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Intertidal distribution of zooxanthellate zoanthids (Cnidaria: hexacorallia) along the coastal Saurashtra, Gujarat, India

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ABSTRACT

Distribution of zooxanthellate zoanthids Palythoa mutuki, Palythoa tuberculosa and Zoanthus sp. was studied on rocky Intertidal areas at Vearval, Sutrapada, Dhamlej and at Kodinar along the coastal Saurashtra, Gujarat, India. The Intertidal area was divided into four zones based on extent of exposure. Distribution and population quantification were studied using belt transects and quadrates. All the species exhibited habitat preference and were confined to large tide pools of mid - lower intertidal area. Palythoa mutukia nd Zoanthus sp. were dominant in zones 3 and 4, respectively at Sutrapada, Dhamlej, and Kodinar while Palythoa tuberculosa was absent at Veraval. Ecological attributes like abundance, density and frequency of occurrence of species exhibited significant spatio-temporal variations. Seasonal variability of sea water parameters was correlated with ecological attributes of species; where pH showed significant correlation with mean seasonal abundance of P. mutuki (R^2= 0.79, p<0.01)and P. tuberculosa (R^2= 0.64, p<0.01) at different study sites.

Key words: Abiotic factors, Gujarat, Intertidal distribution, Saurashtra coast, Zoanthid biodiversity

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INTRODUCTION

The intertidal zone of rocky shores and its faunal and floral community have been studied intensively in last 3-4 decades [1]. Organisms dwelling in intertidal zone are often grouped in specific pattern which are caused by different kinds of physical and biotic factors [2, 3]. The intertidal or coastal environments are highly variable in terms of time and space as compared to the pelagic environment and, therefore, intensive sampling is needed to find out the controlling variables of species distribution [4]. Amongst all the animals dwelling in marine environment, few groups have so far not been studied well. Zoanthids are generally found as prominent animal community in the reef areas where corals are not found extensively [5, 6]. Although common animal of in the marine environment; zoanthids are not often studied because their taxonomy is difficult [7]. So far, a total of 354 species of zoanthids have been reported from the world [8]. Zoanthids have a simple body plan that lacks distinct morphological characters for species level identification, a high level of intraspecific variation in terms of coloration, and trapping of sand and detritus material in the mesoglea makes the internal examination of the body problematic [9, 10].Thus there are several reasons behind the confused taxonomy of the group.

The coastal areas of Saurashtra are rich in marine biodiversity and total 180 species of macrobenthic fauna have been reported so far [11]. The zoanthid fauna of the Saurashtra coast have not been studied well and earlier the identification of the species were at generic level only [12]. In previous studies, two species of the genus *Palythoa* have been identified that include *Palythoa tuberculosa* and *Palythoa mutuki* from the Saurashtra coast [13]. Therefore, the main objective of the study was to examine the variation in the population and distribution pattern of zoanthids at four different study sites with special reference to habitat characteristics, abiotic factors and seasonal variations.

MATERIALS AND METHODS

The present study was carried from April 2011 to March 2013 at four different locations, Veraval (20^0 54’ 37" N, 70^0 21’ 04” E), Sutrapada (20^0 49’ 53" N, 70^0 29’ 17” E), Dhamlej (20^0 46’ 29" N, 70^0 36’ 19” E) and Kodinar (20^0 45’ 29" N, 70^0 39’ 39” E) situated along the Saurashtra coast (Fig. 1). The intertidal area of each location varies in terms of exposure area and geomorphology. The intertidal area of Veraval is rocky with upper zone made up of sandy shore. The lower intertidal zone of Veraval ends with steep slope in sub tidal zone. The intertidal areas of Sutrapada, Dhamlej and Kodinar are mostly rocky in nature with small to large tide pools. The exposure area or width of the intertidal area varies location to location, maximum exposure was observed at Dhamlej (150 m) followed by Sutrapada (140 m), Kodinar (130 m) and Veraval (60 m). The width of the exposure area varies with the season with an average size of 120 meter observed at Dhamlej, Sutrapada and Kodinar while average width of exposed intertidal area at Veraval was 50 meter.

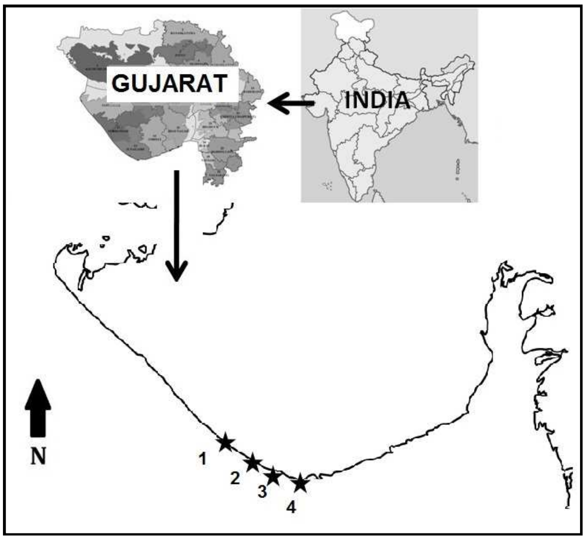

Fig. 1. Map of study area. 1. Veraval, 2. Sutrapada, 3.Dhamlej and 4.Kodinar

In the present study three species of zooxanthellate zoanthids, *Palythoa mutuki* (Haddon & Shackeleton 1891) (Fig. 2a), *Palythoa tuberculosa* (Esper 1791) (Fig. 2b) and *Zoanthus* sp. (Fig. 2c) were identified using the identification key provided by Reimer et al. [14]. Each of the three species forms colonies that are attached to hard substrata. These species are distributed more or less across the entire intertidal area so the intertidal area was divided in upper (Zone 1), middle (Zone 2) and lower zone (Zones 3, 4) to find out the exact distribution pattern. All the four study sites were surveyed on monthly basis for the sampling.

Colony count using the belt transect method is the most appropriate method used for the sampling of zoanthid population [15] but in the present study, the size of the colonies of all the species observed at each study sites were very large (10m× 10m or more) so the colony count could not be adopted for sampling. Therefore, instead of colony count, polyp count method was adopted using 0.25 m^2 quadrate [16]. Total 10 belt transects were laid perpendicular to the shore line and 0.25 m^2 quadrates were laid at about 10 -15m apart on each transect at each study site. Among the abiotic factors, surface water temperature, pH and salinity were recorded using digital instruments.

Each study site was sampled monthly for various ecological attributes such as abundance, density and frequency of occurrence of the species. The monthly data were complied for different seasons viz. winter (November to February), summer (March to June) and monsoon (July to October). Monthly data were also recorded for three different abiotic factors. In statistical analysis of the data two-way ANOVA without replication was applied to determine the spatial and temporal differences between four sites and between three seasons. Regression and correlation coefficient tests were applied to assess the influence of abiotic factors on the population density of the species.

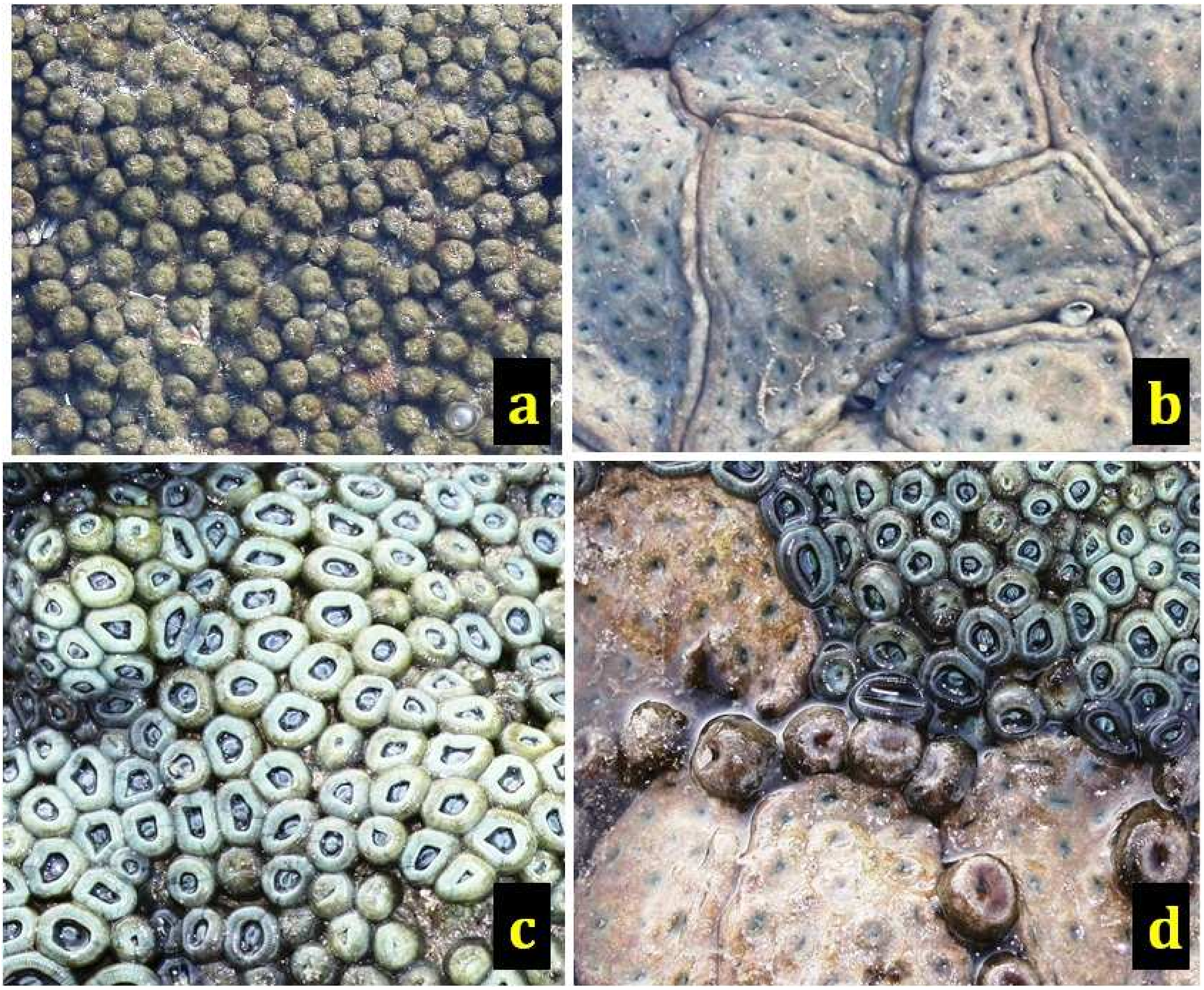

Fig. 2.Zoanthid diversity of study area (a) *Palythoamutuki*(Haddon &Shackeleton, 1891) (b) *Palythoatuberculosa*(Esper 1805) (c) *Zoanthus* sp. (d) Mix colony of zoanthids

RESULTS AND DISCUSSION

The mean sea water temperature varied between different stations. Maximum fluctuation in temperature (33.2 ^{0}C to 27.5^{0}C) was recorded at Veraval (Table. 1). The temperature did not fluctuate much at other stations. The mean sea water pH did not fluctuate between different stations in different seasons. Maximum pH 8.36 was observed at Kodinar during monsoon season while minimum pH 7.77 was recorded at Dhamlej in monsoon. The mean sea water salinity varied between different stations in different seasons. At Veraval, the mean sea water salinity varied between 39.7% in summer to 30.1% in monsoon, possibly due to the addition of fresh water in sea water during monsoon (Table. 1).

Table 1. Seasonal variation in the mean values of different abiotic factors at different stations

	Sutrapada	Dhamlej	Kodinar	Veraval
Sea water temp (°C)				
Winter	28.46 ± 0.78	30.8 ± 0.92	29.76 ± 1.59	27.53 ± 1.70
Summer	30.42 ± 0.55	32.45 ± 1.62	32.27 ± 1.68	33.2 ± 1.70
Monsoon	29.15 ± 0.55	28.7 ± 1.41	30.75 ± 1.06	31.1 ± 0.95
Sea water pH				
Winter	8.27 ± 0.29	8.06 ± 0.09	8.18 ± 0.07	8.12 ± 0.06
Summer	8.12 ± 0.17	8.34 ± 0.19	8.27 ± 0.19	8.26 ± 0.19
Monsoon	8.14 ± 0.10	7.77 ± 0.26	8.36 ± 0.29	8.17 ± 0.23
Salinity				
Winter	36.62 ± 1.09	37.66 ± 1.60	37.63 ± 1.38	39.7 ± 1.53
Summer	39.42 ± 1.78	38.32 ± 1.57	39.63 ± 1.38	37.63 ± 1.38
Monsoon	32.25 ± 0.34	33.7 ± 0.97	30.1 ± 1.80	30.1 ± 1.80

At all study sites, it was observed that each of the species were mostly confined to the lower intertidal zone in association with the presence of deep and large tide pools and probably because of the presence of water during low tide. The average width of the lower intertidal zone was observed to be 40m at Sutrapada, Dhamlej and Kodinar, while at Veraval the width of the lower intertidal zone was observed to be only 20m. In lower intertidal zones of Sutrapada, Dhamlej, and Kodinar, the maximum abundance of *Palythoa mutuki* and *Palythoa tuberculosa* were observed in zone 3while Z*oanthus* sp. was observed abundant in Zone 4 (Table 2).At Veraval, both *Palythoa mutuki* and Z*oanthus* sp. were observed abundant in Zone 3 while the distribution of *Palythoa tuberculosa* was not observed in intertidal zone (Table 3).As mentioned earlier, species of genus *Palythoa* were observed to be abundant in zone 3 of lower intertidal area.

Table 2. Intertidal distribution of zoanthids at Sutrapada, Dhamlej and Kodinar

Species	Study Site	Abundance (No. of Polyps/0.25 m^2)			
		Zone 1	Zone 2	Zone 3	Zone 4
		0- 20 meter	20-80 meter	80-100 meter	100-120meter
P. mutuki	Sutrapada	0	0	406	216
	Dhamlej	0	0	460	308
	Kodinar	0	0	450	435
P. tuberculosa	Sutrapada	0	0	536	484
	Dhamlej	0	0	511	462
	Kodinar	0	0	605	452
*Zoanthus*sp.	Sutrapada	0	0	0	480
	Dhamlej	0	0	110	559
	Kodinar	0	0	140	639

Table 3. Intertidal distribution of zoanthids at Veraval

Study Site	Species	Abundance (No. of Polyps/0.25 m^2)		
		Zone 1	Zone 2	Zone 3
		0- 20 meter	20-40 meter	40-60 meter
Vearaval	*P. mutuki*	0	0	274
	P. tuberculosa	0	0	0
	Zoanthus sp.	0	0	386

Palythoa mutuki was observed as prominent species in zone 3 of all the sites. The abundance of the species was much higher than its density at all the study sites. Maximum density and abundance of the species was observed at Dhamlej followed by Kodinar, Sutrapada and Veraval. The density of the species declined during the monsoon and winter season (Fig. 3a, 4a). The species required specific kind of micro habitat for survival. Maximum density of the species was observed in the large tide pools filled with water. The lower intertidal area of Kodinar, Sutrapda and Dhamlej are mostly covered by large tide pool while small size tide pools were observed at Veraval. The frequency of occurrence of *P. mutuki* was observed increasing during winter and summer but it was observed declining during monsoon season (Fig. 5a).

Palythoa tuberculosa was observed to be prominent species of zone 3 at Dhamlej, Sutrapda and Kodinar, but its distribution was not observed at Veraval. The abundance and population density of the species was observed to be high. Maximum density and abundance of the species was observed to be high at Kodinar, followed by Dhamlej and Sutrapda, respectively, during summer season while the density of the species was declining during the other two seasons (Fig. 3b, 4b). Maximum density of the species was observed in shallow and large tide pools filled with water. The frequency of occurrence of *P. tuberculosa* was observed increasing during winter and summer but it was observed to be declining during monsoon season (Fig. 5b).

Zoanthus sp was observed in Zone 4 of lower intertidal area of all the sites. The abundance of the species was observed to be very high as compared to its density at all the study sites (Fig. 3c, 4c). Maximum density and abundance of the species was observed to be high at Kodinar followed by Sutrapda, Dhamlej and Veraval while the density of the species was declining during other two seasons. The species was mostly observed to be abundant near the lowest low-tide line where water is available during low tide. The frequency of occurrence of *Zoanthus*Sp.was observed in be increasing during winter and summer but it was observed to be declining during monsoon season (Fig. 5c).

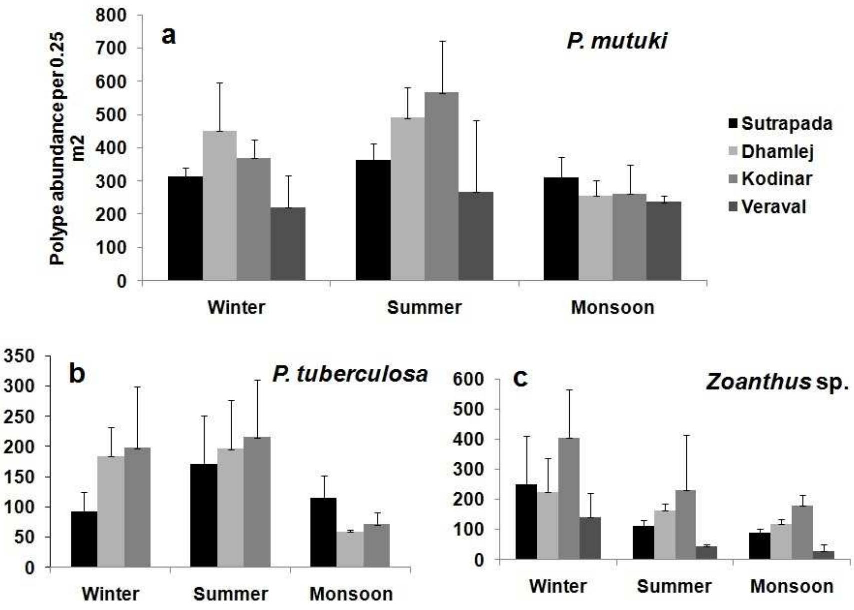

Fig. 3. Seasonal mean variation in density of different zoanthid species of different study sites

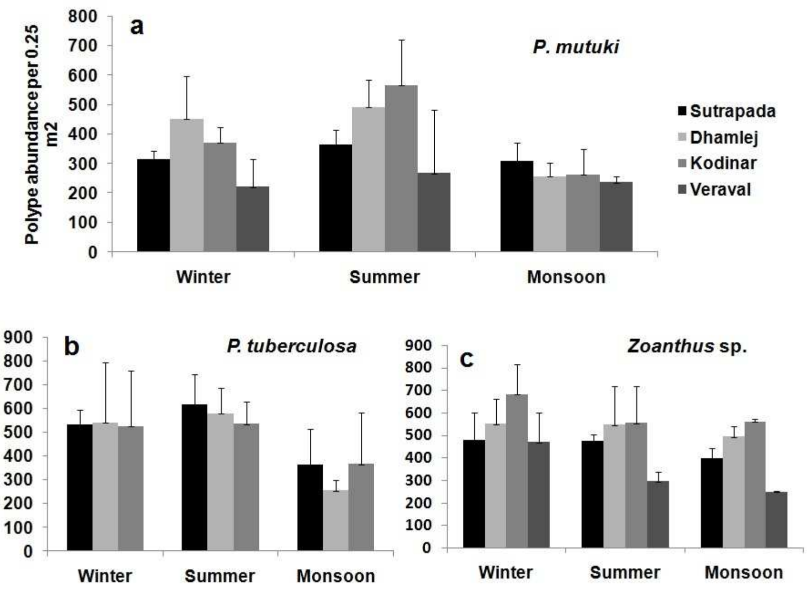

Fig. 4. Seasonal mean variation in abundance of different zoanthid species of different study sites

The species belonging to genera such as *Palythoa* and *Zoanthus* are very common in rocky intertidal areas or coral reefs and have a great influence on the local benthic fauna. Worldwide, several studies have been carried out on the population dynamics and intertidal distribution of zoanthids [17] but as far as the Indian subcontinent is concerned, very few studies have been carried out on the population dynamics and ecology of zoanthids [18]. We observed that zoanthid species required specific kind of microhabitat for survival and growth. *P. mutuki* and *P. tuberculosa* were very common in Zone 3 of the lower intertidal area where specific kind of microhabitats, like wide (2 to 5m) and deep (0.5 to 1m) tide pools were available. Irei et al. [15]conducted a study on the distribution pattern of zoanthids at Okinawa Island, Japan and have reported that density of different species of genera like *Palythoa* and *Zoanthus* were high in different kinds of microhabitats such as reef crest, reef slope and reef moat. Zoanthids use sand particles and detritus material present in the water column to make their structure [19]. Due to different kind of industrial and mining work that are carried out along the coastal region of the study sites, the present study area is facing huge problems of sediment load which on the other hand help the zoanthids to grow their populations. Except for sediment, the geomorphology and physiographic characters, such as flatness of the intertidal area which reduces wave action and presence of wide and large tide pools that remain filled with the water during low tide, also favor the growth of zoanthids.

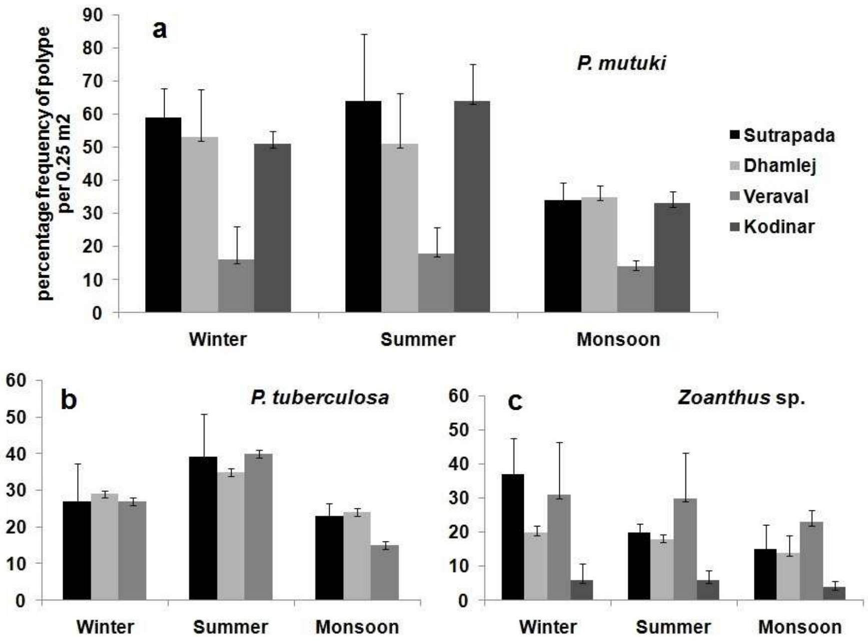

Fig. 5. Seasonal mean variation in frequency of occurrence of different zoanthid species of different study sites

In the present study, *P. mutuki* was observed as the dominant zoanthid species at all the study sites. The results of ANOVA test suggested that non-significant variation was observed for the mean values of density and abundance of the species, but significant variation was noted for the mean values of frequency of occurrence of the species for different study sites and different seasons (Table 4). Maximum density of the species was observed during summer as compared to other seasons which may be due to the maximum exposure observed during the months of summer. Maximum density and abundance of the species was observed at Kodinar, Dhamlej and Sutrapda because the rocky intertidal areas of these study sites are flat platform in shape and made up of large number of tide pools of different sizes and shapes. However, regression and correlation analysis between different abiotic factors and abundance of the species for different sites and seasons showed non-significant results except for pH that showed moderately significant correlation with the abundance of the species in monsoon season at Veraval (Table 5) where pH value fluctuations were observed to be high in different seasons.

Table 4. Results of the Two – way ANOVA without replication analysis of the mean seasonal density, abundance and frequency values of the three species of zoanthids sampled at four different sites (* p < 0.05; ** p < 0.01)

Species	Source of variation	Density	Abundance	Frequency
P. mutuki	Stations	3.63	3.02	**17.05****
	Seasons	2.11	4.32	**9.06****
P. tuberculosa	Stations	0.51	0.77	0.34
	Seasons	5.35	**25.61****	**16.35****
Zoanthus sp	Stations	4.26	**16.13****	**12.23****
	Seasons	2.83	**6.27***	3.74

The distribution of *P. tuberculosa* was patchy at Kodinar, Dhamlej and Sutrapda in Zone 3 of lower intertidal area. As per the ANOVA results, non-significant variation was observed for mean values of density, abundance and frequency of the species between different study sites but significant variation was observed for the mean values of abundance and frequency of the species between different seasons (Table 4). This kind of phenomena was observed due to the discontinuous and patchy distribution of the species at different study sites and another possible reason could be that the species may be competing with *P. mutuki* for space. Perez et al.[20] have studied the structure of animal community associated with *Palythoa caribaeorum* and stated that the animal like barnacles which are associated with *Palythoa caribaeorum* compete for the space for their survival. However, regression and correlation analysis between different abiotic factors and abundance of the species for different sites and seasons showed non-significant results except for pH that showed moderately significant correlation with the abundance of the species at Sutrapada and Kodinar (Table 5). Distribution of the species was not observed at Veraval because *P. tuberculosa* are quires wide and deep tide pools for survival and they were not available at Veraval.

Table 5. Results of the regression and correlation coefficient analysis between mean seasonal abundance of zoanthid species and mean sea water temperature, salinity and pH (* p < 0.05; ** p < 0.01)

	Sutrapada		Dhamlej		Kodinar		Veraval	
	Regression equation	R^2 value	Regression equation	R^2 value	Regression equation	R^2 value	Regression equation	R^2 value
Water Temp. (°C)								
P. mutuki	y = 23.39x - 354.7	0.255	y = -1.425x+ 468.9	0.002	y = 47.54x - 1045	0.221	y = 16.37x - 270.5	0.12
P. tuberculosa	y = 38.67x - 606.0	0.082	y = -19.75x+ 1103.0	0.042	y = -17.34x+ 1033	0.034		
*Zoanthus*sp.	y = -1.145x + 492.1	0.002	y = 4.811x + 424.3	0.004	y = 9.112x + 319	0.012	y = 28.47x - 518	0.427
Salinity								
P. mutuki	y = 6.539x +94.76	0.187	y = 37.02x - 947.7	0.373	y = 28.47x - 616.4	0.463	y = 9.110x - 99.84	0.035
P. tuberculosa	y = 29.45x - 548.2	0.448	y = 37.35x - 890.8	0.153	y = 16.72x - 122.4	0.185		
*Zoanthus*sp.	y = 15.88x - 125.6	0.338	y = 15.64x - 7.336	0.046	y = 17.13x - 29.44	0.257	y = 28.69x - 693.1	0.402
pH								
P. mutuki	y = -325.2x +2990	0.211	y = 325.9x - 2221	0.211	y = 41.16x+ 93.17	0.001	y = 101.6x - 8102	**0.720 ****
P. tuberculosa	y = -165.88x+ 1407	**0.648 ****	y = 557.7x - 4034	**0.573 ****	y = 50.38x+ 910.6	0.002		
Zoanthus sp.	y = -462.5x + 4234	0.13	y = 381.9x - 2528	0.464	y = 77.51x - 38.22	0.006	y = 431.1x - 3174	0.147

The distribution of Zoanthus sp. was observed mostly in zone 4 of the lower intertidal area of different sites. On some occasions, the colonies of *Zoanthus* sp. were observed coexisting with the colonies of *P. tuberculosa* and *P. mutuki* in the intertidal areas (Fig. 2d) of the coastal Saurashtra, but in this kind of mixed colonies *P. tuberculosa* was found as the dominant species. Maximum density and abundance of the species was observed at Kodinar followed bySutrapda, Dhamlej and Veraval because large colonies of the species were distributed in different patches of the zone 4 of the lower intertidal areas of the sites. The results of ANOVA revealed significant variation among the mean values of abundance of the species at different sites in different seasons. The results of ANOVA also showed significant variation for the mean values of frequency of occurrence at different stations (Table 4). This kind of phenomena was observed due to the patchy distribution of the species and the fluctuations in the width of the exposure during different seasons. It has been reported that different kinds of abiotic factors, seasons, and geomorphology of the intertidal area have immense effects on the intertidal distribution of benthic fauna along the Saurashtra coast [21, 22, 23]. However, regression and correlation analysis between different abiotic factors and abundance of the *Zoanthus* sp for different sites and season showed non significant results (Table 5).

CONCLUSION

The present study reports the distribution patterns of three different zoanthid species along the coastal Saurashtra, Gujarat. Significant variations were observed for different kinds of ecological attributes like density, abundance and frequency of occurrence for different zoanthid species. Different kinds of abiotic factors also play significant role in the spatio-temporal distribution of the zoanthid species. Amongst the three species studied, *P. mutuki* was observed to be dominant as compared to other zoanthid species in the study area and it was competing with other two species for the space. Long-term monitoring on the distribution and population dynamics of zoanthid species is needed to find out its impact on the local benthic fauna.

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