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Ecological Assessment of Kottaippattinam Coast, India - An Investigation with Benthic Macro Faunal Abundance Based Indices

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ABSTRACT

Coastal and marine environments experience various perturbations which include a variety of industrial wastes and other toxic compounds accruing from shore line industries. Dumping of fly ash slurry and coolant water from thermal power plant is known to affect the physico-chemical nature of the estuarine environment and thereby causing severe damage to the benthic organisms. To combat this, the European Water Framework Directive (WFD) developed a suite of health indices, of which, the AMBI (AZTI-Marine Biotic Index) index is proved to be efficient in assessing the ecological status of marine environment by using the macro benthic communities. In this backdrop, the present study was made to ascertain the ecological health of Kottaippattinam coast regions using AMBI and M-AMBI (Multivariate- AZTI Marine Biotic Index) indices. The AMBI values (0.409 to 2.414) and M-AMBI ((0.53 to 0.89) indicated relatively undisturbed nature and high ecological quality status. The present study proves that there is an immense scope for application of AMBI & M-AMBI in ecological health assessment studies.

***KEYWORDS:** Benthic macrofauna, Diversity indices, AMBI, M-AMBI index*

1.INTRODUCTION

Coastal zone has high biological potential as it serves as feeding, nursery and spawning grounds with rich biodiversity and as an intermediary biotope between marine and freshwater environments. Although marine resources such as seafood, sand and oil have been valued for decades, it is only recently that we have begun to appreciate the oceans' vital services in maintaining ecological diversity and regulating climate [1]. During the past decades, the concern about environmental issues has largely increased among scientists, managers and general society. Coastal ecosystem is under the pressure of a great number of human activities causing many kinds of impacts and therefore detection of environmental health and functioning of ecosystems has become one of the main themes of modern ecology [2]. Knowledge of an ecosystem, both its ecological functioning and community dynamics, is essential for bio-indicators based assessment using Biotic Indices (BIs) [3].

Hodkinson and Jackson[4] has defined 'Bio-indicator' as "a species or group of species that readily reflects the abiotic or biotic state of an environment, represents the impact of environmental change on habitat, community, or ecosystem, or is indicative of the diversity of a subset of taxa, or of the wholesale diversity, within an area". Anthropogenic activities cause serious damage to health of soft bottom benthic groups such as polychaetes, gastropods, bivalves, amphipods, etc., which resulted in alteration in the composition and community structure of macro invertebrate assemblages [5]. As most of the benthic organisms are sedentary in nature and their movement is limited, it is very difficult for them to avoid environmental disturbance [6]. Macro-benthic bio-indicators are presently utilized and promoted by various organizations (World Conservation Union, International Union for Conservation of Nature), as a means to handle bio-monitoring and evaluate human effects [7].

In this backdrop, recently various ecological health indices have been advocated for ascertaining healthiness of the marine environment [8-10]. Of these biotic indices, the AMBI (AZTI-Marine Biotic Index) is the widely used index for the said purpose [11-12]. AMBI has been successfully applied to different geographical areas perturbed under different impact sources [13]. AMBI has another advanced step using M-AMBI (Multivariate- AZTI Marine Biotic Index), which is a multi-metric index for assessing the ecological status of marine environment and it also provides detailed information on species richness and diversity on AMBI index scale on the particular marine environment. Therefore, the AMBI and MAMBI is the robust tool for assessing the healthiness of marine ecosystem [14].

Studies to ascertain the ecological status of coastal and marine environments using biotic indices are very limited in Indian context [15] and therefore in this study an attempt was made to study the ecological condition of Kottaipattinam coastal waters using biotic indices.

2.MATERIALS AND METHODS

Study area

Kottaipattinam coast (Fig. 1) is located in the central coast of Tamil Nadu extending within the Palk Strait (Lat. 9°57'48.36″ – 9°57'25.70"N and Long. 79°11'42.35″ – 79°11'56.33″E). It experiences a tropical climate, the temperature during April to June is the hottest month with temperature shooting up to 41◦C and the monthly average temperature is generally low at the beginning of the year [16]. Sea in this area appears calm during most of the months with lesser tidal influence with wave height less than 0–0.3 m throughout the year. Moreover, the inter-tidal zones are wide and generally shallow. There is no major riverine discharges expect that of few small rivers, which brings water only during the rainy season. Fishing activities are carried out on a larger scale using wooden dug-out canoes, mechanized boats and trawlers. This coast is dominated by luxuriant growth of sea grasses, seaweeds and is devoid of rocks, corals or any other similar substrates. Aquaculture and agricultural activities is noticed all along the Kottaipattinam coast.

In the present study, the monthly sampling was carried out in Kottaippattinam coastal waters for a period of one year from July 2018 (premonsoon) to June 2019 (summer). Ten sampling sites were selected based on the depth (Table 1, Fig. 1). The monthly data were amalgamated to seasons and the results are presented seasonally. The details of sampling stations are given below:

Fig. 1. Map showing the sampling stations in Kottaippattinam coastal waters

Table 1. Geographical locations of sampling stations in Kottaippattinam coastal waters

Stations Code	Latitude	Longitude
St-1	9°57'48.36"N	79°11'42.35"E
St-2	9°58'50 .20"N	79°11'59.58"E
St-3	9°58'16.22"N	79°12'90.73"E
St-4	9°58'35.83"N	79°12'13.41"E
St-5	9°58'49.74"N	79°12'23.05"E

St-6	9°58'45.13"N	79°12'53.45"E
St-7	9°58'90.10"N	79°13'40.01"E
St-8	9°57'41.85"N	79°12'52.65"E
St-9	9°57'22.98"N	79°12'30.36"E
St-10	9°57'25.70"N	79°11'56.33"E

Water and sediment analysis

Measurements of temperature (hand-held mercury thermometer), salinity (Refractometer, ATAGO, Japan) and pH (pH pen, model LI-120, Eutech Instrument, Singapore) were recorded during each sampling event. Dissolved Oxygen (DO) was estimated by using Winkler's method [17]. Total petroleum hydrocarbon analysis in sediment sample was done by using the methods suggested by Laboratory Analytical Work Instruction (2011). TOC were determined using the wet-oxidation technique [18]. Grain size analysis of the sediments was performed by the pipette method [19].

Heavy metal analysis was done by following [20] by using Inductively Coupled Plasma Mass Spectrophotometer (AGILENT -7700x ICP-MS).

Benthic sample collection

Benthic sampling was done using van Veen grab (0.1m2) and in each station, triplicate samples were collected. Immediately after collection, the larger organisms were handpicked and the remaining sediments were sieved through a 0.5 mm mesh screen. After sieving, the sieve retains were preserved with 5-7% formalin and stained with 0.1% of Rose Bengal for better visibility during sorting and species identification. The organisms were identified by using standard references [21, 22].

Statistical analysis

Both environmental and macrofauna abundance data were statistically analysed using univariate, graphical/distributional and multivariate methods available in the statistical software PRIMER (Ver. 7.0) [23]. Benthic faunal abundance was described using various univariate indices such as diversity (H') [24], richness (d) [25], evenness (J') [26], and dominance (D) [27]. Dendrogram and ordination plots were drawn to illustrate similarities among the stations [28]. Canonical Correspondence Analysis (CCA) was performed using the Vegan library package in the statistical language 'R' Ver. 3.4.4 [29] to relate the relative abundance of macrofaunal taxa with linear representations of environmental variables.

AMBI and M-AMBI indices

Similarly, the data on macro benthic faunal groups were subjected to AMBI and M-AMBI index [13] based on the ecological groups available in AZTI Laboratory (http://www.azti.es). The index value was calculated using the following equation including the percentage of each ecological group and sensitive coefficient for each group [30]:

AMBI = [(0 x %EGI) + (1.5 x %EGII) + (3 x %EGIII) + (4.5 x %EGIV) + (6 x %EGI)]/100

The distributions of these ecological groups were analyzed according to their sensitivity to pollution stress which provides Biotic Index (BI) scale from 0 to 7 [31, 32]. According to [13], each scale represents the following site pollution classification (Table 2):

Table 2. AMBI scale with different pollution classification

Scale	Pollution classification
0 - 1	Unpolluted
1 - 2	Slightly polluted
2 - 3	Moderately polluted
4 - 5	Heavily polluted
5 - 7	Extremely/ Grossly polluted

M-AMBI was found to be the combination of Shannon's diversity, richness and AMBI, into (Factor Analysis) multivariate approach which appears to be a suitable method to evaluate the ecological condition using AMBI software. If the ecological status is 'high', the reference condition may be regarded as an "optimum" where the M-AMBI approaches '1'; when status is 'bad', the M-AMBI approaches '0'. The threshold values for the M-AMBI classification are: 'High' quality, >0.77; 'Good', 0.53 - 0.77; 'Moderate', 0.38 - 0.53; 'Poor', 0.20 - 0.38; and 'Bad', <0.20 [33, 34].

3. Results

Physico-chemical characteristics of water and sediment

The mean and standard deviation (SD) of physico-chemical parameters at each sampling station are summarized in Table 3. Temperature ranged from 26.5 ± 0.69 to 30.5 ± 0.98°C and the minimum was recorded at St-1 during monsoon and maximum was at St-9 during summer. Salinity fluctuated between 20.5 ± 0.73 and 35.5 ± 1.93ppt, with the minimum was recorded at St-1 during monsoon and maximum was at St-9 during summer. Water pH varied from 8.39 ± 0.46 at St-9 during summer and 7.92 ± 0.42 at St-1 during monsoon. Dissolved Oxygen (DO) ranged from 3.79 ± 0.95 mg/l at St-5 during summer to 4.89 ± 0.95 mg/l at St-1 during monsoon. In the sediments, the TOC content ranged from 3.87 ± 0.62 to 11.36 ± 1.5mgC/g with maximum was recorded at St-5 during monsoon and minimum was at St-10 during summer. PHC ranged from 0.93 ± 0.16µg/g at St-10 during premonsoon to 3.32 ± 0.73 µg/g at St-5 during summer. Sand content ranged between 5.69 ± 0.73 and 85.83 ± 0.99%, with maximum value was recorded at St-10 during summer and minimum was at St-1 during monsoon; silt content varied from 4.55 ± 0.89 to 14.86 ± 1.93% with maximum was at St-1 during monsoon and minimum at St-5 in summer and the clay content in the sediment fluctuated between 8.04 ± 0.77 (St-10) and 86.79 ± 1.46% (St-5) with maximum in postmonsoon and minimum in summer.

With respect to heavy metals, the Iron content varied from 5.50 ± 0.82 to 29.68 ± 1.07 mg/kg with the maximum (St-1) in summer and minimum (St-9) in premonsoon. Lead content varied from 0.94 ± 0.15 to 3.93 ± 1.02 mg/kg and the maximum (St-2) in summer and minimum (St-10) in premonsoon. Copper values ranged between 5.26 ± 0.53 and 16.49 ± 0.61 mg/kg with the maximum was recorded during summer (St-5) and minimum during pre-monsoon (St-10). Cadmium varied from 3.25 ± 0.38 to 8.17 ± 0.40 mg/kg and the maximum level was recorded at St-5 during monsoon and minimum at St-10 during premonsoon.

Table 3. Physico-chemical characteristics recorded in various sampling stations of Kottaippattinam coastal waters

Variables	St-1	St-2	St-3	St-4	St-5	St-6	St-7	St-8	St-9	St-10
W. Temp. (°C)	**26.5 ± 0.69**	27.5 ± 0.81	28.0 ± 0.95	28.5 ± 1.06	28.0 ± 0.87	28.5 ± 0.94	29.0 ± 1.08	29.5 ± 1.23	**30.5 ± 0.98**	30.0 ± 1.06
Salinity (ppt)	**20.5 ± 0.73**	25.5 ± 095	32.5 ± 0.77	33.5 ± 0.68	34.5 ± 1.05	34.5 ± 1.44	34.0 ± 1.36	35.5 ± 1.65	**35.5 ± 1.93**	35.0 ± 1.47
W. pH	**7.92 ± 0.42**	8.03 ± 0.53	8.14 ± 0.56	8.15 ± 0.40	8.09 ± 0.63	8.13 ± 0.57	8.16 ± 0.62	8.17 ± 0.71	**8.39 ± 0.46**	8.24 ± 0.53
DO (mg/l)	**4.89 ± 0.95**	4.36 ± 0.86	4.42 ± 0.79	4.17 ± 0.88	**3.79 ± 0.95**	3.92 ± 0.26	4.46 ± 0.83	3.91 ± 0.95	4.58 ± 1.08	4.54 ± 0.87
PHC (µg/g)	1.17 ± 0.27	2.29 ± 0.38	1.22 ± 0.42	2.43 ± 0.19	**3.32 ± 0.73**	1.04 ± 0.54	1.06 ± 0.71	0.99 ± 0.62	1.04 ± 0.26	**0.93 ± 0.16**
TOC (mgC/g)	8.42 ± 0.35	7.89 ± 0.57	5.97 ± 0.63	4.35 ± 0.99	**11.36 ± 1.57**	8.48 ± 0.39	5.71 ± 0.94	4.26 ± 0.55	4.47 ± 0.35	**3.87 ± 0.62**
Sand (%)	**5.69 ± 0.73**	9.78 ± 0.88	9.84 ± 1.06	8.15 ± 0.85	8.66 ± 0.95	78.20 ± 1.73	83.5 ± 1.75	78.67 ± 0.87	82.68 ± 0.76	**85.83 ± 0.99**
Clay (%)	79.45 ± 1.85	79.99 ± 1.92	77.72 ± 1.77	78.06 ± 1.63	**86.79 ± 1.46**	14.29 ± 0.92	9.70 ± 0.85	13.08 ± 0.99	8.17 ± 0.88	**8.04 ± 0.77**
Silt (%)	**14.86 ± 1.93**	10.23 ± 0.74	12.44 ± 0.88	13.79 ± 0.94	**4.55 ± 0.89**	7.61 ± 0.64	6.80 ± 0.93	8.25 ± 0.77	9.15 ± 0.95	6.13 ± 0.82

Fe (mg/kg-1)	**29.68 ± 1.07**	20.16 ± 1.83	21.11 ± 1.54	22.94 ± 1.85	20.47 ± 1.94	7.33 ± 1.18	7.33 ± 0.98	6.58 ± 0.85	**5.50 ± 0.82**	7.07 ± 0.94
Pb (mg/kg-1)	1.45 ± 0.79	1.97 ± 0.72	1.84 ± 0.66	3.51 ± 0.99	**3.93 ± 1.02**	2.21 ± 0.89	1.09 ± 0.65	1.11 ± 0.94	1.08 ± 0.79	**0.94 ± 0.15**
Cu (mg/kg-1)	10.97 ± 1.04	11.17 ± .96	12.41 ± 0.81	13.00 ± 0.74	**16.49 ± 0.61**	12.57 ± 1.03	9.29 ± 1.82	7.79 ± 0.81	6.44 ± 0.63	**5.26 ± 0.53**
Cd (mg/kg-1)	5.77 ± 0.39	6.70 ± 0.41	6.23 ± 0.53	7.96 ± 0.38	**8.17 ± 0.40**	7.94 ± 0.68	5.61 ± 0.47	4.80 ± 0.64	3.50 ± 0.71	**3.25 ± 0.38**

Footnote: W. Temp. - Water Temperature; W. pH - Water pH; DO - Dissolved Oxygen; PHC – Petroleum Hydrocarbon; TOC - Total Organic Carbon; Fe – Iron; Pb – Lead; Cu – Copper; Cd – Cadmium

Benthic Macrofauna

Altogether, 83 species of macrofauna consisting of five groups namely Polychaetes, Bivalves, Gastropods, Crustaceans and Isopods were recorded in various stations in Kottaippattinam coastal waters. Of these, polychaetes topped the list with 51 species. Bivalves were found to be the next dominant group in the order of abundance with 13 species and gastropods, Crustaceans and Isopods came next in the order with 11, 6 and 2 species respectively.

Among the polychaetes, *Ancistrosyllis parva, Glycera unicornis, Glycinde oligodon, Ceratonereis costae, Perenereis cultrifera, Nephtys capensis, Lumbreneris aberrans, Eunice antennata, E. indica, Pherusa monroi, Nerine cirratulus, Capitella capitata, Cossura coasta, Mastobranchus indicus, Pulliella armata, Heteromastus similis, Notomastus aberans* and *Spiochaetopterus costarum* were found to be the most commonly occurring species in the samples collected in surveyed stations. Bivalve species such as *Donax cuneatus, Mactra laevis, Meretrix casta, M. meritrix, Natica tigerina, Sunettta meroe, Tellina angulate* were recorded commonly. Gastropoda, Crustaceans, Isopods species such as *Cerithidea cingulate, Ampithoe rubricate, Gitanopsis bisponosa* were found as common species in the collection.

Population density

The maximum abundance was recorded at station St-8 with 1525 Nos./m^{-2} during postmonsoon and the minimum was at St-5 with 750 Nos./m^{-2} during monsoon. Seasonally, the maximum number of species (52 species) was recorded at offshore station during postmonsoon and minimum (27 species) was recorded at inshore stations during monsoon (Fig. 2).

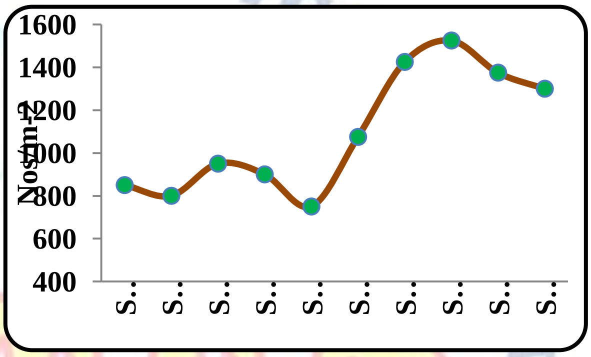

Fig. 2. Population density of Macro benthos recorded in various stations of Kottaippattinam coastal waters

Percentage contribution

The results of percentage composition of macro fauna revealed that polychaetes constituted the maximum with 67% to the total benthic organisms. Next to it, the following groups namely Bivalves (13%) Gastropods (11%) Crustaceans (5%) and Isopods (4%) were recorded in that order (Fig. 3).

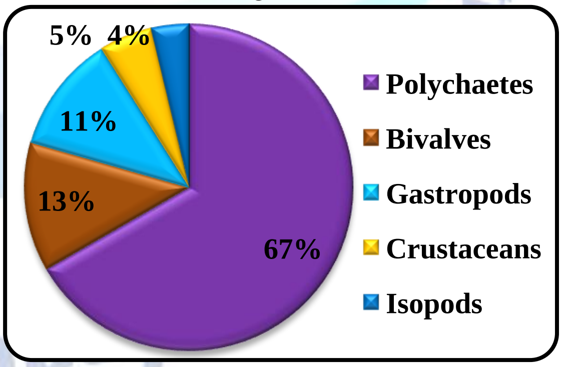

Fig. 3. Percentage contribution of macrofauna groups recorded in various sampling stations of Kottaippattinam coastal waters

Diversity Indices

The benthic faunal diversity (H') varied from 2.281 to 4.079. The maximum was recorded at St-9 and minimum at St-5. The species richness (d) ranged between 5.267 and 7.324 with maximum in St-5 and minimum in St-10. The species evenness values were from 0.572 to 0.969 with the maximum value in St-9 and minimum in St-5. Simpson dominance index varied from 0.508 to 0.857 with less value in St-10 and the high value in St-4 (Table 4).

Table 4. Diversity indices; Shannon diversity (H′), Margalef richness (d), Pielou's evenness (J′) and Simpson dominance (D) calculated for benthic fauna in Kottaippattinam coastal waters

Station ID	Shannon diversity (H')	Margalef richness (d)	Pielou's evenness (J')	Simpson dominance (D)
St-1	3.236	6.749	0.594	0.541
St-2	3.298	6.183	0.584	0.751
St-3	3.344	7.189	0.593	0.725
St-4	2.996	6.475	0.633	0.857
St-5	2.841	7.324	0.572	0.636
St-6	3.392	6.923	0.877	0.529
St-7	3.857	5.414	0.896	0.597
St-8	3.731	5.868	0.942	0.687
St-9	4.079	5.516	0.969	0.687
St-10	3.645	5.267	0.635	0.508

Cluster Analysis and MDS (non-metric Multi-Dimensional Scaling)

In the present study, the benthic macrofauna abundance data collected from Kottaippattinam coastal water were amalgamated together and subjected to cluster analysis. The results revealed that the inshore stations (St-1, St-2, St-3, St-4 and St-5) formed a separate cluster based on species composition and abundance. Similarly, offshore stations (St-6, St-7, St-8, St-9 and St-10) grouped together and formed a separate cluster indicating similar species composition. This fact was further confirmed through MDS, which also confirmed the same pattern of groupings as recognized in cluster analysis. The stress value (0.13), which is overlying on the top-right corner of the MDS plot, was also found to be low, indicating the good ordination pattern of the samples (Fig. 4 & 5).

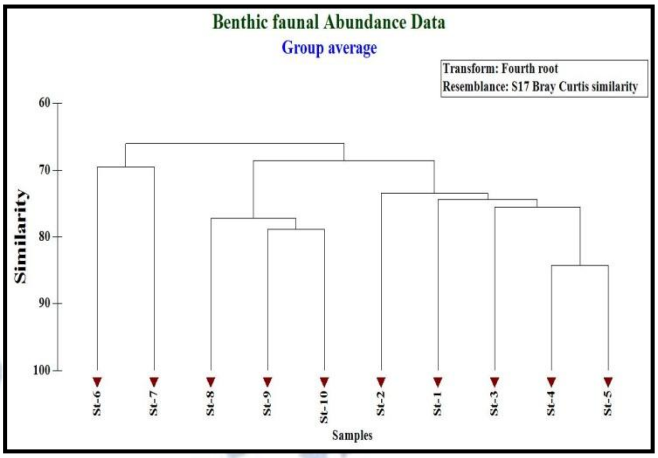

Fig. 4. Cluster analysis drawn for macrofauna abundance data collected from various stations of Kottaippattinam coast during the study period

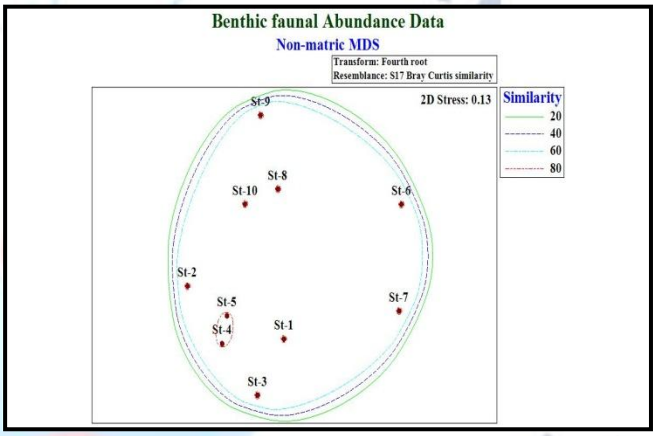

Fig. 5. MDS drawn for macrofauna abundance data collected from various stations of Kottaippattinam coast during the study period

Statistical analyses

The CCA analysis, which was done to find out the correlation among environmental parameters and species abundance, revealed that the vectors for most environmental parameters were relatively short, indicating their relatively limited variability and individual influence on the assemblages of benthic macrofauna. From the CCA plot, it was also evident that species such as *Ancistrosyllis parva, Perenereis cultrifera, Nephtys capensis, Pisione* sp., *Drilonereis filum, Cirriformia tentaculata, Pectinaria crassa, Pherusa monroi, Malacoceros indicus, Donax cuneatus, Mactra laevis, Meretrix meritrix, Umbonium vestiarium Ampithoe rubricate* and *Eurydice pulchra* got positively correlated with temperature, W. pH, salinity, dissolved oxygen, sand, clay, and total organic carbon at St-6, St-7, St-8, St-9 and St-10. It was also further evident that species such as *Glycera uicornis, Glycinde oligodon, Ceratonereis costae, Branchiocapitella singularis, Capitella capitata, Cossura coasta, Euclymene annandalei, Heteromastus similis, Notomastus aberans, Tellina angulate, Bullia vitta, Nassarius veligers, Natica sp., Turritella attenuate and Anthura gracilis* were negatively correlated to the silt, petroleum hydrocarbon and heavy metals at St-1, St-2, St-3, St-4 and St-5 (Fig. 6).

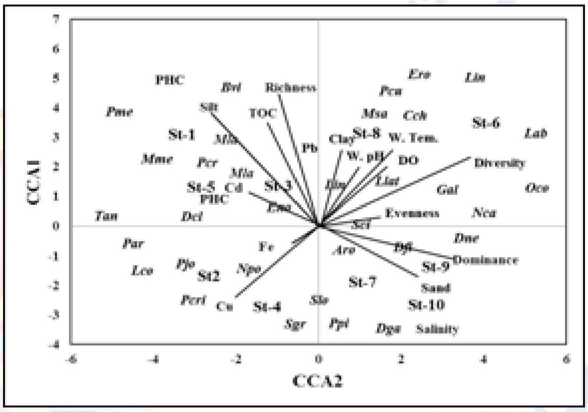

Fig. 6. CCA plot showing inter-relationship between macrofauna species against environmental variables in Kottaippattinam coastal waters

Biotic indices

Added to the diversity indices, biotic indices *viz.*, AMB and M-AMBI were also employed to ascertain the ecological health of Kottaippattinam coastal waters.

AMBI and M-AMBI index

The AMBI & M-AMBI indices works on the response of macrobenthic groups, which are categorized in to the following groups based on the AZTI classification:

Ecological Group I (EG-I): Species sensitive to pollution

Ecological Group II (EG-II) : Species unaffected by pollution

Ecological Group III (EG-III) : Species tolerant to pollution

Ecological Group IV (EG - IV) : Second order opportunistic species

Ecological Group V (EG-V) : First order opportunistic species

Accordingly, the benthic data collected during the present survey were fit into the above said categories.

AMBI index

A total of 83 benthic fauna recorded from Kottaippattinam coast were categorized in to five ecological groups. Of this 83 species, 28 species (34 %) belonged to EG-I, 16 species belonged to EG-II (19 %); 12 species (15 %) got fit into EG-III; 9 species (10 %) to EG-IV; 6 species (7 %) to EG-V and 12 species (15 %) were not-assigned to any of these category (Fig 7).

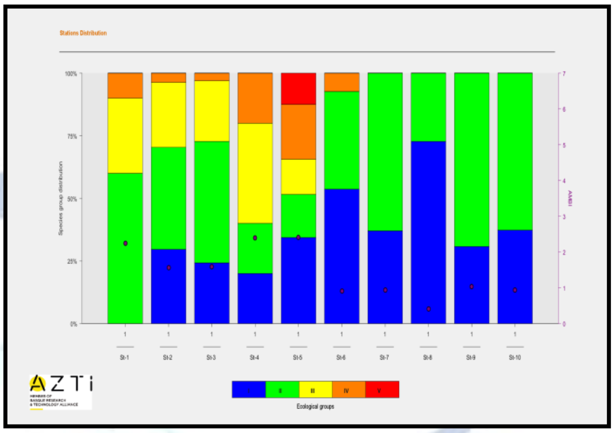

Fig. 7. Percentage composition of various Ecological Groups recorded at various stations in the Kottaippattinam coastal waters

The AMBI values calculated based on the abundance of benthic fauna varied from 0.409 (St-7) to 2.414 (St-5) indicating **'Undisturbed'** and **'Slightly disturbed'** status of the Kottaippattinam coastal waters. The values of AMBI index with disturbance classification in various stations of Kottaippattinam coastal waters are given in Fig. 8 and Table 5.

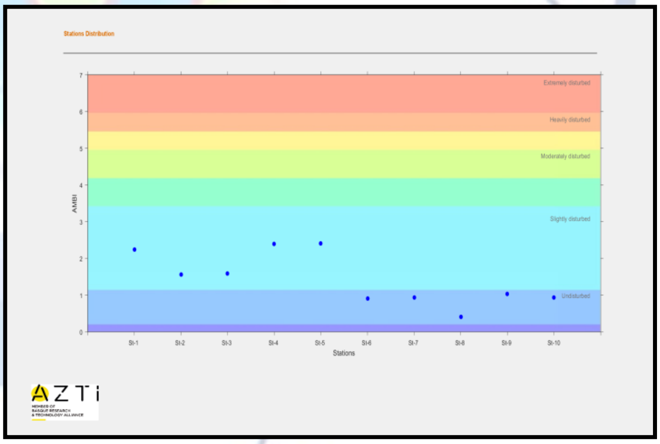

Figure 8. AMBI values of the various stations of Kottaippattinam coastal waters

Table 5. AMBI site disturbance classification in the various stations of Kottaippattinam coastal waters

Station code	AMBI	Biotic index	Disturbance classification
St-1	2.250	2	Slightly disturbed
St-2	1.556	2	Slightly disturbed
St-3	1.591	2	Slightly disturbed

St-4	2.400	2	Slightly disturbed
St-5	2.414	2	Slightly disturbed
St-6	0.915	1	Undisturbed
St-7	0.944	1	Undisturbed
St-8	0.409	1	Undisturbed
St-9	1.038	1	Undisturbed
St-10	0.940	1	Undisturbed

M-AMBI index

The M-AMBI values varied from 0.53 to 0.89, which clearly indicates the "High" to "Good" ecological health status of Kottaippattinam coastal stations. Justifiably, the M-AMBI diversity (3.92 to 4.63) and richness (14 to 29) values also indicated the pristine status of the surveyed stations (Table 6).

Table 6. M-AMBI ecological status classification in various stations of Kottaippattinam coastal waters

Station code	Diversity	Richness	M-AMBI	Ecological status
St-1	4.50	16	0.61	Good
St-2	4.27	18	0.85	High
St-3	4.63	15	0.84	High
St-4	4.51	19	0.62	Good
St-5	4.31	14	0.89	High
St-6	4.06	24	0.66	Good
St-7	4.12	23	0.62	Good
St-8	3.96	29	0.53	Good
St-9	4.18	25	0.60	Good
St-10	4.05	27	0.74	Good

4.DISCUSSION

The composition of the benthic invertebrates has been considered as good indicators of water quality because unlike plankton, they form stable communities in the sediments which integrate change over long time intervals and reflect characteristics of sediment and water. Several abiotic and biotic factors are regarded as important in structuring macro invertebrate communities e.g. temperature [35, 36], pH [37], substratum [38, 39], the depth of water [40], dissolved oxygen [41], predation [42]. In the present study, remarkable variations were noticed in temperature, salinity and pH patterns. Water temperature varied from 26.5 to 30.5°C, hydrogen ion concentration (pH) was from 7.92 – 8.39 and salinity varied from 20.5 to 35.5 ppt. In the present study, higher values of the above parameters was recorded in summer season at offshore stations which might be due to the intensity of solar radiation and evaporation and the lower values was recorded in monsoon season at near shore stations is due to freshwater influx from the land drainage [43-46].

Dissolved Oxygen (DO) varied from 3.79 to 4.89 mg/l with the maximum (7.27) was recorded at offshore stations during wet season and minimum was recorded at near shore stations during dry season. The higher values observed during monsoon could be attributed to the higher influx of fresh water into the study area. The relatively low DO values observed in the summer are attributed to the fluctuations in temperature and salinity, which in turn affect the dissolution of oxygen [47- 50]. The benthic organisms utilize the organic carbon for their metabolic process [51]. It plays an important role in the accumulation and release of different micro pollutants and also reflects more accurately the level of organic pollution. Hence, the measure of organic carbon content in the sediment is a yardstick to study the productivity of an ecosystem.

The distribution of total organic carbon (TOC) closely followed the trend of distribution of sediment types i.e., higher sedimentary organic carbon was found in clay soil and as the clay content increased, the total organic carbon content was also found to increase and seasonally the minimum was recorded during monsoon and maximum in summer which is in good agreement with findings of García Arberas and Rallo [51]. In the present study, the maximum TOC of 11.36mgC/g was recorded at near shore stations during dry season and minimum of 3.87mgC/g was recorded at offshore stations during wet season. Similarly, Hasrizal et al. [52] studied the seasonal changes of organic carbon content in the surface sediments of the Terengganu near shore coastal area of Malaysia with maximum value during postmonsoon and summer seasons. Soto-Jiménez et al. and Coppola et al. [53, 54] reported that the occurrence of about 10-20% of organic carbon content was found to be adhered to the fine particle (<4μm).

Studies on the sediment composition are of paramount importance in benthic ecology. The comprehensive knowledge on the sediment composition is a pre-requisite and inevitable one to understand the benthic ecology [55]. Sediment characteristics have long been recognized as a determining factor directly controlling the presence and abundances of the soft bottom fauna [56]. Hily [57] opined that each species tolerates a specific sediment particle size range, in the present study sandy sediment composition was found high in all the stations. The elevated petroleum hydrocarbons levels during summer season at coastal stations were observed, which might be due to frequent operation of fishing trawlers. The minimum levels recorded during monsoon might be due to the mixing of terrestrial waste through flood and fishing vessels operating in the localized area [58].

The heavy metal levels reported in the study area were well within the permissible range throughout the study with the exception on high mean value of Fe, which could be attributed to leaching from surrounding vicinity. Trace metals such as Fe, Pb, Cd and Cu are primarily mobilized through human activity, whereas others such as Fe and Pb have a lithogenic origin [59]. Moreover, due to good tidal flushing, such pollutants are getting lessened in those regions. Metals go into the marine environment from natural (e.g., mineral weathering, volcanic eruptions, and dust deposition) and anthropogenic sources (e.g., mining, fossil fuel combustion, agriculture, industry, marine traffic, urban development, and sewage) [60].

Percentage contribution of benthic species composition of the present study showed in the order of polychaetes, crustaceans, bivalves, gastropods and groups 'others'. The dominance of polychaetes in terms of density and species composition in diverse ecological niche is due to their high degree of adaptability to a wide range of environmental factors. Similar preponderance of polychaetes has been observed earlier by Kumar [61] in Cochin backwaters, Devi [62] in Coleroon estuary, and Ansari et al.[63] in Mandovi estuary. Athalye and Gokhale [64] reported the dominance of polychaetes followed by gastropods, bivalves, and hermit crabs in Thane creek, Mumbai. The density of macrobenthos showed pronounced variations during different seasons in all the stations. Monsoon months registered low density followed by gradual increase in postmonsoon and peaked during summer season, which is in agreement with the studies of Denadai et al. and Thilagavathi et al.[65, 66].

In the present study, a marked seasonal variation in the Shannon diversity and evenness was found with minimum values in near shore stations during monsoon and maximum in offshore stations during dry season. Similar range of diversity values was recorded earlier by Murugesan [48] in Vellar estuary, Kundu et al. [67] in the shelf waters of southeast coast of India. On the contrary, species richness and dominance values were high during wet month and low during summer and dry season. The trend with respect to richness values of the present study is evident in the studies made by Raveenthiranath Nehru [68] in Coleroon estuary and Palanisamy & Anisa [69] in Pondicherry coastal waters.

In the present study, Bray-Curtis similarity coefficient was used as this has been shown to accurately reflect true similarity [70]. The near shore stations (St-1-St-5) got grouped at the highest level of similarity followed by offshore stations (St-6-St-10) got grouped to form clusters based on the species composition. This fact was further confirmed through MDS, which also revealed the same pattern of groupings as recognized in cluster analysis was formed. The stress value recorded in the present study is comparable with the studies made by Ajmalkhan et al. and Chapman & Tolhurst [71, 72]. Investigation similar to this was carried out by Sivaraj et al. [73] who made a comparative study of Vellar-Coleroon estuarine system using macrobenthic communities through cluster analysis.

Canonical Correspondence Analysis (CCA) was done to ascertain the relationship between the physico-chemical parameters and benthic faunal density. The environmental parameters such as temperature, W. pH, salinity, dissolved oxygen, sand, clay, and total organic carbon were showing strong correlation with the benthic faunal diversity, while other parameters like water temperature, depth, sand and DO had weak correlation with the benthic faunal distribution. Similar combinations of variables influencing benthic faunal distribution was reported by Borja and Tunberg [73] in Nandgaon coastal waters, Maharastra, India; Sivaraj et al. [50] in Vellar-Coleroon estuarine system.

AZTI Marine Biotic Index (AMBI) and Multivariate AZTI Marine Biotic Index (M-AMBI) is the sensitive tool in the assessment of marine and estuarine ecological health assessment against various anthropogenic activities. These biotic indexes predict the actual ecological status based on the concept of indicator groups and mainly used the relative contributions of tolerant and sensitive groups in the taxa [74, 75]. In Kottaipattinam coastal stations, the results of the AMBI index varied from 0.409 to 2.414 which clearly indicated the pristine nature. Similarly, the M-AMBI index values were also high (0.53 to 0.89) in all the stations indicating healthy ecological status due to the distribution of high percentage of sensitive species (EG-1). Justifiably, Kottaipattinam coastal waters have the optimum nutrients high dissolved oxygen level and sea grass bed, which behaves favorable environments for macro benthic organisms [76, 50].

5.CONCLUSION

No doubt, the results of the present study would certainly supplement to the existing knowledge on seasonal variation in macro faunal assemblages in tropical coastal waters. Not only is that, it reflects human-induced environmental perturbation and they can be used as bio-indicators for coastal pollution monitoring. The present study also reported 83 macrofauna species and of these, polychaete species were found to be the dominant group. In this study, macrofaunal abundance based biotic indices such as AMBI and M-AMBI were used and the results obtained were encouraging, which promotes the use of the biotic indices as a bio-monitoring tool to ascertain the health of tropical coastal waters. The biotic indices values estimated presently suggest that the Kottaippattinam coastal stations are relatively pristine and it fall in the category of "Good to High".

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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