CHAPTER

35

CORAL REEF ECOSYSTEM-MONITORING AND ASSESSMENT USING SATELLITE DATA SETS

Grinson George[1], Roshen G. Ninan[2] and Zacharia P. U.[2]

[1]Fishery Resources Assessment Division
[2]Demersal Fisheries Division
ICAR-Central Marine Fisheries Research Institute

Introduction

Remaining in splendid isolation, the Andaman and Nicobar Islands have a great relevance in the study of marine ecosystems. The islands, though remotely located in an ostensibly pristine environment have born witness to serious issues with regard to their ecosystem health. There are significant changes in the temperature and rain fall pattern in the islands and predictive modelling has forecasted further damage in the near future. The inundation of saline water into inland terrestrial ecosystems has created salinity stress to freshwater species while reducing the water available for domestic consumption. Terrestrial flora and fauna are vulnerable to the intruding saline waters. The marine ecosystem also faces grave challenges. There are issues of anthropogenic pollution resulting in damage of corals, regime shifts in community structure, water quality deterioration and other damage to marine fauna. Climate change has taken a toll on the ecosystem with coral bleaching which was observed during 1998, 2002, 2005, 2010 and most recently in 2016. An interactive digital database on corals has been developed to address the regular health status of corals. With the help of satellite remote sensing data, mechanisms of reef bleaching can be uncovered and the probable threats can be addressed by providing advisories developed in collaboration with INCOIS, Hyderabad. The increased incidence of tropical cyclones in the region is also wreaking havoc in the reef and related ecosystem. There are recent changes in the community structure due to the aforementioned challenges and changes are notable in all marine related ecosystems such as reefs and mangroves. There are instances of reefs exposure due to tilting of islands, proliferation of unwanted island flora and fauna due to inadvertent human interventions, wastage of natural resources due to unscientific policy decisions and illegal poaching of island resources by neighbouring countries. Despite all these issues the fishery in the islands remains under-utilized. There is a huge scope for utilizing the fishery to the benefit of the island community. Possible methods of harvesting these resources will also be discussed in the lecture.

Status of coral reefs in Andaman after two major catastrophic events - tsunami of December 2004 and bleaching of May 2005 (Dam Roy *et al.,* 2014)

The 26th December 2004 tsunami, caused by a massive earthquake off the west coast of Sumatra, resulted in widespread devastation of coral reefs in the Andaman and Nicobar Islands. A reef survey carried out in January 2005 indicated that many exposed corals were

dead and corals that suffered breakage were precariously living. Dislocated corals and cracks in the coral reefs were also noted. Coral composition remained the same in protected bays as most of them were shielded from the brunt of earthquake and tsunami.

Shortly after the tsunami, the same area was subjected to a bleaching event in the month of May 2005. Surveys revealed that the live coral cover amounted to only 6.5%. The partially bleached, fully bleached, dead and other coral components were 4.8, 13.3, 19.7 and 55.7% respectively. The extent of coral damage and their subsequent recovery was studied during the following months in order to monitor reef health and it was observed that live coral had increased to 17.9% and the total amount of dead coral was 22.7%, suggesting the recovery of partially bleached corals and the death of fully beached corals. The bleaching was similar to the 1998 bleaching event. Satellite Remote Sensing (SRS) data sets was unable to be utilised during the study. In the subsequent years SRS data was employed for monitoring corals in Andaman Sea. Later on, compilations of SRS data were used to develop a coral reef bleaching alert system with the help of a team from INCOIS, Hyderabad.

Assessment of the coral bleaching during 2005 to decipher the thermal stress in the coral environs of the Andaman Islands using Remote Sensing (Mohanty, P. C. *et al.,* 2013)

SST values derived from NOAA AVHRR satellite data were used to generate both Degree of Heating Weeks (DHW) and Hot Spot (HS) products. Combination of the cumulative temperature anomalies and the thermal stress values were utilized to synoptically identify the probable areas of bleaching. Areas with Hot Spot products > 1°C were assigned a warning. Any areas assigned a warning with Degree of Heating Weeks between 4 and 8° C- week were elevated to *Alert Level-1*, with areas having Degree of Heating Weeks greater than 8° C- week assigned status *Alert Level-2*. At Havelock Island, a bleaching status up to *Alert Level-1* was recorded with a maximum HS of 3° C and DHW 6° C- week. Simultaneous in-situ reef observations conducted in the Andaman Sea confirmed coral bleaching event at this site. The highest rates of mortality in the region due to coral bleaching were shown by the *Acropora* species (43%) followed by *Montipora* species (22%) and *Porites* species (14%). This study focused on facilitation of a coral bleaching warning system based on the SST in complement with *in-situ* observationsfor verification carried out at selected sites.

Elevated sea surface temperature during May 2010 induces mass bleaching of corals in the Andaman (P. Krishnan *et al.*, 2011)

In a study taken up to asses bleaching the 2010 bleaching event, surveys of sites in the Andaman revealed that significant bleaching occurred during April and May 2010. As much as 70 % of certain sites suffered the effects of bleaching. While similar bleaching events

occurred in 1998 and 2002, this has been judged to be one of the most devastating events of this kind to have occurred in the Andamans. Through Line Transect studies, it was found that the fully bleached corals as a percentage of total coral cover were highest at Havelock Island (69.49), followed by South Button Island (67.28), Nicolson Island (56.45), Red Skin Island (43.39), North Bay (41.65) and Chidiyatapu (36.54). SST maps for selected time periods for the areas surrounding these Islands showed consistently high temperatures in the range 31–32° C during the last two weeks of April 2010 in the sites, except in Chidiyatapu, where it ranged from 32.1° C to 33.3° C. Branching corals were the worst affected, whereas the massive corals were found to have relatively withstood the elevated SST. The status of reefs and the variability in bleaching with the fluctuations in SST with respect to different coral species could be studied in detail during 2010.

Studies on the Recovery of Bleached Corals in Andaman: Fishes as Indicators of Reef Health (P. Krishnan *et al.,* 2013)

This study evaluates the degree of recovery of the coral reefs and reef fishes at three sites – North Bay, Tarmugli and Chidiyatapu - a year after the bleaching event in 2010. It was observed that all sites were severely affected during the bleaching period with more than 95 % of the corals being fully or partially bleached. Out of the bleached corals surveyed at the study sites, only 54 % recovered at North Bay, whereas Tarmugli and Chidiyatapu showed significant recovery - 81 and 86% respectively. Live coral cover, which was densest at North Bay prior to bleaching,was most strongly affected at North Bay among the three sites - most likely due to the higher percentage of branching corals such as *Acropora* sp. in this area. Chidiyatapu exhibited significantly fainter signs of bleaching owing to the higher percentage of boulder corals such as *Porites* sp. in these areas. Recovery patterns indicate that the rapid recovery rate of fast growing corals such as *Acropora*, however, have resulted in greater dominance by these species suggesting that climate forcing of coral communities may initially favour coral species with rapid recovery potential, rather than slow growing corals that might otherwise have greater resistance to bleaching. Due to this recovery and new recruitment of corals, live coral cover has increased, resulting in an increase in an apparent abundance of fishes. Understanding the associations between fish and corals could lead to the designationof certain species of fish as indicators of reef health. The results of the study lead to the hypothesis that obligate corallivores, such as those belonging to the families Chaetodontidae, Pomacentridae, Acanthuridae and Scaridae, are strong potential candidates to serve as indicators of reef health.

Tropical storm off Myanmar coast sweeps reefs in Ritchie's Archipelago, Andaman (P. Krishnan *et al.*, 2012)

The reefs in Ritchie's Archipelago, Andaman suffered severe damage following a tropical

storm in the Bay of Bengal off Myanmar coast where maximum wind speeds of 11 m/s was observed during a tropical storm that occurred in March 2011. Satellite Altimetry-based Map of Sea Level Anomaly (MSLA) data of Near Real Time (NRT) available with the Archival, Validation and Interpretation of Satellite Oceanographic Data (AVISO) was used to study the Sea Level Anomaly and Surface Geostrophic currents in the region during 13–23 March 2011. Sea level anomaly and surface geostrophic current vector data were processed to generate sea level anomaly and current maps using ARC-GIS software with the data for the period 13–23 March 2011. Satellite surveys of South Button Island clearly showed the progression of the storm. Physical damage to corals was greater in the northern and northwestern side of the island, which corroborated with the direction of the storm.

Corals in the shallow inshore reefs were broken and dislodged by the thrust of the waves generated in the wake of these winds. Significant damage in the deeper regions and offshore reefs were caused by the settlement of debris and sand brought down from the shallower regions. The fragile branching corals (*Acropora* sp.) were reduced to rubble and the larger boulder corals (*Porites* sp.) were toppled over or scarred by falling debris. Reefs on the windward side which were directly in the path of the storm winds were the worst affected. The investigation exposes the vulnerability of the reefs in the Andamans to oceanographic features which generally go unnoticed unless there is associated damage caused to coastal habitats in these regions.

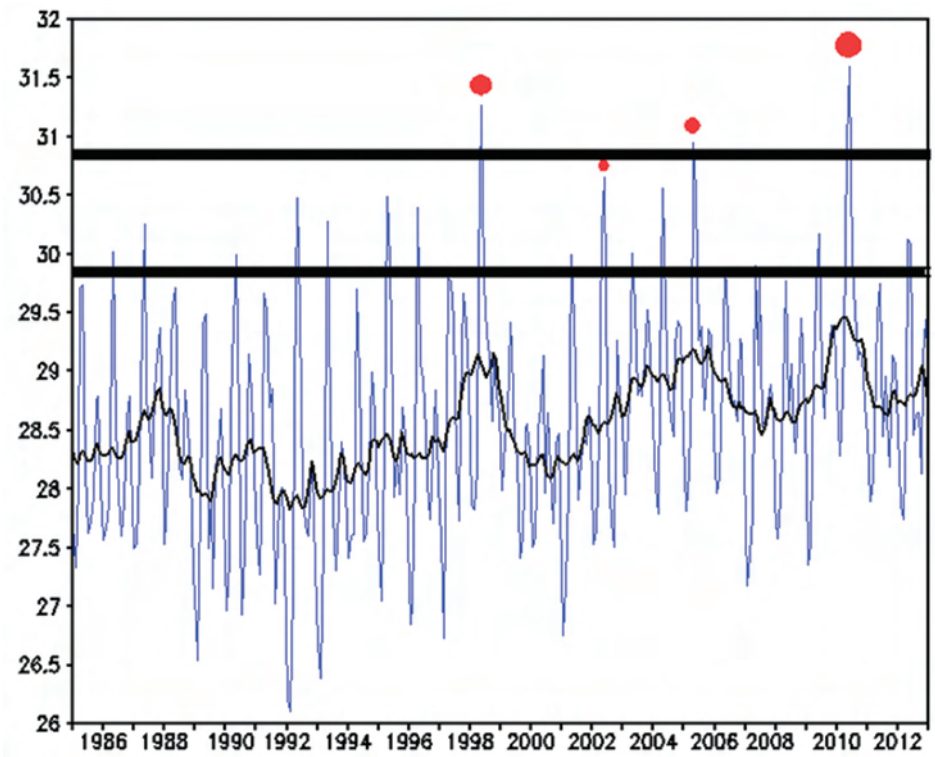
Differential bleaching of corals based on El Niño type and intensity in the Andaman Sea, southeast Bay of Bengal (J.K. Lix *et al.,* 2016)

The purpose of this study was to investigate the role of the El Niño in the coral reef bleaching events of the Andaman region.Both Niño 3.4 and 3 indices were examined to find out the relationship between the mass bleaching events and El Niño, and correlated with sea surface temperature (SST) anomalies in the Andaman Sea.

Inter-annual variability of SST around the Andaman Islands was investigated with NOAA AVHRR Pathfinder V4.1 SST (1985–2002) and AVHRR (GAC) SST (2003–2012) with data averaged over the study area. This data was coupled with monitoring of reef benthic compositions at two stations – North Bay and Chidyapatu during 2010-2012. Areas around the Andaman Islands where the SST exceeded long-term averages by more than 1 °C during the warmest months (March–June) were identified for the mass bleaching during 1998 and 2010.

Field surveys conducted before, during and after bleaching in 2010 show that there have not been any additional bleaching episodes in the Andamans since 2010. Salient observations made at different zones of selected coral reefs aided in identifying the indicators that give information on the health status of the reefs and to identify the reefs at risk.

The analysis demonstrates that a strong El Niño in the Pacific causes a similar warming in the Andaman Sea which leads to mass coral bleaching events around the Andaman Islands. The result shows that abnormal warming and mass bleaching events in the Andaman Sea were seen only during strong El Niño years of 1997 to 1998 and 2009 to 2010. The Andaman Sea SST was more elevated and associated with El Niño Modoki (central Pacific El Niño) than conventional El Niño (eastern Pacific El Niño) occurrences. It is suggested that the development of hot spot patterns around the Andaman Islands during May 1998 and April to May 2010 may be attributed to zonal shifts in the Walker circulation driven by El Niño during the corresponding period. It can be concluded from this study that the effect of El Niño on a particular coral reef region will depend on the timing when the El Niño perturbation propagates to those reefs. The effect is typically more extreme if timing corresponds to the climatological maxima in the seasonal heating cycle.



Box averaged (11.5–14° N; 91.5–94° E) monthly mean SST (°C) for the Andaman region during 1985–2012 with the corresponding 13-month moving average shown as a black curve. The line drawn at 30.84 °C represents a bleaching threshold temperature and line drawn at 29.84 °C represents the climatology in May. The corresponding bleaching events are represented by red dots and their size indicating the intensity of the bleaching event.

Acknowledgement

The second author would like to acknowledge financial assistance provided by National Innovations in Climate Resilient Agriculture (NICRA) sponsored by Indian Council of Agricultural Research (ICAR).

References

S. Dam Roy, Grinson George, R. Soundarajan, P. Krishnan, S. Murugesan and M. Kaliyamoorthy (2014). Status of coral reefs in Andaman after two major catastrophic events - tsunami of December 2004 and bleaching of May 2005. Eco. Env. & Cons. 20(2): 2014; pp. 137-142.

Mohanty, P. C., Mahendra, R. S., Bisoyi, H., Tummula, S. K., Grinson, G., Nayak, S. & Sahu, B. K. (2013). Assessment of the coral bleaching during 2005 to decipher the thermal stress in the coral environs of the Andaman Islands using Remote Sensing. European Journal of Remote Sensing, 46(1), 417-430.

Krishnan, P., Dam Roy, S., George, Grinson, Srivastava, R. C., Anand, A., Murugesan, S., Kaliyamoorthy, M., Vikas, N., Soundararajan, R. (2011) Elevated sea surface temperature during May 2010 induces mass bleaching of corals in the Andaman. Current Science, 100 (1). pp. 111-117.

Krishnan, P., George, Grinson and Immanuel, Titus and Bitopan, Malakar and Anand, A. (2013) Studies on the Recovery of Bleached Corals in Andaman: Fishes as Indicators of Reef Health. In: Ecology and Conservation of Tropical Marine Faunal Communities. Springer-Verlag Berlin Heidelberg, pp. 395-407.

Krishnan, P., George, Grinson, Vikas, N., Titus, Immanuel, Goutham Bharathi, M. P., Anand, A. Vinod Kumar, K., Senthil Kumar, S. (2012) Tropical storm off Myanmar coast sweeps reefs in Ritchie's Archipelago, Andaman. Environmental Monitoring and Assessment. pp. 1-12.

Lix, J. K., Venkatesan, R., George, Grinson, Rao, R. R., Jineesh, V. K., Arul, Muthiah M., Vengatesan, G., Ramasundaram, S., Sundar, R., Atmanand, M. A. (2016) Differential bleaching of corals based on El Niño type and intensity in the Andaman Sea, southeast Bay of Bengal. Environmental Monitoring and Assessment, 188 (175). pp. 1-13. ISSN 0167-6369.