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Distribution pattern and community structure of zoanthids (Zoantharia) along the coast of Saurashtra, Gujarat, India

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Coral reef environments support a great diversity of benthic organisms, of which zoanthids form an integral part. Studies have been carried out regarding the degradation of coral reefs and changes in community structure under the present dynamics of climatic change. Zoanthids are dominant among the observed fauna in these degrading reef ecosystems. Zoanthids are observed at mid and lower intertidal zones beyond 20 m from highest high tide level. In the present study, distribution patterns of zoanthid species along three coastal villages of Saurashtra coast, Gujarat were studied. Line intercept transect method was performed to assess the zoanthid coverage. A total of seven species of zoanthids were recorded during the survey. Palythoa mutuki *formed the abundant species in the area with 45.99% coverage, followed by* Zoanthus sansibaricus *with 33.67% and* Zoanthus *cf.* sansibaricus *with 12.26% coverage. Abiotic parameters (sea surface temperature, salinity, dissolved oxygen, pH) and nutrient data (ammonia, phosphate, total suspended solids and nitrate) were also recorded during sampling to determine their influence on zoanthid colonies. Higher levels of DO were found to favour the growth of* Palythoa mutuki *and* Isaurus tuberculatus*, whereas increased SST was tolerated by* Palythoa tuberculosa *only. Ammonia and phosphate were negatively impacting the growth of* Palythoa mutuki *and* Zoanthus *spp. The study provides new information on quantitative zoanthid distribution and the dynamic changes exhibited by zoanthids in relation to various environmental parameters. Zoanthids could be looked upon as an adaptive species which may support reef resurgence in degraded reefs under stress from climate change effects.*

Keywords: Zoanthids, quantitative distribution, *Palythoa* sp., *Zoanthus* sp., *Isaurus tuberculatus*, abiotic parameters, SST, DO, nutrients

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INTRODUCTION

Marine biodiversity provides unique sets of goods and services to society and generates employment to millions of people involved in fishing, aquaculture and tourism. But these anthropogenic activities often result in overfishing (Hughes *et al.*, 2007), water pollution, extra nutrient input (Szmant, 2002) and sedimentation from terrestrial runoff (De'ath & Fabricus, 2010). The degradation of water quality in reef ecosystems results in a shift from coral (or other alternative taxa) to algal dominated communities (Bellwood *et al.*, 2004; Knowlton & Jackson, 2008) thereby eroding the native species. Water quality and nutrient overloads play crucial roles in determining the succession of pioneering species to climax communities. There are plenty of studies delineating the impact of water quality parameters and nutrient overload on coral benthic communities (Naim, 1993; West & van Woesik, 2001; Bellwood *et al.*, 2004; Loya, 2004; Knowlton & Jackson, 2008) where algae have become dominant due to nutrient overload or degradation of water quality. However, its effects on the occurrence of other benthic taxa are still poorly understood.

The Saurashtra coastline of Gujarat, a species-rich marine region, has reported marine invertebrates, including cnidarians (Venkararaman & Wafer, 2005; Vaghela & Bhadja, 2013). One group of relatively understudied cnidarians are the zoanthids (Zoantharia = Zoanthidea), which are an order of benthic and generally colonial anthozoans that are widespread and occasionally common in many marine ecosystems (Reimer *et al.*, 2010). Zoanthids are widely studied for their bioactive compounds such as pylatoxin and zoanthimine (Moore & Scheuer, 1971; Fukuzawa *et al.*, 1995). Green Fluorescent Protein (GFP) is also a potential resource from zoanthids (Mythili, 2012). Some of the zooxanthellate genera such as *Palythoa* and *Zoanthus* are aggressive benthic competitors (Suchanek & Green, 1981; Sebens, 1982) in favourable environmental conditions. However, they are taxonomically neglected because of high intraspecific variation in their morphological characters. The present study focuses on the biodiversity of zoanthids of the Saurashtra coast and assesses the effect of abiotic and water quality parameters on their distribution, abundance and community structure.

MATERIAL AND METHODS

Study area

The present study was carried out during September to December 2013 along the 8 km stretch of coastal waters in three villages in Saurashtra (Figure 1), viz. Veraval (20.9°N

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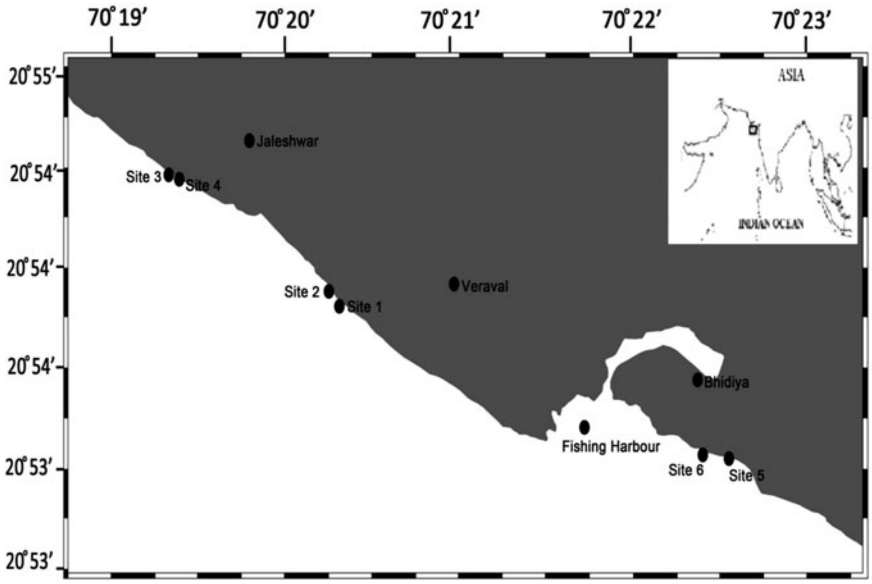

Fig. 1. Sampling sites on the map of Gujarat Coast, India.

70.37°E) (site 1 & 2), Jaleshwar coast (20.91°N 70.33°E) (site 3 & 4) and Bhidiya (20.89°N 70.38°E) (site 5 & 6). All three stations differ significantly in their geomorphology and anthropogenic interference. Veraval intertidal region is rocky with an upper sandy zone that ends in a sharp slope. Jaleshwar is characterized by rocky cliffs and weathered rocks with sharp points. Little human habitation exists near the shore. Bhidiya coast has a rocky intertidal zone which is located at the mouth of Veraval fishing harbour. The shoreline is heavily populated and the coastal waters receive effluents from both domestic households and industries such as fish processing units.

Field survey

The Line Intercept Transect (LIT) method was adopted to estimate intertidal zoanthid distribution, pattern and abundance. The line was stretched perpendicular to the shore towards the zoanthid colony. All biotic and non-biotic components were observed at every 1 m interval along the transect line (Belford & Phillip, 2011). The intertidal zones were divided into five regions to represent the distance from the maximum tide imprint left on the shore during low tide. Zones 1, 2, 3, 4 and 5 were designated based on the depths 0–10, 11–20, 21–30, 31–40 and 41–50 m respectively from the shore line (Belford & Phillip, 2012). Maximum zoanthid abundance was found in zones 3, 4 and 5. Hence, these zones were selected for a horizontal LIT survey (English *et al.*, 1997). Six horizontal LITs with three replicates each spaced at 5 m were done using a 50 m long fibreglass tape stretched parallel to the coast. The fraction of the length of the line intercepted by zoanthids was recorded. This measure of cover expressed as percentage is considered to be an unbiased estimate of the proportion of the total area covered by zoanthids. The intercepts of all underlying zoanthid species, rock, sand, algae and others (anemones, clams and other molluscs) were recorded to the nearest cm. Digital photographs of zoanthids were taken with a Canon D10 camera and videographs of LIT using Sony CybershotRX100. Identification of zoanthids was based on taxonomic characters following Reimer *et al.* (2010); Häussermann (2004). Data for environmental parameters such as sea surface temperature (SST), salinity, dissolved oxygen (DO), pH, total suspended solids (TSS), phosphate (PO_4), nitrate (NO_2) and ammonia (NH_3) were also recorded during the course of sampling. SST was recorded using a centigrade thermometer, salinity and pH values were estimated using WTW multi-parameter kit, DO was estimated by Winkler's method and estimation of ammonia (phenol hypochlorite method), phosphate and nitrate (APHA-AWWA, 1998) was done using a 'Spectroscan UV 2600, Thermo Scientific' spectrophotometer. Geographic position of each transect was fixed using 'GARMIN Model Oregone 6' GPS. Statistical analysis was performed using Primer 6 (Carr, 1996) and SPSS *v*.19.

Community analysis

The relative abundance (RA), which is an index of commonness or rarity, of each zoanthid species was calculated (Rilov & Benayahu, 1998) as:

$$\text{Relative abundance } (RA)\frac{P_i}{P_{\text{total}}} \times 100$$

Where, P_i is the pooled living coverage of the ith species from 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 resulting 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 & George, 2010).

Univariate analysis

Based on zoanthid coverage of each individual species during the transects, various diversity indices including Shannon–Weiner diversity index(H'_e), Simpson's diversity index(1-Lambda), Margalef's richness index (d) and Pielou's evenness index (J') were calculated.

Graphical descriptors

K-dominance curves were constructed in order to find the dominant species at each site and its contribution to the total live coverage. The starting point of curve and its inclination is indicative of the diversity of the site i.e. more elevated curves which start high have lower diversity and vice versa. Hence, K dominance curves help in assessing and comparing sites qualitatively.

Multivariate analysis

A SIMPER analysis to determine the most important taxa responsible for causing dissimilarity (or similarity) was performed using PRIMER. The density data of the species was transformed to ln $(x + 1)$ values, in order to reduce the effect caused by extremes, thus allowing the rare species to exert some influence on the results while reducing the impact of most common taxa. Species falling above a 40% similarity threshold were considered to be those most important in determining community structure.

Statistical analysis

In order to find the correlation between different abiotic parameters, nutrient level and zoanthid abundance, two-tailed Pearson correlation was performed using SPSS *v.* 19. The data were subjected to pre-treatment by transformation to ln $(x + 1)$ values in order to avoid the effects of outliers and to establish a linear relationship between the variables. The density of all the zoanthid species was correlated with abiotic parameters such as SST, pH, salinity, DO, NH_3, PO_4, TSS and NO_3.

RESULTS

A total of seven species of zoanthid, namely *Zoanthus sansibaricus* (Figure 2A, B), *Palythoa tuberculosa* (Figure 2C), *Zoanthus vietnamensis* (Figure 2D), *Isuarus tuberculatus* (Figure 2E) *Palythoa mutuki* (Figure 2F, H), *Zoanthus* cf. *sansibaricus* (Figure 2G) and *Zoanthus* sp. (Figure 2I), belonging to two families, Sphenopidae and Zoanthidae were recorded. Morphotype of *Z. sansibaricus* were observed during the course of study, one with an orange (Figure 2A) and the other with a green oral disk (Figure 2B). *Palythoa mutuki* was also recorded in two variants, one with a green (Figure 2F) and the other with a brown oral disk (Figure 2H). Macrolagae, such as *Ulva* sp., *Caulerpa* sp., *Enteromorpha* sp., *Gracilaria* sp., calcified algae etc., were forming one of the major taxa across all the sites. Other benthic organisms that were observed in different zones were molluscs such as *Onchidium verruculatum, Aplysia* sp., *Turbo* sp., *Patella* sp., *Chiton* sp., sea anemones, *Nereis* sp., crabs and barnacles (Figure 3).

Community analysis

Relative abundance analysis showed that Veraval coast (sites 1 and 2) is rich in zoanthid biodiversity. All the species of the zoanthids found, namely *P. mutuki, Z. vietnamensis, Z. sansibaricus, Zoanthus* cf. *sansibaricus, Zoanthus* sp., *I. tuberculatus* and *P. tuberculosa* were recorded from the Veraval coast out of which *P. mutuki*was found to be the most dominant species. Jaleshwar (sites 3 and 4) showed presence of four species with dominance of *P. mutuki* and *Z. sansibaricus*, while patches of *Z. vietnamensis* and *Zoanthus* cf. *sansibaricus* were also recorded. Three species of zoanthids were observed at Bhidiya (sites 5 and 6) with *Z. sansibaricus* the dominant species (Table 1). Overall dominance of a single species was lacking in the present study, as variations were observed in the number of species and their composition at all the survey sites. *Palythoa mutuki* with overall relative abundance of 45.99% is classified in the 'dominant' category, followed by *Z. sansibaricus*, which showed a relative abundance of 33.67% and also placed in the 'dominant' category. *Zoanthus sansibaricus* showed a patchy distribution with complete absence at sites 1 and 4 (Table 1). The relative abundance of other spp., viz. *Z. vietnamensis, Zoanthus* sp. and *I. tuberculatus* was less than 1%. Therefore, these species were categorised as 'uncommon'. *Isuarus tuberculatus* was observed only at Veraval coast along with *Zoanthus vietnamensis* and *Zoanthus* sp.

Univariate analysis

Margaleff richness index (d), which weights number of species rather than individuals, ranges from 2.5 to 3.5 for any healthy environment (Khan *et al.*, 2004). Margaleff index (d), varied from 1.6 to 6.16 during the course of sampling representing the stressed condition at site 6 and favourable condition at site 2 for the growth of the zoanthid colony (Table 2). Pielou's evenness index (J'), measures the evenness of a habitat and ranges from 0–1 (Turkmen & Kazanci, 2010). A low value for J' indicates less evenness in spatial distribution pattern and as the values approach 1, it indicates that the individuals are distributed equally (Pielou, 1966). Least values for Pielou's evenness index (J') were observed at sites 5 and 6 which show variant distribution of zoanthids at Bhidiya coast. Nevertheless, Veraval and Jaleshwar showed higher J' values indicating relatively even distribution patterns of different zoanthid species. The Shannon–Weiner index (H'_e) which takes into account the number of individuals as well as the number of taxa varies from 0.0–5.0 (Turkmen & Kazanci, 2010). Results are generally found in the range of 1.5–3.5; values above 3.0 are considered to represent stable environmental conditions, whereas values under 1.0 indicate that there is pollution and degradation of the habitat structure (Turkmen & Kazanci, 2010). In our case, the highest value of H'_e was found at site 2 followed by sites 1 and 4, depicting balanced environmental conditions at Veraval and Jaleshwar coast. Simpson diversity index (1-Lambda) measures the evenness of the community and varies from 0–1 (Turkmen & Kazanci, 2010). In the present study, the maximum value for Simpson index was estimated at site 1 followed by site 2, whereas the lowest value was estimated at site 6, thereby indicating an even distribution pattern of species at Veraval coast and an irregular pattern at Bhidiya coast (Table 2). With its low value starting point and gentle slope, the K-dominance curve confirms more diversity at site 2 followed by site 1 and least diversity at site 6 thereby corroborating the above results (Figure 4).

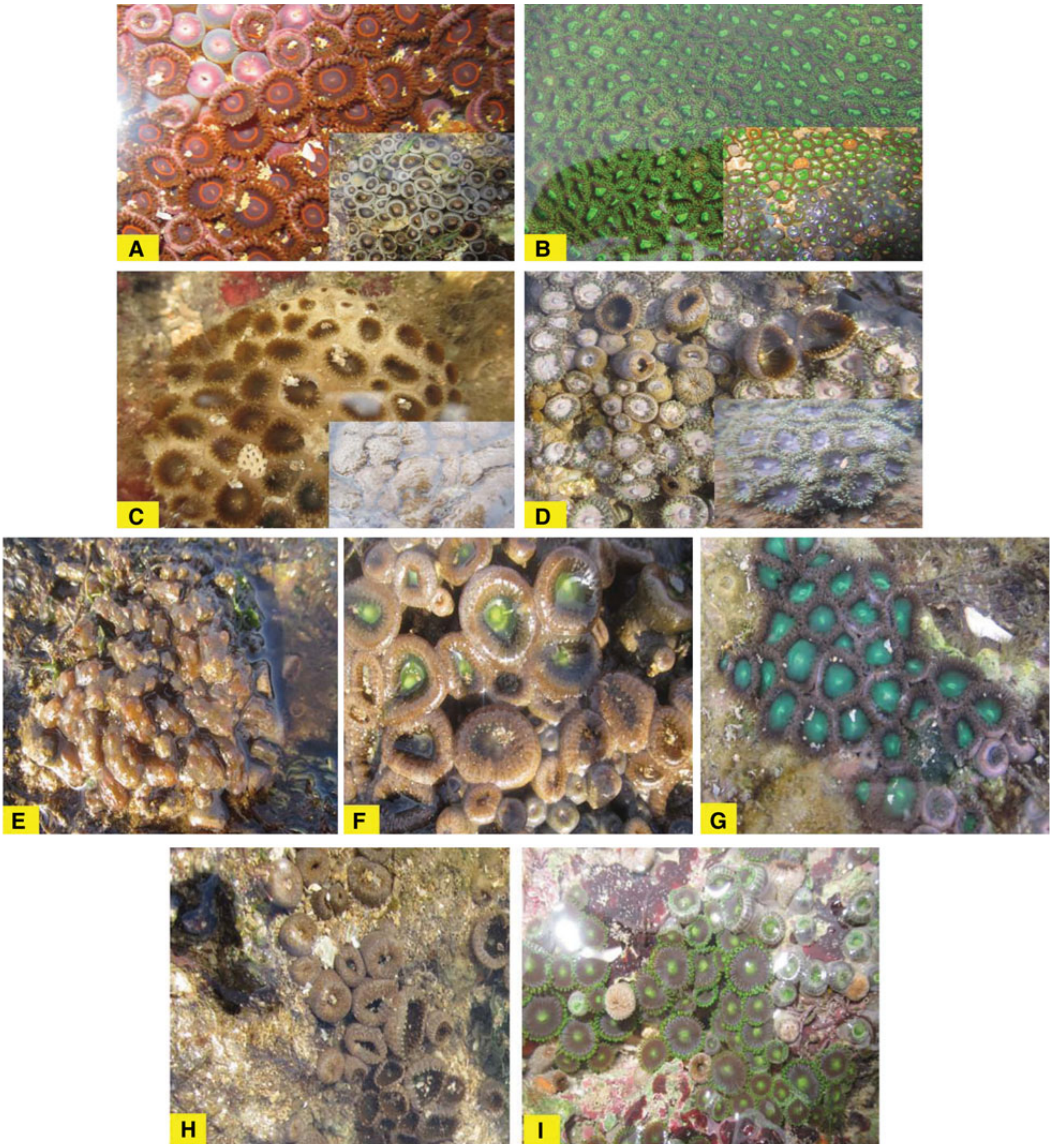

Fig. 2. Brachycnemic zoanthid diversity along the stretch of Saurashtra Coast from Gujarat. (A) *Zoanthus sansibaricus*, orange form, open and closed polyps; (B) *Zoanthus sansibaricus*, green form, open and closed polyps; (C) *Palythoa tuberculosa*, open and closed polyps; (D) *Zoanthus vietnamensis*, open and close polyp; (E) *Isaurus tuberculatus*; (F) *Palythoa mutuki*, green form (G) *Zoanthus* cf. *sansibaricus*; (H) *Palythoa mutuki*, brown form; (I) *Zoanthus* sp.

Multivariate analysis

Results of SIMPER analysis (Table 3) show that presence of *P. mutuki* and *Zoanthus* cf. *sansibaricus* resulted in within-group similarity at Veraval (sites 1 and 2). The average similarity in species composition at Veraval was 46.13%. In a similar manner, *P. mutuki* and *Zoanthus* cf. *sansibaricus* observed at Jaleshwar coast (sites 3 and 4) resulted in within coast similarity, with an average similarity index of 80.72% in species composition. *Zoanthus sansibaricus* was found to be most responsible for Bhidiya (sites 5 and 6) showing within-group similarities with an index value of 61.64%. The highest and lowest average dissimilarity index was observed between Jaleshwar vs. Bhidiya (80.08%) and Veraval vs. Jaleshwar coast (54.81%) respectively. *Palythoa tuberculosa* was found abundant in Veraval and Bhidiya, but absent in Jaleshwar, which made it the most important species accounting for the dissimilarity among zoanthids distributed along the Saurashtra coast.

Statistical analysis

Correlations between different zoanthid species and abiotic factors are shown in Table 4. The results indicate significant

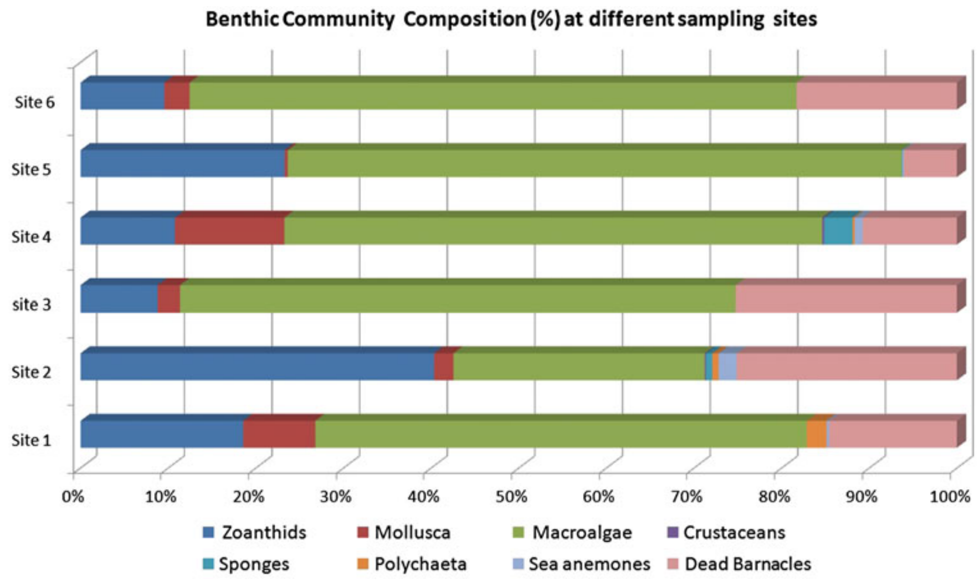

Fig. 3. Benthic community composition at different sampling site.

Table 1. Relative abundance of zoanthids at different sampling sites.

Zoanthid sp.	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Relative abundance
P. mutuki	D	D	D	D	U	U	45.99
Zoanthus vietnamensis	N	U	R	N	N	N	0.33
Zonathus sansibaricus	N	U	A	N	D	D	33.67
Zoanthus cf. *sansibaricus*	U	C	A	A	N	N	12.26
Zoanthus sp.	N	U	N	N	N	N	0.12
Isauruus tuberculatus	N	U	N	N	N	N	0.27
P. tuberculosa	A	N	N	N	N	C	7.49

positive correlation between SST and *Palythoa tuberculosa* with $r = 0.568$ (P value < 0.05). Effect of dissolved oxygen can be seen on species such as *Palythoa mutuki* and *Isaurus tuberculatus*. Pearson correlation analysis shows a significant positive correlation between DO and *P. mutuki* ($r = 0.845$, $P < 0.05$), and a positive correlation of $r = 0.658$ ($P <$ 0.05,) between DO and *I. tuberculatus* (Table 4). Among the nutrients, NH_3 was found to be significantly correlated with *Zoanthus* cf. *sansibaricus* ($r = 0.948$, $P < 0.01$) however negative correlation of $r = -0.973$ (P value < 0.01) was observed with *Palythoa mutuki*. Phosphate (PO_4) was also found to be negatively correlated with *Zoanthus* sp. ($r = -0.654$, $P < 0.05$). No significant effects of salinity, pH, TSS and NO_3 were recorded for different species of zoanthids (Table 4).

Table 2. Biodiversity indices along different sites.

Sample	Margalef index (d)	Pielou's index (J')	Shannon–Weiner index (H'_e)	Simpson index (1-Lambda)
Site 1	4.55	0.8775	2.181	0.9521
Site 2	6.16	0.8696	2.427	0.9485
Site 3	3.62	0.9001	1.978	0.9398
Site 4	4.55	0.8944	2.059	0.9359
Site 5	3.83	0.8614	1.983	0.934
Site 6	1.60	0.8662	1.903	0.9226

DISCUSSION

Relative abundance patterns of zoanthids from three coastal villages (Veraval, Bhidiya and Jaleshwar) were studied. A total of seven species of zoanthids were recorded and variations were observed between the dominant species of zoanthid at each site. This could be due to the difference in geomorphology and water quality parameters at selected sites resulting in different distribution patterns of zoanthids. Environmental factors such as temperature, dissolved oxygen, salinity and nutrient levels played a crucial role in determining the diversity and survival of zoanthids. In the present study, high values of Margalef index, Pielou's evenness index and Shannon–Weiner index were obtained at Veraval, indicating a favourable environment for zoanthid growth whereas low values of d', J' and H'_e represent stressed conditions at Bhidiya. The reason for the high species richness and even distribution patterns at sites 1 and 2 could be due to less pollution at Veraval.

Analysis of water quality parameters revealed high DO at Veraval (5.94 mg L^{-1}) and low DO at Bhidiya (3.27 mg L^{-1}). This supports the Pearson correlation estimation, where a significant positive correlation ($P = 0.034$) was observed between DO and *P. mutuki* followed by DO and *I. tuberculatus* ($P = 0.042$). Both these species were abundant at Veraval but scarce at Bhidiya, thus emphasizing the need for pollution-free waters with high oxygen levels required

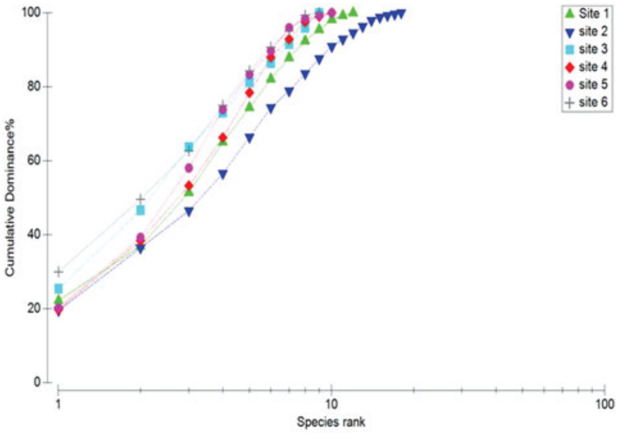

Fig. 4. K dominance curve of the selected sampling sites.

for zoanthid growth. Huang *et al.* (2011) also reported significant positive correlation between zoanthid growth and elevated DO levels.

Sea surface temperature is crucial in determining the concentration of dissolved gases in the sea. Impact of SST on zooxanthellae is responsible for bleaching events affecting zooxanthellae in corals, hydrocorals and zoanthids (Fitt *et al.*, 1993; Saxby *et al.*, 2003; Costa *et al.*, 2005; Kemp *et al.*, 2006). Reimer *et al.* (2007) have studied the seasonal variation of zoxanthellae and reported a positive correlation between *Symbiodinium* zoxanthellae and cold ocean temperatures (<18°C), while a negative correlation has been recorded between *Symbiodinium* and high ocean temperatures (>28°C). However, in the present case, SST was found to be positively correlated with *P. tuberculosa* ($r = 0.568$, $P < 0.05$) similar to the results of Costa *et al.* (2013),where significantly higher densities of zooxanthellae were recorded in

Table 3. Results of SIMPER analysis showing the most important taxa responsible for similarity and dissimilarity between each coast.

Groups	Veraval	Jaleshwar	Bhidiya
Veraval	Average Similarity – 46.13 *P. mutuki* *Zoanthus* cf. *sansibaricus*		
Jaleshwar	Average Dissimilarity – 54.81 *P. mutuki, P. tuberculosa* *Zoanthus* cf. *sansibaricus*	Average Similarity – 80.72 *P. mutuki* *Zoanthus* cf. *sansibaricus*	
Bhidiya	Average Dissimilarity – 79.75 *P. mutuki* *Zoanthus sansibaricus* *Zoanthus* cf. *sansibaricus*	Average Dissimilarity – 80.08 *Zoanthus sanibaricus* *P. mutuki* *Zoanthus* cf. *sansibaricus*	Average Similarity – 61.64 *Zoanthus sansibaricus*

Table 4. Correlation between abiotic parameter and zoanthids.

		Palythoa mutuki	*Zoanthus sansibaricus*	*Zoanthus* cf. *sansibaricus*	*Zoanthus vietnamensis*	*Zoanthus* sp.	*Isaurus tuberculatus*	*Palythoa tuberculosa*
SST	Pearson correlation	−0.219	0.14	0.246	−0.811	0.14	0.14	0.568[a]
	Sig. (2-tailed)	0.676	0.792	0.639	0.05	0.792	0.792	0.024
pH	Pearson correlation	−0.171	0.2	0.105	0.064	0.2	0.2	0.021
	Sig. (2-tailed)	0.746	0.704	0.844	0.904	0.704	0.704	0.968
Salinity	Pearson correlation	−0.064	−0.68	0.015	−0.167	−0.68	−0.68	0.39
	Sig. (2-tailed)	0.904	0.137	0.978	0.751	0.137	0.137	0.445
DO	Pearson correlation	0.845[a]	0.658	−0.778	0.337	0.658	0.658[a]	−0.052
	Sig. (2-tailed)	0.034	0.155	0.069	0.514	0.155	0.042	0.922
TSS	Pearson correlation	−0.66	−0.785	0.598	−0.019	−0.785	−0.785	−0.145
	Sig. (2-tailed)	0.153	0.065	0.21	0.972	0.065	0.065	0.784
NH_3	Pearson correlation	−0.973[b]	−0.443	0.948[b]	−0.605	−0.443	−0.443	0.054
	Sig. (2-tailed)	0.001	0.378	0.004	0.203	0.378	0.378	0.919
PO_4	Pearson correlation	−0.777	−0.654	0.751	−0.142	−0.654[a]	−0.654	−0.25
	Sig. (2-tailed)	0.069	0.159	0.085	0.788	0.042	0.159	0.633
NO_3	Pearson correlation	−0.51	−0.702	0.45	0.193	−0.702	−0.702	−0.273
	Sig. (2-tailed)	0.302	0.12	0.37	0.714	0.12	0.12	0.601

[a]Correlation is significant at the 0.05 level (2-tailed).
[b]Correlation is significant at the 0.01 level (2-tailed).

Zoanthus sociatus with elevated levels of SST. The reason for higher levels of zooxanthellae densities with elevated SST may be due to the influence of other factors regulating their concentration. However, such observations showed negative effects of elevated SST on zooxanthellae densities in *Palythoa caribaeorum* only. Therefore, it can be concluded that different species of zoanthids are impacted differently by temperature. Some zoxanthellae species such as *P. tuberculatus* and *Zoanthus sociatus* are capable of tolerating increases in temperature while species such as *P. caribaeorum* are negatively affected. Neither salinity nor pH was significantly correlated with any zoanthid species in our case unlike the results of Yang *et al.* (2013) where higher correlation has been reported between salinity and *P. tuberculosa* with a conclusion of salinity acting as limiting factor in *P. tuberculosa* growth. Apart from the abiotic factors, the nutrient concentration also affects the benthic distribution pattern. Huang *et al.* (2011), in a study has concluded growth of zoanthid colonies is favoured by nutrient enrichment and increased organic matter concentration. Similar results have been reported by Costa *et al.* (2008) where abundance of Palythoa was noticed from the areas with extra nutrient input. In the present study high levels of NH_3 and PO_4 (3.49 and 0.708 mg L^{-1}) were recorded at Bhidiya and Jaleshwar (0.964, 0.595 mg L^{-1}). A significant positive correlation has been observed between *Zoanthus* cf. *sansibaricus* and NH_3 ($r = 0.948$, $P < 0.01$), while a negative relationship was recorded between *P. mutuki* and NH_3 ($r = -0.973$, $P < 0.01$). A negative correlation of -0.654 ($P < 0.05$) was also found between *Zoanthus* sp. and PO_4, contrary to the results of Hernández-Delgado *et al.* (2008) which reported dominance of zoanthid colonies under hypertrophic, faecal-polluted conditions. The reason for low zoanthid growth despite hypertrophic nutrient conditions could be due to the competition given by extensive growth of macroalgae at both these sites, similar to the studies of Emanuelle *et al.* (2015), where a negative correlation has been obtained between macroalgae and zoanthids. Such negative correlations between algal cover and zoanthids suggest that algae compete for space and probably inhibit the growth of zoanthids. The high nutrient level at Bhidiya could be due to the effluents from polluted water coming from the nearby fishing harbour, fish processing plant, ice plant and other fish processing factories. This is the most polluted site among all the sampled sites resulting in less biodiversity as estimated from biodiversity indices and K dominance curve. Hypertrophic conditions at Jaleshwar were due to discharge of effluents from nearby factories involved in viscose filament yarn manufacturing. In the present study, positive correlations between SST and *P. tuberculosa*, and a positive correlation between *P. mutuki* as well as *I. tuberculatus* with DO, indicate the effect of abiotic factors on zoanthids. A positive correlation of NH_3 with *Zoanthus* cf. *sansibaricus* and negative correlation of *P. mutuki* with NH_3 and negative correlation of PO_4 with *Zoanthus* sp. indicate the effect of nutrient concentrations on zoanthid colonies. Hence it could be inferred that zoanthid distribution pattern varies greatly with abiotic parameters such as SST and DO and nutrient level condition of the habitat. Species such as *P. mutuki* and *I. tuberculatus* prefer certain dissolved oxygen levels for their growth and are not capable of growing in hyperoxic conditions. The elevated levels of SST can be tolerated by species such as *P. tuberculosa* while high levels of NH_3 can be tolerated by *Zoanthus* cf. *sansibaricus*.

The above results in the context of a changing climate indicate that the community structure of zoanthids might be dominated by species which can withstand high SST and high nutrient levels. The study indicates the adaptive capacity of zooxanthellae to environmental changes, which similar species such as corals are lacking. Further, it has been reported that coral reefs will continue to suffer due to high nutrient inputs, bleaching and other anthropogenic activities, leading to shifts in reef patterns towards more aggressive and rapidly growing benthic communities such as zoanthids (Yang *et al.*, 2013). However, the present findings are concerned only with seven species of zoanthids in a particular geographic region. The study calls upon widespread sampling from different locations along with estimation of water quality 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.

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