

Polychaete diversity and its relevance in the rapid environmental assessment of Mumbai Port

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The diversity and spatial patterns of polychaetes, a proven proxy for environmental assessment studies, were studied in 28 stations covering subtidal and intertidal segments as well as bunders and docks of the Mumbai Port. Univariate and multivariate analyses of polychaete data were used to determine the level of environmental degradation in various segments of the port area. The dominance of the deposit feeder, *Paraprionospio pinnata* along with a reduction in species diversity can be considered as indicator of stressed conditions.

Keywords: Anthropogenic, indicator, Mumbai port, *Paraprionospio pinnata*, pollution.

KNOWLEDGE on the dynamics of urban coastal systems through the study of marine communities allows the assessment of ecological and environmental conditions. Soft bottom benthic communities, specifically, polychaetes are considered good indicators of environmental perturbations because they are the most abundant and species-rich component of marine benthos, often comprising more than one-third of the total number of macrobenthic species¹ and many polychaete species have a high level of tolerance to both pollution and natural perturbations². Such bio-indicators can be a veritable tool in evaluating the status of the ecosystem and adopting appropriate management actions for conservation in the impacted area.

Mumbai Port is a major centre for India's import and export, and handles products like fertilizers, rock phosphate, sulphur, food grains, metals, chemicals, petroleum oil, lubricants and containerized cargo. The marine environmental quality of the port is affected by accidental spillages due to inadequate care in the handling cargo and also from port-related activities like dredging, frequent vessel movement, sewage releases and discharges from the industrial conglomerates established on both banks of the Thane Creek³. The present study aims to scrutinize if any indicator species could be identified to rapidly evaluate the relative marine environmental status of different

segments of the port area by studying the spatial patterns of polychaete diversity using statistical methods. This attempt of comprehensive sampling and identification of polychaete species in the port area could also be the baseline for future environmental monitoring programmes.

Material and methods

Study area

Mumbai Port, located on the western bank of the Thane Creek, is a shallow V-shaped tidal inlet with a broad mouth (10 km) narrowing considerably (700 m) at the upper extremity. The region covering the entire port (180 km²) was considered the domain for marine environmental studies (Figure 1) and sampling was conducted during November–December 1996. In addition to the

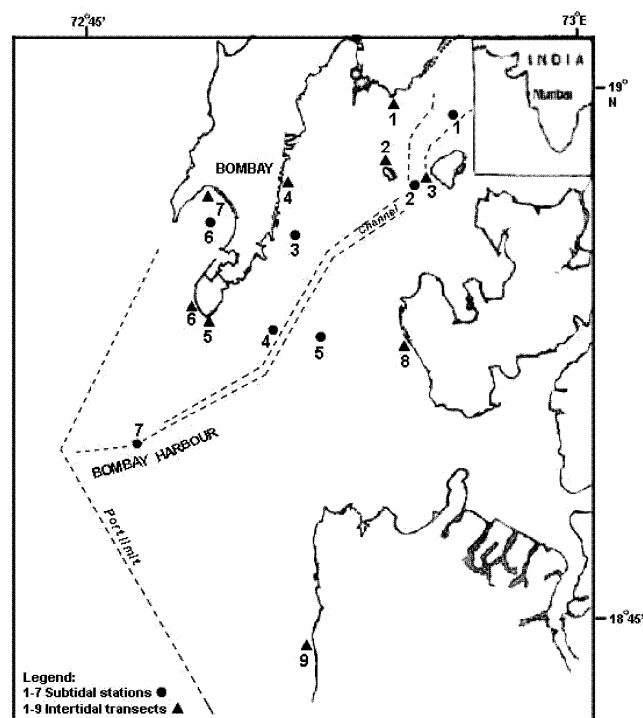


Figure 1. Subtidal and intertidal sampling stations.

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main water body of the Thane Creek, there are several natural and artificially created enclosed and semi-enclosed basins which include the docks namely Indira, Victoria and Prince's Docks which cater to import and export traffic, and the bunders (major jetties) that are used by passenger and small sailing vessels, country crafts and fishing trawlers. The ecological status of these areas differed markedly from that of the main Thane Creek due to reduced tidal flushing and hence were sampled separately.

Sampling locations

The main water spread area (subtidal area) of the Mumbai Port was sampled at seven stations (Figure 1). Stations 1 and 2 were within the inner port limit whereas stations 3–5 represented the middle port environment, and stations 6 and 7 were in the outer port limits. The bunders and docks (Figure 2) namely Sassoon Fish harbour (Sh), Apollo Bunder (Ab), Naval Dock (Nd), Fish Jetty (Fj), Mazgaon Dock (Md), Coal Bunder (Cb), Brick Bunder (Bb), Hay Bunder (Hayb) and Sewri Bunder (Sb). Prince's Dock (Pd), Victoria Dock (Vd) and Indira Dock (Id) were sampled at one station each within the basin. The intertidal area was sampled at nine transects as marked in Figure 1.

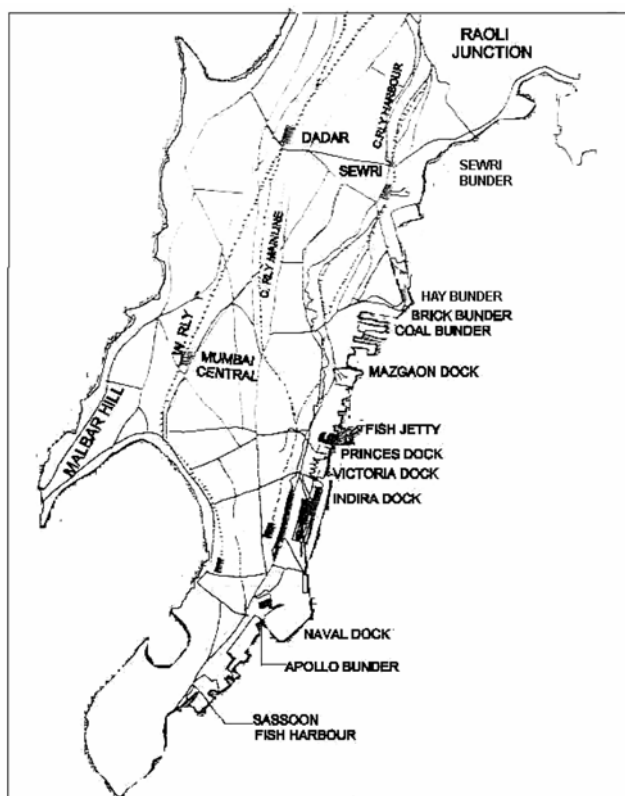


Figure 2. Bunders and docks sampled.

Sampling and analytical procedures

Four replicate sediment samples for each of the 28 stations were collected using a van-Veen grab (0.04 m² area) for subtidal macrobenthos and quadrats (0.04 m²) for the intertidal collections between the Highest High Water and the Lowest Low Water. The sediment was sieved through a 0.5 mm mesh sieve and animals retained were preserved in 5% buffered formaldehyde. The most common group, viz. polychaetes, was identified up to species level as far as possible in the laboratory and total population estimated (no. m⁻²).

Statistical analyses

Data analyses using the statistical software, PRIMER, included univariate techniques like Shannon–Wiener diversity index on log_e basis, H' , Margalef's index, d and Pielou's evenness index, J' . Analysis of variance (ANOVA) was performed to note differences in the H' values and indicator species abundances between locations. Multivariate techniques included ordination of square-root transformed polychaete data using Bray–Curtis similarities by non-metric multi-dimensional scaling (MDS). To test the ordination, stress coefficient of Kruskal was employed⁴.

Results and discussion

About 84 polychaete species (Appendix 1) were identified from the studied area, of which 31 species were identified from the subtidal area, 29 species from the bunders and docks, and 75 species from the intertidal segment. The study area, in general, had moderate Shannon diversity values (0.06–2.6) suggesting environmental deterioration associated with anthropogenic activities (Table 1). In Visakhapatnam Harbour, the H' for polychaetes was in the range of 0–4.74 (ref. 5). Higher diversity values were reported from Vancouver Harbour and Baja California^{1,6}.

Spatial variations in polychaete diversity were significant as confirmed by ANOVA ($P < 0.01$) (Table 2a). In a healthy environment, the Shannon diversity and Margalef richness are higher and in the range of 2.5–3.5 (ref. 7). However, in the present study all subtidal stations except station 5 ($H' = 2.6$) had their values below 2.5. The inner port stations 2, 4 and 7 located either in or adjacent to the navigational channel showed low diversity values ($H' < 0.5$) possibly due to the regular maintenance dredging of the waterway. Stations 1 and 5, which had relatively better diversity, were away from the main port activities and waste disposal sites in the creek. Thus, the subtidal segment of the port area revealed moderate to severe environmental stress based on proximity to port activities.

Table 1. Polychaete statistics in different subtidal stations, bunders, docks and intertidal stations

| Station | Number of species (S) | Total number (no.) | Margalef richness (<i>d</i>) | Pielou's evenness index (<i>J'</i>) | Shannon diversity (<i>H'</i>) |
|-----------------|-----------------------|--------------------|--------------------------------|---------------------------------------|---------------------------------|
| 1 | 11 | 1039 | 1.43 | 0.77 | 1.84 |
| 2 | 4 | 4852 | 0.35 | 0.40 | 0.06 |
| 3 | 8 | 2428 | 0.90 | 0.29 | 0.60 |
| 4 | 3 | 1413 | 0.28 | 0.13 | 0.14 |
| 5 | 15 | 294 | 2.46 | 0.94 | 2.56 |
| 6 | 2 | 63 | 0.24 | 0.73 | 0.51 |
| 7 | 4 | 489 | 0.48 | 0.26 | 0.37 |
| Sassoon Harbour | 8 | 1877 | 0.93 | 0.57 | 1.19 |
| Apollo Bunder | 8 | 352 | 1.19 | 0.85 | 1.77 |
| Naval Dock | 7 | 853 | 0.89 | 0.36 | 0.70 |
| Fish Jetty | 6 | 352 | 0.85 | 0.48 | 0.87 |
| Mazgaon Dock | 7 | 414 | 0.99 | 0.84 | 1.64 |
| Coal Bunder | 6 | 268 | 0.89 | 0.72 | 1.28 |
| Brick Bunder | 12 | 1966 | 1.45 | 0.68 | 1.70 |
| Hay Bunder | 3 | 1813 | 0.27 | 0.57 | 0.63 |
| Sewri Bunder | 9 | 402 | 1.33 | 0.93 | 2.04 |
| Indira Dock | 6 | 148 | 1.0 | 0.57 | 1.03 |
| Victoria Dock | 2 | 6 | 0.56 | 1.0 | 0.70 |
| Prince's Dock | 2 | 69 | 0.24 | 0.84 | 0.59 |
| Transect 1 | 19 | 861 | 2.66 | 0.70 | 2.09 |
| Transect 2 | 17 | 733 | 2.42 | 0.83 | 2.34 |
| Transect 3 | 20 | 948 | 2.77 | 0.73 | 2.18 |
| Transect 4 | 28 | 1583 | 3.66 | 0.47 | 1.57 |
| Transect 5 | 23 | 438 | 3.62 | 0.82 | 2.57 |
| Transect 6 | 28 | 601 | 4.22 | 0.75 | 2.51 |
| Transect 7 | 31 | 1438 | 4.13 | 0.72 | 2.46 |
| Transect 8 | 23 | 255 | 3.97 | 0.82 | 2.57 |
| Transect 9 | 31 | 311 | 5.23 | 0.75 | 2.56 |

Table 2. Results of analysis of variance (ANOVA) for (a) *H'* values, (b) *Pararionospio pinnata* (%) obtained from different locations (subtidal, bunders and docks, intertidal)

| Source of variation | SS | df | MS | F | P-value | F crit |
|---------------------|---------|----|--------|------|---------|--------|
| <i>(a)</i> | | | | | | |
| Between groups | 10.0 | 2 | 5.0 | 13.7 | <0.001 | 3.4 |
| Within groups | 9.1 | 25 | 0.4 | | | |
| Total | 19.1 | 27 | | | | |
| <i>(b)</i> | | | | | | |
| Between groups | 9133.8 | 2 | 4566.9 | 5.9 | 0.007 | 3.4 |
| Within groups | 19315.3 | 25 | 772.6 | | | |
| Total | 28449.1 | 27 | | | | |

H' values were low at bunders (except Sb) and docks indicating poor environmental health (Table 1). The docks in particular had lower values than the bunders probably because they act like stagnant basins isolated from the harbour waters when the gates are closed leading to restricted water exchange and low-dissolved oxygen levels. Also the docks and bunders are dredged often. The highly frequent vessel navigation at the bunders resulting in turbulence and unstable bottom conditions besides polluting the water would certainly have influenced their shallow benthic system.

As evident from the ecological indices of all stations (Table 1), the transects had better species richness,

healthier diversity indices and lower numbers of dominant polychaete species than the subtidal stations, bunders and docks. All transects except transect 4 had *H'* values above 2, suggesting fairly good benthic health. Transect 4, which was the worst affected among the intertidal stations, was located near the bunders that experienced deteriorated environment. Factors like reduction in species diversity, abundance and biomass, and rise in dominance by small bodied pollution-tolerant species are considered to be responses to the negative effects of environmental stress⁸. A similar response in the benthic environment of Mumbai Port was evident. The multi dimensional scaling (MDS) plot (stress = 0.18) of all the stations based

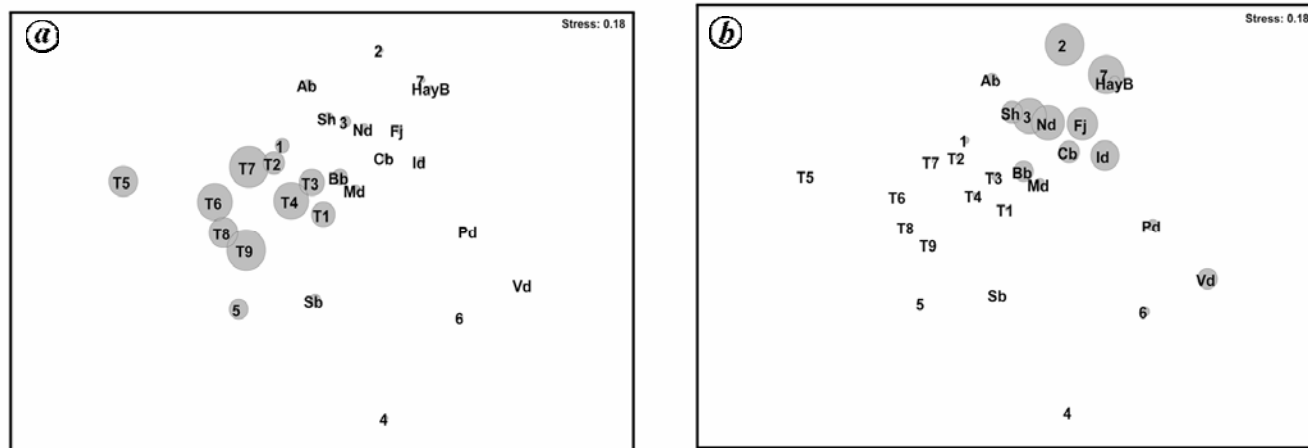


Figure 3. Non-metric multidimensional scaling ordination of square-root transformed polychaete data using Bray–Curtis similarities for subtidal stations, bunders and docks. *a*, The species richness (*d*) of polychaetes is superimposed as bubbles. *b*, Percentage composition of *Paraprionospio pinnata* is superimposed as bubbles.

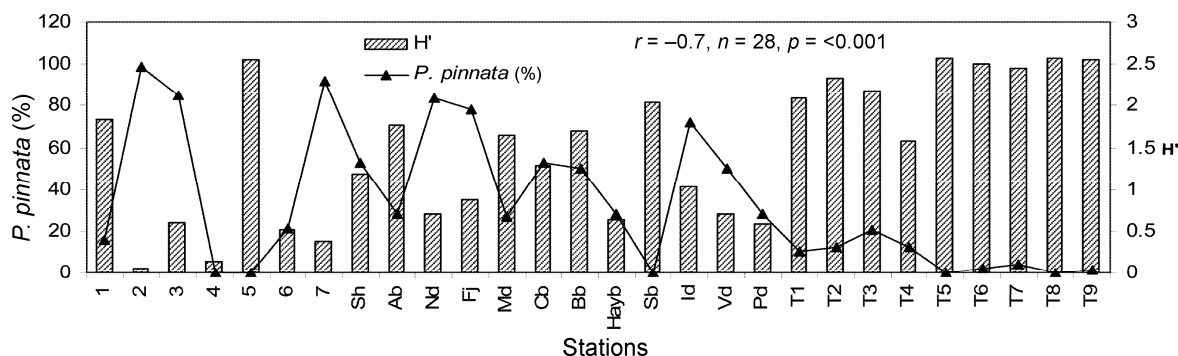


Figure 4. Shannon diversity (H') and percentage composition of *P. pinnata* for all stations sampled.

on species similarity indicated that the transects had a species composition different from the rest of the stations (Figure 3 *a*).

The polychaete *Paraprionospio pinnata* (family Spiionidae) was the dominant species at stations 2 (99%), 3 (85%) and 7 (92%) whereas *Polydora giardi* (family Spiionidae) was dominant at stations 4 (97%) and 6 (79%) which explains the low H' and J' values at these stations. *P. pinnata* had a negligible presence or was absent in the stations with robust diversity indices (stations 1 and 5) (Figure 4). *P. pinnata* was the most abundant species ($\geq 50\%$) in Sh, Nd, Fj, Cb, Bb, Id and Vd, and was also present in good numbers at Ab, Md, Hayb and Pd. It was absent at Sb which was the only station among the docks and bunders with $H' > 2$. The predominant polychaete at Hayb was *Ancistrosyllis constricta* (72%) (family: Pilarigididae) whereas in Pd, samples were dominated by the polychaete, *Paraheteromastus tenuis* (72%) (family Capitellidae). *P. pinnata* had an insignificant presence ($\leq 20\%$) in the polychaete composition of the intertidal stations which had high H' and J' values. The exception was transect 4 ($J' = 0.4$, $H' = 1.6$) where the population

was dominated by *Minuspia cirrifera* (family Spiionidae), an opportunistic species. The juxtaposing of Figure 3 *a* and *b* clearly shows that the stations with good species richness (*d*) inevitably had meagre presence of the ubiquitous polychaete, *P. pinnata*.

In a pollution-stressed environment, the conservative species are replaced by opportunistic species characterized by small body size and a short-life span which dominate numerically resulting in low species diversity⁹. Rygg¹⁰ has proposed that opportunistic species which increase their dominance under pollution can be regarded as positive pollution indicators. *P. pinnata* was the dominant polychaete in a majority of the subtidal stations, bunders and docks which had low species diversity (H') and evenness (J'), and had a low occurrence in stations with healthy ecological indices where the dominance of the above species reduced markedly due to competition from other polychaete species (Figure 4). The percentage composition of *P. pinnata* had a significant inverse relationship with H' ($r = -0.7$, $n = 28$, $p < 0.001$) and was significantly different in the three segments as was confirmed by the ANOVA (Table 2 *b*). Spiionids recorded in

high numbers were identified as indicator species of pollution in many studies^{11,12}. The other dominant polychaetes in the study region belonged to mainly three families, viz. Spionidae (*P. giardi*, *M. cirrifera*), Capitellidae (*P. tenuis*) and Pilargidae (*A. constricta*). Members of these families are deposit feeders (except Pilargidae). Capitellids, in particular, have been identified as indicators for stressed environments in harbours¹.

The criteria proposed by Gaufin and Tarzwell¹³ that should be considered when testing possible indicators of pollution were: (1) high numerical density, (2) few species in the fauna, (3) principally scavenger feeding habits and (4) tolerance for low dissolved oxygen (DO) or possess some adaptation to a low DO environment. It is also important that the same species should have no/negligible presence in stations with good diversity indices to have

'bio-indicator' tag. *P. pinnata* is a widely distributed spionid and often found to colonize disturbed habitats¹⁴ and is able to endure very low oxygen conditions through biochemical adaptations to hypoxic conditions^{15,16}. Under hypoxic conditions, larvae of *P. pinnata* are also known to delay settlement and remain in the water column until DO increased to tolerable limits¹⁷. Accordingly, we have concluded that the dominant presence of *P. pinnata* with low species diversity indicates unhealthy environment in the Mumbai Port as it fulfills all of these criteria.

Conclusion

As long-term monitoring can be time-intensive and expensive, biological indicators like *P. pinnata* could be

Appendix 1. Polychaete species identified from different segments of Mumbai Port

| Polychaete species | Subtidal | Bunders and docks | Intertidal | Polychaete species | Subtidal | Bunders and docks | Intertidal |
|---------------------------------------|----------|-------------------|------------|-------------------------------------|----------|-------------------|------------|
| <i>Ampharete capensis</i> | | + | | <i>Mediomastus capensis</i> | | | + |
| <i>Amphinome</i> sp. | | + | | <i>Micronereis capensis</i> | | | + |
| <i>Ancistrosyllis constricta</i> | + | + | + | <i>Minuspio cirrifera</i> | + | + | + |
| <i>Aphrodita alta</i> | + | | | <i>Myriochele oculata</i> | | | + |
| <i>Arabella iricolor</i> | | | + | <i>Nephtys dibranchis</i> | + | + | + |
| <i>Branchiocapetella singularsi</i> | | | + | <i>Nephtys inermis</i> | | | + |
| <i>Capitella capitata</i> | + | + | + | <i>Nephtys spiracirrata</i> | | + | + |
| <i>Cirratulus chrysoderma</i> | | | + | <i>Notomastus aberans</i> | + | + | + |
| <i>Cirratulus cirratus</i> | + | + | + | <i>Notomastus fauveli</i> | + | | + |
| <i>Cirratulus concinnus</i> | | + | + | <i>Notomastus latericeus</i> | | | + |
| <i>Cirriformia afer</i> | + | | + | <i>Ophelina acuminata</i> | | | + |
| <i>Cirriformia filigera</i> | | | + | <i>Orbinia angrapequensis</i> | + | | + |
| <i>Cossura coasta</i> | + | + | + | <i>Owenia fusiformis</i> | + | + | + |
| <i>Cossura longocerrata</i> | | + | | <i>Paraheteromastus tenuis</i> | + | + | + |
| <i>Ctenodrilinae</i> | + | | | <i>Paraonella</i> sp. | | | + |
| <i>Dendronereis aesturina</i> | | | + | <i>Perenereis cavifrons</i> | | + | + |
| <i>Diopatra cuprea</i> | | + | | <i>Pista herpini</i> | | | + |
| <i>Diopatra neapolitana</i> | | | + | <i>Pista indica</i> | + | + | + |
| <i>Drilonereis</i> sp. | | | + | <i>Pista pachybranchiata</i> | + | | + |
| <i>Eteone siphonodonta</i> | | | + | <i>Platynereis</i> sp. | + | | + |
| <i>Euclymene annandelei</i> | | | + | <i>Polydora capensis</i> | | | + |
| <i>Euphrosine capensis</i> | | | + | <i>Polydora giardi</i> | + | + | + |
| <i>Glycera alba</i> | | | + | <i>Praxillella affinis pacifica</i> | | | + |
| <i>Glycera longipinnis</i> | + | + | + | <i>Parapriospio pinnata</i> | + | + | + |
| <i>Glycera emerita</i> | + | | + | <i>Priospio polybranchiata</i> | + | + | + |
| <i>Glycera incerta</i> | | + | + | <i>Protula tubularia</i> | + | | + |
| <i>Haploscoloplos kerguelensis</i> | | | + | <i>Pulliella armata</i> | | | + |
| <i>Hesionidae</i> | + | | + | Questidae | | | + |
| <i>Heteromastides bifidus</i> | + | + | + | Sabellidae | + | | |
| <i>Heteromastides filiformis</i> | | | + | <i>Salmacina dysteri</i> | | | + |
| <i>Heteromastus similis</i> | + | | + | Scalibregmidae | | | + |
| <i>Hydroides heteroceros</i> | | | + | <i>Scolopella capensis</i> | | | + |
| <i>Hydroides norvegica</i> | | | + | <i>Scyhoproctus djiboutiensis</i> | | + | + |
| <i>Irmula spissipes</i> | | | + | <i>Serpula vermicularis</i> | | | + |
| <i>Lepidonotus tenuisetosus</i> | | | + | <i>Sphaerosyllis sublaevis</i> | | | + |
| <i>Lumbriconereis hartmani</i> | | | + | <i>Spiophanes bombyx</i> | | + | |
| <i>Lumbriconereis notocirrata</i> | | | + | <i>Sternapsis scutata</i> | + | | + |
| <i>Lumbriconereis pseudobifilaris</i> | | | + | <i>Sthenelais boa</i> | + | | + |
| <i>Lumbriconereis simplex</i> | + | | + | <i>Syllis hyaline</i> | | | + |
| <i>Magelonidae</i> | | + | + | <i>Syllis spongicola</i> | | + | + |
| <i>Maldane sarsi</i> | | + | + | <i>Tharyx filibranchia</i> | + | + | + |
| <i>Marphysa</i> sp. | | + | | Trochochaetidae | | | + |

RESEARCH ARTICLES

effectively utilized to assess ecological changes in a highly disturbed environment as represented by the port in a cost-effective manner. The present data can form a baseline for future monitoring programmes in the area.

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MEETINGS/SYMPOSIUM/SEMINARS

Symposium on New Perspectives in Plant Research – Promising more Food, Fodder, Medicine and Environmental Protection

Date: 29–31 January 2010
Place: Kolkata

Topics include: From evolution of plant kingdom to plant genomics and biotechnology, from plant tissue culture to urban, peri-urban and marine agriculture, from development of salt resistant and drought-resistant plants to development of genetically altered plants providing more protein food, human and animal vaccine.

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International Symposium on Trace Organic Pollutants in the Environment

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Topics include: Ecotoxicology of pesticides, Organometals, PBDEs, PFOS, PPCPs, PCBs, PAHs, Phenolic compounds, Plasticizers, Perchlorates, Dioxins and Furans, and their degradation and remediation studies.

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