CHAPTER 7

CONCLUSIONS

7.1 Conclusions

Worldwide attention towards climate change and global warming over the last decade has brought coral reefs into the limelight. Extensive contemporary research has been conducted, revealing many important features pertaining to reefs, including environmental factors that support and threaten their survival. Although reefs are universally known to be shallow, warm water ecosystems, their physico-environmental condition varies greatly from one location to another. All over the world, reefs are therefore exposed to different threats localized to that particular area. For example, Caribbean reefs experience the greatest harm from over-fishing, hurricane damage, and high nutrient load. In contrast, reefs of Lakshadweep and the Maldives are under threat from temperature-induced photo bleaching. Meanwhile, the Great Barrier Reef is facing competition from the occasional outbreak of *Acanthester planci*, and Jamaican reefs are experiencing an extensive effect of coral algal phase shift.

In the case of the GoK, reefs are under pressure from a combination of diverse threats. These include the effects of sedimentation, high nutrient content, algal overgrowth, toxic invaders such as *Palythoa,* industrialization, oil spills, fishing activities, and heavy tidal fluctuation. **Figure 7.1** gives a diagrammatic representation of the various threats contributing towards the damage of the GoK reefs. In turn, and over time, the GoK reefs have adapted to survive,

becoming more tolerant to these threats. For example, the GoK reefs have adapted to the environmental extremities they are exposed to, and the consistently high temperatures have increased their tolerance limit for increased SST (Gates, 1990; Cook, 1990; Arthur, 2000; Vivekanandan et al., 2009). Therefore, threats persisting in the GoK must be viewed in a multidimensional manner, and should account for their increased tolerance. This is of particular importance when methods for the protection and prevention of further damage to the GoK reefs are designed.

The aim of this study and the accompanying thesis was to investigate and report the selected threats and their effects on existing coral reefs. The thesis also proposes possible protection measures and precautions that may be implemented to minimize further destruction from these threats.

Additionally, the thesis emphasizes the use of the latest techniques for temporal, synoptic observations. The maps generated for this thesis can be very useful for managers and conservators in directing specific protection strategies, as well as assist in maintaining overall ecosystem supervision. The method used to generate the maps from different areas is explained in chapter 6. An eco-geomorphologically classified habitat preference map can act as a useful resource for future reef researchers, as it can show the preferred location for field data collection.

It is hoped that the identification of the major threats in the GoK and the assessment of their long-term effects can contribute to current efforts to sustain the remaining reefs within the region, and ultimately, save this productive ecosystem so that it can continue to maintain and nurture the population of the area for centuries. **Table 7.1** outlines the prevailing threats, their effects on the reef, and a suitable approach to manage the damage caused by them.

7.1.1 Mitigatory Measures

1. Regular monitoring of SST is necessary to determine the trend. SST data is available from the NOAA and NESDIS, which assist in tracking any SST anomaly for reefs globally.

2. Sedimentation is a problematic phenomenon existing in the GoK, adversely affecting the growth and endurance of reefs. Though the flow and hydrodynamics of the Gulf cannot be changed, increasing the number of mangroves and their distribution near the vicinity of the reefs can help in reducing the impact of the sediment. This is because mangrove trees provide biological control over sedimentation, as mangrove roots bind the sediments and thus reduce the deposition of sediments on reef.

- ➔ Reforestation of mangrove plantation has been commenced in recent years by the Forest Department (Hirway and Goswami, 2004; Biswas, 2009). However, only a limited variety of mangroves are included in the plantation (Singh, 2006; Biswas, 2009). Reforestation should ideally include a diversity of all the endangered and threatened species of mangroves, otherwise the succession effect can result in destruction of the whole ecosystem. For example, *Prosopis juliflora* (Gando Bawal), an invading species, was first introduced for wasteland management on the boundaries of the desert, but it has now become an overgrown nuisance in many areas and removed many native species (Joshi et al., 2009).
- ➔ Additionally, the loss of mangrove diversity can be a potential threat to the ecosystem. In a scenario where an epidemic arises, the ecosystem consisting of multiple species can survive, because the epidemic can only cause harm to a limited population. However, in the case of a mono-species ecosystem, the epidemic can cause significant destruction rapidly, making it difficult to eradicate the prevailing epidemic.

3. Industries within close vicinity of the GoK reefs should be closely monitored. Their impact on the environment through disposal of waste

and runoffs should be appropriately regulated. Although the formation of the Marine National Park and Sanctuary has reduced the utilization of reef resources, and legislation has been implemented to limit industrial growth of the area, ships and oil pipelines continue to cause significant impact on the reefs. Appropriate techniques to immediately identify oil spills and stringent policies on immediately cleaning them should be designed and applied. Strict legislation should be enforced on new industries regarding the disposal of their waste.

4. The surrounding areas of the GoK are home to coastal villagers, for whom fishery is the sole source of income and sustenance. Fishermen often capture organisms such as octopuses or crabs if possible, as these are valuable and expensive. However, in the process of seeking these reef-based organisms, coral boulders and live coral colonies are often destroyed. Furthermore, fishing nets are placed within the reefs in order to catch fish with the tidal inundation, resulting in damage to the reefs. Hence, it is important to provide education to the fishing communities regarding safe fishing practices and on employing methods that will minimize the adverse effects on the reefs. While it is understood that the livelihood of these fishermen depend upon the marine environment, educating them on optimal fishing practices to protect the reefs from

unnecessary and destructive practices can make a difference to the survival of the ecosystem.

5. Finally, regular monitoring for biological threats is important, as they can easily go unnoticed while a localized effect progresses at the site. Here, remote sensing is a precise technique that can be extensively used, as it provides a synoptic coverage of the area. Furthermore, the recent advancements in sensor technology allows a maximum resolution of up to two metres, which can greatly aid in tracing the changes that occur in the reefs, making it much easier to compare to previous data. Past studies have also reported the identification of bleached colonies through remote sensing, and hence, further research in this direction is imperative.

In conclusion, this thesis outlines the threats posed to the reefs of the GoK by various environmental factors, discusses how the technique of remote sensing can be utilized to monitor the progression of these threats, and provides recommendations to manage these threats and ensure the optimal survival and maintenance of this important ecosystem.

Table 7.1 Threats to Gulf of Kachchh Reefs, their effects and proposed recommendations

No.	Indicator	Effects	Recommendations
1.	**Temperature anomaly**	Bleaching and high algal growth	Regular check on any temperature anomaly, NOAA SST data bank
2.	**Sedimentation**	Sediments cover the coral polyps and cause death of colony, damage reefs, restrict the light penetration capacity of the standing water column on reef	Regular checks, plantation of mangroves, restrictions on dredging activities in close vicinity of reefs
3.	**Industrial Pressure**	High nutrients from the industrial runoff, high sediments, oil spills cause mortality of reef biota	Marine National Park and Sanctuary developed in 1980 and 1982 respectively to reduce industrial pressure. Stricter legislation should be implemented
4.	**Fishing Methods**	Bottom Trawl fishing, Anchoring on reef areas: Damages the reefs long term	Fishing activities, now restricted outside reef area Anchor damage needs more attention from authorities. Educating fishermen may be helpful.
5.	**Algal Overgrowth**	Fast growing algae overgrows the coral colonies and blocks the sunlight reaching polyps.	Check on the SST anomaly, and nutrient influx in the system
6.	**Palythoa intrusion**	Fast growing toxic competent: biotic threat	Regular monitoring to check on this otherwise silent intruder of the reef

Figure 7.1 Flow Chart showing various threats affecting the Gulf of Kachchh reefs