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Occurrence of Scleractinian corals from the outer Gulf of Kachchh, West coast of India

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Coral reefs of the outer Gulf of Kachchh were surveyed for abundance and occurrences of scleractinian coral. The survey was conducted in the intertidal zone of three selected sites, namely Okha, Mithapur, and Shivrajpur. The maximum live coral cover area percentage was observed at Shivrajpur (72 %) followed by Mithapur (55.5 %) and Okha (45 %). In the present study, 23 species of scleractinian corals belonging to eight different families and 12 genera were recorded. The highest numbers of the scleractinian corals were recorded from the Shivrajpur with 22 species belonging to 12 genera followed by Mithapur with 16 species belonging to ten genera, and Okha 12 species belonging to eight genera. The Poritidae family contributed the highest number of scleractinian coral species assemblage followed by the Faviidae and Merulinidae family at all the stations. Geo-morphology of the coast and anthropogenic pressures are the two factors that seemed to have more impact on the distribution and diversity of scleractinian corals.

[**Keywords**: Biodiversity, Coral reef, Gulf of Kachchh, India, Scleractinian]

Introduction

Coral reefs are one of the world's most salient, biologically rich, and economically valuable ecosystems on Earth[1]. They represent a diverse group that belongs to the phylum Cnidaria. Coral reefs support more species per unit area than any other ecosystem[2]. Reef ecosystems are distributed in the warm tropical waters between latitude 30° N and 30° S, where the temperature range is optimum, 23 – 29° C[(ref. 3)] Celsius[3]. Although the coral reef ecosystems correspond to less than 0.2 % of the total marine environment, they are among the most productive ecosystems of the oceans[4]. Colonies of coral reefs grow very slowly, at a rate of less than 1 to 10 cm every year[5].

Survival of the coral reef ecosystem depends on the local community's self-awareness, traditional fishing activities, maintaining the knowledge and capacity to conserve the coral reefs, and related ecosystem sustainability. Apart from livelihood sustenance, the coral reefs are of great ecological importance: increase shore stability, offer protection against tidal surges, and provides shelter, food, and breeding ground for fishes, crabs, prawns, and other marine organisms[6]. Coral reefs contribute to the sustenance of the country's economics through fisheries, tourism, pharmaceuticals, etc.; these '*rainforests of the sea'* provide economic and environmental services to millions of people[7-9].

Coral reefs are known to be fragile and very sensitive to fluctuations in water temperature and sedimentation. The reefs are deteriorating rapidly due to various harmful anthropogenic activities[10]. To protect such ecologically important areas, India has initiated Marine Protected Areas (MPAs) networking programs. The Gulf of Kachchh (GoK) Marine National Park (MNP) and Marine Sanctuary (MS) provide shelter for more than 49 species of hard corals and 23 species of soft corals[11].

The outer GoK, although having the potential of harboring healthy coral reefs, were not surveyed earlier. Being exposed to high tidal fluctuations, they are also vulnerable to climate change, tourism, pollution, ungoverned fishing practices, sedimentation, coastal development, and industrialization. A study has been conducted at Mithapur by the Zoological Survey of India, GEER Foundation, and NIO. Thus, the present study was undertaken to observe the occurrence and distribution of the scleractinian corals in this area, to understand the present status of the coral reef ecosystem in the outer part of the gulf and to suggest conservation measures.

Materials and Methods

The coral reef covering area of Port Okha, Mithapur, and Shivrajpur is a part of outer GoK extending from 22°28'7.3272" N, 69°4'11.3664" E; 22°24'21.09" N, 69°1'52.36" E and 22°25'9.12" N, 73°36'44.64" E, respectively. Port Okha is located on a narrow strip of land that projects into the sea (22°27'57.24" N, 69°4'12.72" E). Mithapur is on the extreme tip of the lower jaw of Gujarat (22°24'21.24" N, 69°1'52.32" E) and Shivrajpur is located near Dwarka (22°19'14.88" N, 68°56'52.8" E).

Data were collected at monthly intervals from November 2017 to February 2019 using Line Intercept Transect (LIT) method[12]. All the coral species and associated flora and fauna were recorded (*i.e.*, algae, seaweeds, seagrass, crabs, prawns, sponges, echinoderms, nudibranchs, finfishes, shellfishes, bivalves, gastropods, and cephalopods). Six transects with ten quadrates of 50 cm on each site were placed along the three coral reef sites of the outer gulf region. Total 60 quadrates on each site covered the intertidal zone of exposed coral reef area during the low tide period. All Scleractinian corals intercepted by the transect were recorded, and their maximal projected size was measured based on the quadrates grid. All individual colonies of coral have examined either the colony growing independently or connected to the nearby reef. Further statistical analysis such as the diversity index of the coral reefs and multivariate analysis such as Principal Component Analysis (PCA) was examined by pulled data of live coral cover of all selected sites by using PAST Version 3.25[(ref. 13)].

Coral reef species identification up to genus level has been made in-situ assisted by photography and morphological observation because live coral specimen collection is legally restricted in GoK, MNP and MS. Because of that, different online databases like the digital archives of ZSI and Central Marine Fisheries Research Institute (CMFRI), Web of Science, and Google Scholar has been used. The taxonomical nomenclature presented by World List of Scleractinia (WoRMS)[14], and Coral Reef of the World[15] has been used for the identification of the coral species. An online website like Corals of the World is used to know the distribution pattern of the recorded species. In the case of uncertainty, photographs taken at the site were further examined after the data collection.

Results and Discussion

The substratum and geo-morphology of the outer Gulf of Kachchh is of limestone, rocks, and a gradual slope conducive for coral growth. The rocky substratum surrounds the coral reef zone of the Okha region is surrounded by a rocky substratum and the drainage slope is from south to north. The low-lying coastal reef distributing area forms an approximately two km wide coastal belt. An approximate intertidal expanse is about 0.8 km. There are small tidal pools near about 0.5 m found in the rocky shore area. The total area surveyed was 1.6 km^2 of which the coral-covered area was 0.72 km^2, which is approximately 45 % of the total area. The coral reef zone of the Mithapur region is surrounded by sandy substratum in the supratidal zone and rocky substratum in the mid tidal and subtidal zone. The low-lying coastal reef distributing area forms an approximately 3 km wide coastal belt. An approximate intertidal expanse is about 1.2 km. There are about 3 to 6 meter tidal pools found in rocky shore areas. Out of total 3.6 km^2 area survey, the reef covering area was 2 km^2, *i.e.*, about 55.5 %. The Shivrajpur site has mainly a rocky substratum with large and small tidal pools. The total area surveyed at this site was 3 km^2, out of which corals were noted at 2.16 km^2 area covering 72 % of the intertidal expanse.

The lesser reef coverage at Okha can be attributed to the increased pressure from tourists and locals frequenting the coast damaging the young corals. Several study excursions from several colleges and institutes also visit the site for the collection of marine flora and fauna affecting coral growth. Shivrajpur site is comparatively pristine as no tourism or any industrial growth is around.

Total 23 species of Scleractinian corals belong to 8 different families, and 12 genera were recorded from three sites of the outer Gulf of Kachchh region. Poritidae contributes the highest number of Scleractinian corals followed by the family Faviidae and Merulinidae. The highest number of the scleractinian corals were recorded from the Shivrajpur with 22 species belongs to 12 genera followed by Mithapur with 16 species belongs to 10 genera and Okha 12 species belong to 8 genera (Table 1).

Earlier reports have recorded 31 species of live corals belonging to 8 different families and 18 genera from the MNP and Marine Sanctuary of GoK[16]. Similarly, maximum live coral cover was recorded from Pirotan Island, followed by Laku Point (Poshitra Island), Mithapur, and Boriya reef[17]. Gopinathan & Patel[18] reported 37 species of Scleractinian corals among 24 genera from GoK. Out of which, 20 genera with 33 species were hermatypic and the rest 4 genera

Table 1 — List of coral reef species recorded from outer GoK

Sr. No.	Family	Coral reef species	Acronyms	Okha	Mithapur	Shivrajpur
1	Acroporidae	*Montipora foliosa* (Pallas, 1766)	*mf*			X
2		*Montipora* sp. 1	*msp1*			X
3		*Montipora* sp. 2	*msp2*			X
4		*M. venosa* (Ehrenberg, 1834)	*mv*	X	X	X
5	Coscinaraeidae	*Coscinaraea* sp.	*csp*			X
6	Faviidae	*Dipsastraea favus* (Forskal, 1775)	*df*	X	X	X
7		*Dipsastraea* sp.	*dsp*	X		
8		*D. speciosa* (Dana, 1846)	*ds*	X	X	X
9		*Leptastrea purpurea* (Dana, 1846)	*lp*		X	X
10	Lobophylliidae	*Homophyllia bowerbanki* (Milne Edwards & Haime, 1857)	*hb*	X	X	X
11		*Lobophyllia radians* (Milne Edwards & Haime, 1849)	*lr*	X	X	X
12	Merulinidae	*Favites* sp. 1	*fssp1*	X	X	X
13		*Faviets* sp. 2	*fssp2*	X	X	X
14		*Faviets* sp. 3	*fssp3*		X	X
15		*F. spinosa* (Klunzinger, 1879)	*fss*	X	X	X
16	Poritidae	*Goniopora pedunculata* (Quoy & Gaimard, 1833)	*gpd*	X	X	X
17		*Goniopora* sp.	*gsp*			X
18		*Porites compressa* (Dana, 1846)	*pc*		X	X
19		*Porites* sp.	*psp*		X	X
20		*P. lutea* (Milne Edwards & Haime, 1851)	*plu*	X	X	X
21	Psammocoridae	*Psammocora* sp.	*psp*		X	X
22	Siderastreidae	*Pseudosiderastrea tayamai* (Yabe & Sugiyama, 1935)	*pt*			X
23		*Siderstrea savignayana* (Milne Edwards & Haime, 1851)	ss	X	X	X

and 4 species were ahermatypic. The study reported a total of 11 species of Scleractinian corals from Okha port. During the present study, 12 species of scleractinian corals were reported from the Okha region, showing stagnant growth of coral reefs and no decline in the coral reef ecosystem of the outer GoK.

Recently, De *et al.*[19] presented a revised checklist of scleractinian corals from the four major Indian reefs including other small reefs across the West coast of India representing a total of 585 species belonging to 95 genera and 25 families. They have reported a total of 76 species of scleractinian corals belonging to 30 genera and 12 families[19]. Total 15 genera of corals were recorded from Grande Island, located at the Central West coast of India of which *Turbinaria* and *Goniopora* spp. were dominant in the mid-shelf zone. While *Pseudosiderastrea* and *porites* spp. were dominant in the shallow and deep zones[20].

According to the reports, 56 coral reef species were recorded from the GoK of which 44 species were hard corals[21]. Kumar *et al.*[22] reported two species of soft coral, *Carijoa riisei* and *Subergorgia suberosa* belonging to families Clavulariidae and Subergorgiidae, respectively from GoK for the first time. These were not recorded earlier in the GoK region. Lakhmanpurkar & Gavali[23] reported 24 species of Scleractinian corals from the Kachhigarh, Devbhumi Dwarka from outer GoK.

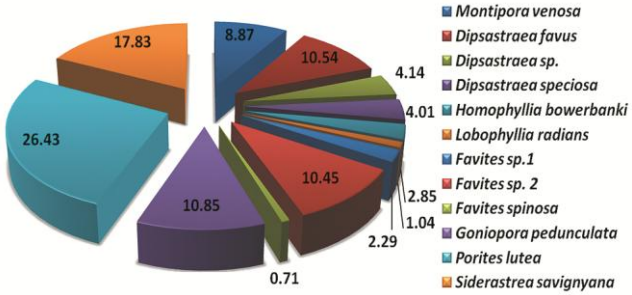

Fig. 1 — Area cover percentage of coral species at Okha

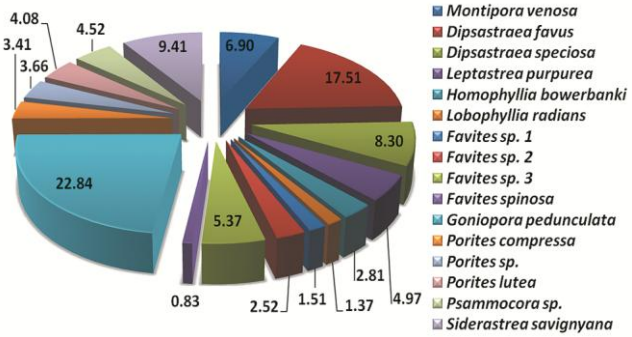

Fig. 2 — Area cover percentage of coral species at Mithapur

They showed similar results between *Dipsastraea*, *Favites*, and *Porites* species in this area.

The reef benthic cover at all three sites is given in Figures 1 – 3. At Okha, *Porites lutea* (26.43 %)

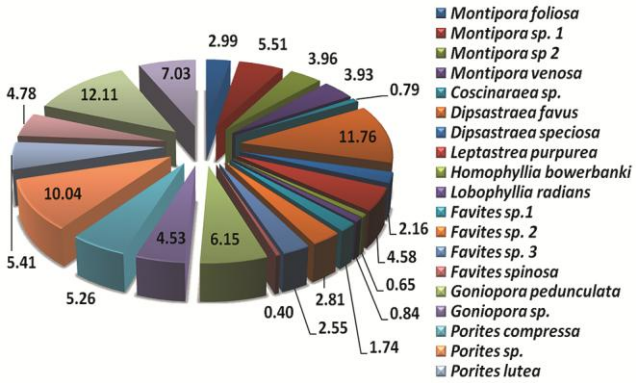

Fig. 3 — Area cover percentage of coral species at Shivrajpur

Table 2 — Diversity indices of the coral species recorded during the present study

	Okha	Mithapur	Shivrajpur
Taxa_S	7.25	9.69	18.63
Individuals	18.69	34.00	109.25
Simpson's index (D)	0.80	0.79	0.90
Shannon-Wiener index (H)	1.78	1.89	2.58
Evenness (E)	0.88	0.74	0.73
Species richness (S)	2.11	2.49	3.81

Table 3 — Principal components based on Eigen value

PC	Eigen value	% Variance
1	967860	87.312
2	110157	9.9374
3	30489.7	2.7505

contributed maximum percentage coverage area followed by *Siderastrea savignyana* (17.83 %). *Favites spinosa* contributed a minimum percentage coverage area of 0.71 % (Fig. 1). It is found that at Mithapur, *Goniopora pedunculata* contributed the highest coverage of 22.84 %, followed by *Dipsastraea favus* with 17.51 %, whereas *F. spinosa* contributed to minimum 0.83 % (Fig. 2). At Shivrajpur site, *Pseudosiderastrea tayamai* contributed to the highest percentage coverage area 12.11 %, followed by *D. favus* (11.76 %) and *F. spinosa* contributed to a minimum of 0.40 % (Fig. 3).

Diversity indices of Scleractinian corals of the outer GoK show the highest number of taxa is recorded from Shivrajpur (18.63), followed by Mithapur (9.69). The number of individuals is highest at Shivrajpur (109.25), followed by Mithapur (34), whereas Simpson's index is highest at Shivrajpur (0.90) followed by Okha (0.80). In the present study, the Shannon-Wiener index found highest at Shivrajpur (2.58), followed by Mithapur (0.79). Highest evenness in the occurrence of Scleractinian corals found at Shivrajpur, followed by Mithapur. Species richness is highest at Shivrajpur (3.81), followed by Mithapur (2.49) (Table 2). Among three selected sites at outer gulf, site Shivrajpur is having less anthropogenic pressure than the other two sites and hence the diversity indices values of reef diversity are higher at Shivrajpur site than Okha and Mithapur.

A study based on community structure and spatial patterns of Scleractinian corals in the Kilakarai group of islands in the GoM reported the highest value of the Shannon diversity index in the reef of Mulli Island (2.53) and the lowest values in Anaipar Island (1.72). Simpson's richness index also followed the same trend with values of 0.91 and 0.81, respectively, for Mulli and Anaipar island reefs. Pielou's evenness value was the maximum (0.88) in Mulli island reefs and the minimum (0.81) in the Valimunai Island reef[24].

PCA analysis of all selected sites supported the statement that maximum live coral cover was found at Shivrajpur followed by Mithapur and Okha (Fig. 4). The axis is ranked in order of important differences among the first principal component axis PCA1 are more important than differences among the second principal component axis PCA2. PCA1 contributed a maximum (87.312 %) followed by PCA2 (9.9374 %; Table 3). A scatter plot plotted based on eigenvalue scores of a live coral cover of the selected sites. The adequacy of variables in species differentiation and classification power of the PCA model has been shown by the scatterplot. It is also found that at Okha site species such as *P. lutea*, *G. pedunculata*, *S. savignyana*, and *M. venosa* are frequently distributed while at Mithapur *G. pedunculata* and at Shivrajpur *P. tayamai*, *and Porites* sp. were frequently distributed. The factors responsible for this pattern could be the anthropogenic pressures at these sites. Mithapur is subjected to high pollution and industrial growth, whereas the Okha site frequented with tourism. Compared to these two sites, Shivrajpur is a pristine condition with no anthropogenic activities, thus supporting higher biodiversity and coverage of the scleractinian corals.

A similar study had been done by Kumar *et al.*[25] at 11 selected sites of MNP GoK from West to East to assess the status of live coral cover with their associates. Multivariate analysis of this study supported that the contribution of live coral cover was more at Pirotan Island and Laku Point at Poshitra Island. It is also indicated that the availability of coral

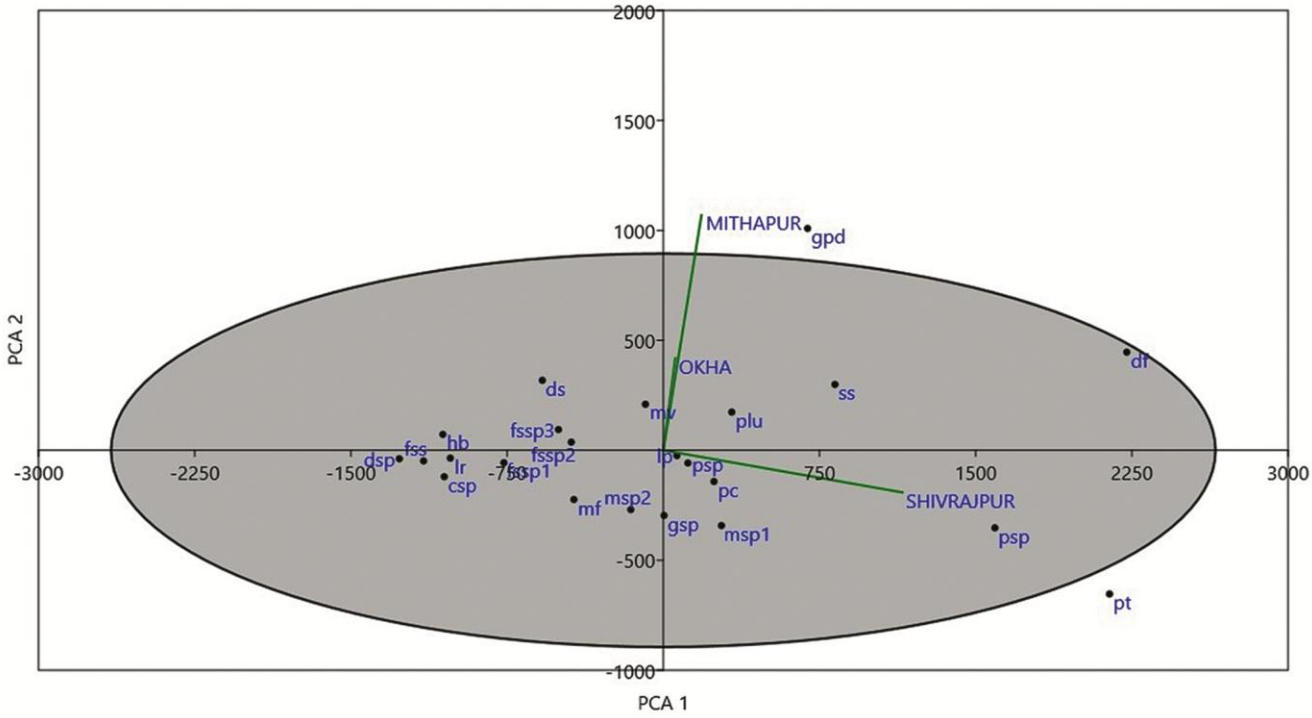

Fig. 4 — PCA analysis of coral cover for all the stations

species such as *Paracyathus*, *Polycyathus*, *Goniastrea*, *Goniopora*, and *Turbinaria* sp. was more at Laku Point than on the other selected sites.

Conclusion

It can be thus concluded that outer GoK has great potential for coral biodiversity, which yet remained unexplored. From the present study, the coral reef's status in the outer part of GoK was studied. Coral reef site Mithapur is vulnerable to tourism and industrialization. Therefore, the present study can be helpful to know the present status of corals and it can be used as baseline data to spread awareness among the local communities. To protect the coral reef ecosystem in the outer GoK reef management activities should be strengthened and negative anthropogenic pressure should be weakened. It is also essential to undertake the measures for conservation and protection of the reefs from future exploitation threats from tourism, coastal development, and industrialization.

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Conflict of Interest

Authors declare no conflict of interest.

Author Contributions

KN: Conceptualization; Investigation; Formal analysis; Software; Writing - original draft; Writing - review & editing; BB: Resources; Supervision; AK: Resources; Software; Supervision; NH: Investigation; Writing - review & editing; HK: Investigation; Formal analysis; Writing - original draft; Writing - review & editing; GD: Conceptualization; Investigation; Formal analysis; Funding acquisition; Resources; Software; Supervision; Writing - original draft; Writing - review & editing.

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