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18F Does monitoring lead to improved coral reef management

Coral reefs of Gulf of Mannar, India - signs of resilience

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Abstract. The coral reefs of Gulf of Mannar experienced severe degradation during 1980s and 90s primarily due to rampant mining and destructive fishing. The coast is densely populated and the reef status is also affected by sewage discharge. The coral disease prevalence increased from 6.9 ±1.7% in 2007 to 10.6±1.6% (mean ± SD) in 2011 (p.1.451E-08). However, the reefs of GoM exhibit signs of resilience, especially since 2005 after coral mining was halted and with a reduction in destructive fishing activities. The live coral cover increased from 36.98±13.12% in 2005 to 42.85±10.74% (mean ± SD) in 2009 (P 2.89E-30). Coral mortality due to elevated sea surface temperature and bleaching reduced live coral cover to 33.20±10.23% (mean ± SD) in 2010. An estimated 9.99% of coral colonies bleached, and less than half of these recovered. Steady recovery in 2011 increased the live coral cover to 37.31±10.38% (mean ± SD) (p 0.0315). This was in part due to recruitment, with recruits relatively unaffected by bleaching, along with recovery of partially dead colonies. Coral recruit density in 2005 was 0.41±0.58 per m^2 and 0.78±0.87 per m^2 (mean ± SD) in 2011 (p 0.9591) and the difference in not statistically significant. Continuous monitoring, timely management action, awareness and capacity building and enforcement hold the key to sustain reef resilience in Gulf of Mannar.

Key words: Gulf of Mannar, Coral status, Monitoring, Management, Resilience

Introduction

The Gulf of Mannar reefs are located in southeastern India, mainly between Rameswaram on the north and Tuticorin on the south (Fig.1). The south side of the reef area is having several industries and a major port. The reefs are formed around the 21 islands situated between lat. 8’ 47 - 9’ 15’ N and long. 78’ 12 ‘ - 79’ 14’ E and the area comes under Gulf of Mannar Marine National Park. For administrative reasons and also to provide better managerial service, the 21 islands are grouped in to four viz. Mandapam (7 islands), Keezhakkarai (7 islands), Vembar (3 islands) and Tuticorin (4 islands) based on the geographic

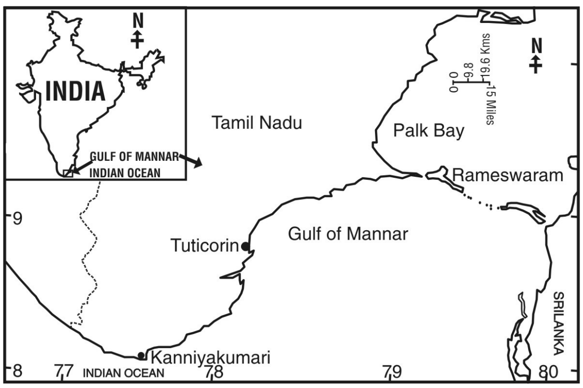

Fig.1: Map showing study area, Gulf of Mannar

distribution. The islands are coming under three forest (wildlife) ranges such as Mandapam, Keezhakkarai and Tuticorin (include Tuticorin and Vembar groups). The islands lie at an average distance of 8-10 km from the main land. Narrow fringing reefs are mostly located at a distance of 100 to 350 m from the islands and patch reefs rise from depths of 2.5 m to 8 m, extend 1- 4 km in length and are up to 50 m wide (Patterson et al., 2007). The reef flats are extensive in almost all the reefs areas (Pillai, 1977). The coast is densely populated and traditional fisher folk numbering over 100,000 mainly depend on the reef and seagrass associated fishery resources for livelihood. The anthropogenic pressures on this coastal area and the reefs is multifaceted, including coral mining (Mahadevan and Nayar, 1972); destructive fishing practices (Patterson et al., 2007); Sewage disposal (Ramachandran et al., 1989); discharge from certain chemical industries and thermal plant (Easterson, 1998); and bio-invasion of exotic seaweed, *Kappaphycus alvarezii* (Chandrasekaran *et al.,* 2008; Patterson and Bhatt, 2012). In addition, reefs and associated fishery experience the effect of climate change (Patterson et al., 2008; Patterson and Samuel, 2004). The conservation and management of coral reefs therefore become complex in Gulf of Mannar and focus on systematic and scientifically supported data collection and monitoring will not only help to obtain authentic data on the coral status, but also to protect the reefs from various local threats and global factors like climate change issues and to support resilience.

Material and Methods

The percentage cover of corals and other sessile benthic categories were assessed by Line Intercept Transect (LIT) method following English *et al.* (1997). Each island is having 3 permanent transects and 3 permanent monitoring quadrates (1 X 1m) on the reef area. The annual data on coral status and size class distribution was collected from transects and pattern of coral recruitment was recorded from quadrates. Coral colonies which were less than 10 cm in diameter were recorded as recruits (Tamelander, 2002).

Coral disease prevalence survey was conducted in detail by LIT method (English et al., 1997) to quantify coral disease prevalence. Each transect was covering an area measuring 20m x 4m (2m on each side of the transact line). Coral diseases were identified by following the coral disease handbook of Raymundo et al., (2008). Diseased coral colony and total number of colonies were recorded. Disease prevalence was calculated by using the formula.

$$\text{Disease prevalence} = \frac{\text{No. of diseased colonies/ site}}{\text{No. of colonies examined/ site}} \times 100$$

This formula was used for individual population (genus), as well as for each particular disease/syndrome.

The invasion of the exotic seaweed species *K. alvarezii* in terms of percentage cover was assessed using LIT method (English et al., 1997). Measurements of the biomass of *K. alvarezii* overgrowing live coral colonies of the species *Acropora formosa* and *Acropora nobilis* were done in Krusadai Island. Four smaller (41-80 cm) and four larger (81-160 cm) colonies of each coral species were monitored. Totally eight individuals (each 300 g) of *K. alvarezii* (4 on the smaller and 4 on the larger colonies) were tagged on the selected each coral colonies and monthly insitu measurement was done for four months. Every month tagged *K. alvarezii* was taken out of the coral colony and weighed to find out the difference in the biomass covering live coral colonies over time. Photo quadrats of 25 cm^2 were fixed over the algae to assess the mode of growth on corals. Monthly photographs were taken. Four permanent monitoring sites were fixed (3 invaded sites and 1 healthy site) to assess the fish population and benthic faunal diversity. Belts transect and quadrate methods (English et al., 1997) were followed to collect data on fish and benthic fauna.

Results

The live coral cover during 2003-2005 was 36.98% and increased gradually to 42.85% in 2009. During 2010, coral cover decreased to 33.2% due to severe bleaching and mortality, however it started to recover and was 37.31% in 2011 (Fig.2). The variations in live coral cover from year to year are significant (P 2.89E-30). The dominant coral species in Gulf of Mannar are *Pocillopora damicornis, Acropora formosa, A. intermedia, A. nobilis, A. cytherea, Montipora digitata, M. foliosa, Favia pallida, Favites abdita, Echinopora lamellosa. Goniastrea retiformis, Porites solida, P. lutea Hydnopora microcono., and Platygyra daedalea.*

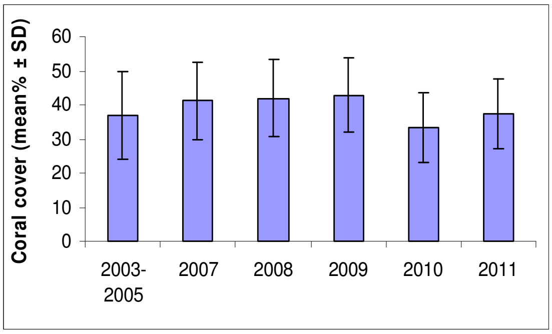

Fig.2:% of live coral cover in Gulf of Mannar during 2005- 2011

Coral recruitment is on the rise in recent years. During 2003-2005, the overall average recruit density was 4.1 per m^2 and it increased gradually to 7.77 per m^2 in 2011 (Fig.3). Among all the coral recruits, genus *Montipora* followed by *Acropora* were dominant with 2.52±0.29 and 2.14±0.2 per m^2 during 2011. Increase in recruit density was noticed in all the observed coral genera during the course of the study: *Montipora* (1.44±0.1 to 2.52±0.29 per m^2) and *Acropora* (1.52±0.17 to 2.14±0.2 per m^2) (Fig.4). Among the coral recruits, fast growing branching corals *Montipora digitata* followed by *Acropora cytherea* were dominant and the other abundant recruit species include *A. nobilis, A. intermedia, A. formosa, Pocillopora damicornis, Montipora divaricata* and *M. foliosa*.

Among the coral size class categories, the coral population is dominated by the 21-40 cm size class

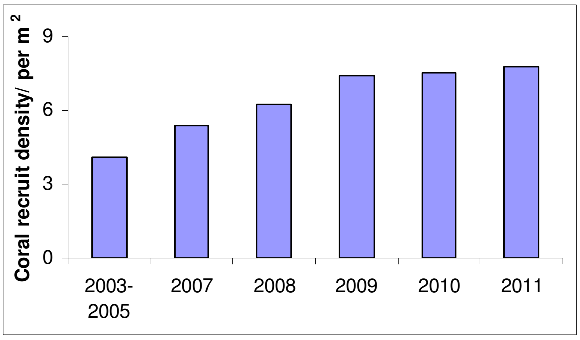

Fig.3: Overall average recruits density during 2005-2011

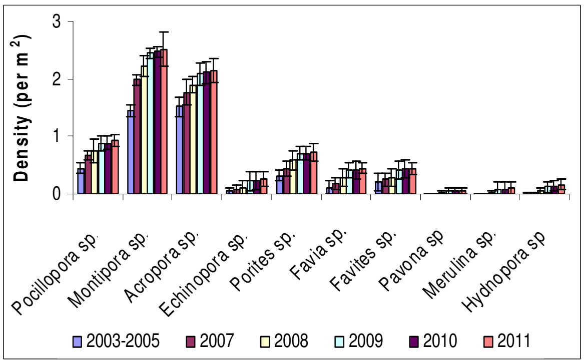

Fig.4: Mean recruit density by genus during 2007-2011

followed by 11-20 and 41-80 cm size classes in area cover. This has been the trend throughout the study period. Every year new recruits (0-10 cm) were added to the smaller categories (0-5 and 6-10) increasing the contribution of smaller categories. However, good growth made the recruits to adults (above 10 cm) and by the way keeping the trend almost unchanged. The bigger categories (81-160 cm and above) were mostly massive corals and especially *Porites* spp. and few table coral species *A. cytherea* were also bigger in size. Mortality during bleaching happened mostly in the bigger colonies (above 41 cm).

The reef areas of Gulf of Mannar have faced annual elevated sea surface temperature and resultant coral bleaching during summer since 2005, significant coral mortality was only recorded in 2010 when elevated temperatures (32.2 to 33.2^{0}C) persisted for four months (April to July). An estimated amount of 9.99% live coral colonies bleached and more than 50% mortality among the bleached colonies. The coral species which died because of bleaching include *Pocilopora damicornis*, *Acropora formosa*, *A. intermedia*, *A. nobilis*, *A. cytherea*, *Montipora digitata, Montipora foliosa, Favia* sp. and *Echinopora* sp. Recovery was primarily noted in the partially bleached colonies of coral species species, *Pocillopora damicornis, Acropora formosa*, *A. nobilis*, A. cytherea, *Montipora foliosa* and *M. divaricata.* The live coral cover increased to 37.31% during 2011 which was also predominantly due to coral recruits (0-10 cm) and young adult colonies (11-40 cm) as they were relatively unaffected by bleaching.

Both domestic and industrial pollution impact the reefs, however, nowadays untreated sewage disposal along the entire coast is perennial, and the data indicates that this forms the major cause for coral disease prevalence, which increased from 6.9 ±1.7% in 2007 to 10.6±1.6% (mean ± SD) in 2011 (p.1.451E-08).

The introduction of exotic seaweed, *K. alvarezii* in South Palk Bay in Mandapam coast in 2005 without adequate environmental impact assessment facilitated its invasion into coral reef areas in the Islands of Gulf of Mannar. The bio-invasion was noted in 2008 covering small area (10 m^2) in 3 islands (Shingle, Krusadai and Poomarichan) and it was noted in March 2011 that it spreads over 1.24 km^2 reef area in Krusadai Island where *Kappaphycus* invaded in the reefs of seaward side in the south east and south west directions. The detached fragments from the *Kappaphycus* cultivation drift through the Pamban pass and reach the seaward side of Krusadai Island and settled firmly here on the live corals and grow undisturbed. The most affected coral species are *Acropora nobilis, A. formosa, A. cytherea, Monipora digitata, M. foliosa and Porites lutea* with coral colony sizes 20-160cm. Out of the total live coral area of 5.4 km^2 in Krusadai Island in 2009, over 23% reef area are now fully covered and destroyed by *Kappaphycus*.

The short-term study revealed that the biomass of the *Kappaphycus* which overgrew both the small and larger coral colonies increased significantly (Figs. 5). The average increase of algal biomass on corals was from 300±0 to 734±25 g within the 4 months. No significant deviation was found in the growth over the larger and smaller colonies. The trend of spreading of *K. alvarezii* was towards both vertical and horizontal directions over the live coral colonies. As this algae spreads in both ways it forms a tight thick green mat over the coral colonies which die because of suffocation eventually. Some parts of the mat made of *K. alvarezii* over the coral colonies can get detached by strong winds, waves and currents and subsequently, get attached to a nearby healthy coral colony to spread over and increase in invaded area. Because of its fast growing and spreading nature some of the nearby massive corals (*Porites* sp.) have also got affected by this alga and the invaded area has changed to pink colour as a sign of deterioration. The abundance of benthic communities and fish were significantly less in the affected sites than the non-affected site. The fishes, *Lujanus* sp., *Lethrinus* sp., *Siganus* sp., *Scarus* sp., *Chaetodon* sp., and *Upeneus* sp. (0.71 to 3.21 per 50 m^2) were common in the non-affected reef area, while *Siganus* sp., *Chaetodon* sp. and *Upeneus* sp. were the only genera seen rarely (0 to 1.1 per 50 m^2) in affected sites.

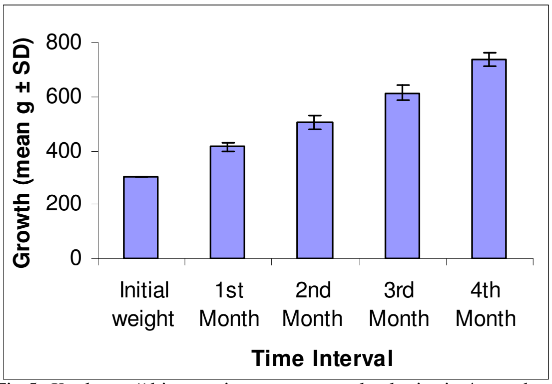

Fig.5: *K. alvarezii* biomass increase on coral colonies in 4 months

Discussion

The fisher population along Gulf of Mannar coast has increased by about 30% over the last 20 years and accordingly the addition of large and small fishing crafts also increased, which cause greater stress not only to corals but also to adjacent seagrass beds and other associated habitats. The destructive fishing practices including inshore trawling, shore seine and push net operation, trap fishing and seaweed collection are year round and benthic forms are continuously disturbed. In addition, several other issues like pollution, both domestic and industrial, bio-invasion of exotic seaweed, *K. alvarezii* and climate change contribute considerably. Based on the impact to reefs, the stressors can be ranked as follows; destructive fishing, domestic sewage, bio-invasion, climate change, industrial pollution and poaching of rare and protected species.

The impact of industrial discharge near the reef areas is mainly localized. An underwater survey near Tuticorin Thermal Power Station (TTPS) during March to September 2011 showed a clear distinction between the "near discharge point zone" (where TTPS discharge point located) and the farthest stations with regard to marine biodiversity in this area and ascertains the localization of impact. Corals, seagrasses, fishes and benthic fauna were almost absent in this zone. (up to about 1.5 km). Beyond 1.5 km and upto 5.44 km distance, patch seagrassess and low density and diversity of macrofauna and fish were observed. A patch coral formation was observed at 5.44 km. Beyond 7 km, all benthic faunal assemblages, including corals and seagrass beds were healthy (SDMRI Report, 2011).

The coral disease prevalence is increasing every year. The high prevalence of coral disease could be seen at entire Gulf of Mannar coast in shallow areas of 2m depth. The shallow areas are nearer to sewage outlets with high microbial load and water temperature (Thinesh, 2009). Corals are more susceptible to diseases when it is coupled with human disturbance with temperature (Hughes *et al.*, 2003; Ben haim *et al*, 2003).

Many coral reefs, especially damaged reefs, depend on larval sources from adjacent reefs. Human activities may deplete larval sources by altering dispersal routes, e.g. reef mining, land fill, or by creating local pollution barriers that coral larvae must encounter on their way to the sink reefs (Nystrom et al. 2000). Human pressure on marine systems may result in the loss of diversity within and among functional groups (Mc Clanahan and Muthiga 1998), resulting in the simplification of coral reef habitats and a decreased ability to buffer disturbances. Hughes and Connell (1999) stated that the physical conditions on a reef may be chronically affected by anthropogenic impacts such as pollution or destructive fishing practices, which negatively affect the ability of coral assemblages to recover from natural disasters.

SDMRI Report (2010) described that trap fishing in the reef areas of Gulf of Mannar, in particular Mandapam and Keezhakkarai coasts inflict damages to 3-6% of live corals. Uprooting of coral colonies and coral recruits, breaking of coral branches, dislodgement of dead corals and other benthic organisms were the damages observed. There is a high danger of macro algae proliferation in the reef area due to heavy exploitation of herbivore reef fishes such as parrot fish, *Scarus* sp. Bio-invasion of exotic seaweed, *K. alvarazii* is also damaging the reef habitat. Patterson and Bhatt (2012) recorded that the invasion of *K. alvarazii* in reef areas in Gulf of Mannar caused coral mortality in 150-180 days and the dead corals subsequently become smothered.

The bench mark data on coral status was collected during 2003-05 in Gulf of Mannar (Patterson et al., 2007) and regular coral monitoring was initiated since 2005 which also happened to be the period when the coral mining was stopped. A positive trend in the coral recruitment in Tuticorin group has been reported from 2006 by Raj, (2010). Further to that resilience factors that are extrinsic to the biological characteristics of the community include physical factors such as current patterns that may favor larval dispersal among sites, or physical conditions that enhance coral survivorship and growth (West and Salm, 2003). It is also evidenced that several recruits which were not present in Tuticorin coast earlier were recorded after 2006 (Raj, 2010) which is mainly due to the dispersal of recruits from northern islands through current and availability of suitable substrate.

The reef areas are predominantly shallow, between 0.5-3 m depths, and high sea surface temperatures (SST), around 29ºC, prevail throughout the year (Patterson, 2009). Coral bleaching, as a result of elevated SST has been noticed during summer every year since 2005. Average percentage of bleached corals during 2005, 2006, 2007, 2008 and 2009 was 14.6, 15.6, 12.9, 10.5 and 8.93 respectively (Patterson, 2009), but no mortality was recorded. There may be environmental characteristics that favor pre-adaptation of corals to resist coral bleaching - such as the presence of regularly stressful environmental conditions, e.g., periods of elevated solar radiation prior to sea-temperature warming events (Brown et al. 2000; Dunne and Brown 2001). No difference was found between the years in terms of maximum SST as it was always around 33° C during summer peak. But, prolonged period of elevated temperature was the factor during 2010 when mortality observed.

The several anthropogenic and natural factors threat to coral reefs in Gulf of Mannar, however, conservation and management initiatives, in particular comprehensive bench mark data, monitoring, timely interventions like restoration to support natural recovery process, enforcement for protection of reef areas and associated biodiversity from destructive fishers and poachers and capacity and awareness building among all stakeholders not only help to keep up the coral health, abundance, distribution and diversity, but also holds the key to sustain the resilience. Although successful spawning and good supply of recruits hold the key to resilience, the effective conservation and management help in its sustainability under various stress factors.

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