Journal of Threatened Taxa

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ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

Note

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26 November 2019 | Vol. 11 | No. 14 | Pages: 14908–14911
DOI: 10.11609/jott.4767.11.14.14908-14911

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14908–14911

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM OPEN ACCESS

New recruitment of staghorn corals in the Gulf of Mannar – the emergence of a resilient coral reef

Koushik Sadhukhan [1], Ramesh Chatragadda [2], T. Shanmugaraj [3] & M.V. Ramana Murthy [4]

[1,2,3] National Centre for Coastal Research (NCCR), NCCR Field Office, Mandapam Camp, Ramanathapuram, Tamil Nadu 623519, India.
[4] National Centre for Coastal Research (NCCR), Ministry of Earth Sciences (MoES), Pallikaranai, Chennai, Tamil Nadu 600100, India.
[1] sadhukhan.1985@gmail.com (corresponding author), [2] chrameshpu@gmail.com, [3] raj@nccr.gov.in, [4] mvr@nccr.gov.in

Coral reefs in the Gulf of Mannar (GoM) have faced severe disturbances from the ever increasing human pressure which resulted in the rapid decline of marine biodiversity and biomass of the coastal ecosystems over the past few decades. Despite severe climatic and non-climatic stresses, scleractinian coral *Acropora* sp. in GoM exhibits new recruitment of coral colonies in recent times. The genus *Acropora* is commonly called staghorn corals for the antler like colony form (Johnson et al. 2011). Bleaching susceptibility among coral taxa depends on the resistance capacity of corals to subsequent bleaching episodes and broad geographic ranges, and staghorn corals are thought to be one of the most vulnerable species in scleractinian family (IUCN 2009). *Acropora* sp. and other corals reproduce both sexually and asexually and both are important to restore a degraded reef area (Zayasu et al. 2018). *Acropora* corals can grow fast by asexual reproduction method called fragmentation, which leads to the swift recovery of the degraded reef system. They contribute significantly to the reef growth (5.23cm^2/month) and form dense colonies which supports in island formation, coastal protection and fisheries (Bruckner 2002; Johnson et al. 2011). GoM Marine National Park has fringing type coral reefs which are distributed in 21 offshore islands ranging in between Rameswaram and Tuticorin (ENVIS 2015). During the 1998 coral bleaching event, shallow water coral reefs of GoM faced a severe mortality of 75% leading to a significant reduction in the live coral cover especially of *Acropora* spp. (Venkataraman 2000; Kumaraguru et al. 2003). Post bleaching assessment stated that recovery was too slow and live coral coverage increased to 36.98% during 2003–2005 (Edward et al. 2018). Thereafter, during 2009, live coral coverage was further increased to 42.85%. But coral bleaching in 2010 resulted in mass mortality of corals in GoM that reduce the coral cover upto 33.20% and in 2011, coral again started recovering and percentage of live coral cover increased to 38.86% (Edward et al. 2012). It was indicated that the recovery potential of a reef primarily depends on the successful sexual reproduction followed by coral recruitment and survival of the coral larvae (Vermeij et al. 2009). Therefore, an occurrence of new recruitment of corals brings back the reef to its previous state and maintains a healthy reef ecosystem. This study mainly describes the in situ observation on new recruitment of staghorn corals at selected sites of the GoM and also indicates possible resilient factors linked to this new recruitment.

The National Centre for Coastal Research (NCCR) team

DOI: https://doi.org/10.11609/jott.4767.11.14.14908-14911

Editor: M. Nithyanandan, Kuwait Institute for Scientific Research (KISR), Salmiya, Kuwait. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #4767 | Received 16 December 2018 | Final received 31 July 2019 | Finally accepted 01 October 2019

Citation: Sadhukhan, K., R. Chatragadda, T. Shanmugaraj & M.V.R. Murthy (2019). New recruitment of staghorn corals in the Gulf of Mannar – the emergence of a resilient coral reef. *Journal of Threatened Taxa* 11(14): 14908–14911. https://doi.org/10.11609/jott.4767.11.14.14908-14911

Funding: Ministry of Earth Sciences (MoES), Government of India; National Centre for Coastal Research (NCCR).

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors thank the secretary, Ministry of Earth Sciences (MoES), Government of India and Director, NCCR, MoES, Government of India for the financial support and facilities. We are thankful to the field assistants for the field support.

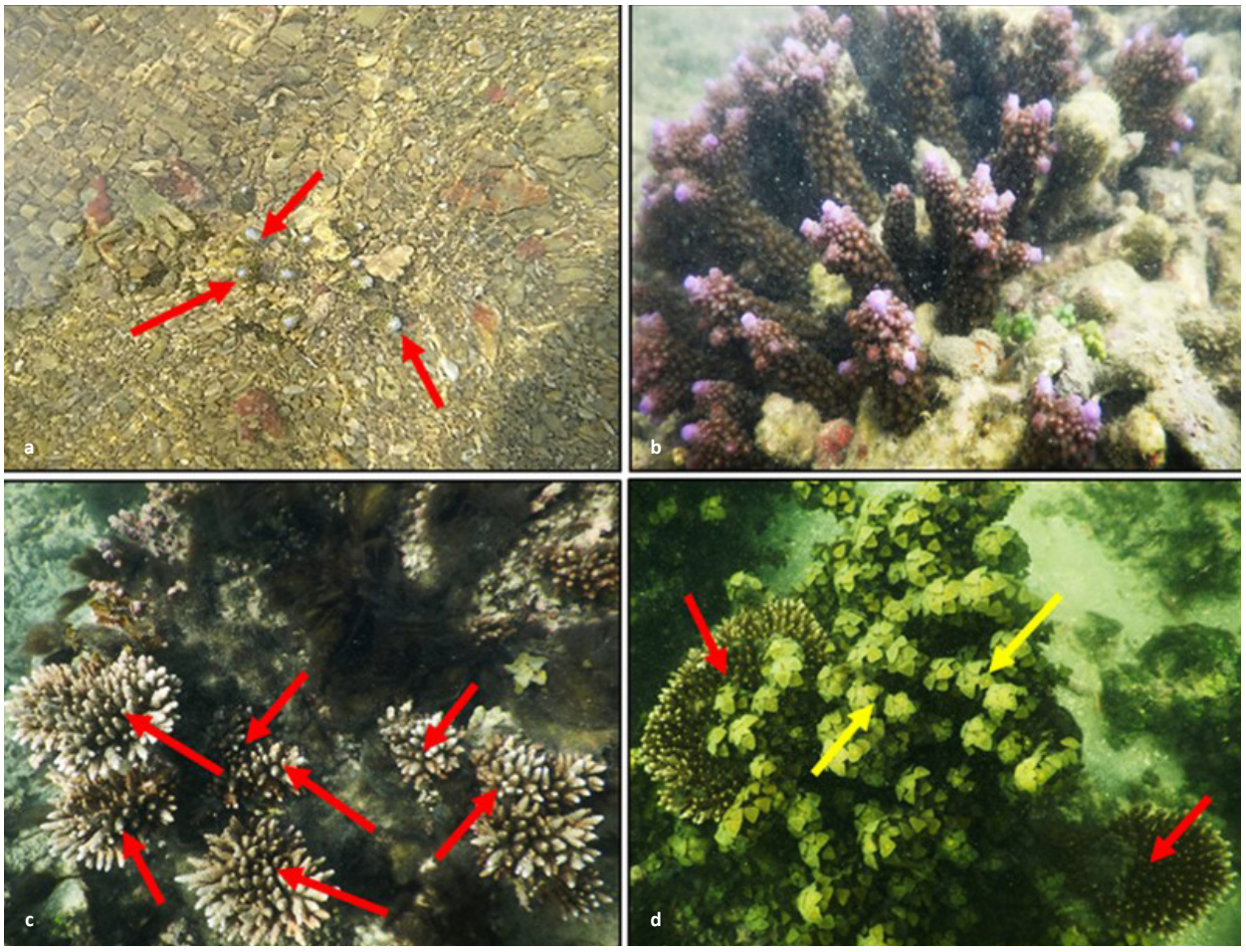

Image 1. a—*Acropora* colony (Size 0.5–2 cm) growing on undisturbed substratum at Hare Island | b—recruitment density (12–20 colonies/m^2) in Manoli & Manoliputti Island | c—newly recruited healthy coral colony (1.3–15.5 cm) on Hare Island | d—growth of native algal species *Turbinaria* sp. (Yellow arrow) with *Acropora digitifera* (red arrow) colony. © NCCR, Mandapam Field Office.

carried out several underwater surveys in Hare Island, and Manoli & Manoliputti islands of the Mandapam group, GoM from August 2018 to October 2018. Newly recruited corals distributed in different sites were marked with GPS location (Hare Island northern side: 09.206^{0}N, 79.084^{0}E; Hare Island southern side: 09.190^{0}N, 79.075^{0}E; Manoli & Manoliputti northern side: 09.219^{0}N, 79.134^{0}E; Manoli & Manoliputti southeastern side: 09.206^{0}N, 79.140^{0}E) and also photographed. Line intercept transect and quadrat sampling methods (English et al. 1997) were performed at the new recruitment sites. For detailed assessment, a 20-meter long flexible underwater tape was laid on selected reef areas, roughly parallel to shoreline with three replicates at each site and covering an area 20m × 2m (1m on each side of the transect line) for each transect. A total of four sites were selected and 12 transects and 36 quadrats (1m × 1m) were employed to estimate the live coral cover and recruitment density.

Recruitment of *Acropora* sp. was encountered at northern and southern sides of Hare Island, northern and southeastern sides of Manoli & Manoliputti Islands. The recruitment of different growth forms of *Acropora* such as *Acropora* branching (ACB), *Acropora* tabular (ACT), and *Acropora* digitate (ACD) were found on the dead *Acropora* branches and coral rubbles. The southern side of Hare Island, has several dead patches of coral comprising *Acropora* rubbles, and dead colonies of massive and submassive corals with algal growth. In Manoli & Manoliputti, many dead patches of massive corals were encountered and heavy sedimentation was also observed. Among the staghorn coral species, *Acropora formosa* and *Acropora hyacynthus* represented the maximum recruitment at both the study sites. The average coral cover of Hare Island and Manoli & Manoliputti Island was 58.4% and 51.5% of which *Acropora* sp. represented live coverage of 48.1% and 15.6%, respectively (Figure 1). The size of each individual coral colony ranges from 0.9 to 8.2 cm.

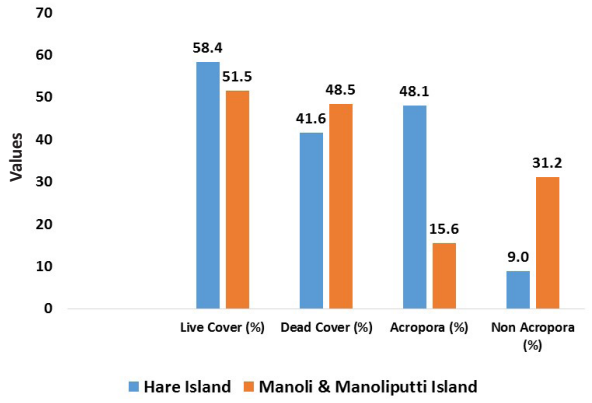

Figure 1. Average live coral coverage of Hare and Manoli & Manoliputti Islands.

Tropical reefs are increasingly impacted by multiple stressors that result in landscape loss of coral cover primarily due to adult coral mortality, aborted reproduction effort as well as unsuccessful recruitment at the disturbed habitat (Connell 1997; Graham et al. 2015). Reef resilience can protect these disturbances either by resisting change or by rapidly recovering to their pre-disturbed state (Holbrook et al. 2018). Reefs in GoM were challenged by intensive coral mining during the 1980s before the Indian Ocean tsunami event, which might have resulted in the destruction of *Acropora* sp. forming rubbles in the benthic substrate. After the Tsunami, the coral mining was completely stopped in GoM (Edward et al. 2008). We observed many new *Acropora* colonies (0.5–2 cm) on Hare Island coming up on largely undisturbed dead corals and rubbles (Image 1a). The percentage cover of live coral in Mandapam group of GoM has also significantly increased from the earlier report of 22.69% in 2016 (Edward et al. 2018) to 58.6% in the present study (Figure 1). We don't have a direct observation on coral spawning and larval settlement, but the emergence of new coral communities following disturbances indicates a function of multiple processes including coral recruitment, growth and survival of new recruits. As per the earlier report, the coral spawning of *Acropora* sp. mainly happened here during March every year (Raj & Edward 2010). Earlier studies also revealed that recruitment to reef habitats is dependent on the ability of juveniles to find a suitable substratum to settle and metamorphose (Graham et al. 2011). The reef structure of Manoli & Manoliputti is mainly made of rubbles and dead massive coral with algal growth. But on the southeastern side of Manoliputti Island we observed a significant density (12–20 colonies/m^2) of new recruits of *Acropora formosa* (Image 1b). The northern side of the Hare Island has a major settlement of *Acropora formosa*, *A.humilis* and *A.digitifera* whose colonies range 1.3–15.5 cm (Image 1c).

In degraded reefs, many negative driving forces also result in the mortality of post larval settlement of corals (Harrington et al. 2004). The major threat to successful coral recruitment is the excessive growth of algae on which coral planula may have settled, but later suffered severe mortality (Vermeij et al. 2009). In our observation, we have noticed that new recruits have high competition against the growth of native algal species *Turbinaria* sp. and *Caulerpa* sp. on the reef substrate (Image 1d). An earlier study also reported that GoM has faced heavy sedimentation ranging from 1.97 mg/cm2/day to 12.31 mg/cm2/day that was found to be the highest during the month of August and lowest during the month of April (Mathews & Edward 2006; Kumar et al. 2014). Despite high sediment deposition at the northern side and southeastern side of Manoli & Manoliputti Island, we have observed that the new recruitment of corals in this region is high. Staghorn corals play an important role in reef formation but are easily susceptible to environmental and anthropogenic stress (Johnson et al. 2011). The density of coral recruits is on the rise in Gulf of Mannar. The average density of coral recruits in GoM has increased from 4.1/m^2 in 2003–2005 to 7.7/m^2 in 2011 (Edward et al. 2012). In the present study, recruitment density was found to be the highest on the southeastern side of Manoli & Manoliputti Island with 12–20 colonies/m^2. Observation on the coral reproduction in GoM is rare, but studies using the experimental set up were carried out to assess the recruitment rate of coral spats in Krusadai Reef complex (Raj et al. 2014; Marimuthu et al. 2018). Coral recruitment is one of the indicators of coral reef health in marine protected areas, and also provide a positive sign of coral reef recovery of a degraded ecosystem (Acosta et al. 2011). The findings reported here suggest that increased percentage of coral cover brings a new hope for the researcher to find out the possible driving forces for the successful post larval settlement and survival of new recruits, which results in better conservation and management plan for the coral reefs of GoM Marine National Park. Therefore, NCCR initiated long term monitoring plan of the selected reef areas to assess the growth and survivability of newly recruited corals and investigate factors for reef resilience.

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PLATINUM OPEN ACCESS

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

November 2019 | Vol. 11 | No. 14 | Pages: 14787–14926
Date of Publication: 26 November 2019 (Online & Print)
DOI: 10.11609/jott.2019.11.14.14787-14926

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