

Study of different hydrographic variables at Ennore and Chennai fisheries harbour region of Chennai, India

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ABSTRACT

The knowledge of hydrographic variables is very important in determining the abundant availability of fishes in a particular region. The study site selected includes an industrially polluted area, Ennore and Chennai fisheries harbour region. The hydrographic variables selected for study includes temperature, salinity, pH, dissolved oxygen, chlorophyll a, b and c, primary productivity, gross and net and the nutrients, phosphate, ammonia and nitrate. The important hydrographic variables and its effect on the region and that influence the fish abundance throughout the year are discussed. At Ennore, the salinity level was maximum during the month of July, 37.00 ppt at a lowest temperature of 27.00 °C and at a highest temperature of 31.00 °C in the month of Sept'09, the salinity level was 32.00 ppt. At Chennai fisheries harbour, the lowest temperature recorded was 26.40 °C at Jan'09 and the highest temperature was 30.0 °C at April'09, lowest salinity level was 26.80 ppt at Feb'09 and highest salinity level was 38.50 ppt at July'09. The variations among months and from 2 different locations viz. Ennore and Chennai Fisheries harbour were studied during the entire year. The interaction effects between the two locations were also studied. Temperature, salinity, chlorophyll a, b and c primary productivity, gross and net are non significant $p \geq 0.05$ at Ennore and at Chennai Fisheries harbour location. The response optimization of the different hydrographic variables viz. temperature, 28.14 °C, salinity, 30.80 ppt, pH, 6.37, dissolved oxygen, 3.12 ml/l, and total soluble solids, 0.40 mg/l for a predicted response of chlorophyll a of 3.35mg/m³ at Ennore and at Chennai Fisheries harbour region the hydrographic variables viz. temperature, 30.00 °C, salinity, 26.80 ppt, pH, 6.38 dissolved oxygen, 2.86 ml/l and total soluble solids of 0.40 mg/l for a predicted chlorophyll a response of 1.88mg/m³ were worked out.

Key words: Hydrography, Temperature, Environment, Marine fish, Ennore, Nutrients

Introduction

India produces 1,20,000 t of garbage/day. Chennai coast has become a dumping site of garbages, industrial effluents and other waste materials. Sewage

and other pollutants has doubled the oxygen deficient zone and needs monitoring the hydrographic variable change then and there to sustain the marine the fish growth. Environment plays a major role in fisheries since the flora and fauna of the sea ecosys-

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tem is highly dependent on the environmental changes. Chennai coast extends along the fisheries harbor and Ennore, an industrially polluted area and these coast are nowadays polluted by anthropogenic activities such as plastics, tea cups, used clothes and has become an area of pollution. The sea environment variables include temperature, pH, salinity and dissolved oxygen. The physiochemical parameters of sea water are temperature, pH, oxygen, salinity, dissolved nutrients in the ocean, nitrate, phosphate and ammonia helps in improving the marine life for human utilization. The hydrographic variables of the seawater included for study are temperature, salinity, pH, dissolved oxygen and total soluble solids. The coastal marine environment includes the study of change in chlorophyll, a, b & c, the primary production, gross and net and the nutrients, phosphate, nitrate and ammonia.



Fig. 1. Ennore location in Tamilnadu map

Methods and Materials

Two sampling points were selected, viz. Ennore, industrially polluted area and Chennai Fisheries Harbour region, control area. The number of samples collected was 12/month. The sea water samples were collected for the months from Jan-Dec



Fig. 2. An effect of pollution, the dead fish in Ennore



Fig.3. Effluent discharge in the Ennore Creek

at two different localities, Ennore and Chennai Fisheries Harbour in properly labeled bottles. The study site is Ennore (Latitude, 80°E, Longitude,13°N) and Chennai fisheries harbor region (Latitude, 80°28'99"E and Longitude 13°08'44"N) Temperature was measured using mercury-thermometer, (Range-0 °C-100 °C,76 mm,1mm) salinity using salinometer, (Model N ERMA Refractometer), pH using pH meter, (Model N.H198107), dissolved oxygen were measured using Winkler's method (titrimetric method), total soluble solids (Model N H198302) were measured using residue filtration method, chlorophyll 'a', 'b' and 'c' were measured using spectrophotometric method, primary productivity, gross and net was measured using light and dark bottle method, the nutrients, phosphate were estimated using ascorbic acid method, ammonia was estimated using phenol hypochlorite method and nitrate was estimated using Moris and Riley method, (Kaladharan *et al.*, 2001). The statistical analysis performed was ANOVA and MINITAB-16.0 was used for contour plots. The data were collected at equal intervals of 1month for the months from Jan-Dec'09. The effects of different variables on different months, effect of interaction at two differ-

ent localities were studied.

Results and Discussion

Temperature

Water temperature is an environmental factor that affects the growth of fish and the biological aspects of fish. Temperature decides the phytoplankton growth (Eric narh Agbesi, 2002). The range of temperature is 28.00 °C (Jan'09) -31.00 °C (Sep'09) at Ennore, and 26.40 (Jan'09) -30.00 °C (Aug'09) at Chennai fisheries harbour. At Chennai fisheries harbour location, the lowest temperature recorded was 26.40 °C, Jan'2009 and the maximum temperature recorded was 30.00 °C at April, June, Aug and Sep'2009 (Fig. 4) The study area selected is Ennore in Tamilnadu map (Fig. 1). At Ennore location, the minimum temperature recorded was 27.00 °C at July'09 and the maximum temperature recorded was 31.00 °C at Sep'09. On an average higher temperature is recorded in Ennore, (station1) at 29.21 °C and Chennai Fisheries Harbour (CFH) (station 2) the average temperature was 28.73 °C. The temperature at Ennore is 1.64% more than CFH. At Ennore, the minimum temperature recorded was high, 27.00 °C than the Chennai Fisheries harbour, 26.40 °C. This may be due to the industrial effluent being discharged into the sea through the outlet. Temperature gradually increases from Jan to Dec'09 month and the level drips down at June'09 month at Ennore and at CFH (Fig. 4 and 5). The normal temperature of the ocean is -2 °C to 30 °C. The temperature at Ennore and Chennai fisheries harbor region falls within the range for the growth of marine fisheries. Among the different months tested, temperature is significant between months, $p \leq 0.05$. An effect of pollution the dead fish in Ennore creek is given in Fig. 2, the pollution is mainly due to effluent discharge in the Ennore creek (Fig.3). The bar chart showing the comparison between Ennore and Chennai fisheries harbor region with respect to temperature (Fig. 6). The R^2 value of the Ennore and CFH region are below average in their dependence of the variable with the months. (Fig.7). In Ennore, the positive pearson correlation coefficient between hydrographic variables, temp.-sal.($r=0.16$), temp.-pH ($r=0.19$), temp.-tss ($r=0.34$), temp.-chl.a ($r=0.13$), temp.-chl.b ($r=0.01$), temp.-chl.c ($r=0.24$), temp.-pp.gross ($r=0.31$), temp.-N-phos ($r=0.187$), temp.-N.Nit ($r=0.14$). In Chennai fisheries harbour region, the

pearson correlation coefficient is temp.-sal. ($r=0.35$), temp.-pH($r=0.36$), temp.-do ($r=0.06$), temp.-tss ($r=0.23$), temp.-chl.a ($r=0.27$), temp.-chl.b ($r=0.26$), temp.-chl.c ($r=0.27$), temp.-pp-gross ($r=0.14$), temp.-pp-net ($r=0.25$), temp.-N-amm ($r=0.08$).

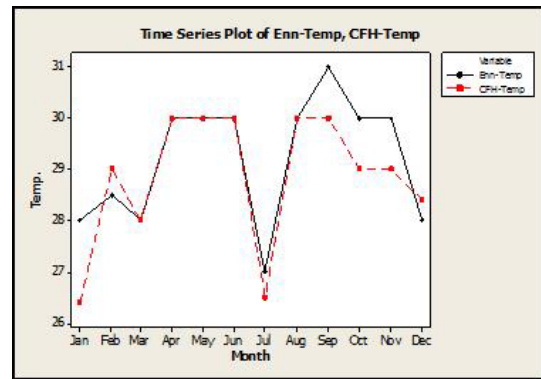


Fig. 4. Temperature distribution for the year'2009 at Ennore and Chennai fisheries harbor region

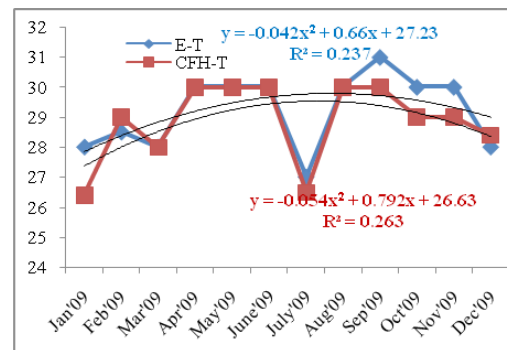


Fig. 5. Temperature distribution in Ennore and Chennai fisheries harbour region

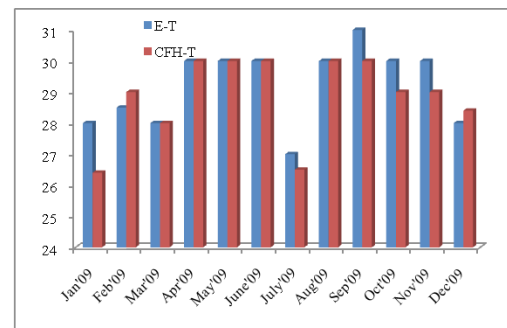


Fig. 6. Trend analysis graph for temperature distribution both in Ennore and CFH

Salinity

Salinity is the actual concentration of dissolved sodium chloride ion in water and is usually measured in ppt. Changes in salinity can affect fish survival

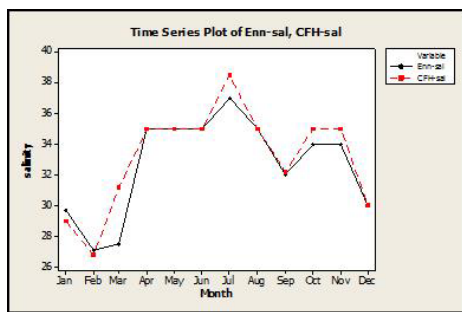


Fig. 7. Time series plot for salinity distribution at Ennore and at CFH

rate and otolith formation in small pelagic fishes. At CFH location the lowest salinity ranged from 26.80ppt at Feb'09 and the highest 38.50ppt at July'09 (Fig. 9) At Ennore location the minimum salinity was 27.10 at Feb'09 and the maximum salinity was 37.00ppt at July'09(Fig. 8). The salinity level of 15.52% at Ennore and the salinity level of 14% at

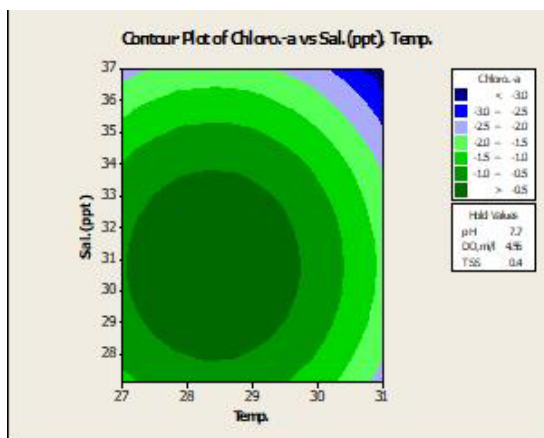


Fig. 8. Salinity distribution in Ennore and Chennai fisheries harbour region

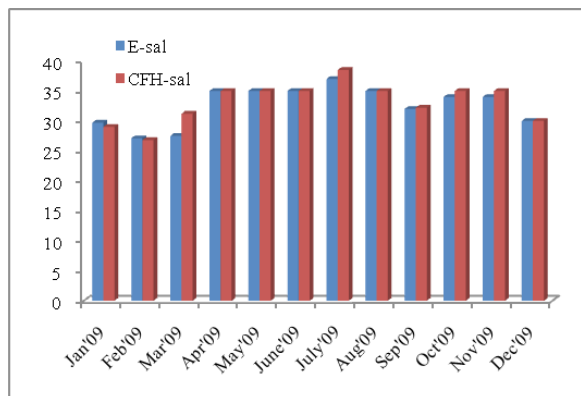


Fig. 9. Contour plot of chlorophyll 'a' Vs salinity and temperature

Chennai fisheries harbour location with sea as a whole was noted. The normal salinity level in ocean for the growth of fishes are 35ppt and the salinity range falls within the range.

The Pearson correlation coefficient for Ennore is sal.-tss (r=0.29), sal.-chl.a (r=0.07), sal.-chl.c (r=0.09), sal.-pp.gross (r=0.04), sal.-pp-net (r=0.41), sal.-N-phos (r=0.29), sal.-N-Nit (r=0.20) and for Chennai fisheries harbor region, the Pearson correlation coefficient is sal.-pH (r=0.18), sal.-tss (r=0.05), sal.-chl.a (r=0.17), sal.-chl.b (r=0.26), sal.-chl.c (r=0.31), sal.-pp.gross (r=0.12), sal.-pp-net (r=0.25), sal.-N-phos (r=0.31).

The salinity of both Ennore and CFH are compared in a bar chart (Fig.10). The salinity distribution in Ennore and Chennai fisheries harbor region is shown. On an average salinity is lower in station 1 at Ennore was 32.61 ppt than station 2, Chennai Fisheries Harbour at 32.77 ppt. Salinity at Chennai fisheries harbour is 0.30% more than Ennore. In this study the lower values of salinity during Jan-Mar at

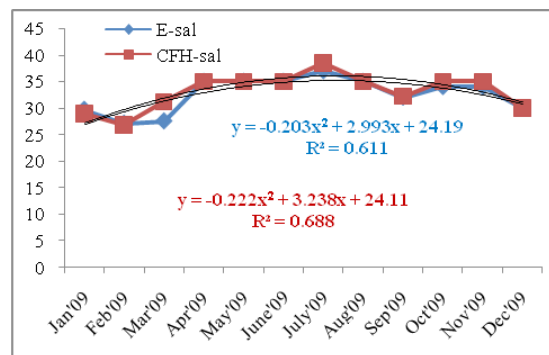


Fig. 10. Salinity distribution in Ennore and Chennai Fisheries Harbor region

Ennore coincided with the earlier findings of Soundarapandian Premkumar and Dinakaran, 2009. The highest salinity occurs at second quarter in the year 2009. The chlorophyll a is greater than 0.50 mg/m³ at a salinity level of 28 ppt and a temperature of 27.1°C. (Fig. 11). Salinity gradually increases from Jan to Dec'09 month and the peak occurs at 38.5 ppt. Among the months tested, salinity is non-significant, p>0.05. The r² value of Ennore and CFH is average in its dependence of salinity with that of the months (Fig.12).

pH

pH indicates the acidity of the ocean and the normal range is neutral for safe living of fish. Low pH in saltwater is hazardous and will result in excess toxic

ammonia. A change in pH can increase the solubility of the metals, such as aluminium, poisonous to the fish. Water pH affects the fish growth. Some of the silica in ground rock and soil may oxidize into silicic acid. At CFH location, the lowest pH was 6.38 at Mar'09 and the highest pH was 7.80 at Dec'09. (Fig. 14) At Ennore location, the lowest pH was 6.27 at Mar'09 and the highest pH was 7.70 at Dec'09 and the increase in pH from lowest to highest was 18.57%. (Fig.13). On an average the pH of Ennore is equal to the pH of Chennai fisheries harbour. The highest pH of 7.80 occurs at highest dissolved oxygen, 3.775 ml/l at CFH and at Ennore the highest pH 7.70 occurs at dissolved oxygen of 4.31ml/l. The normal range for pH is 8.1 and the pH at Ennore and Chennai fisheries harbour region is in and around this range for the normal growth of fishes. Among the months tested, there are significant differences among the months tested at $p \leq 0.05$. The interaction effect of pH and salinity variables are significant in the month of April'09. The effect of pH and dissolved oxygen are significant $p \leq 0.05$ Sept'09 month. The peak appears at 7.25 pH at a tempera-

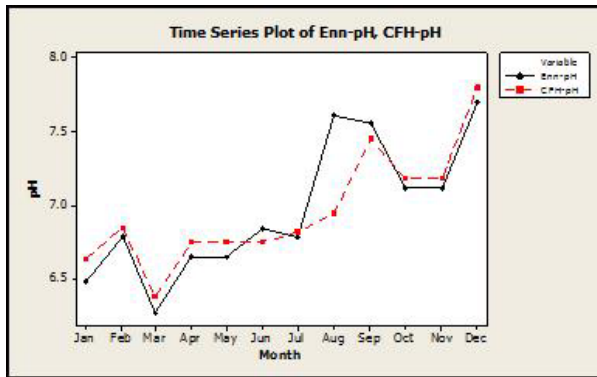


Fig. 11. Time series plot of pH at Ennore and at Chennai fisheries harbor region

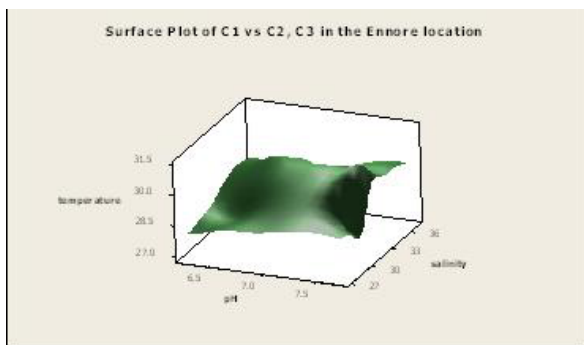


Fig. 12. Contour plot of temperature, pH and salinity at Ennore location

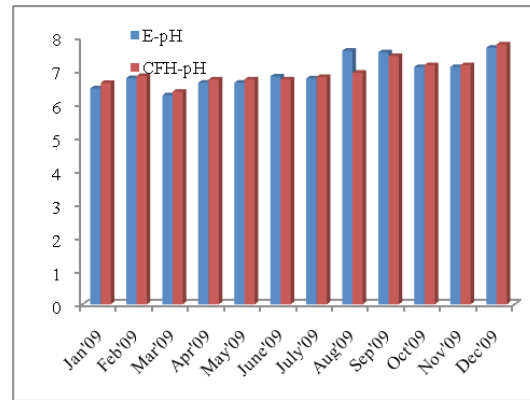


Fig. 13. pH distribution in Ennore and Chennai and Chennai fisheries harbour region

ture of 32.50 °C and at a salinity level of 36 ppt (Fig.15). The pH of the Ennore location and Chennai fisheries harbor location are clearly seen in the bar chart (Fig. 16). pH of the location indicates the acidity of the area and the two locations clearly states that the pH is in the neutral zone. The r^2 value of the CFH location indicates a good correlation between the pH and the months and the r^2 value of the Ennore location indicates an average correlation between the pH and the months. The higher value at CFH gives a better forecast of pH from months (Fig.17).

The Pearson correlation coefficient of pH-do ($r=0.04$), pH-tss ($r=0.37$), pH-Chl-b($r=0.68$), pH-chl.c ($r=0.82$), pH-pp-gross($r=0.009$), pH-N-Nit.($r=0.54$) at Ennore and the Pearson correlation coefficient of pH-tss $r=0.04$, pH-chl.b ($r= 0.003$), pH-pp-gross ($r=0.25$), pH-pp-net ($r=0.36$), pH-N.Nit ($r=0.50$), pH-N-amm.($r= 0.25$) at Chennai fisheries harbor region.

Dissolved oxygen

The amount of dissolved oxygen in water depends upon the amount of salinity and temperature. The

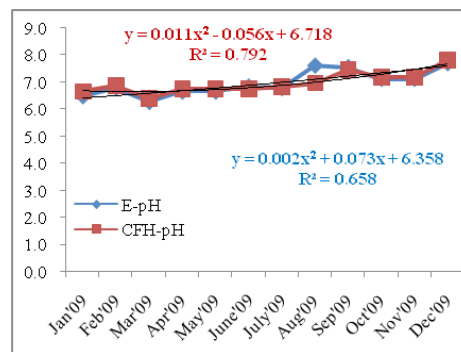


Fig. 14. Trend analysis graph of pH distribution in Ennore and Chennai fisheries harbour region

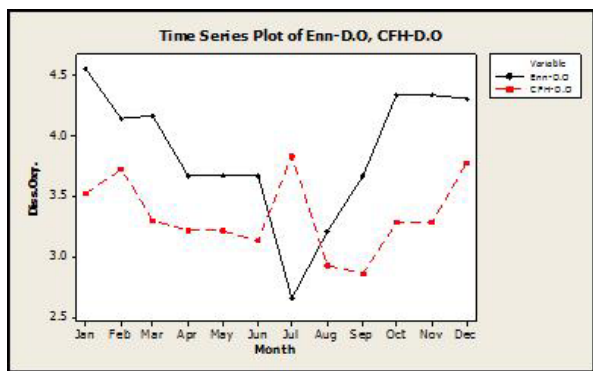


Fig. 15. Dissolved oxygen distribution at Ennore and at CFH

dissolved oxygen content of seawater is significantly influenced by marine organisms. The distribution range is 2.66-4.56 ml/l. At CFH location the lowest value, 2.89 ml/l at Sep'09 and the highest value was 3.84 ml/l at July'2009, (Fig.19) At Ennore, the lowest was 2.66 ml/l at Jul'09 and the highest was 4.56 ml/l at Jan'09 (Fig.18). On an average dissolved oxygen is more in Ennore, 3.87 ml/l than Chennai fisheries

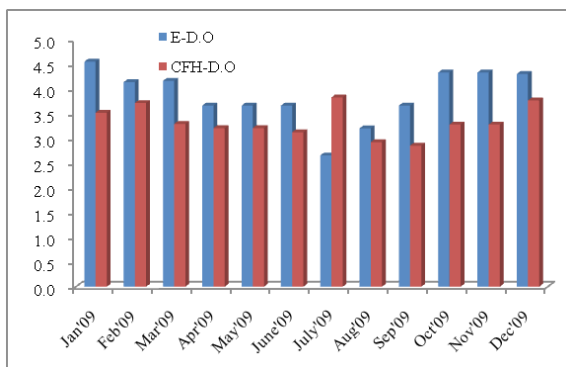


Fig. 16. Dissolved oxygen distribution in Ennore Chennai fisheries harbour region

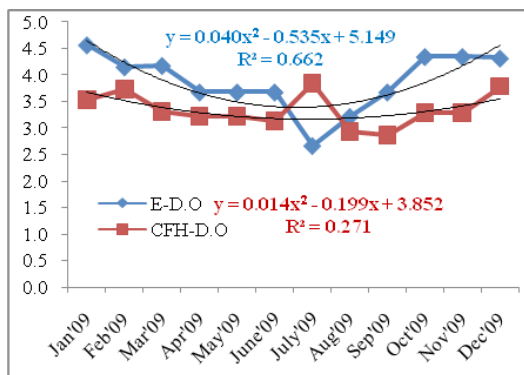


Fig. 17. Trend analysis graph of dissolved oxygen and distribution in Ennore and Chennai fisheries harbour region

harbor by 3.36 ml/l. At Ennore, primary productivity is less at monsoon season at Oct-Dec, 0.24gC/m³/d at a higher dissolved oxygen 4.31ml/l. Dissolved oxygen showed inverse trend against salinity and temperature and this coincided with the earlier findings of Damotharan, *et al.*, 2010. The dissolved oxygen increases gradually from Jan to Dec'09 and the peak occurs in the month of July'09 at 3.84 ml/l. The normal dissolved oxygen is 5.0 ml/l and the dissolved oxygen of Ennore and Chennai fisheries harbor region lies within the range for the range of fishes to grow. Among the months tested, there are significant differences among the months tested at $p \leq 0.05$.

The dissolved oxygen distribution both at Ennore and Chennai fisheries harbour region are compared and shown (Fig. 20). The dependence of dissolved oxygen to that of the months, is poor in Chennai fisheries harbour region and there is average depen-

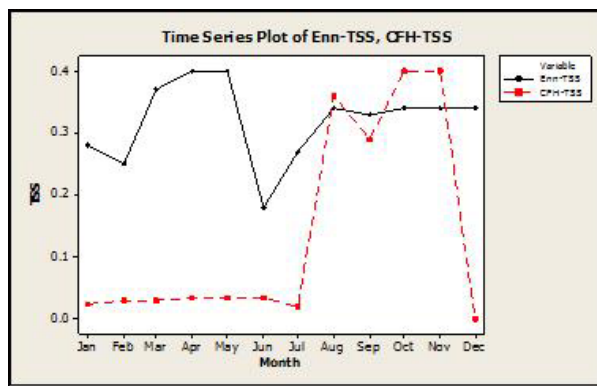


Fig. 18. TSS distribution in time series plot at Ennore and at CFH

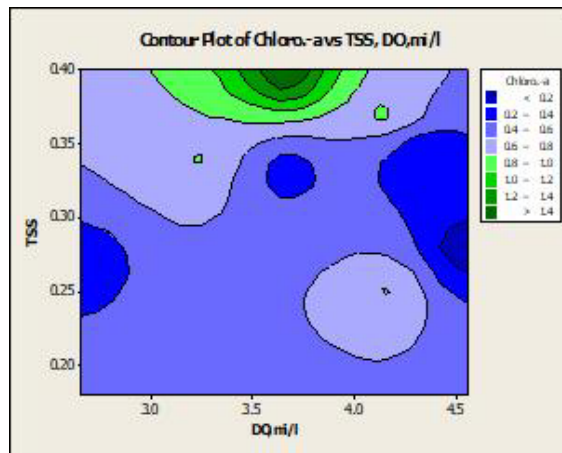


Fig. 19. Contour plot of chlorophyll 'a' Vs TSS and dissolved oxygen

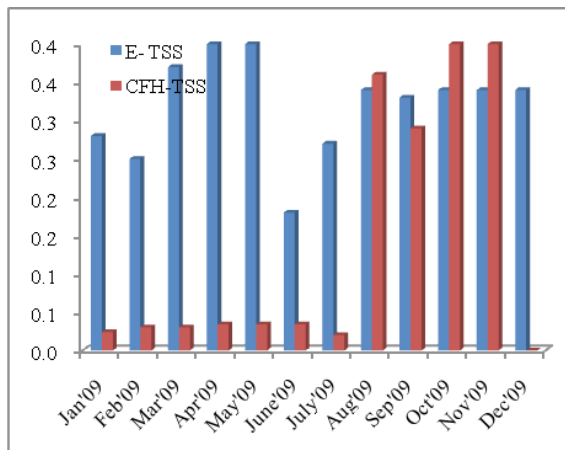


Fig. 20. TSS distribution in Ennore and Chennai fisheries harbour region

dance between dissolved oxygen and months at Ennore region (Fig. 21). The positive pearson correlation coefficient of do-chl.b ($r=0.38$) at Ennore region. do-tss ($r=0.09$), do-N-Nit($r=0.25$) at Chennai fisheries harbor region.

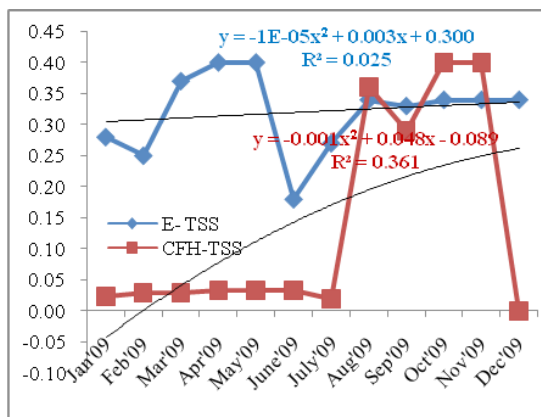


Fig. 21. Trend analysis in Ennore and Chennai fisheries harbour region for tss distribution

Total Soluble Solids

Total soluble solids are too high or too low the growth of many fish can be limited and death may occur. High concentration of TSS may also reduce water clarity contribute to a decrease in photosynthesis, combine with toxic compounds and heavy metals and lead to an increase in water temperature. High concentrations can produce laxative effects and can give an unpleasant mineral taste to water. The distribution range is 0.18-0.40 mg/l at Ennore. At CFH region, there was almost negligible TSS in

the month of Dec'09 and maximum value was 0.02 ml/l, July'09 (Fig. 23).

The total soluble solids distribution evenly increases from the month of July'09 to Dec'09 and the peak occurs in the month of Apr'09 is 0.40 mg/l (Fig. 22). The peak occurs at TSS value of 0.325 mg/l and dissolved oxygen of 3.25 ml/l and the pH of greater than 7.50 (Fig. 24). On an average total soluble solids is more in Ennore, ie.0.320 mg/l and in Chennai fisheries harbor is 0.12 g/l. The total soluble solids at Ennore is 62.50% more than Chennai fisheries harbour. The contribution of the temperature variable is 8.85%, salinity 15.52%, pH is 23.88%, dissolved oxygen 23.88%, total soluble solids is 23.88% for Ennore region. The distribution of the hydro-graphic variables, temperature (40%), salinity(14%), pH, (10%) dissolved oxygen (2%) and TSS (34%) for Chennai Fisheries Harbor region. Among the months tested, the differences among total soluble solids was significant, $p \leq 0.05$. The tss distribution both at Ennore and Chennai fisheries harbor region are compared in bar chart (Fig. 25). The trend analysis graph shows that there exists below average dependence of one variable to the other at Ennore and good dependence at CFH exists (Fig. 26). The pearson correlation coefficient of tss-chl.a ($r=0.31$), tss-chl.b ($r=0.31$), tss-chl.c ($r=0.60$), tss-pp.gross($r=0.37$), tss-pp-net($r=0.09$), tss-N-phos ($r=0.70$), tss-N-Nit. ($r=0.83$) is at Ennore. and tss-chl.a($r=0.48$). tss-N-Nit ($r=0.098$) is at Chennai fisheries harbor region.

Chlorophyll 'a'

Chlorophyll a is the principle photosynthetic pigment responsible for primary production. High concentration of phytoplankton, chlorophyll would result in high values of productivity and this reflects on high phytoplankton biomass. Chlorophyll a is found in algae and many other organisms. The distribution range of chlorophyll a is 0.06-1.68 mg/m³ at CFH and 0.07-1.58 mg/m³ at Ennore region. At CFH region, the minimum value was 0.07 mg/m³ at Sep'2009 and the maximum value was 1.69 mg/m³ at Aug'2009 (Fig. 28). At Ennore region, the minimum value was 0.07mg/m³ at Sep'09 and the maximum value was 1.69 mg/m³ at Aug'09 (Fig. 27). At Ennore region, the minimum value was 0.07 mg/m³ at Jun'09 and the max value was 1.58 mg/m³ at April and May'09. The chlorophyll a is more than 4.0 mg/m³ at a salinity level of 27ppt and temperature level of 29 °C. The chlorophyll a was highest at

0.64 mg/m³ in pre-monsoon at July-Sept and was lowest at 0.22 mg/m³ in summer season at Apr-June'09. Out of the 2 stations examined chlorophyll a was higher in Ennore by 41.89% than CFH and primary productivity was less in Ennore but higher in CFH at 27.9%. On an average, chlorophyll a is higher in Ennore at 0.64 mg/m³ and less in CFH at 0.39 mg/m³, the chlorophyll a is 39.06% higher at Ennore than Chennai fisheries harbour. The minimum chlorophyll a is 6.03 µg/ml and the chlorophyll a at Ennore and Chennai fisheries harbor region is within the range for normal growth. Among the months studied, chlorophyll a is significant (p≤0.05) at Aug'09. The correlation coefficient of chlorophyll a and phosphate for Ennore is 0.15 and for CFH is 0.006 (Dillon and Rigler, 1974). When contour plots are drawn it is seen that the peak lies at a chlorophyll 'b' score of 0.8 mg/m³ and a chlorophyll 'a' score of 3.0mg/m³, chlorophyll 'a' in these peak regions are greater than 1.4 mg/m³. The peak occurs at chlorophyll 'a' 1.25 mg/m³ at chlorophyll 'b', 0.35 mg/m³ at chlorophyll 'c', 0.5 mg/m³. The chlorophyll 'a' is more than 4.0 mg/m³ at a salinity level of 27 ppt and temperature level of 29 °C. The response optimization for the hydrographic variables viz. temperature, 28.414°C, salinity, 30.80 ppt, pH is 6.87, dissolved oxygen is 3.120 ml/l, total soluble solids is 0.4 mg/l for a predicted response of chlorophyll 'a' is 3.35mg/m³. The chlorophyll a shows greater than 1 at a TSS of 0.3 mg/l and DO of 3.2 ml/l, while holding the hydrographic variables of temperature, 32°C, salinity, 37 ppt and pH of 7.7 while chlorophyll 'a' versus temperature is concerned the temperature levels of 27, 28, 28.5,30 and 31 °C is statistically significant. (p≤0.05) for better chlorophyll production.

Regression Analysis at Ennore : Chl.-a versus Temp., Sal., pH, do, and tss

The regression equation is

$$\text{Chloro.-a} = 1.39 + 0.19 \text{ temp.} - 0.04\text{sal.} - 0.58 \text{ pH} - 0.52 \text{ do} + 3.66 \text{ tss}$$

Predictor	Coef	SE Coef	T	P
Constant	1.39	3.39	0.41	0.69
Temp.	0.19	0.12	1.58	0.16
Sal.(ppt)	-0.04	0.05	-0.82	0.44
pH	-0.58	0.28	-2.03	0.08
DO,mi/l	-0.52	0.32	-1.63	0.15
TSS	3.66	1.98	1.84	0.11

$$S = 0.40 \quad R\text{-Sq} = 64.1\% \quad R\text{-Sq(adj)} = 34.2\%$$

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	5	1.80	0.36	2.14	0.19
Residual Error	6	1.00	0.16		
Total	11	2.80			

The percentage contribution of temperature is 8.85%, salinity is 19.52%, pH is 23.88%, dissolved oxygen is 23.88% and total soluble solids is 23.88% at Ennore for a predicted response of 3.35. The percentage contribution of temperature at Chennai Fisheries Harbour is 30 °C, salinity is 26.80 ppt, pH is 6.38, dissolved oxygen is 2.86 ml/l, total soluble solids is 0.40 mg/l for a predicted response of 1.88. The regression equation at Chennai fisheries harbor is

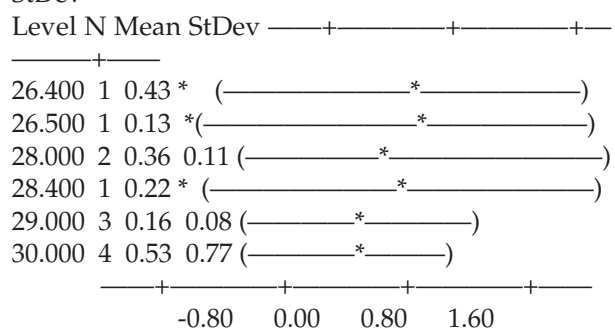
$$\text{Chloro} = 6.31 + 0.08\text{temp} - 0.03\text{salinity} - 1.07 \text{ pH} - 0.07\text{do} + 2.54 \text{ tss}$$

One-way ANOVA: Chloro versus Temp

Source	DF	SS	MS	F	P
Temp	5	0.30	0.06	0.20	0.95
Error	6	1.83	0.30		
Total	11	2.14			

$$S = 0.55 \quad R\text{-Sq} = 14.39\% \quad R\text{-Sq(adj)} = 0.00\%$$

Individual 95% CIs For Mean Based on Pooled StDev



Pooled St Dev = 0.55

Chlorophyll a dependence on months is below

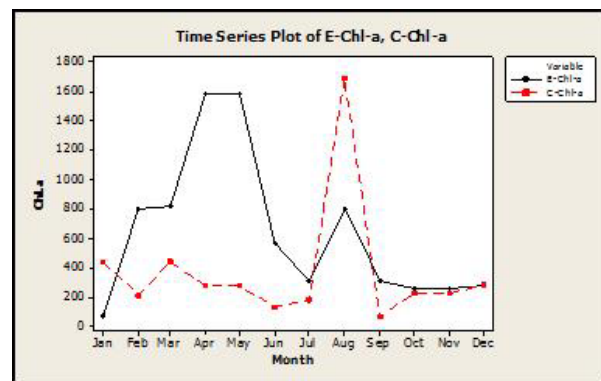


Fig. 22. Chlorophyll a distribution at Ennore and at CFH

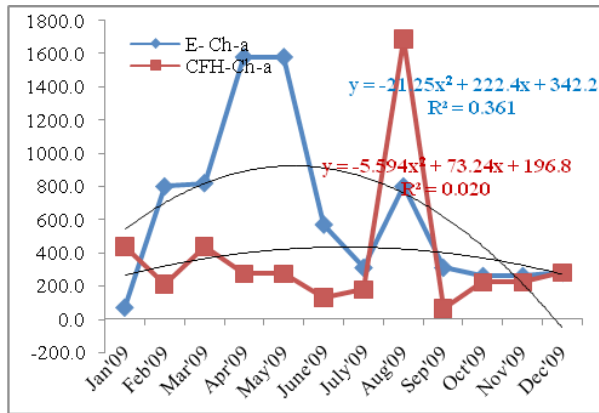


Fig. 23. Trend analysis of Chlorophyll a distribution in Ennore and Chennai fisheries harbour region

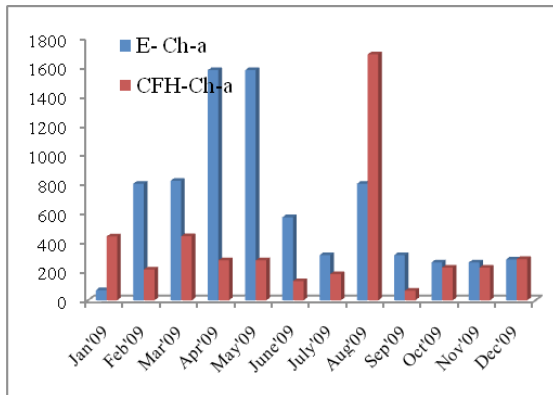


Fig. 24. Chlorophyll a distribution at Ennore and CFH

average for Ennore and negligible for CFH. (Fig. 29). The comparison of chlorophyll a occurrence at CFH and Ennore is shown (Fig. 30). The chlorophyll a values are more than chlorophyll b and c values and this coincided with the earlier findings of Meera and Bijoy Nandan, 2010. The peak of chlorophyll 'a' of more than 1.0 mg/m³ occurs at a tss of .030 mg/l and dissolved oxygen of 0-3.8 ml/l. The lowest temperature occurs at 30.75°C and the lowest Chlorophyll a occurs at 0.2 mg/m³ and salinity is 30 ppt. The chlorophyll 'a' is greater than 1.4 mg/m³ at a tss value of 0.37 mg/l and dissolved oxygen value of 3.5 ml/l. The chlorophyll 'a' is greater than 0.50 mg/m³ at a salinity level of 28 ppt and at a tempera-

Table 1. ANOVA Chlorophyll 'a'

Sou of Varia	SS	df	MS	F	P-value	F crit
Between Groups	0.42	1	0.42	1.93	0.17	4.30
Within Groups	4.83	22	0.21			
Total	5.25	23				

ture of 27.1 °C.

The pearson correlation coefficient of chl.a -chl.c (r= 0.31), chl.a-pp-gross (r=0.71), chl.a-pp-net (r=0.27) is at Ennore and chl.a-chl.b (r=0.24), chl.a -chl.c (r=0.30), chl.a-pp-net (r= 0.06) is at Chennai fisheries harbor region.

Chlorophyll b

Chlorophyll b is found in most plants. It aids in the process of photosynthesis. The distribution range is 0.16(Oct'09) -1.80 mg/m³ (June'09) at Ennore region, 0.004 (Sep'09) and 0.38(Dec'09) at CFH. At CFH region, the minimum value was at Jan, Mar & Apr'09 and the maximum value was at Dec'09.(Fig. 32) At Ennore region, the minimum

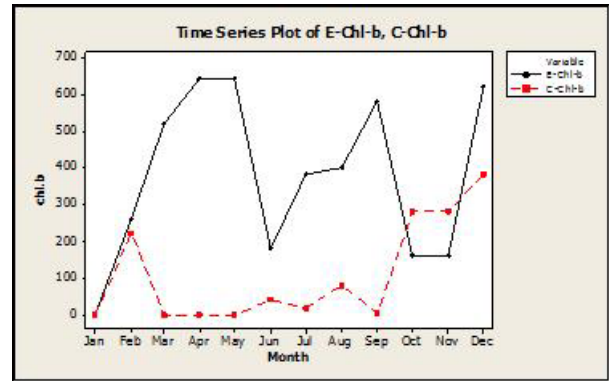


Fig. 25. Chlorophyll b distribution at Ennore and at CFH in time series plot

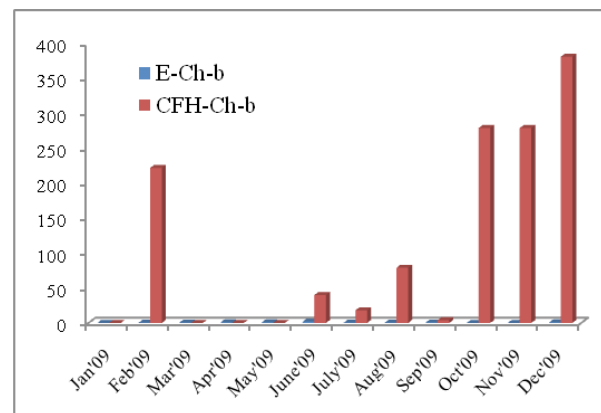


Fig. 26. Chlorophyll b distribution in Ennore and Chennai fisheries harbour region

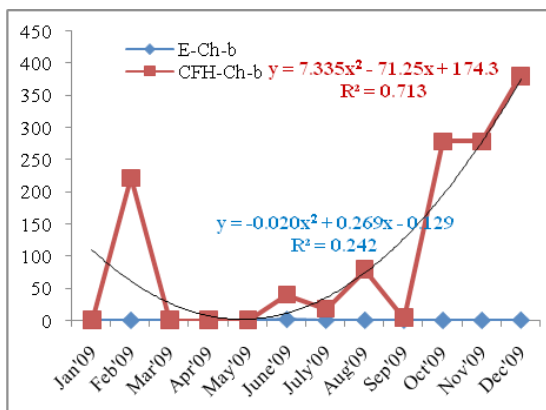


Fig. 27. Trend analysis in Chlorophyll b distribution in Ennore and CFH

chlorophyll b was at Jan'09 and the maximum value was 1.80 mg/m³ at June'09 (Fig. 31). On an average chlorophyll b is high in Ennore at 0.51 mg/m³ than in Chennai fisheries harbor at 0.10 mg/m³, chlorophyll b at Ennore is 20.31 is lower and chlorophyll c at Ennore is lower by 43.33%. On the whole, the chlorophyll b at Ennore is 68.0% is higher than Chennai fisheries harbour. The chlorophyll b at Ennore is 80.39% higher than Chennai fisheries harbour. The minimum chlorophyll b is 1.08 µg/ml and this is also within the range. Among the months studied, chlorophyll b in June'09 is significant at p≤0.05. The bar chart showing the comparison between Ennore and Chennai fisheries harbor region for chlorophyll b (Fig. 33). The dependence between chlorophyll b and months is below average at Ennore and the dependence between chlorophyll b and months is above average at CFH (Fig. 34).

The pearson correlation coefficient of chl.b-chl.c (r=0.55), chl.b-N-phos (r= 0.31), chl. b- N-nit. (r=0.65) is at Ennore region and for chl.b- chl.c (r=0.81), chl.b-pp. gross (r=0.03), chl.b-pp-gross (r=0.03), chl.b- ppnet (r=0.11), chl.b-N-Nit (r=0.07) is at Chennai fisheries harbor region.

Chlorophyll c: Chlorophyll c is mostly found in marine and fresh water algae. Chlorophyll c is actually an accessory pigment that works in conjunction with chlorophyll a aid photosynthesis. This type of chlorophyll is found mostly in marine algae. The distribution range is 0.23-3.82 mg/m³. At CFH location, the chlorophyll c recorded was negligible at Feb'2009 and the maximum value was 0.63 mg/m³ at Dec'09, (Fig. 36) at Ennore location, the chlorophyll c recorded was minimum at Jan, Feb & Nov'2009 and maximum at 3.82 mg/m³ at June'2009

(Fig. 35). Chlorophyll c is much higher in Ennore at 3.80 mg/m³ than in Chennai fisheries harbor at 0.62 mg/m³. On an average chlorophyll c is higher in Ennore at 0.9 mg/m³ than in Chennai fisheries harbor at 0.25 mg/m³. The chlorophyll c at Ennore is 44.44% higher than Chennai fisheries harbour. The minimum chlorophyll c is 4.87µg/ml and the values obtained are within the range for both Ennore and Chennai fisheries harbor region. Among the months tested, the chlorophyll c is non significant p≥0.05. The contour plot of chlorophyll b and chlorophyll c is shown for Ennore location, (Fig. 37) the surface plot of chlorophyll a, b & c in Chennai fisheries harbor region (Fig. 38). Chlorophyll c distribution in Ennore and Chennai fisheries harbor region are compared and shown (Fig. 39). Chlorophyll c distribution dependence on months with below average at Ennore and above at CFH (Fig. 40).

The pearson correlation coefficient of chl.c- pp-

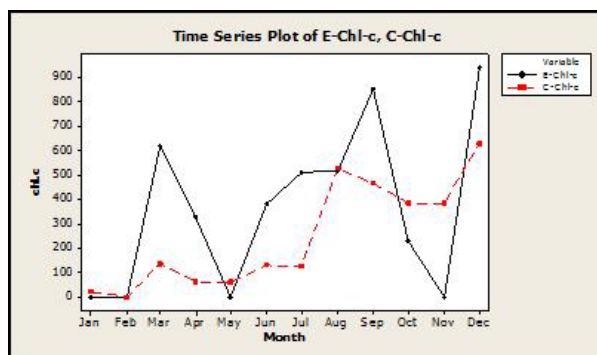


Fig. 28. Chlorophyll c distribution at Ennore and at CFH

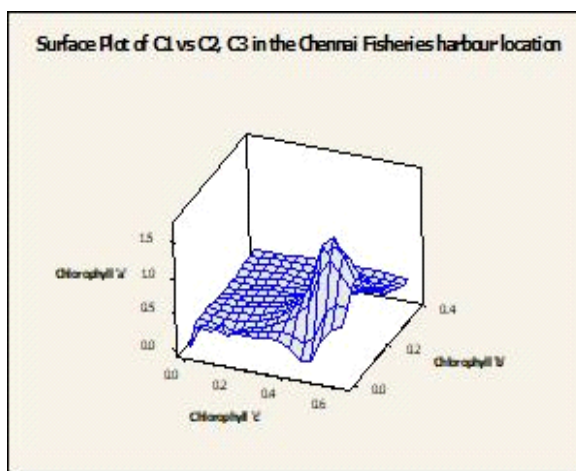


Fig. 29. Contour plot of Chlorophyll 'a' Chlorophyll 'b' and 'c'

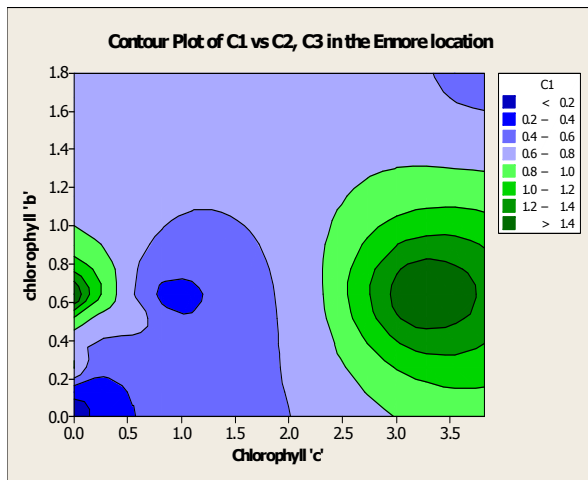


Fig. 30. Contour plot of chlorophyll a Vs Vs b and c

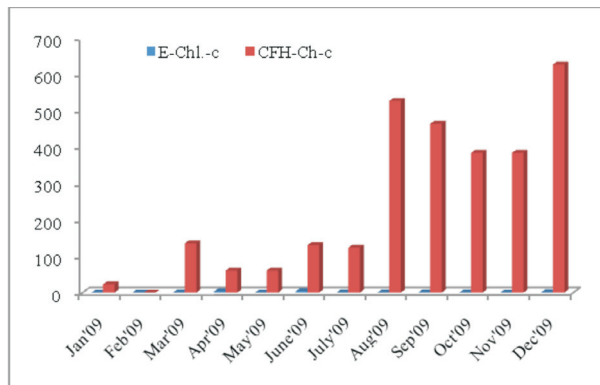


Fig. 31. Chlorophyll c distribution in Ennore and Chennai fisheries harbour region

gross ($r=0.40$), chl.c-pp-net ($r=0.15$), chl.c-N-phos ($r=0.06$), chl.c-N-nit. ($r=0.59$) is at Ennore and chl.c-pp-gross ($r=0.21$), chl.c-pp-net ($r=0.28$), chl.c-N-phos ($r=0.002$), chl.c-N-Nit ($r=0.01$) is at Chennai fisheries harbor region.

Gross Primary productivity: Gross primary productivity (GPP) is the total amount of energy produced by vegetation for the growth and development of the plant. The distribution range is 0.10(Oct'09)-5.93gC/m³/d(Aug'09) at CFH. Gross primary productivity values showed a wide range of fluctuations in the present study at 0.30 (Dec'09)-1.94gC/m³/h (Sep'09) at Ennore (Fig. 32) as reported by Govindasamy (1992) from the coromandel coast, Sampath Kumar (1992) from the Tharangampadi - Nagapattinam coast. At CFH location, the lowest primary productivity, gross was 0.11gC/m³/d, Oct'09 and the maximum value was 5.93gC/m³/d,

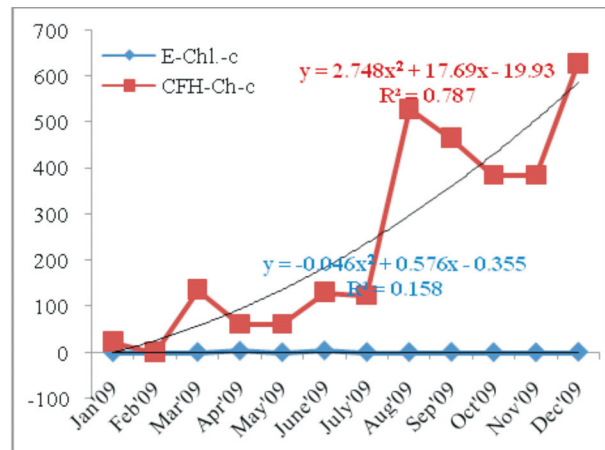


Fig. 32. Chlorophyll c distribution in Ennore and Chennai fisheries harbour region

Aug'09 (Fig. 42). At Ennore, the gross primary productivity was negligible, May and Nov'09, maximum was 1.94gC/m³/d Sep'09 (Fig. 41). The increase is 84.76%. Primary productivity gross is much less in Ennore than in Chennai fisheries harbor. The primary productivity gross at CFH is higher by 39.87% than at Ennore. A positive correlation significant at $p \leq 0.01$ ($r^2=0.62$) was observed between gross and net primary productivity this coincided with the earlier findings of Meera and Bijoy Nandan, 2010. The high primary productivity is 150gC/m³/year and the primary productivity at Ennore and at Chennai fisheries harbor region is in the range of 107.67gC/m³/y for the growth of fishes in this location. Primary productivity, gross at Jan'09, Aug; 09 and Sept'09 are significant at $p \leq 0.05$ among the months tested. The comparison of primary productivity, gross values both at Ennore and CFH are shown in Fig. 43. Primary productivity gross at

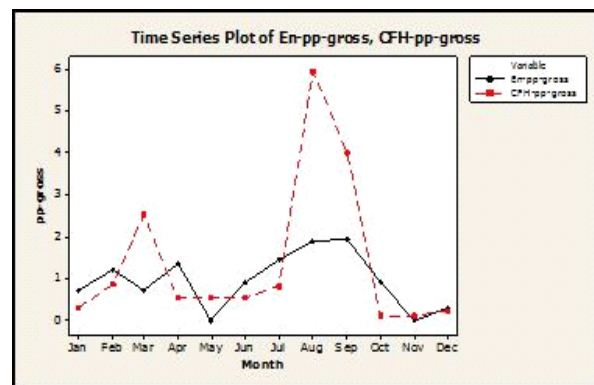


Fig. 33. Primary productivity, gross distribution at Ennore and at CFH

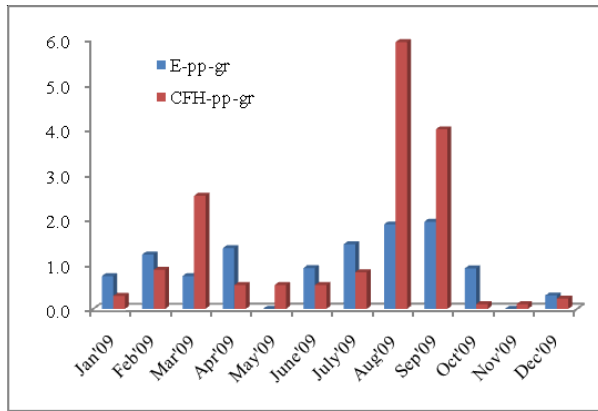


Fig. 34. Primary productivity distribution at Ennore and CFH in the year 2009

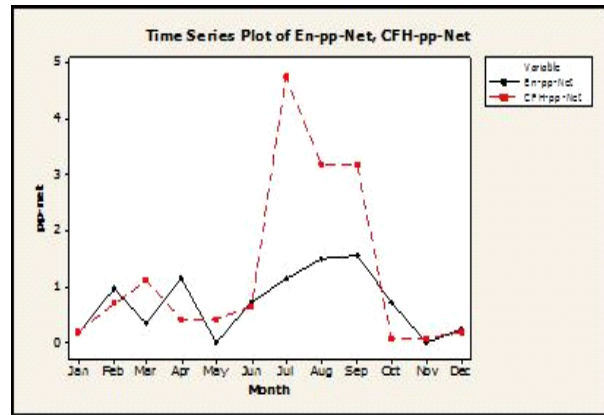


Fig. 36. Primary productivity, net distribution at Ennore and at CFH

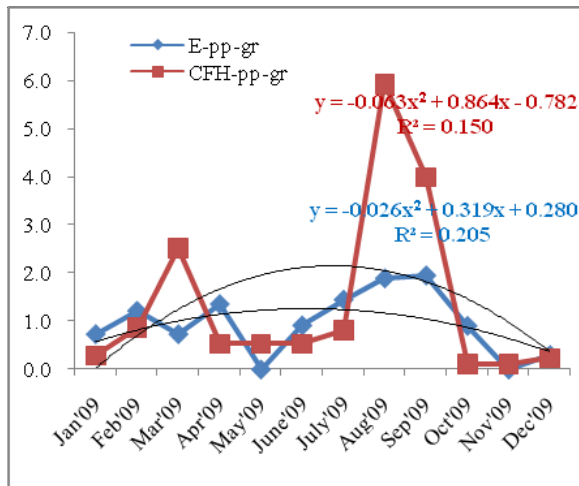


Fig. 35. Trend analysis graph of PP-gross distribution in Ennore and Chennai fisheries harbour region

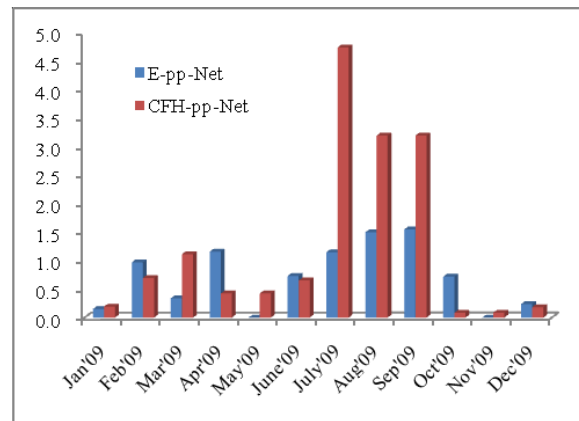


Fig. 37. Primary productivity, net distribution at Ennore and CFH

Ennore region in trend analysis shows that the dependence is below average at CFH region and negligible at Ennore region (Fig. 44).

The pearson correlation coefficient of pp-gross-pp-net ($r=0.96$), pp-gross-N-Phos($r=0.68$), pp-gross-N-amm ($r=0.55$) is at Ennore and pp-gross-pp-net ($r=0.61$), N-phos-N-nit ($r=0.79$) is at Chennai fisheries harbor region.

Net Primary productivity

Net primary production (NPP) represents the total available energy in an ecosystem, the form of dry plant biomass. The range is 0.08-4.74 $gC/m^3/d$ at CFH and 0.24-1.5 $5gC/m^3/h$ at Ennore. At CFH location, the minimum value was 0.09 $gC/m^3/d$ at Oct'09 and maximum value was 4.75 $gC/m^3/d$ at July'09(Fig. 45) at Ennore location, the minimum value was at May and Nov'09 and the maximum

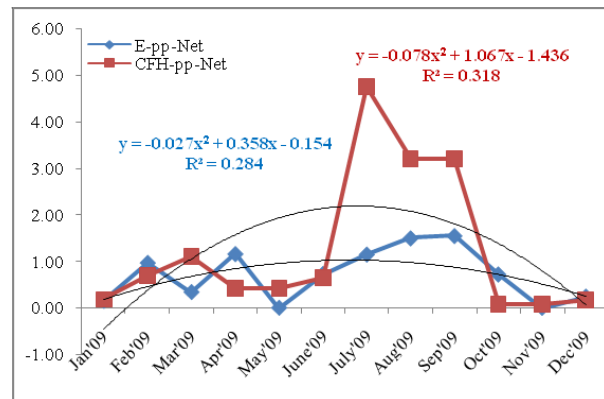


Fig. 38. Trend analysis graph of pp, net both at Ennore and CFH

value was 1.55 $gC/m^3/d$ at Sept'09 (Fig. 44) Primary productivity net values are less at Ennore than primary productivity net values of CFH. On an average primary productivity net is much higher in

Chennai fisheries harbour, 1.45gC/m³/d than 0.71gC/m³/d at Ennore. The primary productivity net at CFH is higher by 50.96% than in Ennore. Among the months tested, primary productivity, net in Jan'09, July'09, Aug'09, Sept'09, Oct'09 and Dec'09 is significant at p≤0.05. The July'09 primary productivity net is significant at p≤0.01. The primary productivity, net between Ennore and CFH are compared (Fig. 46). Primary productivity, net both at Ennore and CFH dependence with months is below average (Fig. 47).

The pearson correlation coefficient of pp-net-N-phos (r=0.66) and pp-net-N-Amm(r=0.48) is at

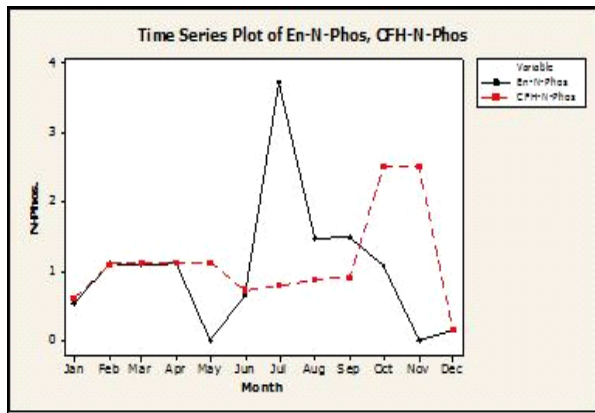


Fig. 39. Nutrient phosphate distribution at Ennore

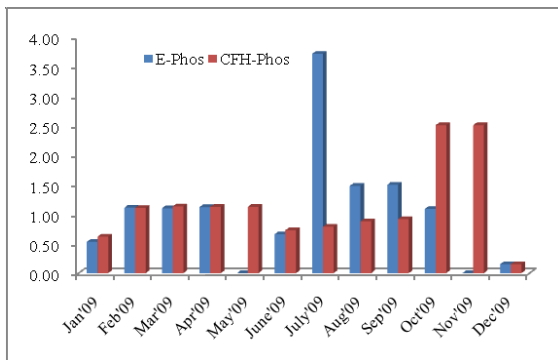


Fig. 40. Phosphate nutrient distribution in Ennore and Chennai fisheries harbor region

Ennore.

Nutrient-phosphate

Phosphorous, a macro nutrient is a limiting factor for the primary productivity and it affects the species distribution and the ecosystem. The distribution range is 0.15(Dec'09)-2.51 mg/l (Oct'09) at CFH and 0.15 (Dec'09)-1.50 (Sep'09) at Ennore. At Ennore lo-

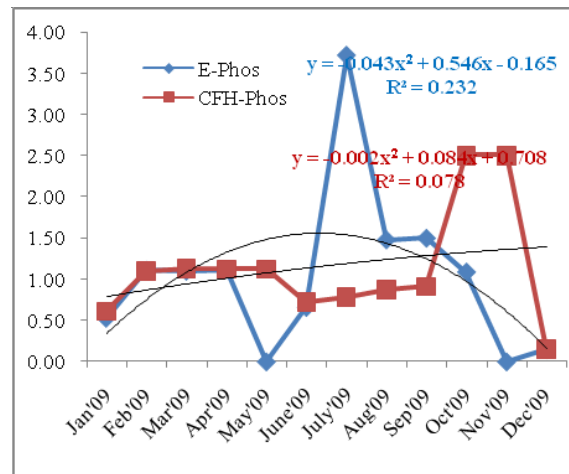


Fig. 41. Trend analysis of Phosphate nutrient both at Ennore and CFH

cation, the minimum value for nutrient phosphate was May and Nov'09 and the maximum value of nutrient phosphate is 3.72 mg/l, July'09. (Fig. 48). At CFH location, the minimum value is 0.15 mg/l at Dec'09 and the maximum value is 2.51 mg/l at Oct'09 (Fig. 49). Nutrient phosphate is high during monsoon season at Oct-Dec, 2.51 mg/l, most favourable for phytoplankton growth. Nutrient phosphate is high in Ennore than in Chennai fisheries harbor. On an average, nutrient phosphate at Ennore, 1.04 mg/l is much higher than Chennai fisheries harbor, 0.99 mg/l region, the nutrient phosphate is higher by 4.80% at Ennore than Chennai fisheries harbor region. The minimum nutrient phosphate required is 0.05 mg/l to 0.20 mg/l and the phosphate of the seawater at Ennore is within the range. Phosphate nutrient distribution in Ennore and Chennai fisheries harbor region are compared and shown in Fig. 50. Nutrient phosphate distribution among the months is below average in dependence with one another at Ennore and negligible at CFH. (Fig. 51). In the seasonal effect, 4 seasons are above average in their dependence with the hydro-graphic variables (Fig. 52).

The pearson correlation coefficient of N-Phos-N-Amm (r=0.30) is at Chennai fisheries harbor region.

Nutrient – Nitrate

A high nitrate level indicates fish waste and poor water quality and fish disease and a low nitrate represents good health of fish. The distribution range is 0.19mg/l (Dec'09)-0.61(Oct'09) at CFH. At Chennai fisheries harbour, nutrient nitrate is negligible at

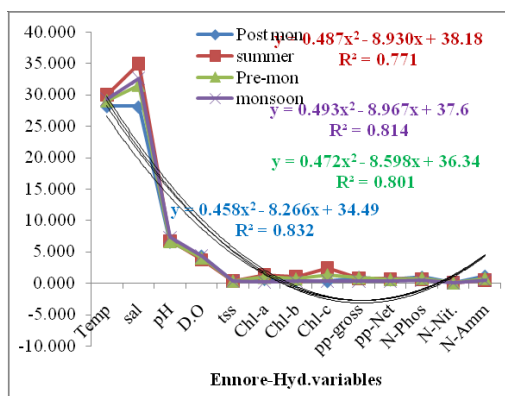


Fig. 42. Nutrient phosphate distribution in Ennore and Chennai fisheries harbor region

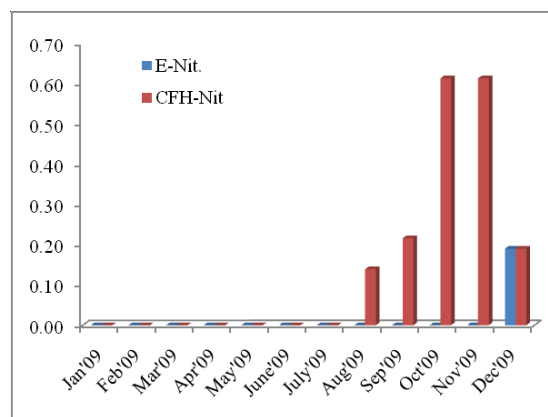


Fig. 45. Nutrient nitrate distribution during the year' 2009 at Ennore and CFH region

Oct'09 and maximum at 0.613 mg/l at Jan, Feb, Mar, Apr, June, (Fig. 53) July'09 at Ennore, the minimum value is 0.19 mg/l at Dec'09. The peak of nutrient nitrate, occurs at 0.6 mg/l in the month of Oct'09 at CFH. Nutrient nitrate is less in Ennore, 0.19 mg/l than Chennai fisheries harbor, 0.61 mg/l. On an average nutrient nitrate is less in Ennore, 0.19 mg/l

than in Chennai fisheries harbor, 0.12 mg/l, the nutrient nitrate at Chennai fisheries harbour is 83.33% than at Ennore. The peak occurs at phosphate nutrient of 3.0 mg/l and ammonia nutrient of 1.5 mg/l and nitrate nutrient of 0.1 mg/l. The peak of nutrient nitrate, occurs at 0.6 mg/l in the month of Oct'09. The distribution of the nutrient ammonia is less compared to the nitrate nutrient and still less compared to phosphate nutrient. The minimum nutrient, nitrate is 0.003 mg/l and the range at Ennore and Chennai fisheries harbor region is within this range for the normal growth of fishes. Among the months tested, nutrient, nitrate is significant $p \leq 0.05$. The nitrate distribution both at Ennore and Chennai fisheries harbor region's dependence with months are average (Fig. 54). The comparisons of the nutrient nitrate is represented as bar chart for 12 months are given (Fig. 55).

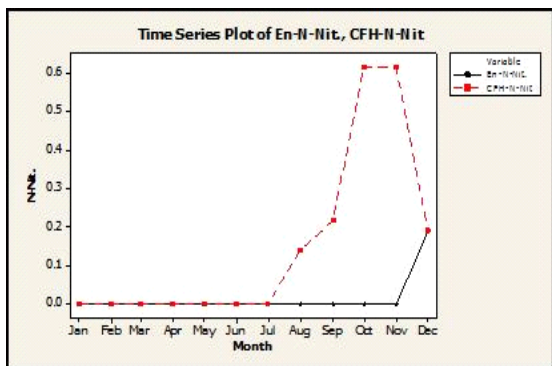


Fig. 43. Time series plot of the distribution of nutrient, nitrate at CFH

The pearson correlation coefficient of N-Nit-N-Amm ($r=0.03$) is at Chennai fisheries harbor region.

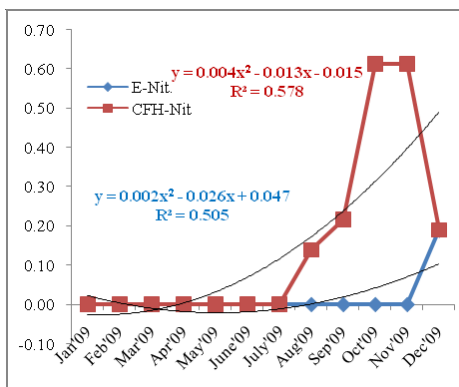


Fig. 44. Trend analysis of nutrient nitrate distribution both at Ennore and CFH region

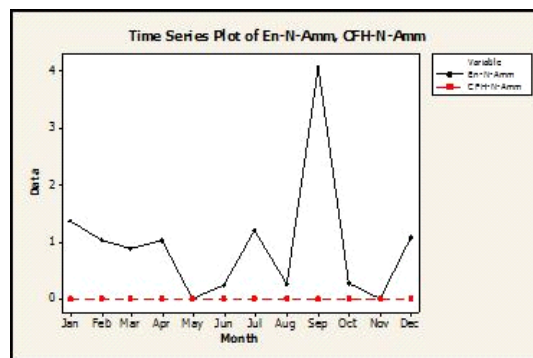


Fig. 46. Nutrient Ammonia distribution in the year 2009 at Ennore.

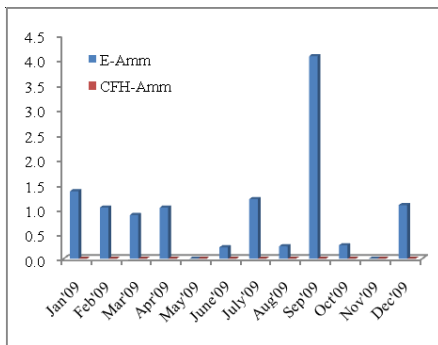


Fig. 47. Ammonia nutrient distribution in Ennore and Chennai fisheries harbor region

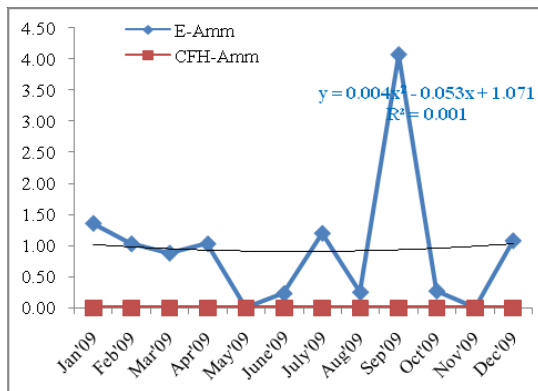


Fig. 48. Trend analysis graph of nutrient ammonia distribution at Ennore and CFH

Nutrient Ammonia

Fish are very sensitive to ammonia and healthy phytoplankton populations remove ammonia from water. Ammonia affects fish by causing the blood to lose its ability to carry oxygen. The distribution range is 0.23- 4.01 mg/l at Ennore. At Chennai Fisheries harbour location, the nutrient ammonia was not present, at Ennore location, the nutrient ammonia at May and Nov'09 was negligible and maximum was of 4.08 mg/l at Sep'2009. At station 1 the ammonia was high in Sep't'09, 4.08 mg/l at a dissolved oxygen of 3.67 ml/l at a highest primary productivity of 1.94gC/m³/d. On an average nutrient nitrate is at Ennore is higher than Chennai fisheries harbour region. The optimum ammonia for the abundance of fishes in marine water is 0.25 mg/l and the ammonia at Ennore is more than the optimum limit and this may be due to the hot water being discharged into the sea. Among the months tested, nutrient ammonia is significant $p \leq 0.05$. The comparison bar graph for nutrient ammonia distribution both at Ennore and Chennai fisheries harbor

region is shown (Fig. 48). The dependence of the nutrient ammonia with that of the months are negligible both at Ennore and CFH.

The correlation coefficient between the 2 locations, viz. Ennore and Chennai fisheries harbour region are temperature ($r=0.86$), ph ($r=0.86$), salinity ($r=0.93$), pH ($r=0.88$), dissolved oxygen ($r=0.11$), tss ($r=0.20$), chl.a ($r=-0.24$), chl.c ($r=0.13$), pp-gross ($r=0.67$), pp-net ($r=0.69$), nutrient phosphate ($r=-0.15$), nutrient nitrate ($r=0.05$). The r^2 value for temperature at Ennore was 0.23 and Chennai fisheries harbour region was 0.26.

Conclusion

Higher phosphate content of 1.50 mg/l is recorded for the highest gross primary production, 1.94gC/m³/d in the month of Sep'09 the highest phosphate content of 3.72 mg/l leads to 1.44 gC/m³/day (medium) primary production growth in July'09. The evolution of Ammonia was highest 4.08 mg/l in Sep'09 at a gross primary production of 1.94gC/m³/d, the lowest ammonia was 0.23 mg/l at 0.91gC/m³/d gross primary production in the month of June'09. Total soluble solids is lowest in June'09 at 0.18 mg/l at a salinity level of 35 ppt and highest TSS of 0.40 mg/l was recorded in 30ppt in the months of April and May'09. The chlorophyll 'a' was lowest 0.07 mg/m³ in Jan'09 at a salinity of 29.7 ppt, highest chlorophyll 'a' was 1.58mg/m³ in Apr'09 at 30 ppt, chlorophyll 'b' was recorded in 0.16 mg/m³, Oct'09 at a salinity level of 34 ppt, chlorophyll 'c' was highest in 3.82 mg/m³ at June month at a salinity of 35 ppt and lowest in 0.23 mg/m³ in Oct'09. Dissolved oxygen was lowest, 2.66 ml/l, July'09 at highest salinity of 37 ppt and highest dissolved oxygen, 4.56 ml/l at a salinity level of 29.70ppt in Jan'09. Total soluble solids is lowest in June'09 at 0.18 mg/l at a salinity level of 35 ppt and highest total soluble solids of 0.40 mg/l in April and May'09 was recorded at 35 ppt. The study of regression of different sea water characteristics at two different locations on the co-variance test shows that temperature, salinity and pH are significantly different between Ennore and Chennai Fisheries harbor location is significant at $p \leq 0.05$. The variables dissolved oxygen, total soluble solids, chlorophyll a, b and c, nutrient phosphate, nitrate and ammonia, primary productivity, gross and net are non significant, $p \geq 0.05$ between the two localities tested. The values of all the hydro-graphic variables were sig-

nificant both at 5% and 1% level of significance between Ennore and Chennai fisheries harbor region and was non significant both at 5% and 1% level of significance between different months. The mean of different hydrographic variables at Ennore'09 viz. temperature, 29.33 °C, salinity, 32.66 ppt, pH, 7.31, dissolved oxygen, 4.33 ml/l, tss, 0.34 mg/l, chlorophyll a, 0.26 mg/l, chlorophyll b, 0.31 mg/l, chlorophyll c, 0.39 mg/l, pp-gross, 0.40 gC/m³/d, pp-net, 0.32gC/m³/d, N-phos, 0.41 mg/l, N-Nit, 0.06mg/l and N-ammonia, 0.45 mg/l and at Chennai fisheries harbor region is temperature, 28.80°C, salinity, 33.33 ppt, pH, 7.38, dissolved oxygen, 3.44 ml/l, tss, 0.26 mg/l, chlorophyll a 0.24 mg/l, chlorophyll b 0.31 mg/l, chlorophyll c 0.46 mg/l, pp-gross, 0.14 gC/m³/d, pp-net, 0.11 gC/m³/d, N-phos, 1.72 mg/l and N-Nitrate, 0.47 mg/l.

Acknowledgement

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