

Integrated Coastal Zone Management Project funded Coral restoration processes in the Gulf of Kachchh –A present scenario

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About fifty-three hard coral species recorded till date in the Gujarat coast based on the available literature. One of the projects under Integrated Coastal Zone Management Programme, Coral transplantation, are in progress to improve the quality of reefs at GoK. Major aim of this project is to develop a protocol for coral transplantation processes and making transplanted reef park at GoK by using local massive coral species as well as re-introducing the *Acropora* spp. from other parts of Indian reef ecosystems.

[Keywords: Integrated Coastal Zone Management Project; Coral reefs; Coral status; Gulf of Kachchh; Coral transplantation].

Introduction

Coral reefs are communities of living organisms forming some of the most diverse ecosystems in the world. They are marine polyps found in colonies in the shallow water environment and breathing diffused gas through their exposed epidermal and gastrodermal surfaces¹. It would not be wrong to say that corals are the core of marine ecosystems². However, they are also fragile ecosystems as they are very sensitive to natural and anthropogenic disturbances. In India, coral reefs are the least fortunate of marine organisms as they face threats-mostly because of the lack of balance between the application of the principles of natural science and development science in coastal conservation and sustainable use of coastal resources for economic purposes.

Corals are the richest depository which helps to maintain marine biodiversity. Even though reef is occupying only 0.17% of the world's ocean surface³, it is the only natural community distinctly visible from space. Corals contain symbiotic algae called zooxanthellae, within their gastrodermal cells. Coral provides protected environment as well as the essential compounds for the algae to photosynthesize. These include carbon dioxide, produced by coral respiration, and inorganic nutrients such as nitrates and phosphates, which are metabolic waste products of the coral. In return, the algae produce oxygen and help the coral to remove wastes. Most importantly, they supply the coral with organic products of photosynthesis such as glucose,

glycerol, and amino acids. These compounds are utilized by the coral as raw materials in the production of proteins, fats, and carbohydrates, as well as the synthesis of calcium carbonate (CaCO₃). The mutual exchange of high-energy algal substances from photosynthesis and cnidarian metabolites is the key to the remarkable biological productivity and limestone-secreting capacity of reef-building corals.

Materials and Methods

The present study reviewed the present status of coral reefs and restoration efforts taken for improving the quality of reefs. It also compared the secondary information of the reef status of Gulf of Kachchh (GoK) from 1978 to till date. Most of the studies related to coral cover and its diversity assessment conducted at GoK were carried out through Quadrat method⁴ and some of the studies were carried out through Line Intercept Transect method⁴.

Results and Discussion

Coral reefs of Gujarat coast are the fringing type and are the most northern coral reefs in India. The estimated reef area in India is 2,374.9 km² of which 352.5 Km² are in the GoK, Gujarat⁵. This core ecosystem of Gujarat is rich in the reef edge and reef slope of the marine benthic environment. Marine National Park of GoK, Kuchchh coastal region (Mundra, Mandvi, and Kandla) and Saurashtra coast (Dwarka, Veraval, and Mahuva) were reported as rich sites for coral reef resources in the Gujarat coast. Good live coral cover and species diversity Index were reported in Pirotan Island and Lakupoint (Poshitra) respectively⁶. Totally fifty-three hard coral species recorded till date in the Gujarat coast based on the available literature (Table 1). *Barabattoia amicornum* Milne Edwards and Haime, 1850, a coral species was recorded in the Gujarat coast⁷ for the first time in India. Gregory (1900) (ref 8) reported about 71 coral species of Jurassic year from the Kachchh region. The age of the coral reefs⁹ is observed in the GoK between 5240 years B.P. (Salaya reef) and 45,000 years B.P. (Okha reef).

Table 1. Checklist of Hard and Soft corals observed in the Gujarat coast (+, available; -, not available; δ, Dead form recorded)

No.	Name of the Species	1978-1988 (ref. 12-16)	2000-2014 (ref. 3,6,7, 17-22)
1	<i>Acropora humilis</i> Dana, 1846	+	-
2	<i>Acropora squarrosa</i> Ehrenberg, 1834	+	-
3	<i>Acropora microphthalma</i> Verrill, 1859	-	δ
4	<i>Acanthastrea hillae</i> Wells, 1955	-	+
5	<i>Acanthastrea simplex</i> Crossland, 1952	+	-
6	<i>Barabattoia amicornum</i> Milne Edwards and Haime, 1850	-	+
7	<i>Coscinaraea columna</i> Dana, 1846	-	+
8	<i>Coscinaraea monile</i> Forskal, 1775	+	+
9	<i>Cyphastrea serailia</i> Forskal, 1775	+	+
10	<i>Dendrophyllia minuscula</i> Bourne, 1905	+	+
11	<i>Echinophyllia aspera</i> Ellis and Solander, 1788	-	+
12	<i>Favia fava</i> Forskal, 1775	+	+
13	<i>Favia lacuna</i> Veron, 2000	-	+
14	<i>Favia speciosa</i> Dana, 1846	+	+
15	<i>Favites chinensis</i> Verrill, 1866	-	+
16	<i>Favites complanata</i> Ehrenberg, 1834	+	+
17	<i>Favites flexuosa</i> Dana, 1846	-	+
18	<i>Favites halicora</i> Ehrenberg, 1834	-	+
19	<i>Favites pentagona</i> Esper, 1794	-	+
20	<i>Favites melicerum</i> Ehrenberg, 1834	+	+
21	<i>Goniastrea pectinata</i> Ehrenberg, 1834	+	+

22	<i>Goniopora planulata</i> Ehrenberg, 1834	+	+
23	<i>Goniopora minor</i> Crossland, 1952	+	+
24	<i>Goniopora nigra</i> Pillai, 1969	+	+
25	<i>Goniopora stutchburyi</i> Wells, 1955	-	+
26	<i>Goniopora tenuidens</i> Quelch, 1886	-	+
27	<i>Hydnophora exesa</i> Pallas, 1766	+	+
28	<i>Leptastrea purpurea</i> Dana, 1846	+	+
29	<i>Montipora explanata</i> Brueggemann, 1879	+	+
30	<i>Montipora foliosa</i> Pallas, 1766	+	+
31	<i>Montipora hispida</i> Dana, 1846	+	+
32	<i>Montipora monasteriata</i> Forskal, 1775	+	+
33	<i>Montipora turgescens</i> Bernard, 1897	+	+
34	<i>Montipora venosa</i> Ehrenberg, 1834	+	+
35	<i>Mycedium elephantotus</i> Pallas, 1776	+	+
36	<i>Paracyathus stokesi</i> Edwards and Haime, 1848	-	+
37	<i>Platygyra pini</i> Chevalier, 1975	-	+
38	<i>Platygyra sinensis</i> Edwards and Haime, 1849	+	+
39	<i>Plesiastrea versipora</i> Lamarck, 1816	+	+
40	<i>Polycyathus verrilli</i> Duncan, 1889	+	+
41	<i>Porites compressa</i> Dana, 1846	+	+
42	<i>Porites lichen</i> Dana, 1846	+	+
43	<i>Porites lutea</i> Milne Edwards and Haime, 1860	+	+
44	<i>Psammocora digitata</i> Edwards and Haime, 1851	+	+
45	<i>Pseudosiderastrea tayami</i> Yabe and Sugiyama, 1935	+	+
46	<i>Siderastrea savignyana</i> Edwards and Haime, 1850	+	+
47	<i>Symphyllia radians</i> Edwards and Haime, 1849	+	+
48	<i>Turbinaria frondens</i> Dana, 1846	-	+
49	<i>Turbinaria reniformis</i> Bernard, 1896	-	+
50	<i>Turbinaria peltata</i> Esper, 1794	+	+
51	<i>Turbinaria mesenterina</i> Lamarck, 1816	-	+
52	<i>Turbinaria crater</i> Pallas, 1766	+	+
53	<i>Tubastrea aurea</i> Lesson, 1834	+	+
	Total number of Scleractinian corals recorded	36	49

Raising Sea surface temperature (SST) in summer by even 1°C may lead to mass bleaching of this community and its simultaneous degradation. Corals of Gujarat coast have already faced two bleaching events, one in 1998 and the other in 2010. High sedimentation is also another factor in coral reef degradation, and there was no reasonable literature found related to Gujarat coast. Ocean acidification (the ability to dissolve nature of CO₂ into the seawater) is also a major threat to the coral reef ecosystem which will make inability to coral reefs to secrete CaCO₃ skeleton.

Also, Oil spill may also lead to maximum damage on the corals in the intertidal region. Salaya reef was reported¹⁰ as a susceptible area because oil may stand on reef flats during low tide time and this site was reported as a high-protection priority site for the oil spill. Due to rising of coastal dependant industries, coral reefs need restoration process to survive.

The biophysical monitoring and taxonomical update on coral reef ecosystem are being conducted and reported on the Gujarat coast from 1978 onwards. Under Integrated Coastal

Zone Management Project (ICZMP), Gujarat Ecology Commission (GEC) is updating the available coral reef resources and associated communities such as soft corals, sponges, crabs, gastropods, etc. The non-Acroporid corals such as massive forms (*Porites* sp., *Goniastrea* sp., *Favia* sp., *cyphastrea* sp., *Coscinaraea* sp., *Favites* sp., *Goniopora* sp., *Platygyra* sp., *Pseudosiderastrea* sp. and *Siderastrea* sp.) and Foliose forms (*Montipora* sp. and *Turbinaria* sp.) are common in the Gujarat coast⁶. Among these, *Turbinaria mesenterina*, *T. peltata* and *T. reniformis* are on vulnerable status in the IUCN. Acroporid coral forms were recorded during the period between 1978 and 1988 and are currently not reported in any part of the coast. Corals of Gujarat coast⁶ are in degraded conditions when compared to the other Indian coastal reefs such as Gulf of Mannar, Palk Bay, Lakshadweep group of Islands and Andaman & Nicobar Islands.

Coral Atlas of Gujarat coast¹¹ published in 2011 under ICZMP, and this type of documentation was published for the first time in the country for understanding about the current status of coral reefs and coralline area of GoK and available impacts on reef ecosystem, through thematic maps based on satellite imageries. It was prepared particularly for the purpose of enabling effective policy which ensures better conservation and management of the coral reef ecosystem. Based on the available literature^{3,6,7,12-22}, thirty-seven coral species were recorded before the 1990s whereas forty-nine were recorded between the year 2000 and 2014 on the Gujarat coast. Even though a higher number of hard coral species observed and recorded recently, a study needs to be conducted in the sub-tidal environment (Reef slope) is the need of the hour to explore more species diversity. Because most of the studies related to coral reef diversity, have been conducted in the intertidal region due to sedimentation/water clarity issue and heavy water current. Moreover, detailed analysis, followed by a compiled report or publication related to the ground analysis of coral reef diversity of entire GoK and Gujarat coast is necessary. Towards this, GEC aimed to analyze the collected data of life-form categories and their diversity under ICZMP to explore the health status of the coastal ecosystem on a pilot basis at GoK. This study will also be extended to the other parts of Gujarat coast for identifying degraded ecosystem. The outcome will be beneficial information to help in applying appropriate strategies for the conservation and development of reef in the degraded areas through scientific

restoration in the Gujarat coast. This Project (ICZMP) is also aimed to develop a protocol for coral transplantation process and completed 1000 square metre area of transplanted reef park at GoK. It was carried out by Zoological Survey of India, Marine National Park, Jamnagar, and GEER Foundation at GoK by using local massive coral species as well as *Acropora* spp. from Gulf of Mannar, Tamil Nadu. The post-transplantation monitoring work like survival rate assessment and the reports are under progress for documentation purpose. Hence, this restoration process helps to enrich and promote the benthic cover with transplanted coral nubbins in this most degraded reef ecosystem of India. Ultimately, this process will also protect the coastlines as a bio-shield from erosion.

Conclusion

The baseline information and checklist of corals reported from this review, based on the earlier publications published between the year 1978 and 2014. Gujarat Ecology Commission is working on conservation and management of this habitat at GoK through Integrated Coastal Zone Management project as one of its objectives. In order to protect this habitat and associated marine organisms, current bio-physical status assessment project under ICZMP needs to be monitored continuously due to the exposure of this habitat with current climate change.

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References

1. Pechenik, J.A., The Cnidarians. *Biology of the Invertebrates*. McGraw-Hill Co., USA, 2000, p. 98.
2. Joshi, H., and N. Marimuthu, Forbidding invasive species - a way to attain sustainability of the coastal ecosystem. *Current Science*, 108(2) (2015) 751-752.
3. Ramamoorthy, K., G. Sankar, and K. Sakkaravarthi, Assessment of reef associated biota in the Pirotan Island, Gulf of Kachchh, Gujarat, India. *European J Exp. Biol.*, 2(3) (2012) 551-561.
4. English, S., C. Wilkinson, and V. Baker, Survey manual for Tropical Marine Resources. Australian Institute of Marine Science, Townsville, Australia, 1997, 390 p.
5. Bahuguna, A., Chaudhury, R., Bhattji, N., Ajai, and Navalgund, R., Spatial inventory and ecological status of coral reefs of the Central Indian Ocean using Resourcesat-1. *Indian J. Mar. Sci.*, 42(6) (2013) 684-696.
6. Kumar, J.S.Y., Marimuthu, N., Geetha, S., Satyanarayana, Ch., Venkataraman, K. and Kamboj,

- R.D., Longitudinal variations of coral reef features in the Marine National Park, Gulf of Kachchh. *J. Coast. Conser.*, 18(3) (2014) 167-175.
7. Satyanarayana, Ch., and Ramakrishna, Handbook on Hard corals of GoK. Zoological survey of India, Kolkata, India, 2009, 114 p.
 8. Gregory, J.W., Jurassic fauna of Cutch: The corals. *Memoirs of the Geol. Survey of India. Palaeontologia Indica Series*, 9,2(2) (1900) 1-195.
 9. Gupta, S.K., Chronology of the raised beaches and inland coral reefs of Saurashtra coast. *J. Geol.*, 7 (1972) 1-7.
 10. Kankara, R.S., and Subramanian, B.R., Oil Spill Sensitivity Analysis and Risk Assessment for Gulf of Kachchh, India, using Integrated Modeling. *Journal of Coastal Research*, 23(5) (2007) 1251-1258.
 11. GEC, and BISAG, Coral Atlas of Gujarat State. SPMU-ICZMP, Gujarat Ecology Commission, Gandhinagar, Gujarat, India, 2011, 96 p.
 12. Patel, M.I., Generic diversity of Scleractinians around Poshetra point, Gulf of Kutch. *Indian J. Mar. Sci.*, 7 (1978) 30-32.
 13. Patel, M.I., Patchy corals of the Gulf of Kutch. *Proc. Symp. Endangered Marine Animals and Marine Parks*, 1 (1985) 411-413.
 14. Rashid, M.A., Gujarat's Gulf of Kutch. *Proc. Symp. Endangered Marine Animals and Marine Parks*, 1 (1985) 467-474.
 15. Pillai, C.S.G., and M.I. Patel, Scleractinian corals from the Gulf of Kutch. *J. Mar. Biol. Assoc. of India*, 30(1&2) (1988) 54-74.
 16. Pillai, C.S.G., Rajagopalan, M.S., and Varghese, M.A., Preliminary report on a reconnaissance survey of the major coastal and marine ecosystems in the Gulf of Kutch. *Mar. Fish. Inf. Serv. Tech. Ext. Ser.*, 14 (1979) 16-20.
 17. Deshmukhe, G., Ramamoorthy, K., and Gupta, R.S., On the coral reefs of Gulf of Kachchh. *Curr. Sci.*, 79(2) (2000) 160-162.
 18. Raghunathan, C., Gupta, R.S., Wangikar, U., and Lakhmapurkar, J., A record of live corals along the Saurashtra coast of Gujarat, Arabian Sea. *Curr. Sci.*, 87(8) (2004) 1131-1138.
 19. Parasharya, D., and Padate, G., Status of Scleractinian Corals of Narara Reef in the Gulf of Kachchh, Western India. *Jalaplavit*, 4(3) (2013) 49-59.
 20. Adhavan, D., Kamboj, R.D., Marimuthu, N. and Bhalodi, M.M., Seasonal variation and climate change influence coral bleaching in Pirotan Island, Gulf of Kachchh Marine National Park, Gujarat. *Curr. Sci.*, 107(11) (2014) 1780-1781.
 21. Dixit, A.M., Kumar, P., Kumar, L., Pathak, K.D., and Patel, M.I., Economic Valuation of Coral Reef Systems in Gulf of Kachchh. Final Report. *World Bank aided Integrated Coastal Zone Management (ICZM) Project*. Report submitted to Gujarat Ecology Commission, Forest and Environment Department, Gandhinagar, India, 2010, 158 p.
 22. GEER Foundation, Database for Marine Biodiversity and Coral transplantation experiment in Gulf of Kachchh. In. *Integrated Coastal Zone Management Project, 2nd Interim Progress report submitted to Gujarat Ecology Commission*. Gandhinagar, India, 2012, 172 p.