



GIS based mapping of zoanthids along Saurashtra coast, Gujarat, India

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Original Article

Abstract

Zooxanthellate zoanthids (or. Zoantharia) are the third largest order of Hexacorallia and are an integral part of the coral reef ecosystem. Worldwide coral reefs will continue to suffer under the synergistic effect of anthropogenic agent and climate change, thereby shifting towards more adaptive and resilient species. Zoanthids are looked upon as adaptive species under the current dynamics of climate change. Zoanthids are also studied for their biochemical properties like extraction of zoanthamine, Oxytoxic agent, Green Fluorescence Proteins (GFP). Hence understanding the ecology and spatial distribution patterns of zoanthids is important in formulating conservational and management policies pertaining to marine ecosystems. The present study encompasses the spatial distribution pattern of zoanthids along the Saurashtra coast of Gujarat, India. Nineteen stations have been selected from Okha to Bhavnagar and spatial distribution patterns of eight zoanthid species have been studied using modified belt transect method, GIS and IDW interpolation technique. The results indicated *Palythoa mutuki* as the most common and abundant species along the Saurashtra coast of Gujarat followed by *Zoanthus sansibaricus* and *Palythoa tuberculosa*. While species such as *Zoanthus gigantus* and *Palythoa heliodiscus*, been the rarest species along this coast. The study is first of its kind and attempt has been made to incorporate the modern tools which overcome the constraints of spatial variation in the distribution over traditional methods of biodiversity studies. The study also forms baseline

study to monitor zoanthid progression in the future and developing geo-referenced database along the Saurashtra coast of India for long term permanent transect monitoring and policy framework development.

Keywords: Diversity, distribution, Zoantharia, interpolation, Inverse Distance Weighted (IDW), spatial pattern

Introduction

Zooxanthellate zoantharians (Anthozoa: Hexacorallia: Zoantharia) are a group of marine benthic cnidarians, which are known to play an important ecological role in many marine ecosystems (Santos *et al.*, 2016). Zoanthids enjoy a cosmopolitan distribution from temperate to tropics and from shallow water to deep sea below 5000 m and has been reported to thrive well in the extreme environment such as methane cold seeps (Fossa and Nilsen, 1998; Reimer *et al.*, 2007a; Reimer and Miyake, 2009) showing extreme range of adaptability.

The ecological importance of the zoanthids has been established by Belford and Philip (2012), and highlighted outgrowth of

zoanthids over their more famous scleractinian cousins in southern Caribbean reef ecosystem and indicate the hardness of zoanthid species under present climate variability. A rapid and aggressive growth of *Palythoa tuberculosa* under stressed conditions has been demonstrated by Yang *et al.* (2013), while the consequence of reef phase shifts from corals to zoanthid dominated communities has been documented by Cruz *et al.* (2015). These studies indicate that coral reef will continue to suffer under the synergistic effect of anthropogenic pressure and climate change leading to shifts from coral dominated communities to non reef building organisms such as zoanthids and macroalgae (Done, 1992; Yang *et al.*, 2013; Woesik *et al.*, 2014; Cruz *et al.*, 2015).

Despite being an obvious and ubiquitous part of the coral reef ecosystem, studies pertaining to zoanthids and their significance were always neglected, the reason could be attributed to intraspecific morphological variations and high level of morphoplasticity (Burnett *et al.*, 1997; Reimer *et al.*, 2004; Ong *et al.*, 2013) shown by this group causing difficulty in their taxonomic identification. As a result of this, the taxonomy, diversity and hence distribution of zoanthids remain poorly understood worldwide and even species identification remains problematic (Burnett *et al.*, 1997; Reimer *et al.*, 2004; Sinniger *et al.*, 2005). Hence, further studies are required to fill this lacuna and investigate the diversified role of zoanthids.

Zoanthids along the Indian coast are mainly studied for their role as biochemical compound (Babu *et al.*, 1997; Lakshmi *et al.*, 2004; Veena *et al.*, 2008; Mythili, 2012), for their diversity (Hornell, 1914; Bhattiji, 2010; Pandya *et al.*, 2013, 2015; Trivedi *et al.*, 2014, Joseph *et al.*, 2014,) and for their associates (Chakravarty *et al.*, 2016). The effect of environmental parameters on diversity, distribution pattern and community has been documented by Kumari *et al.* (2015) whereas the negative interaction of corals and zoanthids along the Gulf of Kutch has been reported by Sreenath (2014). However, these studies are based on conventional ways, which provide constraints with respect to time and space with no incorporation of modern techniques such as GIS and remote sensing which helps in formulating geo-referenced database. The geo-referenced database or spatial continuous data (or spatial continuous surface) plays a significant role in planning, risk assessment and decision-making in environmental management. However, such information is not readily available and often difficult and expensive to acquire, especially for marine regions (Li and Heap, 2008). The Geographic Information system (GIS) and modeling techniques provide a powerful tool in natural resource management and biological conservation (Collins and Bolstad, 1996; Hartkamp *et al.*, 1999). As the values of unsampled points could be estimated by using point data, interpolation techniques provide useful tools in generating continuous layers of spatial data over the region to make effective and justified interpretations (Li and Heap, 2008).

Therefore, the present study aims at mapping the spatial distribution pattern of zoanthids coverage along intertidal zones of Saurashtra coast using GIS and interpolations techniques, with an aim to contribute towards the formulation of viable strategies for monitoring and conservation of resources. The study also forms the baseline study to monitor zoanthid movement in the future and developing zoanthid geo-referenced data base along the Saurashtra coast of India.

Material and methods

The present study was carried out along the Saurashtra coast of Gujarat, India. To assess the zoanthid diversity and distribution, nineteen sampling stations were selected along 500 km stretch of Saurashtra coast from Okha to Bhavnagar. The surveys were conducted during 2013 to 2016 (Fig. 1). A preliminary survey conducted along the Veraval and Adri stations showed that maximum intertidal zoanthid spread was observed in the mid and lower eulittoral zones. Two belt quadrat transects were made simultaneously, parallel to each other one along the mid-eulittoral and the other at lower eulittoral zone during the lowest low tides. Care was taken that each sampling station was at distance of minimum 20 km from the other. Quadrat frames of 0.5 x 0.5 m² were used and each quadrat was further divided into 100 equal subdivisions to easily measure the spread of the underlying objects. The quadrats were laid at about 10-15 m apart on each transect at each study site and were stretched to a maximum distance of 4 km. Extensive digital photographs were taken using GPS assisted camera Nikon Cool Pix AW 130. Photo quadrat method (Nakajima *et al.*, 2010) was adopted to reduce the time of sampling, there by covering maximum stretch at each sampling station within the available exposure period of 4 hours. Identification of zoanthids was carried out based on taxonomic characters following Häussermann (2004) and Reimer *et al.* (2006, 2007 and 2010). The amount of coverage of each substrate type was estimated in each subsquare and then summed to determine the total cover for each species in

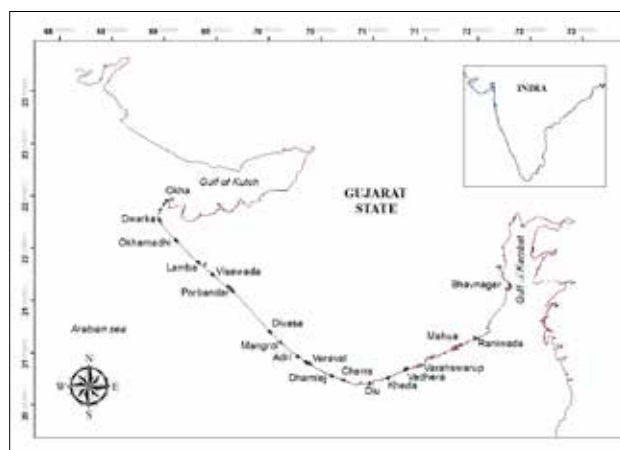


Fig. 1. Map showing the sampling stations.

a manner similar to the *in-situ* quadrat method by following the methodology of Joliel *et al.* (2015).

The spatial data collected was exported into ArcGIS version 10 and Inverse Distance Weighted (IDW) interpolation method was adopted for mapping the spatial distribution pattern of each zoanthid species following Walker *et al.* (2012) and Sreenath (2014). IDW works on the basic principle of spatial autocorrelation that assumes things closer together are more similar than those further apart. It uses the surrounding data to predict values between data points, weighing closer points more heavily (Walker *et al.*, 2012). The weights can be expressed as:

$$z\lambda_i = \frac{1/d_i^p}{\sum_{i=1}^n 1/d_i^p}$$

where d_i is the distance between known data points, p is a power parameter (usually taken as 2), and n represents the number of sampled points used for the estimation.

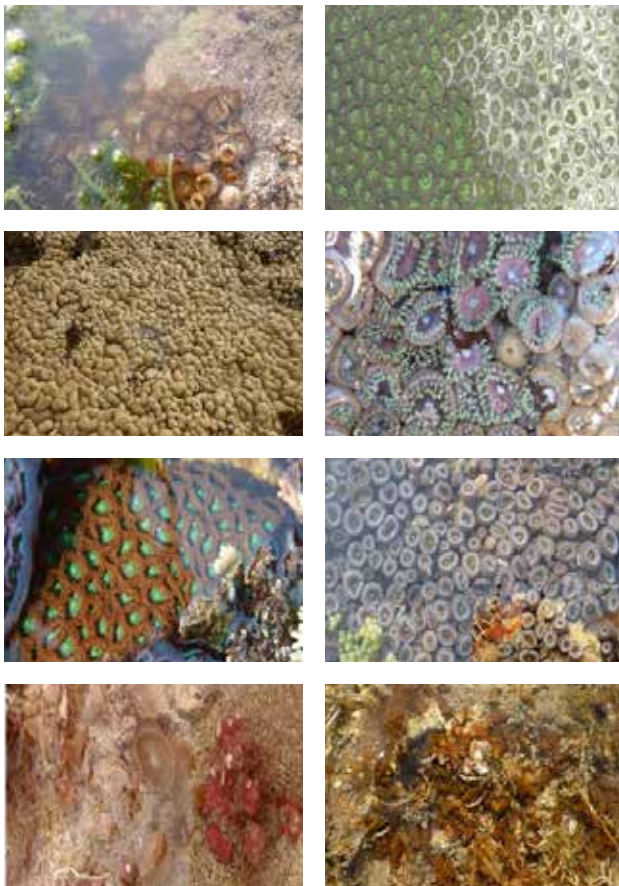


Fig. 2. Brachycnemic zoanthid diversity along the Saurashtra coast of Gujarat. A) *Palythoa mutuki* B) *Zoanthus sansibaricus* C) *Palythoa tuberculatus* D) *Zoanthus vietnamensis* E) *Zoanthus cf. sansibaricus* F) *Zoanthus gignatus* G) *Palythoa heliodiscus* H) *Isarus tuberculatus*

Results and discussion

The zoanthid diversity greatly varied among the sampled stations and a total of eight species belonging to three genera and two families were recorded in the present study. Family Sphenopidae recorded three species viz., *Palythoa mutuki*, *P. tuberculosa* and *P. heliodiscus*, while *Zoanthus sansibaricus*, *Z. cf. sansibaricus*, *Z. gigantus*, *Z. vietnamensis* and *Isarus tuberculatus* form the representative of Zoanthidae family (Fig. 2)

The results of percentage composition show that *P. mutuki* formed the most abundant zoanthid species across the Saurashtra coast, as the species was recorded from most of the station except Bhavnagar, Mahua, Raniwada, Varahswarup and Kheda. The study forms first records of *Palythoa mutuki* along Adri, Charra, Diu, Divasa, Lamba, Mangrol, Okhamadhi, Porbander, Vadera and Visawada across Gujarat Coast. The previous records of this species were only from Okha, Veraval, Dwaraka, Sutrapada, Dhamlej and Kodinar (Pandya and Mankodi, 2013; Trivedi and Vachhrajani, 2014) where the authors have reported an abundance of *P. mutuki* in mid-lower intertidal area. The maximum occurrence of *P. mutuki* was observed at Dhamlej and Charra where the species has contributed 27.36 % and 27.80 % respectively of total zoanthid coverage. *P. mutuki* also observed to be dominant at Charra. Lamba with 0.08 % and Porbandar with 0.04% formed the stations where least occurrence of the species has been noted (Table 1). The same has been depicted by the results of IDW univariate analysis where the highest amount of live coverage of *P. mutuki* have been depicted at Dhamlej and Charra with 60% (Fig. 3).



Fig. 3. Spatial distribution pattern of *Palythoa mutuki* along Saurashtra coast, India

Zoanthus sansibaricus formed the second most abundant species along the Saurashtra coast with maximum percentage coverage at Adri (15.15%) followed by Veraval (14.20%). Sparse colonies of the species have been recorded from Charra (0.32

%) and Okhamadhi (0.21 %), with no records from Bhavnagar, Lamba, Mahua and Raniwada (Table 1). This species has been previously reported along the coast of Okha, Dwarka, Sutrapada, Diu and Veraval from mid littoral and infra littoral zone by Pandya (2013, 2015), Joseph *et al.* (2014), Kumari *et al.* (2015). The occurrence of species has also been reported from Goa by Mythili *et al.* (2012). The present study reports *Z. sansibaricus* as one of the most abundant species along the Saurashtra coast with new records from Okhamadhi, Charra, Vadhera, Visawada, Varshwarupa, Kheda, Divasa, Dhamlej and Adri in ascending order to percentage coverage. Results of univariate analysis corroborate the above finding (Fig. 4), depicting the coverage of *Z. sansibaricus*.

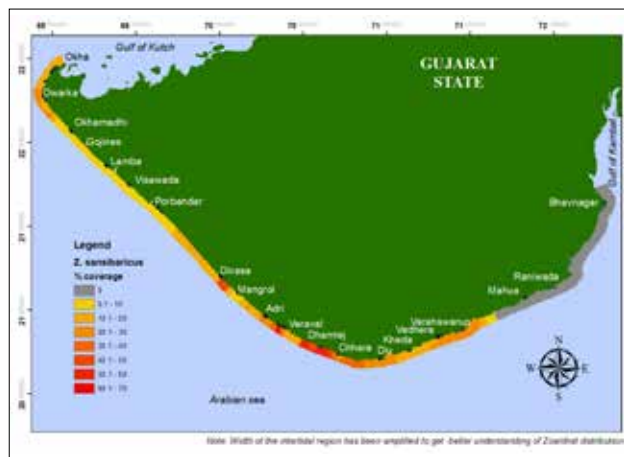


Fig. 4. Spatial distribution pattern of *Zoanthus sansibaricus* along Saurashtra coast, India.

New distributional records of *P. tuberculosa*, from Okha, Adri, Okhamadhi, Mangrol, Lamba and Visawada have been reported in the current study. The species was first time recorded from the coast of Dwarka by Hornell (1916), with later records by Bhattiji *et al.* (2010), Pandya (2013), Trivedi (2014), Joesph *et al.* (2014), Kumari *et al.* (2015) along Sutrapada, Veraval, Kodinar and Dhamlej coast. The occurrence of *P. tubercuolsa* was also



Fig. 5. Spatial distribution pattern of *Palythoa tuberculosa* along Saurashtra coast, India

very common among the sampled stations and *P. tuberculosa* formed the third most dominant species along the Saurashtra coast. Massive colonies (> 100 polyps) of the species have been recorded in the lower eulittoral zones Dhamlej (9.26%), Adri (7.36%) and Okhamadhi (7.43%) respectively (Table 1, Fig. 5).

Colonies of *Zoanthus vietnamensis* have been observed at Mangrol (10.54%), Okhamadhi (3.79%) and Adri (3.59%) in mid eulittoral and lower eulittoral zones (Table 1). Though this species has been reported from Okha, Sutrapada and Veraval (Pandya, 2015; Kumari *et al.*, 2015), there have been no records of this species from Mangrol, Diu, Okhamadhi, Dhamlej, Adri and Visawada. The species was least abundant at Okha followed by Divasa, which is clearly depicted in Fig. 6.



Fig.6. Spatial distribution pattern of *Zoanthus vietnamensis* along Saurashtra coast, India

Zoanthus cf. sansibaricus is another species that has been encountered in the present study with an overall abundance of 2.2 % among the sampled sites. *Z. cf. sansibaricus* was abundant (5.41%) at Charra followed by Adri, Divasa, Mangrol, Veraval, Varahswarup Dhamlej, Diu, Okhamadhi and Vadhera



Fig.7. Spatial distribution pattern of *Zoanthus cf sansibaricus* along Saurashtra coast, India

Table 1. Average percentage cover of zoanthids along the sampled stations

Species	<i>Zoanthus sansibaricus</i>	<i>Palythoa mutuki</i>	<i>Palythoa tuberculosa</i>	<i>Zoanthus vietnamensis</i>	<i>Zoanthus cf sansibaricus</i>	<i>Zoanthus gigantus</i>	<i>Isaurus tuberculatus</i>	<i>Palythoa heliodiscus</i>
Adri	15.16	10.54	7.36	3.59	3.65	0.00	0.23	0.00
Bhavnagar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Charra	0.32	27.80	0.00	0.00	5.41	0.00	0.07	0.00
Dhmalej	12.83	27.36	9.26	3.30	1.00	3.36	0.00	0.00
Diu	1.17	9.90	0.00	0.75	0.81	0.00	0.00	0.00
Divasa	12.08	0.64	0.00	0.29	2.86	0.00	0.79	0.00
Dwarka	4.34	1.81	2.37	0.00	0.00	0.00	0.00	0.02
Kheda	8.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lamba	0.00	0.08	1.19	0.00	0.00	0.00	0.01	0.00
Mahua	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mangrol	5.86	4.71	1.48	10.54	1.99	0.00	0.40	0.00
Okha	1.79	0.44	3.22	0.11	0.00	0.00	0.00	0.25
Okhamadhi	0.21	9.40	7.43	3.79	0.53	0.00	0.11	0.00
Porbandar	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Raniwada	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vadhera	0.44	0.84	0.00	0.00	0.04	0.00	0.02	0.04
Varahswarup	2.78	0.00	0.00	0.00	1.70	0.00	0.00	0.00
Veraval	14.21	19.48	5.49	2.86	1.96	0.00	0.68	0.00
Visawada	2.35	1.54	0.04	3.30	0.00	0.00	0.01	0.00

(0.04, Table 1). The spatial distribution pattern of the *Z. cf sansibaricus* is shown in Fig. 7 and it could be clearly inferred that species show restricted distribution.

The present study also forms the new distributional range extension of *Zoanthus gigantus*, a species that has been previously reported only from Taiwan and south China (Reimer *et al.*, 2006, 2011, 2013 and 2015). There are no records of this species from South Asia. Four colonies of *Z. gigantus* were noticed inhabiting the lower eulittoral zone of Dhamlej coast (0.36%, Table 1), just above the lowest low tide line, similar

to the findings of Reimer *et al.* (2007), where *Z. gigantus* was observed at the extreme low tide line. No records of the species have been made from other sampling stations indicating the rare distribution of species along the Indian coast (Fig. 8). Similar to *Z. gigantus*, an isolated presence of *P. heliodiscus* have also been noticed in some of the sampled stations. The species has been reported at Okha (0.25%) at mid eulittoral zone and small catches are recorded from Dwarka (0.02%) and Vadhera (0.04%) with Fig. 9 depicts the spatial distribution pattern of these two species. Only a single species from the genus *Isaurus* has been observed in the present study. *Isaurus tuberculatus*

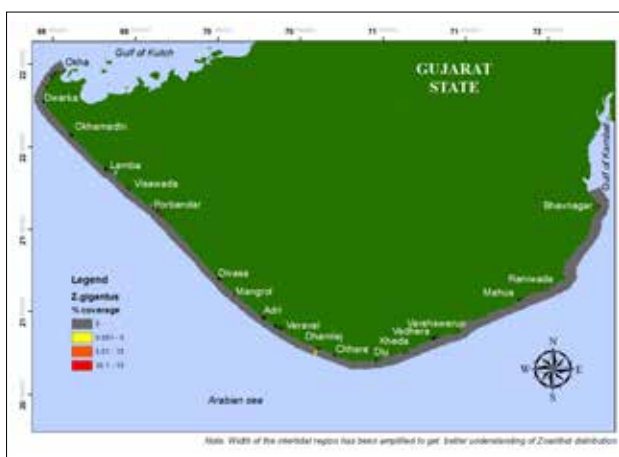


Fig. 8. Spatial distribution pattern of *Zoanthus gigantus* along Saurashtra coast, India

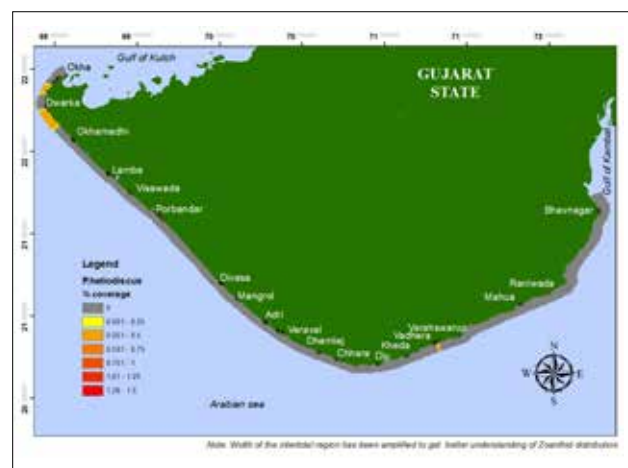


Fig. 9. Spatial distribution pattern of *Palythoa heliodiscus* along Saurashtra coast, India

is known for its cryptic coloration and camouflaging nature. The species is widely distributed in tropical and subtropical regions and has been reported by Pandya, (2014 and 2015) from the coast of Veraval and Sutrapada. The mtDNA COI study by Joseph *et al.* (2014) confirms the occurrence of this species from Mangrol and Veraval. The present study documents the first record of *I. tuberculatus* from Lamba, Visavada, Vadhera, Charra, Okhamadhi, Adri, and Divasa in increasing order of their percentage coverage (Table 1), with a highest abundance at Mangrol, Dhamlej and Veraval (Fig.10).



Fig.10. Spatial distribution pattern of *Isaurus tuberculatus* along Saurashtra coast, India

Stations at the southeastern arm of the Saurashtra coast namely Bhavnagar, Raniwada and Mahua lacked any growth of zoanthid species. The reason could be attributed to the geomorphology of these areas which are characterized by muddy shores with a huge expanse of mudflats mostly due to the influence of Gulf of Khambat.

A clear understanding of species distribution is necessary for the conservation and environmental management of coastal ecosystems. In an era of unprecedented global changes, the study on the diversity and distribution of resilient taxa like those of zoanthids is very important. The findings of the present study form the baseline study for long term permanent transect monitoring studies which are essential for formulating conservational policies. The study also elucidates the preference of hard substratum for their growth. The methodology adopted provides a useful tool to generate continuous spatial data, which can overcome the constraints of sparsely and unevenly sampled data, providing the possibility of estimating bio-physical variables for the unsampled locations too. Future studies in this direction will help in generating resource based geo-referenced maps, which could be used for habitat classification, prediction of biodiversity and conservational studies.

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