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Longitudinal variations of coral reef features in the Marine National Park, Gulf of Kachchh

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Abstract The Gulf of Kachchh is characterised by a strong tidal variation and the reef communities are capable of higher exposure time during negative tides. About 11 sites located along the Marine National Park (MNP) from west to east were studied for assessing the present status of live coral cover along with other life-form categories. In the present study, the maximum live coral cover was recorded in Pirotan Island, followed by Laku Point, Mithapur and Boriya reef. Multivariate analyses such as Principal Component Analysis and Correspondence Analysis supported that the contribution of live coral cover was more towards Pirotan Island whereas the contribution of coral species cover was more towards Laku Point. Bray-Curtis cluster analysis categorized all the study sites into four major clusters with 78 % similarity based on life-form categories. Among them, two clusters from western region (one forming site from Mithapur Reef to Lakku Point and another one forming from Ashaba Gugar Reef to Dabdaba Island), the third one combines the western and eastern regions (Boriya Reef to Kalubar Island), the fourth one comprises the eastern region (Narara Reef to Sikka), and one outlier Pirotan Island. Based on coral species cover, two major clusters with 55 % similarity were formed. Among them, one cluster was formed from Pirotan Island to Kalubar Island in the eastern side of MNP and the second one comprised the western region of MNP (Boriya Reef to Laku Point), and one outlier Mithapur Reef. Thirty one species of live corals belonging to 8 families and 18 genera were recorded in the Marine National Park itself during the study period.

Keywords Coral reef · East–west gradient · Gulf of Kachchh (GoK) · Marine National Park (MNP)

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Introduction

India has a long coastline of 7,500 km and some parts of it have environments rich in coral reefs. One such distinct area is the Gulf of Kachchh where coral reef ecosystems are present. The Gulf of Kachchh occupies an area of 7,300 Km^2 (Nair 2002) which comprises 42 islands with a diverse group of fauna and flora. In the GoK, the tidal variations are high, forming about 1,500 km^2 of intertidal area with the ecosystem components of creeks, marshy tidal flats and rocky regions. It provides affable environment to a wide variety of marine organisms (George et al. 2011). The southern part of GoK has islands and islets which provide shelter for coral reefs and mangroves, whereas the northern part is completely covered by sandy or muddy shore (Nair 2002). The southern part is endowed with a variety of marine organisms such as corals, sponges, molluscs, mangroves, algae, prawns, fishes, reptiles, and mammals. In order to protect the rich biodiversity of the Gulf, several intertidal mudflats and

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islands having coral reefs and the southern shore have been declared as Marine National Park as well as Marine Sanctuary.

The main objective of this study is to observe the current status of live coral cover along with its associated and other life-form categories on pilot based report with statistical support.

Methodology

This study was carried out from August 2012 to May 2013 on pilot based in the MNP area of GoK. About 11 sites (Fig. 1) were selected to represent the entire MNP from west (Mithapur) to east (Pirotan Island). Line Intercept Transect (LIT) method (English et al. 1997) was adopted for estimating the sessile benthic community of corals, present in the subtidal region. A 20-m long flexible underwater tape was laid on the reefs roughly parallel to the shore with five replicates at each site. The benthos coming under the transition points were recorded using the following international codes.

The present study classified the coral reef life-form categories such as Live Coral (LC), Dead Coral (DC). Abiotic forms are categorised as Dead Coral with Algae (DCA), Rubble (R), Rock (RCK) and Sandy bottom (S). The algal cover was also recorded and categorized as Algal Assemblage (AA). Sponges and Soft corals were denoted as SP and SC respectively. Other associated organisms like sea stars, sea cucumber, giant clam and bivalves observed in the reef ecosystem were categorized as Others (OT) in this study. The collected raw data were processed using AIMS Reef Monitoring Data Entry System (ARMDES V1.6) (ARMDES 1996). The percentage cover of Scleractinian and Non-Scleractinian corals, abiotic and other associated organisms were estimated using this package. Further statistical analyses were carried out using PAST Version 2.15 (Hammer 2012).

Results

Among 11 study sites selected in the MNP, Pirotan Island was recorded as a coral rich site in live cover (36.3 %), followed by Laku Point (35 %), and Mithapur (28.1 %) (Fig. 2a). However, Shanon-Weiner Diversity index (Fig. 2d) of Laku Point was more than Pirotan Islands (Fig. 2d). Multivariate analyses such as Prinicipal Component analysis (PCA) and Correspondence analysis (CA) supported that the contribution of live coral cover was observed more in Pirotan Island and Laku Point (Figs. 3 and 4a). The CA (Fig. 4b) also indicated that the availability of coral species such as *Paracyathus*, *Polycyathus, Goniastrea, Goniopora* and *Turbiaria* sp. was more at Laku Point than on the other sites. The abiotic form, Silt (SI) and Dead Coral with Algae (DCA) were observed more in Manmarodi Island, Dabdaba Island and Sikka coast (Figs. 2 and 4a). Soft coral cover was recorded more in Manmarodi Island whereas sponges cover was observed dominantly in Paga Reef (Fig. 2). Maximum Algal Assemlage (AA) cover was observed in Narara Reef (14.4 %) followed by Dabdaba Island (11.9 %) Bray-Curtis Cluster analysis under paired linkage was also studied based on species cover and life-form cover (Fig. 5). Based on the availability of coral species, two major clusters with 55 % similarity

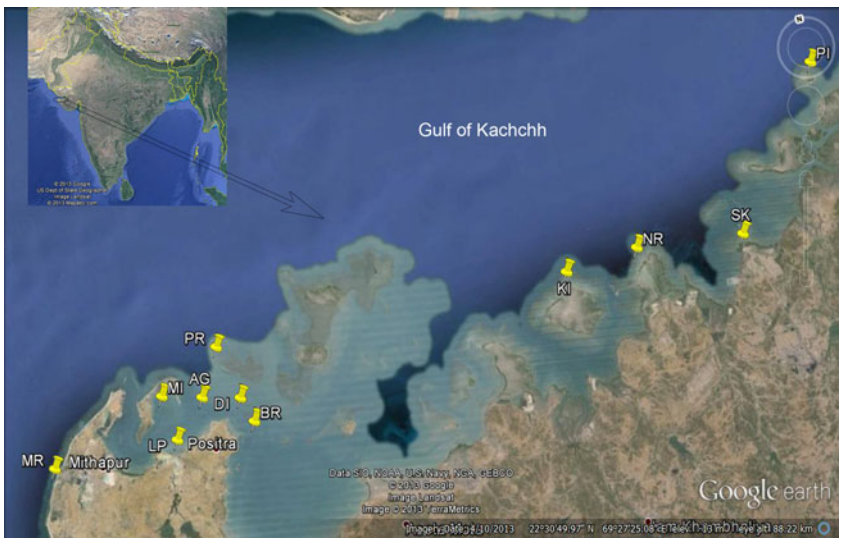

Fig. 1 Map showing the study sites

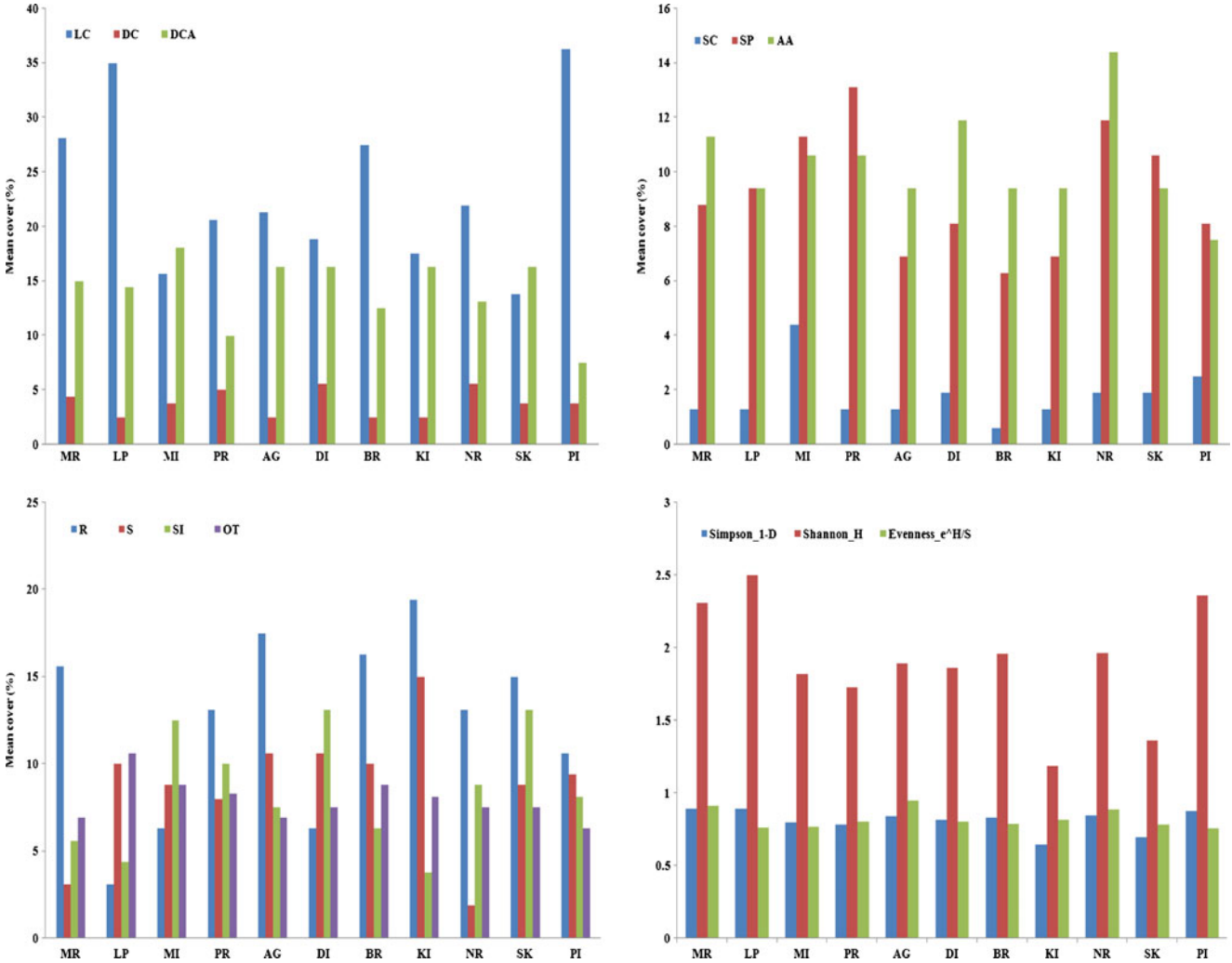

Fig. 2 Life-form categories and Species Diversity Indices observed in the MNP, GoK. *MR* Mithapur, *LP* Laku Point, *MI* Manmarodi Island, *PR* Paga reef, *AG* Ashaba Gugar reef, *DI* Dabdaba Island, *BR* Boriya reef, *KI* Kalubar Island, *NR* Narara reef, *SK* Sikka, *PI* Pirotan Island

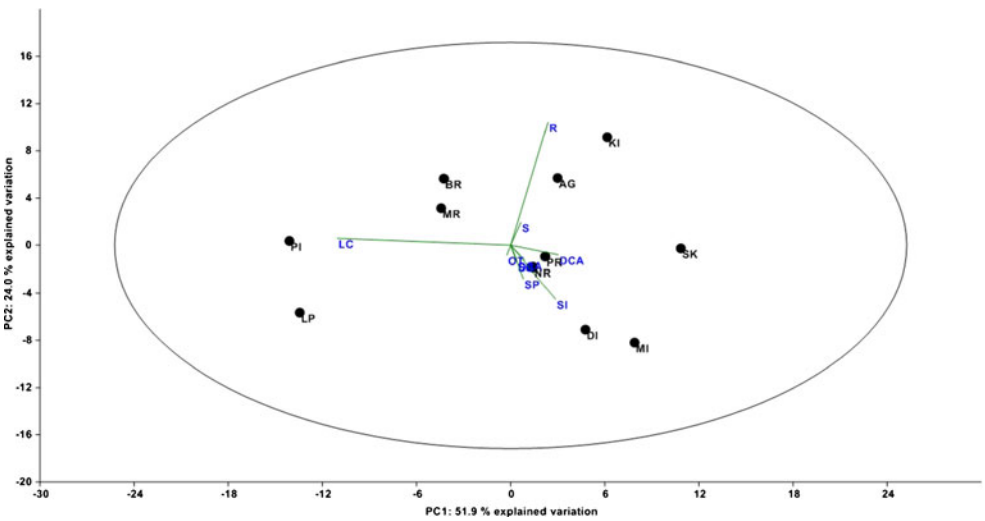

Fig. 3 Principal Component Analyses (PCA) of life-form categories recorded in the MNP, GoK. *LC* live coral, *DC* dead coral, *DCA* dead coral with algae, *SC* Soft coral, *SP* sponge, *AA* algal assemblage, *R* rubble, *S* sand, *SI* silt, *OT* other organisms, *MR* Mithapur, *LP* Laku Point, *MI* Manmarodi Island, *PR* Paga reef, *AG* Ashaba Gugar reef, *DI* Dabdaba Island, *BR* Boriya reef, *KI* Kalubar Island, *NR* Narara reef, *SK* Sikka, *PI* Pirotan Island

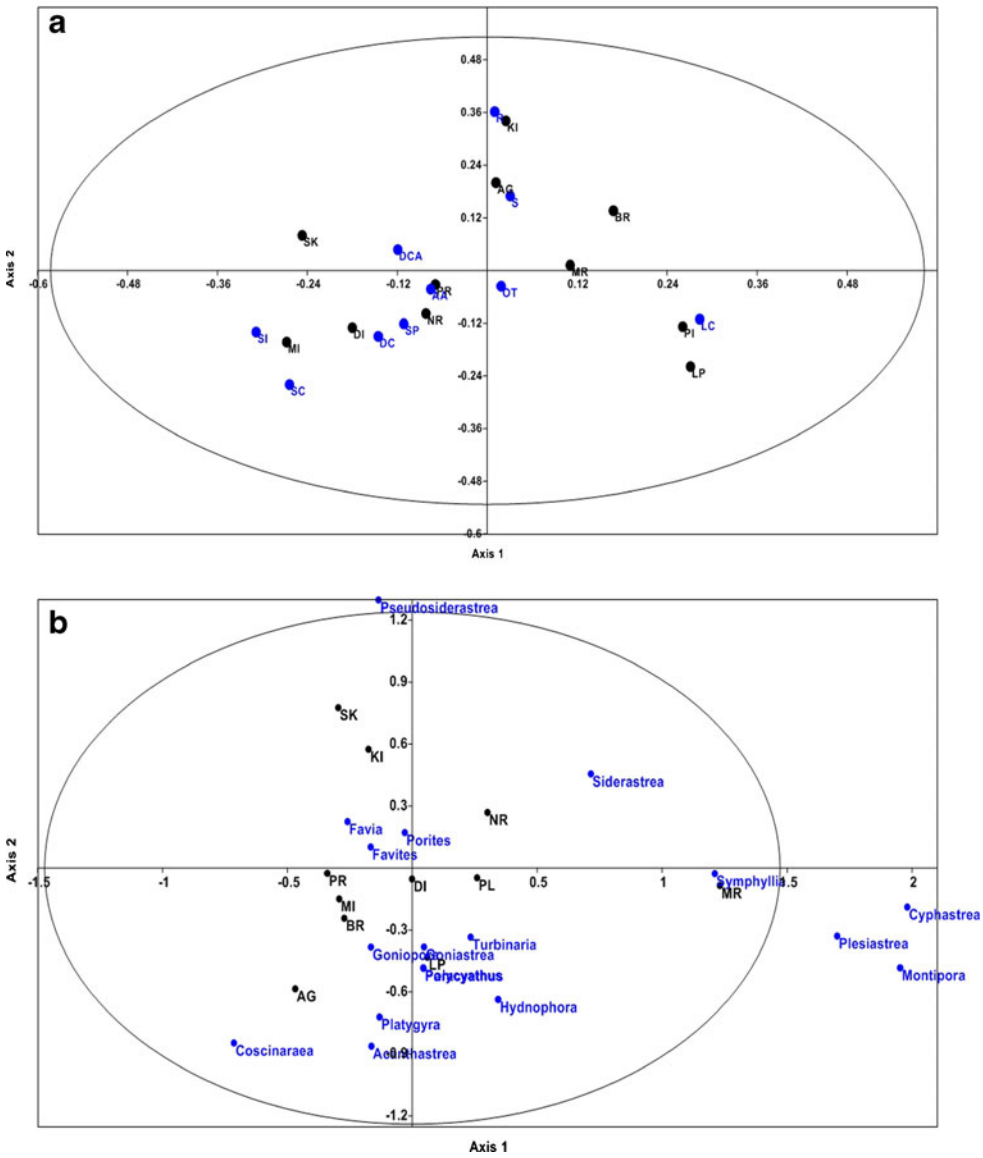

Fig. 4 Correspondence analysis of life-form categories and coral genus cover recorded in the MNP, GoK. *LC* live coral, *DC* dead coral, *DCA* dead coral with algae, *SC* Soft coral, *SP* sponge, *AA* algal assemblage, *R* rubble, *S* sand, *SI* silt, *OT* other organisms, *MR* Mithapur, *LP* Laku Point, *MI* Manmarodi Island, *PR* Paga reef, *AG* Ashaba Gugar reef, *DI* Dabdaba Island, *BR* Boriya reef, *KI* Kalubar Island, *NR* Narara reef, *SK* Sikka, *PI* Pirotan Island

were formed. Among them, one cluster covering the area from Pirotan Island to Kalubar Island in the eastern side of MNP and the second one comprising the western region of MNP (Boriya Reef to Laku Point), and one outlier Mithapur Reef. Based on the availability of ten different life-form categories in the study sites, four major clusters with 78 % similarity were formed. Among them, two clusters from the western side (Mithapur to Laku Point and Ashaba Gugar Reef to Dabdaba Island), the third one (mixed cluster) forming from western Boriya Reef to eastern Kalubar Island and fourth one comprising the eastern side of MNP (Narara Reef to Sikka coast), and one outlier Pirotan Island.

During this study, the available Scleractinian coral fauna checklist has been prepared (Table 1; Figs. 6 and 7). About 31 species of 8 families were identified in this study and verified (Venkataraman et al. 2003; Veron 2000). The dominant genera recorded were *Favia, Porites, Favites, Goniopora, Goniastrea, Siderastrea, Acanthastrea* and *Turbinaria*. However, *Coscinaraea, Cyphastrea, Hydnophora, Plesiastrea, Polycyathus* and *Montipora* were rarely found in the study sites (Figs. 6 and 7).

Discussion

The Gujarat coast has a long coastline, with 1,650 km forming 21 % of the Indian coastline and serving as a natural gateway to India (Singh et al. 2012). The coastline of Gujarat has

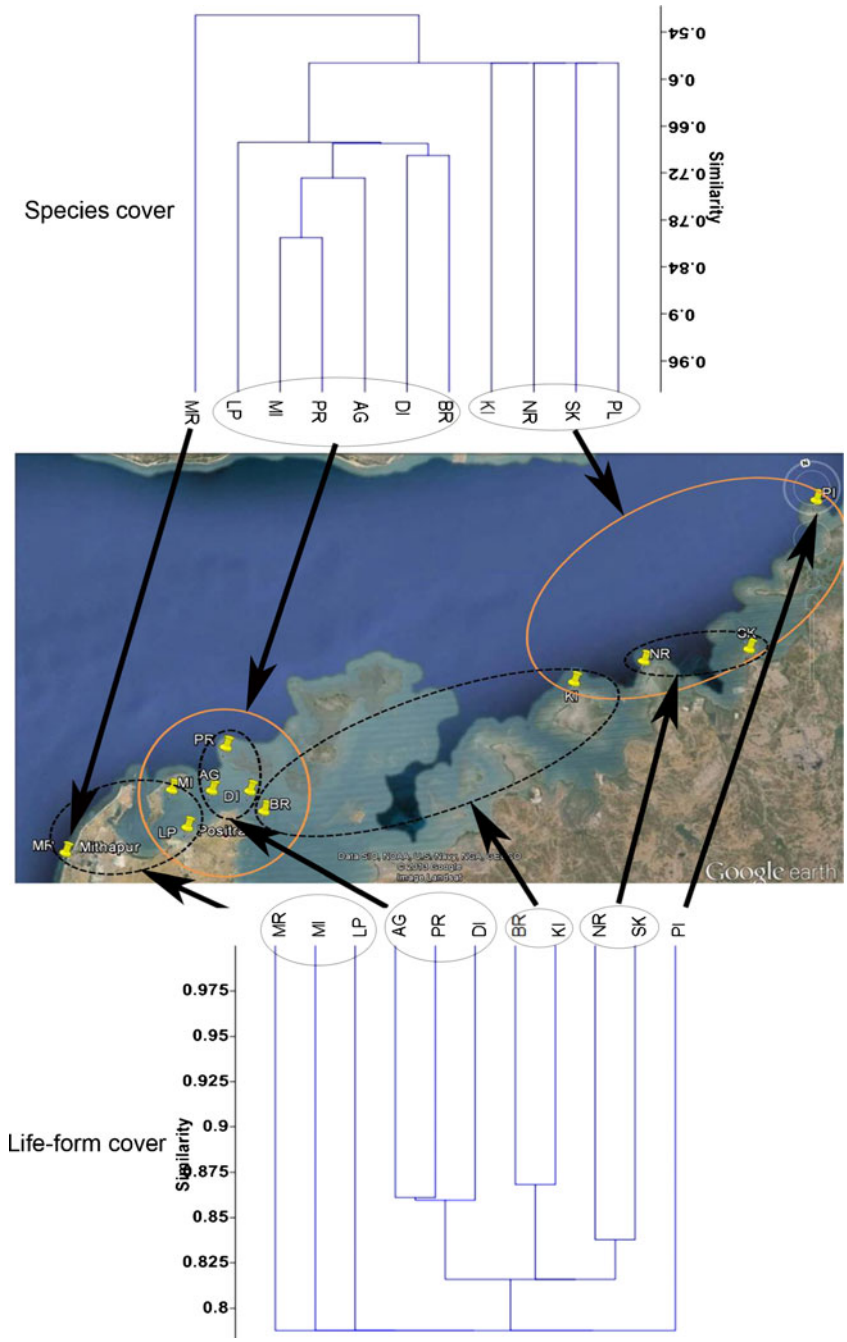

Fig. 5 Bray-Curtis Cluster analysis under paired linkage based on life-form categories and coral genus cover recorded in the MNP, GoK. *MR* Mithapur, *LP* Laku Point, *MI* Manmarodi Island, *PR* Paga reef, *AG* Ashaba Gugar reef, *DI* Dabdaba Island, *BR* Boriya reef, *KI* Kalubar Island, *NR* Narara reef, *SK* Sikka, *PI* Pirotan Island

two gulfs- Gulf of Kachchh and Gulf of Khambhat, which covers about 60 % of the state coastline. Of these gulfs, coral reefs are quite distinctive in terms of their isolation and surviving in extreme oceanographic and climatic conditions (Dixit et al. 2010). Pillai and Patel (1988) reported in their study that the Scleractinian corals of the Gulf of Kachchh are represented by 37 species belonging to 24 genera. Among them, 33 species are hermatypes and 4 species are ahermatypes. In addition to this, 12 species were reported first time from this region (Satyanarayana and Ramakrishna 2009). But in this rapid assessment, MNP of Gulf of Kachchh itself comprised of about 31 species belonging to 18 genera and 8 families. The present status of corals and reef associated organisms are in the following order: Pirotan Island > Laku Point > Mithapur > Boriya Reef > Narara Reef > Ashaba Gugar Reef > Paga Reef > Dabdaba Island > Kalubar Island > Manmarodi Island > Sikka reef. Among the study sites,

Table 1 Checklist of Scleractinian fauna of Marine National Park of Gulf of Kachchh

S. No.	Name of the Species	1	2	3	4	5	6	7	8	9	8	9
1	*Acanthastrea hillae* Wells, 1955	+	+	+	−	+	−	+	−	−	−	+
2	*Coscinaraea columna* Dana, 1846	−	−	−	−	−	−	+	−	−	−	−
3	*Coscinaraea monile* Forskal, 1775	−	+	+	+	+	−	−	−	−	−	−
4	*Cyphastrea serailia* Forskal, 1775	+	−	−	−	−	−	−	−	−	−	+
5	*Favia favus* Forskal, 1775	+	+	+	+	+	+	+	+	+	+	+
6	*Favia lacuna* Veron, 2000	−	+	−	−	−	−	−	+	−	−	+
7	*Favia speciosa* Dana, 1846	+	−	−	−	+	−	−	−	−	−	+
8	*Favites chinensis* Verrill, 1866	+	+	−	−	−	−	−	−	+	+	+
9	*Favites complanata* Ehrenberg, 1834	+	+	−	+	+	−	+	+	−	+	+
10	*Favites flexuosa* Dana, 1846	+	+	+	−	−	−	−	−	−	−	+
11	*Favites halicora* Ehrenberg, 1834	−	+	−	−	−	−	−	+	−	+	+
12	*Favites pentagona* Esper, 1794	−	−	−	+	−	−	−	−	−	−	+
13	*Goniastrea pectinata* Ehrenberg, 1834	+	+	+	+	+	+	+	−	+	−	+
14	*Goniopora planulata* Ehrenberg, 1834	−	+	−	+	+	−	−	−	−	−	+
15	*Goniopora minor* Crossland, 1952	−	+	−	+	+	+	+	−	+	−	+
16	*Hydnophora exesa* Pallas, 1766	−	+	−	−	−	−	−	−	−	−	+
17	*Montipora foliosa* Pallas, 1766	+	+	−	−	−	−	−	−	−	−	−
18	*Paracyathus stokesi* Edwards and Haime, 1848	−	+	−	−	−	+	−	−	−	−	−
19	*Platygyra pini* Chevalier, 1975	−	+	−	−	−	−	+	−	−	−	+
20	*Plesiastrea versipora* Lamarck, 1816	+	+	−	−	−	−	−	−	−	−	+
21	*Polycyathus verrilli* Duncan, 1889	−	+	−	−	−	+	−	−	−	−	−
22	*Porites compressa* Dana, 1846	+	+	−	−	−	−	−	−	−	−	+
23	*Porites lichen* Dana, 1846	+	+	−	+	+	−	−	−	+	−	+
24	*Porites lutea* Milne Edwards and Haime, 1860	+	+	+	+	+	+	+	+	+	+	+
25	*Pseudosiderastrea* tayami Yabe & Sugiyama, 1935	−	−	−	−	−	−	−	−	+	+	+
26	*Siderastrea savignayana* Edwards & Haime, 1850	+	+	−	−	−	+	−	+	+	+	+
27	*Symphyllia radians* Edwards & Haime, 1849	+	+	+	−	−	−	−	−	+	−	+
28	*Turbinaria frondens* Dana, 1846	−	−	−	+	−	−	−	−	−	−	+
29	*Turbinaria reniformis* Bernard, 1896	−	−	−	−	−	+	+	−	−	−	−
30	*Turbinaria peltata* Esper, 1794	−	+	+	+	+	−	+	−	−	−	+
31	*Turbinaria mesenterina* Lamarck, 1816	+	+	−	−	−	−	+	−	−	−	+

1 Mithapur, *2* Laku Point, *3* Manmarodi Island, *4* Paga reef, *5* Ashaba Gugar reef, *6* Dabdaba Island, *7* Boriya reef, *8* Kalubar Island, *9* Narara reef, *10* Sikka, *11* Pirotan Island

Pirotan and Laku Point exhibited the highest live coral cover, while the Sikka coast and Manmarodi Island exhibited the least live coral cover. CA (Fig. 4a) supports this observation. This might be due to the settlement of the fine sediments (silt and clay) and recruitment of algal populations on the coral colonies. CA also coincides with these observed results, that the contribution of DCA and Siltation are more towards Sikka (Fig. 4a). The results of this study provide several useful insights in terms of longitudinal variation in the distribution of both life-form categories as well as coral diversity. Figure 5 shows complete variation between western and eastern side of MNP based on coral species cover. Meanwhile, two clusters from western side, one cluster from eastern side and one mixed cluster between western and eastern side of MNP were formed based on life-form categories observed in this study.

The coral reef ecosystem monitoring and assessment by estimating the percentage covers has been periodically reported worldwide. There were a lot of reports published both on global (Wilkinson 2008) as well as regional levels (Venkataraman and Rajan 1998; Hassan et al. 2002; Venkataraman and Wafar 2005; Tamelander and Rajasuriya 2008; Marimuthu et al. 2011; Geetha and Kumar 2012) on the status of coral reefs. The LIT methodology plays a vital role in estimating the current status of live coral and its associated life-forms cover (Marsh et al. 1984; Winter et al. 1998; Celliers and Schleyer 2002; Kumaraguru et al. 2003; Beenaerts and Berghe 2005; Kumar and Raghunathan 2012;

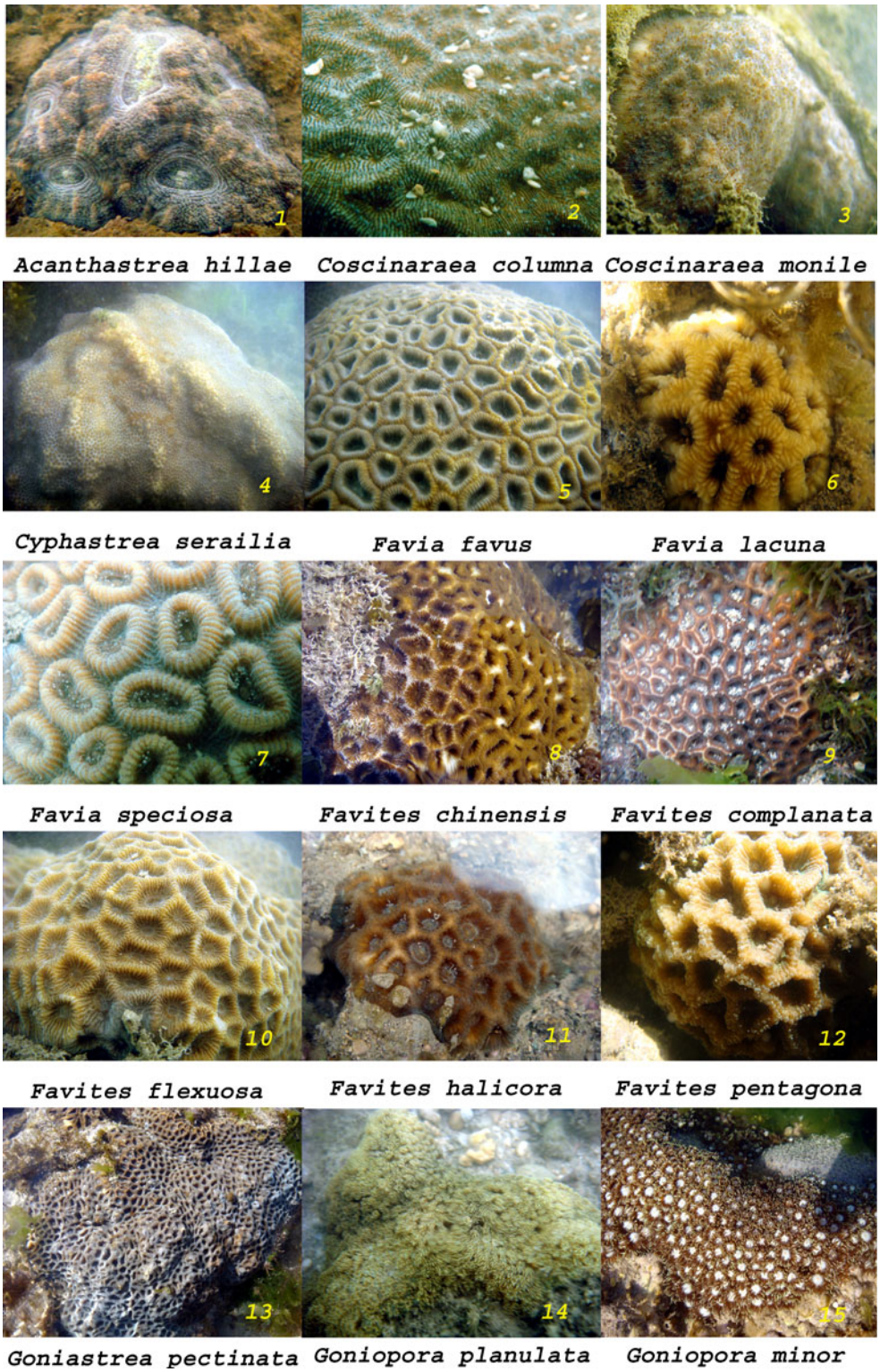

Fig. 6 Scleractinian corals of MNP, GoK

Jha et al. 2013; Marimuthu et al. 2013) in various parts of the world. It also helps to assess the present situation after natural disturbances such as tsunami (Kumaraguru et al. 2005) and catastrophic bleaching events (Arthur 2000; Kumaraguru et al. 2003; Marimuthu et al. 2013) and subsequent recovery studies (Kumar and Raghunathan 2012; Marimuthu et al. 2013). These natural impacts on the corals may vary according to the availability of life-form categories in the ecosystem. Hence, this present result along with multivariate analyses support will be

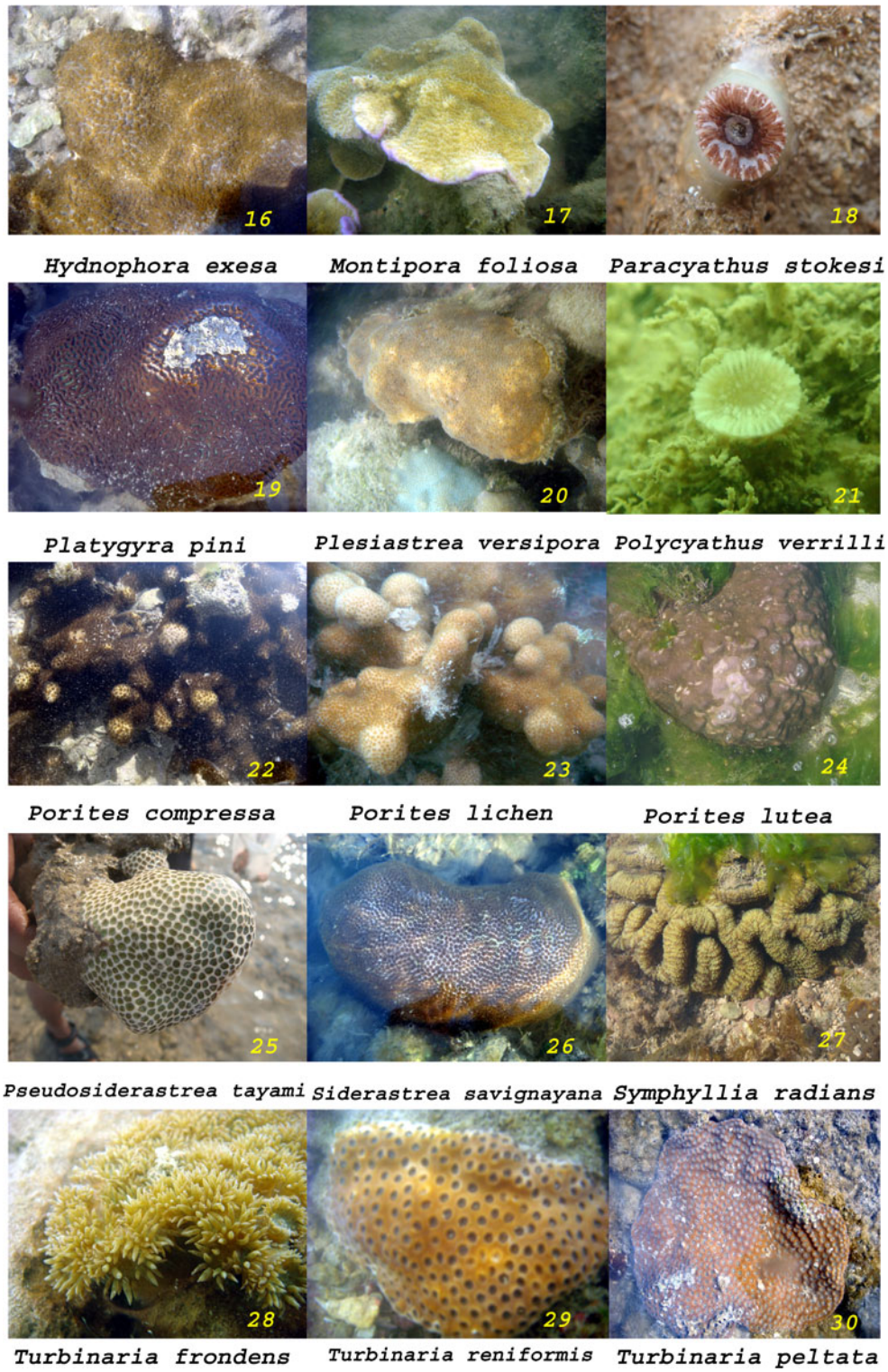

Fig. 7 Scleractinian corals of MNP, GoK

helpful to identify the baseline information, and the similarity and longitudinal variations of the selected study sites along the MNP area. Ultimately, it will be a useful source of information to aid in decision-making regarding employing appropriate and sustainable management strategies for the conservation and development of coral reef ecosystem by way of scientific restoration in the Gulf of Kachchh.

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