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Distribution pattern and a new coverage range index identification of zoanthids in littoral zone of Hormuz Island, Persian Gulf

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Abstract

This study aimed to investigate the spatio-temporal changes in zoanthids abundances and to assess the influences of sea water parameters on their distribution. According to this, 2 sites in littoral zone of Hormuz Island were monthly studied from June 2015 to June 2016. Coverage range index (CRI) was also introduced as a new index in this study to assess the influence of the substrate composition on distribution of zoanthids. Line intercept transect method was performed to assess the zoanthid coverage along 6 transects. The results indicated significant relationship between substrate composition and coverage range of zoanthids. Hence, CRI proved to be a reliable index because of its strong fluctuations resulting mainly from total abundance of zoanthids. Also, the results indicated that zoanthids tended to colonize in low-littoral and mid-littoral zones, which are least exposed to air. Apparently, *Zoanthus sansibaricus* can tolerate desiccation conditions better than *Palythoa* cf. *mutuki* and *Palythoa tuberculosa*. From the results obtained, the abundances of 3 zoanthids during winter season showed an increasing trend, while during spring season it showed a reverse trend. Seasonal variations of sea water parameters were correlated with ecological attributes of species; where dissolved oxygen showed a positive significant correlation with mean seasonal abundance of each zoanthids at different study sites. Consequently, based on the findings of this study, zoanthids could be utilized as a bioindicator species of various environmental conditions in coastal waters.

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1. Introduction

Distribution of the organisms or zonation is one of the considerable specifications of rocky littoral communities, and each species has a specific limited distribution along a vertical or horizontal slope (Raffaelli and Hawkins, 1999; Little *et al.*, 2010). Several basic factors generally are responsible for zoanthid zonation: substrate composition, food supply, water salinity, oxygen concentrations, current energy, temperature, turbidity, sedimentation rates and bathymetry (Wilson, 1991; Bromley, 1996; Olenin, 1997; Laine, 2003; Coleman *et al.*, 2007). According to the present study, the causes of zoanthid zonation have shown that the

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species have different abilities in response to various environmental conditions in coastal waters, which allow them to survive for long periods without submersion.

The marine ecosystem is known to be influenced by a composition of physicochemical factors and biological components, which has a direct influence on the entirety of marine species and habitats (Nybakken, 1993). The successful management of the marine ecosystem needs data from all its ecological levels. This needs crucial science about the natural variation of marine ecosystem and dynamics of living resources on the temporal and spatial scales (Choudhury *et al*., 2002; Seen, 2003). Marine ecosystem management is often confronted with segmented data on the temporal and spatial distribution of marine species and habitat, mainly this is because the marine ecosystem is difficult to monitor (Green *et al*., 2009; Robinson *et al*., 2011).

Among the benthos that shows a dominant distribution pattern for marine ecosystem management are zoanthids. They are benthic cnidarians belonging to the order Zoantharia within the subclass Hexacorallia of the class Anthozoa. They are commonly known as carpet sea anemones (Haywick and Mueller, 1997) and usual benthic cnidarian found ubiquitously (Reimer and Todd, 2009; Reimer, 2010; Belford and Phillip, 2012), from shallow tropical coral reefs to cold deep sea (Burnett *et al*., 1997). However, they appear to be more abundant at shallow coral reefs of tropical and subtropical waters (Irei *et al*., 2011; Reimer *et al*., 2011). Zoanthids are common benthos in littoral reefs affect the distribution of other benthos by competing for space, forming toxic colonies on the hard bottom substrate (Suchanek and Green, 1981; Rabelo *et al*., 2013).

Zoanthids are widely used for their toxic compounds such as palytoxin (Moore and Scheuer, 1971; Fukuzawa *et al*., 1995). Green Fluorescent Protein (GFP) is also a potential resource from zoanthids (Mythili, 2011). The simple body plan of zoanthids that lacks distinct morphological characters for identification of species level, a high level of intraspecific variation in terms of coloration, and trapping of gravel and detritus matter in the mesohyl makes the description of each organ system inside the body of zoanthids problematic (Burnett *et al*., 1997; Reimer, 2010). Thus there are several reasons behind the confused taxonomy of the group.

Zoanthids are widely distributed along the Persian Gulf coast, where they form dense aggregations in littoral environments and shallow waters (Mirzabagheri *et al*., 2008). Recently, there are some studies on morphological identification and molecular taxonomy of zoanthids along coast of the Persian Gulf islands (Bahmani *et al*., 2015 a,b; Noori-Koupaei *et al*., 2014, 2015, 2016). In the Persian Gulf, quantitative surveys focusing on distribution of zoanthid are almost nonexistent despite the general abundance of zoanthids (Mirzabagheri *et al*., 2017). However, despite the studies on zoanthids distribution outside of the Persian Gulf (Irei *et al*., 2011; Rabelo *et al*., 2013; Trivedi and Vachhrajani, 2014; Kumari *et al*., 2015), the ecological role and biogeography correspondence of zoanthids with favorable habitats based on quantitative survey is still relatively limited, when compared with other Hexacorallia orders such as Scleractinia and Actiniaria (Hoeksema and Van Der Meij, 2013; Irei *et al.*, 2011; Reimer *et al.*, 2011). According to this, the main aims of the present study were: (1) to evaluate the spatio-seasonal distribution pattern of zoanthids in littoral zone of Hormuz Island; (2) to investigate relationships between zoanthids distribution and abundance

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with different environmental gradients. Also, this study aimed to advance knowledge of the ecology of zoanthids, introduces coverage range index (CRI) as a new index to calculate of area coverage by all zoanthids along each transects to assess the influence of the substrate composition.

2. Materials and methods

2-1. Site selection

This study was conducted in six transects located along the west and east of Hormuz Island in the Persian Gulf (Fig. 1). Maximum abundance of zoanthids was found at the west and east coasts of Hormuz Island. Hence, these coasts were selected for a horizontal Line Intercept Transect survey (English *et al*., 1997). The predominant substrate composition was classified based on Udden-Wentworth scale (1922): (1) Rocky (boulder) in T_1 and T_4; (2) Rubble and muddy (cobble) in T_2 and T_5; and (3) Gravel and sandy (pebble) in T_3 and T_6.

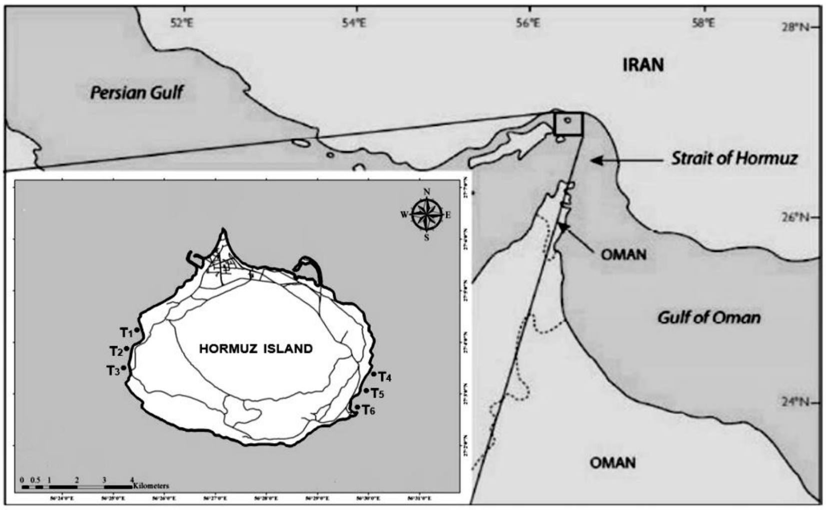

Fig. 1. Map of Hormuz Island in the Persian Gulf, showing the sampling transects

2-2. Sampling methodologies

The littoral region of Hormuz Island was divided into three zones (upper, mid and low), based on the overall average exposure of the zone (Fig. 2).

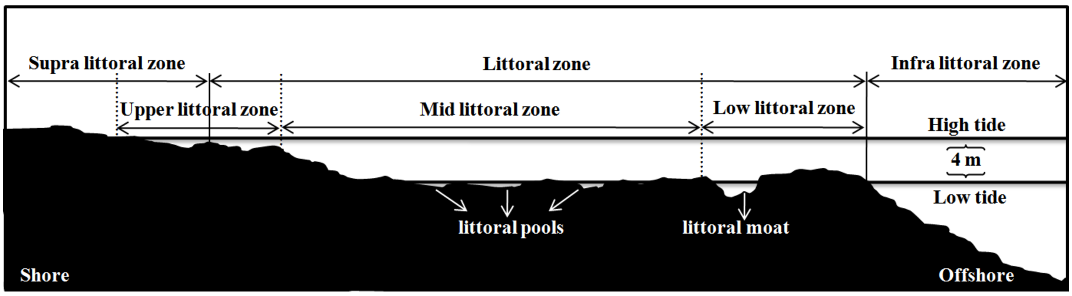

Fig. 2. Typical geographical structure of a littoral zone investigated in this study

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In the present study, at the west (Fig. 3A) and east coast (Fig. 3B) of Hormuz Island littoral zone, three species of zoanthids, *Palythoa* cf. *mutuki* (Carlgren, 1937) (Fig. 3C), *Palythoa tuberculosa* (Klunzinger, 1877) (Fig. 3D) and *Zoanthus sansibaricus* (Carlgren, 1900) (Fig. 3E) were identified using the identification key provided by Reimer *et al*., (2010). Each of the three species forms colonies that are attached to hard bottom substrate. Physico-chemical data, including water dissolved oxygen, pH, salinity and temperature, were measured using the Horiba U-10 water quality meter in littoral zone of all transects. Each sampling transect was sampled monthly from June 2015 to June 2016.

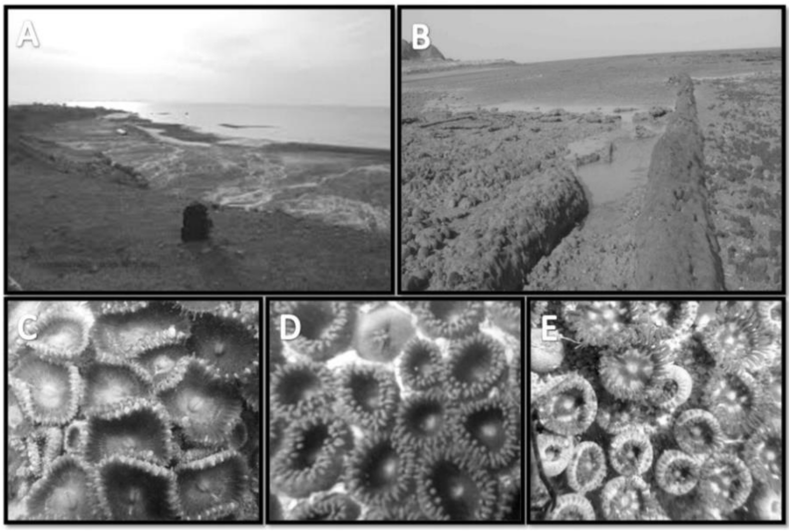

Fig. 3. Study site in littoral zone of Hormuz Island, Persian Gulf, Iran, showing the west (A) and east coast (B). Details of *Palythoa* cf. *mutuki* (C); *Palythoa tuberculosa* (D) and *Zoanthus sansibaricus* (E)

The Line Intercept Transect (LIT) method was adopted to estimate zoanthid distribution and abundance in littoral zone. The line was stretched perpendicular to the shore towards the zoanthid colony (Belford and Phillip, 2011). Three horizontal LITs were delimited at each site in littoral zone of Hormuz Island, perpendicular to the shoreline. Each transect was around 100 m long, depending on the width of the shore, with about 500 m distance between transects. These transects were extended from the upper-littoral zone to the low-littoral zone, in order to sample the entire habitat during spring low tide periods between June 2015 and June 2016. Polyp count method was adopted using 0.5 × 0.5 m quadrats which were positioned on the substrate (Raghunathan *et al*., 2004). Continuously along each transect, four 0.25 m^2 quadrats subdivided into 100 smaller quadrats were laid at about 5-10 m apart in each littoral zone. In each quadrat, the percentage cover of zoanthids was analyzed. Spatial distributions of zoanthid were determined as the percentage of the zoanthid cover (relative abundance) in each quadrat along transects. The relative abundance (RA), which is a component of commonness or rarity of each zoanthid species, was calculated using the formula 1 (Rilov and Benayahu, 1998) as following:

$$\text{Relative Abundance (RA)} = \frac{p_i}{p_{\text{total}}} \times 100 \qquad (1)$$

Where, P_i is the pooled living coverage of the *i*th species in all transects at a given site and P_{total} is the pooled total living coverage of all species in all transects at a given site. The calculated values were transformed into abundance categories (%) as not recorded (RA = 0), rare (0 < RA < 0.1), uncommon (RA = 0.1 - 1), common (RA = 1 - 10), abundant (RA = 10 - 20) and dominant (RA > 20) (Sukumaran and George, 2010). Also, the coverage range index (CRI), which is a novel index of area coverage by all zoanthids along each transect, was calculated using an innovative formula 2 given by Mirzabagheri (2018) as following:

$$\text{Coverage Range Index (CRI)} = \frac{P_{Ti}}{P_{\text{total}}} \times 100 \tag{2}$$

Where, P_{Ti} is the pooled living coverage of all species in *i*th 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 zoanthids. Accordingly, the calculated values were transformed into coverage range categories (%) as narrow (0 < CRI < 20), middle (CRI = 20 - 50) and wide (CRI > 50) (Mirzabagheri, 2018). Eventually, based on the coverage range category of all transects at each site, can be estimated the coverage range category of total area covered by zoanthids.

2-3. Statistical analysis

For the analysis of the spatial distribution, asymmetrical graphs were constructed to show the abundance of zoanthids along each transect. For analysis of CRI, a dendrogram was prepared to graphically visualize the differences among 6 transects using the software Past version 3. The Pearson correlation was used to evaluate the influence of sea water parameters (dissolved oxygen, pH, salinity, temperature) on distribution of zoanthids. The significance level ($p<0.05$) of the correlation coefficient was determined. The Pearson correlation coefficient was calculated using the software SPSS version 16.

3. Results and discussion

In this study, relative abundance patterns of zoanthids were surveyed among different littoral zones (upper, mid and low), correlating with sea water parameters (dissolved oxygen, pH, salinity and temperature), that were recorded in different sampling transects and showed little variation along all transects. The coverage range index of zoanthids was also calculated for evaluation of area coverage of all zoanthids along 6 transects, which is also introduced as a new index to assess the influence of the substrate composition on distribution of zoanthids (Mirzabagheri, 2018).

Colony count using the belt transect method is the most appropriate method used for the sampling of zoanthid population, but in the present study, the size of the colonies of all the species observed at each study sites were large. So the colony count could not be adopted for sampling. Therefore, instead of colony count, polyp count method was adopted using 0.5 × 0.5 m quadrats were positioned on the substrate (Raghunathan *et al*., 2004).

In total polyp number, 341294 zoanthid polyps were counted in 6 transects (with a total surveyed area of 600 m^2 along 6 transects) recorded in this study. Zoanthids covered 60.2% of the total polyp number in the east site and 39.8% of the total polyp number at the west site (Table 1).

A total of three species of zoanthids, namely *Zoanthus sansibaricus*, *Palythoa* cf. *mutuki* and *Palythoa tuberculosa*, belonging to two families, Zoanthidae and Sphenopidae were recorded. In family Zoanthidae, the polyps of *Zoanthus* are erect and smooth and often open in daytime. It is the only family of the order Zoantharia found without encrustation of sand. Zoanthids are attached to hard bottom substrate, generally rocks and reefs. In family Sphenopidae, the specific feature of this family is the encrustation of sand or detritus in the mesoglea. The representative genus in this family is *Palythoa*.

According to Table 1, *Z. sansibaricus* with highest relative abundance is classified in the ‘dominant’ category and *P. tuberculosa* with lowest relative abundance is classified in the ‘common’ category.

Table 1. Polyp numbers of 3 zoanthid species, observed at 2 sites around Hormuz Island

Site	Transect No.	Zoanthid species			Total
		P.* cf. *mutuki	***P. tuberculosa***	***Z. sansibaricus***	
West	T_1	9012	4456	68472	81940
	T_2	5548	2044	30268	37860
	T_3	3826	964	11216	16006
East	T_4	6896	5908	98127	110931
	T_5	4015	2704	67833	74552
	T_6	2275	1229	16501	20005

According to Table 2, zoanthids showed a distinct zonation, mainly in low- and mid-littoral, and covered 62.9% and 35.6% of the total polyp number, respectively. Zoanthids were also observed in upper-littoral zone with overall relative abundance of 1.5%. The relief in upper-littoral zone was irregular, and together with some higher rocky areas in low-littoral zone remained exposed for long periods during low tide.

Polyp numbers of each zoanthid species greatly varied from transect to transect, suggesting a patchy nature of distribution for the 3 zoanthid species. Despite this, distribution patterns among the 3 littoral zones were generally consistent and clear for all 3 species among different transects. This could be due to the difference in geomorphology, biotic and abiotic factors at selected sites resulting in different distribution patterns of zoanthids (Kumari *et al*., 2015). It was shown that sea surface temperature (Ono *et al*., 2003), sedimentation (Sebens, 1982; Ono *et al*., 2003), predation and desiccation during low tides (Sebens, 1982) affect the distribution of zoanthids.

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Table 2. Polyp numbers of all zoanthids, observed in 3 littoral zones at 2 sites around Hormuz Island

Site	Transect No.	Littoral zone			Total
		Upper	Mid	Low	
West	T_1	1525	29794	50621	81940
	T_2	653	8783	28424	37860
	T_3	0	3633	12373	16006
East	T_4	2100	43869	64962	110931
	T_5	760	32563	41229	74552
	T_6	0	2817	17188	20005

Coverage range index for each transect is shown in Table 3. The results indicate significant relationship between substrate composition and coverage range of zoanthids. According to the substrate composition in each transect, all species had a similar distribution pattern. So that zoanthids were most abundant in the boulder and cobble substrates, and covered 56.5% and 32.9% of the total polyp number, respectively. Zoanthids were also observed in the pebble substrates with overall relative abundance of 10.6%.

Table 3. Relationship between substrate composition and coverage range of zoanthids

Site	Transect No.	Predominant substrate composition	CRI	Coverage range of zoanthids		
				Wide	Middle	Narrow
West	T_1	Boulder	60.3	√		
	T_2	Cobble	27.9		√	
	T_3	Pebble	11.8			√
East	T_4	Boulder	54	√		
	T_5	Cobble	36.3		√	
	T_6	Pebble	9.7			√

The dendrogram in Fig. 4 shows three different groups. T_3 and T_6 are grouped together; these are clustered with T_2 and T_5. Also T_1 and T_4 form a third and separate group which is joined with the other two groups.

Distribution of zoanthids appears to be influenced by the substrate composition, as suggested by Irei *et al*., (2011). The result of this study using CRI indicated that the substrate composition plays an important role on coverage range of zoanthids. It clearly shows that there is a significant relationship between paired groups of dendrogram based on the CRI with the substrate composition of zoanthid habitat. In zoanthid habitat with boulder substrate, coverage range of zoanthids is wide and thus CRI is higher than CRI calculated for zoanthid habitats with cobble substrate. Areas surrounded by pebble, therefore, appeared to be a factor of exclusion for zoanthids. The presence of some zoanthids could be explained by its ability to colonize unconsolidated substrates where other zoanthids cannot survive. Polyps of these zoanthids colonies tend to be taller than those other zoanthids (Koehl, 1977), and the oral disc that emerges from the sand can facilitate colonization and feeding, even on sandbars. However, it is clear from the present observations that the species is able to survive in situations with high sedimentation with the column buried, exposing only oral disc. Perhaps zoanthids can tolerate desiccation conditions during low tide using the interstitial water in the sediment.

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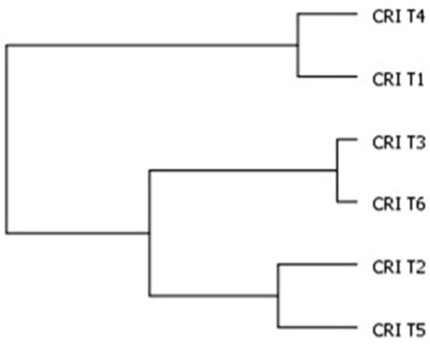

Fig. 4. Dendrogram based on CRI with data from Table 3; Transect (T)

As shown in Table 4, the zoanthid cover during winter season showed an increasing trend, while during spring season it showed a reverse trend. Despite the difference in polyp numbers of all zoanthids in different seasons, there was not much difference. The levels of nutrient played an important role in defining the diversity and survival of zoanthids (Kumari *et al*., 2015). The cause for low zoanthid growth despite hypertrophic nutrient situations could be due to the competition given by wide growth of macroalgae (Kumari *et al*., 2015), So that in the present study area, the most abundant of macroalgae have been recorded in spring (Emadabadi, 2008). According to Tanner (1995), macroalgae are among the main components of many rock and reef communities and may compete with corals. Further, it has been reported that coral reefs will continue to suffer due to rapidly growing benthic communities such as zoanthids (Yang *et al*., 2013). The negative correlation between algal cover and zoanthid cover suggests that the algae compete for space and likely prevent the growth of these sessile cnidarians (Rabelo *et al*., 2015). Birrell *et al*., (2005) showed that coral cover and growth might be retarded by algae in some places due to the decline or even prevention of coral settlement.

Due to the study of Rabelo *et al*., (2013), we believe that inter-specific competition among zoanthids also impresses their distribution on these reefs. Glynn (1976) implied that competitive activities limit some species by exclusion, or species may be limited to sheltered areas where competition is decreased. The possible effects of competition on distribution of zoanthids must be considered together with the indirect effects of other biological factors such as predation, that predation affects the distribution of zoanthids (Sebens, 1982). Nevertheless, this needs to be better considered at the study site to confirm this hypothesis.

In the present study, sea water parameters (dissolved oxygen, pH, salinity and temperature) were recorded in different sampling transects and showed little variation along

Table 4. Polyp numbers of all zoanthids, observed in 4 seasons at 2 sites around Hormuz Island

Site	Transect No.	Season				Total
		Summer	Autumn	Winter	Spring	
West	T_1	20460	20495	20737	20248	81940
	T_2	9413	9455	9775	9217	37860
	T_3	3972	4013	4278	3743	16006
East	T_4	27700	27573	28735	26923	110931
	T_5	18529	18736	19194	18093	74552
	T_6	4929	5025	5245	4806	20005

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all transects. These parameters did not vary much between different sites, but fluctuated at each site in different seasons and showed a correlation with distribution of zoanthids over the entire study site. Correlations between different zoanthid species and sea water parameters are shown in Table 5. The results indicate a positive significant correlation between dissolved oxygen and any zoanthid species. Pearson correlation analysis shows non-significant correlation between pH, salinity, temperature and any zoanthid species.

Table 5. Correlation between sea water parameters and zoanthids

Sea water parameters Zoanthid species	West site			East site		
	Pearson correlation	**N**	**Sig. (2-tailed)**	**Pearson correlation**	**N**	**Sig. (2-tailed)**
Dissolved oxygen						
P. cf. *mutuki*	0.446	12	0.146	0.607*	12	0.036
P. tuberculosa	0.601*	12	0.039	0.631*	12	0.028
Z. sansibaricus	0.603*	12	0.038	0.542	12	0.069
pH						
P. cf. *mutuki*	-0.209	12	0.515	-0.356	12	0.256
P. tuberculosa	-0.306	12	0.334	-0.396	12	0.202
Z. sansibaricus	-0.326	12	0.301	-0.239	12	0.455
Salinity						
P. cf. *mutuki*	-0.445	12	0.147	-0.397	12	0.201
P. tuberculosa	-0.575	12	0.051	-0.561	12	0.058
Z. sansibaricus	-0.354	12	0.259	-0.357	12	0.255
Temperature						
P. cf. *mutuki*	-0.358	12	0.253	-0.473	12	0.121
P. tuberculosa	-0.442	12	0.150	-0.541	12	0.069
Z. sansibaricus	-0.418	12	0.176	-0.364	12	0.244

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

Analysis of sea water parameters revealed high dissolved oxygen at the east site, followed at the west site. This supports the Pearson correlation estimation, where a positive significant correlation was observed between dissolved oxygen and any zoanthid species. Huang *et al*., (2011) reported a positive significant correlation between zoanthid and elevated dissolved oxygen levels. Kumari *et al*., (2015) also reported a positive significant correlation between *P. mutuki* and elevated dissolved oxygen levels. Thus, emphasizing the need for pollution-free waters with high oxygen levels required for zoanthid growth, due to the zoanthids are not capable of growing in hypoxic conditions. Correlation analysis between sea water temperature and abundance of any zoanthid species for different sites showed non-significant results, similar to the results of Trivedi and Vachhrajani (2014). Also, neither salinity nor pH was significantly correlated with any zoanthid species in our case similar to the results of Kumari *et al*., (2015). Hence it could be inferred that distribution pattern of zoanthids varies greatly with sea water parameters such as dissolved oxygen. It was shown that sea surface temperature affects the distribution of zoanthids, because it is crucial in defining the concentration of dissolved gases in the sea water (Ono *et al*., 2003).

Z. sansibaricus was present in almost the entire littoral zone (Fig. 5). It was most abundant in low- and mid-littoral zones, and covered 52.9% and 31.3% of the total polyp number, respectively; also was observed in upper-littoral zone with overall relative abundance of

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1.5%. According to Table 1, maximum abundance of the species was observed to be high at the east site, making up 53.5% of the total polyp number, followed at the west site (32.2%). This species was observed to form large colonies with “liberae” polyps and colonies are up to 30-100 polyps. The polyp abundance of *Z. sansibaricus* during winter season showed an increasing trend, while during spring season it showed a reverse trend (Fig. 6).

P. cf. *mutuki* was present in low- and mid-littoral zones (Fig. 5), and covered 6.4% and 2.8% of the total polyp number, respectively. According to Table 1, maximum abundance of the species was observed to be low at the west site, making up 5.4% of the total polyp number, followed at the east site (3.8%). In this species, polyps are ‘liberae’ and small colonies are up to 50 polyps. This species is closely related to *P. mutuki*. The polyp abundance of *P.* cf. *mutuki* during winter season showed an increasing trend, while during spring season it showed a reverse trend (Fig. 6).

P. tuberculosa was present in low- and mid-littoral zones (Fig. 5), and covered 3.6% and 1.5% of the total polyp number, respectively. According to Table 1, maximum abundance of the species was observed to be low at the east site, making up 2.9% of the total polyp number, followed at the west site (2.2%). In this species, Polyps are “immersae” and the small rounded colonies are approximately 30 cm in diameter. The polyp abundance of *P. tuberculosa* during winter season showed an increasing trend, while during spring season it showed a reverse trend (Fig. 6).

Z. sansibaricus was abundant in littoral zone of Hormuz Island and it had a horizontally wider distribution than *P.* cf. *mutuki* and *P. tuberculosa*. The main habitat of *Z. sansibaricus* was the rock crest, due to the intense need to light, while *P.* cf. *mutuki* and *P. tuberculosa* was observed on both rock crests and rock slopes. Thus, in general, it appears that *P.* cf. *mutuki* and *P. tuberculosa* have a vertically wider distribution than *Z. sansibaricus*. Also we observed that *P.* cf. *mutuki* and *P. tuberculosa* required specific kind of microhabitat for survival and growth, because they were common in littoral zone where specific kind of microhabitats, like wide (2 to 5m) and deep (0.5 to 1m) littoral pools were available.

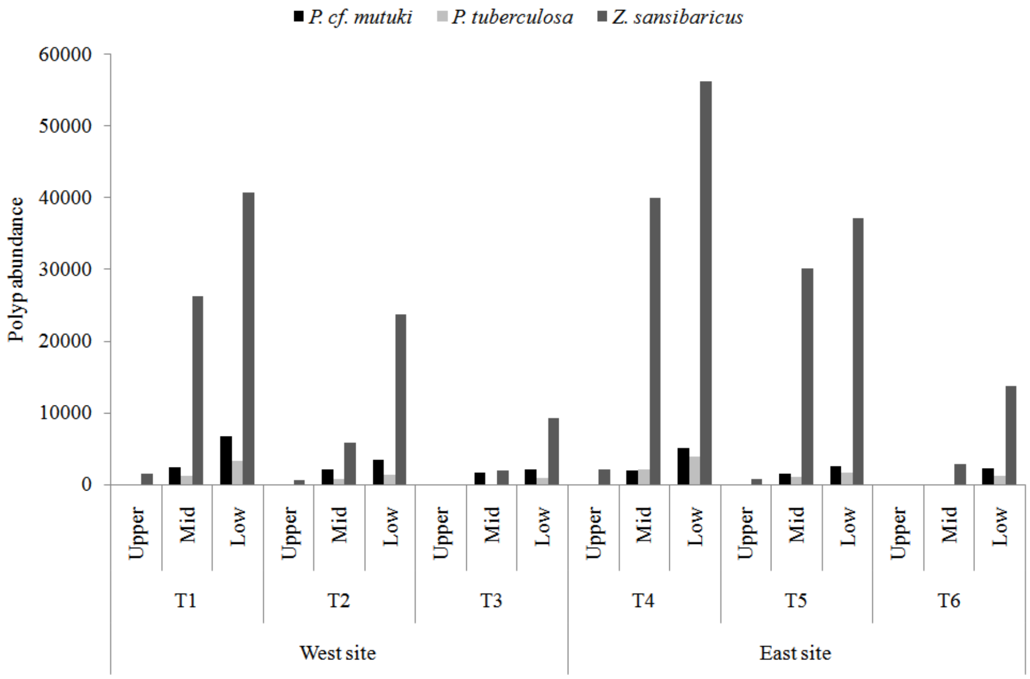

Fig. 5. Polyp abundance of 3 zoanthid species in different littoral zones in sampling transects; Transect (T)

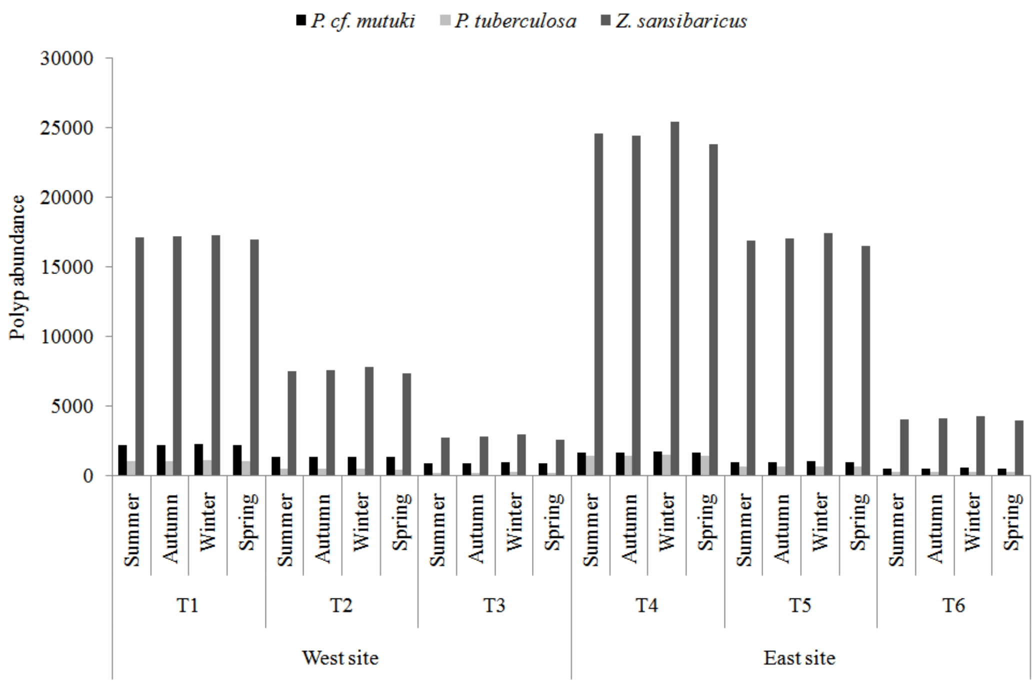

Fig. 6. Polyp abundance of 3 zoanthid species in different seasons in sampling transects; Transect (T)

Due to human actions such as red clay mining works that are carried out around the coastal region of the study sites (Mirzabagheri *et al*., 2007). The present study area is facing huge problems of sediment load which on the other hand help zoanthids to grow their populations. It was shown that sedimentation affects the distribution of zoanthids (Sebens, 1982; Ono *et al*., 2003). Except for sediment, the geomorphology and physiographic characters, such as flatness of littoral zone which reduces wave action and presence of littoral pools that remain filled with the water during low tide, also favor the growth of zoanthids. At all study sites, it was observed that each of the species was frequently limited to mid-littoral zone in association with the presence of littoral pools and probably because of the presence of water during low tide (Trivedi and Vachhrajani, 2014).

In littoral moats of Hormuz Island, only a few zoanthids were recorded, and sedimentation or undesirable salinity could have been cause of this. For example, due to commonly weak currents in moats, the substratum was mostly covered by drifted sand (Nakai, 2007), making survival of zoanthids and other benthic cnidarians difficult. Moreover, littoral moats are mostly affected by runoff of fresh water from terrestrial ecosystems, which lowers the salinity and in Hormuz Island, causes red clay sedimentation particularly after heavy rains (Mirzabagheri *et al*., 2007). As the water circulation in littoral moats is relatively poor (Nakai, 2007), such unfavorable low-salinity conditions can insist for a relatively longer period than on the rock crest or rock slope. Thus, such harsh conditions may confine the number of colonies of zoanthids in littoral moats. In a study at 2 sites of Okinawa Island; however, relatively large numbers of zoanthid colonies were observed in the moats. The moats at these 2 sites have relatively higher water flow, and thus they may be similar environments to reef crests (e.g., more favorable for zoanthids) (Irei *et al*., 2011).

In the reefs to the east of Hormuz Island, whereas reef-building corals were heavily affected by the recent bleaching event and its subsequences, due to the overgrowth of invasive and sessile organisms such as macroalgae and pathogenic bacteria, zoanthids showed no sign of bleaching or illness (Kavousi *et al*., 2013). The results suggest that zoanthids making use of a wide variety of morphological, physiological and behavioral adaptive strategies against various environmental stresses, which account for their success on consolidated substrates, as observed by Karlson *et al*., (1996) and Karlson (1988).

Zoanthids primarily colonize more constant environments such as low- and mid-littoral. The spatial distribution of zoanthids studied here might be affected directly by their different tolerances to desiccation conditions and substrate composition. The topographic profile defined the degree of air and sunlight (UV) exposure, influencing the distribution of zoanthids. Our observations suggest that *Z. sansibaricus* is the most tolerant species, occurring in the most exposed zones such as upper-littoral zones that are more subject to drying. These data agree with those of Rabelo *et al*., (2015), who found that some *Zoanthus* occurs in the most exposed reef areas.

According to Connell (1972), the most likely reason that species of mid-littoral live in physiologically difficult conditions, where they are strongly affected by drying, is that they are less competitive than other species that occupy the lowest tidal levels. The identification of *Z. sansibaricus* in upper-littoral zone supports this hypothesis, suggesting that this species is more tolerant to desiccation conditions and sunlight (UV) exposure, occurring at sites that are well exposed during low tide and where no other cnidarian occurs.

For many benthic organisms of rocky shores, desiccation tolerance implicates aspects of cellular biochemistry, such as lowering the water content of the cells and the ability to deal with the rise in osmotic pressure due to water loss (Little *et al*., 2010). However, the biochemical and physiological mechanisms that account for the tolerance of *Z. sansibaricus* are unknown. Apparently, *Z. sansibaricus* is able to cope with these problems better than the other zoanthids studied. *Z. sansibaricus* shows greater tolerance to desiccation conditions compared with *P*. cf. *mutuki* and *P. tuberculosa*, as indicated by its wide distribution along the entire littoral zone. At a Caribbean coral reef, Koehl (1977) observed a similar pattern, where a zoanthid species colonized areas near infra-littoral zone, in areas with high water flow, whereas another zoanthid species settled drier areas.

The morphology of polyps can also influence the distribution of zoanthids in littoral zones. *Z. sansibaricus* and *P. tuberculosa* were found in areas subject to strong currents and waves, whereas *P*. cf. *mutuki* occurred in more sheltered areas. Koehl (1977) offered that the small, connected polyps of some zoanthids can minimize the mechanical effect of constant water flow, simplifying their occurrence near infra-littoral zone, compared with the large, separate polyps of other zoanthids. The strong inter polyp attachment of colonies of some zoanthids may raise the tolerance of a polyp colony to waves and constant water flow, generating a distribution pattern based on their adaptive morphological specifications (Rabelo *et al*., 2015).

Unlike to the dominant water currents of Oman Sea on the eastern coast of Hormuz Island, these currents at the west coast are weak. Accordingly, it can be concluded that the transmission of zoanthid larvae by these currents and consequently higher rate of reproduction (Bahmani *et al*., 2015a) lead to higher abundance of zoanthids at the east site than the west site. However, *P*. cf. *mutuki* was more abundant at the west site than the east site due to its lower adaptation in coasts with the strong sea water currents. This zoanthid species occurred in areas that are exposed only occasionally, where it formed dense colonies. In littoral zone of Hormuz Island, *P*. cf. *mutuki* is found mainly in shallow submerged areas, where it is more abundant. Its limited occurrence in low-littoral zone suggests that *P*. cf. *mutuki* is less adapted to adverse factors than other species, and although it is a tight competitor, it lacks tolerance to drying and long periods of exposure to sunlight.

It was shown that desiccation stress during low tides affects the distribution of zoanthids. Sebens (1982) observed that some of zoanthids can survive only a few hours of exposure to

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the sunlight because of its disability to retain water. According to Herberts (1972), the degree of exposure appears to be the defining factor on distribution of zoanthids. Lower substrate slope causes less exposure of zoanthids to drying in tide time, resulting in increased abundance of zoanthids (Bahmani *et al*., 2015b). Since the substrate slope in the west coast is higher than the east coast slope, the abundance of zoanthids in the west coast is lower than the east coast.

4. Conclusion

The present study identified some physical and biological factors responsible for distribution of zoanthids in littoral zone of Hormuz Island at north of the Strait of Hormuz of the Persian Gulf. Apparently, distribution of zoanthids in littoral zone is influenced by both physical and biological factors. Exposure to desiccation seems to be one of the main reasons for distribution of zoanthid species in sampling transects, given that these benthic animals are exposed during spring low tides; therefore, the time of exposure determines the area of occurrence, some species being less tolerance than others. The substrate composition also had measurable effects using CRI. On the other hand, CRI reflects and describes the range of the species' distribution which is related to the response of the zoanthid communities to substrate composition. Knowledge of the ecology of zoanthids and their spatial distribution is important for understanding the survival capability and dynamics of marine communities developed on hard bottom substrate, and continuous monitoring is necessary to follow the changes in the long term. Also, changes in distribution pattern of zoanthids over time can be used as indicators of human impact, encouraging the implementation of reef conservation programs. However, the findings of present study are concerned only with 3 species of zoanthids in a particular geographic region. The study calls upon widespread sampling from different locations along with estimation of sea water parameters to further understanding of the interaction of benthic communities with their environments and how they evolve under rapidly changing environmental conditions affected by anthropogenic activities. Further studies are also needed to evaluate the possibility of any negative consequence of abiotic factor variation on the morphology, types and survival of zooxanthellae of zoanthids in littoral zone of Hormuz Island.

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