A new indicator macro invertebrate of pollution and utility of graphical tools and diversity indices in pollution monitoring studies

The usefulness of benthos in pollution monitoring programme to ascertain the health of estuarine and marine environments has been known since the classical study made by Wilhelmi[1]. There are several reasons why the benthos is used as an indicator of ecosystem change. First, the longevity of benthos provides long-term exposure to toxic substances; secondly, they live in close contact with sediments, which enhances their intimacy with many pollutants and lastly, the infaunal organisms reflect the situations not only at the time of sampling but also during yesteryears. Studies made on benthos[2–4] led to the development of the indicator organism concept, which is the presence of a particular species or a group of species in a given locality reflecting the status of the environment. Among benthos, polychaetes are ideal indicator organisms, since they constitute well over half of the total number of organisms in and on the bottom and thus give a good indication of benthic conditions. In India, indicator species from the benthic realm of the estuarine and marine environments have been reported[5–8]. The present study proposes an indicator organism of pollution from the Uppanar estuary flowing on the southeast coast of India and explains the effectiveness of graphical tools and diversity indices in pollution-monitoring studies.

Sediment samples were collected from five stations along the course of Uppanar estuary (lat 11°42′N; long 79°46′E) using a long-armed Peterson grab, which covered an area of 0.0251 m^2. The stations were located near the discharge point of five major industries situated on the bank of Uppanar estuary, namely Pioneer Miyagi Chemicals (P) Ltd, Square 'D' Pharma, Spic Pharma, Pentasia Chemicals (P) Ltd and Shasun Chemicals and Drugs (P) Ltd (Figure 1). Collections were made during high tide. Four replicate benthic samples were collected in each station. Immediately after collection of samples, the larger organisms were picked out and then sieved through a 0.5 mm screen[9]. The organisms retained by the sieve were preserved in 5% formalin. Subsequently, the organisms were stained with Rose Bengal solution for enhanced visibility during sorting. The abundance and biomass data collected were treated using the PRIMER statistical package.

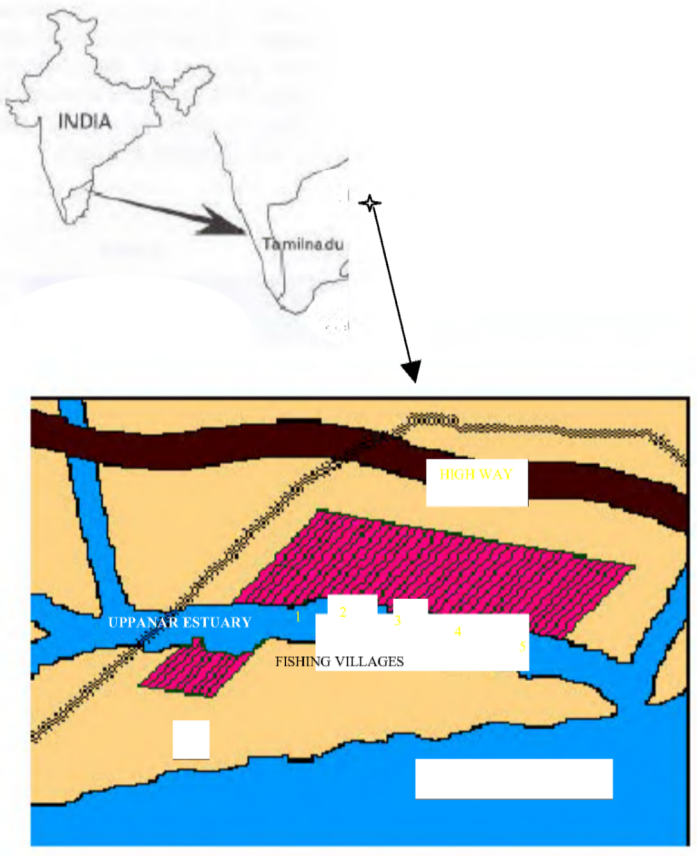

Figure 1. Map showing the stations sampled in Uppanar estuary. 1, Pioneer Miyagi Chemicals (P) Ltd; 2, Square 'D' Pharma; 3, Spic Pharma; 4, Pentasia Chemicals (P) Ltd; 5, Shasun Chemicals and Drugs (P) Ltd.

The benthic fauna comprised of polychaetes, crustaceans and a phoronid (Table 1). Among the 15 species of organisms collected, polychaetes constituted a major component with ten species, namely *Prionospio cirrobranchiata*, *P. cirrifera*, *P. sexoculata*, *Malacoceros indicus*, *Tharyx* sp. *Dendronereis* sp, *Capitella* sp. *Branchiocapitella singularis*, *Ancistrosyllis parva* and *Nephtys sphaerocirrata* belonging to five families. Crustaceans formed the second dominant group. Among the ten species of polychaetes recorded, *P. cirrobranchiata* was dominant in all the stations with a frequency of 87, 82, 92, 83.1 and 95% in stations 1–5 respectively. Contribution by other polychaetes and crustaceans, which were not recorded in all the five stations, was meagre.

As diversity indices are increasingly used to assess the well-being/health of the habitats, presently four diversity measures were used to estimate the ecological status of the Uppanar estuary. The data were also subjected to graphical techniques, namely ABC (Abundance Biomass Comparison) and dominance plots. The results of Shannon diversity (H') showed comparatively lesser values in all the stations (Table 2). The maximum value of 1.034 was recorded in station 4 and minimum of 0.338 in station 5. Similarly, the Margalef richness (d) values were on the lower side (in the range of 0.272 in station 5 to 0.691 in station 4); so also the evenness (J') values (0.213 in station 5 to 0.434 in station 2). In contrast, the dominance values were more in all the stations. The maximum dominance value of 0.903 was recorded in station 5 and minimum of 0.688 in station 2. Besides the above diversity indices,

V-statistics was also calculated to compare the observed diversity (H') with predicted diversity ($E(H')$) through the Caswell neutral model. The *V* values in all the five stations were on the negative side and ranged from –0.034 (station 2) to –0.527 (station 3), indicating that the observed diversity was lower than the predicted diversity. In keeping with the trend observed in the diversity indices, the negative value was on the lower side in station 2 which showed relatively higher richness, evenness and diversity and lower dominance values, while the negative value was on the higher side in station 5 which showed lower richness, evenness and diversity and higher dominance values. All the diversity indices calculated besides the *V*-statistics showed clearly the polluted nature of the estuary.

The ABC-plots drawn for the selected stations also signalled unequivocally the polluted nature of the estuary by the fact that the abundance curve was found to fall over the biomass curve throughout its length in all the stations (Figure 2 *a*). The *W* values that were overlying on the ABC-plot were also found to be on the negative side, ranging from –0.084 to –0.112. As in the *V*-statistics, the lowest negative value was found in station 2 and the highest in station 5. The dominance plot for all the stations (Figure 2 *b*) showed steep rise compared to the sigma-shaped curve noticed under healthy conditions. Station 5 was lying above all the other stations, showing the highly disturbed nature of this station. The abundance of the dominant polychaete *P. cirrobranchiata* in all the five stations is shown as bubbles in the MDS (non-metric Multi Dimensional Scaling) ordination plot (Figure 3). Bubble size was smaller in station 2 and larger in station 3 commensurate with the minimum and maximum abundance found respectively, in the above stations.

With annual fish landings of about 2000 tonnes, Uppanar estuary is an important source of livelihood for several fishermen living in the 20 villages dotting the banks of Vellar estuary. Of late it has been in the news for the wrong reasons. All is not well here since the setting up of the SIPCOT (State Industrial Promotion Council of Tamil Nadu) industrial complex in 1984. The 43-odd chemical and pharmaceutical units functioning in the complex, by letting out untreated effluents into the estuary have converted it into a virtual death

Table 1. Abundance (number per m^2) of benthic organisms recorded in stations 1–5

Species	Station				
	1	2	3	4	5
Prionospio cirrobranchiata	1035	916	1792	1155	1474
P. cirrifera	39	78	–	–	–
Malacoceros indicus	39	–	–	–	–
Tharyx sp.	39	–	–	–	–
Dendronereis sp.	–	39	39	–	–
Capitella sp.	–	–	39	–	–
Branchiocapitella singularis	–	–	39	–	–
Ancistrosyllis parva	–	–	–	39	–
P. sexoculata	–	–	–	39	–
Nephtys sphaerocirrata	–	–	–	–	39
Isopod	39	–	–	–	–
Phoronis sp.	–	39	–	–	39
Apseudes chilkensis	–	39	39	78	–
Copepod	–	–	–	39	–
Diogenes avarus	–	–	–	39	–

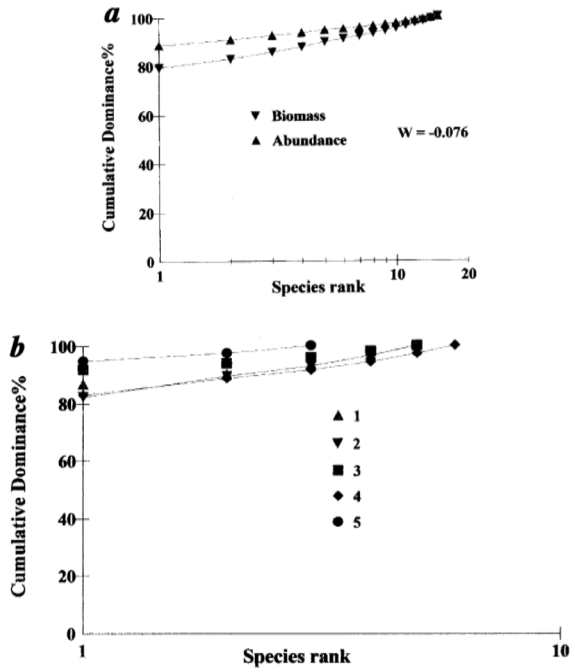

Figure 2. ABC-plot (***a***) and dominance plot (***b***) drawn for the selected stations.

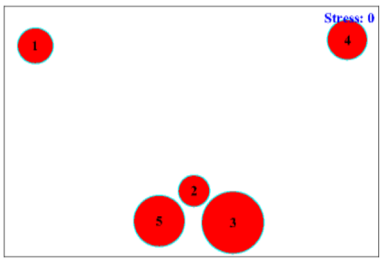

Figure 3. MDS plot showing the abundance (super-imposed) of *Prionospio cirrobranchiata* in the selected stations.

Table 2. Diversity index calculated for stations 1–5

Station	Diversity measure			
	H' (log 2)	d	J'	D
1	0.822	0.565	0.354	0.759
2	1.008	0.570	0.434	0.688
3	0.563	0.528	0.242	0.848
4	1.034	0.691	0.399	0.780
5	0.338	0.272	0.213	0.903

trap, resulting in periodic mass mortality of fishes and skin burns to fisherman due to estuarine water contaminated with acids leading to social problems. No systemic study was done to investigate the impairment to the estuary using the biotic component. In this backdrop the present work was done on benthos (used successfully elsewhere to study the disturbance) by collecting samples in the Uppanar estuary near SIPCOT with the objective of assessing the status of the estuary which has brought to light an indicator organism of pollution.

Through studies[10–12] made in other places, polychaete species from families Spionidae, Capitellidae, Cirratulidae and Eunicidae recorded more in number were identified as indicator species of pollution, in particular species belonging to genera *Priospio*, *Capitella*, *Streblospio* and *Mediomastus* at places where organic load is extremely high with low oxygen. Similarly, cirratulid polychaete *Tharyx* sp. was found to be the indicator species of pollution in the Tumangang river mouth, Russia[13]. In India, benthos of Cochin backwaters[6,7] was studied and polychaetes like *Dendronereis aestuarina*, *Prionospio polybranchiata* and *Lycastis indica* which showed higher dominance were reported as indicator species of industrial pollution. Other polychaetes like *P. cirrifera*, *P. sexoculata*, *A. parva*, *N. sphaerocirrata*, *Tharyx* sp., *B. singularis*, *M. indicus* and *Dendronereis* sp. and crustaceans, namely *Apseudes chilkensis* and hermit crab, *Diogenes avarus* were reported as pollution-tolerant species, even though they were less abundant[7]. Through the present study the polychaete species *P. cirrobranchiata* is proposed as an indicator species of industrial pollution.

The continuous discharge of effluents which got settled down at the bottom has led to decimation of other species and dominance of the opportunistic polychaete species *P. cirrobranchiata*. This fact is exemplified by the results of diversity indices. Generally, in a healthy environment, the Shannon diversity and Margalef richness are higher[14] and in the range of 2.5–3.5. However in the present study, the Shannon diversity was in the range 0.338–1.034, while Margalef richness was in the range 0.278–0.691. Similarly, the evenness values were also low in all the stations. In contrast, values of dominance index were relatively more in all the stations. As this index is unduly influenced by the evenness properties of the sample, the maximum dominance (0.903) was noticed in station 5 where the evenness was minimum (0.213)[14]. The *V*-statistics values also suggested a similar trend as that of diversity indices. The *V*-statistics is helpful in comparing the observed diversity with that computed through Caswell neutral model[15]. While the *V* value of zero indicates neutrality, positive values indicate greater diversity than predicted diversity and negative values lower diversity. The negative values observed in the present study again indicated the disturbed nature of the estuary.

The trend obtained through diversity indices was evident in the ABC-plot also. This plot is of immense use in determining the pollution status of a particular environment. The advantage of plotting this technique is that the distribution of species abundance and biomass among individuals could be compared on similar terms. Under stable environment, the *k*-selected or conservative species with large body size and long life span will be dominant in terms of biomass. Therefore the biomass curve lies above the abundance curve in the abundance plot. When the pollution perturbs the community, the conservative species are wiped out and the *r*-selected or opportunistic species with small body size and a short life span dominate numerically[16]. Now the abundance curve moves to the top and biomass curve to the bottom. The ABC-plot of the present study with the abundance curve above and biomass curve below showed clearly the polluted nature of the estuary. The dominance plot also revealed the trend noticed in the ABC-plot. This plot is used for comparing diversity besides its utility in the determination of pollution. Curves for the unpolluted sites will be sigma-shaped and those for the polluted habitats will be steep and elevated[16]. In the present study, the dominance plots drawn showed steep rise in all the stations.

Overall in the benthic realm of Uppanar, *P. cirrobranchiata* was found dominant. Besides the rich organic sediment, abundant detritus also provides the right substratum for the colonization of this species. Above all, the basically euryhaline and eurythermal nature coupled with adaptability to extreme environmental conditions might have helped this species to become dominant in the estuary. This species can be effectively used for monitoring pollution in the estuary. The diversity indices calculated, the Casewell neutral model (*V*-statistics) and the graphical tools clearly indicated the polluted nature of the estuary. The graphical tools can also be used successfully for monitoring pollution in the estuary.

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