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A New Coverage Range Index for Assessing Impact of Substrate Composition on Distribution of Hard Bottom Macrobenthos

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ABSTRACT

This study evaluated the impact of substrate composition on macrobenthos distribution using a new Coverage Range Index (CRI), and diversity index variables and macrobenthos data sets obtained over a period of 12 months, between June 2015 and June 2016, along 6 sampling transects at 2 sites. The selected transects were all situated in littoral zone of Hormuz Island in the Persian Gulf and had hard bottom type with different substrate compositions. Accordingly, macrobenthos samples at each site were taken from 3 hard bottom types: boulder, cobble, and pebble. CRI and diversity indices (Simpson, Shannon-Wiener, Pielou, Brillouin, Menhinick, Margalef and Berger-Parker) were employed to evaluate the abundance of macrobenthos. CRI was also selected to tentatively assign the investigated abundance range of macrobenthos into 3 coverage range categories: wide, middle, narrow. CRI boundary of the categories was estimated. The analyses of CRI and diversity indices revealed a similar clustering between the sampling transects. These findings indicate that CRI is a simpler indicator in assessing abundance of macrobenthos than diversity indices, because CRI is only based on species abundance, but diversity indices are based on both species number and abundance. Hence, *CRI* proved to be a universal ecological index due to its different ranges of small to large samples, rare species to dominant ones, and individual specimens to polyps of animal colonies. Future study should focus on extending the database to test CRI in other bottom types. Finally, the results from this study may be useful not only for developing countries but also for any organization struggling to use macrobenthos based indices with restricted financial resources and knowledge.

Keywords: *CRI*, Diversity indices, Hormuz Island, Littoral zone, Species abundance.

INTRODUCTION

A wide array of models are now often used in species distribution modelling (Guisan and Zimmerman, 2000; Elith *et al*., 2006). Most of these models have been used primarily for species in terrestrial habitats (Segurado and Araujo, 2004; Elith *et al*., 2006; Moisen *et al*., 2006; Aertsen *et al*., 2010). Macrobenthos studies are also known as the most applied models for identification of aquatic habitats (Lindegarth and Hoskin, 2001) and have suggested an important part of standards efforts for marine ecological quality assessment (Borja *et al*., 2003; Borja, 2004; Borja *et al*., 2004; Rosenberg *et al*., 2004; Mistri and Munari, 2008).

Macrobenthos, through the long history of the Persian Gulf research, has been tested to be a bio-indicator which can be reliably used for the classification of coastal areas and the state of ecosystems (Gerami *et al*., 2016). This is due to the stability and consistency of community structure and species composition under given natural conditions and the uniformity of the different types of habitats encountered throughout the Persian

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Gulf (Mirzabagheri and Mirzabagheri, 2007).

Assessment of diversity indices and identification of bioindicator can be major practical tools to assess different aspects of the structure and the sensitivity of communities (Washington, 1984). Diversity indices, which have been used traditionally in biomonitoring studies in marine ecosystems, e.g. Simpson, Shannon-Wiener, Pielou, Brillouin, Menhinick, Margalef and Berger-Parker, were also used for classifying coastal and transitional water bodies (Dauvin *et al*., 2007; Albayrak *et al*., 2010). Overall, diversity indices are quantitative tools in expressing the general status of ecosystems through the description of abundance, diversity, evenness, and richness (Desrochers and Anand, 2004). However, these metrics that are based on taxonomic identification of animals, from family to species level, have become somewhat of a problem. The main problem in obtaining estimates of diversity indices is the basic, but often painstaking, effort necessary to collect the samples in the field and to sort and determine the animals present in the sample (Heip, *et al*., 1998).

Diversity indices are a dual concept that includes the number and abundance of species in the community and the evenness with which the individuals are divided among the species (Magurran, 2004). Therefore, we have developed a new index here, which has one metric involving the absolute abundance of individuals and is easy to calculate and easy to use at any time. The novelty of this new index called *CRI* (Coverage Range Index) lies in the idea of treating macrobenthos species as thus reducing the number of the statistical parameters used in the formula compared to diversity indices. This reduction aims to simplify the interpretation of the results of species abundance without needing species number and identification. This index can be also used without limits on the abundance of all collected animals along transects and on abundance of individual specimens to polyps of animal colonies (Mirzabagheri *et al*., 2017). However, the usage limits of the diversity indices for validation of CRI are that the conditions for application of *CRI*, e.g. the differences in abundance of particular taxa, are not considered.

According to this, the cost and the effort of calculations based on *CRI* are now minor in comparison with diversity indices. Also, based on the resulting values of *CRI* at each site, the species distribution in total area covered can be estimated. Hence, in the case of rapid and urgent need for estimation of macrobenthos distribution in a particular littoral zone, usage of *CRI* is beneficial for providing an initial quick assessment of distribution status.

Some studies have been conducted on the macrobenthic structure in littoral zone of Hormuz Island (Mirzabagheri and Mirzabagheri, 2007; Mirzabagheri *et al*., 2008; 2009; 2013; 2015). However, opportunities for comparison between diversity indices are rare. Hence, this study was conducted with the aim of developing indices compliant with the Persian Gulf, and proposing Coverage Range Index (CRI) for hard bottom macrobenthos communities in littoral zone of Hormuz Island. The scores of *CRI* were compared with those of the widely-used diversity indices such as Simpson, Shannon-Wiener, Pielou, Brillouin, Menhinick, Margalef and Berger-Parker. Finally, this paper provides a guidance of classification for macrobenthos distribution using *CRI* which is an approach which minimizes macrobenthos data volume to a great extent and simplifies the expression of distribution status.

MATERIALS AND METHODS

Study Area

The study area was located in littoral zone of Hormuz Island (27° 03' 51" N and 56° 27' 20" E) at north of the Strait of Hormuz of the Persian Gulf (Figure 1). The sites were selected on hard bottoms submitted to

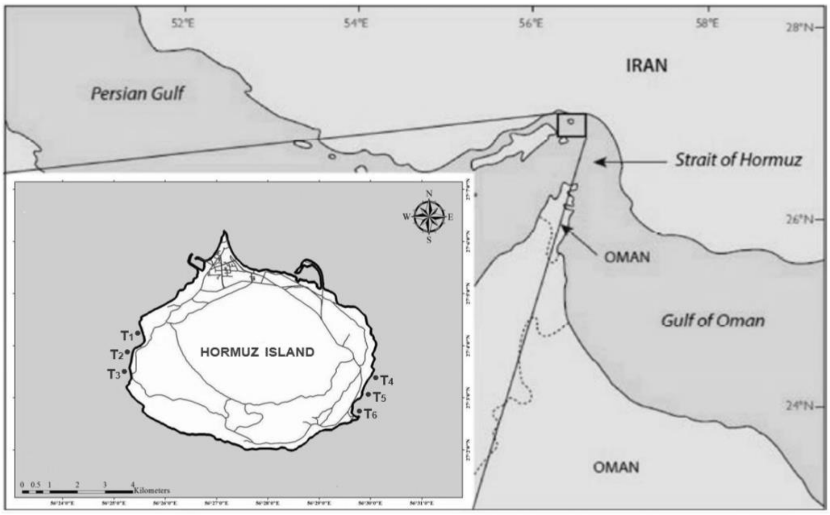

Figure 1. Map of Hormuz Island in the Persian Gulf, showing the sampling transects.

different substrate compositions based on Wentworth scale (1922).

Sample Collection

Samples were collected in low tide time monthly from June 2015 to June 2016 along 6 transects (Table 1). Continuously along each transect, four 0.25 m^2 quadrats were laid at about 5-10 m apart. On each quadrat, we analyzed the abundance of macrobenthos and the composition of predominant substrate. According to this, samples were poured into plastic jars and transferred to the laboratory. In the laboratory, samples were washed in fresh water through a 0.5 mm mesh sieve; the species remaining on the sieves were preserved in 4% formalin and preserved in 70% ethanol. Then, the macrobenthos species were separated, counted, and identified to genus level under a loupe microscope, using validated articles and appropriate identification guide (Mirzabagheri and Mirzabagheri, 2007).

Diversity Indices

The diversity indices of this study were calculated using the formula 1, 2, 3, 4, 5, 6 and 7 as follows:

Simpson's dominance index (λ)= $\sum\left(\frac{n_i}{N}\right)^2$ (Simpson, 1949) (1)

Shannon-Wiener's diversity index: (H´) = $\sum\left[\frac{n_i}{N}\times \mathrm{Log}\left(\frac{n_i}{N}\right)\right]$ (Shannon and Wiener, 1949) (2)

Pielou's evenness index (J´)= $\frac{H'}{\mathrm{Log}(S)}$ (Pielou, 1966) (3)

Brillouin's diversity index (HB)= $\ln\frac{N!}{N_1!N_2!\ldots N_s!}$ (Brillouin, 1960) (4)

Menhinick's richness index (d_1) = $\frac{S}{\sqrt{n}}$ (Menhinick, 1964) (5)

Margalef's richness index (d_2)= $\frac{(S-1)}{\mathrm{Log}(N)}$ (Margalef, 1958) (6)

Berger-Parker's dominance index (Berger and Parker, 1970) (7)

Table 1. Sampling transects, position, and predominant substrate composition of studied region.

Site	Transect no.	Latitude and longitude	Predominant substrate composition
West	T_1	27° 04' 09.9" N 56° 25' 30.1" E	Boulder
	T_2	27° 04' 00.3" N 56° 25' 26.6" E	Cobble
	T_3	27° 03' 34.2" N 56° 25' 15.3" E	Pebble
East	T_4	27° 03' 21.1" N 56° 30' 07.5" E	Boulder
	T_5	27° 03' 01.4" N 56° 29' 53.9" E	Cobble
	T_6	27°02'39.6"N 56°29'44.8"E	Pebble

$$(d_3)=\frac{N_{\max}}{N}$$

Where, N= Total Number of individuals; S= Number of taxa, n_i= Number of individuals of taxon i.

Calculation of *CRI*

Coverage Range Index (CRI), which is a new index of area coverage by all species along each transect, was calculated using an innovative formula by Mirzabagheri (2018) as following:

$$CRI=\frac{p_{Ti}}{p_{total}}\times 100 \qquad (8)$$

Where, P_{Ti} is the pooled living coverage of all species in ith transects at a given site and P_{total} is the pooled total living coverage of all species in all transects at a given site.

This measure of cover, expressed as percentage, is considered to be an unbiased estimate of the proportion of the total area covered by species. Accordingly, the resulting values were transformed into coverage range categories (%) by Mirzabagheri (2018) (Table 2).

Eventually, based on the coverage range category of all transects at each site, the species distribution in total area covered can be estimated.

Table 2. Classification of boundaries among species distribution status based on CRI.

Boundaries of CRI (%)	Coverage range categories
0< *CRI*< 20	Narrow
CRI= 20 - 50	Middle
CRI> 50	Wide

Validation of *CRI*

In modern ecological comparison, diversity indices are nearly always used in conjunction with multivariate analysis (Heip, *et al*., 1998). *CRI* was therefore evaluated and compared to the diversity indices, using multivariate analysis, based on macrobenthos abundance in littoral zone of Hormuz Island. The usage limits of the diversity indices for validation of *CRI* are that the conditions for application of *CRI*, e.g. the differences in abundance of particular taxa, are not considered (but, note that the actual number of species in the community is usually immeasurable).

Statistical Analyses

Macrobenthos were analyzed based on the diversity indices and *CRI*. Diversity indices were calculated using Past 3.14 software. Pearson’s correlation coefficient was used to test between macrobenthos abundance with diversity indices and *CRI* and it was calculated using the IBM SPSS Statistics ver. 24 software. The clustering analysis based on macrobenthos abundance, diversity indices, and *CRI* in each transect was also done using Past 3.14 software.

RESULTS

A total of 45,495 individuals in 105 taxa were counted in total of 6 transects (Table 3).

Table 3. Genera list of macrobenthos in the present study and their abundances in sampling transects.

Genera	West site			East site		
	T_1	T_2	T_3	T_4	T_5	T_6
Acar sp.	75	23	0	42	13	0
Actaea sp.	0	0	0	0	2	0
Alpheus sp.	226	350	47	203	241	70
Ammothella sp.	0	0	0	0	0	1
Amphibalanus sp.	2981	6249	0	2079	5157	0
Anachis sp.	20	6	0	12	22	0
Aplysia sp.	1	3	0	0	0	0
Aquilonastra sp.	24	10	0	12	3	0
Arabella sp.	3	3	3	1	2	3
Asaphis sp.	0	3	5	0	0	0
Aspidopholas sp.	0	4	0	0	0	0
Barbatia sp.	93	42	0	122	44	0
Baseodiscus sp.	3	3	1	1	2	1
Blennius sp.	10	25	0	5	13	0
Brachidontes sp.	82	14	0	33	13	0
Bullia sp.	11	0	0	2	5	0
Cafius sp.	0	0	1	0	0	0
Catostylus sp.	0	2	0	0	0	0
Cellana sp.	4	0	0	3	0	0
Ceritihium sp. 1	114	88	39	34	36	26
Ceritihium sp. 2	528	464	147	258	378	95
Charybdis sp.	22	40	9	17	25	14
Chiton sp.	16	0	0	8	0	0
Circenita sp.	0	10	47	0	6	6
Clausidium sp.	0	0	0	6	0	0
Clibanarius sp.	1197	929	267	908	811	260
Clypeomorus sp.	47	53	28	84	180	39
Cronia sp.	66	70	45	85	60	24
Cyathura sp.	0	2	0	2	1	0
Cyclaspis sp.	0	0	2	0	0	0
Cypraea sp. 1	4	0	0	4	0	0
Cypraea sp. 2	0	0	0	2	0	0
Cypraea sp. 3	0	0	0	3	0	0
Diodora sp. 1	2	0	0	3	0	0
Diodora sp. 2	3	0	0	0	0	0
Diplodonta sp.	0	1	1	0	0	0
Ebalia sp.	17	0	0	10	0	0
Echinometra sp.	14	0	0	0	0	0
Elamena sp.	41	0	0	21	0	0
Elasmopus sp.	234	1008	120	243	574	171
Epinephelus sp.	0	7	0	0	0	0
Epixanthus sp.	16	0	0	9	0	0
Eretmochelys sp.	0	0	0	2	0	0
Eriphia sp.	15	11	0	11	7	0
Euchelus sp.	511	437	189	331	401	125
Eurycarcinus sp.	8	0	0	0	0	0
Gastrochaena sp.	8	21	0	10	36	0
Gobius sp.	7	30	0	0	0	0
Gonodactylus sp.	0	2	0	0	2	0
Grapsus sp.	10	4	0	13	7	0

Continued…

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Continued of Table 3.

	West site			East site		
Genera	T_1	T_2	T_3	T_4	T_5	T_6
Gyrineum sp.	0	4	0	0	0	0
Heliacus sp.	4	4	0	3	5	0
Heteropilumnus sp.	4	6	0	2	3	0
Hexaplex sp.	19	12	0	5	7	0
Holothuria sp.	25	19	0	20	15	0
Ibla sp.	18	0	0	6	0	0
Isognomon sp.	12	0	0	0	0	0
Leiosolenus sp.	4	6	0	0	0	0
Lepas sp.	0	0	33	0	0	87
Lepidonotus sp.	11	10	0	20	14	4
Leptodius sp.	112	78	10	78	91	7
Leptoplana sp.	10	8	0	7	12	0
Ligia sp.	26	0	0	18	0	0
Lunella sp.	155	226	52	414	257	66
Lysidice sp.	85	125	43	51	50	41
Metopograpsus sp.	78	125	28	143	56	20
Mitrella sp.	3	2	0	2	4	0
Morula sp.	106	67	25	229	135	34
Nassarius sp.	256	163	65	161	153	42
Natica sp.	0	1	1	0	0	0
Neotrapezium sp.	13	7	0	10	5	0
Nereis sp.	21	18	12	8	13	6
Nerita sp. 1	35	32	0	74	35	0
Nerita sp. 2	13	0	0	11	0	0
Niphates sp.	6	0	0	2	0	0
Notoplana sp.	19	6	0	13	9	0
Octopus sp.	0	0	0	1	1	0
Onchidium sp.	4	0	0	0	0	0
Ophiocoma sp.	7	4	0	0	0	0
Patella sp.	4	0	0	7	0	0
Petrolisthes sp.	270	231	129	320	269	126
Pilumnopeus sp. 1	13	8	0	6	6	0
Pilumnopeus sp. 2	27	20	0	8	8	0
Planaxis sp.	710	428	69	434	386	93
Rhinoclavis sp.	4	0	0	2	5	0
Rupellaria sp.	5	0	0	0	0	0
Saccostrea sp.	643	0	0	457	0	0
Sepia sp.	0	0	0	5	7	6
Sphaeroma sp. 1	0	0	0	0	2	0
Sphaeroma sp. 2	0	3	0	0	6	0
Spirobranchus sp.	93	167	0	170	292	0
Spondylus sp.	0	0	0	2	0	0
Stichodactyla sp.	0	13	0	0	3	0
Strombus sp.	1	0	0	0	2	0
Terebella sp.	0	0	0	2	4	0
Tetraclita sp.	6	5	0	4	4	0
Thais sp. 1	31	25	0	18	14	0
Thais sp. 2	265	182	66	171	164	58
Tornus sp.	0	0	0	0	0	3
Trachycardium sp.	0	3	5	0	0	0

Continued…

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Continued of Table 3.

Genera	West site T_1	West site T_2	West site T_3	East site T_4	East site T_5	East site T_6
Trochus sp.	404	390	202	383	286	207
Turbo sp. 1	449	401	175	290	271	82
Turbo sp. 2	3	0	0	1	0	0
Tytthosoceros sp.	0	0	0	0	2	0
Umbonium sp.	0	0	25	0	0	13

Macrobenthos abundance was higher at the West site than the East site, probably due to the weak water currents.

Results of diversity indices and *CRI* in each transect are shown in Table 4. Based on the Pearson' correlation analysis in Table 5, the diversity indices, e.g. Pielou, Margalef and Berger-Parker, and macrobenthos abundance was correlated with *CRI*.

Unlike Cluster analysis based on macrobenthos abundance (Figure 2), Cluster analysis based on the diversity indices and *CRI* in each transect, demonstrated three distinct clusters (Figures 3 and 4).

DISCUSSION

The present study proposed a new index, i.e. Coverage Range Index (CRI), to assess the impact of substrate composition on distribution of hard bottom macrobenthos.

Table 4. Diversity indices and *CRI* for hard bottom macrobenthos of Hormuz Island at 2 study sites.

	West site T_1	West site T_2	West site T_3	East site T_4	East site T_5	East site T_6
Number of taxa (S)	75	65	32	73	62	30
Total number of individuals (n)	10387	12713	1891	8137	10637	1730
Simpson's dominance index (λ)	0.8834	0.7388	0.9269	0.9013	0.7472	0.9251
Shannon wiener's diversity index (H´)	2.85	2.213	2.874	2.931	2.259	2.845
Pielou's evenness index (J´)	0.2305	0.1407	0.5532	0.2568	0.1544	0.5735
Brillouin's diversity index (HB)	2.832	2.201	2.834	2.91	2.245	2.804
Menhinick's richness index (d_1)	0.7359	0.5765	0.7359	0.8093	0.6011	0.7213
Margalef's richness index (d_2)	8.001	6.772	4.109	7.996	6.579	3.89
Berger-Parker's dominance index (d_3)	0.287	0.4915	0.1412	0.2555	0.4848	0.1503
Coverage Range Index (CRI)	41.6	50.9	7.5	39.7	51.9	8.4

Table 5. Pearson' correlation between *CRI* with macrobenthos abundance and diversity indices.

	Total number of individuals (n)	Simpson's dominance index (λ)	Shannon-Wiener's diversity index (H´)	Pielou's evenness index (J´)	Brillouin's diversity index (HB)	Menhinick's richness index (d_1)	Margalef's richness index (d_2)	Berger-Parker's dominance index (d3)
Pearson correlation	0.980**	-0.805	-0.659	-0.998**	-0.636	-0.494	0.839*	0.905*
Sig (2-tailed)	0.001	0.053	0.154	0.000	0.174	0.319	0.037	0.013
N	6	6	6	6	6	6	6	6

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

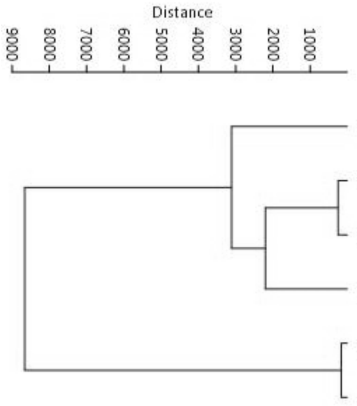

Figure 2. Dendrogram based on macrobenthos abundance with data from Table 4; Transect (T).

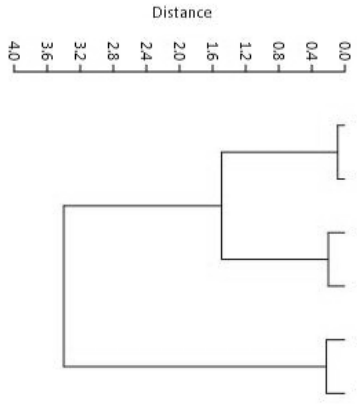

Figure 3. Dendrogram based on the diversity indices with data from Table 4; Transect (T).

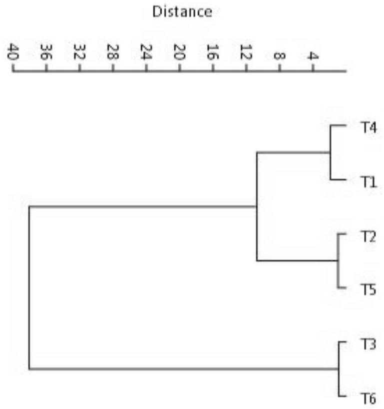

Figure 4. Dendrogram based on CRI with data from Table 4; Transect (T).

The performance of this index has not been tested in soft substrata yet. *CRI* has one metric: abundance of macrobenthos. *CRI* is categorized under three classes, namely, narrow, middle and wide. However, according to Table 2, the assessment of values in formula varies among them. Although *CRI* is similar to *RA* (Relative Abundance), which is a component of commonness or rarity of each species (Rilov and Benayahu, 1998), but it is a new index of area coverage by all species along each transect. Also, the main difference between the formula suggested in this study for deriving *CRI* and the formula of the diversity indices is that the diversity indices are based on the species number and species abundance, while *CRI* takes into account only the species abundance.

The need of the interpretation of the macrobenthic data and its use in detecting environmental stress, disturbance, and change has led to the development of an extensive number of concepts and numerical techniques: diversity indices, multivariate tools, indicator species, graphical representations (Elliott, 1994). Among them, diversity indices are actually an approach to ecological quality through the community structure and have been applied mostly to communities of species or other taxonomic levels (Hill, 1973). In this case, two different aspects are commonly accepted to contribute to the intuitive concept of community diversity: species evenness, which refers to how evenly the individuals in an environment are distributed over the different species, and species richness, which is a measure of the total number of different species represented in an ecological community (Peet, 1974).

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Heterogeneity measures confound species richness and evenness in a single index of diversity (Heip, 1974). The use and interpretation of these indices has been subjected to too much debate (Warwick and Clarke, 1993). The values of all these indices are influenced by sampling methodology, sample size, and identification procedures. Their validity with hard bottom communities is further argued because colonies of animals are not easily enumerated. Consequently, species richness and community diversity values can only be compared if the same sampling methodology has been followed, including same level of taxonomic relationship (Warwick and Clarke, 1995). Also, these indices are habitat type dependent, which means that different ranges of values or classification schemes should apply for different habitat types.

The variation in approach and suites of measures contained in various benthic indices leads to questions about whether the usage of the various indices would yield different results (Ranasinghe *et al*., 2002). Hence, this paper presents an evaluation of the use of diversity indices such as Simpson, Shannon-Wiener, Pielou, Brillouin, Menhinick, Margalef and Berger-Parker and compares them with *CRI*. In this comparison, Pielou's evenness, Margalef's richness and Berger-Parker's dominance indices showed distinct differences between different habitat types. On the other hand, Simpson's dominance, Shannon-Wiener's diversity, Brillouin's diversity and Menhinick's richness indices did not show great differences between transects (Table 4). This is attributed to the fact that the area is generally moderately populated with present high densities of toxic species of zoanthids species (Mirzabagheri *et al*., 2016).

In the present study, the correlation of *CRI* with Margalef's richness index (r= 0.839) and Berger-Parker's dominance index (r= 0.905) were found to be high. The scores of *CRI* were strongly correlated with those of Pielou's evenness index (r= -0.998) in the area (Table 5). Species richness can be good estimated only in easily censuses communities with few species (Chiarucci, 2012), but, communities with large numbers of species require the rarefaction technique that allows one to adjust a series of samples to a common sample size (Colwell *et al*., 2012). So, based on the high correlation of *CRI* with Margalef's richness index, *CRI* is an easier index due to its different ranges of small samples to large ones. Species evenness is easy to determine when it is decided whether to emphasize or de-emphasize the rare species in the community samples (Gotelli and Chao, 2013). So, based on the strong correlation of *CRI* with Pielou's evenness index and the high correlation of *CRI* with Berger-Parker's dominance index, *CRI* is also an easier index due to its different ranges of rare species to dominant ones.

As a result, values of *CRI* depend on the abundance of all collected animals along transects, e.g. sessile to mobile animals, free living animals to those living in cases/tubes/exoskeletons, and on abundance of individual specimens to polyps of animal colonies (Mirzabagheri *et al*., 2017). Mendes *et al*. (2008) suggested that a unified index is invariant due to independence of the number of species when looking at the entire animal dataset. Accordingly, *CRI,* which is independent of the species number and applies to the different ranges of hard bottom type and does not require exhaustive taxonomic effort, is invariant and practicable. On the other hand, *CRI* reflects and describes distribution range of species which relate to the response of the benthic communities to substrate composition.

Environmental factors such as substrate type and sediment texture are known to influence the structure of macrobenthos assemblages in the Persian Gulf (Gray, 1974; Capaccioni-Azzati *et al*., 1991; Mirzabagheri *et al*., 2007). Macrobenthos difference between Iranian and Arabian shorelines can be related to the type of studied habitat and biological interaction between various communities (Nourinezhad *et al*., 2013). Although it is not yet well established, it seems that specific types of habitats or ecosystems are common throughout the Persian Gulf and that the corresponding communities can be classified into types which are similar in their basic structure and composition throughout the Persian Gulf. Therefore, a single system of benthic habitat types may be adopted for the Persian Gulf and used for typology testing, so that a core set of species characterizing each type of habitat may be derived including species presenting wide or limited distribution patterns.

Multivariate techniques such as clustering, unlike diversity measures, take into account changes in taxa and base their comparisons on the extent to which different data sets share particular species, at comparable levels of abundance. Multivariate statistics have also been used at higher taxonomic levels (genus, family, and phylum) (Warwick and Clarke, 1993). Dendrogram based on *CRI* showed that the cluster in the sampling transects was similar to diversity indices (Figures 3 and 4), but differed with the cluster based on macrobenthos abundance (Figure 2). On the basis of the cluster analysis, it can be concluded that study regions had 3 major substrate types, consisting of boulder, cobble, and pebble. Transects with substrate composition of boulder and cobble showed relatively higher macrobenthos abundance than the others, due to substrate heterogeneity with some shelters from waves and currents in their parts (Mirzabagheri *et al*., 2017). The unexpected position of transects 3 and 6 in the classification of the clustering could be attributed to unstable structure of pebble (Figure 2). Thus, having adequate knowledge of the substrate composition is of special importance in river and coastal engineering (Javadi *et al*., 2015).

Water quality evaluation provides a scientific basis for development and management of water resources (Chu *et al*., 2013). According to Wilhm and Dorris index (1968), values between 1.0 and 3.0 based on Shannon-Wiener’s diversity index, indicate moderate water pollution at the study sites. Shannon-Wiener’s diversity values in this study ranged from 2.213 to 2.931, suggesting that sampling sites in littoral zone of Hormuz Island were moderately polluted and the macrobenthic community was under stress due to the toxic pollution of littoral zoanthids as a natural factor. This was in agreement with Mirzabagheri *et al*. (2016). The distribution of zoanthids appears to be influenced by the type of substrate, as suggested by Irei *et al*. (2011). Hence, the study on the relationship between zoanthids and distribution of macrobenthos associated with them is important.

CONCLUSIONS

The concept of a universal ecological index based only on the species abundance and using a formula which gives a series of continuous values has not developed yet. Hence, our study suggests that applying *CRI* to cluster the sampling sites can provide results similar to other diversity indices. Although some of the mismatch between indices was related to substrate composition, more comparison studies should be undertaken in order to improve the assessment of ecological integrity. According to this, *CRI* is principally designed to: (1) Provide numbers so that various littoral zones can be compared directly with one another, (2) Provide data which managers and other nontechnical personnel can use more easily to categorize macrobenthos distribution, (3) Render the index convenient for initial quick assessment of overall ecological classification due to its independence of the species number, and (4) Determine initial condition for future use such as biomonitoring.

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یک شاخص محدوده پوشش جدید برای ارزیابی اثرات ترکیب بستر روی پراکنش ماکروبنتوزهای بستر سخت

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چکیده

این مطالعه تأثیر ترکیب بستر در توزیع ماکروبنتوزها را با استفاده از شاخص جدید محدوده پوشش (CRI) و متغیرهای شاخص های تنوع و مجموعه داده های ماکروبنتوزی به دست آمده در طی یک دوره 12 ماهه بین ماه های تیر 1394 و تیر 1395 بین 6 ترانسکت نمونه برداری از 2 ایستگاه ارزیابی می کند. همه ترانسکت های انتخاب شده در منطقه ساحلی جزیره هرمز در خلیج فارس واقع شده اند و دارای بستر از نوع سخت با ترکیبات مختلف بودند. بر این اساس، نمونه های ماکروبنتوزی هر ایستگاه از 3 نوع بستر سخت گرفته شدند: تخته سنگ، قلوه سنگ، خرده سنگ. به منظور بررسی فراوانی

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ماکروبنتوزها از CRI و شاخص های تنوع (سیمپسون، شانون- وینر، پیلو، بریلویین، منهینیک، مارگالف و برگر- پارکر) استفاده شد. همچنین CRI به طور آزمایشی با اختصاص به محدوده فراوانی مورد بررسی ماکروبنتوزها به 3 دسته محدوده پوشش (وسیع، متوسط، باریک) انتخاب شد. مرز CRI برای دسته ها برآورد شد. تجزیه و تحلیل CRI و شاخص های تنوع، خوشه مشابهی را در ایستگاه های نمونه برداری نشان داد. این یافته ها نشان می دهد که در ارزیابی فراوانی ماکروبنتوزها، CRI شاخص ساده تری از شاخص های تنوع است، چرا که CRI تنها بر اساس فراوانی افراد گونه ها است اما شاخص های تنوع هم بر اساس فراوانی افراد گونه ها و هم تعداد گونه ها می باشند. از این رو، CRI به دلیل دامنه های مختلف آن از نمونه های کوچک تا بزرگ، گونه های نادر تا غالب و گونه های منفرد تا پولیپ از کلنی ها به یک شاخص اکولوژیکی عمومی در آمده است. کار آینده باید بر روی گسترش پایگاه داده ها برای آزمودن CRI در دیگر انواع بستر متمرکز شود. در نهایت، نتایج این مطالعه ممکن است نه تنها برای کشورهای در حال توسعه، بلکه برای هر سازمان در تلاش برای استفاده از شاخص های متکی بر ماکروبنتوزها با منابع مالی و دانش محدود، مفید باشد.

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