

this fragile ecosystem. Due to such threats reefs are facing biological and economical losses. Therefore it is essential for the reef researchers to find out causes and solutions for various threats. Regular monitoring of the reefs for these threats is essential for reef research, and rapid check for any deformity is required. Reefs can be studied by various methods, but the new techniques developed in past few decades have improved the monitoring of the reef's environmental conditions at rapid rate. Video transacting, underwater remote operated instruments and remote sensing has given a chance to explore vast areas in less time. Out of all remote sensing gives a synoptic coverage of the vast area with repeated data and high resolutions. Remote sensing data has been used for study of reef ecosystem from late 70's, and improvisation in sensor and satellite technology has allowed studying reef from ecosystem level to organism level. The use of technology has allowed us to monitor threats and damage on a regular basis.

Reefs of Indian subcontinent are located at four different locations, Andaman and Nicobar Islands, Lakshadweep Islands, Gulf of Mannar reefs, and Gulf of Kachchh (GoK) reefs. Out of them Lakshadweep reefs are atolls where as other three are Fringing reefs. According to biodiversity Andaman and Nicobar (177 species), Lakshadweep (91 species) and Gulf of Mannar reefs (82 species) are having higher diversity of hard corals in comparison to Gulf of Kachchh (36 species)

(Venkataraman et al., 2003). Despite of low coral diversity, Gulf of Kachchh sustains rich biodiversity in few of the most northerly located reefs. Gulf of Kachchh reefs are at the risk of various environmental threats but the highly turbid waters has restricted the growth of reef research activities. In GoK, reefs get exposed during semi diurnal tides and daily exposure to high temperatures due to rapid air exposure. More over industrial growth of the coastal region has given its impacts on near shore coral colonies. Reefs have been destructed by dredging and other industrial development in this region. It is only after the declaration of Marine National Park (MNP) and Sanctuary in that such activities were restricted for the protection of the reefs. Although strict protection has been provided by the MNP authorities, the natural environmental changes are proved to be harmful to coral reefs. The thesis is dealing with such few threats prevailing in the region and the monitoring and protection options for the same.

The major threats prevailing for reefs of GoK includes Abiotic threats like, Heavy Sedimentation, Temperature, Pollution and impact of industrial growth. Whereas, harmful fishing practices, Algal over growth, Loss of associated habitat and invasion of other zoanthid can be considered as major biotic threats. Therefore, keeping a regular monitoring and measures to check the extent of such threats is important for the sustainability of the reefs. Remote sensing has been used as a tool to

study these reefs and new dimension to study reefs of GoK has been given.

Sedimentation is considered to be natural phenomena and some amounts of sediments are always present in reef ecosystem. But GoK sedimentation is far beyond the tolerant limit for corals. Heavy sedimentation in the system by the perennial rivers is causing highly turbid waters with visibility less than one meter (Ramaswamy et al., 2007). Satellite based images showed early sedimentation history on Pirotan reef. As Pirotan reef is located at the place where residing tide of the funnel shaped gulf strikes first for the deposition of the sediments, the eastern side of the reef is inundated with thick layer of mud.

The problem of sediment loading as has been monitored with the help of periodic data of RESOURCESAT IRS P6 LISS IV. This attempt shows the efficacy of space borne remote sensing technique to study reef scale sedimentation patterns and processes. The flow dynamics for the reef has been generated to understand the direction and effect of hydrodynamics on morphodynamic changes on Pirotan reef. Following this approach the future scenario of the reef has been projected with the established knowledge of animal-sediment relationship. This study also helps in understanding ecological changes with changes due to changes in the substratum of the reef. The benthic community structure can also be predicted.

Dead skeletons of coral are major constituents of the reefs, but calcareous algae along with many other sessile and motile organisms are playing important role in reef building. Algae has important role in construction of a healthy reef ecosystem. And balance of coral algal assemblage is essential. But due to increased nutrients and other environmental factors sometimes algae starts growing in excess amount. Such conditions creates imbalance in the reef ecosystem. As it is popularly known as coral algal phase shift noticed at various other locations of the world (Roger and Miller, 2006), considered to be situation created due to high nutrient contain of the water.

Paga reef is off shore patch reef. Its location away from shore and submergence feature gives it a chance to be away from direct anthropogenic effects. The reef was considered to be in pristine condition until a field survey was done to check the coral cover of the area. The observation of high algal amount present on the reef was the inspiration for this study to trace back what has gone wrong with this otherwise healthy reef. Remote sensing came in aid in such scenario as it can provide the images of the previous years. Analysis of the previous images proved that the algal overgrowth was a recent phenomena and it was also co-related with the high temperatures in the summer months. But it was found out to be seasonal phenomena, and it was concluded that Paga reef is having algal overgrowth but not a complete coral algal phase shift. Field

observations together with satellite data proves that algae are overgrowing on already stressed corals due to high sedimentation. If such phenomenon happens on a large extent then large area of coral cover may be lost. Thus this technique is useful to find the correlation with the past history of the reef. In case of absence of previous field data, analysis of the satellite images can give the idea of the condition prevailing in past. The study of such cases can give an idea of the future scenario as well. And can also give a chance to prevent the adverse effect through proper planning. This study also shows that a slight change in the environment can be deleterious for ecological balance.

Other major threat to coral colonies is the overgrowth of invasive species. A new Zoanthid species has been recorded from GoK is considered to be a major threat to reefs of GoK. Two species of genus *Palythoa* has been found out growing on intertidal regions of Dwarka coast and reef flat regions of Bural Chank, Paga and Narara reefs. The two species namely *P. tuberculosa* and *P. mutuki* are found under competition of space with each other and with other adjacent organisms. The species has limited distribution amongst Indian coast and also misinterpreted as a coral colonies by many reef researchers. The high molecular weight non protein toxin produced by the organism is considered to be the major reason for its superior competition strategies. It is considered that the hydrodynamic of the water has limited its major distribution to a limited area for many

years, but the recent discovery of the species on the reefs of MNP is an alarming signal for GoK reefs. The fast growth rate and adaptability to extreme environmental conditions is giving them more chance to win the race against the delicate coral colonies. As there is little biological and ecological control possible over *Palythoa* the species can prove as a major threat to the reef biota. And therefore, need for its regulation and monitoring is essential.

As GoK is full of environmental extremities, they creates high pressure on the reefs giving a combination of effects, which are more harmful than the single sever factor. Such combined effect is also more deleterious to entire ecosystem and can be harmful to all the members of the ecosystem and related food chains of the ocean. Moreover interrelations of one or the other factors make them difficult to manage. Reef is a multidimensional ecosystem, which functions in interrelationship with the associated ecosystems and organisms deeply. Therefore damage to associated ecosystems also play important role in the sustainment of the reef corals. Hence need to understand the technique for regular monitoring and protection is required.

Remote sensing can be a very useful tool in such conditions as regular synoptic coverage of the entire MNP can be generated at faster rate than the individual field data collection. More over it also provide the coverage and condition of the entire region frequently.

Eco-geo-morphological map can be useful source of information for the reef researchers and managers to understand such reefs more precisely. Bural Chank reef has been taken as a model to prepare such maps. The high resolution remote sensing data together with tidal contours and pre existing animal habitat relationship information has been incorporated to generate the Habitat Preference Map. This was the first study that investigated the accuracy of remote sensing data in predicting the habitat preferences of organisms. It shows that there is good correlation between the predicted habitat preference map and actual field data. Furthermore, this study demonstrates the importance of reef geomorphology in understanding its biota. It demonstrates that tidal contours are an important feature of Gulf of Kachchh reef research, and tide amplitude variations effect reef biota significantly. Such technique can be composed to make computerized model to take such study at regional, national or global level.

This study outlines selected threats and their effects on existing coral reefs, furthermore it also emphasis the use of latest techniques for the reef research. Major threats of the GoK are already having long term effect on reefs and therefore large amount of reef area is already lost. But the current efforts may hold a torch of light to save the remaining few reefs of Gulf of Kachchh. And in turn save the productive ecosystem sustaining and nurturing the population of the area for centuries. The maps generated

Summary

by this study can act as a useful source for managers and conservators to give better direction to protect and manage this valuable ecosystem.

Thus the entire study provides insight to the threats of the GoK reefs in detail. Continuous generation of such data and related maps etc. will be very useful tool for possible management aspects for the reefs in such adverse conditions.