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Larval Fish Assemblage Around the Spawning Ground of Japanese Eel

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Abstract: A total of 20,326 fish larvae were collected by IKPT net in June and July, 1994 from 21 stations distributed between 134° and 141°E, and 13° and 18°N, and were identified to 66 families, 109 genera, and 218 species or types. The most dominant family and specie was an engraulid *Encrasicholina punctifer* followed by Gonostomatidae, Myctophidae, Scombridae and Scopelarchidae. Densities of all fish larvae were higher along 134°E. Densities and ratios to total density of *E. punctifer* did not show any distinct spatial trend. Numbers of species were higher at north and west. Diversity indices did not show any distinct spatial trend. Percentage similarity indices indicated no distinct faunal area.

Key words: fish larvae, Japanese eel spawning ground, faunal analysis, *Encrasicholina punctifer*

Introduction

In 1994, Ocean Research Institute, University of Tokyo, made the cruise KH-94-2 of Hakuho-maru to reconfirm the spawning ground (10°-20°N; 130°-140°E) of Japanese eel *Anguilla japonica* suggested by Ozawa *et al*. (1992), and collected 1,110 *A. japonica* leptocephali of 11-31 mm TL, which doubled the total number of leptocephali of this specie ever collected (Tsukamoto, 1995). Most of the fish larvae other than eel leptocephali collected during the cruise were distributed to the present authors.

Studies on fish larvae are important not only for spawning ecology of individual species but also for faunistic analysis of the sea because as members of plankton, they are easy to collect with scientific gears. Studies on fish larvae in the area inclusive of Japanese eel spawning ground are mainly specie-specific and not quantitative (e.g., flying fish by Kovalevskaya, 1980; *Encrasicholina punctifer* by Ozawa and Tsukahara, 1973; a gonostomatid genus *Cyclothone* by Ozawa and Oda, 1986). To characterize the fish larvae around the spawning ground of Japanese eel, this study analyzed some faunistic items with all of the fish larvae collected during the Cruise KH-94-2.

Materials and Methods

Samples of fish larvae were collected during R/V Hakuho-maru cruise, KH-94-2, of Ocean Research Institute, University of Tokyo, from June 16 to July 7, 1994 in the western north Pacific (Fig. 1). Four major longitudinal survey lines were set at 134°, 137°, 140°, 141°E, and on each line, five major sampling stations were set from 17°N to 13°N at every one latitude except 13°N and 141°E with additional four stations, E-1 (13°N, 135°E), E-2 (17°N, 138°E), S-2 (14° 30'N, 141° 20'E), and S-6 (18°N, 141°E), totaling 23 stations.

The sampling device was an Isaacs-Kidd plankton trawl (IKPT) which was different only in mesh size (1.0 mm) from IKMT net used for collection of mesopelagic adult fish with a mouth area of 8.7 m^2. A depressor was attached to the lower part of its rectangular mouth. Without opening-closing device, the net was hauled obliquely with a maximum wire length ranging from 650 to 1286 m at a ship speed of 3.0-5.0 knots during delivery and 2.0 knots during retrieval. The wire was paid out at a speed of 1.0 m/sec and retrieved at a speed of 0.5 m/sec. A flow-meter and a depth recorder attached to the mouth of net allowed measurement of volume of water filtered and depth of net reached.

Ship time was recorded with local mean time. Two collection times were distinguished, day and night time. The middle of duration of one collection was considered its collection time. In this study, only the samples made at night were used to reduce differential net avoidance. Therefore, day time samples at Sts. (stations) 5 and S-5 were excluded from the results.

Immediately after collection, samples were fixed in 10% formalin. As they included many animals (jellyfish, shrimp, sagitta, etc.) other than fish, in the laboratory fish were sorted out from the bulk, one by one and preserved in 70% ethyl alcohol.

Specimens were identified to the lowest taxon possible. Leptocephali were identified by Mochioka *et al*. (1995) and the others by the present authors. Larvae of some genera and families were categorized in types using roman numbers because of inability to go further in identification. Specimens identified were examined on number of individuals, developmental stage, and range of standard length. Developmental stages were divided into prelarval stage with yolk, postlarval stage inclusive of metamorphosis without fixed fin rays, and juveniles after completion of fin rays. However, no prelarvae were included, and juveniles were rarely collected. Therefore only postlarvae were used in this paper. Larvae were classified into five types based on adult habitats principally after Moser (1996) and supplementarily after Nakabo (1995): epipelagic, mesopelagic, bathypelagic, neritic and continental slope fish. Catadromous fish, e.g., *Anguilla* spp. were considered neritic species.

Density of larvae was expressed as number per 10^4 m^3 of water filtered.

As a diversity index, the reciprocal of Simpson' s index, ß was calculated:

$$ß = N(N-1)/\Sigma X_i(X_i-1)$$

where X_i is the number of specimens of a particular taxon in a net collection and N, the number of total specimens in the same net collection. The index is higher when specie composition is more complex.

The percentage of similarity index (PSI) was estimated for comparison of composition of fish larvae between stations:

$$PSI = 100 - 0.5\ \Sigma\ |P_{ij} - P_{ik}|$$

where P_{ij} and P_{ik} represent the percentage of ith species in samples j and k respectively. PSI varies between 0 (no overlap of species between samples) and 100 (complete overlap).

For the items analyzed except PSI, the averages along longitude and latitude were calculated: in four additional stations, two (E-1 and E-2) were excluded from the calculation along longitude but included in that along latitude, and Sts. S-2 and S-6 without any counterpart at the other longitudes were included in the calculation along longitude 141°E.

Results

In 21 stations, the duration of sampling ranged from 37 min at St. (station) 11 to 87 min at St. S-2 with an average of 50 min 48.6 sec and maximum depth of net, from 295 (St. E-2) to 356 m (St. 3) with an average of 306.2 m. The volume of water filtered ranged from 11,103 (St. 4) to 49,569 m^3 (St. 1) with an average of 25,403.43 m^3.

Systematic composition: A total of 20,326 specimens were identified to 66 families, 109 genera, and 218 species or types. In Table 1, abundant families and species, rarely genera or types, are shown for each habitat type.

By the adult habitat the samples comprised 13,109 specimens (64.49% of the total) of epipelagic, 6,880 (33.85%) of mesopelagic, 13 (0.06%) of bathypelagic, 168 (0.83%) of neritic, 3 (0.01%) of continental slope, and 148 (0.73%) of unidentified species.

Epipelagic fish larvae were relatively poor in composition of only 13 families, 22 genera and 32 species or types (Table 1). The engraulid, *Encrasicholina punctifer* represented 61.00% of the total individuals, being the first in abundance both as family and as species. The other epipelagic families captured in substantial numbers included: Scombridae 2.97% (4th family), Nomeidae 0.21% (9th), and Coryphaenidae 0.08% (19th). The scombrids were mainly composed of the following three species: *Katsuwonus pelamis* (5th species in abundance), *Thunnus alalunga* (10th) and *Euthynnus affinis* (22th). The nomeids included two genera and four species. They were composed principally of *Cubiceps pauciradiatus* (28th) and *Psenes cyanophrys*. The coryphaenids comprised one genus and two species: *Coryphaena equiselis* and *C. hippurus*.

Mesopelagic fish larvae showed a variety of composition of 24 families, 64 genera, and 142 species or types (Table 1). They were mainly composed of six families: Gonostomatidae 21.15% (2nd), Myctophidae 7.52% (3rd), Scopelarchidae 1.24% (5th), Paralepididae 1.17% (6th), Gempylidae 0.85% (7th) and Sternoptychidae 0.76% (8th). Gonostomatidae sensu included seven genera and 16 species (Ahlstrom 1974). *Vinciguerria nimbaria* occupied 13.89% (2nd as species) of the total specimens. *Cyclothone alba* (3rd), *Gonostoma atlanticum* (14th), *Valenciennellus tripunctulatus* (16th), *Gonostoma elongatum* (19th), and *Cyclothone pseudopallida* (20th) were also abundant. Fifteen genera and 37 species or types composed the myctophid fish. *Ceratoscopelus warmingii* (4th), *Diaphus* spp. (6th), *Symbolophorus evermanni* (8th), *Lampanyctus nobilis* (9th), *Hygophum proximum* (11th), and *Bolinichthys longipes* (15th) were the main components of the family. Scopelarchidae comprised two genera and four species or types. They were principally composed of *Scopelarchus analis* (7th) and *Scopelarchus guentheri*. Seven genera and 23 species or types composed the family Paralepididae. *Lestidium atlanticum* (13th), *Sudis atrox* (21st) and *Lestidiops jayakari* (22nd) were the main components of paralepidid fish. Gempylidae was composed of seven genera and seven species. *Lepidocybium flavobrunneum* (17th) and *Gempylus serpens* (18th) were the principal components of this family. Sternoptychidae was composed of three genera and eight species or types, with *Sternoptyx* sp. I (12th), and *Sternoptyx* sp. III (24th) being the main components.

Neritic fish larvae showed a variety of composition of 25 families, 19 genera, and 37 species or types (Table 1). They were composed mainly of the following families: Anguillidae 0.19% (10th), Triacanthodidae 0.15% (13th), Congridae 0.10% (17th), Mullidae 0.05% (23th), Champsodontidae 0.04% (28th), Percichthyidae 0.03% (29th), and Serranidae 0.03% (29th). Anguillidae included *A. japonica* (27th) and *Anguilla* sp. Triacanthodidae comprised the species *Atrophacanthus japonicus*. Congridae and Mullidae could not be identified further.

The bathypelagic species were represented by only three families, two genera and four species or types (Table 1). Following were the families and species: Ophidiidae with *Brotula multibarbata* and Ophidiidae spp., Derichthyidae with Derichthyidae spp., and Caulophrynidae with *Caulophryne* sp.

The continental slope fish were represented only by one family, Trichiuridae with two genera and three species: *Assurger anzac*, *Benthodesmus elongatus*, and *B. tenuis* (Table 1).

Unidentified larvae were composed of damaged specimens in large number and truly unknown ones in small number.

Density of fish larvae: Total larval density (/10^4 m^3) ranged from 40.7 at St. 15 to 2,438.9 at St. S-3 with an average of 367.1 (Fig. 2). High density of more than 500 occurred at three (Sts. 1, 2 and 4) of four westernmost and one (St. S-3) of six easternmost stations. Low density of less than 150 occurred at southern stations along 137°E (Sts. 6 and 7), 140°E (Sts. 14 and 15), and 141°E (St. S-1); and at northern stations along 137°E (St. 10), 140°E (St. 11) and 141°E (St. S-4). Along latitude the average of total density was highest at 15°N (747.9), and decreased to north and south (Table 2). However, the densities at each station along latitude were highly variable, e.g., the highest one along 15°N was due to St. S-3 of extreme high density of 2,438.9 with the other three of less than the average. Along longitude, averages of total density were higher at east (654.1 at 141°E) and west (619.5 at 134°E) and lower at middle transects (156.1 at 137°E and 123.0 at 140°E) (Table 2). The higher density at 134°E was due to the higher three of the four stations. On the other hand, the higher one at 141°E was due to St. S-3 of extreme high density, and the densities at the other four stations were highly variable. Except along 134°E of higher densities, no distinct spatial separation of total densities could be recognized.

The density of *E. punctifer* (/10^4 m^3), the most abundant species, ranged from 0.0 at St. 1 to 2,406.5 at St. S-3 with an average of 251.2 (Fig. 2). High values of more than about 300 occurred at two westernmost (Sts. 2 and 4), one additional E-1, and two easternmost (Sts. S-3 and S-6) stations. Low values of less than 50 were widely spread in the sampled area: Sts. 1, 6, 9, 10, 15, and S-4. Along latitude, average density was highest at the middle transect (694.6 at 15°N) and decreased to north and south (Table 2). The densities at all stations along 17°N were low, bringing the extremely low average density (33.4), but the density (335.4) at more northern station, S-6, was one of the highest ones. The densities of *E. punctifer* at each station along the other latitudes were highly variable: the highest one along 15°N was due to St. S-3 of extremely high density of 2,406.5. Along longitude, average densities were higher at east (601.3 at 141°E) and west (315.6 at 134°E) and lower at middle transects (44.6 at 137°E and 82.3 at 140°E) (Table 2). The higher density was due to two higher stations both at 134°E (Sts. 2 and 4) and at 141°E (Sts. S-3 and S-6), and the densities at the other stations of both longitudes were less than the average. The densities of *E. punctifer* at each station along 137° and 140°E were lower than the average, but variable, with those along 137°E being from 1.5 at St. 10 to 119.7 at St. 8 and those along 140°E from 16.7 at St. 15 to 177.1 at St. 12. The densities of *E. punctifer* were highly variable both along latitude and longitude, and no distinct spatial trend could be recognized.

The ratios of density of *E. punctifer* to total density ranged from 0.0% at St. 1 to 98.7% at St. S-3 with an average of 54.1%. The higher ratios of more than 75% and lower ones of less than 40% were spread randomly at Sts. 4, E-1, 8, 14, S-2, S-3 and S-6 and at Sts. 1, 6, 9, 10, 15, and S-4, respectively (Fig. 2). Along latitude, average ratios were higher at 15°N (74.7%) and 14°N (69.2%) and lowest at 17°N (28.3%) (Table 2). The higher averages at 14° and 15°N were due to the ratios at all stations higher than the total average (54.1%). At the other latitudes, the ratios were highly variable, e.g., along 17°N from 0% at St. 1 to 69.3 at St. 11. Along longitude, the average ratios were higher at two

Table 1: List of main fish larvae according to adult habitats. Families are separated each other with semicolons. Species names are shown only in cases that more than 50 specimens were collected. Roman numerals after family name denote the rank of top 30 families, and Arabic ones without and with parentheses after species name denote the number of specimens collected and the the rank of top 30 species, respectively

(1) **Epipelagic fish**: 13 families, 22 genera, and 32 species or types, and 13,109 specimens.
Engraulidae I (1 genus and species and 12,398 specimens): *Encrasicholina punctifer* 12,398 (1); Scombridae IV (7 genera and 12 species, and 604 specimens): *Katsuwonus pelamis* 332 (5), *Thunnus alalunga* 121 (10); Nomeidae IX (2 genera and 4 species, and 43 specimens); Coryphaenidae XIX (1 genus and 2 species, and 16 specimens); Istiophoridae XX (2 genera and 2 species, and 14 specimens); Hemiramphidae XXV (2 genera and 3 species, and 9 specimens).

(2) **Mesopelagic fish:** 24 families, 64 genera, 142 species or types, and 6,880 specimens.
Gonostomatidae II (7 genera, 16 species, and 4,299 specimens): *Vinciguerria nimbaria* 2,824 (2), *Cyclothone alba* 1,133 (3), *Gonostoma atlanticum* 68 (14), *Valenciennellus tripunctulatus* 63 (16), *Gonostoma elongatum* 54 (19), *Cyclothone pseudopallida* 51 (20); Myctophidae III (15 genera, 37 species or types, and 1,529 specimens): *Ceratoscopelus warmingii* 399 (4), *Diaphus* spp. 321 (6), *Symbolophorus evermanni* 199 (8), *Lampanyctus nobilis* 139 (9), *Hygophum proximum* 81 (11), *Bolinichthys longipes* 66 (15); Scopelarchidae V (2 genera and 4 species or types, and 253 specimens): *Scopelarchus analis* 217 (7); Paralepididae VI (7 genera and 23 species or types, and 237 specimens): *Lestidium atlanticum* 72 (13); Gempylidae VII (7 genera and 7 species, and 173 specimens): *Lepidocybium flavobrunneum* 61 (17), *Gempylus serpens* 60 (18); Sternoptychidae VIII (3 genera and 8 species or types, and 155 specimens): *Sternoptyx* sp. I 79 (12); Chiasmodontidae X (3 genera and 9 species or types, and 39 specimens); Bregmacerotidae XII (1 genus and 6 species, and 32 specimens); Idiacanthidae XIV (1 genus and 1 type, and 29 specimens); Bramidae XV (1 genus and 3 species or types, and 28 specimens); Howellidae XVI (1 genus and 1 type, and 26 specimens); Melamphaidae XVIII (1 genus and 2 species, and 19 specimens); Melanostomiidae XX (5 genera and 9 species or types, and 14 specimens); Evermannellidae XXII (2 genera and 2 species, and 13 specimens); Astronesthidae XXIII (1 genus and 2 species or types, and 10 specimens); Nemichthyidae XXV (1 type and 9 specimens); Notosudidae XXV (1 genus and 2 species or types, and 9 specimens).

(3) **Bathypelagic fish:** 3 families, 2 genera, 4 species or types, and 13 specimens. Ophidiidae (1 genus and 2 species or types, and 6 specimens); Derichthyidae (1 type and 5 specimens); Caulophrynidae (1 genus and 1 type, and 2 specimens).

(4) **Neritic fish**: 25 families, 19 genera, 37 species or types, and 168 specimens.
Anguillidae X (1 genus and 2 species or types, and 39 specimens); Triacanthodidae XIII (1 genus and 1 species, and 30 specimens); Congridae XVII (1 type and 21 specimens); Mullidae XXIII (1 type and 10 specimens); Champsodontidae XXVIII (1 genus and 1 type, and 8 specimens); Percichthyidae XXIX (1 genus and 2 species, and 7 specimens); Serranidae XXIX (3 types and 7 specimens).

(5) **Continental slope fish:** 1 family, 2 genera, 3 species, and 3 specimens.
Trichiuridae (2 genera and 3 species, and 3 specimens).

easternmost transects (66.5% at 141°E and 63.5% at 140°E), and lowest at 137°E (30.6%). In higher averages, lower ratios were included (e.g., St. S-4) and in the lowest one higher ratios (Sts. 7 and 8). The ratios at all stations along 14° and 15°N were higher than the average, but those along the other latitudes and all longitudes were highly variable. Therefore, in total, no distinct spatial trend could be recognized in the ratios of *E. punctifer*.

Number of species and index of diversity: The number of species varied from 14 at St. 11 to 80 at St. 1 with a mean of 43.7. The higher numbers of more than 54 occurred at northern stations along 134°E (Sts. 1 and 2), 137°E (Sts. 9 and 10), 138°E (St. E-2), and 141°E (St. S-4), and at the southern station, St. 6 along 137°E. The lower ones of less than 28 were seen along 137°E (St. 8), 140°E (Sts. 11, 14, and 15), and 141°E (Sts. S-1 and S-3) (Fig. 3). Along latitude, averages of number of species were higher at the two northernmost transects (56.5 at 16°N and 55.7 at 17°N) and lower at middle ones (31.2 at 14°N and 34.7 at 15°N) (Table 2). The number of species was higher than the average at eight of nine stations at or north of 16°N, and lower than that at eight of 12 stations at or south of 15°N. Therefore, the numbers of species were higher at north than south. Along longitude, averages of number of species were higher at two western longitudes (59.5 at 134°E and 49.4 at 137°E) than at two eastern ones (27.2 at 140°E and 38.2 at 141°E) (Table 2). The number of species was higher than the average (43.7) at nine of 11 stations at or west of 138°E, and lower than that at seven out of 10 stations east of that longitude. Therefore the numbers of species were higher at west than east.

The Simpson' s index of diversity for all species ranged from 1.0 at St. S-3 to 22.4 at St. S-4 with an average of 5.0. The higher values (> 11) were obtained at stations along 137°E (Sts. 6, 9 and 10) and 141°E (St. S-4). The lower values (< 2) were spread widely in the sampled area: Sts. 2, 4, E-1, 8, 12, 14, S-2, S-3, and S-6 (Fig. 3). Along latitude, averages of Simpson' s index of diversity for all species were lower at the middle transects (2.0 at 15°N and 2.1 at 14°N), and the largest at 16°N (9.4) (Table 2). The indices at all stations along 14° and 15°N were smaller than the average. Those at stations along the other latitudes of higher average were highly variable, e.g., the indices along the latitude of highest average (16°N) were lower at two stations (Sts. 2 and 12) and higher at the other two (Sts. 9 and S-4) than the average. Therefore, no distinct latitudinal trend could be recognized in the Simpson' s index. The averages along longitude were higher at 137° and 141°E than at 134° and 140°E. The indices at all stations along 134° and 140°E were lower than the average. Those lying between them along 137°E of highest average index were highly variable with three stations of higher and two stations of lower than the average. The higher average along 141°E was due to the highest of all at St. S-4: the indices at the other stations were lower than the average.
When excluded the dominant species, *E. punctifer*, the Simpson' s index increased significantly except a few stations (Sts. 1, 6, 9, 10, and S-4), ranging from 2.1 at St. 2 to 22.6 at St. S-3 with an average of 13.3. The higher values (> 15) were spread widely in the sampled area: Sts. E-1, 7, 8, 10, 12, S-3, S-4, and S-6. The lower values (< 10) were also widely spread in the sampled area: Sts. 1, 2, 11, 15, and S-

Table 2: Average along latitudes and longitudes of the total larval density (n10^4m^3), the density and ratio (%) of *Encrasicholina punctifer*, the number of species, and the Simpson's index of diverrsity with and without *Encrasicholina punctifer*

	13°N	14°N	15°N	16°N	17°N	134°E	137°E	140°E	141°E
Total density	190.0	215.3	747.9	380.8	281.8	619.5	156.1	123.0	654.1
Density of E. *punctifer*	109.1	155.2	694.6	224.6	33.4	315.6	44.6	82.3	601.3
Ratio of E. *punctifer* (%)	42.1	69.2	74.7	39.4	28.3	53.9	30.6	63.2	66.5
Number of species	41.0	31.2	34.7	56.5	55.7	59.5	49.4	27.2	38.2
Simpson's index	6.4	2.1	2.0	9.4	7.4	2.0	9.9	2.7	5.7
Simpson's index withour E. *punctifer*	12.4	13.7	16.6	12.9	10.5	8.0	14.7	12.1	16.7

2 (Fig. 3). Along latitude, averages of Simpson' s index of diversity after exclusion of *E. punctifer* were highest at 15°N (16.6) and lowest at 17°N (10.5) (Table 2). The indices at all stations along 15°N were higher than the average. Those at stations along the other latitudes were highly variable, e.g., the indices at 16°N were lower at two stations (Sts. 2 and 9) and higher at the other two (Sts. 12 and S-4) than the average. Therefore, no distinct latitudinal trend could be recognized in the Simpson' s index when *E. punctifer* is excluded. The averages along longitude were highest at 141°E (16.7) and lowest at 134°E (8.0). The indices at stations along all longitudes were highly variable, e.g., at 137°E the indices were lower at two stations (Sts. 6 and 9) and higher at the other three (Sts. 7, 8, and 10) than the average. No distinct longitudinal trend could be recognized in the Simpson' s index when *E. punctifer* is excluded..

Comparison between stations, Percentage similarity index: Percentage similarity indices between all of the stations are shown in Table 3. They ranged from 0.7 (between Sts. 1 and S-3) to 87.6 (between Sts. S-2 and S-6). In their averages, three groups were recognized: St. 1 of less than 10, Sts. 6, 9, 10, and S-4 of between 20 and 30, and the other stations of more than 40. PSIs of St. 1 ranged from 0.7 (between St. S-3) to 25.4 (between St. 2), indicating no similarities with the other stations. In this station at the northwest corner of the study area, the most dominant species in the study area, *E. punctifer*, was not collected at all, with the dominant species being *V. nimbaria*. PSIs of the second group ranged from 2.1 (between Sts. 9 and S-3) to 64.4 (between Sts. 9 and 10). Their PSIs with the stations of the other two groups were less than 48.1 (between Sts. E-2 and S-4), but those between the stations of this group were 45.0 (between Sts. 6 and S-4) to 64.4 (between Sts. 9 and 10). Therefore, these stations did not show similarities with the stations of other groups, and showed similarity and dissimilarity within them. In these stations the most dominant species, *E. punctifer*, occupied low percentage (1.0% at St = 10 to 9.4% at St. 6), with the dominant species being *Diaphus* spp. for St. 10 and *C. warmingii* for the other three stations. These stations spread randomly in the sampling area.

In the third group of 16 stations, PSIs between the stations of the other two groups were less than 48.1 (between Sts. E-2 and S-4), indicating low similarity. PSIs between the stations of this group ranged from 41.7 (between Sts. 15 and S-3) to 87.6 (between Sts. S-2 and S-6), and their average PSIs from 50.0 (St. 15) to 76.7 (St. S-2). PSIs of two stations, E-2 and 15, of less than 60 average PSIs were lower than 50 in three of 15 at St. E-2 and in seven of 15 at St. 15, showing similarity or dissimilarity with the other stations. These stations were separate with each other in the study area, and their dominant specie was *E. punctifer*. PSIs between the rest 14 stations in this group were more than 55.8 (between Sts. 13 and S-3), showing similarities between them. The dominant specie at these stations was *E. punctifer*. Some of these stations showed strong similarity of more than 80 PSI, e.g., St. E-1 with Sts. 3, 4, 8, 12, 14, S-2, and S-6, and St. 8 with 4, E-1, 12, 14, S-2, and S-6. These stations of strong similarities were spread widely in the study area. Therefore, no distinct faunal area could be recognized in the study area.

Discussion

Although engraulid fish are typically coastal ones, the most dominant specie in this study, *Encrasicholina punctifer*, was regarded as an oceanic epipelagic engraulid of Indo-West Pacific region by Ozawa and Tsukahara (1973) based on the dominant occurrence of its larvae in the ocean of tropical west Pacific during two cruises (August to November and November to December). For the same purpose with the present study, similar studies but in wider area, from 10° to 22°N and 130° to 155°E, were carried out by R/V Hakuho-maru in June and July 1991 (KH-91-4). The larvae of *E. punctifer* occupied the third in rank at species level in that cruise (Ozawa, 1994). They were limited to southwest 10 stations in the study area, and dominated at three stations (10°N, 137°E; 12°N, 137°E; and 10°N, 143°E) with the highest density of 334/ 10^4 m^3 (Ozawa and Mitsui, unpublished data). Irrespective of almost the same area, season, and collection methods in the two cruises (KH-91-4 and KH-94-2 of this study), the larvae of *E. punctifer* occurred differently: they dominated throughout the study area with the highest density of 2,406.5/ 10^4 m^3 in this study, but limited to the southwest area with the highest density of 334 in KH-91-4. According to Ozawa (1994) and this study, the larvae of *E. punctifer* occur dominantly from June to December in the ocean of tropical west Pacific. However, as stated above, its dominance seems to fluctuate in space and abundance from year to year, which seems to have significant effects on larval fish composition in the area concerned (see below). Aspects of spawning ecology of this specie should be studied much more, especially on eggs which were not discovered by Ozawa and Tsukahara (1973).

The present study area is included in the oligotrophic ocean variously called such as northern Subtropical Pacific (Backus, 1986) or north Pacific Tropical Gyre (Longhurst, 1998). At about the center (ca. 28°N; 155°W) of this region, i.e., north Pacific Tropical Gyre, Loeb (1979) examined larval fish collected with obliquely hauled IKPT net being different mainly in mesh size (0.5 mm) from that (1.0 mm) in this study, and compared the top ranking families of larval fish with those at Eastern tropical Pacific, California Current and Indian Ocean. Mesopelagic families dominated as follows. In all the regions, Myctophidae ranked the first and *Gonostomatidae sensu* Ahlstrom (1974) the second, and in the Tropical Gyre and Eastern tropical Pacific, Sternoptychidae ranked the third. Moreover, in the Tropical Gyre, the ranks fourth to sixth were occupied by the mesopelagic families Melamphaidae, Paralepididae and Bregmacerotidae, respectively. In the present study area, mesopelagic families ranked in the top ten as follows: Gonostomatidae the second, Myctophidae third, Scopelarchidae fifth, Paralepididae sixth, Gempylidae seventh and Sternoptychidae eighth. The others in the top ten families were three epipelagic, Engraulidae (the first), Scombridae (fourth), and Nomeidae (ninth), and one neritic, Anguillidae (tenth). This ranking is quite different from that in Loeb (1979) both in the total and in mesopelagic families. However, when mesopelagic fish are compared at species level, the top three are the same in both studies: *Vinciguerria nimbaria* the first, *Cyclothone alba* second, and *Ceratoscopelus warmingii*, third.

Table 3: Percentage similarity index (PSI) between stations. The averages at each station are given in the column X. The numbers in the column X′ are the averages after exclusion of the following stations: 1, 6, 9, 10, and S-4.

Sts.	1	2	3	4	E-1	6	7	8	9	10	E-2	11	12	13	14	15	S-1	S-2	S-3	S-4	S-6	X	X′
1		25.4	6.8	6.5	7.4	13.9	7.5	3.9	16.2	19.0	16.6	1.2	4.4	5.9	3.5	2.2	2.9	2.5	0.7	18.4	6.8	8.6	
2			75.5	75.9	77.0	18.9	64.9	75.2	15.0	10.6	49.7	70.2	75.3	59.2	74.6	43.1	68.7	74.7	72.1	13.1	75.8	55.7	68.8
3				79.2	83.7	25.6	72.7	78.5	21.2	19.2	57.8	79.7	80.4	69.8	77.1	50.4	76.3	82.6	71.0	24.1	78.9	60.5	74.2
4					83.8	21.9	69.3	82.4	19.5	14.9	55.9	71.8	82.6	64.6	81.5	44.7	71.4	81.7	76.7	18.9	84.7	59.4	73.7
E-1						26.0	73.3	87.2	20.8	17.2	55.5	76.1	86.8	68.0	84.9	51.2	75.6	86.5	76.7	21.6	84.1	62.2	76.7
6							31.4	24.7	56.7	46.0	41.0	17.0	22.6	31.4	21.4	22.3	27.5	20.4	10.2	45.0	21.1	27.3	
7								72.2	23.6	20.6	59.1	68.7	73.6	69.7	69.0	56.1	76.9	69.8	60.4	25.9	68.1	56.6	68.2
8									19.3	14.2	54.1	77.3	86.7	66.2	86.2	52.6	77.9	84.4	77.0	23.0	83.5	61.3	76.1
9										64.4	46.2	13.2	21.9	26.6	18.2	14.4	18.2	15.2	8.2	57.9	19.5	25.8	
10											43.4	10.4	22.3	29.3	12.7	13.6	16.5	13.9	2.1	61.4	16.0	23.4	
E-2												51.9	56.4	60.8	52.6	49.1	53.3	54.6	43.7	48.1	55.5	50.3	54.0
11													77.6	66.6	76.5	49.2	75.8	80.0	69.7	17.0	73.7	56.2	71.0
12														70.8	85.5	50.8	77.2	85.1	75.5	22.5	84.0	62.1	76.5
13															67.3	51.2	67.9	66.8	55.8	33.5	66.2	54.9	64.7
14																49.2	76.2	86.0	78.8	18.8	86.5	60.3	75.5
15																	64.4	50.4	41.7	22.6	46.1	41.3	50.0
S-1																		77.5	66.2	24.7	72.4	58.4	71.8
S-2																			83.0	19.2	87.6	61.1	76.7
S-3																				6.7	81.7	52.9	68.7
S-4																					20.0	27.1	
S-6																						60.6	75.2

Sts.: stations

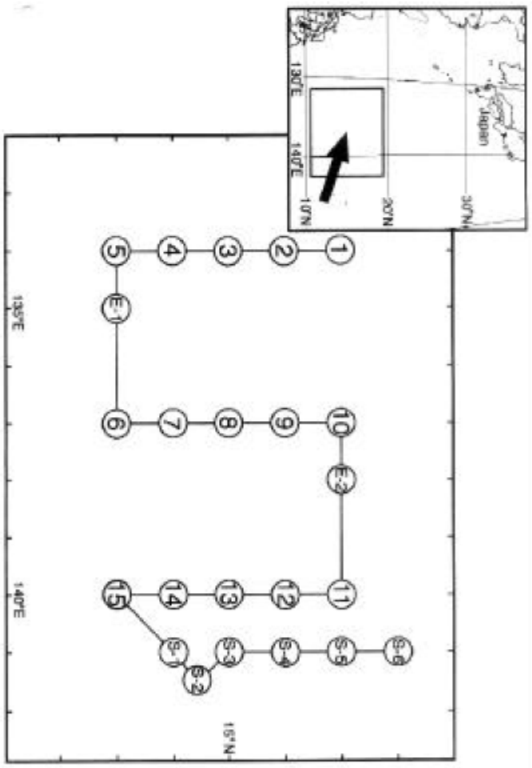

Fig. 1: Sampling map

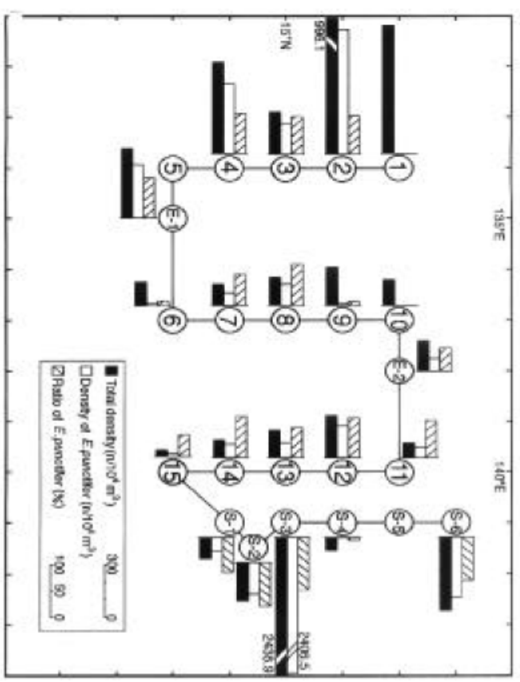

Fig. 2: Total larval density, density and percentage of *Encrasicholina punctifer*

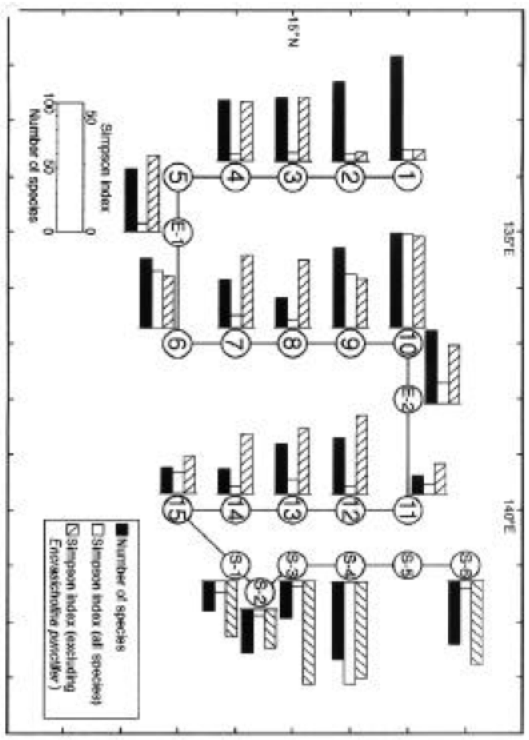

Fig. 3: Number of species and Simpon's index of diversity for all species and after exclusion of *Encrasicholina punctifer* at the different stations

Although included in the same faunal region, i.e., north Pacific Tropical Gyre, this study at about the periphery of the region showed the differences and similarities of larval fish composition with those at about the center of the region (Loeb, 1979). The Tropical Gyre is a vast area spreading from about 10 or 11°N to 30-32°N and from offshore edge of Kuroshio (at about 130°E) to the edge of offshore California Current (at about 130°W) (Longhurst, 1998). It is natural to see the difference of fish larvae composition between regions of this vast area. The fish larvae in summer in the present study area can be characterized by the dominance of epipelagic families such as Engraulidae and Scombridae.

Two cruises (KH-91-4 and KH-94-2 of this study) of R/V Hakuho-maru for the study of Japanese eel spawning ground were almost similar to each other in area, season and study methods (Inagaki and Tsukamoto, 1995). Hydrographic structure was fundamentally similar, but composition of fish larvae was very different between both cruises as follows.

KH-91-4 Cruise covered wider study area (10° to 22°N and 131° to 155°E) than this study (13° to 18°N and 134° to 141°E). Limited to the survey area of the present study, typical hydrographic structures in both cruises were as follows (Kimura *et al*., 1994; Hasumoto and Inagaki, 1995). Temperature below about 150 m depth gradually got warmer towards north. For example, the depth of about 20°C at 13 and 17°N along 137°E were about 170 and 220 m respectively in KH-91-4, and about 170 and 240 m respectively in KH-94-2. Salinity was less than 34.60 p.s.u. (practical salinity unit) in the surface layer shallower than 100 m, higher between 100 and 200 m (Tropical Water), and gradually lowered below (north Pacific Intermediate Water). For example, at 137°E, 13°N, the highest salinity 34.85 p.s.u. was located at about 150 m, and 34.60 p.s.u.

at about 100 and 220 m in KH-91-4, and the first 34.80 at about 180 m and the latter at about 140 and 230 m in KH-94-2. Geostrophic current in the surface layer to 150 m depth was mainly westwards. For example, at all latitudes along 137°E, the direction was westwards in both cruises. The clear difference between both cruises was the presence (KH-91-4) or absence (KH-94-2) of surface salinity front. For example, it was observed at 15-17°N all over the survey area in KH-91-4, but only between 16-17°N along 134°E in KH-94-2.

Ozawa (1994) showed the summaries of fish larvae composition in KH-91-4. Limited to the items analyzed in this study, they were as follows (for comparison, the results in this study are in parenthesis). Dominant five families were in order of abundance Gonostomatidae, Myctophidae, Engraulidae, Scopelarchidae, and Scombridae (Engraulidae, Gonostomatidae, Myctophidae, Scombridae, and Scopelarchidae), and dominant five species were in order of abundance gonostomatids *C.alba* and *V. nimbaria*, engraulid *E. punctifer*, and myctophids *C.warmingii* and *S. evermanni* (*E. punctifer*, *C.alba*, *V.nimbaria*, *C.warmingii* and scombrid *K. pelamis*). Densities of total fish larvae and numbers of species were significantly higher northwards (no latitudinal trend in the former and the same trend in the latter). Diversity indices were higher southwards (no distinct trend). The most typical difference was the composition of top dominant three families. According to the unpublished data of Ozawa and Mitsui, the average total density of fish larvae at night was 338.1/ 10^4 m^3 in KH-91-4 and 367.1 in this study, being nearly the same. In KH-91-4, gonostomatid larvae were collected at all stations and occupied 41.4% of all larvae with the average density of 164.6 at night (in this study, at almost all stations, 21.1%, and 48.1). Myctophid larvae were collected at all stations and occupied 28.7% of all larvae with the average density of 84.3 at night in KH-91-4 (in this study, at all stations, 7.5%, and 28.4%). Engraulid larvae were collected only at southwest stations and occupied 6.9% of all larvae with the average density of 30.1 at night in KH-91-4 (in this study, at almost all stations, 61.0%, 251.2).

As stated above, the most dominant fish larvae are myctophids and gonostomatids in other oceanic areas as well as in KH-91-4. The secondary dominance or low densities of both families in this study seem not due to the absence of surface salinity front, since they are distributed widely in latitudes and longitudes and most of them show diel vertical migration, indicating the tolerance to wide hydrographic variation. They seem to be related with the remarkable dominance or high densities of the engraulid *E. punctifer* at almost all stations. If this is true, followings are the study subjects in the future: why the engraulid dominated widely and why myctophid and gonostomatid larvae were low in density or their of spawning was depressed? The above difference in two three faunal items analyzed between the two cruises can be considered to be influenced by the occurrence of the engraulid fish larvae.

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