J. mar. biol. Ass. India., 1995, **37** (1 & 2) : 56 – 73

CERTAIN ECOLOGICAL IMPACTS ON THE DISTRIBUTION AND ABUNDANCE OF FISH EGGS AND LARVAE OF VELLAR ESTUARY, PORTO NOVO (BAY OF BENGAL)

M. THANGARAJA*

Centre of Advanced Study in Marine Biology, Annamalai University, Porto Novo 608 502

ABSTRACT

Distributional fluctuations of fish eggs and larvae in different zones of Vellar Estuary during lowtide and hightide, day and night and newmoon and fullmoon have been studied from November 1977 to October 1979. Environmental parameters such as rainfall, atmospheric and surface water temperature and surface salinity have also been recorded. It has been observed that salinity plays a major role over the distribution of eggs in the estuary. The eggs and larvae were abundant in plankton during hightide, night and newmoon time. A significant correlation in the distribution of eggs and larvae with season reiterates the well known fact of seasonal influence on the organism. Maximum eggs and larvae was noticed during the postmonsoon (January-March), and subsequently, minimum number of eggs was recorded during the monsoon (October-December).

The influence of such factors as salinity and solar periodicity on the availability of eggs was highly significant ($P < 0.01$), whereas the effect of temperature was not significant. This clearly indicated that salinity of water and solar periodicity were affecting the egg availability in the estuary. Though the effect of temperature on the egg number was not significant, there was an indication that there was a slight reduction in the number of eggs as the temperature increased. Variation in the stationwise distribution of eggs was highly significant ($P < 0.001$). Highest egg count was recorded in Station I and a progressive reduction of eggs was noticed in all the other 3 stations. However, stationwise analysis of larvae did not indicate any significant variation. In accordance with the tidal influence, the distribution of both eggs and larvae was highly significant. The abundance of eggs and larvae was very high during hightide. Hightide showed 4.9 times more eggs than lowtide and 2.1 times more larvae than lowtide. The interactions of station x tide ($P < 0.1$) and season x tide ($P < 0.05$) on egg and larval availability and abundance were significant. Lunar periodicity was found to be highly significant on the distribution of eggs ($P < 0.01$) and larvae ($P < 0.001$). It was evident that the newmoon has much greater influence than the fullmoon on the abundance of both eggs and larvae.

INTRODUCTION

EVERY species is adapted for life under a particular range of conditions. Changes in the environment beyond the limits to which the species is adapted leads to disruption in their development and to the death of the developing organism. Estuarine organisms are affected not only by the magnitude of salinity changes, but also by the rate of change (Bassindale, 1943). It is well known that if salinity changes very slowly, many organisms can adapt themselves to live in the new salinity, whereas a rapid change of similar magnitude may prove fatal. The fluctuations in physico-chemical

* *Present address :* Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries, P.O. Box 467, Muscat, Sultanate of Oman.

characteristics of estuarine environment have a profound influence on the aperiodic and seasonal occurrence of eggs and larvae of fishes. The changes in this brackishwater environment cause fluctuations on the survival, growth and breeding of fishes and thereby the recruitment of larvae. Therefore, changes in the distribution of fish eggs and larvae in relation to different salinities from the marine to the freshwater zone of Vellar Estuary together with such factors as temperature, lunar periodicity (new and full moon), tidal rhythms and solar periodicity (day and night) were studied for various seasons in the present investigation.

Vellar Estuary situated in Porto Novo at 11° 20′ N, 79° 46′ E, has a variety of biotopes; linked with open coastal waters such as backwaters and mangroves. The estuary is always subjected to long term fluctuations in salinity with the current of sea water diurnally and with variations in the inflow of freshwater or by rainfall seasonally. The width of the estuary is 100 m at the mouth and its maximum width is 200 m. The maximum depth recorded is 5 m at the time of high tide. The estuary shows semidiurnal tides and the tidal flushing extends upstream to a distance of 10-14 km. The prime factor on the basis of which the zonation of the estuary could be classified, is the chlorinity. Based on hydrological data (chiefly the chlorinity conflict), Ramamoorthi (1954) demarcated the estuary into (1) the marine zone, (2) the gradient zone, (3) the tidal zone and (4) the freshwater zone (Fig. 1).

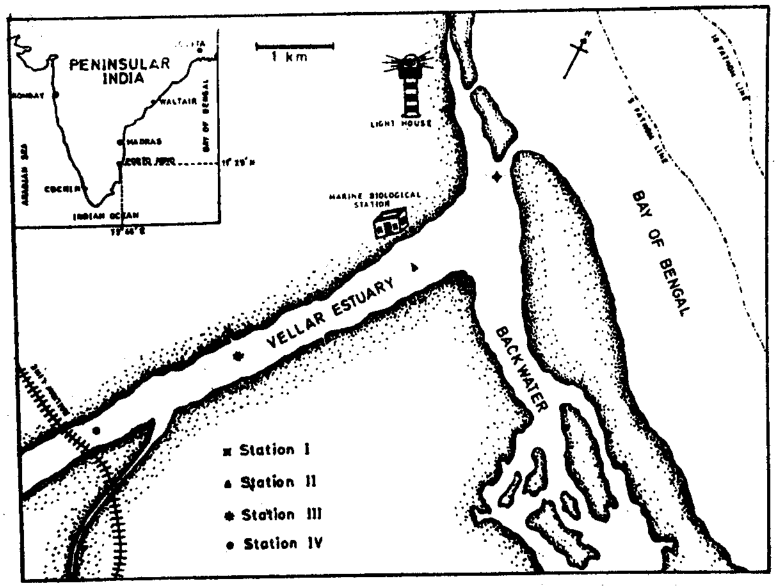

Fig. 1. Vellar Estuary showing the location of stations investigated during November 1977 to October 1979.

The author expresses his sincere thanks to late Dr. K. Ramamoorthi, CAS in Marine Biology, Porto Novo and the authorities of the Annamalai University for providing facilities; to Dr. M. Devaraj, Dean, Fisheries College, Tuticorin for critically reviewing the manuscript; to Dr. M. George, System Analyst, University of Guelph, Canada and Mrs. Vijaya Thangaraja for their help in the statistical interpretation and for computerising the numerical data.

Materials and Methods

Zooplankton sampling cruises were conducted by mechanised boats '*Medusa*' and '*Calanus*' at all the four zones of the Vellar Estuary from November 1977 to October 1979. Samples were collected for 5 minutes from each station during all the 4 tides on full and newmoon days. The plankton net (No. 10 bolting silk, 158 μm) was towed along the surface at uniform speed and depth as followed by Venkataramanujam (1975). The samples were preserved in 5% neutralised formalin. For the numerical estimation of the abundance of eggs of different species, the subsamples were used. It was possible to count all the individual eggs in the subsample except the less abundant groups. If the eggs of a particular species were found in superabundance, only a small fraction of the subsample was examined. All the larvae in the samples were counted, irrespective of their abundance.

During each collection, atmospheric temperature, surface temperature and salinity were recorded. Temperature was recorded with a celsius thermometer. Salinity was estimated as described by Strickland and Parsons (1972). The silver nitrate solution was checked with standard sea water and the correction factor applied. Seasonwise rainfall was also recorded.

Based on the annual meteorological changes in Proto Novo, the whole year could be divided into four seasons, *viz.* NE monsoon (October to December), postmonsoon (January to March), summer (April to June) and premonsoon (July-September). The season is determined by rainfall and temperature.

In order to assess the effect of lunar periodicity (fullmoon and newmoon), tides, seasons and stations on the distribution of eggs and larvae, the 2 year data were statistically treated using the following newly developed 4-way analysis of variance with interaction model :

$$Y_{ijklm} = \mu + L_i + S_j + T_k + Z_l + (LS)_{ij} + (LT)_{ik} + (LZ)_{il} + (ST)_{jk} + (SZ)_{jl} + (TZ)_{kl} + (LST)_{ijk} + (LSZ)_{ijk} + (LTZ)_{ijl} + (STZ)_{jkl} + (LSTZ)_{ijkl} + e_{ijklm}$$

where

Y_{ijklm} = m^{th} egg or larval collection of the l^{th} station, k^{th} tide, j^{th} season and i^{th} lunar periodicity.

μ = population mean

L_i = effect of i^{th} lunar periodicity

S_j = effect of j^{th} season

T_k = effect of k^{th} tide

Z_l = effect of l^{th} station

$(LS)_{ij}$ = interaction effect of the j^{th} season and i^{th} lunar periodicity

$(LT)_{ik}$ = interaction effect of the k^{th} tide and i^{th} lunar periodicity

$(LZ)_{il}$ = interaction effect ot l^{th} station and i^{th} lunar periodicity

$(ST)_{jk}$ = interaction effect of k^{th} tide and j^{th} season

$(SZ)_{jl}$ = interaction effect of l^{th} station and j^{th} season

$(TZ)_{kl}$ = interaction effect of l^{th} station and k^{th} tide

$(LST)_{ijk}$ = interaction effect of k^{th} tide, j^{th} season and i^{th} lunar periodicity

$(LSZ)_{ijl}$ = interaction effect of l^{th} station, j^{th} season and i^{th} lunar periodicity

$(LTZ)_{ikl}$ = interaction effect of l^{th} station, k^{th} tide and i^{th} lunar periodicity.

$(STZ)_{jkl}$ = interaction effect of l^{th} station, k^{th} tide and j^{th} station

$(LSTZ)_{ijkl}$ = interaction effect of l^{th} station, k^{th} tide, j^{th} season and i^{th} lunar periodicity

e_{ijklm} = error of m^{th} collection, l^{th} station, k^{th} tide, j^{th} season and i^{th} lunar periodicity.

The effects of salinity (x_1), temperature (x_2) and solar periodicity (day and night) (x_3) on the distribution of eggs and larvae were studied by multiple regression analysis as given below :

$$\log\ y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3$$

where

log y = the numerical abundance of eggs or larvae transformed into logarithmic value

b_0 = the constant

b_1 = regression coefficient of y on x_1 (salinity)

b_2 = regression coefficient of y on x_2 (water temperature)

b_3 = regression coefficient of y on x_3 (day and night)

The distribution of eggs and larvae was made normal by logarithmic transformation. The transformed eggs and larvae numbers were used for fitting the regression equation. In order to study the solar effect, dummy variables zero for day and one for night were given while analysing the data.

702.1 mm in 1977-'78 and 1.0 to 503.9 mm in 1978-'79. In 1977-'78 maximum rainfall was observed in November and in 1978-'79 in December. The monthly rainfall data during 1977 to 1979 is given in Fig. 2.

Temperature

The atmospheric temperature during the study period ranged from 23° to 36°C. There was no marked stationwise fluctuation in atmospheric temperature. The daily temperature maximum, measured during the midday at lowtide ranged from 26°C to 36°C. Monthwise distribution of temperature indicated maximum values during April to May (Summer) and minimum in December to January. The monthly mean temperature varied from 25°C in December to 33.4°C in April. The monthly mean temperature distribution for the period November 1977 to October 1979 is given in Fig. 2.

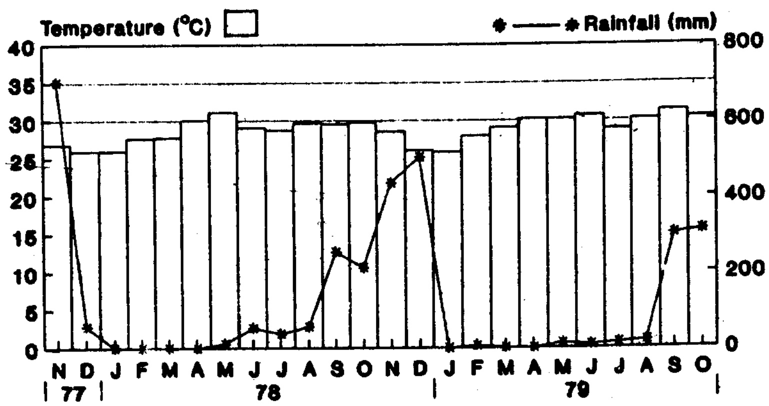

Fig. 2. Mean monthly rainfall and atmospheric temperature.

RESULTS

Rainfall

Porto Novo in the east coast of India receives rainfall as a result of the Northeast monsoon (October to December). Monthly rainfall at Porto Novo varied from 10.4 to

Spatial and temporal variations in temperature differences were not remarkable. The surface water temperature ranged from 26.45°C to 32.88°C. It was at its lowest in November and December (monsoon) and highest in April (summer) and was high in all the zones at lowtide in daytimes. Between stations, temperature difference was not appreciably high. In the first station, the temperature ranged from 26.45°C to 32.58°C; second station 26.58°C to 32.38°C; third station 26.90°C to 32.38°C and fourth station 26.90 to 32.88°C. Monthly mean temperature data analysed using multiple regression method. The result showed that there is no significant relationship of temperature with the distribution of eggs and larvae. The mean temperature for the whole two years was 28.99 ± 1.21.

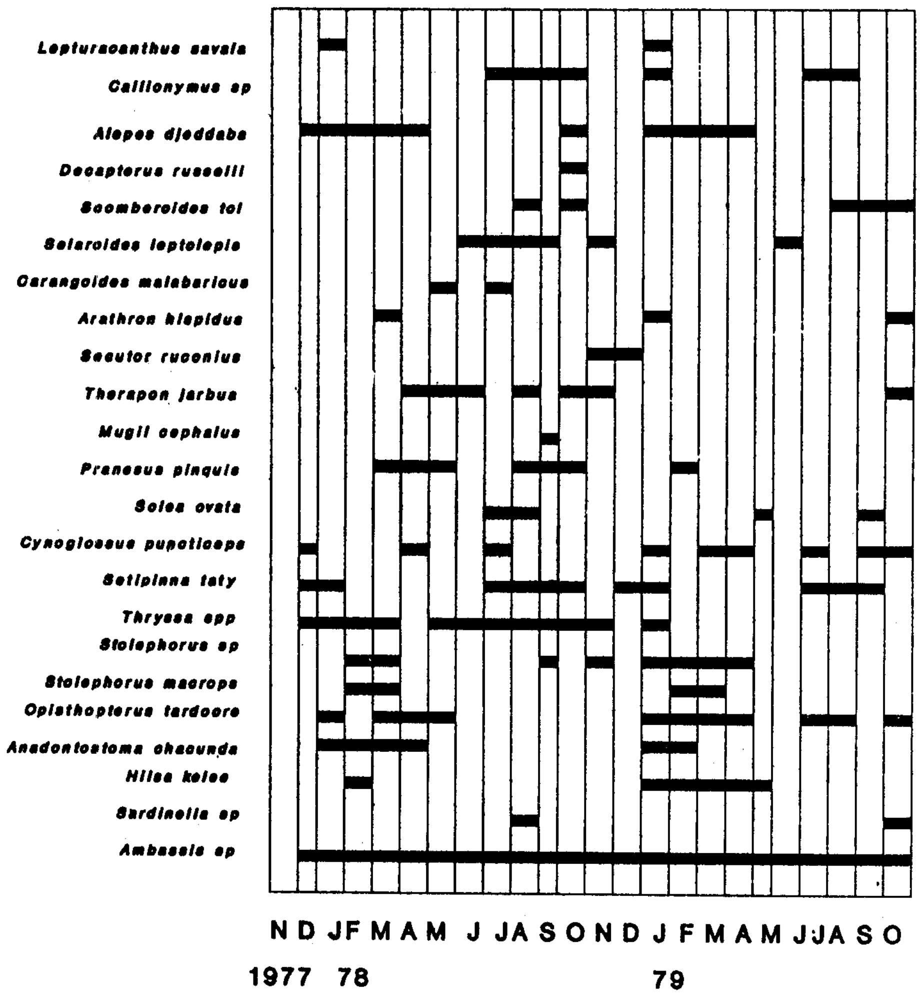

Fig. 3. Monthly occurrence of fish eggs in Vellar Estuary.

for stations I to IV at low and high tides are depicted in Fig. 7 to 10.

The effect of temperature on the distribution of eggs and larvae was statistically

Salinity

Horizontal stratification in salinity was quite apparent in the present study. A gradual decrease in salinity was observed from the marine zone (Station I) to the freshwater zone (Station IV). In all the four zones, low salinity was recorded during the monsoon and high salinity in the summer. In the first station, salinity was low during the monsoon (0.25‰) and high in the summer (36‰). For the other 3 stations, salinity during the above periods was 0.10‰ and 35.08‰ in the second station; 0.10‰ and 35.08‰ in the ''ird station; and 0.07‰ and 30.44‰ in the fourth station. Monthly mean salinity data for Stations I to IV at low and high tides are shown in Fig. 7 to 10. The mean salinity for the whole two years was 21.89 ± 2.95‰.

TABLE 1. *Lunar periodicitywise mean of eggs and larvae (number)*

	eggs	larvae
Newmoon	18.66	7.00
Fullmoon	8.21	3.82

TABLE 2. *Stationwise mean of eggs and larvae (number)*

	eggs	larvae
Station I	38.83	5.98
II	14.58	4.46
III	8.02	4.57
IV	5.19	5.84

TABLE 3. *Tide-wise mean of eggs and larvae (number)*

	eggs	larvae
High tide	27.47	7.57
Low tide	5.58	3.53

TABLE 4. *Seasonwise mean of eggs and larvae (number)*

	eggs	larvae
Monsoon	1.34	4.36
Postmonsoon	38.20	11.30
Summer	19.67	4.17
Premonsoon	23.39	3.47

TABLE 5. *Tide-wise and stationwise mean of eggs and larvae (number)*

			eggs	larvae
High tide	×	Station I	112.15	11.99
Low tide	×	Station I	13.44	2.99
High tide	×	Station II	47.38	7.88
Low tide	×	Station II	4.46	2.53
High tide	×	Station III	18.30	6.18
Low tide	×	Station III	3.51	3.38
High tide	×	Station IV	5.84	5.63
Low tide	×	Station IV	4.61	6.06

TABLE 6. *Seasonwise and tide-wise mean of eggs and larvae (number)*

			eggs	larvae
Monsoon	×	High tide	2.26	7.48
Postmonsoon	×	High tide	182.07	19.19
Summer	×	High tide	34.49	5.15
Premonsoon	×	High tide	40.08	4.44
Monsoon	×	Low tide	0.79	2.55
Postmonsoon	×	Low tide	8.02	6.65
Summer	×	Low tide	11.21	3.37
Premonsoon	×	Low tide	13.65	2.71

The analysis of the data showed that the factors like season, salinity, solar effect, station, tides and lunar periodicity influenced significantly the distribution of ichthyoplankton. But the interaction between Lunar x station; Lunar x tide; Lunar x season; Station x seaso: Lunar x station x tide; Lunar x station x season; Lunar x tide x season; Station x tide x season; Lunar x Station x tide x season on the distribution of eggs, and larvae were not significant. However, Station x tide and season x tide interactions effect were significant on the distribution of eggs. The mean number of eggs and larvae along with various significant factors alone are given in Tables 1 to 6. The densities of eggs and larvae in relation to various factors are presented in Tables 7 and 8.

Variations in the distribution of eggs and larvae

Seasonal distribution of eggs and larvae : Monsoon - Maximum number of eggs was recorded during the northeast monsoon, th:

total number for the season (from all the 4 stations) being 13.616 × 10^3. Larval abundance was second to that for the postmonsoon period, the total count being 1.643 × 10^3. Postmonsoon - Maximum number of eggs and larvae were encountered during this season, the total number of eggs and larvae being 129.434 × 10^3 and 2.617 × 10^3 respectively. Summer - Among four seasons, the summer ranked third with respect to the abundance of both eggs and larvae, their total number for the two year period being 32.253 × 10^3 and 1.13 × 10^3 respectively. Premonsoon - During this season, the abundance of eggs was next only to that for the postmonsoon season, but larval abundance was the least in the premonsoon

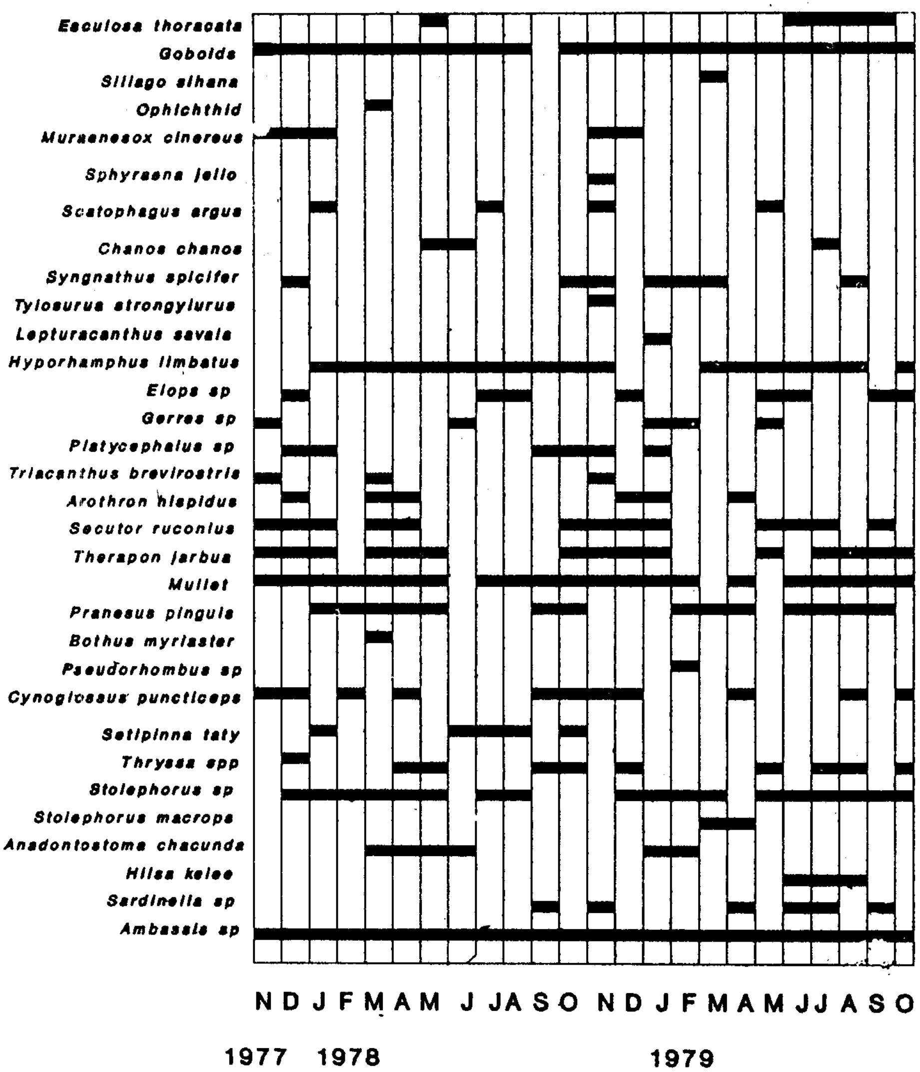

Fig. 4. Monthly occurrence of fish larvae in Vellar Estuary.

period. In all, 47.989 × 10^3 eggs and 0.968 × 10^3 larvae were collected over the 2 year

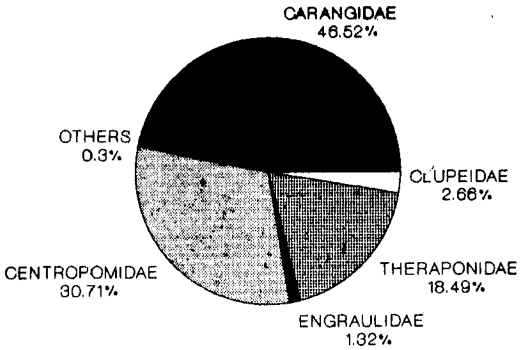

Fig. 5. Familywise percentage composition of fish eggs in Vellar Estuary.

study period.

The seasonwise variation was highly significant on the abundance of eggs ($P < 0.001$) and larvae ($P < 0.001$) and explained 14.29% and 6.41% of variability in eggs and larvae respectively. The seasonwise average eggs and

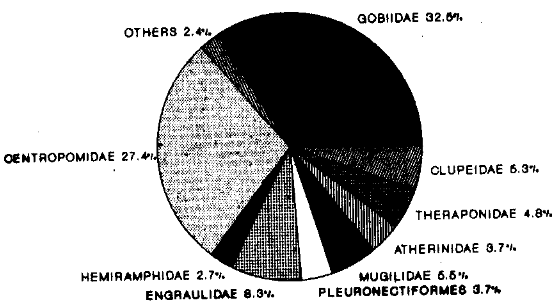

Fig. 6. Familywise percentage composition of fish larvae in Vellar Estuary.

larvae are presented in Table 4. Highest egg count was recorded in postmonsoon with a mean egg count of 38.20 numbers; summer recorded a mean of only 19.67, a reduction of 1.94 times; and premonsoon recorded 23.39. a reduction of 1.63 times in comparison to that of postmonsoon. Monsoon showed very poor egg counts with a mean of 1.34 eggs, the reduction being 28.51 times in comparison to that of postmonsoon. In the case of larvae, the

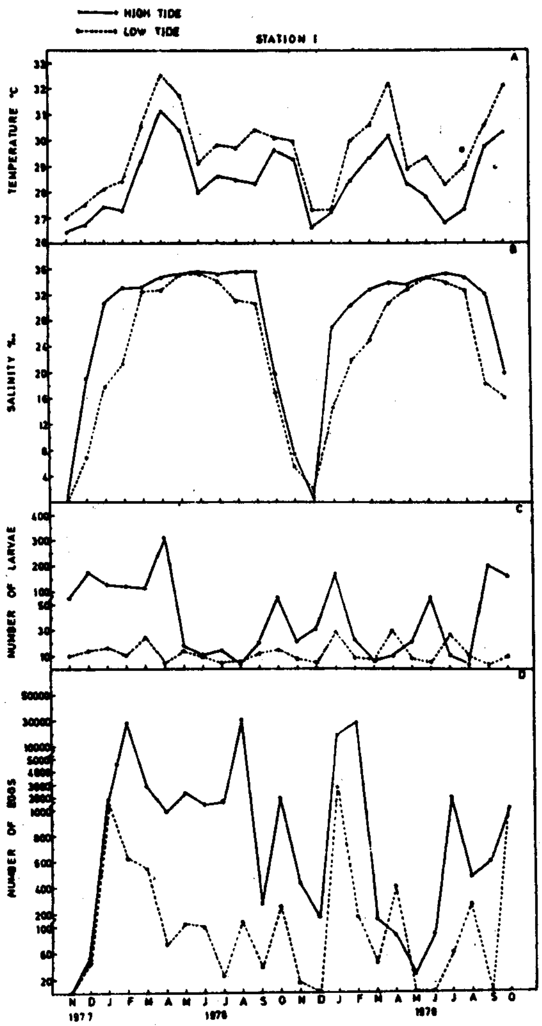

Fig. 7. Surface temperature, salinity, fish larvae and eggs at Station I.

highest number of larvae was recorded in postmonsoon with a mean of 11.30 number, while in summer it was 4.17 a reduction of 2.71 times. In comparison with the larval number of postmonsoon, premonsoon showed 2.59 times lesser larvae and 2.59 times lesser in monsoon.

Effect of temperature, salinity and solar periodicity on the distribution of eggs and larvae

In 708 day and night observations on the number of eggs and larvae, salinity and temperature, the data showed that the mean

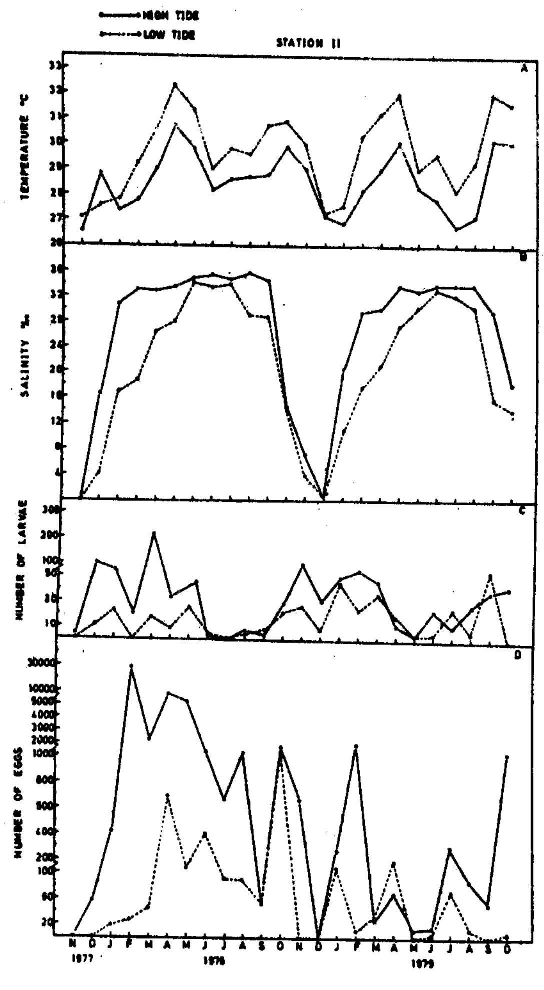

Fig. 8. Surface temperature, salinity, fish larvae and eggs at Station II.

eggs, larvae, salinity and temperature of Vellar Estuary were 16.65 ± 4.23, 2.82 ± 1.28, 21.89 ± 2.95‰ and 28.99 ± 1.21°C respectively.

The regression coefficients due to salinity, temperature and solar effect (dummy variables) were calculated. The fitted regression equation for egg is :

$$\log y = -0.3299 + 0.1221x_1 + 0.0640x_2 + 1.4904x_3$$

where y is egg number, x_1 is salinity, x_2 is temperature and x_3 is solar effect.

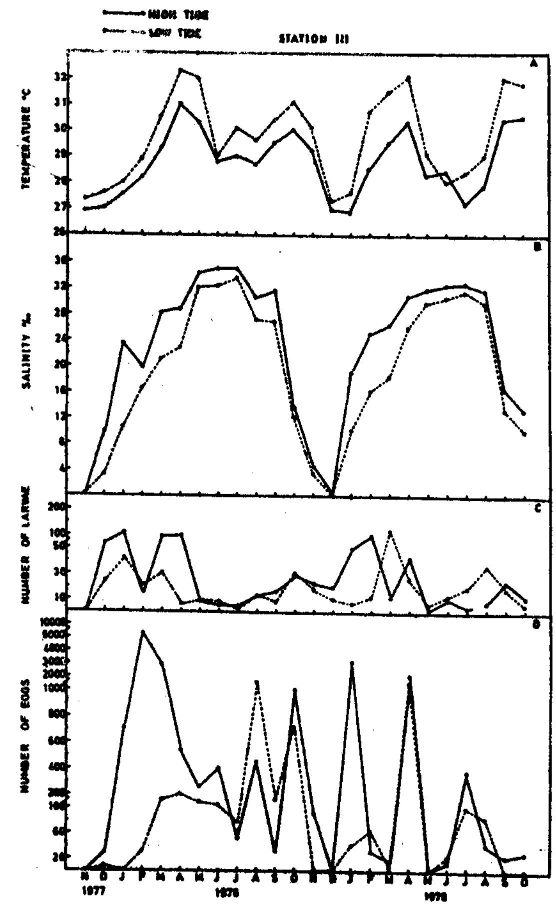

Fig. 9. Surface temperature, salinity, tısh larvae and eggs at Station III.

The regression coefficients due to salinity and solar periodicity were highly significant ($P < 0.01$), whereas it was not significant for

TABLE 7. *Analysis of variance (total eggs)*

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F	Percentage of Significance	R^2
Lunar periodicity	1	12.1979	12.1979	6.8126	1	1.41
Station	3	41.2278	13.7426	7.6753	0.1	4.76
Tidal change	1	45.9444	45.9444	25.6601	0.1	5.30
Season	3	123.8630	41.2877	23.0593	0.1	14.29
Lunar × Station	3	0.3438	0.1146	0.0640	>10	0.04
Lunar × Tide	1	0.0372	0.0372	0.0208	>10	0.004
Lunar × Season	3	4.4857	1.4952	0.8351	>10	0.52
Station × Tide	3	12.2760	4.0920	2.2854	10	1.42
Station × Season	9	17.8268	1.9806	1.1062	>10	2.06
Tide × Season	3	14.1428	4.7143	2.6330	5	1.63
Lunar × Station × Tide	3	1.6862	0.5621	0.3139	>10	0.19
Lunar × Station × Season	9	1.2086	0.1343	0.0750	>10	0.14
Lunar × Tide × Season	3	7.9260	2.6420	1.4756	>10	0.91
Station × Tide × Season	9	7.3240	0.8138	0.4545	>10	0.84
Lunar × Station × Tide × Season	9	3.3211	0.3690	0.2061	>10	0.38
Error	320	572.9596	1.7905			66.10
Total	383	866.7711				

R^2 for all effects = 33.90

5

TABLE 8. *Analysis of variance (total larvae)*

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F	Percentage of significance	R^2
Lunar periodicity	1	6.6547	6.6547	12.1392	0.1	2.79
Station	3	1.3276	0.4425	0.8072	>10	0.56
Tidal change	1	10.5643	10.5643	19.2709	0.1	4.42
Season	3	15.3153	5.1051	9.3125	0.1	6.41
Lunar × Station	3	1.3229	0.4410	0.8045	>10	0.55
Lunar × Tide	1	0.0172	0.0172	0.0314	>10	0.01
Lunar × Season	3	3.4691	1.1564	2.1094	10	1.45
Station × Tide	3	5.6951	1.8984	3.4630	2.5	2.38
Station × Season	9	2.0085	0.2232	0.4072	>10	0.84
Tide × Season	3	1.6892	0.5631	1.0272	>10	0.71
Lunar × Station × Tide	3	0.4993	0.1664	0.3035	>10	0.21
Lunar × Station × Season	9	4.0717	0.4524	0.8252	>10	1.71
Lunar × Tide × Season	3	1.3333	0.4444	0.8107	>10	0.56
Station × Tide × Season	9	7.1114	0.7902	1.4414	>10	2.98
Lunar × Station × Tide × Season	9	2.3099	0.2567	0.4683	>10	0.97
Error	320	175.4082	0.5482			73.45
Total	384	238.7976				

R^2 for all effects = 26.55

temperature effect. This clearly indicated that salinity and solar periodicity were affecting the egg availability in the estuary. Though the effect of temperature on the egg was not significant, there was an indication that there was a slight reduction in the number of eggs as the temperature increased. The calculated values of regression coefficients in the regression of egg and larvae on salinity, temperature and solar periodicity are given in the Table 9.

The fitted regression equation for was larva is :

$\log y = 0.3845 - 0.0020\ x_1 - 0.0057\ x_2 + 0.5574\ x_3$

where y is the larva number.

The regression coefficient due to solar periodicity was significant, whereas it was not significant for temperature and salinity effects.

Since the regression equation was fitted using dummy variable zero for day and one for night, the equation for day is :

$\log y = 0.3845 - 0.0020\ x_1 - 0.0640\ x_2$;

and for night it is :

$\log y = 0.3845 - 0.0020\ x_1 - 0.0057\ x_2 + 0.5574\ x_3$

The above two equations showed that during night there was an increase in larvae. The R^2 value for model was 1.82, which was very less.

Stationwise distribution of eggs and larvae

Remarkable salinity gradation was noticed from Station I (marine zone) to Station IV (freshwater zone). High salinity values were recorded in all the stations at high tides and low values at the subsequent low tides.

Station I : Maximum eggs and larvae were recorded. The total number of eggs and larvae collected was 127.423×10^3 and 2.117×10^3 respectively. Monthly abundance of eggs and larvae is given in Fig. 7.

Station II : Abundance of eggs in the second station was next only to that in the first station. The total number of eggs and larvae were 61.351×10^3 and 1.454×10^3 respectively. Monthly abundance of eggs and larvae is shown in Fig. 8.

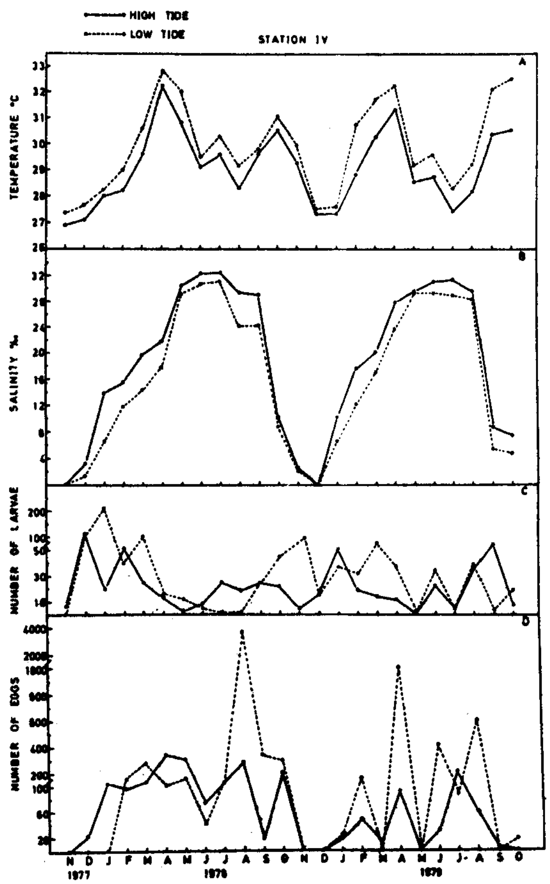

Fig. 10. Surface temperature, salinity, fish larvae and eggs at Station IV.

Station III : A total of 24.622×10^3 eggs and 1.257×10^3 larvae were collected from Station III which obviously is less rich in eggs and larvae than Station I and II. Monthly abundance of eggs and larvae is depicted in Fig. 9.

Station IV : The number of eggs (9.905×10^3) was comparatively less than that from the other stations. Although the larvae (1.577×10^3) were less abundant than in the first station, they outnumbered the abundance from the other stations. Monthly abundance of eggs and larvae is indicated in Fig. 10.

TABLE 9. *Regression coefficients of eggs and larvae on salinity, temperature and solar periodicity*

Source	d.f.	Regression coefficient (b)	Standard error (SE)	b/SE
Eggs				
Salinity	704	0.1221	0.001395	8.7526382**
Temperature	704	0.0640	0.052837	1.2112724 NS
Day and night	704	1.4904	0.220775	6.7507644**
Larvae				
Salinity	704	0.0020	0.0065	0.30769 NS
Temperature	704	0.0057	0.0428	0.13318 NS
Day and night	704	0.5574	0.1587	3.51229**

** Significant at 1% level
NS - not significant
For n-4 *i.e.* 708-4 = 704 d.f.

Eggs of *Anadontostoma chacunda, Arothron hispedus, Cynoglossus puncticeos, Stolephorus macrops, Therapon jarbua, Scomberoides tol, Selaroides leptolepis, Decapterus russelli* and *Carangoides malabaricus* were recorded from the first two stations. Eggs of *Secutor ruconius, Solea ovata* and *Mugil cephalus* were collected only from the first station. Eggs of *Lepturacanthus savala* were taken from the second station only. Eggs of *Ophisthopterus tardoore, Setipinna taty* and *calionymus* sp. were recorded from the second, third and fourth stations. The eggs of all these species were less abundant in the second station, but more abundant in the third and fourth stations. Eggs of *Ambassis* sp., *Stolephorus* sp., *Hilsa kelee* and *Thryssa mystax* were recorded from all the four zones of the estuary. The monthly occurrence of 23 species of fish eggs in the Vellar Estuary during 1977-79 is given in Fig. 3.

Larvae of *Tylosurus strongylurus, Sphyraena jello, Bothus myriaster* and leptocephalus of an ophichthyid were recorded only from the first station. In the second station, *Pseudorhombus* sp. and *Lepturacanthus savala* were met with. Larvae of *Anadontostoma chacunda, Triacanthus brevirostris* and *Muraenesox cinereus* were present in the first three stations. Larvae of *Chanos chanos* were collected from the third and fourth stations only. Larvae of *Ambassis* sp., *Therapon jarbua, Pranesus pinguis, Arothron hispidus, Cynoglossus puncticeps, Hilsa kelee, Stolephorus macrops, Thryssa mystax, Setipinna taty, Secutor ruconius, Scatophagus argus, Elops magnata, Syngnathus specifer, Gerrus* sp., *Hyporhamphus* sp., *Platycephalus* sp., mullets and gobids were collected from all the four stations of the estuary. The monthly occurrence of 32 species of fish larvae in the Vellar Estuary is given in Fig. 4. The percentage abundance of eggs and larvae belonging to different taxonomic categories is given in Fig. 5 and 6.

The stationwise distribution of eggs was highly significant ($p < 0.001$) and station effect explained 4.76% of variability, whereas effect of station did not significantly influence the variability in larval distribution. The stationwise means of eggs and larvae are presented in Table 2. Highest egg count was recorded in Station I (marine zone) and in the subsequent stations, the number of egg was far less. In comparison to Station I, which recorded a mean eggs of 38.83 numbers, Station II recorded only 14.58, a reduction of 2.7 times. Station

III showed a reduction of 1.8 times in eggs in comparison to that of Station II. A comparison between Station III and IV indicated that Station IV showed 1.5 times less eggs.

Effects of tides on the distribution of eggs and larvae

The effect of tide was significant at 0.1% and the R^2 value due to tide was 5.30%. Similarly tide affected significantly the distribution of larvae ($P < 0.001$) and explained 4.42% of variability. The means of eggs and larvae are presented in Table 3. High tide showed a mean of 27.47 eggs, whereas low tide showed only 5.58 number, thus high tide showed 4.9 times more eggs than low tide. However, high tide showed only 2.1 times more larvae than the low tide.

Station × tide ($P < 0.1$) and season × tide ($P < 0.05$) interactions were significant (Table 5 and 6).

The egg population decreased by 2.4 times from Station I to Station II, by 2.6 times from Station II to Station III and 3.1 times from Station III to Station IV. Thus, there was a progressive reduction in the number of eggs from Station I to Station IV during high tide.

During low tide the egg count decreased by 3.01 times from Station I to Station II, by 1.27 times from Station II to Station III and 1.31 times increased from Station III to Station IV. Thus, there was a reduction in the number of eggs from Station I to Station III and again increased from Station III to Station IV during low tide.

Lunar periodicity in the distribution of eggs and larvae

The effect of lunar periodicity was found to be highly significant on the distribution of eggs ($P < 0.01$) and larvae ($P < 0.001$) and explained 1.41% and 2.79% of variability found respectively in eggs and larvae. The eggs and larvae means for newmoon and fullmoon are presented in Table 1. It was found that new moon showed about double the number of eggs and larvae in comparison to fullmoon.

Discussion

Occurrence of planktonic eggs and larval stages of two different species of fish shows seasonal variation of species distribution. This might be related to their spawning period. The population can be roughly classified into those that spawn in the (1) monsoon, (2) past-monsoon, (3) summer and (4) premonsoon seasons. This type of seasonal spawning is prominent in species inhabiting cold waters. But, in some warmer water species, the spawning period is extended from one to another season (Qasim, 1956). The present findings show highly significant seasonal distributions of eggs and larvae (R^2 for eggs is 14.29 and for larvae 6.41). More eggs and larvae are observed during postmonsoon period (mean egg number 38.20). This is apparently due to a favorable salinity. During this period, the neritic waters were found to penetrate into the estuary along the bottom during high tide. Vertical stratification of salinity is conspicuous during this season at all tides. Only during low tides, salinity was low with marked vertical salinity gradient (Chandran, 1982). Moreover, the heavy rainfall during monsoon period depletes salinity of the estuarine water, which increases during the postmonsoon seasons. Since the primary productivity seems to be more during this period, it is quite natural to expect a successful spawning of fishes during postmonsoon. Next to postmonsoon, higher number of eggs is noticed during premonsoon (mean egg number 23.39). This corresponds to a decline in salinity from that of the previous season. However, the larval population was less than in the other seasons (mean larval number 3.47). The reason is that during summer month the egg production is less (mean egg number 19.67) resulting in concomitant reduction in the larval population during the premonsoon. During the summer, the entire estuary was dominated with neritic water and the difference between surface and bottom was negligible even during low tides. The decline in freshwater flow resulted in the increase of surface salinity. This abnormal increase might be responsible for the decrease in the spawning activities during the summer season. In the monsoon period, egg production is meagre (mean egg number 1.34). This is due to the decline of salinity during this period. But, the larval count is higher than in the summer and premonsoon seasons (mean larval number 4.36). Comparatively higher egg population during premonsoon might be responsible for the presence of higher larval population during the monsoon season. Moreover, during the period most of the larvae belong to the euryhaline species such as *Therapon jarbua*, *Ambassis* spp., *Pranesus pinguis*, *Hyporhamphus*, mullet and gobids that have greater salinity tolerance range.

The day and night observations showed that both the eggs and larvae population were more in number during night than in the day. During night, there was an increase in the egg number by 1.4904. Since the temperature was not significantly affecting the eggs, the difference in day and night effect might be due to the light effect. This means that spawning takes place more during the dark time. Nikolsky (1963) found that a vast majority of fishes spawn at night. He observed the species that have short incubation period spawn in the evening. It was found that the eggs became slightly heavier as the embryo develops and there was a tendency for the eggs in the advanced stages of development to slightly immerse in deeper water than the ones in early stages (Jacobsen and Johansen, 1908; Fransz, 1910; Remotti, 1921). Yashouv (1969) reported sinking of mullet eggs towards the end of incubation. Since the regression coefficients were not significant for temperature and salinity effects on the distribution of larvae, it is inferred that solar light and not temperature, is affecting the larval counts. From the regression equation for day and night, it is evident that during night there is an increase in the larval numbers. Since temperature is not affecting eggs and larval numbers, the difference in day and night effect might be due to the light effect. This means that when there is sun light the larva migrate to certain depth from the surface. Larvae and postlarva of different species show differences in their vertical distribution in the day time. As regard to changes in vertical distribution during 24 hours, Johansen (1925) concluded that majority of larvae kept below 16 m from the surface in the day time. He found that greater numbers of herring postlarvae were taken at night than in the day time. Johansen (1925) discussed the possibility that postlarvae might avoid the net in the daytime as suggested by Franz (1911). He concluded that this might be the fast moving stage. This might be the reason that he has found a greater increase in numbers of the postlarvae at night. A number of investigations have been made with the net towed at high speed to test the possibility of net avoidance of larvae (Bridger, 1956; Colton *et al.,* 1961; Colton, 1965). It is found that young clupeids above a length of about 15 mm can avoid the net, but smaller specimens can not. Thus, an increase in number of smaller post-larvae at night must indicate vertical migration. Although there are more postlarvae of many species in the upper water layers at night, the general day time distribution is not greatly altered. The two marked exceptions to this are the postlarvae of the Clupeidae and Gobiidae, both of which occurring in greater numbers at night. Similar observations were reported at Plymouth by Russell (1926, 1928).

In this study, stationwise distribution of eggs is significant. Higher number of eggs was collected from Station I (marine zone) and progressive reduction was noticed in the other three stations. In the first station, number of species and number of eggs are more. This would suggest significant tidal influence over eggs of the coastal area by which those might be drifted to the marine zone, which is also evident from the significance of station × tide interaction. Moreover, the hydrographical features, particularly of the salinity of the marine zone, are more or less similar to those of the coastal water. Since the regression coefficient due to salinity was positive, it is clear that for every one part per thousand increase in salinity there is an increase of 0.1221 number of eggs. Although, the specific gravity of the pelagic egg is close to that of the water, it varied due to many factors (Nikolsky, 1963). From Station I to IV there is a reduction in salinity gradient, which might be responsible for the concomitant reduction in the egg counts observed in the stations. The dispersal of eggs in Stations III and IV is not very much different from each other. The gradual reduction in salinity at Station II, III and IV, made a decrease in the buoyancy of the eggs. The buoyance of marine fish eggs differs greatly. The fertilized eggs of live milkfish *Chanos chanos* were observed to sink slowly at a salinity of 30‰, when the salinity was increased to 34‰ or above (Chaudhuri *et al.*, 1978). However, the eggs were either at the surface or floating at the surface of the water. Blaxter (1969) observed that the pelagic eggs of most marine fishes sank when put in salinities below a certain threshold. Therefore, the reduction in the number of eggs at these stations would probably reveal that the eggs drifted from the coastal zone might have immersed below the water surface where the salinity is some what higher. However, if the salinity is below the tolerable range, less tolerant eggs would perish. The R^2 value due to the effect of salinity, temperature and solar periodicity is 25.2%. This means that out of the total variance 25.2% is explained mainly by salinity and solar periodicity. The rest of variance might be due to observable effects like tide, lunar periodicity, seasons, stations and many other unobservable causes. It is a well know fact that the larvae of euryhaline species are more tolerable than that of stenohaline species in the estuarine habitat. So the larvae of stenohaline species that are drifted by tidal action would either perish or migrate to the bottom water. Since most of the larval populations of the estuary belong to the euryhaline species (gobids, *Ambassis* spp., *Mugil* sp., *Therapon jarbua*, *Pranesus pinguis*, *Hyporhamphus xanthopterus*, etc.), the stationwise differences of larvae would probably be not significant. So the R^2 value of larvae was negligible. Therefore, in the case of larvae, salinity, solar periodicity and temperature might not be playing greater roles in their distribution. Therefore, the major causes must be other unobservable factors. In the case of larvae, the regression coefficients are significant, but they are not of great value because the R^2 is very less (R^2 = 1.82%).

Significant effect of tide is observed on the distribution of eggs and larvae. During high tide, egg and larvae were abundant. During high tide, large mass of saline water from the sea enters into the estuary causing ingression of eggs and larvae from the coastal waters. Thus, the high tide should bring 4.9 times more eggs than the low tide. Hora (1945) suggested a possible stimulation of spawning with the rising water level, at a particular phase of the moon. During low tide, the inflow of freshwater would be more and, so, the eggs drifted during the high tide might once again be transported back into the coastal water. Further, most of the stenohaline eggs might die due to the decrease in salinity. Due to these factors during low tide, lower mean (5.58) of eggs were recorded. As far as larvae were concerned, the high tide showed only 2.1 times more larvae than the low tide. When compared to the difference of eggs, the larval difference between the tides was less. The reason might be the high percentage composition of the residential species (*Ambassis* spp., *Therapon jarbua*, Gobids, *Hyporhamphus xanthopterus*, *Pranesus pinguis* and mullets), which can tolerate wide ranges of salinity fluctuations.

There was a remarkable influence of tidal effect on the distribution of eggs and larvae in different stations. As far as eggs were concerned, in all the four stations during high tide, the number of eggs were comparatively more than at low tides. Maximum number of eggs were noticed in the 1st station than in the other stations. The stationwise reduction of eggs during high tide (2.4 times between I and II and 2.6 times between II and III and 3.1 times between III and IV) was due to the effect of dilution of marine water with the freshwater. But, at low tides, in the 4th station the eggs were more than in the 3rd station. This shows the spawning of some residential species in the 4th station. In the case of larvae during high tide, except in the 4th station, in all the other stations the population of larvae were more than that at low tide. When the low tide × stations interaction means are compared, the highest number was noticed in the 4th station, followed by stations 3rd, 1st and 2nd. The maximum population in the 4th and 3rd stations might be due to the larvae of residential spawners. Rao (1975) reported that the salinity tolerance of larvae was influenced by incubation salinity; larvae that hatched in lower incubation salinities exhibited greater freshwater tolerance than those hatched in higher salinities.

Lunar and solar periodicities affect significantly the availability of fish eggs and larvae in the estuary. Eggs and larvae were significantly higher in number during new moon than during full moon. Similarly, night time collections recorded higher number of eggs and larvae than those recorded during day time. The temperature of the water ranged between 26.45°C and 32.88°C. As the temperature variation recorded in the estuarine water does not seem to have any significant influence on the availability of eggs and larvae, it seems reasonable to conclude that the intensity of light is responsible for the presence of eggs and larvae in the estuary.

The availability of higher number of eggs during night and especially so on new moon nights indicates that the spawning activity of fishes is high in dark. It is well known that photoperiodicity plays a major role in many biological activities. Lagler *et al.* (1962) showed that the main extrinsic factor affecting reproduction of fishes was due to the relationship between periods of light and darkness. As in the case of eggs, higher number of larvae might be sensitive to light. Therefore, they might migrate into the deeper waters during day time and emerge to the surface during the period when the intensity of light is low. Experiments in the laboratory had been made by Blaxter (1973) for monitoring vertical movement in a cylinder with thermistors at different levels. The experiments gave definite indications that herring larvae and postlarvae moved upwards at the light intensities of dusk and dawn, and remained very active at dark. With the present observations, it is clear that light might be one of the main factors which influences the distribution of pelagic eggs and larvae.

References

Bassindale, R. 1943. A comparison of the varying salinity conditions of the Tees and Severn estuaries. *J. Anim. Ecol.*, **12** : 1-10.

Blaxter, J. H. S. 1969. Development : Eggs and larvae. *In* : W. S. Hoar and D. J. Randall (Ed.) *Fish physiology*. Academic Press, New York. Vol. 3. pp. 485.

——— 1973 Monitoring the vertical movements and light responses of herring and plaice larvae. *J. Mar. Biol. Ass. U.K.*, **53** : 635-647.

Bridger, J. P. 1956. On day and night variation in catches of fish larvae. *J. cons. perm. int. Explor. Mer.*, **22** : 42-57.

CHANDRAN, R. 1982. Hydrobiological studies in the gradient zone of the Vellar Estuary. *Ph.D. Thesis. Annamalai University*, 195 pp.

CHAUDHURI, H., J. V. JUARIO, H. JURGENNE PRIMAVERA, RA. SAMSON AND R. MATEO 1978. Observations on artificial fertilization of eggs and the embryonic and larval development of milkfish *Chanos chanos* (Forsskal). *Aquaculture*, **13** : 95-113.

COLTON, J. B. 1965. The distribution and behaviour of pelagic and early demersal stages of haddock in relation to sampling techniques. *Spec. Publs. int. commn. N.W. Atlant. Fish.*, **6** : 317-333.

———, K. A. HONEY AND R. F. TEMPLE 1961. The effectiveness of sampling methods used to study the distribution of larval herring in the Gulf of Maine. *J. cons. perm. int. Explor. Mar.*, **26** : 180-190.

FRANZ, V. 1910. Die eiproduction der scholle *(Pleuronectes platessa)*. *Wiss. Meeresunters Helgoland*, NF **9** : 59-141.

——— 1911. Phtoaxis and Wenderung. Nach Versuchen min Junfischen und Fischlargen. *Int. rev. ges. Hydrobiol. Hydrogr.*, **3** : 306-334.

HORA, S. 1945. Analysis of the factor influencing the spawning of carps. *Proc. Nat. Inst. Sci. India*, **11** (3).

JACOBSEN, J. P. AND A. C. JOHANSEN 1908. Remarks on the changes in specific gravity of pelagic fish eggs and the transportation of same in Danish waters. *Medder Kommn Havunders., ser. Fiskeri*, **3** (2) : 24 pp.

LAGLER, K. F., J. E. BARDACH AND R. R. MILLER 1962. *Ichthyology*. John Wiley and Sons, Inc., New York. London. 545 pp.

JOHANSEN, A. C. 1925. On the diurnal vertical movements of young of some fishes in Danish waters. *Meddr. Kommu Dann. Fish. –og Havunders., Ser. Fiskeri*, **8** (2) : 27 pp.

NIKOLSKY, G. V. 1963. *The ecology of fishes*. Academic press, London, 352 pp.

QASIM, S. Z. 1956. Sex ratio in fish populations as a function of sexual difference in growth rate. *Curr. Sci.*, **35** : 140-142.

RAMAMOORTHI, K. 1954. A preliminary study of the hydrology and fauna of Vellar Estuary. *Proc. Indo-Pacific fish Cons. Symp.*, **9** Bangkok.

RAO, T. P. 1975. Salinity tolerance of laboratory reared larvae of the california Killifish *Fundulus parripinnis* Ginard. *J. Fish. Biol.*, **7** (6) : 783-790.

REMOTTI, E. 1921. Variazieni di pese specific nella uova gallegianti dei Teleostei durante le Sviluppe. *Memorie R. com. talassegrital.*, **80** : 1-42.

RUSSELL, F. S. 1926. The vertical distribution of marine macroplankton. III Diurnal observations on the pelagic young of teleostean fishes in the Plymouth area. *J. Mar. Biol. Ass. U.K.*, **14** : 387-414.

——— 1928. The vertical distribution of marine macroplankton. VIII. Further observations on the diurnal behaviour of the pelagic young of teleostean fishes in the Plymouth area. *Ibid.*, **15** : 829-850.

STIRCKLAND, J. D. H. AND T. R. PARSONS 1972. A manual of sea water analysis. *Bull. Fish Res. Bd. Canada*, **167** : 310 pp.

VENKATARAMANUJAM, K. 1975. Studies on fish eggs and larvae of Porto Novo coastal waters. *Ph.D. Thesis, Annamalai University*, 293 pp.

YASHOUV, A. 1969. Preliminary report on induced spawning of *M. cephalus* (L) reared in captivity in freshwater ponds. *BAMIDGBH*, **21** (2) : 19-24.