The second "rescue a reef" crown of thorns starfish removal in the Maldives

10-16 September, 2017

CORAL REEF CPR
CONSERVATION·PROTECTION·RESTORATION

CARPE DIEM
MALDIVES

Acknowledgements

This trip would not have been possible without the dedication and hard work from all of the recreational divers. We are extremely grateful for their time, effort, enthusiasm and endless amounts of fun during the expedition. A special thank you to the repeat divers – we are so appreciative and excited that you were able to join us for a second 'Rescue a Reef' mission. We would also like to offer a huge thank you to the hard-working team aboard Carpe Vita, particularly the dive team who had the arduous task of counting and burying the 1,423 crown of thorns starfish! Thank you to the Ministry of Fisheries and Marine Research Centre for their ongoing support. Finally, thank you to our partners, Carpe Diem Pvt. Ltd., for their support and true dedication to save the critically important reefs in the Maldives. These reefs need more people like you!

Fig. 1. The volunteer divers and Carpe Diem staff participating in the "rescue a reef" crown of thorns starfish removal program in September 2017.

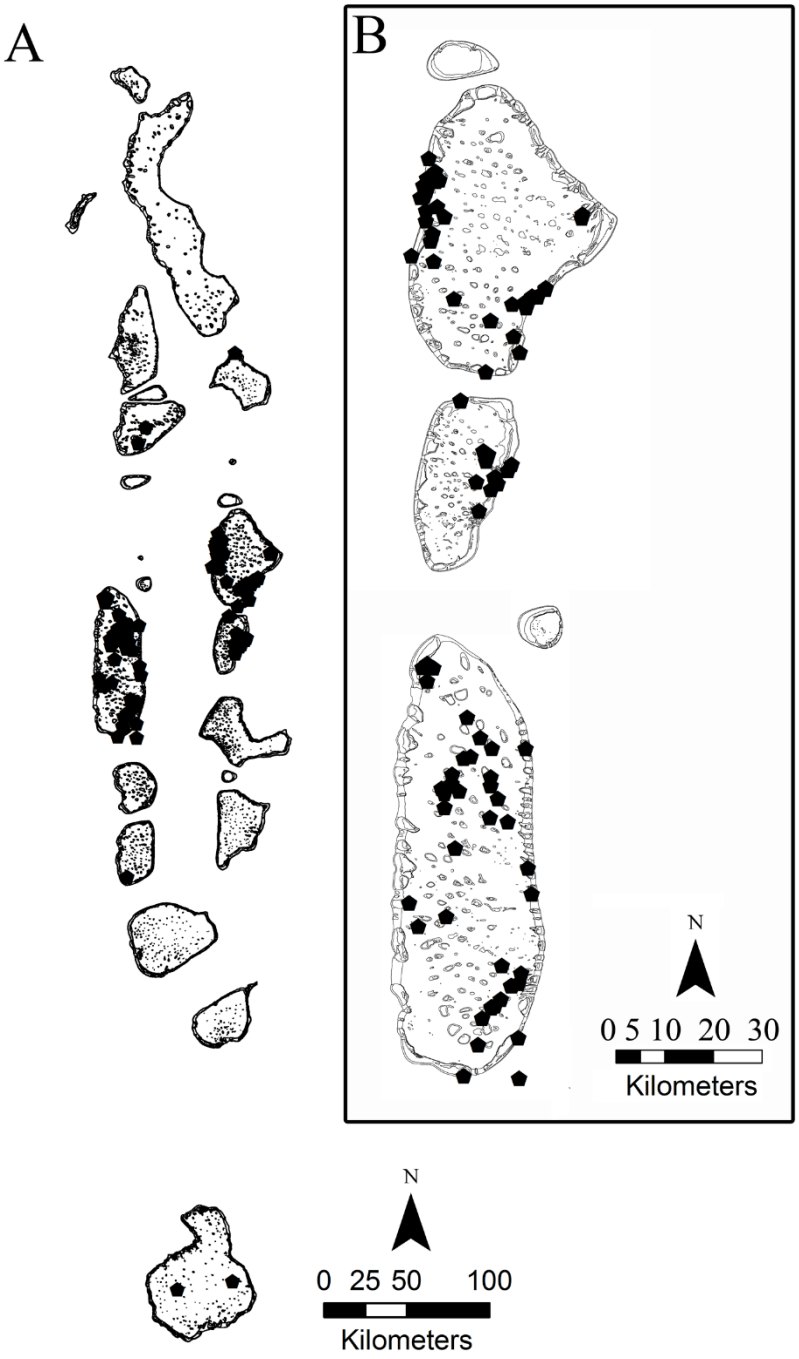
Executive Summary

From September 10-16, 2017 Coral Reef CPR in partnership with Carpe Diem Maldives Pvt. Ltd undertook the second "rescue a reef" crown of thorns starfish (COTS) removal program. With involvement from Carpe Diem crew, Coral Reef CPR scientists and 17 recreational divers, a total of 1423 COTS (*Acanthaster* spp.) and 91 cushion stars (*Culcita*) from eight reefs on North Malé, South Malé and North Ari Atoll. The starfish were collected from depths of <1 m to 30 m, counted and assessed on board the dive dhoni, and disposed of through burial on uninhabited sand islands. This program has demonstrated the utility and effectiveness of the use of recreational divers to assist in COTS outbreak mitigation. One of the key benefits gained by involving recreational divers is the increased awareness they acquired through participation in daily seminars, and recognition that there are tangible actions that can be undertaken to reduce localized impacts. Furthermore, this study demonstrated 1) the effectiveness of the removal efforts through revisiting of sites cleaned up in May 2016, and 2) the benefit of using a large team as this offers an ability to cover a large area of reef and remove starfish efficiently and thoroughly from the entire reef system. It is estimated that the removal saved a total of 68,304 square meters of reef habitat, based on an annual consumption of 6 m^2 per starfish per year over its lifespan. A secondary benefit is the reduced potential for a secondary outbreak, as these have been removed from the reproductive pool on Maldivian reefs.

Fig. 2. Bags of COTS removed from a reef on South Malé Atoll.

Background

Reefs in the Maldives are currently being impacted by the third outbreak of crown of thorns starfish (COTS; *Acanthaster* spp.), following a minor outbreak in the 1970s on Alifu Atoll and a second outbreak between 1987-1991 that started near Reethi Rah and spread throughout North Malé and to Ari Atoll. The current outbreak began in 2014 at the western end of North Malé Atoll, near Reethi Rah, and has progressively spread throughout North Malé Atoll, South Malé Atoll and Ari Atoll, with smaller infestations reported on x other atolls. During the 2016 bleaching event (March-June), most starfish disappeared, presumably moving into deeper, cooler water. The starfish reemerged in July, and have continued to spread throughout the region.



While limited efforts to control COTS were undertaken during the second outbreak, many more resorts and dive centers have removed COTS from neighboring refs during the current outbreak. An analysis of all reported removals, compiled from the Ministry of Fisheries Marine Research Centre, Facebook Posts and queries made by Coral Reef CPR, over 85,000 COTS have been removed to date, with up to 25,000 from individual reefs in Ari Atoll. As of May, 2017, our database includes reports of 128 outbreaks between 2014 and 2017.

Fig. 3. Location of crown of thorns starfish outbreaks reported from 2014-2017.

Carpe Diem began dedicating efforts to remove COTS in November 2016, when Coral Reef CPR scientists collected 199 starfish from three locations. Since this time Carpe Diem dive crew have continued to collect COTS, and the first dedicated COTS removal trip was undertaken in May 2017. As of August 12, 2017, Carpe Diem had removed 1851 starfish. Coral Reef CPR has removed over 10,600 COTS from reefs in the Maldives between October 2015-September 2017 from 43 reefs on North Male, South Male and Ari Atoll (Fig 4).

Fig. 4. All of the sites in the Maldives where Coral Reef CPR scientists have removed crown of thorns starfish since 2015.

Recent findings

The reemergence of starfish in the summer of 2016 has been characterized by a different pattern and behavior. Unlike pre-bleaching outbreaks, when the starfish were concentrated in high numbers among stands of table, staghorn and digitate acroporids, the starfish are now much more spread out, occurring at a lower density over a larger number of reefs and depths. This change is primarily due to a scarcity of food, as most of their preferred food items were killed during the bleaching event (e.g. *Acropora*, *Montipora* and *Pocillopora*).

Fig. 5. On most reefs crown of thorns starfish occurred at a low density, with individuals scattered throughout the reef. Three reefs had more severe outbreaks, but aggregations rarely exceeded 2-3 starfish per square meter.

There are now two to three different age classes present on most reefs, with an increasing number of smaller starfish intermixed with large, older starfish. On many reefs, especially those that have undergone periodic removal efforts, the few starfish still remaining were primarily small.

Fig. 6. A juvenile COTS, approximately 8 cm diameter (left) and a large (35 cm) adult COTS (right).

In response to the scarce food source, the starfish have changed their feeding behaviors. Whenever present, they are still found feeding on acroporids and *Pocillopora*. However, the vast majority of starfish were found feeding on boulder corals, primarily *Porites lobata*. They were also preying on other less preferred stony coral species, including: *Goniopora* spp., *Porites rus, Porites cylindrica, Diploastrea, Physogyra, Lobophyllia, Pachyseris, Pavona, Gardineroseris, Psammocora, Fungia, Ctenactis*, as well as all surviving faviid corals. COTS were also identified on non-coral cnidarians including false corals and leather coral. A large number of COTS were removed from sand and rubble areas, where they were actively migrating through the reef in search of food. In general, they appeared to avoid small corals, except on one reef (Aquarium) on North Ari Atoll. On this reef the majority of the larger corals had been previously killed, but certain areas of the reef (especially the reef flat and shallow reef slope) had high numbers of new recruits and juveniles of both *Acropora* and *Pocillopora*. These were being rapidly consumed by COTS, with individual animals feeding on up to six neighboring small corals at once.

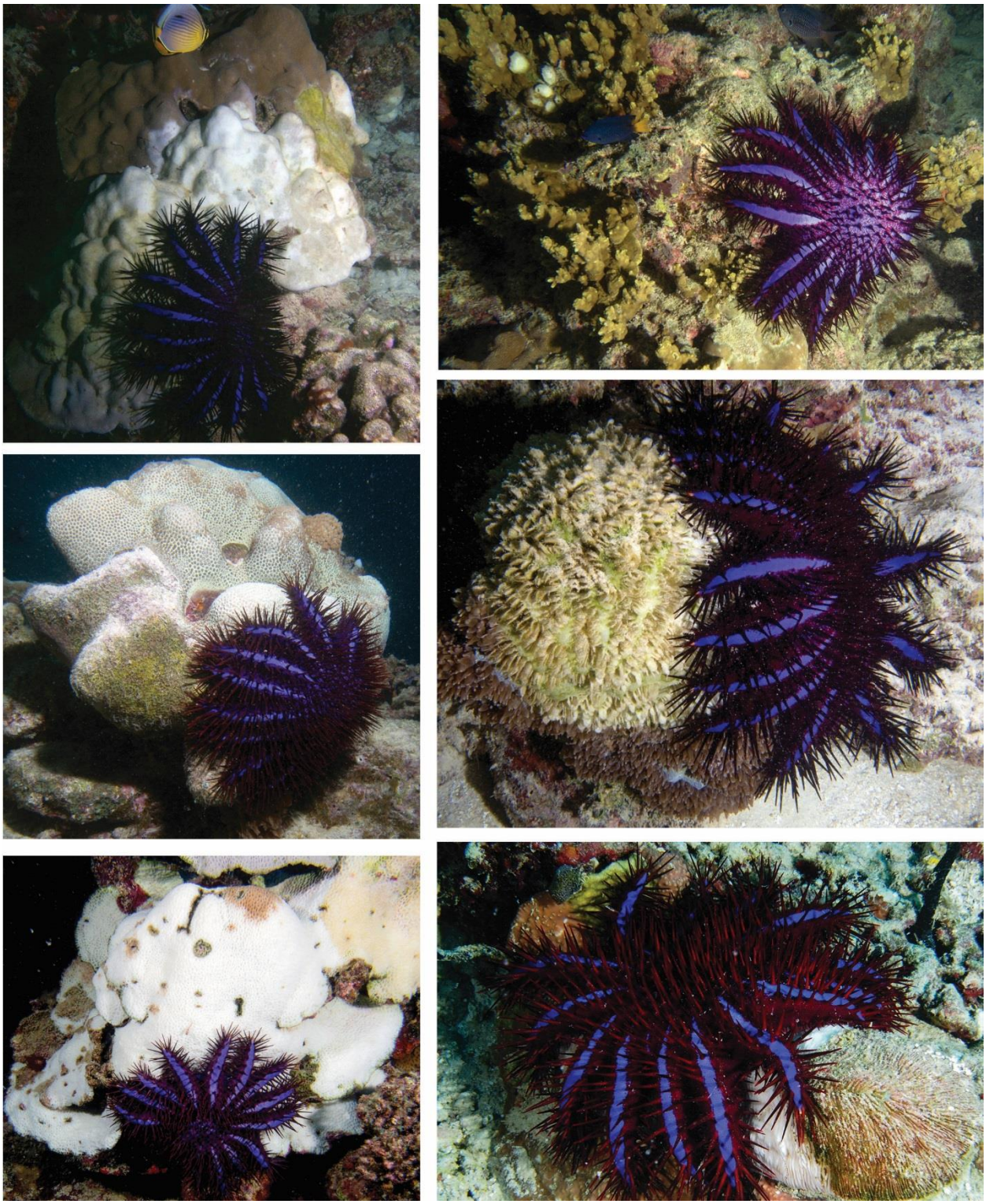


Fig. 7. Various coral prey being eaten by crown of thorns starfish on reefs examined during this mission. *Porites lobata* (top left), *Porites rus* (top right), *Goniopora* (center left), *Physogyra* (center right), *Gardineroseris* (bottom left) and *Ctenactis* (bottom right).

Collection efforts

During the week long COTS removal program we examined 14 reefs for crown of thorns starfish. Starfish were identified and collected from eight reefs, and they were absent from six reefs.

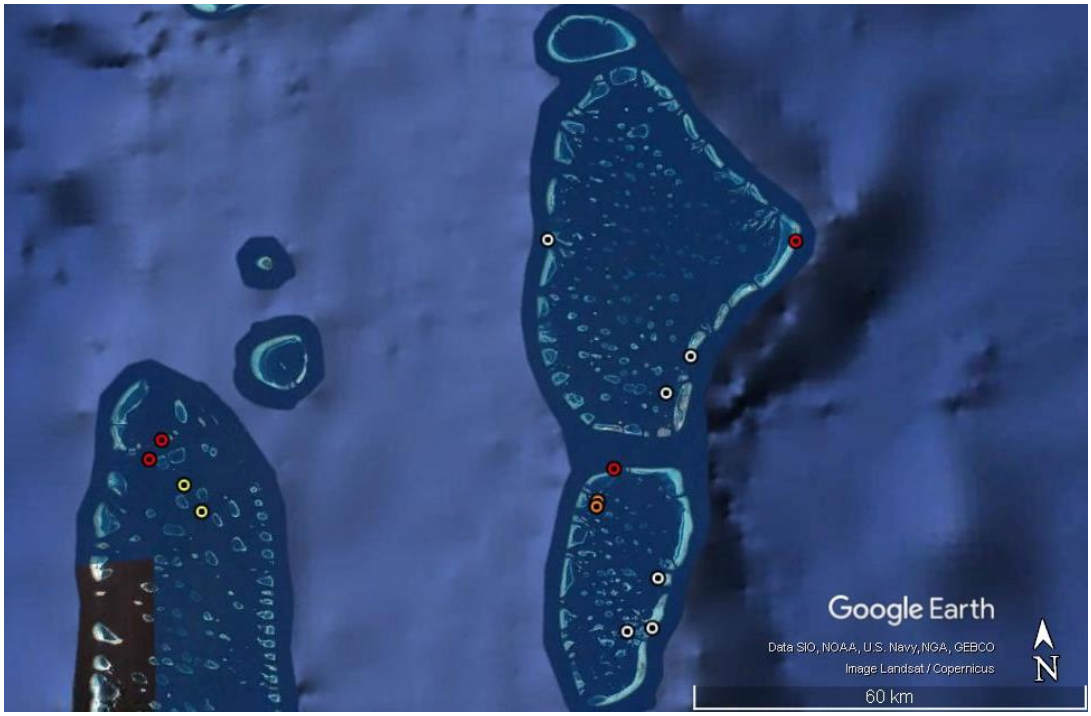


Fig. 8. Location of the reefs examined for COTS during September 2017. White dots indicate sites without COTS, yellow dots had a low number of COTS and red dots indicate sites with outbreaks.

On six of the reefs, we were able to successfully remove COTS from the entire reef system. On two reefs (Lagoona Caves and Aquarium), we only collected from a portion of the reef system, and high numbers of COTS remain in other areas. The outbreak at Lagoona Caves was the most severe. We conducted four dives in this location, but due to strong currents and waves we were unable to remove starfish from the northern end of the reef system (above the water villas).

Fig. 9. Lagoona Caves was affected by a severe outbreak of COTS with COTS occurring in high numbers throughout the reef to depths of 30+ m. One concern is that this reef still supported Acropora, and these were being targeted by COTS.

Aquarium was a very extensive reef system and we were successfully able to clean approximately 30% of the outer reef. We did not examine the lagoonal reef or the western side due to time constraints. One of the main concerns at Aquarium was that the starfish were feeding on new recruits and small juvenile corals in the genus *Acropora* and *Pocillopora*.

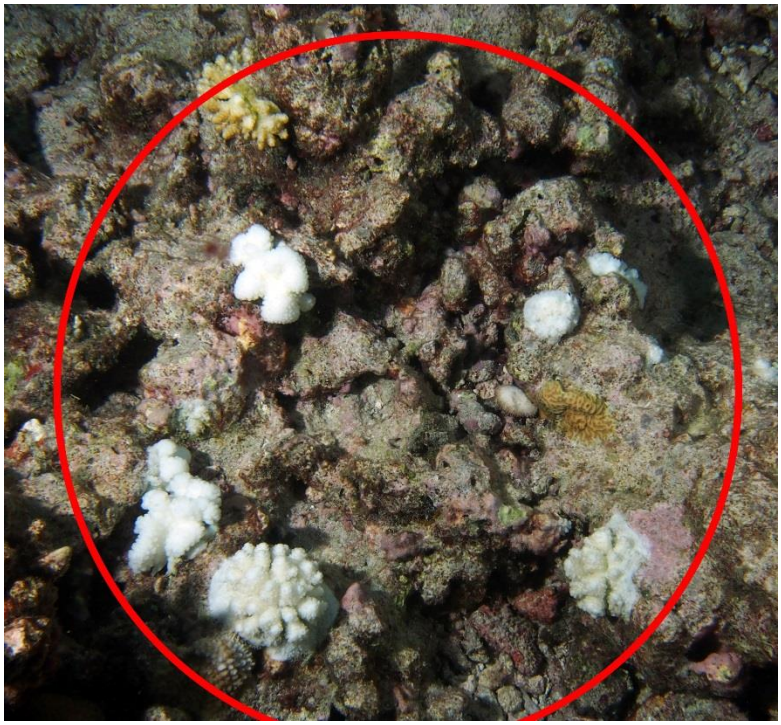


Fig. 10. Juvenile corals and new recruits were being eaten by COTS on Aquarium reef.

We examined three reefs visited during the May, 2017 COTS removal effort (Hondali Bodu Giri, Maaya Thila and Boduhuthiu Thila). On Hondali Bodu Giri, very little live coral remained and the reef was covered in thick turf and macroalgae. The remaining COTS were feeding primarily on *Porites rus, P. lobata* and *P. cylindrica*, as these were the only remaining corals. COTS tend to avoid *P. rus* and *P. cylindrica*, but will consume these corals when food is scarce. Fortunately, we were able to search the entire reef, and remove all remaining starfish. Boduhuthiu Thila did not contain any COTS. The reef was showing promising signs of recovery, and it exhibited high survival of boulder corals, scattered patches of staghorn coral and many other species that either resisted bleaching or had fully recovered from the bleaching event in 2016.

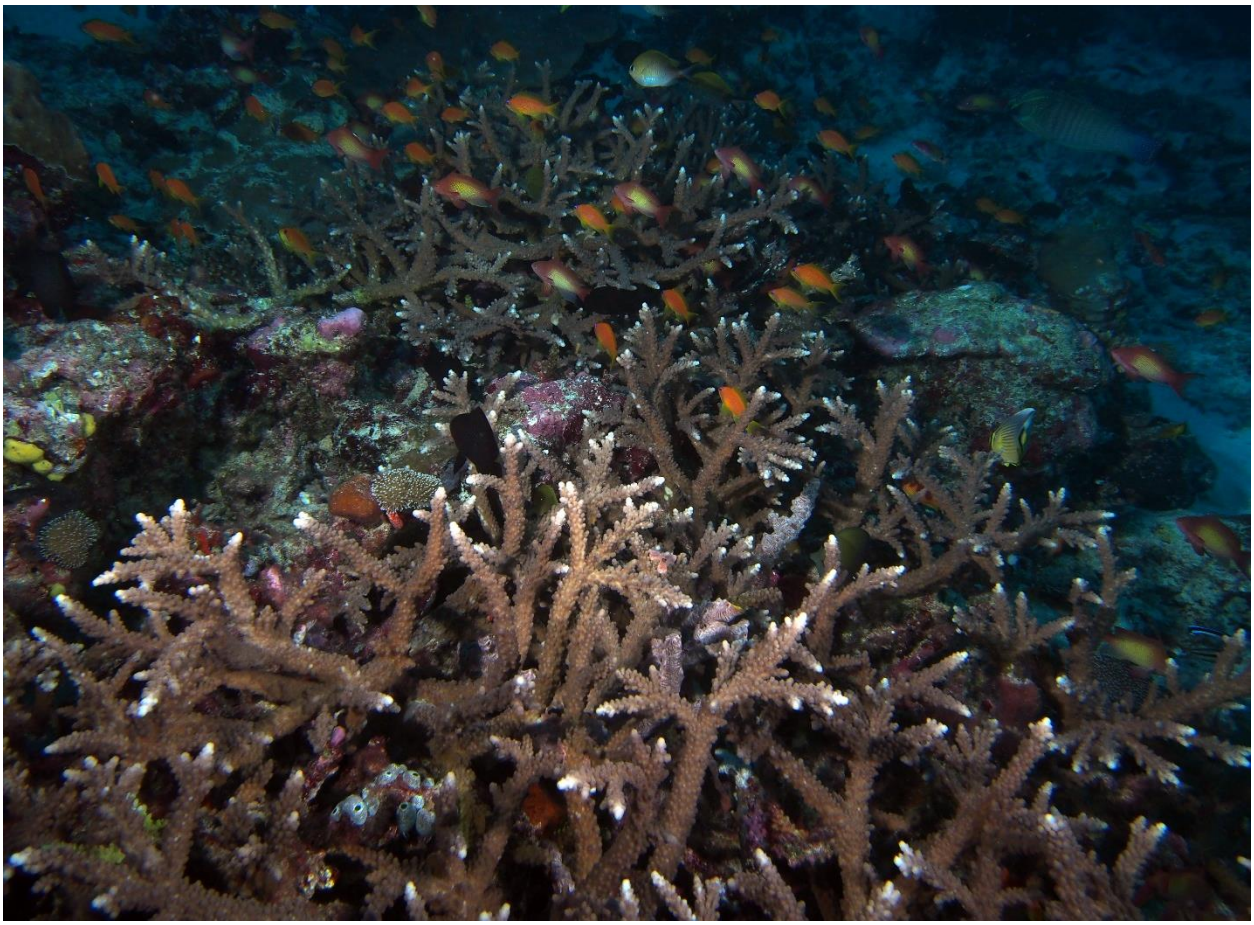


Fig. 11. Stands of *Acropora hemprichi* were common on Boduhuthia Thila.

On Maaya Thila, we have removed COTS on three separate occasions, including the May 2017 mission, and Carpe Diem divers have also removed COTS during their frequent visits to this reef. There were very few remaining starfish on this reef. We only identified five COTS during a survey during daylight. I also observed eight additional COTS at night, but did not have any collection bags. What was unique about this reef is that all COTS were small, consisting of two size classes: 1-2 year old juveniles and 2-3 year old adults; no larger starfish were found. This suggests that the efforts to remove starfish have been highly successful, but there has been a secondary recruitment over the last few years.

We also examined Hafsa Thila, which was heavily infested with COTS in 2016. Coral Reef CPR removed 60 from this reef in August 2016 and 130 in November 2016, but this was only a portion of the total infestation. Carpe Diem divers continued to collect starfish from the site. Unfortunately, this reef was completely devastated, and >98% of the coral has been consumed by starfish. Because of an absence of food, most remaining starfish had moved away from the reef or died; only 8 COTS were seen in September 2017.

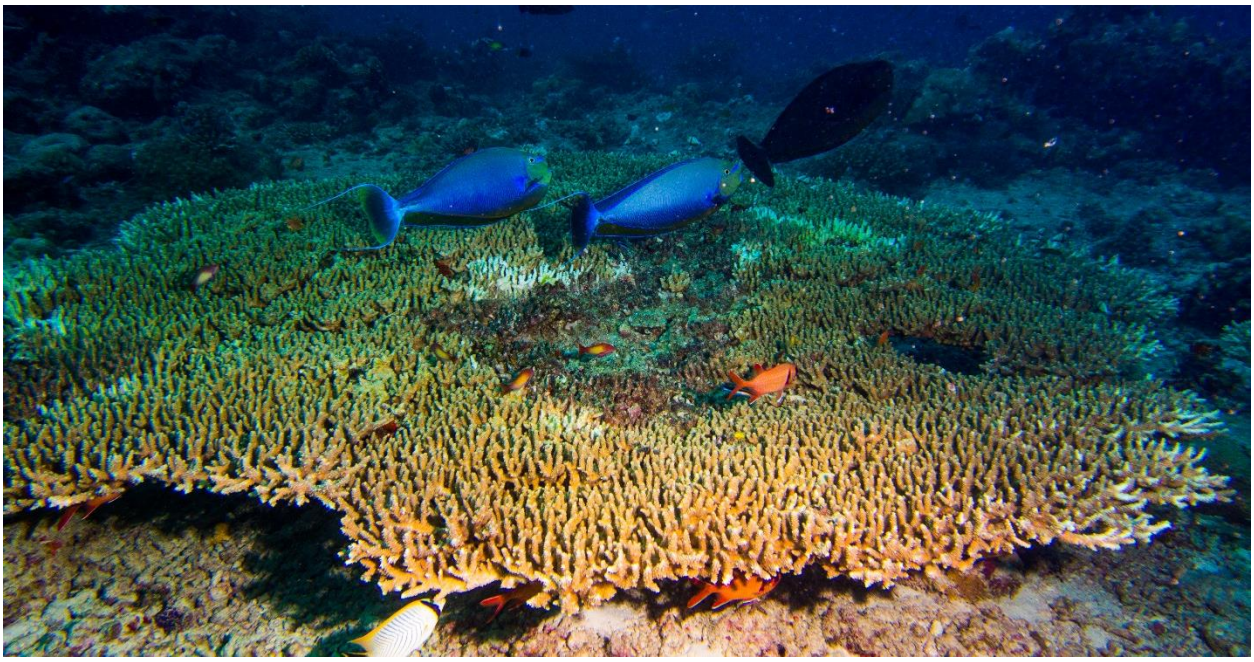


Fig. 12. Hafsa Thila was an important refuge for table corals (Acropora). The shallow reef platform contained numerous 1-3 m diameter table corals that survived the bleaching event and were mostly live in August 2016.

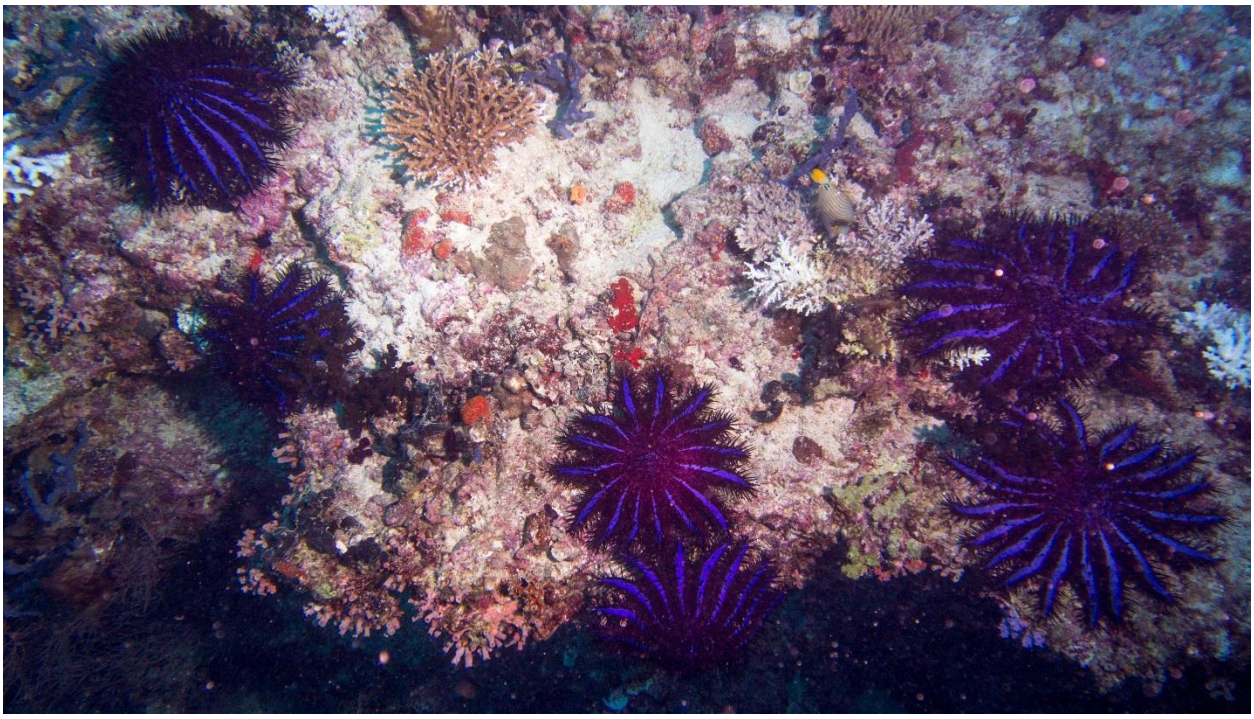


Fig.13. Hafsa Thila was affected by a severe outbreak of COTS in 2016. We removed 190 starfish during two separate periods, but many remained.

Fig. 13. In September 2017, all of the large table acroporids on the reef terrace of Hafsa Thila were completely dead.

Table 1. Total number of crown of thorns starfish (*Acanthaster*) and cushion starfish (*Culcita*) removed between September 11-15, 2017.

Date	Site Name	Atoll	Total COTS removed	Total cushion star removed
11/9/2017	Komas Faru	North Malé	147	82
11/9/2017	Lagoona caves	South Malé	684	0
13/9/17	Hoandali Bodu Giri	South Malé	69	0
13/9/17	Finolhu Faru	South Malé	78	0
14/9/17	Maya Thila	Ari	5	0
15/9/17	Hafsa Thila	Ari	8	4
15/9/17	Velidhu House Reef	Ari	252	0
15/9/17	Aquarium	Ari	180	5
Total			**1423**	**91**

All starfish were removed from the reef using a PVC pipe, placed in large mesh collection bags and transported to the surface of the water using a SMB. The COTS were then carried onto the dive boat, where they were counted and stored in large bins till disposal. Starfish were buried in a pit dug in the sand of uninhabited islands.

Fig. 14. From the reef to the boat. Volunteers and Carpe Diem divers collecting COTS.

Fig. 15. All of the starfish removed from the reefs were buried on sandy islands above high water.

Importance of continued efforts to eradicate COTS

Reefs in the Maldives are at a critical juncture. Both localized and global stressors are accelerating, due to a recent tourism expansion and increasing impacts associated with climate change. Recent disturbances associated with the 2016 coral bleaching event have severely damaged reefs throughout the country (and worldwide, with 70% of the world's reefs experiencing bleaching). When the COTS outbreak emerged in 2014, living coral cover was very high, and reefs were dominated by fast growing branching, staghorn, table and digitate acroporids. These tend to be the preferred food for COTS, and outbreaks observed in the Maldives were characterized by a front of starfish consisting of unusually large aggregations (hundreds to thousands). These moved in a wave through reef systems, quickly eliminating fast growing corals. While they had a noticeable and devastating impact to affected reefs, once the starfish moved to a new location, the corals could quickly rebound, as the target species are fast growing and have very high rates of recruitment (settlement of coral larvae). Characteristically, an Acropora dominated reef that is destroyed by COTS can recover within approximately 5 years.

During the 2016 bleaching event, most of the starfish disappeared, moving into deeper cooler water. Once temperatures returned to normal, the starfish reinvaded shallow reefs, but much less food remained. As mentioned above, this has resulted in a wider dispersion of starfish, and lower densities of animals spread over a much greater number of reef systems. This makes removal efforts much more difficult. Further, due to the absence of their preferred fast growing corals, the starfish are now primarily eating slow-growing boulder corals. *Porites lobata* is the primary food source, as this is the most abundant coral on Maldivian reefs now. They also consume every other

species of reef building coral found on these reefs. This is highly problematic for several reasons:

1) The corals they eat are slow growing (1 cm per year) and exhibit much lower rates of recruitment than branching corals. A starfish can eat a 25 year old coral (the size of a basketball) in 1-2 days.

Fig. 16. A large (1 m diameter) *Porites lobata* colony that has five prominent, overlapping feeding scars (circular white patches) representing five days of predation by a single starfish. This coral is at least 50-75 years old.

2) The corals they are eating are the primary frame building corals. If these disappear, the reef will begin to bioerode and disappear.
3) The remaining corals found on these reefs are those that either resisted bleaching, or they bleached and recovered. This indicates that these corals are more resistant to temperature stress. As climate change increases in severity, and the frequency of El Niño events increases, the reefs are predicted to face elevated sea water temperatures that are much higher than in the past and more frequent, with predictions of annual bleaching in the Maldives by 2041. Hence, the corals that

resisted the bleaching are extremely important as these are stronger, more resilient colonies and they are more likely to adapt to increasing sea water temperatures

4) On many locations *Acropora* fragments and tissue remnants survived and high numbers of juveniles and first year recruits exist, and these are the corals that are being eaten by COTS. These are critical for the recovery of the branching, table and digitate coral community. All of these either survived the bleaching or they are the result of spawning in 2016 (prior to the bleaching) and 2017. Because so few of these corals remain, the loss of these corals could set back recovery times, as an absence of adult colonies mean that the annual spawning events are likely to fail (surviving corals are at too low a density for effective fertilization).

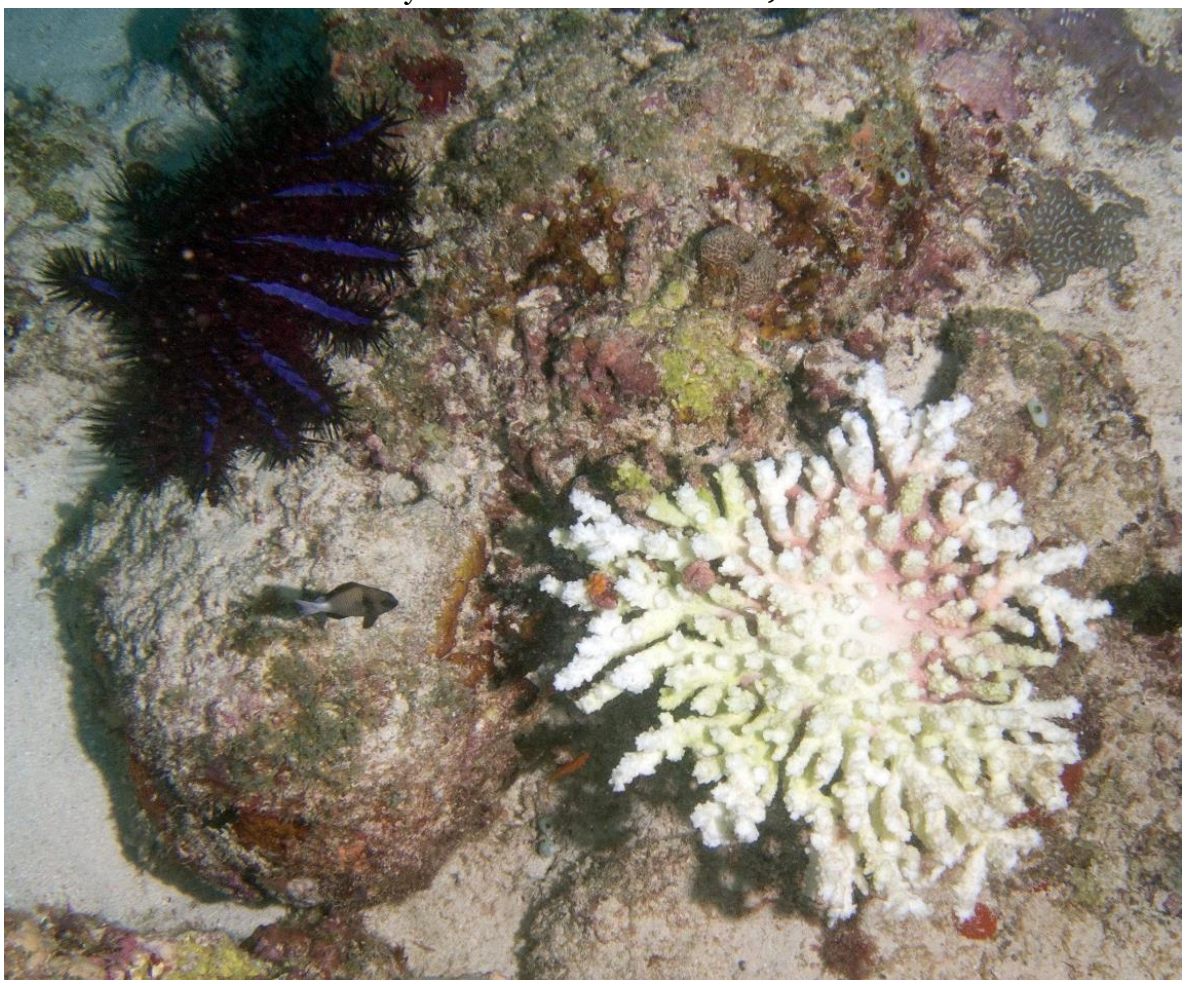


Fig. 17. A refuge from bleaching was identified in deeper water on the fore reef (Lagoona Caves) near Vellasaru. On this reef, the COTS were preying on the remaining Acropora table corals.

5) Because COTS can go for prolonged periods without feeding, they can migrate great distances in search of food. During this mission (and in past surveys) we have identified bleaching refuges that still contain adult colonies of *Acropora*. These are the most important sources of new larvae to repopulate degraded reefs. While some

of these refuges currently did not contain COTS (Kandooma Thila, Kuda Giri), starfish had invaded others (Lagoona Faru). By removing starfish from these sites, we are saving the remaining corals and we are also reducing the potential of secondary outbreaks by eliminating breeding adults.

Fig. 18. A group of starfish moving across the sand in deeper water in search of food.

Value of volunteer recreational diver engagement

- Increased awareness: likely to spread the word about the threats and vulnerability of reefs and concrete actions that can be taken to reverse these impacts; also value in highlighting the HARP Program (Holistic Approach to Reef Protection) being undertaken by Coral Reef CPR in partnership with Anantara Resorts and Carpe Diem. This also showcases the high importance Carpe Diem places on coral conservation, which is unlike the common business practices of many other dive operators and safari boat operators.

- More effective removal: High numbers of divers are needed to completely clean individual reefs, as the starfish are spread throughout all depths and they cover a large area. By positioning dive teams in different sections of the reef, we can cover the entire reef system very quickly and safely.

Conclusion

The second ”Rescue a Reef” program implemented by Carpe Diem in partnership with Coral Reef CPR was highly successful both in terms of the numbers of starfish removed and the amount of coral reef habitat saved and the increased awareness of the recreational divers on coral reefs. After a brief safety and training exercise in proper collection practices, the dive team participated in daily seminars on various aspects of coral reef ecology, threats, and conservation practices. The divers left with an increased understanding of the changes that occurred to Maldivian reefs since 2015, the causes of these changes, the context of these changes in relation to global coral reef crisis, and low tech but effective strategies we are implementing to conserve and restore Maldivian reefs.

Immediately following this mission another team continued clean-up efforts. They targeted Lagoona Caves on South Malé Atoll as well as Aquarium and surrounding reefs on Ari Atoll to increase the likelihood of complete eradication of COTS from these areas.

The Carpe Diem dive team and the volunteer divers that participated in the COTS clean-up were responsible and dedicated and worked together as a team to conduct a safe and comprehensive starfish removal effort. We are grateful for the time this team dedicated to the program.

APPENDIX I. Locations examined for COTS in September 2017 and prevalence of COTS

Reef	Atoll	Latitude	Longitude	COTS
Aquarium	North Ari	4.16638	72.7901	Outbreak
Hafsa Thila	North Ari	4.128933	72.8381	Few
Maaya Thila	North Ari	4.091217	72.86212	Few
Velidhu House Reef	North Ari	4.1925	72.8077	Outbreak
Boduhuthi Thila	North Malé	4.453528	73.36292	None
Koamas Faru	North Male	4.436765	73.717435	Outbreak
Kurumba Faru	North Malé	4.228182	73.51827	None
Lankan Faru	North Malé	4.278383	73.5562	None
Finolhu Faru	South Male	4.074833	73.411483	High
Hudeli Bodi Giri	South Male	4.08225	73.41364	High
Kandooma Thila	South Male	3.906667	73.47894	None
Kuda Giri	South Male	3.973597	73.49099	None
Lagoona caves	South Male	4.1258	73.43867	Outbreak
Vilivari Giri	South Male	3.903556	73.4442	None

Appendix 2. Trip Participants

Name	Nationality	Role
Ms. Agnes Van Linden	Netherlands	Carpe Diem Asst. Managing Director
Mr. Andrew Bruckner	United States	Coral Reef CPR Director
Ms. Georgia Coward	United Kingdom	Coral Reef CPR Manager
Mr. Brendan McElhinney	Ireland	Volunteer Diver
Mr. Henry Wild	Switzerland	Volunteer Diver
Mr. Christopher John Wills	United Kingdom	Volunteer Diver
Mr. Nicola Graham	United Kingdom	Volunteer Diver
Ms. Hannah Campbell	United States	Volunteer Diver
Ms. Simone Dinshaw	India	Volunteer Diver
Ms. Celine Schoups	Belgium	Volunteer Diver
Ms. Hayat Sadri	India	Volunteer Diver
Mr. Rohin Unvalla	India	Volunteer Diver
Mr. Krishna Ashok	India	Volunteer Diver
Mr. Bushan Bagadia	India	Volunteer Diver
Mr. Arjun Manghnani	India	Volunteer Diver
Mr. Johan Top	Belgium	Volunteer Diver
Mr. Robert Thomas	United Kingdom	Volunteer Diver
Ms. Kim Thomas	United Kingdom	Volunteer Diver
Mr. Douwe Theodoor de Graaf	Netherlands	Volunteer Diver
Mr. Söenke Harders	Germany	Volunteer Diver
Chakku	Maldives	Carpe Diem Staff – Dive Team Leader
Shaifan	Maldives	Carpe Diem Staff – Dive Instructor
Ibbe	Maldives	Carpe Diem Staff – Asst. Instructor
Naathi	Maldives	Carpe Diem Staff - Dive Master