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Assessment of Tsunami Impact on Fish Eggs and Larvae along Parangipettai Coast (Southeast Coast of India)

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Abstract: The tsunami on 26th December 2004 caused extensive damage to coastal communities and affected many marine ecosystem in Southern regions of India and Andaman and Nicobar Islands affecting 2,260 km of coastline. The most affected regions were the State of Tamil Nadu and the Andaman and Nicobar archipelago. The present research analyzes the impact of tsunami on finfish eggs and larvae and its distribution patterns. It deals how the tsunami impinges directly on ichthyoplankton ecology. After the tsunami effect, the eggs and larvae samples were collected and compared with previous year data of the same month (January 2004 and January 2005). We selected five stations, 0.5, 1, 3, 5 and 10 km distance from the shoreline. During the present study a total of 1067 eggs and 285 larvae belonging to 29 families and 57 species were sorted and identified. The pre and post tsunami collection shows the significant variation on eggs and larvae distribution. During pre tsunami the zooplankton biomass was highly correlated with ichthyoplankton density with all the five station significant at 1% level (p-value <0.01) but there is no correlation observed in the post tsunami samples.

Key words: Tsunami, ichthyoplankton, eggs, larvae, zooplankton

INTRODUCTION

The early developmental stages of fishes are interesting and essential study subject in academic sciences besides its use in estimating the spawning ground, spawning season and the size of the spawning stock (Rankine and Bailey, 1987; Acevedo and Fives, 2001). Such studies also help in locating shoals of fishes and their breeding places. Every species is adapted for life under a particular range of conditions. However, environmental features may affect communities through changes in physiological and behavioral responses of organisms and by directly affecting the distribution and abundance patterns of individual species (Pearcy *et al*., 1996; Moser and Smith, 1993) The sudden changes in the environment may cause fluctuation on the survival, growth and breeding of fishes and thereby the recruitment of larva. Turbulence (MacKenzie and Leggett, 1991) and pray aggregation (Lasker, 1975) are also important factors which affect the fish larval distribution.

Tsunami has triggered by massive earthquake on the sea floor of the Indian Ocean, off the West Coast of Northern Sumatra, Indonesia on 26th December 2004. It was the second largest instrumentally recorded event following the 1960 magnitude 9.5 Chile earthquake (Ghobarah *et al*., 2006). The uplift of the ocean floor created a tsunami that affected 19 countries, including India, the most horrible affected regions were the State of Tamil Nadu and the Andaman and Nicobar Island and it generated grater effect on coastal environments. This powerful tsunami could have substantially altered few shallow water benthic habitats, reducing their effectiveness as nurseries and shelters for fish and other organisms. The overall objective of this study is to understand whether there is any impact of tsunami on the distribution, abundance and species composition of finfish eggs and larvae.

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MATERIALS AND METHODS

The present investigation is based on the finfish larval collections made during 2004 and 2005 January from the Parangipettai coast. Located along the southeast coast of India, which is known for its unique, potential for marine and brackish water resources, being endowed with various aquatic biotopes viz., neritic, estuarine, backwater and mangroves. Stations were located 0.5 km (11°30'N; 79°46' E), 1 km (11°30'N; 79°47' E), 3 km (11°30'N; 79°48' E), 5 km (11°31'N; 79°49' E) and 10 km (11°32'N; 79°51'E) distance from the Vellar river mouth.

The fish eggs and larvae samples were collected by oblique tows with Bengo nets, with 158 µm mesh size. Samples were fixed in 4% seawater formalin buffered with sodium borate. The volume of water filtered was quantified with the help of General Oceanics flowmeter placed at the mouth of the nets. The samples were analyzed by using Utermohl's inverted plankton microscope, eggs and larvae were identified up to generic or species level following the method mainly based on the standard reserch done by Delsman (1972) and Prince Jeyaseelan (1998). Ichthyoplankton abundance was standardized to 10 m^3. Hydrographic measurements such as temperature, salinity, dissolved oxygen and pH were recorded with the help of SeaBird Model SBE-19 plus CTD and BOD was analyzed by using method Strickland and Parsons (1972). Simple correlation co-efficient were made to analyze the variation between finfish eggs and larvae with environmental parameters (Table 1 and 2).

RESULTS

Environmental Conditions

The water column along Parangipettai coast presented typical post monsoon seasons in both 2004 and 2005. The environmental parameters like salinity, temperature, DO, pH and Plankton bio volume observed from five stations has been presented (Fig. 1-7).

Table 1: Sample correlation co-officiant between finfish eggs, larvae, zooplankton biovolume, BOD, DO, salinity, water temperature and air temperature during January 2004 (before tsunami) from stations 1, 2, 3, 4 and 5

Parameters	A.temp	W.temp	Salinity	DO	pH	BOD	Plan. bio	Eggs	Larvae
A.temp	1								
W.temp	0.2322	1							
Salinity	0.7357c	-0.4805	1						
DO	0.4941	0.7381c	-0.1202	1					
pH	0.9851d	-0.9517d	0.6762b	-0.7377c	1				
BOD	0.7407c	0.6760b	0.1601	0.9482d	-0.5839a	1			
Plan. bio	-0.1480	0.7119b	-0.5589a	0.0895	-0.6217b	0.0602a	1		
Eggs	-0.0425	0.9196d	-0.6687b	0.6490b	-0.9299d	0.5161	0.7601c	1	
Larvae	0.0235	0.9700d	-0.6492b	0.6901b	-0.9752d	0.5664a	0.7449c	0.9822d	1

Table 2: Sample correlation co-officiant between finfish eggs, larvae, zooplankton biovolume, BOD, DO, salinity, water temperature and air temperature during January 2004 (before tsunami) from stations 1, 2, 3, 4 and 5

Parameters	A.temp	W.temp	Salinity	DO	pH	BOD	Plan. bio	Eggs	Larvae
A.temp	1								
W.temp	0.8864d	1							
Salinity	0.7168c	0.7213c	1						
DO	-0.3766	-0.6605b	-0.6315b	1					
pH	0.6583b	0.7647c	0.9411d	-0.8522d	1				
BOD	-0.1860	0.1850	0.4189	-0.6071b	0.5003a	1			
Plan. bio	0.7939c	0.9581d	0.4970a	-0.6087b	0.5903a	0.1060	1		
Eggs	0.16443	0.1923	-0.5155a	0.2710	-0.4619	-0.5294a	0.4342	1	
Larvae	0.2687	0.0691	-0.4537	0.3379	-0.4148	-0.8848c	0.2407	0.8092c	1

a) Significant at 5% level ($p<0.05$); b, Significant at 2% level ($p<0.02$); c, Significant at 1% level ($p<0.01$); d, Significant at 0.1% level ($p<0.001$); A. temp-Atmospheric temperature; W. temp- water temperature; Plan. bio-Zooplankton biovolume

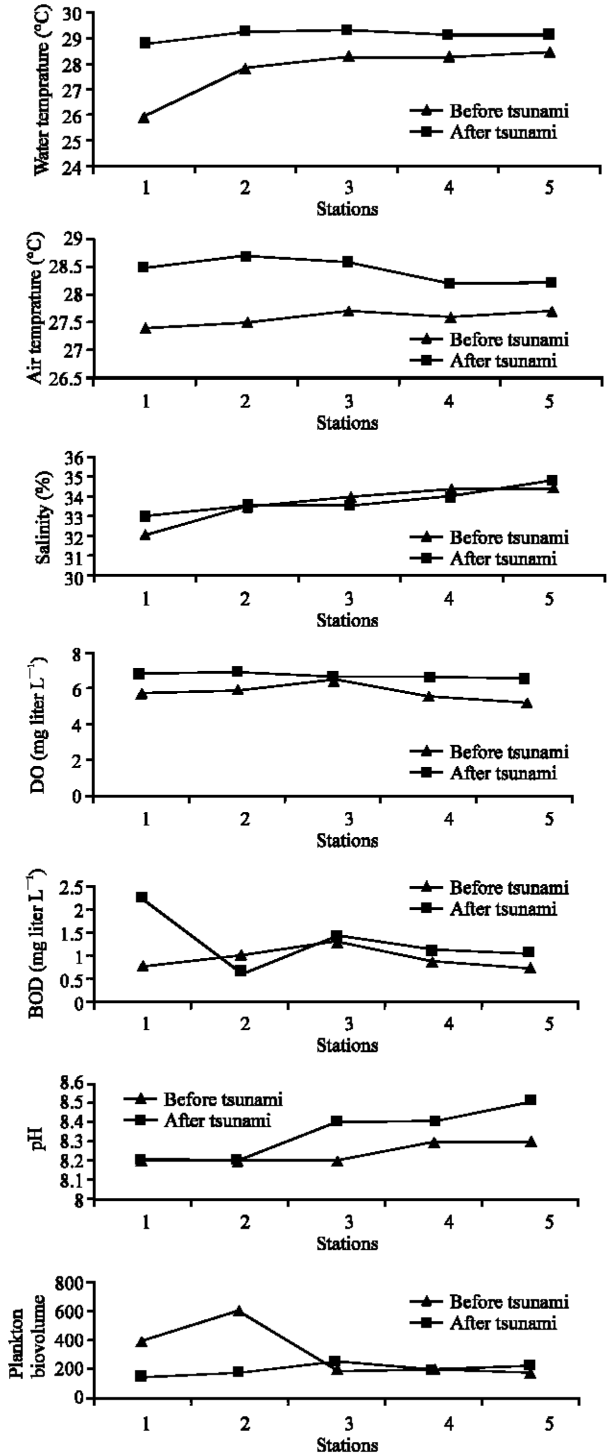

Fig. 1-7: Variations in water temperature, air temperature, Salinity, DO, BOD, pH and Plankton bio volume recorded during January 2004 and January 2005 from stations 1, 2, 3, 4 and 5

Temperature

The atmospheric temperature during the study period ranged from 27.4 to 28.7°C. There is no marked fluctuation between all the stations during pre and post tsunami (Fig.1 and 2). The surface water temperature shows similar to that of atmospheric temperature there is no much variations was observed both pre and post tsunami collections (Fig. 2). The lowest value (25.9°C) was observed at 0.5 km distance when the fresh water mixing area and the highest temperature (29.1°C) was recorded at 10 km distance.

Salinity

Horizontal stratification in salinity was quit apparent in the present study. A gradual increase in salinity was observed from the 0.5 to 10 km distance from the shoreline. In both the collection minimum 32 ‰ was observed at 0.5 km distance and maximum 34.8 ‰ was observed in 10 km distance. There is no significant variation between pre and post tsunami collections (Fig. 3). The temperature and salinity did not show any great difference between the pre and post tsunami collections.

Dissolved Oxygen

Pre tsunami collection the DO was minimum (5.2 mg) at 10 km distance and the maximum (6.5 mg) at 3 km distance. In post tsunami the lowest DO (6.54 mg) was observed at 5 km distance and the highest DO (6.91 mg) was observed at 1 km distance (Fig. 4). When compared to pre tsunami the post tsunami samples show the maximum DO concentrations.

Biological Oxygen Demand

The BOD distribution in the surveys differed notably. During pre tsunami the minimum BOD was observed at 10 km distance (0.72 mg) and the maximum (1.3 mg) at 3 km distance. In post tsunami the lowest BOD (0.64 mg) was observed at 1 km distance and the highest BOD (2.24 mg) was observed at 0.5 km distance (Fig. 5). Post tsunami samples show the maximum BOD concentrations.

Plankton Bio Volume

During January 2004, the higher zooplankton bio volume at 1 km distance (60 mL 10 m^{-3}) and lesser volume at 10 km distance (20 mL 10 m^{-3}) (Fig. 7) were observed. However in January 2005, after tsunami, variations were also observed in zooplankton bio volume, the maximum density at 3 km distance (25 mL 10 m^{-3}) and minimum at 1 km distance (18 mL m^{-3}) (Fig. 7).

Total Abundance

In the ichthyoplankton samples made prior to tsunami the density of eggs and larvae were ranged from 54 to 237 10 m^{-3} and 11 to 75 10 m^{-3}, respectively. However in the post tsunami collection eggs and larval density varied from 49 to 146 and 12 to 28 10 m^{-3}. From both the collections lesser numbers were evident in 10 km region but the maximum density at 2 km distance in pre tsunami and 3 km distance during post tsunami. After the tsunami the mean density of eggs and larvae decreased to 43.76 and 53.88% when compared to that of previous collection (Fig. 8 and 9).

Family Wise Larval Density

During the year 2004 the representative of the family Engraulidae and Clupeidae were more dominant, the mean density being 9.2 and 8.6 10 m^{-3} however after the tsunami it was considerably decreased to 1.6 and 1.4 10 m^{-3}. Taxa like Elopidae, Chirocentridae Chandidae, Muraenesocidae, Hemirhampidae, Mugilidae, Ambassidae, Apogonidae, Carangidae, Serranidae, Pomadasyidae and Leognathidae were also decreased when compared with pre tsunami collection

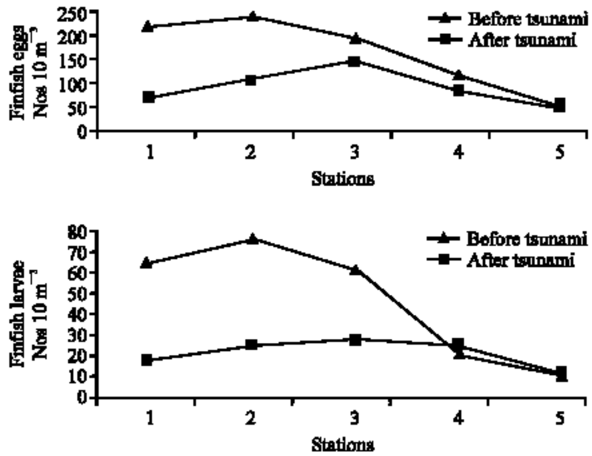

Fig. 8 and 9: Density of finfish larvae recorded during January 2004 and January 2005 from stations 1, 2, 3, 4 and 5

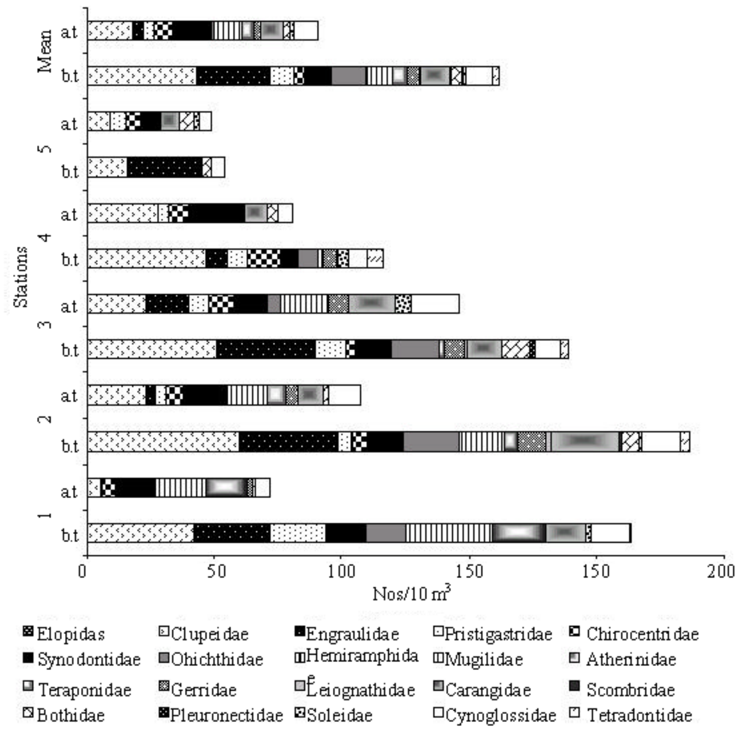

Fig. 10: Family wise finfish eggs density recorded during January 2004 and January 2005 from stations 1, 2, 3, 4 and 5

(Fig. 10 and 11) and also the number of eggs and larvae belonging to different families were highly decreased towards the shoreline region 0.5, 1, 3 km distance when compared with offshore region 5 and 10 km.

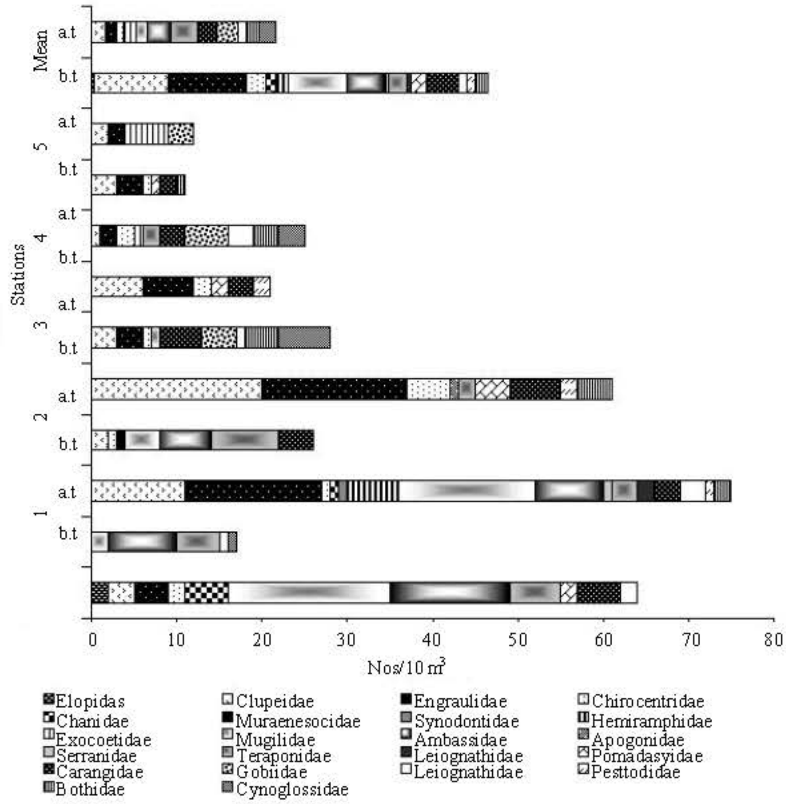

Fig. 11: Family wise finfish larvae density recorded during January 2004 and January 2005 from stations 1, 2, 3, 4 and 5

Table 3: Species wise percentage composition of finfish eggs recorded during January 2004 and January 2005 from stations 1, 2, 3, 4 and 5

		0.5 km		1 km		3 km		5 km		10 km	
S. No.	Species Name	Before tsunami	After tsunami	Before tsunami	After tsunami	Before tsunami	After tsunami	Before tsunami	After tsunami	Before tsunami	After tsunami
	Clupeidae										
1	*Esculosa thoaracata*	5.63	-	6.28	7.48	6.88	4.11	4.31	11.1	14.8	-
2	*Sardinella fimbriata*	7.51	6.94	5.22	10.3	5.82	8.22	13.8	14.8	9.26	18.4
3	*S.gibbosa*	5.16	-	10	-	9.52	-	10.3	-	5.56	-
4	*S.longiceps*	-	-	1.26	-	-	-	-	-	-	-
5	*S.clupeoides Anadontostoma*	0.47	-	-	-	-	-	-	-	-	-
6	*chacunda*	0.94	-	2.51	3.74	4.76	3.42	5.17	8.64	-	-
7	*Nematolosa nasus*	-	-	-	-	-	-	6.9	-	-	-
	Engraulidae										
8	*Setipinnataty*	2.82	-	3.77	-	2.12	-	-	-	7.41	-
9	*Stolephorustri*	2.35	1.39	0.84	-	3.7	1.37	0.86	-	38.9	-
10	*S. punctifer*	1.41	-	4.6	-	4.76	-	3.45	-	5.56	-
11	*S.heterolobus*	-	-	-	-	4.23	-	-	-	-	-
12	*S. macrops*	0.94	-	-	-	-	-	-	-	-	-

Table 3: Continued

		0.5 km		1 km		3 km		5 km		10 km	
S. No.	Species Name	Before tsunami	After tsunami	Before tsunami	After tsunami	Before tsunami	After tsunami	Before tsunami	After tsunami	Before tsunami	After tsunami
13	*Thyrssa dussumieri*	-	-	0.42	-	-	-	-	-	-	-
14	*T. mystax*	6.57	-	6.8	3.74	5.82	10.3	2.59	-	-	-
	Pristigasteridae										
15	*Opisthopterus tardoore*	10.3	-	2.09	3.74	6.35	5.48	6.9	4.94	-	12.2
	Chirocentridae										
16	*Chirocentrus dorab*	-	6.94	2.51	6.55	1.59	6.85	11.2	9.88	-	12.2
	Synodontidae										
17	*Saurida gracilis*	-	1.39	0.42	2.8	-	-	-	11.1	1.85	12.2
18	*S. tumbil*	-	1.39	0.84	-	0.53	1.37	4.31	4.94	-	-
19	*Saurida* sp.	7.04	16.7	4.6	5.61	4.76	5.48	1.72	7.41	-	-
20	*Saurus* sp.	-	2.78	-	7.48	2.12	2.05	-	3.7	-	4.09
	Ophichthidae										
21	*Ophichthys* sp.	7.51	-	9.22	-	10.1	3.42	6.9	-	-	-
	Hemiramphidae										
22	*Hemiramphus* sp.	-	-	0.42	-	-	-	1.72	-	-	-
	Mugilidae										
23	Liza dussumieri	6.57	2.78	5.12	0.93	-	3.42	-	-	-	-
24	*L. tade*	0.94	8.33	0.42	0.93	-	1.37	-	-	-	-
25	*Mugil cephalus*	8.45	16.7	1.26	13.1	-	8.22	-	-	-	-
	Atherinidae										
26	*Pranesus pinguis*	-	-	0.42	-	-	-	-	-	-	-
	Teraponidae										
27	*Terapon jarbua*	9.86	22.2	2.09	6.54	1.06	-	-	-	-	-
	Gerridae										
28	*Gerrus oblongus*	-	2.78	4.7	4.67	4.23	5.48	4.31	-	-	-
	Leiognathidae										
29	*Secutor ruconius*	-	-	0.84	-	-	-	-	-	-	-
30	*S. insidiator*	-	-	-	-	0.53	-	-	-	-	-
	Carangidae										
31	*Caranx* sp.	5.63	-	3.35	9.35	7.41	12.3	0.86	11.1	-	14.3
32	*Decapterus russelli*	-	-	1.67	-	-	-	-	-	-	-
33	*Scomberoides tol*	1.88	-	6.38	-	-	-	-	-	-	-
	Scombridae										
34	*Scomberomorus* sp.	-	-	0.42	-	-	-	-	-	-	-
	Bothidae										
35	*Pseudorhambus javanicus*	-	1.39	2.93	1.87	5.82	-	-	4.94	7.41	12.2
	Pleuronectidae										
36	pleuronectid egg	-	-	-	-	1.06	-	-	-	-	-
	Soleidae										
37	*Solea ovata*	0.94	-	0.42	-	-	4.11	3.45	-	-	4.09
	Cynoglossidae										
38	*Cynoglossus arel*	1.88	1.39	5.22	3.74	2.12	1.37	6.03	1.23	9.26	10.2
39	*C. puncpiceps*	5.16	2.78	1.26	2.8	3.17	1.37	-	-	-	-
40	*Cynoglossus* sp.	-	4.16	-	4.67	-	10.3	-	6.17	-	-
	Tetraodontidae										
41	*Arothron hispidus*	-	-	1.67	-	-	-	5.17	-	-	-
42	*Arothron* sp.	-	-	-	-	1.59	-	-	-	-	-

Species Composition

A total of 1067 eggs and 285 larvae were collected, sorted out and identified during this survey. The list of taxa compiled in the present study (Table 3 and 4) including 57 species in 29 families. Finfish eggs belonging to 42 species and larvae belonging to 31 species were identified.

Table 4: Species wise percentage composition of finfish larvae recorded during January 2004 and January 2005 from stations 1, 2, 3, 4 and 5

		0.5 km		1 km		3 km		5 km		10 km	
S. No.	Species Name	Before tsunami	After tsunami	Before tsunami	After tsunami	Before tsunami	After tsunami	Before tsunami	After tsunami	Before tsunami	After tsunami
	Elopidae										
1	*Elops machnata*	3.13	-	-	-	-	-	-	-	-	-
	Clupeidae										
2	*Esculosa thoracata*	1.56	-	4	-	13.11	-	19.05	-	18.18	-
3	*Hilsa kelee*	3.13	-	10.67	-	19.67	-	9.52	-	9.09	-
4	*Sardinella fimbriata*	-	-	-	4	-	7.14	-	4	-	-
5	*S.longiceps*	-	-	-	4	-	3.57	-	-	-	-
6	*Anadontostoma chacunda*	-	-	-	-	-	-	-	-	-	16.67
	Engraulidae										
7	*Stolephorus tri*	3.13	-	10.67	-	4.92	7.14	4.76	4	9.09	16.67
8	*S. punctifer*	-	-	-	-	-	3.57	-	4	-	-
9	*S. indicus*	-	-	-	-	6.56	-	23.81	-	-	-
10	*T. mystax*	3.13	-	10.67	-	16.39	-	-	-	18.18	-
	Chirocentridae										
11	*Chirocentrus dorab*	3.13	-	1.33	4	8.2	3.57	9.52	8	9.09	-
	Chanidae										
12	*Chanos chanos*	7.81	-	1.33	-	-	-	-	-	-	-
	Muraenesocidae										
13	*Muraenesox cinreus*	-	-	1.33	-	-	-	-	-	-	-
	Hemiramphidae										
14	*Hirundichthys coramandelensis*	-	-	8	-	-	-	-	-	-	-
15	*Cypselurus comatus*	-	-	-	-	-	-	-	4	-	41.66
	Mugilidae										
16	*Mugil cephalus*	29.69	11.76	21.33	16	-	3.57	-	-	-	-
	Ambassidae										
17	*Ambassis commersoni*	21.88	47.06	10.67	24	-	-	-	-	-	-
	Apogonidae										
18	*Apogon* sp.	-	-	-	-	1.64	-	-	-	-	-
	Serranidae										
19	*Epinephelus* sp.	-	-	1.33	-	-	-	-	-	-	-
	Teraponidae										
20	*Terapon jarbua*	9.38	29.42	4	32	3.28	-	-	8	-	-
	Leiognathidae										
22	*Secutor insidiator*	-	-	2.67	-	-	-	-	-	-	-
	Pomadasyidae										
23	*Pomadasys maculatus*	3.13	-	-	-	6.56	-	9.52	-	9.09	-
	Carangidae										
24	Caranx sp.	7.81	-	4	16	9.84	17.86	14.29	12	18.18	-
	Gobiidae										
25	*Glossogobius giuris*	-	-	-	-	-	14.29	-	20	-	25
	Platycephalidae										
26	*Platycephalus indicus*	3.13	5.88	4	-	-	3.57	-	12	-	-
	Pesttodidae										
27	*Psettodes erumei*	-	-	1.33	-	3.28	-	9.52	-	-	-
	Bothidae										
28	*Bothus pantherinus*	-	-	1.33	-	3.28	14.29	-	12	9.09	-
29	*Engyprosopon grandisquama*	-	-	1.33	-	3.28	-	-	-	-	-
	Cynoglossidae										
30	*Cynoglossus arel*	-	5.88	-	-	-	14.29	-	12	-	-
31	*C. puncpiceps*	-	-	-	-	-	7.14	-	-	-	-

The dominant taxa in eggs were *Sardinella fimbricata*, *Caranx* sp., *Saurida* sp., *Escualosa thoracata*, *Mugil cephalus*, *Opisthopterus tardoore* and *Chirocentrus dorab* accounted for around 44% of total collection. *Ambassis commersoni*, *Mugil cephalus*, *Terapon jarbua*, *Caranx* sp., *Stolephorus tri* and *Glossogobius giuris* were the dominant species among the larvae constituted about 52% of the total density. During pre tsunami the diversity was greatest with higher number of species of eggs (39) and larvae (22) whereas during post tsunami diversity was lowest during January 2005, where only 25 eggs and 16 species of larvae were taken.

DISCUSSION

In the study we found that the eggs and larvae is higher during January 2004 when compared with January 2005. Patterns of distribution and abundance of fish eggs and larvae are associated with environmental parameters, which may act as a favorable factor for successful spawning of fish and survival of eggs and larval stages. The period of developmental stages in a spatial feature is an important characteristic feature of the life cycle of fish. Thus the pattern of distribution and the area of availability of eggs and larvae may vary with the fluctuation of environmental conditions.

Among the five stations the environmental parameters shows a significant variation between eggs and larval distribution only during pre tsunami sampling, water temperature and pH are highly correlated with eggs and larvae density with all the five station significant level was at 0.1% and $<$p-value <0.001 while the other parameters like salinity and DO correlated with 2% significant level (p-value <0.02). However post tsunami collection of the eggs and larvae are not significantly correlated with environmental parameters.

Higher BOD values was observed during post tsunami samples it indicates the increasing of organic load in the surrounding environment it shows the negative impact on eggs and larvae distribution. During post tsunami collections BOD was negatively correlated with ichthyoplankton distribution significant at 1% level p-value less than 0.01.

In pre tsunami collections at station 2, the maximum number of larvae (237 10 m^{-3}) was recorded in highest volume of zooplankton (60 mL 10 m^{-3}) while the second highest (231 10 m^{-3}) observed at station 1 was form a zooplankton biomass of (40 mL 10 m^{-3}). The zooplankton biomass was highly correlated with eggs and larvae density with all the five station significant at 1% level (p-value <0.01). Cushing, (1977) found the largest concentration of fish eggs and larvae are in the region where zooplankton bio volume is most abundant. Since zooplanktonic organism represent the main source of food for larvae and juveniles of marine pelagic fishes. The partial overlap between the distribution of zooplankton bio volume and fish eggs suggests a synchrony between the spawning and food availability for the future larvae. The synchronization between ichthyo and zooplankton has already been observed by Katsuragawa *et al*. (1993). Further the eggs and larval abundance is also determined by the environmental features and plankton predators, is observed by (Koutsikopoulos and Lacroix (1992) Mackezie and Leggett (1991).

In the case of post tsunami there was no correlation between the number of fish eggs and larvae and zooplankton biomass it may be seemed to the tsunami impact not only observed in the ichthyoplankton and also affected the zooplankton biomass so uneven relationship observed between the fish eggs and larvae and zooplankton density were observed. Peter (1982) observed that the maximum number of larvae was not positively correlated with the samples of larger biomass, but from samples that were neither high nor low. The effect and pattern of prevailing current is one of the important factors that facilitate the distribution of larvae. Since the fish larvae are capable of free swimming, to some extent they can resist water movements but not with strong currents (Lalithambika Devi, 1999). The fish larvae being the least protected, from easy prey to the predators, may also contribute to their low density together with natural mortality.

The tsunami has scraped the sediments from seafloor results; the water was completely turbid and vigorously pressed towards land. Since early life stages of fish have poor swimming capability and are fragile, they are vulnerable to rapid changes in hydrodynamic pressure resulting from movement in the water column. Laboratory studies have evaluated individual physical forces that have the potential to cause mortality, including shear, turbulence and shoreline dewatering (Adams *et al*., 1999; Holland 1987; Killgore *et al*., 1987; Morgan *et al*., 1976; Payne *et al*., 1990).

The early stages of epipelagic groups of fishes such as Engraulidae and Clupeidae are characterized by an elongate body with small fins and their swimming abilities are poorly developed (Hewitt, 1981; Blaxter and Hunter, 1982). In the present observation after the tsunami minimum number of eggs and larvae of epipelagic species were observed when compared with before tsunami. It may be chance during the tsunami the eggs and larvae poorly developed fishes has swamped up in to land. At Izmit Bay, Turkey after the tsunami the water was flooded up to 35 m inland since some mussel and dead fishes were seen in this inundation area (Altinok *et al*., 1999).

The pattern of distribution and seasonal occurrence of eggs and larvae are not similar during the present study period of two years. Relatively more eggs and larvae were recorded in the first year rather than the second year. When compared with first year data the density of eggs and larvae were highly decreased at 0.5 and 1 km distance. This pattern may be influenced by the changes in hydrographical and topographical features particularly increase in the turbidity nearer to costal region during the tsunami effect. As a result, some near shore fisheries is likely to be affected by very low recruitment success over the next few years.

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