Coral reef structure at Kachhigarh, Gujarat

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Presence of corals in the Kachhigarh area, located around 10 km from Marine National Park is reported for the first time with occurrence of 24 species. The paper describes the abiotic features of the area that sustain the corals, outside Marine protected area. Area harness threatened coral species such as *Favia lacuna, Favites complanata, Favites halicora, Goniopora minor* categorised as Near Threatened species (ver 3.1, IUCN 2015). Cluster analysis showed strong relation between *Favia, Favites* and *Porites* species.

[**Keywords**: Corals, Kachhigarh, Marine National Park]

Introduction

Coral reefs are highly productive and diverse marine ecosystems found throughout the world's tropical and sub-tropical oceans. This ecosystem is based around reef-building corals, a symbiotic association between cnidarian animals (corals), endosymbiotic dinoflagellate algae (*Symbiodinium* spp.), and various other microbial taxa (bacteria, archaea, endolithic algae, apicomplexans, fungi, etc.)[1,2]. Indian subcontinent has the long coastline of 7, 517 km and the reefs are distributed along the east and west coasts at restricted places. Fringing reefs are found in Gulf of Mannar and Palk Bay. Platform reefs are seen along the Gulf of Kachchh. Patchy reefs are present near Ratnagiri and Malvan coasts. Fringing and barrier reefs are found in Andaman and Nicobar Islands. Atoll reefs are found in Lakshadweep[3]. The coral reefs of adjoining Marine National Park in Gulf of Kachchh are well documented and there are few studies indicated presence of corals on the open Saurashtra coast, facing Arabian Sea[4,5,6]. These locations include Dwarka, Harshad, Veraval, Dhamlej and Diu and the corals are patchy in distribution. The present study describes the corals in the Kachhigarh area. Kachhigarh is located in continuation to the Marine National Park and Sanctuary in the southern tip and lies facing the open Arabian Sea between Dwarka and Okha. The characteristics feature of the area is shallow lagoon and development of water pools during the low tide. These unique features provide the apt habitat for corals during the low tide and also protect the corals against strong wave action.

Present study consist the water quality, nature of substratum and the distribution of corals in the region.

Materials and Method

Kachhigarh is located in continuation to the Marine National Park and Sanctuary (Fig 1) in the southern tip. Dwarka coastline is trending NW-SE, facing Arabian Sea, is smooth and straight, and marked by well developed sandy beaches. The sea here is marked by long shore currents and high wave energy with strong surf action. Tides are generally low in the range of 2 to 3 m. Study was conducted in 2014 December and water samples in replicates were collected during the low tide and high tide from the marked ten locations in the area. Water samples were collected at the same time when the corals study was conducted.
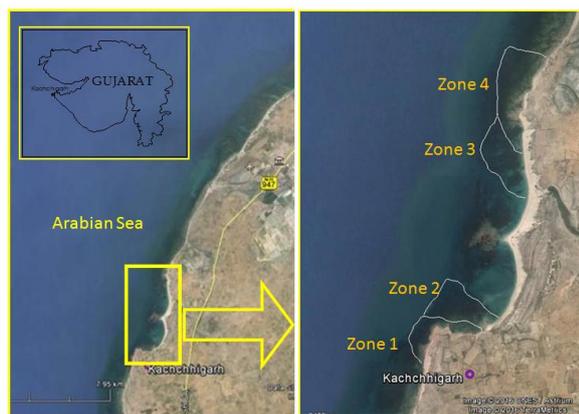
Figure 1- Study area map

The surface sea water samples from the overlying water column of intertidal region were collected from the various stations to assess the coastal water quality like Salinity, pH, total suspended solids (TSS), Dissolved oxygen (DO) and Biochemical Oxygen Demand (BOD), total phosphorous (TP), and total nitrogen following titration standard methods [7,8].

The species diversity of corals was calculated using the Shannon–Weiner formula,

$$H = -\Sigma[(pi) * \ln(pi)]$$

Where, pi= Number of individuals of species i/total number of samples

S = Number of species or species richness

H_{max} = Maximum diversity possible

Evenness was calculated using the formula

$$E = Evenness = H/H_{max}$$

Dominance percentage = (Area of occupancy of particular species/total area of occupancy of all the species) *100

The density of coral polyps was determined by line transect intersect method by employing a 0.25 m² quadrant at every 10 m interval, above the zero of the chart datum to the highest high-tide mark of the intertidal belt. The coral species were identified up to species level by following standard references and published literature [9,10]. The percentage cover of corals and other sessile benthic categories (soft coral, sponges,

zoantdhis, oysters, barnacles, ascidians, anemones, gorgonians, algae etc.) were assessed to understand the nature of substratum.

For the purpose of quantification the study area was divided into four zones viz.; zone 1, zone 2, zone 3 and zone 4. (fig 1) The central part of the lagoon has sandy bottom, while the North and south of the bays have partly exposed hard rock, towards land which merges into rocky cliffs. Landward side the of the bays have a narrow but well defined, crescent shaped, sandy beaches containing medium to fine sized calcareous sand. The beaches are flanked by active and partly stabilized sand dunes.

Results and Discussion

Water quality was estimated from 5 locations and results presented in table 1. Surface water temperature ranged from 22 to 23°C, which is normal in case of tropical waters. The salinity of the water ranged from 35-36 ppt. Earlier studies have also reported similar salinity in the region[4,9].Total Suspended solids (TSS) was reported very low in the range of 0.07 to 0.08 g/l and low TSS indicated clear water with higher light penetration.

The DO value recorded was above 5 mg/l and BOD levels were reported below 5 mg/l. This is comparable with equatorial costal ecosystems[11] supporting healthy aquatic lives[12]. Thus, the water of Kachhigarh area has the required conditions for the corals to sustain and flourish.

Coral diversity

A total of 24 coral species belonging to 14 genus were reported from the study area. Common ones include *Acanthastrea hillae* Wells, 1955*, Coscinaraea monile (*Foskål, 1775)*, Cyphastrea serailia (*Foskål, 1775)*, Favia favus (*Foskål, 1775)*, Favia lacuna* (Veron Turak & DeVantier, 2000)*, Favia pallid* (Dana, 1846), *Favia speciosa* (Dana, 1846), *Favites complanata* (Ehrenberg, 1834), *Favites halicora* (Ehrenberg, 1834)*, Favites pentagona (Esper, 1794), Goniastrea*

Table 1: Physico-Chemical Parameters of the water quality

Station	pH	Salinity ppt	TSS (g l⁻¹)	DO (mg l⁻¹)	BOD (mg l⁻¹)	Total N (mg l⁻¹)	Total P (mg l⁻¹)
Lighthouse - intertidal	7.4	33.07	0.07	5.7	3.43	0.28	0.12
Lagoon- south bay	7.6	36.54	0.08	7.2	5.03	0.27	0.11
South Shore – south bay	7.9	36.75	0.07	0.00	0.00	0.48	0.10
North bay	7.9	35.52	0.07	5.7	1.71	0.44	0.10
Lighthouse Low Tide	8.0	37.36	0.08	8.2	2.06	0.42	0.10

*pectinata (*Ehrenberg, 1834)*, Goniopora minor* (Crossland, 1952)*, Goniopora nigra (*Pillai, 1967)*, Montipora monasteriata* (Forskål, 1775)*, Platygyra sinensis* (Milne Edwards & Haime, 1849)*, Platygyra daedalea* (Ellis & Solander, 1786)*, Plesiastrea versipora* (Lamarck, 1816)*, Porites compressa* (Dana, 1846), *Porites lichen* (Dana, 1846), *Porites lutea (*Milne Edwards & Haime, 1851)*, Porites solida* (Forskål, 1775), *Siderastrea sp.,* and *Symphyllia radians (*Milne Edwards & Haime, 1849). Important finding includes the presence of *Favia lacuna, Favites complanata, Favites halicora, Goniopora minor*, categorised as Near Threatened species (ver 3.1, IUCN 2015).

The maximum representation of coral taxa was reported at zone 2 (11), followed by zone 3 and 4 (8) and zone 1 (6). The diversity index was high at zone 2 (H'=1.892), followed by zone 3 (H'=1.694) and 4 (H'=1.616). The evenness indices varied from 0.61 at zone 2 to 0.68 at zone 3 indicative of even distribution of corals at the studied zones. The percentage dominance was calculated to record the dominance of particular species in the zones (Table 2). Spatial difference in distribution of coral species was reported where in *Favia* sp., dominated in zone 2 and 3, *Porites* sp., dominated in zone 1 and 4. *Favites* sp., was reported from all the zones and represented the second dominating species at zone 2, 3 and 4. Zone 1 showed dominance of *Favia* sp., *Goniopora* sp and *Porites* sp. *Montipora* sp*.,* and *Siderastrea* sp*.* was reported from zone 2 and 3 only.

Table 2: Relative Dominance (%) of coral species in zones of the study area

Genus	Zone			
	1	2	3	4
Acanthastrea	Nil	1.61	2.71	11.53
Cyphastrea	3.43	2.22	Nil	1.29
Favia	26.03	35.51	31.89	11.95
Favites	4.52	19.53	26.96	20.19
Goniastrea	Nil	2.44	Nil	Nil
Goniopora	30.54	13.47	Nil	7.88
Montipora	Nil	4.95	12.21	Nil
Porites	33.91	11.81	16.68	42.45
Symphyllia	1.58	3.95	4.82	3.57
Siderastrea	Nil	3.42	2.50	Nil
Coscinaraea	Nil	Nil	2.23	Nil
Platygyra	Nil	1.09	Nil	1.14

Zone 3 and 4 reported low coral occupancy, but the coral diversity was comparable with that of zone 1 and 2. This suggests that similar water quality and connectivity of zone 1 & 2. In zone 3 and 4, low availability of tidal pools have

exposed the corals to desiccation under temperature stress and solar radiation[13] thereby limiting the expansion of corals.

Substratum study of the region indicates presence of live corals, algal growth, barren rock, sand and other benthos community. Barren rock dominates the substratum base in all the zones (Fig 2, 3, 4 and 5). Live corals was found dominant in the zone 2 (8.47%), followed by zone 1 (7.91%) and zone 3 (4.22%). Zone 4 showed the low distribution of corals and only 3.06% was reported (Fig 5).
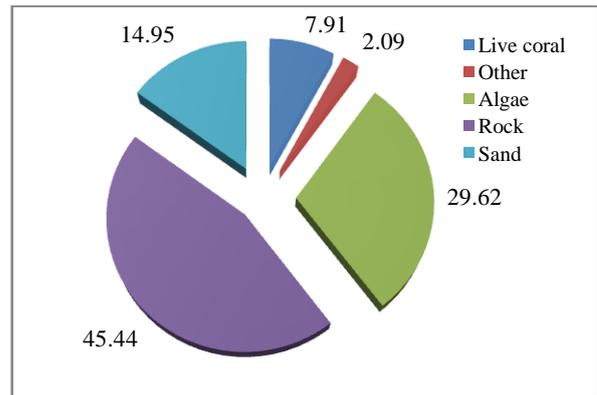

Fig 2 - Percentage composition of the substratum in zone 1
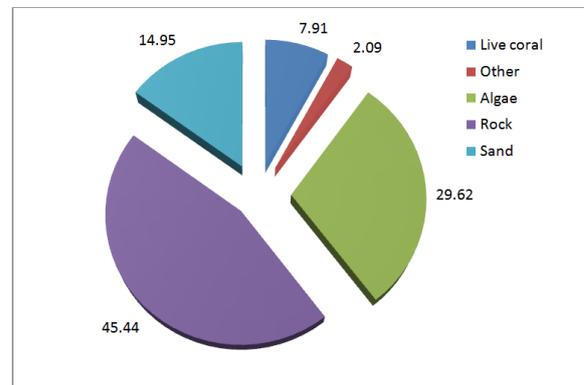

Fig 3 - Percentage composition of the substratum in zone 2
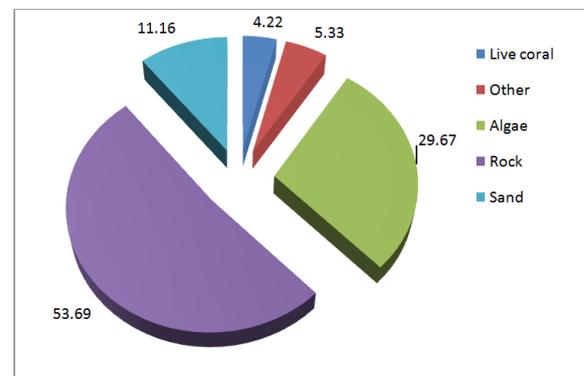

Fig 4 - Percentage composition of the substratum in zone 3
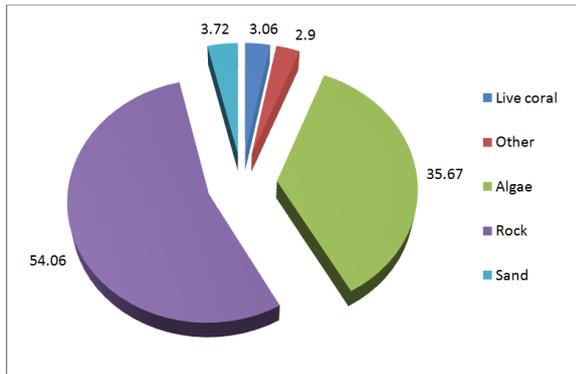
Fig 5 - Percentage composition of the substratum in zone 4

The low distribution of corals at zone 4 was observed as the northern part of the bay has less tidal pools, which can support corals[14]. Algal association was reported more than 25% in all the zones with high occupancy at zone 4. Association of macro algal species like *Caulerpa racemosa, Caulerpa scalpelliformis, Enteromorpha compressa, Sargassum wightii* in the bed plays role as sediment trap[15].

By removing sand particles and keeping the water clean aided growth of corals. Sand was the next dominated substratum and was reported high at zone 2 (71.2%) and low at zone 4 (3.72%). Others category included the benthos (soft coral, sponges, zoanthids, oysters, barnacles, ascidians, anemones, gorgonians, etc.), reported high at zone 3. Relation was found between occurrence of corals and benthos in negative correlation (P significant at 0.1 level). High density of invertebrates, both grazers and predators are known to have adverse impact on corals[16,17,18]. Rocky intertidal with small-small pot holes as substratum, zone 1 and 2 represent better coral occupancy as compared to zone 3 and 4. Zone 1 and 2 is in better continuation with the Marine National Park and there is transportation of coral polyps in these regions via the currents[19].

Cluster analysis of grouping of coral species for all the zones in Kachhigarh area was performed. The results suggested strong co-relation between *Favia, Favites* and *Porites* species (Fig 6).
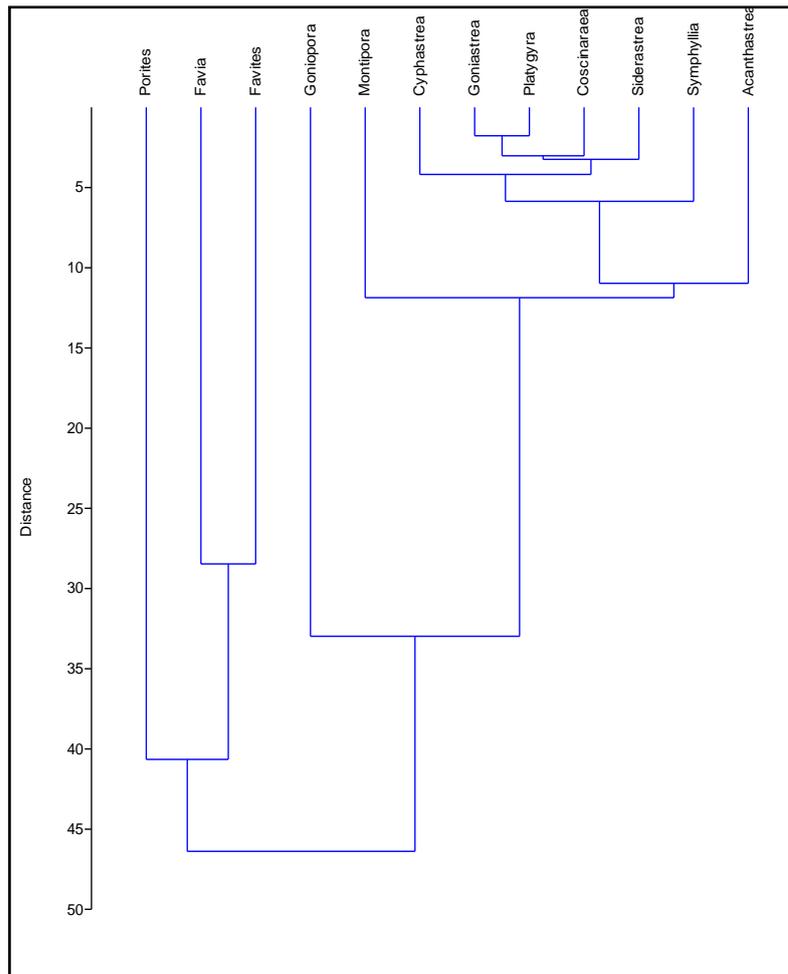

Fig 6 - Cluster analysis of corals species

Close association of *Favia* and *Favites* with *Porites* also indicate their domination at all the stations. These corals are comparatively massive as compared to other corals and therefore represent the dominating group. The region is known for strong tidal currents these massive corals have relatively better survival rates [20] inferred that *Favia, Porites, Goniopora and Favites* are massive and do not get easily damaged under physical forces like waves and human interventions. Similar results were reported from the present study. Different researchers have indicated on higher survival rate of *Porites lutea* due to its ability to remove silt from the surface and are more resistant to bleaching[21,22]. *Goniopora sp.* though is another dominating genus its more closely associated with corals with relatively less relative density. The growth rate of corals depends on factors such as light intensity, water temperature, salinity, turbidity, food availability, competition for space and predation.

The presence of corals in Kachhigarh area is significant and qualifies as one of biodiversity hot spots outside Marine National Park of Jamnagar. The Marine National Park is under heavy pressure from port and industrial development[23]. Coral-reef organisms are stenotype in nature and can tolerate only a narrow range of environmental conditions and are sensitive to environmental changes. At present the area is notified under Shivrajpur Forest area for the protection of turtle nesting on the beaches, but little is mention on the corals. Close proximity of the corals to the Marine National Park attracts attention and call for conservation and protection of this area on long term basis.

Conclusions

Shallow lagoons with rocky bottom marked by several water pools provided an ideal habitat for different species of stony corals and algae in Kachhigarh. The presence of these corals on mouth of the gulf gives hope for the future conservation. This region includes threatened species which has declining trend at the global level and therefore conservation of this area is vital.

Acknowledgment

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