if data were not normally distributed and were considered to be statistically significant if $P < 0.001$. Statistical packages JMP 3.1 and Statview 4.02 were used for analysis.

Table 2. Rank by abundance (number per 1000 m^3) of families of fishes collected as larvae at 31 stations located in the South China Sea (Area III, west coast of Philippines), based on collections made during 17 April to 9 May 1998. Uncertain identification is denoted by a question mark. Percentage for contributions of each family and species to total larval fish fauna are given when they exceed 0.1%.

Rank	Family/Species	Total contribution Family (%)	Species (%)
1	Myctophidae	2285.2 (31.0)	
	Undetermined spp.		2285.2 (31.0)
2	Gonostomatidae	779.3 (10.6)	
	Cyclothone spp.		306.4 (4.2)
	Vinciguerria spp.		237.1 (3.2)
	Undetermined spp.		193.8 (2.6)
	Diplophos spp.		41.9 (0.6)
3	Bregmacerotidae	543.8 (7.4)	
	Bregmaceros spp.		543.8 (7.4)
4	Gobiidae	376.4 (5.1)	
	Undetermined spp.		376.4 (5.1)
5	Hemiramphidae	271.8 (3.7)	
	Undetermined spp.		271.8 (3.7)
6	Scombridae	216.6 (2.9)	
	Thunnus spp.		99.7 (1.4)
	Undetermined tuna		67.4 (0.9)
	Katsuwonus pelamis		13.2 (0.2)
	Euthynnus spp.		15.9 (0.2)
	Auxis spp.		5.6 (0.1)
	Acanthocybium spp.		12.6 (0.1)
	Scomberomorus sp.		2.2 (< 0.1)
7	Labridae	181.7 (2.5)	
	Undetermined spp.		181.7 (2.5)
8	Carangidae	162 (2.2)	
	Undetermined spp.		162 (2.2)
9	Apogonidae	149.3 (2.0)	
	Undetermined spp.		149.3 (2.0)
10	Engraulidae	116.9 (1.6)	
	Undetermined spp.		116.9 (1.6)
11	Lutjanidae	115.2 (1.6)	
	Undetermined spp.		115.2 (1.6)
12	Bothidae	90.2 (1.2)	
	Undetermined spp.		90.2 (1.2)
13	Paralepididae	79.8 (1.1)	
	Lestidiini		51.2 (0.7)
	Undetermined spp.		17.9 (0.2)
	Sudinae		9 (0.1)
	Stemonosudis sp.		1.8 (< 0.1)
14	Serranidae	65.8 (0.9)	
	Anthiinae		32.3 (0.4)
	Epinephilinae		12.4 (0.2)
	Grammistine		10.9 (0.1)
	Undetermined spp.		7 (0.1)
	Serraninae		3.2 (< 0.1)
15	Mullidae	62.6 (0.8)	
	Undetermined spp.		62.6 (0.8)
16	Gempylidae	58.0 (0.8)	
	Undetermined spp.		58.0 (0.8)
17	Caesionidae	55.9 (0.8)	
	Undetermined spp.		55.9 (0.8)
18	Scaridae	51.8 (0.7)	
	Undetermined spp.		51.8 (0.7)
19	Nemipteridae	45.5 (0.6)	
	Nemipterus spp.		45.5 (0.6)
20	Priacanthidae	38.2 (0.5)	
	Undetermined spp.		38.2 (0.5)
21	Synodontidae	36.9 (0.5)	
	Undetermined spp.		29.6 (0.4)
	Synodus spp.		7.3 (0.1)

Table 2 (continued)

Rank	Family/Species	Total contribution Family (%)	Species (%)
22	Scorpaenidae	36.3 (0.5)	
	Undetermined spp.		33.8 (0.5)
	Helicolenus sp.		2.5 (< 0.1)
23	Teraponidae	35.4 (0.5)	
	Undetermined spp.		29.2 (0.4)
	Terapon spp.		6.2 (0.1)
24	Exocoetidae	34.8 (0.5)	
	Undetermined spp.		34.8 (0.5)
25	Pomacentridae	32.6 (0.4)	
	Undetermined spp.		16.0 (0.2)
	Abudefduf spp.		16.6 (0.2)
26	Astronesthidae	24.2 (0.3)	
	Undetermined spp.		24.2 (0.3)
27	Balistidae	20.1 (0.3)	
	Undetermined spp.		20.1 (0.3)
28	Lutjanidae/Caesionidae	18.9 (0.3)	
	Undetermined spp.		18.9 (0.3)
29	Callionymidae	18.4 (0.2)	
	Undetermined spp.		18.4 (0.2)
30	Melanostomiidae	15.9 (0.2)	
	Undetermined spp.		9.6 (0.1)
	Eustomias spp.		4.6 (< 0.1)
	Photonedes sp.		1.7 (< 0.1)
31	Acanthuridae	15.6 (0.2)	
	Undetermined spp.		15.6 (0.2)
32	Congridae	15.4 (0.2)	
	Undetermined spp.		15.4 (0.2)
32	Leiognathidae	15.4 (0.2)	
	Undetermined spp.		15.4 (0.2)
34	Holocentridae	15.0 (0.2)	
	Undetermined spp.		15.0 (0.2)
35	Champsodontidae	14 (0.2)	
	Undetermined spp.		14 (0.2)
36	Leptobramidae?	13.8 (0.2)	
	Undetermined spp.		13.8 (0.2)
37	Gempylidae?	13.3 (0.2)	
	Undetermined spp.		13.3 (0.2)
38	Siganidae	13.1 (0.2)	
	Undetermined spp.		13.1 (0.2)
38	Schindleriidae	13.1 (0.2)	
	Undetermined spp.		13.1 (0.2)
40	Clupeidae	12.1 (0.2)	
	Undetermined spp.		7.4 (0.1)
	Dussumieriinae		2.4 (< 0.1)
	Dussumieria		2.4 (< 0.1)
41	Crediidae	9.9 (0.1)	
	Undetermined spp.		9.9 (0.1)
41	Cynoglossidae	9.9 (0.1)	
	Undetermined spp.		9.9 (0.1)
43	Pomacanthidae	8.9 (0.1)	
	Undetermined spp.		8.9 (0.1)
44	Ophidiidae	8.8 (0.1)	
	Undetermined spp.		8.8 (0.1)
45	Gerreidae	8.5 (0.1)	
	Undetermined spp.		8.5 (0.1)
46	Coryphaenidae	8.2 (0.1)	
	Undetermined spp.		8.2 (0.1)
47	Monacanthidae	8.1 (0.1)	
	Undetermined spp.		7.5 (0.1)
	Stephanolepis cirrhifer		0.6 (< 0.1)
48	Sphyraenidae	7.6 (0.1)	
	Undetermined spp.		7.6 (0.1)

Table 2 (continued)

Rank	Family/Species	Total contribution Family (%)	Species (%)
49	Trichiuridae	7.5 (0.1)	
	Undetermined spp.		7.5 (0.1)
49	Diodontidae	7.5 (0.1)	
	Undetermined spp.		7.5 (0.1)
51	Scopelarchidae	7.2 (0.1)	
	Undetermined spp.		7.2 (0.1)
52	Evermannellidae	7.1 (0.1)	
	Undetermined spp.		7.1 (0.1)
52	Cirrhitidae	7.1 (0.1)	
	Undetermined spp.		7.1 (0.1)
54	Bythitidae	6.5 (0.1)	
	Undetermined spp.		6.5 (0.1)
55	Chiasmodontidae?	5.9 (0.1)	
	Undetermined spp.		5.9 (0.1)
56	Anguillidae	5.8 (0.1)	
	Undetermined spp.		5.8 (0.1)
57	Muraenesocidae	5.6 (0.1)	
	Undetermined spp.		5.6 (0.1)
58	Pleuronectidae	5.5 (0.1)	
	Undetermined spp.		5.5 (0.1)
59	Emmelichthyidae	5.4 (0.1)	
	Undetermined spp.		5.4 (0.1)
60	Ophichthidae	5.3 (0.1)	
	Undetermined spp.		5.3 (0.1)
61	Oneirodidae	5.1 (0.1)	
	Undetermined spp.		5.1 (0.1)
62	Muraenidae	5 (0.1)	
	Undetermined spp.		5 (0.1)
62	Tetraodontidae	5 (0.1)	
	Undetermined spp.		5 (0.1)
64	Fistulariidae	4.8 (0.1)	
	Undetermined spp.		4.8 (0.1)
65	Blenniidae	3.5 (< 0.1)	
	Undetermined spp.		0.7 (< 0.1)
	Nemophini		2.8 (< 0.1)
66	Haemulidae	3.3 (< 0.1)	
	Undetermined spp.		3.3 (< 0.1)
67	Malacosteidae	3.2 (< 0.1)	
	Undetermined spp.		3.2 (< 0.1)
68	Atherinidae	3.1 (< 0.1)	
	Undetermined spp.		3.1 (< 0.1)
69	Synanceidae	2.9 (< 0.1)	
	Undetermined sp.		2.9 (< 0.1)
70	Bramidae	2.8 (< 0.1)	
	Undetermined sp.		2.8 (< 0.1)
71	Belonidae	2.5 (< 0.1)	
	Undetermined sp.		2.5 (< 0.1)
71	Malacanthidae	2.5 (< 0.1)	
	Undetermined sp.		2.5 (< 0.1)
71	Acropomatidae	2.5 (< 0.1)	
	Undetermined sp.		2.5 (< 0.1)
71	Platycephalidae	2.5 (< 0.1)	
	Undetermined sp.		2.5 (< 0.1)
75	Linophrynidae	1.9 (< 0.1)	
	Undetermined sp.		1.9 (< 0.1)
76	Kuhliidae	1.8 (< 0.1)	
	Undetermined sp.		1.8 (< 0.1)
76	Ammodytidae	1.8 (< 0.1)	
	Undetermined sp.		1.8 (< 0.1)
78	Giganturidae	1.7 (< 0.1)	
	Undetermined sp.		1.7 (< 0.1)
79	Istiophoridae	1.5 (< 0.1)	
	Undetermined spp.		1.5 (< 0.1)

Table 2 (continued)

Rank	Family/Species	Total contribution Family (%)	Species (%)
80	Caulophrynidae	1.4 (< 0.1)	
	Undetermined spp.		1.4 (< 0.1)
81	Scomberesocidae?	1.1 (< 0.1)	
	Undetermined spp.		1.1 (< 0.1)
82	Ipnopidae?	0.6 (< 0.1)	
	Undetermined spp.		0.6 (< 0.1)
82	Antennariidae	0.6 (< 0.1)	
	Histrio histrio		0.6 (< 0.1)
84	Triglidae	0.6 (< 0.1)	
	Undetermined spp.		0.6 (< 0.1)
85	Chlorophthalmidae	0.4 (< 0.1)	
	Undetermined spp.		0.4 (< 0.1)
86	Unidentified	1002.6 (10.9)	
	Total fish larvae	**7371.67 (100)**	
	Fish eggs	**11398.1**	

Results

Family and species composition

A total of 11398.1 eggs/1000 m^3 and a total of 7371.67 fish larvae/1000 m^3, representing 85 families, 19 genera, and 2 species, were collected from the 31 sampling stations in the South China Sea (west coast of Philippines) during 17 April to 9 May 1998 (Table 2). Unidentified larvae accounted for 10.9% of the total catch. These larvae could not be identified because they were either too small, damaged or not described. The Myctophidae was the most abundant family, comprising 31.0% of the total number of larvae, followed by the Gonostomatidae (10.6%), Bregmacerotidae (7.4%), Gobiidae (5.1%), Hemiramphidae (3.7%), Scombridae (2.9%), Labridae (2.5%), Carangidae (2.2%), Apogonidae (2.0%), Engraulidae (1.6%), Lutjanidae (1.6%), and Bothidae (1.2%).

Abundance of fish larvae and fish eggs

Total fish larvae were most abundant in the central region, followed by the north, and the south (Fig. 2). Within zones (distances offshore) the total number of larvae were most abundant at the inshore zone, followed by in the middle zone and the offshore zone (Fig. 2). However, total numbers of fish larvae did not significantly differ between regions or zones and there was no effect for the interaction term on the abundance of total fish larvae ($P > 0.05$ in all cases, Table 3).

There was no significant difference between regions or zones and no interaction of region and zone on the abundance of fish eggs ($P > 0.05$ in all cases, Table 3). However, there was a trend for the highest abundance of fish eggs to occur in the northern region, followed by the central region, with the southern region having lowest abundance (Fig. 3). Amongst zones, the highest concentration of fish eggs occurred inshore with the concentration decreasing towards the offshore zone. (Fig. 3).

Differences in larval and egg density due to tow type and day and night capture

In this study there were two tow types: just below the water surface and a double oblique tow. There did appear to be an effect of depth, as significantly fewer larvae were caught by surface tows than by double oblique tows (Fig. 4, $P < 0.0001$, Table 4). Time of sampling (day and night) appeared to affect the abundance of larvae as well. The larvae collected during the

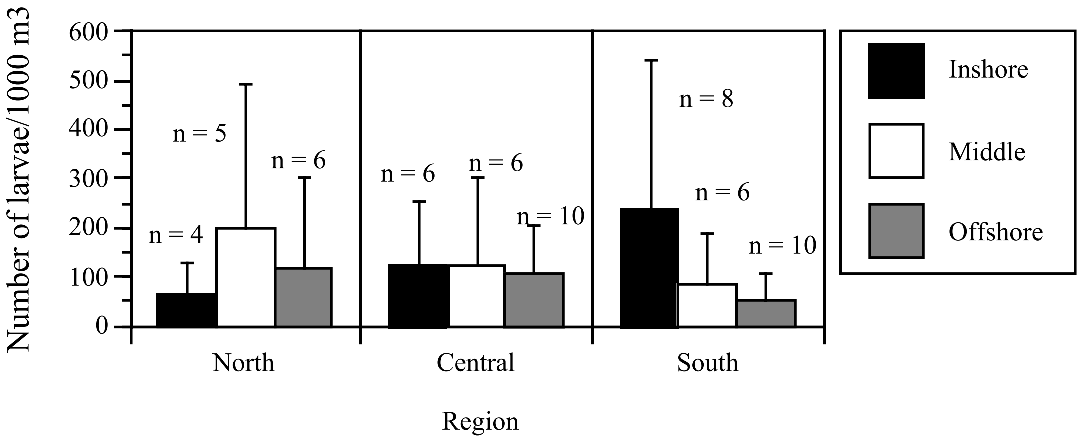

Figure 2. Mean abundance of total fish larvae at each region and zone collected during April/May 1998 in South China Sea (west coast of Philippines). Column charts show mean number of larvae/ 1000 m^3, vertical lines show standard deviation

Table 3. Results of ANOVAs. Z = zone of sampling (3 levels), R = region of sampling (3 levels).

Family **Significant factor**	**Number of stations included**	**d.f.**	**F**	**P**
Total fish larvae				
R	61	2	0.2142	> 0.05
Z	61	2	0.1713	> 0.05
R*Z	61	4	0.3022	> 0.05
Fish eggs				
R	61	2	0.2863	> 0.05
Z	61	2	0.2388	> 0.05
R*Z	61	4	0.5046	> 0.05

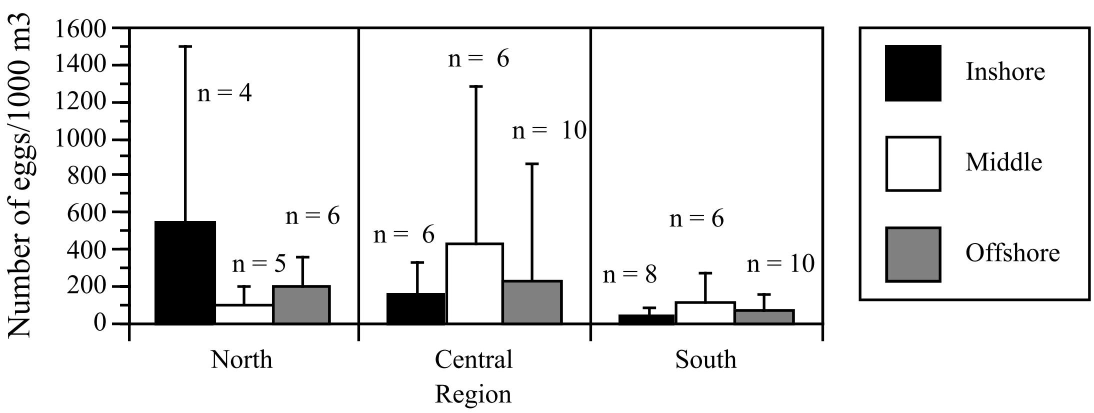

Figure 3. Mean abundance of fish eggs at each region and each zone collected during April/May 1998 in South China Sea (west coast of Philippines). Column charts show mean number of eggs/1000 m^3, vertical lines show standard deviation.

Table 4. Significant results of ANOVAs. Tow = towing type (2 levels; surface and double oblique tow), Time = time of day (2 levels; day and night).

Family Significant factor	Number of stations included	d.f.	F	P
Total fish larvae				
Tow	61	1	143.652	< 0.0001
Time	61	1	3.9132	0.05
Tow*Time	61	1	3.9187	0.05
Fish eggs				
Tow	61	1	7.2594	< 0.01
Time	61	1	7.7470	< 0.01
Tow*Time	61	1	0.6005	> 0.05

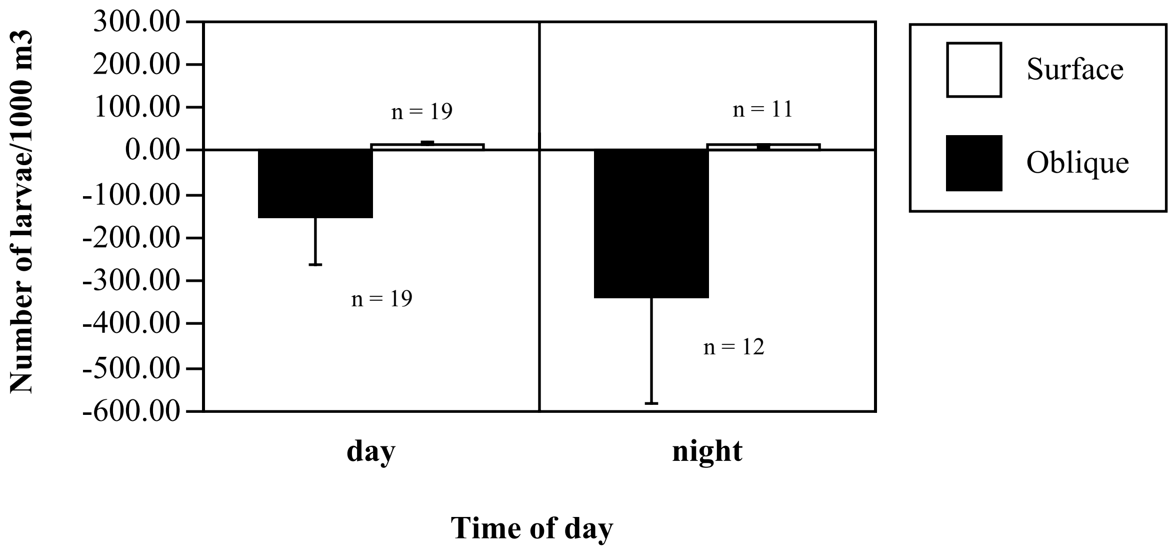

Fig. 4. Mean total larval abundace collected during night and day by surface and double oblique tows. Column charts indicate number of larvae, vertical lines indicate standard deviation.

night were more abundant than larvae caught during the day (Fig. 4, P = 0.05, Table 4). There also appeared to be an effect of the interaction of tow type and towing time on the abundance of total larvae (P = 0.05, Table 4).

There appeared to be an effect of tow type and towing time on abundance of fish eggs (P < 0.001, Table 4), but there was no effect of the interaction of tow type and towing time on fish eggs abundance (P > 0.05, Table 4). Fish eggs collected by surface tows were significantly more abundant than eggs collected by double oblique tows (Fig. 5). Likewise, fish eggs were more abundantly collected during the day than at night (Fig. 5).

Distribution of the ten most abundant families

The ten most abundant families of fish larvae in this study were found in different regions and zones (Table 5). The larvae of Hemiramphidae were found predominantly in the north. By contrast, the larvae of Myctophidae, Gonostomatiidae, and Scombridae were found mainly in the central region. Although the Scombridae were, in general, mostly found in the central region,

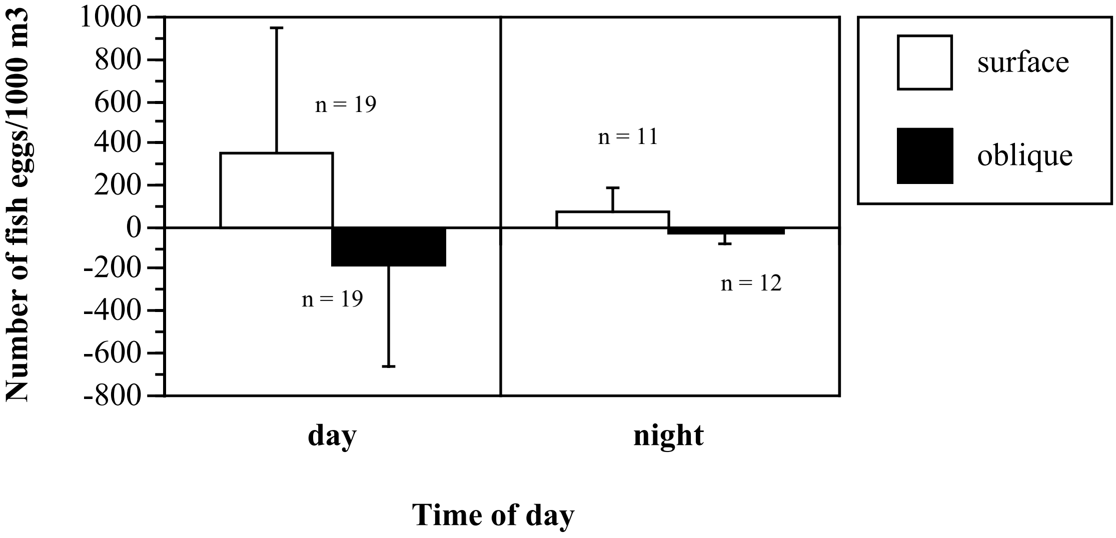

Fig. 5. Mean abundance of fish eggs during day and night by surface and double oblique tows collected during April/May 1998 in South China Sea (west coast of Phillippines). Column charts show number of fish eggs/1000 m^3, vertical lines indicate standard deviation.

the distribution of each species varied within this region. *Euthynnus* spp. and *Auxis* spp. were mostly found in the north but *Katsuwonus pelamis* occurred throughout the study area. The rest of ten most abundant families were found primarily in the south with exception of family Labridae which were found throughout the study area (Table 5).

Within zones, the Myctophidae and Gonostomatidae, occurred predominantly in the offshore zone, whereas the Bregmacerotidae, Gobiidae, Carangidae, and Apogonidae were found mainly at inshore stations. The Hemiramphidae, Labridae, and Engraulidae occurred mostly at middle zone while the Scombridae were found in similar numbers at middle and offshore zones. However, when considering each species separately, *Euthynnus* spp., *Katsuwonus pelamis* and undetermined tuna were found mostly at middle zone while *Auxis* spp. were predominantly found at inshore (Table 5).

The ten most abundant families were collected in greater numbers by double oblique tows than surface tows with exception of the Hemiramphidae, *Auxis* spp., and undetermined tuna (Table 5). This suggests that larvae mostly maintain in the deeper water column.

Abundance of tuna larvae (Family Scombridae)

Tuna larvae belonging to the Family Scombridae were found 201.8 larvae/1000 m^3, representing 4 genera, 1 species, and undetermined spp. (Table 2). There were no effects of region or zone on the number of tuna larvae ($P > 0.05$, Table 6). However, there was a trend of high abundance of tuna larvae occurring in the central region, followed by in the north, and the south (Fig. 6). Among zones, there was high abundance of tuna larvae found in the middle zone (Fig. 6). Interestingly, there was a significant interaction between region and zone affecting abundance of tuna larvae ($P > 0.01$, Table 6), which suggests the pattern was inconsistent throughout the sampling area.

Differences in tuna larval density due to tow type and day and night capture

The number of tuna larvae caught by surface and double oblique tows did not differ significantly ($P > 0.05$, Table 6). There was no significant effect of time of day on the abundance of tuna larvae ($P > 0.05$, Table 6), nor was there a significant interaction between tow type and time of day ($P > 0.05$, Table 6). However, there was a trend of high abundance occurring in double oblique tow sampling during the night (Fig. 7).

Table 5. Percentage of the ten most abundant families occurring at each zone (inshore, middle, and offshore), each region (north, central, and south), and at each tow type (surface tow and double oblique tow).

Rank	Family/Species	Zone			Region			Tow type	
		inshore (%)	middle (%)	offshore (%)	north (%)	central (%)	south (%)	surface (%)	oblique (%)
1	Myctophidae	25.20	31.11	43.69	24.16	51.43	24.41	2.36	97.64
2	Gonostomatidae	17.68	31.62	50.70	33.92	43.92	22.16	2.24	97.76
3	Bregmacerotidae	95.50	4.39	0.11	0.00	0.97	99.03	0.10	99.90
4	Gobiidae	71.79	14.96	13.25	3.83	26.96	68.41	2.99	97.01
5	Hemiramphidae	6.4	58.52	35.08	85.02	4.49	8.80	43.29	56.71
6	Scombridae	23.04	37.02	39.94	24.98	43.06	24.92	30.36	69.64
	Thunnus spp.	19.44	27.31	53.25	14.16	44.30	41.54	21.81	78.19
	Undetermined tuna	27.92	41.25	30.83	33.57	60.76	5.67	50.72	49.28
	Katsuwonus pelamis	21.92	56.39	21.69	38.47	21.54	39.83	15.80	84.20
	Euthynnus spp.	18.26	78.21	3.53	78.21	0	21.79	3.46	96.54
	Auxis spp.	100	0	0	100	0	0	60.78	39.22
7	Labridae	33.22	58.15	8.63	38.34	20.52	37.66	1.56	98.44
8	Carangidae	70.37	15.22	14.41	15.17	8.05	73.54	8.32	91.68
9	Apogonidae	89.65	7.88	2.47	8.56	4.74	86.70	2.40	97.60
10	Engraulidae	28.96	47.32	23.72	10.62	0.64	88.73	6.22	93.78

Table 6. Results of ANOVAs. R = region (3 levels), Z = zone (3 levels), Tow = tow type (3 levels), Time = time of day (2 levels).

Family Significant factor	Number of stations included	d.f.	F	P
Total tuna larvae				
R	61	2	0.4033	> 0.05
Z	61	2	2.2999	> 0.05
R*Z	61	4	4.5266	< 0.01
Tow	61	1	2.9597	> 0.05
Time	61	1	0.4661	> 0.05
Tow*Time	61	1	0.0115	> 0.05

Length-frequency distribution of tuna larvae

Tuna larvae caught in this study were preflexion, flexion, and postflexion stages of development. Most of the larvae collected were at the preflexion stage. Larvae ranged in length from 2.3 to 17.0 mm SL (n = 148 larvae, mean = 4.3 ± 1.9, Fig. 8). The flexion stage larvae collected in this study were generally 5.0 mm SL.

The size range and mean length of larvae at each region and zone is shown in Fig. 9. Tuna larvae caught in the north were larger than larvae caught in other two areas. Length of tuna larvae at each region were found to be significantly different ($P < 0.01$, Kruskal-Wallis test, n = 148, Table 7), but length of tuna larvae among zones did not appeared to differ ($P > 0.05$, n = 148, Kruskal-Wallis test, Table 7). However, there was a trend for larger larvae from the inshore zone. The interaction between region and zone on length of tuna larvae was not analysed due to lack of offshore larvae in the northern region.

Differences in size distribution due to tow type and day and night collection.

No differences in larval sizes were detected when comparing tows taken from the surface with tows taken from a depth of approximately 60 m ($P > 0.05$, Table 6, Fig. 10). On the other hand, there was a significant effect of towing time of day on the length of larvae ($P < 0.0001$, Table 7). The length of larvae caught at night appeared to be larger than those collected during the day (Fig. 10). The interaction between tow type and time of day was not found to affect length of larvae ($P > 0.05$, Table 7). Thus, differences in capture of large individuals between day and night tows were not ascribed to vertical migration of tuna larvae.

Discussion

Fish larval composition

The fish larval assemblage of the South China Sea was overwhelmingly dominated by the Myctophidae at the time collections were made for this study. The Gonostomatidae was the next most abundant group. Although adults of myctophids and gonostomatids are of no importance in the commercial or sport fisheries of the area, the larvae of these families are frequently a dominant component of the ichthyoplankton in many deep oceans. The major contribution made by the Myctophidae and the Gonostomatidae to the larval assemblage of this study area parallels the situation found in the eastern tropical Pacific (Ahlstrom, 1972). The myctophiform fishes are a mostly deep-water group (Leis and Rennis, 1983).

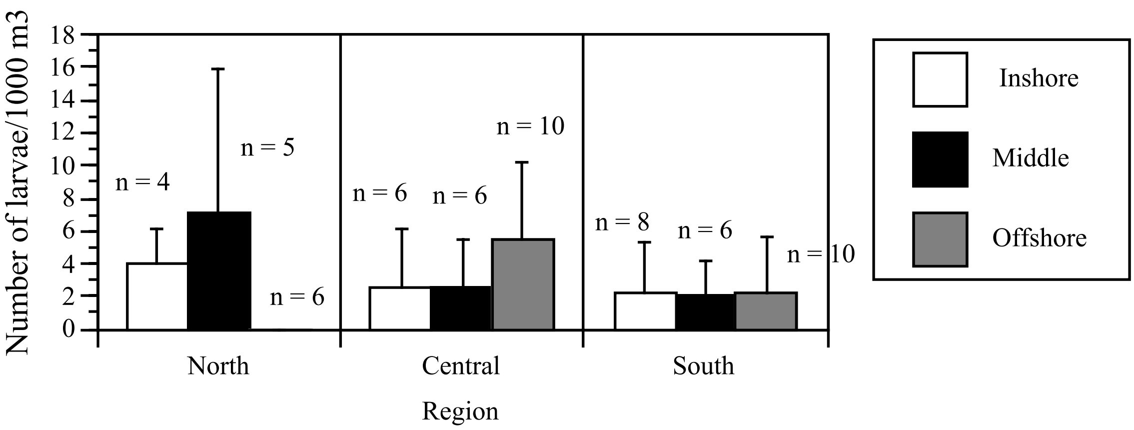

Fig.6. Mean abundance of tuna larvae (Scombridae) at each region and zone collected during April/ May 1998 in South China Sea (west coast of Philippines). Column charts show number of larvae/1000 m^3, vertical lines show standard deviation.

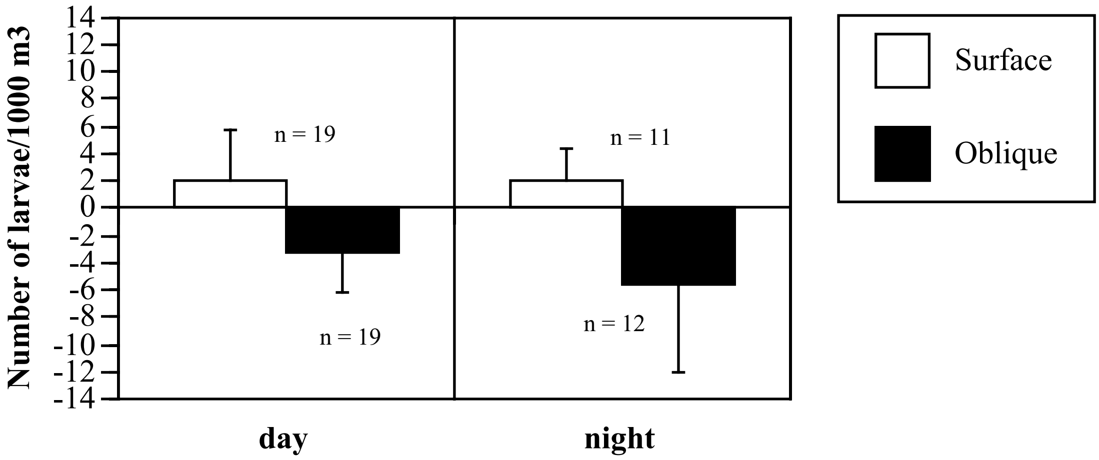

Fig. 7. Mean abundace of tuna larvae (Scombridae) during day and night collected by surface and double oblique tows during April/May 1998 in South China Sea (west coast of Philippines). Column charts indicate number of larvae/1000 m3, vertical lines show standard deviation.

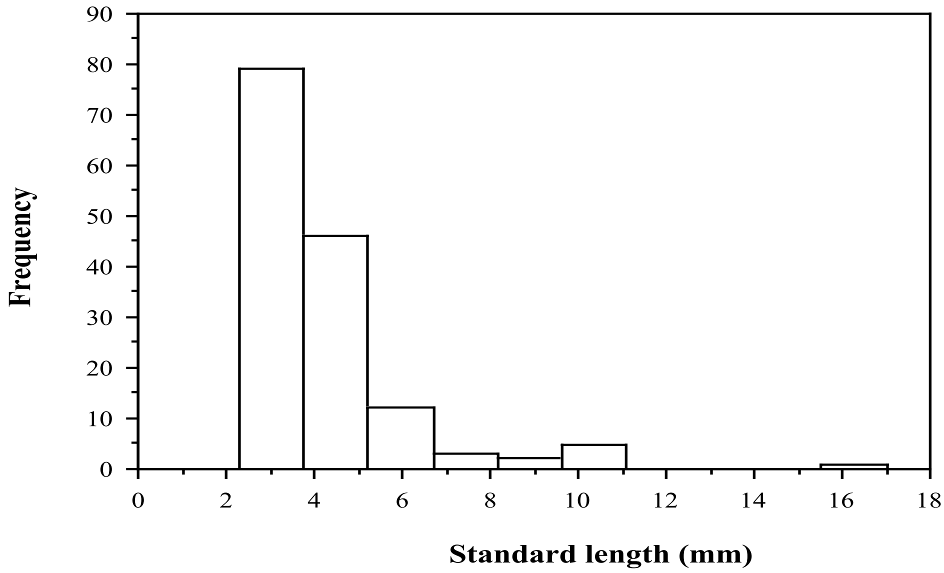

Fig. 8. Length-frequency distribution of tuna larvae (Scombridae) collected during April/May 1998 in South China Sea (west coast of Philippines). Column charts show frequency of larvae.

Table 7. Results of ANOVAs. R = region (3 levels), Z = zone (3 levels), Tow = tow type (3 levels), Time = time of day (2 levels)

Length of tuna larvae				
Significant factor	**Number of larvae included**	**d.f.**	**P**	
R	148	2	$\chi^2 = 10.8803$	< 0.01
Z	148	2	$\chi^2 = 0.1890$	> 0.05
R*Z	148	-	-	-
Tow	148	1	F = 0.0039	> 0.05
Time	148	1	F = 24.7653	< 0.0001
Tow*Time	148	1	F = 3.7984	> 0.05

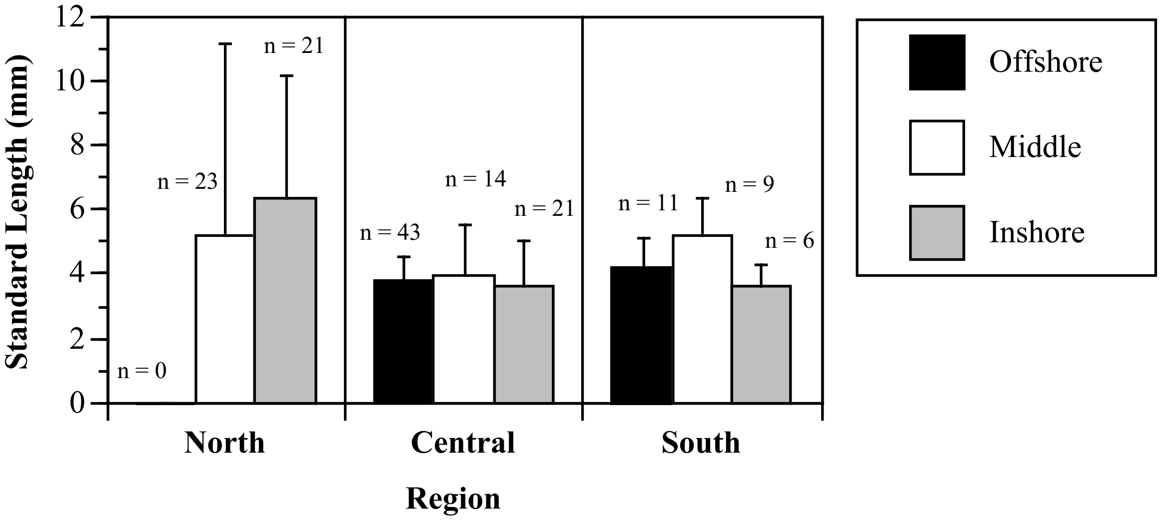

Fig. 9. Mean standard length of tuna larvae collected at each region and zone during April/May 1998 in South China Sea (west coast of Philippines). Column charts show standard length, vertical lines indicate standard deviation.

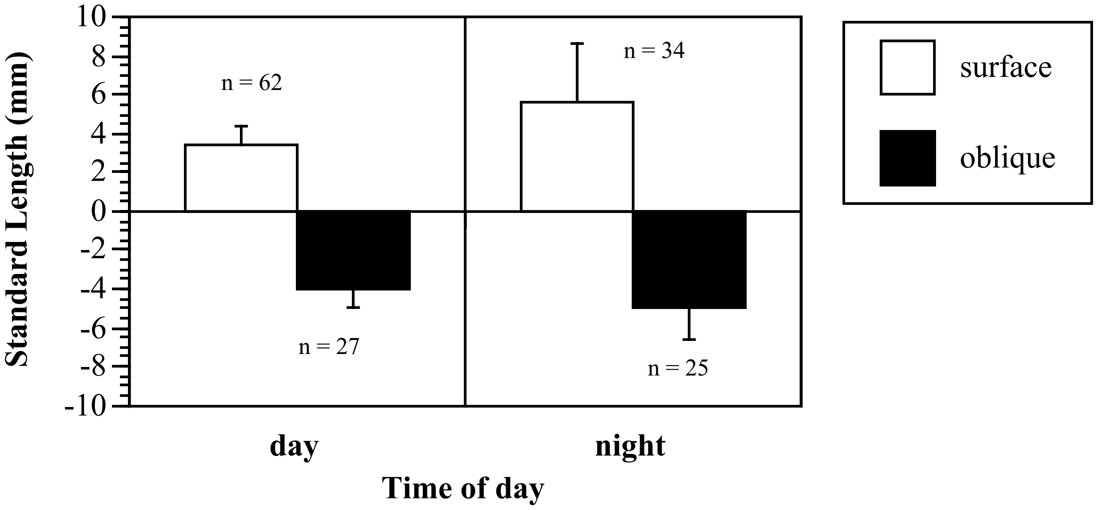

Fig. 10. Mean standard length of tuna larvae collected during day and night by surface and double oblique tows during April/May 1998 in South China Sea (west coast of Philippines). Column charts show mean standard length (mm), vertical lines show standard deviation.

Distribution of larvae

Of the three zones, there was no significant difference of larval fish abundance. Fish larvae appeared to be distributed throughout the study area. However, the inshore stations generally showed the highest numbers of fish larvae and the offshore the lowest.

There was no effect of region or zone on the abundance of fish eggs which suggests that fish eggs are distributed throughout the areas. However, fish eggs were found in high numbers at inshore stations in the northern region. This implies that it might be a spawning ground.

The larvae of the 10 most abundant fish families caught in the study area can be separated into three broad categories: (1) those for which the greatest concentrations were in the inshore zone, represented by the Bregmacerotidae, Gobiidae, Apogonidae, and the Carangidae; (2) those for which the greatest concentrations were in middle zone, represented by the Hemiramphidae, Labridae, and Engraulidae; (3) those for which the greatest concentrations were in the offshore zone, represented by the Myctophidae and Gonostomatidae. The high concentration of larvae in the inshore zone from the first group suggests that these fish may be coastal spawners. The last group of larvae are characterised as a marine deep-water group (Leis and Rennis, 1983).

More larvae were caught by double oblique tows than by surface tows during both day and night. This indicated that larvae did not migrate towards the surface at night which is similar to Ropke's (1989) finding. He found that the species of larvae sampled were deeper at night than during the day. These findings were opposite to other study in which most species appear to migrate towards the surface at night (Kendall and Naplin, 1981).

In this study, fish eggs were collected mainly by surface tows and this should be expected as fish eggs are often buoyant and tend to float towards the surface (Coombs, 1981; Coombs *et al*., 1990).

Abundance and distribution of tuna larvae

Tuna larvae occurred in low densities in this study which is similar to the findings of Wade (1951), Strasburg (1960), and Conand and Richards (1982). The low density of tuna larvae may result from not sampling at the correct depths. Tuna larvae were distributed throughout the study area, however, there appeared to be a trend of high abundance in the central and the north. Tunas require warm water for spawning and larval survival; consequently, the limits of larval distribution are governed largely by water temperature (Matsumoto *et al*, 1984). In the south, the water may be colder than the central and the northern regions, resulting in low larval densities in the south. Further study on the relationship between water temperature and abundance of tuna larvae is needed particularly in this study region.

Tuna larvae did not show diel vertical migration in this study as number of larvae did not significantly differ between oblique tows and surface tows. In addition, the number of larvae caught at night were not different from those caught during the day. This contradicts Matsumoto (1958), Strasburg (1960), Klawe (1963), Ueyanagi (1969), and Richards and Simmons (1971). They showed that skipjack tuna larvae generally are limited to the upper 50 m of water, that they undergo diel vertical migration, and that the vertical migration is most pronounced in the upper 30 m. All of these studies show that surface tows at night caught considerably more larvae than day tows. At a site in the eastern Indian Ocean, larval southern bluefin tuna moved towards the surface during daylight and descend at night, whilst at the same location, skipjack tuna larvae undertook the reverse migration (Davis *et al*., 1990).

When diel variations in vertical distribution correlated with the day/night cycle have been demonstrated, the amplitude of the vertical migration has often been shown to increase with larval size (Fortier and Leggett, 1984; Health *et al*., 1991). In the case of North Sea herring, larvae moved closer to the surface in daylight and closer to the sea bed at night with increasing length in the range 10-30 mm (Health *et al*., 1991). Those studies also contradict our findings. Large tuna larvae did not show vertical migration as similar length of larvae were found both surface and double oblique tows. However, larvae caught at night were larger than those caught during the day. This may due to net avoidance of larger larvae during the day (Heath, 1992).

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