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Study of the Macro Faunal Associates of the Littoral Zoanthid *Palythoa mutuki* (Cnidaria, Anthozoa) from Saurashtra Coast, Gujarat, India

Trivedi J. N., Arya S., Vachhrajani K. D.
Marine Biodiversity and Ecology Lab, Department of Zoology, Faculty of Science, M. S. University of Baroda, Vadodara, Gujarat, India
Corresponding author email: kauresh@gmail.com

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Abstract The macrobenthic community associated with the encrusting zoanthid *Palythoa mutuki* was studied in the littoral zone of four different sites situated along the coasts of Saurashtra (Gujarat, India). A total of 20 random quadrates (0.25 m^2) were laid in the lower littoral zone where *Palythoa mutuki* was abundant. All the animals present in the quadrate area were collected or photographed and brought to the lab for species identification. A total of 67 different species belonging to 6 phyla were identified. The most abundant taxa were Arthropoda (44.8%), Mollusca (38.7%), Cnidaria (4.5%), Annelida (4.5%), Porifera (4.5%) and Echinodermata (3%). The maximum diversity of associates amongst the studied sites varied between 31 and 53 species, with the highest value recorded at Sutrapada followed by Dhamlej, Kodinar and Veraval. The diversity and species composition of associated community with *P. mutuki*, tested with MDS, PCA and Bray Curtis Similarity, is significantly homogeneous in all sites, with the exception of Veraval probably as a consequence of the habitat heterogeneity.

Keywords *Palythoa mutuki*; Benthic community, Brachyuran crabs, Gastropods, Saurashtra coast, India

Introduction

One of the major biological forces for the establishment of benthic associations is the competition for space, a factor that has been often considered to make predictions about the benthic community structure (Dayton, 1971). Associations of commensal, mutualistic and parasitic cnidarians are among the most important and widespread in the marine ecosystems and include hydroids (Genzano, 1998), gorgonians (Goh-Nigel, 1999), pennatulaceans, corallimorpharians, scleractinians, and zoanthids and sessile sponges (Suchanek and Green, 1981) etc.

Although common in the marine environment, zoanthids are poorly studied from the taxonomic point of view (Reimer et al., 2006). So far, a total of 354 species of zoanthids have been reported worldwide. They are generally dominant in the intertidal communities of the rocky shores and reefs where corals are not found extensively (Cooke, 1976; Sebens, 1977). Zoanthids, together with corallimorpharians and stolonifera, are characterized by sessile colonial forms that are connected by a basal reticulum (Reimer et al., 2006). Several species of the genera *Epizoanthus* and *Parazoanthus* are known to establish numerous symbiotic relationships (West, 1979; Crocker and Reiswig, 1981), primarily with crustaceans, mollusks and polychaetes (Wirtz et al., 2009; Martinez et al., 2012).

The coastal areas of Saurashtra are very rich in marine biodiversity and about 180 macrobenthic species have been reported so far (Vaghela, 2010; Trivedi and Vachhrajani, 2012a, b; Trivedi and Vachhrajani, 2013a, b). The zoanthid fauna of the Saurashtra coast has not been studied well and, so far, the identification was carried up to generic level only (Hornell, 1916). In previous studies, two species of the genus *Palythoa* have been identified from the Saurashtra coast, *Palythoa tuberculosa* (Esper, 1791) and *Palythoa mutuki* (Haddon and Shackeleton, 1891) (Bhattji et al., 2010; Pandya and Mankodi, 2013). *P. mutuki* is a colonial zoanthid that inhabits the rocky intertidal areas (Figure 1a) and dense patches of this species have been observed in the lower intertidal region (Trivedi and Vachhrajani, 2014). The aim of the present study was to describe and compare the species composition and the impact of characteristics of rocky

intertidal zone on various macro faunal communities associated with *P. mutuki* along four different locations situated on Saurashtra coast, Gujarat, India.

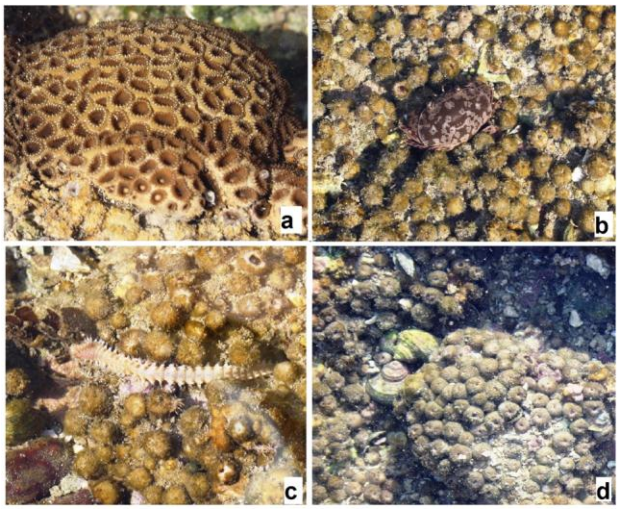

Figure 1 Associated macrobenthic community of *P.mutuki*. a. *P. mutuki* colony with individual open polyps; b. *Atergatis floridus* in *P. mutuki* colony; c. *Nereis* sp. in *P. mutuki* colony; d. *Turbo intercoastalis* in *P.mutuki* colony

1 Results

A total of 67 different macro faunal species belonging to 56 genera, 41 families, 12 classes and 6 different phyla were found to be associated with *Palythoa mutuki*. Amongst the six phyla associated with *P. mutuki*, the Phylum Arthropoda (30 species) was dominant in terms of species richness followed by the Phyla Mollusca (26 species), Cnidaria (3 species), Anellida (3 species), Porifera (3 species), and Echinodermata (2 species) (Table 1). Amongst all the studied sites, the maximum diversity of the macro faunal associates of *P. mutuki* was recorded from the site of Sutrapada followed by Kodinar, Dhamlej and Veraval (Figure 1).

At Veraval, a total of 31 species were reported associated with *P. mutuki* (Figure 2). In Phylum Annelida only one species (*Eulalia* sp.) belonging to family Phyllodocidae, class Polycheta was reported (Table 1). Species belonging to phylum Echinodermata was not observed associated with *P. mutuki* at Veraval. Out of three families, three species and two classes reported under phylum Porifera, two families (Microcionidae, Tethyidae) and two species (*Microceiona* sp., *Tethya* sp.) belonged to class Demospongiae while one family (Oscarellidae) and one species (*Oscarella* sp.) belonged to class Homoscleromorpha (Table 1). Only one species *Paracondylactis sinensis* Carlgren, 1934 belonging to family Actiniidae, Class Anthozoa was reported under phylum Cnidaria associated with *P. mutuki* (Table 1). Total 15 species belonging to 13 genera, 8 families

Table 1 Systematic checklist and abundance (number of individual m^{-2}) for the four considered localities (VL- Vearaval, SU- Sutrapada, DH- Dhamlej, KO- Kodinar) of macro faunal taxa associated to *Palythoa mutuki* ("√" denotes presence of the species)

Class	Family	Species	VL	SU	DH	KO
Phylum Annelida						
Polycheta	Nereididae	*Nereis* sp.	0	√	0	√
	Phyllodocidae	*Eulalia* sp.	√	√	0	√
	Sabellidae	*Sabella* sp.	0	√	√	√
Phylum Porifera						
Demospongiae	Microcionidae	*Microceiona* sp.	√	√	0	√
	Tethyidae	*Tethya* sp.	√	0	0	√
Homoscleromorpha	Oscarellidae	*Oscarella* sp.	√	0	√	√
Phylum Echinodermata						
Ophiuroidea	Ophiodermatidae	*Ophioderma brevispina*	0	√	0	√
Echinoidea	Echinidae	*Echinus sp.*	0	0	0	√
Phylum Cnidaraia						
Anthozoa	Poritidae	*Porites lutea*	0	√	√	0
		Porites compressa	0	√	√	0
	Actiniidae	*Paracondylactis sinensis*	√	√	√	√
Phylum Mollusca						
Cephalopoda	Octopodidae	*Octopus vulgaris*	0	√	0	√
Polyplacophora	Chitonidae	*Chiton chiton*	0	4	0	6

Table 1 continued

Class	Family	Species	VL	SU	DH	KO
Gastropoda	Muricidae	*Chicoreus brunneus*	6	5	5	7
	Muricidae	*Indothais lacera*	6	5	8	5
	Muricidae	*Purpura panama*	0	0	4	4
	Conidae	*Conus cumingii*	0	0	6	5
	Bursidae	*Bursa granularis*	7	5	5	5
	Bursidae	*Bufonaria echinata*	0	0	5	5
	Buccinidae	*Cantharus spiralis*	5	4	5	4
	Buccinidae	*Pollia fumosa*	5	0	11	5
	Buccinidae	*Canthraus undosus*	7	4	7	0
	Cypraeidae	*Erronea caurica dracaena*	0	0	0	4
	Cypraeidae	*Talparia talpa*	0	0	4	0
	Rostellariidae	*Tibia curta*	0	6	11	4
	Babyloniidae	*Babylonia spirata*	0	0	4	0
	Littorinidae	*Echinolittorina interrupta*	0	5	0	0
	Turbinidae	*Turbo intercostalis*	8	7	9	11
	Turbinidae	*Turbo bruneus*	5	4	5	6
	Turbinidae	*Lunella coronata*	23	9	4	7
	Turbinidae	*Astrea stellata*	23	15	4	7
	Turbinidae	*Astrea semicostata*	0	6	0	7
	Columbellidae	*Pyrene flava*	4	4	0	5
	Potamididae	*Cerithidea cingulata*	11	13	8	6
	Cerithiidae	*Cerithium scabridum*	20	11	10	11
	Neritidae	*Nerita oryzarum*	5	4	0	0
	Neritidae	*Nerita chamaeleon*	5	0	0	0
	Nacellidae	*Cellena radiata*	0	0	0	6
Phylum Arthopoda						
Maxillopoda	Balanidae	*Amphibalanus amphitrite*	28	22	19	13
Crustacea	Portunidae	*Charybdis annulata*	1	3	2	3
	Portunidae	*Charybdis orientalis*	3	2	1	1
	Portunidae	*Charybdis sagamiensis*	0	0	3	0
	Portunidae	*Portunus pelagicus*	1	1	0	0
	Xanthidae	*Atergatis intergerrimus*	4	4	2	1
	Xanthidae	*Atergatis subdentatus*	0	1	1	1
	Xanthidae	*Atergatis floridus*	0	4	2	4
	Xanthidae	*Atergatis roseus*	2	2	0	0
	Xanthidae	*Platypodia cristata*	0	1	0	1
	Xanthidae	*Zozymodes pumilus*	0	1	1	0
	Xanthidae	*Etisus laevimanus*	1	3	2	3
	Xanthidae	*Demania baccalipes*	0	1	1	0
	Xanthidae	*Leptodius exaratus*	0	2	4	2
	Xanthidae	*Macromedaeus crassimanus*	0	1	1	0
	Pilumnidae	*Pilumnus vespertilio*	3	3	4	4
	Grapsidae	*Grapsus albioneatus*	0	2	3	1
	Matutidae	*Matuta planipes*	0	1	0	0
	Oziidae	*Epixanthus frontalis*	0	1	1	0
	Plagusiidae	*Plagusia squamosa*	0	1	0	0
	Eriphiidae	*Eriphia smithii*	0	2	1	1
	Menippidae	*Myomenippe hardwickii*	1	2	0	1
	Parthenopidae	*Cryptopodia angulata*	0	1	0	0
	Majidae	*Schizophrys aspera*	0	1	0	0
	Epialtidae	*Hyastenus diacanthus*	0	0	1	0
	Diogenidae	*Clibanarius zebra*	5	2	3	4
	Diogenidae	*Clibanarius nathii*	1	1	3	1
	Porcellanidae	*Petrolisthes lamarckii*	0	3	0	1
	Porcellanidae	*Petrolisthes boscii*	0	1	0	1

were reported under class Gastropoda of phylum Mollusca, associated with *P. mutuki* at Veraval. Maximum species associated with *P. mutuki* were reported belonging to family Turbinidae (4 species) followed by Buccinidae (3 species), Muricidae (2 species) and Neritidae (2 species) while other families represented one species each. Genera like *Turbo*, *Nerita* and *Cantharus* contributed two species each while other genera contributed single species each. Out of 15 species of gastropods associated with *P. mutuki* reported, maximum abundance is reported for *Lunella coronata* (Gmelin, 1971) followed by *Astrea stellata* (Gmelin, 1971), *Cerithium scabridum* Philippi, 1848 and *Cerithidea cingulata* (Gmelin, 1971) (Table 1). Total 11 species belonging to 8 genera, 6 families and 2 different classes were reported under phylum Arthopoda associated with *P. mutuki* at Veraval. Out of two classes reported, class Maxillopoda was represented by one family (Balanidae) and one species *Amphibalanus amphitrite* (Darwin, 1854). Class Crustacea was represented by 8 species of brachyuran crabs and 2 species of anomuran crabs. Maximum species associated with *P. mutuki* belonged to families Portunidae (3 species), Xanthidae (3 species) and Diogenidae (2 species) while other families contributed single species each. Genera like *Charybdis*, *Atergatis* and *Clibanarious* contributed two species each while other genera contributed single species each. Out of 11 species of Arthropods associated with *P. mutuki*, maximum abundance is reported for *Amphibalanus amphitrite* followed by *Clibanarius zebra* (Dana, 1852), *Atergatis intergerrimus* (Lamarck, 1801), *Charybdis orientalis* Dana, 1852 and *Pilumnus vespertilio* (Fabricius, 1793) (Table 1).

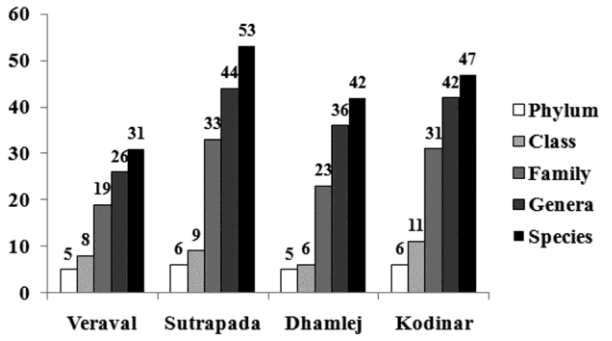

Figure 2 Taxonomic diversity of the macro faunal associates of *Palythoa mutuki* at the different study sites

At Sutrapada total 53 species reported associated with *P. mutuki* (Figure 2). Total three species (*Nereis* sp. (Figure 1c), *Eulalia* sp., *Sabella* sp.) belonging to three different families (Nereididae, Phyllodocidae, Sabellidae) of class Polycheta were reported under phylum Annelida (Table 1). Phylum Porifera and phylum Echinodermata were represented by single species like *Microceiona* sp (family Microcionidae, class Demospongiae) and *Ophioderma brevispina* (Say, 1825) (family Ophiodermatidae, class Ophiuroidea). Total three species belonging to phylum Cindaria, class Anthozoa were reported associated with *P.mutuki* from Sutrapada. Out of three species reported under phylum Porifera, two species were belonged to family Poritidae, Genus *Porites* (*Porites lutea* Quoy & Gaimard, 1833, *Porites compressa* Dana, 1846) while family Actiniidae contributes single species *Paracondylactis sinensis* (Table 1). Total 18 species belonging to 15 genera, 12 families and 3 classes were reported under phylum Mollusca, associated with *P. mutuki* at Sutarapada. Out of three classes reported maximum number of families and species belonged to class Gastropoda (12 families, 16 species) while one family and one species each belonged to class Polyplacophora (Family Octopodidae, Species *Octopus vulgaris* Cuvier, 1797) and Cephalopoda (Family Chitonidae, Species *Chiton chiton*). In class Gastopoda associated with *P. mutuki*, maximum species were reported belonging to family Turbinidae (5 species) followed by Buccinidae (2 species) and Muricidae (2 species) while other families represented one species each. Genera like *Turbo*, *Astrea* and *Cantharus* contributed two species each while other genera contributed single species each. Out of 16 species of gastropods associated with *P. mutuki*, maximum abundance is reported for *Astrea stellata* followed by *Cerithidea cingulata*, *Cerithium scabridum* and *Turbo intercoastalis* Menke, 1846 (Figure 1d) at Sutrapada (Table 1). Total 28 species belonging to 23 genera, 15 families and 2 different classes were reported under phylum Arthopoda associated with *P. mutuki* at Sutrapada. Out of two classes reported, class Maxillopoda was represented by one family (Balanidae) and one species *Amphibalanus amphitrite*. Class Crustacea was represented by 24 species of brachyuran crabs and 4 species of anomuran crabs. Maximum brachyuran crab species associated with *P. mutuki* belonged to families Portunidae (4

species) and Xanthidae (10 species) while in case of anomuran crab, both family Diogenidae and Porcellanidae contributed 2 species each. Genera like *Atergatis* (4 species), *Charbdis* (3 species), *Clibanarious* (2 species) and *Petrolisthes* (2 species) have contributed more species while other genera contributed single species each. Out of 29 species of arthropods associated with *P. mutuki* reported, maximum abundance is reported for *Amphibalanus amphitrite* followed by *Atergatis intergerrimus* and *Atergatis floridus* (Linnaeus, 1767) (Figure 1b) (Table 1).

At Dhamlej total 42 species were reported associated with *P. mutuki* (Figure 2). Only one species (*Sabella* sp.) belonging to familily Sabellidae of class Polycheta was reported under phylum Annelida (Table 1). Phylum Porifera was represented by single species like *Oscarella* sp. (family Oscarellidae, class Homoscleromorpha) while species belonging to phylum Echinodermata was not observed associated with *P. mutuki* at Dhamlej. Total three species belonging to phylum Cindaria, class Anthozoa were reported associated with *P. mutuki* from Dhamlej. Out of three species reported under phylum Porifera, two species belonged to family Poritidae, Genus *Porites* (*Porites lutea*, *Porites compressa*), while family Actiniidae contributes single species *Paracondylactis sinensis* (Table 1). Total 18 species belonging to 16 genera, 10 families were reported under class Gastropoda of phylum Mollusca, associated with *P. mutuki* at Dhamlej. Maximum species associated with *P. mutuki* were reported belonging to family Turbinidae (4 species) followed by Buccinidae (3 species), Muricidae (3 species) and Bursidae (2 species) while other families represented one species each. Genera like *Turbo* and *Cantharus* contributed two species each while other genera contributed single species each. Out of 15 species of gastropods associated with *P. mutuki* reported, maximum abundance is reported for *Pollia fumosa* **(**Dillwyn, 1817) followed by *Tibia curta* (G. B. Sowerby II, 1842) , *Cerithium scabridum, Turbo intercoastalis* and *Cerithidea cingulata* (Table 1). Total 19 species belonging to 14 genera, 9 families and 2 different classes were reported under phylum Arthopoda associated with *P. mutuki* at Dhamlej. Out of two classes reported, class Maxillopoda was represented by one family (Balanidae) and one species *Amphibalanus amphitrite*. Class Crustacea was represented by 16 species of brachyuran crabs and 2 species of anomuran crabs. Maximum brachyuran crab species associated with *P. mutuki* were belonged to families like Xanthidae (8 species) and Portunidae (3 species) while in case of anomuran crab both family Diogenidae contributed 2 species. Genera like *Atergatis* (3 species), *Charbdis* (3 species), and *Clibanarious* (2 species) contributed more species while other genera contributed single species each. Out of 29 species of arthropods associated with *P. mutuki* reported, maximum abundance is reported for *Amphibalanus amphitrite* followed by *Leptodius exaratus* **(**H. Milne Edwards, 1834) and *Pilumnus vespertilio* (Table 1).

At Kodinar, total 47 species were reported associated with *P. mutuki* (Figure 2). Total three species (*Nereis* sp., *Eulalia* sp., *Sabella* sp.) belonging to three different families (Nereididae, Phyllodocidae, Sabellidae) of class Polycheta were reported under phylum Annelida (Table 1). Out of three families, three species and two classes reported under phylum Porifera, two families (Microcionidae, Tethyidae) and two species (*Microceiona* sp., *Tethya* sp.) belonged to class Demospongiae while one family (Oscarellidae) and one species (*Oscarella* sp.) belonged to class Homoscleromorpha (Table 1). Two species like *Ophioderma brevispina* (family Ophiodermatidae, class Ophiuroidea) and *Echinus sp.* (family Echinidae, class Echinoidea) belonged to phylum Echinodermata were associated with *P. mutuki*. Only one species *Paracondylactis sinensis* belonging to family Actiniidae, class Anthozoa under phylum Cindaria, was reported associated with *P. mutuki* at Kodinar (Table 1). Total 21 species belonging to 19 genera, 13 families and 3 classes were reported under phylum Mollusca, associated with *P. mutuki* at Kodinar. Out of three classes reported maximum number of families and species belonged to class Gastropoda (11 families, 19 species) while one family and one species each belonged to class Polyplacophora (Family Octopodidae, species *Octopus vulgaris*) and Cephalopoda (Family Chitonidae, species *Chiton chiton*). In class Gastopoda, maximum species associated with *P. mutuki* belonged to family Turbinidae (5 species) followed by Muricidae (3 species) Buccinidae (2 species) and Bursidae (2 species) while other families represented one species each. Genera like *Turbo* and *Astrea* contributed two species each while other genera contributed single species each. Out of 16 species of gastropods

associated with *P. mutuki* reported, maximum abundance is reported for *Turbo intercoastalis* followed by *Cerithium scabridum*, *Astrea stellata*, *Astrea semicostata* (Kiener, 1850), *Lunella coronata* and *Chicoreus brunneus* (Link, 1807) at Kodinar (Table 1). Total 17 species belonging to 12 genera, 9 families and 2 different classes were reported under phylum Arthopoda associated with *P. mutuki* at Sutrapada. Out of two classes reported, class Maxillopoda was represented by one family (Balanidae) and one species *Amphibalanus amphitrite*. Class Crustacea was represented by 12 species of brachyuran crabs and 4 species of anomuran crabs. Maximum brachyuran crab species associated with *P. mutuki* belonged to families Xanthidae (6 species) and Portunidae (2 species) while in case of anomuran crab both family Diogenidae and Porcellanidae contributed 2 species each. Genera like *Atergatis* (3 species), *Charbdis* (2 species), *Clibanarious* (2 species) and *Petrolisthes* (2 species) contributed more species while other genera contributed single species each. Out of 17 species of arthropods associated with *P. mutuki* reported, maximum abundance is reported for *Amphibalanus amphitrite* followed by *Atergatis floridus*, *Pilumnus vespertilio* and *Clibanarious zebra* (Table 1).

The results of the diversity indices calculated on the entire dataset are given in Table 2. The highest species richness and abundance is observed at Sutrapada followed by Kodinar, Dhamlej and Veraval. The values of the Shannon Diversity Index (log 2) was higher in Sutrapda (3.534) followed by Kodinar (3.523), Dhamlej (3.411) and Veraval (2.932). The Margalef Species Richness Index showed higher values at Sutrapda (9.920) followed by Kodinar (8.926), Dhamlej (7.938) and Veraval (5.689), while the Evenness Index values were higher for Kodinar (0.735) followed by Dhamlej (0.721), Sutrapada (0.646) and Veraval (0.605).

Table 2 Diversity indices for the associated macrofaunal communities of *Palythoa mutuki* in the four study sites

	Veraval	Sutrapada	Dhamlej	Kodinar
Taxa_S	31	53	42	47
Individuals	195	189	175	173
Shannon_H	2.932	3.534	3.411	3.523
Evenness_e^H/S	0.605	0.646	0.721	0.735
Margalef	5.689	9.920	7.938	8.926

Bray- Curtis Similarity Index is calculated to know the similarity in terms of species diversity between the study sites. The dendrogram (Figure 3) shows three different groups. Sutrapada and Kodinar are grouped together with a maximum similarity of 70%; these are clustered with Dhamlej and linked with 63% of similarity. Veraval forms a third and separate group which is joined with the other two groups with a 57% similarity. The same pattern was also put in evidence by the PCA (Figure 4) and MDS plot (Figure 5) graphs, where study sites like Sutrapda and Kodinar showing maximum similarity in species composition forms a single cluster.

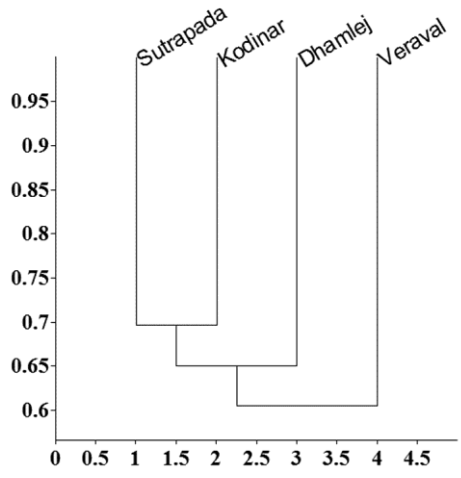

Figure 3 Dendrogram of the macro faunal associates to *Palythoa mutuki* recorded in the four study sites

2 Discussion

Zoanthid species belonging to the genus *Palythoa* have the specific ability to trap the sediment floating with the sea current which is then incorporated in the polyps wall (Reimer et al., 2006). The sediment load is very high in the coastal waters off Saurashtra probably triggering the extensive presence of *Palythoa mutuki* in the four study sites (Trivedi and Vachhrajani, 2014). In the present study, a total of 67 species of

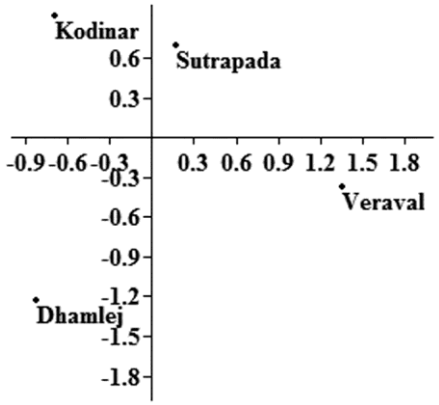

Figure 4 PCA analysis of the macro faunal associates of *Palythoa mutuki* recorded in the four study sites

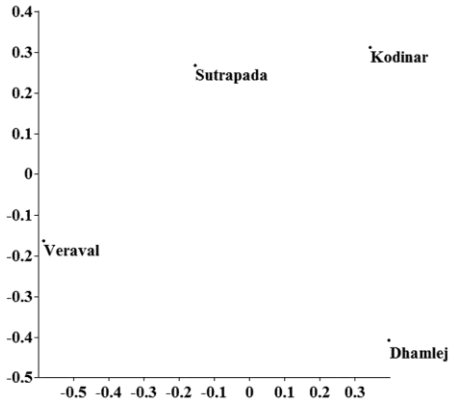

Figure 5 MDS plot of macro faunal associates of *Palythoa mutuki* recorded in the four study sites

macrofaunal organisms associated to the patches of *P. mutuki* with arthropods being the dominant taxonomic group. In the present study, a higher number of species of macrofaunal associated organisms was recorded if compared to a similar study carried out by Perez et al. (2005) who conducted study on associated macrobenthic community of *Palythoa ceribaeorum* (Duchassaing and Michelotti, 1860) in littoral zone of Pernambuco, Brazil and have recorded 28 associated macrobenthic species. The results of the present study showed that the entire study area supports similar kind of associated macrofaunal diversity of *P. mutuki* in terms of phylum and class but huge difference is observed in case of species, genera and families. Sutrapada has the highest macro faunal diversity in terms of family, genera and species associated with the zoanthid *P. mutuki* while the site of Veraval showed least diversity. This kind of phenomena may be occurring because the rocky intertidal zone at Sutrapada is flat in nature with an average exposure of 120 meters. The intertidal zone is covered with small to large shallow tide pools which is suitable habitat for *P. mutuki* and its associated macrobenthic fauna, while on the other hand the rocky intertidal area of Veraval is very narrow with an average exposure of 50 meters which submerges in subtidal zone with steep slope. The results revealed by the different analyses like Bray-Curtis similarity, PCA and MDS showed significative differences in the faunal diversity in the different study sites which implies that geomorphology of rocky intertidal zone plays an important role in the structure of macro faunal community association with *P. mutuki.*

3 Materials and Methods

The study was conducted in four different sites of the coastal area of the Junagadh district: (1) Veraval (20^0 54’ 37" N, 70^0 21’ 04” E), (2) Sutrapada (20^0 49’ 53" N, 70^0 29’ 17” E) (3) Dhamlej (20^0 46’ 29" N, 70^0 36’ 19” E), and (4) Kodinar (20^0 45’ 29" N, 70^0 39’ 39” E) (Figure 6). The intertidal zone of Veraval is mostly rocky, while the upper intertidal zone is composed of sandy shore. The lower intertidal area grades into a sub tidal zone with a steep slope. The exposure of the intertidal zone is not uniform and shows a maximum exposure of 60 to 90 m at different tidal levels. The rocky intertidal area of Veraval is mostly covered by small tide pools of varied depth, small boulders, and crevices. The intertidal areas of Sutrapada and Dhamlej are flat and rocky in nature with maximum

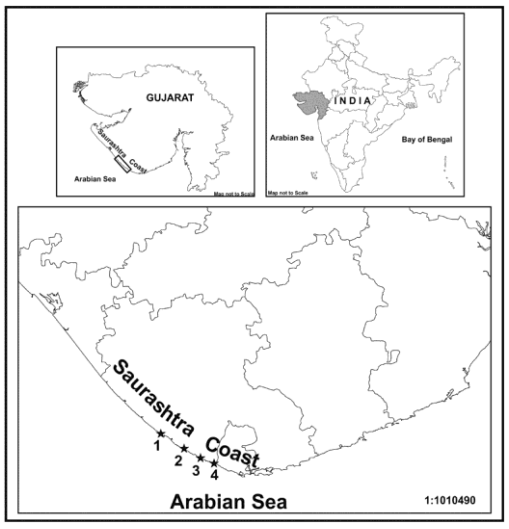

Figure 6 Location of study areas: (1) Veraval (2) Sutrapada (3) Dhamlej (4) Kodinar

exposure of 120 to 130 m. The intertidal zone of both the sites is shallow and presents small tide pools with sandy or algae–covered substrata. The intertidal zone at Kodinar is also flat with numerous small tide pools with maximum exposure of 120–130 m. The lower intertidal zone contains large tide pools filled with zoanthids. An evident zonation pattern of the benthic communities in the intertidal area was observed at all the study sites (Trivedi and Vachhrajani, 2012a).

To study the macro faunal community associated to the patches of *P. mutuki*, random quadrate sampling method was used. A total of 20 quadrates (1 m^2) were laid randomly in the lower littoral zone where *P. mutuki* was found to be abundant. All the benthic specimens present in the quadrate were either photographed or collected and fixed in 10% formalin and brought to the laboratory for identification. Different identification keys, descriptions and monograms were used for macro fauna (Chhapgar, 1957; Hortog and Venam, 1993; Apte, 1998; Seturamlingam and Khan, 1991; Jeyabaskaran et al., 2000; Trivedi and Vachhrajani 2013c, Trivedi et al., 2013). Since the occurrence of certain species was less frequent their quantification was not carried out, instead of that presence or absence data was collected to mark their occurrence in the quadrate. The phyla Molluscs and Arthropods were represented by several species and were quantified at all the study sites. Species abundance was used to define the macro faunal community structure associated with *P. mutuki* because the macrofaunal species were distributed patchily in the intertidal zone of the study area. Different diversity indices were calculated to compare the diversity of *P. mutuki*'s associated communities. Bray-Curtis similarity was calculated and a dendrogram was prepared to graphically visualize the differences among the four sites in terms of species composition. Non-metric MDS and PCA analysis were also carried out to find out the relationship between the different study sites in terms of associated macro faunal species diversity with *P. mutuki*.

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Authors' contributions

JNT and KDV both have designed the study and drafted the manuscript. JNT has conducted the field work and collected the required faunal samples. JNT and KDV both have conducted survey for the quantification of faunal community and carried out the analysis of the data. JNT and KDV have read the manuscript and there is no issue of conflict.

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