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Effect of thermal effluent discharge on benthic fauna off Tuticorin bay, south east coast of India

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Benthic fauna of Tuticorin bay in relation to thermal effluent discharge was studied for a period of two years (March 1990 to April 1992). Station I situated closer to thermal effluent discharging site was characterized by high water temperature (surface mean 38.92°C, Bottom mean 38.86 °C), low dissolved oxygen (surface mean 3.79±0.29 ml/l) and high percentage of sand (mean sand 87.96%, mean silt 7.57%, mean clay 4.87 %) with the record of only three benthic species mainly dominated by *Cerithedia fluviatilis*. Occasional record of *Prionopsio* sp. and *Nassa pulla* was also noticed at st. I. Higher water temperature recorded at st. I had resulted elimination of other benthic species with survival of fewer organisms. Station IV, situated far away from thermal effluent discharging site had better water quality parameters of temperature (surface mean 30.84°C,), dissolved oxygen (surface mean 4.08 ml/l) and improved sediment particle size composition (mean sand 76.27 %, mean silt 16.11 %, mean clay 7.68%) with the record of 23 benthic species. Station I was recorded with the lowest benthic population density (480-1084 no/m^2) and species diversity (0-0.44) while other stations showed the highest faunal density (2327-3452 no/m^2 at st.VI) and species diversity (2.12-2.54 at st. V). Temperature showed significant negative correlation with species diversity (1%), benthos density (5%) and benthos biomass (1%) at st. I, while in other stations, temperature was positively correlated with species diversity, benthos density and benthic biomass but statistically insignificant. Thermal effluent increased the temperature of receiving waters and thereby by affected the benthic population of Tuticorin bay.

[**Key words** : Thermal effluent, water quality, benthic faunal, Tuticorin bay]

Introduction

The discharge of heated effluent in the coastal waters by thermal power plants is a regular problem. The continuous operation of thermal power plant with a parallel discharge of thermal effluent has resulted the possibilities for increasing the temperature of receiving water. Thermal effluent not only can produce adverse effects on the coastal water but also can affect the aquatic organisms such as planktonic community and bottom fauna[1-3]. Being sedentary and sessile, the benthic fauna are the major causalities of any environmental changes[4,5].

The Tuticorin Thermal Power Plant (TTPP) is located at the southern part of the Tuticorin bay (lat.8°; long. 78° 'E) in the Gulf of Mannar along southeast coast of India (Fig. 1). The TTPP discharges thermal effluent at the rate of 115×10^6 liters/day into the adjacent water body with the temperature range between 40 and 44°C. There is also a high deposition of ash (at the rate of 4000 mt/day). The present study has been undertaken at Tuticorin bay with a view of assessing the impact of the thermal effluent on the water quality in relation to the distribution of bottom fauna.

Materials and Methods

For studying the effect of thermal effluent discharge, six stations were fixed at Tuticorin bay in relation to horizontal proximity of thermal effluent discharge point (TEDP) of TTPP (Fig. 1). Station I is located about 100 m away to the TEDP. Stations II and III are located 300 m away from the TEDP at the lower zone towards the sea and upper zone towards the coast respectively. Station II is also located very close to bottom ash dumping site and exposed to continuous deposition of ash. Station III is also located very close to the Liquid Waste Discharging Point (LWDP) when compared to other stations.

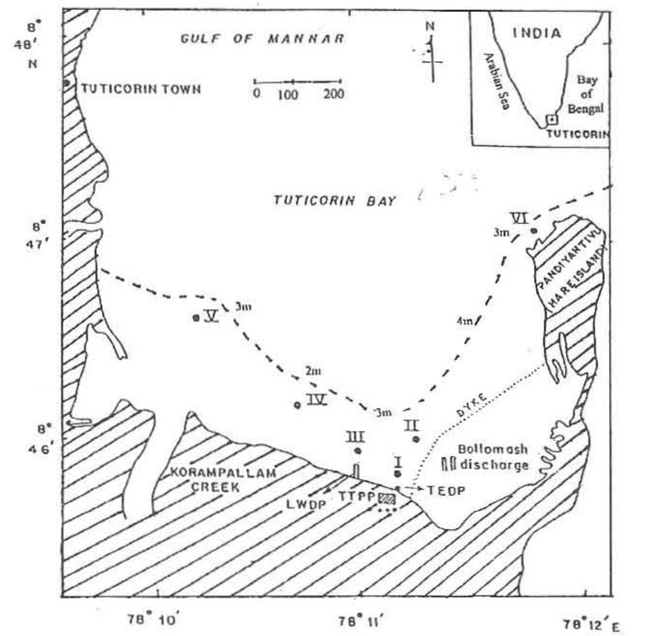

Fig. 1—Map showing the location of study area. Inset shows south east coast of India

Station IV is located in the upper zone of about 750 m away. Stations V and VI were fixed in upper zone and lower zone respectively at a distance of 1500 m and 1750 m away from TEDP.

Samples of surface and bottom water, sediment and benthic fauna were collected from six stations at fortnightly intervals for a period of two years from April 1990 to March 1992. Bottom water samples were collected using specially deviced bottom sampler for temperature, salinity, *p*H and turbidity estimation and for estimation of dissolved oxygen concentration, water sample was collected in 250 ml BOD bottles. A van Veen grab (0.05 m^2 area) was used for collecting bottom fauna and sub samples were collected for sediment analysis. The water temperature was determined using centigrade thermometer having an accuracy of 0.5°C. Salinity, dissolved oxygen and turbidity were estimated as mentioned by Stickland & Parsons[6]. *p*H of the water was measured with a digital *p*H meter. The sediment particle size composition was made by following standard procedures[7]. Benthic fauna was separated by passing the sediment through a 0.5 mm mesh sieve. The organisms retained on the sieve were considered for macrobenthic faunal analysis. After sieving, the fauna were preserved in 5% formalin-Rose Bengal solution for further analysis and identification. Population density and biomass of benthic fauna, species diversity, richness and evenness were estimated by following standard methods[8-10].

Results

Hydrographical parameters

Data on physico-chemical parameters such as temperature, salinity, dissolved oxygen, *p*H and turbidity are given in Table 1. Surface and bottom water temperature at st. I recorded the highest range from 34.3 to 42.3°C and 34.3 to 42.0°C respectively. In the succeeding stations, temperature decreased significantly and the lowest ranges of 28.0-32.8°C and 27.8-32.0°C were noticed respectively in surface and bottom at st. VI. Over all mean temperature indicated maximum of 38.92°C±1.78°C at st. I and minimum of 30.81±1.24°C at st. VI in surface water. Bottom water showed maximum of 38.86±1.68°C at st. I with the minimum of 30.36±1.22°C at st. VI. High salinity was recorded at st. I both in surface and bottom water with the range from 31.6 to 36.30 ppt and 31.5-36.3 ppt respectively. Station 3 recorded the lowest salinity range of 22.10-31.90 ppt in surface and 23.5-31.78 ppt in bottom

In surface water, dissolved oxygen (DO) indicated lower range at st. I between 3.38 and 4.43 ml/l while it was higher from 3.55 to 5.03 ml/l at st. III. Bottom water DO was recorded with lower range of 3.33-4.88 ml/l at st. I with the higher range of 3.38-4.93 ml/l at st. III. Station I had the lowest mean DO both in surface and bottom waters. Though remaining within a narrow range, high *p*H was observed at st. I (8.18-8.50) and low *p*H at st. III (8.08-8.35) in surface. Similarly, in bottom water also higher *p*H range was observed at st. I (8.15-8.50) with lower range (8.05-8.40) noticed at st. III. The overall mean *p*H showed minimum of 8.19±0.07 at st. III and maximum of 8.31±0.11 at st. V in surface and in bottom pH was minimum of 8.24±0.11 and maximum of 8.33±0.07 at st. VI. Surface water turbidity showed minimum range between 1.0 NTU and 3.2 NTU at st. I and maximum range from 1.88 to 9.40 NTU at st. III. Over all mean turbidity was lower at st. I (1.74±0.52 NTU), while it was higher at st. III (4.38±1.72 NTU). Similar trend was noticed in bottom water turbidity with lower range at st. I (1.00±0.24 NTU) and higher range at st. III (2.4-10.00 NTU). Likewise, the overall mean turbidity was low at st. I (1.7±0.5 NTU) while it was high at st. III (4.62±2.03 NTU).

Table 1—Mean variations (1990 - 1992) of some physico-chemical parameters of water and sediments (mean ± SD) and range

Parameters	St. I		St. II		St. III		St. IV		St. V		St. VI	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Temp. (°C)	38.92 ± 1.78 (34.3 – 42.3)	38.86 ± 1.68 (34.3 – 42.0)	34.92 ± 1.83 (31.8 – 39.0)	34.78 ± 1.87 (31.0 – 37.0)	31.8 ± 1.60 (29.8 – 36.5)	31.70 ± 1.62 (28.5 – 35.8)	30.84 ± 1.20 (28.5 – 33.0)	30.78 ± 1.16 (28.0 – 32.0)	30.88 ± 1.30 (28.8 – 33.0)	30.58 ± 1.28 (28.5 – 32.5)	30.81 ± 1.24 (28.0 – 32.8)	30.36 ± 1.22 (27.8 – 32.0)
Salinity (ppt)	34.1 ± 1.40 (31.6 – 36.3)	33.95 ± 1.36 (31.5 – 36.3)	33.3 ± 1.70 (29.4 – 36.1)	33.34 ± 1.75 (30.15-35.63)	27.00 ± 2.80 (22.1 – 31.9)	27.95 ± 2.84 (23.5 – 31.78)	33.44 ± 2.32 (29.3 – 36.4)	33.26 ± 2.36 (29.8 – 36.28)	33.76 ± 2.26 (29.3 – 36.9)	34.16 ± 2.46 (31.39-36.70)	33.64 ± 1.83 (30.3 - 36.1)	33.57 ± 1.87 (31.0 – 36.8)
Dissolved Oxygen (ml/L)	3.79 ± 0.29 (3.38 – 4.43)	3.38 ± 0.18 (3.33 – 4.88)	3.87 ± 0.37 (3.40 – 4.63)	3.68 ± 0.26 (3.35 - 4.63)	4.18 ± 0.50 (3.55 – 5.03)	4.13 ± 0.15 (3.38 – 4.93)	4.08 ± 0.57 (3.33 – 5.00)	4.03 ± 0.42 (3.40 – 5.28)	3.94 ± 0.46 (3.33 – 5.05)	3.86 ± 0.20 (3.23 – 4.63)	4.10 ± 0.10 (3.55 – 4.62)	3.98 + 0.18 (3.48 – 4.95)
pH	8.28 ± 0.09 (8.18-8.50)	8.30 ± 0.07 (8.15 – 8.50)	8.29±0.08 (8.08-8.45)	8.31 ± 0.07 (8.10 – 8.40)	8.19 ± 0.07 (8.08-8.35)	8.24 ± 0.11 (8.05 – 8.40)	8.30 ± 0.10 (8.10 – 8.40)	8.31 ± 0.08 (8.10 – 8.43)	8.31 ± 0.11 (8.10 – 8.40)	8.33 ± 0.08 (8.10 – 8.45)	8.28 ± 0.10 (8.15 – 8.42)	8.33 ± 0.07 (8.81 – 8.40)
Turbidity (NTU)	1.74 ± 0.52 (1.00 – 3.20)	1.7 ± 0.5 (1.00 – 2.40)	3.50 ± 1.20 (1.8 - 6.4)	3.49 ± 1.38 (1.80 – 6.80)	4.38 ± 1.72 (1.88-9.4)	4.62 ± 2.03 (2.4 – 10.00)	3.60 ± 1.30 (1.60 – 6.60)	3.69 ± 1.14 (2.00 – 6.00)	3.53 ± 1.40 (1.60 – 6.80)	4.39 ± 1.36 (2.2 – 6.80)	3.10 ± 1.36 (1.40 – 6.60)	3.41 ± 0.92 (1.80 – 5.00)
Sand (%)	87.96 ± 2.99 (80.98 – 92.82)		*		86.15 ± 3.55 (78.15 – 91.77)		76.27 ± 6.71 (62.96 – 86.19)		62.96 ± 6.90 (51.40 – 76.16)		78.36 ± 5.41 (69.87 – 86.73)	
Silt (%)	7.57 ± 2.12 (5.28 – 13.89)		*		9.23 ± 2.93 (5.24 – 15.74)		16.11 ± 5.69 (8.49 – 29.16)		25.31 ± 5.40 (15.23 – 32.61)		13.84 ± 3.48 (7.21 – 19.53)	
Clay (%)	4.87 ± 1.02 (3.31 – 6.11)		*		4.62 ± 1.1 (2.97 - 6.95)		7.68 ± 2.04 (8.49 – 12.11)		11.72 ± 2.88 (7.40 – 17.71)		7.80 ± 2.28 (4.44 – 12.33)	

Sediment particle size distribution

Mean value and range of sediment particle size constituents at different stations are presented in Table 1. Particle size composition of the sediment indicates that sand content ranged from 51.40% (st. V) to 92.82% (st I), silt content from 5.28% (st I) to 32.61% (st V) and clay content from 3.31 (st I) to 17.21% (st V). In general, all the stations had higher percentage of sand particles and relatively lower percentage of silt and clay. However, station II had no sediment particles since the bottom was completely deposited with coal ash.

Faunal composition and distribution

The mean annual percentage of benthic organisms in different stations is shown in Figs 2 and 3. In st. I (Fig. 2A) gastropod was the dominant group with themean annual percentage of 96.3% followed by polychaeta with 3.55%. Station III (Fig.2B) also recorded gastropod as major group with 93.35% followed by bivalvia (3.90%) and miscellaneous species (2.75%). Station IV (Fig. 2C) rcorded five groups of benthic fauna in the order of gastropod (37.06%), crustacean (33.20%), bivalvia (21.36%), polychaeta (5.70%) and miscellaneous species (2.68%). The mean annual percentage of benthos at st. V (Fig. 3A) showed crustacean as dominant group (32.30%) followed by gastropod (26.80%), polychaeta (26.68%), bivalvia (12.33%) and miscellaneous species (1.89%). Crustacea recorded dominantly (51.98%) in st. VI (Fig.3B followed by gastropod (33.47%), bivalvia (7.88%), polychaeta (3.52%) and miscellaneous species (3.15%).

Table 2 reveals annual mean total of benthic fauna in different stations. A total of 24 species of macrobenthic organisms belonging to five major groups namely crustacea, polycheata, gastropoda, bivalvia and miscellaneous species were recorded. Station I had only three species namely gastropoda *Cerethdia fluviatilis* and polychaeta, *Nepthys* sp and *Prionopsio* sp. Among the three species *Cerithedia fluviatilis* was dominantly observed at st. I. St. II had no benthic fauna since the bottom was continuously disturbed by the deposition of bottom ash. In st III, nine species were encountered predominantly by gastropoda *Cerethedia fluviatilis, Nassa pulla* and *Umbonium vestiarium* followed by crustacea *Balanus* sp, *Scylla serrata* and *Penaeus semisulcatus*, miscellaneous species such as *Sillago sihama* and sea anemone and bivalvia *Mesodesma* sp. A total of 23 species were recorded at st IV. They were constituted

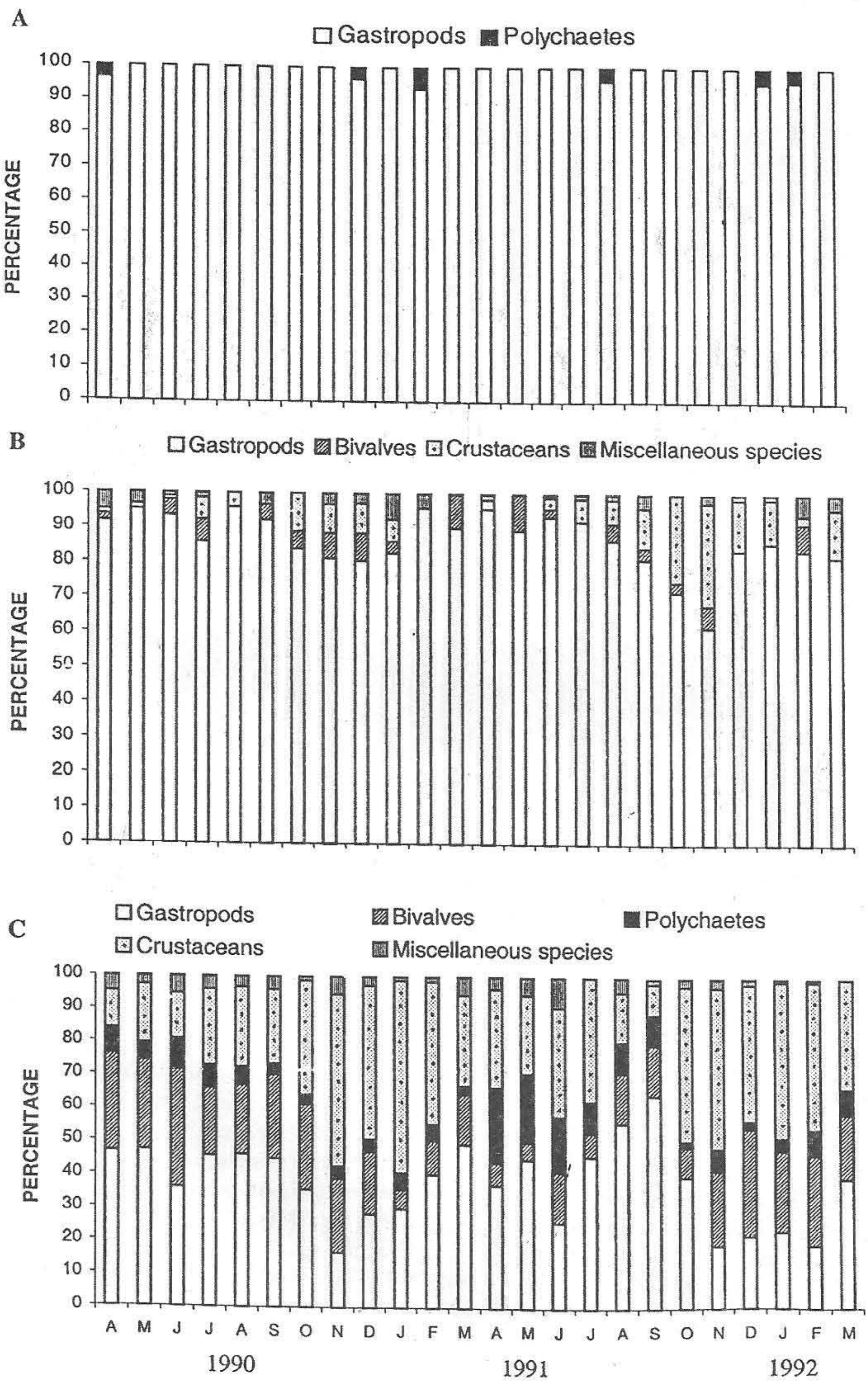

Fig. 2—Group wise composition of benthic organisms in stations I (A), III (B) and IV (C)

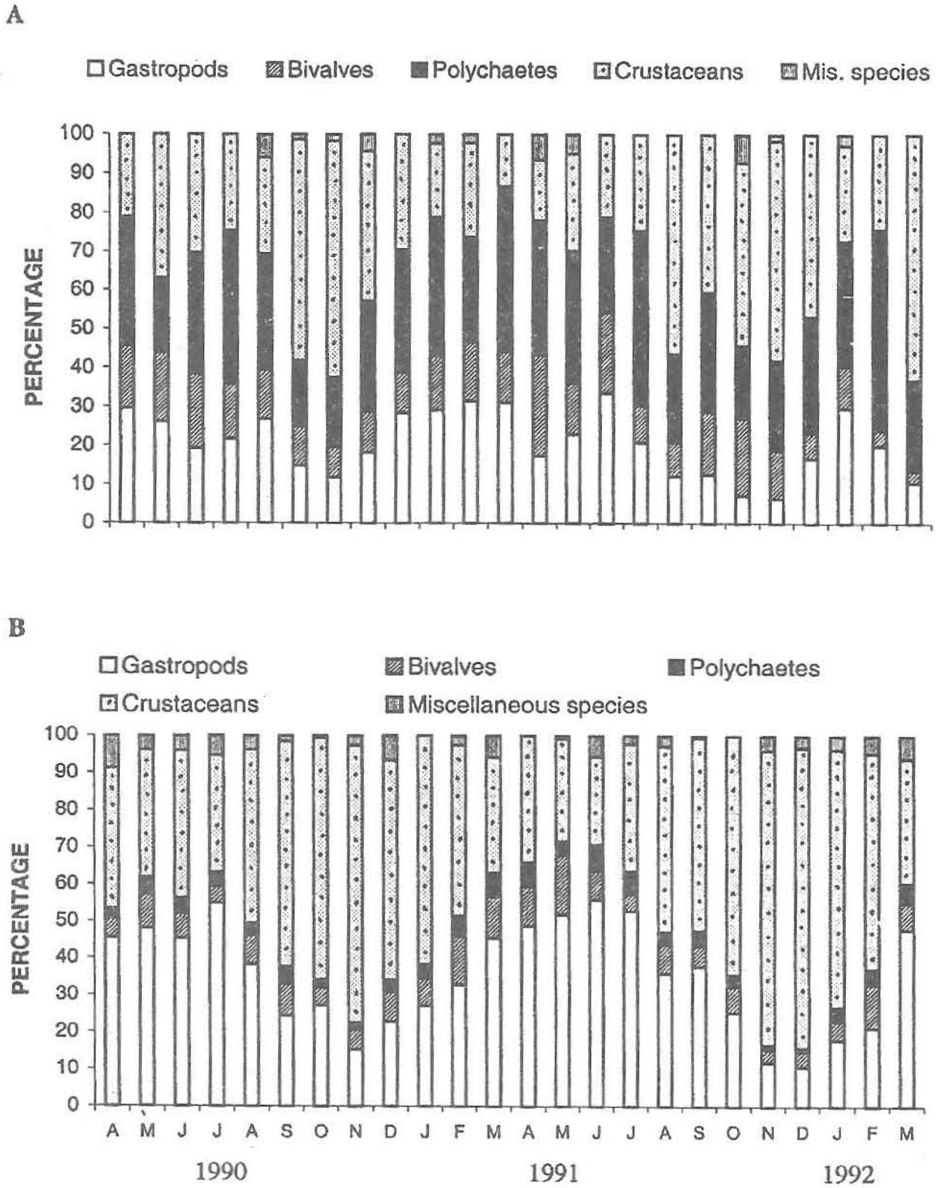

Fig. 3—Group wise composition of benthic organisms in stations V (A) and VI (B)

by crustacea *Tolerchestia gracilis, Sphaeroma* sp., *Balanus* sp., *Branchiopods, Alphids, Scylla serrata, Penaeus semisulcatus* and *P. indicus* followed by Polychaeta, *Nepthys* sp., *Prionopsio* sp., *Capitellids,* Nerieds, *Terebellids* and *Diopatra* sp., gastropoda, *Cerethedia fluviatilis, Nassa pulla* and *Umbinium vestiarium*, Bivalvia, *Mesodesma* sp. and *Solen* sp and miscellaneous species such as *Therapon* sp, *Sillago sihama,* sea anemone and *Trochus* sp. Station V had 18 species consists of crustacea *Tolerchestia gracilis, Balanus sp., Alphids, Scylla serrata, and P. semisulcatus,* polychaeta, *Nepthys* sp., *Prionopsio* sp., *Capitellids, Nerieds, Terebellids* and *Diopatra* sp., gastropoda *Cerithedia fluviatilis, Nassa pulla* and *Umbonium vestiarium*, bivalvia *Mesodesma* sp. and *Solen* sp., Miscellaneous species, sea anemone and *Trochus* sp. A total of 14 species were noticed in st. VI. They were constituted by crustacea *Tolerchestia gracilis, Sphaeroma* sp., *Branchiopods* and *Scylla serrata* followed by polychaeta, *Nepthys* sp., *Prionopsio* sp. and *Nerieds* gastropoda *Cerethedia fluviatilis* and *Nassa costata* bivalvia *Mesodesma* sp. and Mescellaneous species such as *Therapon* sp., *Sillago sihama*, sea anemone and *Trochus* sp.

Table 2—Annual mean total of benthic species in different stations during April 1990 - March 1992

BENTHIC FAUNA	Stations					
	St. I	St. II *	St. III	St. IV	St. V	St. VI
CRUSTACEANS						
Tolerchestia gracilis	–	–	–	456	242	1503
Sphaeroma sp.	–	–	–	3	–	14
Balanus sp.	–	–	168	19	53	–
Branchiopods	–	–	–	3	–	14
Alphids	–	–	–	7	16	–
Scylla serrata	–	–	8	6	6	15
Penaus semisulctus	–	–	9	8	17	–
P. indicus	–	–	–	7	–	–
POLYCHAETES						
Nepthys sp.	24	–	–	23	37	21
Prionopsio sp.	28	–	–	15	39	36
Capitellids	–	–	–	5	66	–
Nerieds	–	–	–	25	37	48
Terebellids	–	–	–	4	18	–
Diopatra sp.	–	–	–	5	30	–
GASTROPODS						
Cerethedia fluviatilis	686	–	1568	335	126	222
Nassa pulla	–	–	275	73	26	–
N.costata	–	–	–	–	–	776
Umbonium vestiarium	–	–	122	93	17	–
BIVALVES						
Mesodesma sp.	–	–	89	272	50	235
Solen sp.	–	–	–	39	56	–
MISCELLNEOUS SPP						
Therapon sp.	–	–	–	2	–	11
Sillago sihama	–	–	3	3	–	11
Sea anemone	–	–	46	23	12	9
Amphioplus intermedis	–	–	–	–	3	–
Trochus sp.	–	–	–	13	–	64

• Station II had no benthic organisms.
– Not available

Among all the stations, st. IV had more number of species followed by st. V, VI, III, and I. Group wise, crustacea contributed more species followed by polychaeta miscellaneous species, gastropods and bivalvia. Among the species, *Cerithedia fluviatilis* recorded dominantly in all stations followed by *Tolerchestia gracilis* noticed only in stations IV, V and VI.

Even though st. I was highly influenced by the thermal effluent discharge, total benthos was varied between 430-1111 no/m^2 indicating low density during summer and high density during monsoon and postmonsoon seasons. Crustacea recorded higher percentage during monsoon (September-December) and post-monsoon (January-March) months in station IV, V and VI. The variation in benthic faunal density noticed among different stations could be due to seasonality (Fig. 4).

Faunal density and biomass

Population density of benthic organisms estimated at different stations is shown in Fig. 4. Among all the stations, st I had the lowest population density of benthic fauna ranged from 480 to 1074 no/m^2 with the highest density recorded at st VI ranged from 2327 to 3452 no/m^2. Station II with thick fly ash deposition was devoid of any faunal population. Total benthic biomass (dry weight) values (Fig. 4A) showed the lowest range from 1.20 to 1.72 g/m^2 at st. V with the highest range observed at st. IV from 1.56 to 3.54 g/m^2.

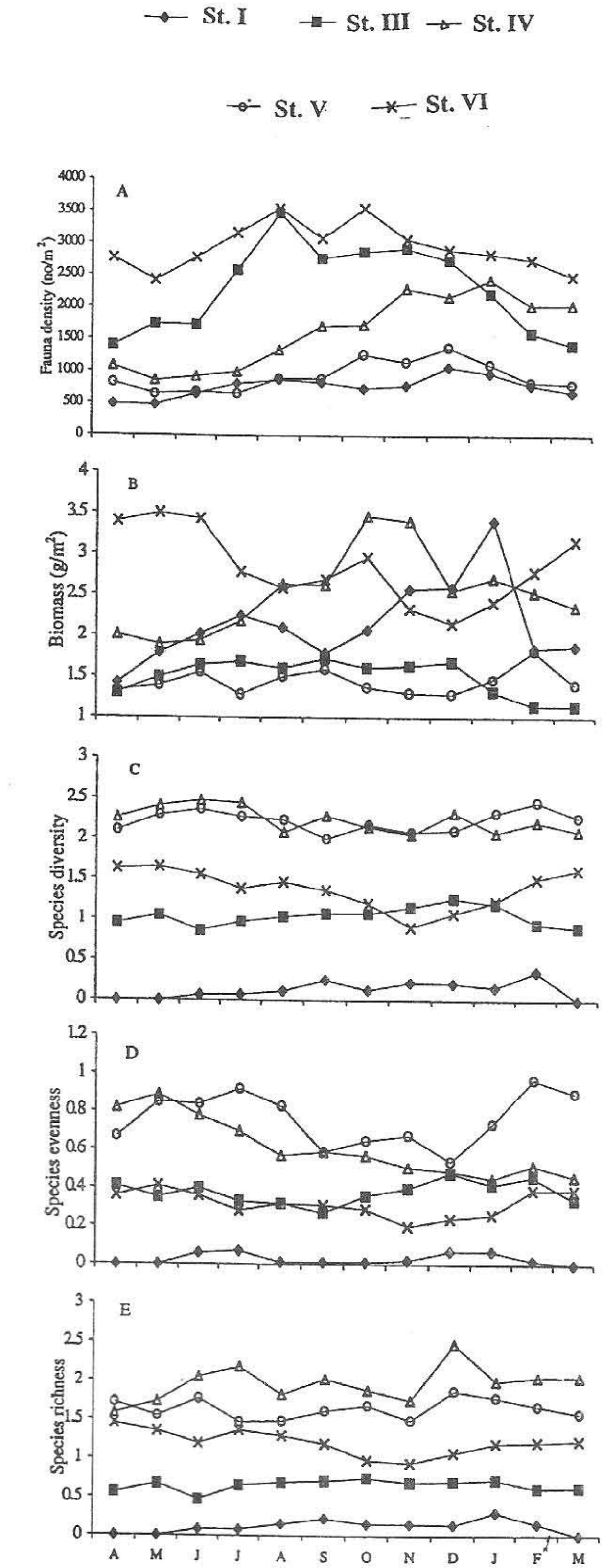

Fig. 4—Monthly mean variation of benthic fauna (A-E) during the period 1990-1992.

Species diversity, richness and evenness

In general, st. I registered the lowest diversity index ('H' value) among all the stations (Fig. 4B). Even though benthic fauna at st. I was constituted by three species species, *Cerithedia fluviatilis* was dominated throughout the study period.During summer months, species diversity was nil at st. I and increased to 0.44 during postmonsoon period of February 1992. Species diversity showed negative correlation with water temperature at st. I whereas in other stations it was positively correlated. Similarly, st. I had the lowest species richness and species evenness during summer months and the highest species richness and species evenness at st. V (Fig. 4 C, D).

Discussion

Distribution of benthic organisms, species diversity, species evenness, and species richness were closely accompanied by changes in the physical and chemical characters of the water and sediment resulting from anthropogenic effect on the ecosystem[11]. In this study, stations I and II recorded the highest mean seawater temperature than other stations, since these stations were located closer to thermal effluent discharging point. Statistically variations of temperature among the stations were highly significant both in the surface and bottom waters. Similar observation was made by Mukhopadhyay[12] while studying the power plant effect on Hooghly estuary who reported that the heated effluent increased the temperature significantly downstream up to 400-500 m during low tide and up to 100 m in upstream during high tide. In the present study water temperature showed positive correlation with salinity, while dissolved oxygen showed negative correlation with temperature both at stations I and II. Higher salinity may be attributed due to evaporation and precipitation of the seawater and lower oxygen possibly due to solubility of gases decreases with increasing temperature[13]. Lower turbidity values recorded at st. I may be due to reduction of silt and clay particles, which might have taken away by water current through continuos discharge of thermal effluent at this station. Low salinity encountered at st. III was attributed due to discharge of fresh water liquid waste from TTPP.

The density of benthic fauna could be largely decreased when associated with the increased temperature range of 34.0°C-37.0°C produced by a power plant[14]. In the present study also the density of macrobenthic organisms has not been found to be as low as 480 no/m^2 at station I where the bottom water temperature range was recorded between 34.3 and 42.0, thus showing the higher temperature regime may be one of the factors influencing the density of benthic organisms. Kinne[15] has opined that high temperature regime can alter the normal physiological functions of aquatic fauna by creating stress to the organisms and thereby affecting the population density. Station II had no benthic faunal population because of bottom ash deposition.

Occurrence of only gastropod *Cerithedia fluviatilis* at st. I indicated temperature tolerance of this species. Gastropods can withstand even at higher temperature regime by adapting behavioral responses such as burrowing in the sediment and forming cluster[16]. In general, dominance of molluscan species at Tuticorin bay was mainly due to sandy nature of the sediment[17]. Polychaete population was some what moderate at stations IV and V may be due to increased silt and clay contents[18].

Species diversity can be used as an index for assessing a stressful environment[19]. Low density and higher population of a few organisms denote some major stressful conditions eliminating many species but survival of a few. Increased water temperature at st. I has caused lower species diversity coupled with record of only three benthic fauna. At stations III, IV and V where temperature and salinity were lower, the benthic population density and species diversity were comparatively higher than st. I. Similar observation was also made by Ahmed[20], who have reported reduction of benthic organisms at Kalpakkam coast due to increased water temperature caused by heated effluent. Temperature showed significant negative correlation with faunal density and biomass while species diversity had insignificant negative correlation at st. I. In all the other stations temperature was negatively correlated with faunal density, biomass and diversity, which were statistically insignificant. The heated effluent increased the water temperature of Tuticorin bay and thereby affected benthic population.

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