Holistic Approach to Reef Protection

Coral Nurseries on South Malé Atoll and Baa Atoll

Field Report

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Andrew Bruckner
Georgia Coward

HARP
Holistic Approach to Reef Protection

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Executive Summary

The HARP Program, led by Coral Reef CPR in partnership with Anantara Kihavah/Anantara Dhigu, Minor Hotels and Silver Sands LTD, has created coral nurseries in shallow marine environments near the resorts to grow corals for use in rehabilitating coral reefs degraded in 2016 by the mass coral bleaching event. At Dhigu, there were 2,462 fragments in five nursery areas in October 2016. These nursery areas exhibited 91% survival in March 2017. At Kihavah there were 1,634 fragments in two nursery areas in October 2016. These exhibited 94.6% survival. Surviving coral fragments have fused to the rope and overgrown the cable ties, adding on numerous new branches. The branching corals (*Acropora*) have exhibited the most substantial growth, increasing in size by 2-5 times. Other corals have also grown, although at slower rates (comparable to growth rates reported in the literature). In March 2017, two additional nurseries were established near Aquabar (Dhigu) and SEA restaurant (Kihavah) and additional ropes containing coral fragments were added to three nursery areas. In total, 1,914 fragments were added and the eight nurseries now contain 5,509 coral fragments.

Nursery Design: Coral nurseries were established in two locations at Kihavah and five locations at Dhigu in November, 2016 and one additional nursery site was established in each location in February/March 2017. Nurseries consist of mesh-covered tables at 7 sites, suspended ropes and tables at five sites and suspended ropes only at two sites. Each table is approximately 1 m x 2m and contained approximately 100 fragments when first established, with two tables per site.

Fig. 1. Coral table at the Advanced Snorkel Area, Dhigu three months after it was deployed. The table is at 6 m depth.

Rope nurseries varied in size,

number of ropes, length of ropes and numbers of fragments. Ropes were approximately 5 m long, except for ropes off Aquabar (9-10 m length), with 1-5 ropes per frame and 30-60 fragments per rope. Additional ropes were added to the nursery off Plates restaurant (Kihavah), Dhigu deep snorkel area (5 ropes) and Veli water villas (1 rope) and new rope nurseries were established at SEA (Baa Atoll) and Aquabar (South Malé Atoll; 20 ropes and 1,312 fragments). Nurseries were located in the shallow lagoon adjacent to each resort, and nearby, on a patch reef, channel reef and a fore reef. Tables and ropes were placed at 1-6 m depth in sand and rubble habitats.

Fig. 2. One rope nursery with 5 six meter ropes at Dhigu House Reef in 7 m depth. The fragments were attached to ropes in October 2016 and are shown here in March 2017.

Coral Types and Sources: Coral nurseries are predominantly branching, digitate and tabular growth forms of *Acropora*, with mixed species (*Acropora, Cyphastrea, Hydnophora, Pocillopora, Porites, Leptastrea, Psammocora, Pavona,* and *Turbinaria*) at two sites. All corals were sourced from locations and colonies that would have died if left on site. This included sand extraction sites, colonies being eaten by predators or affected by disease, and broken, detached fragments that were being buried by sand, abraded, or had accumulated at the base of the reef .

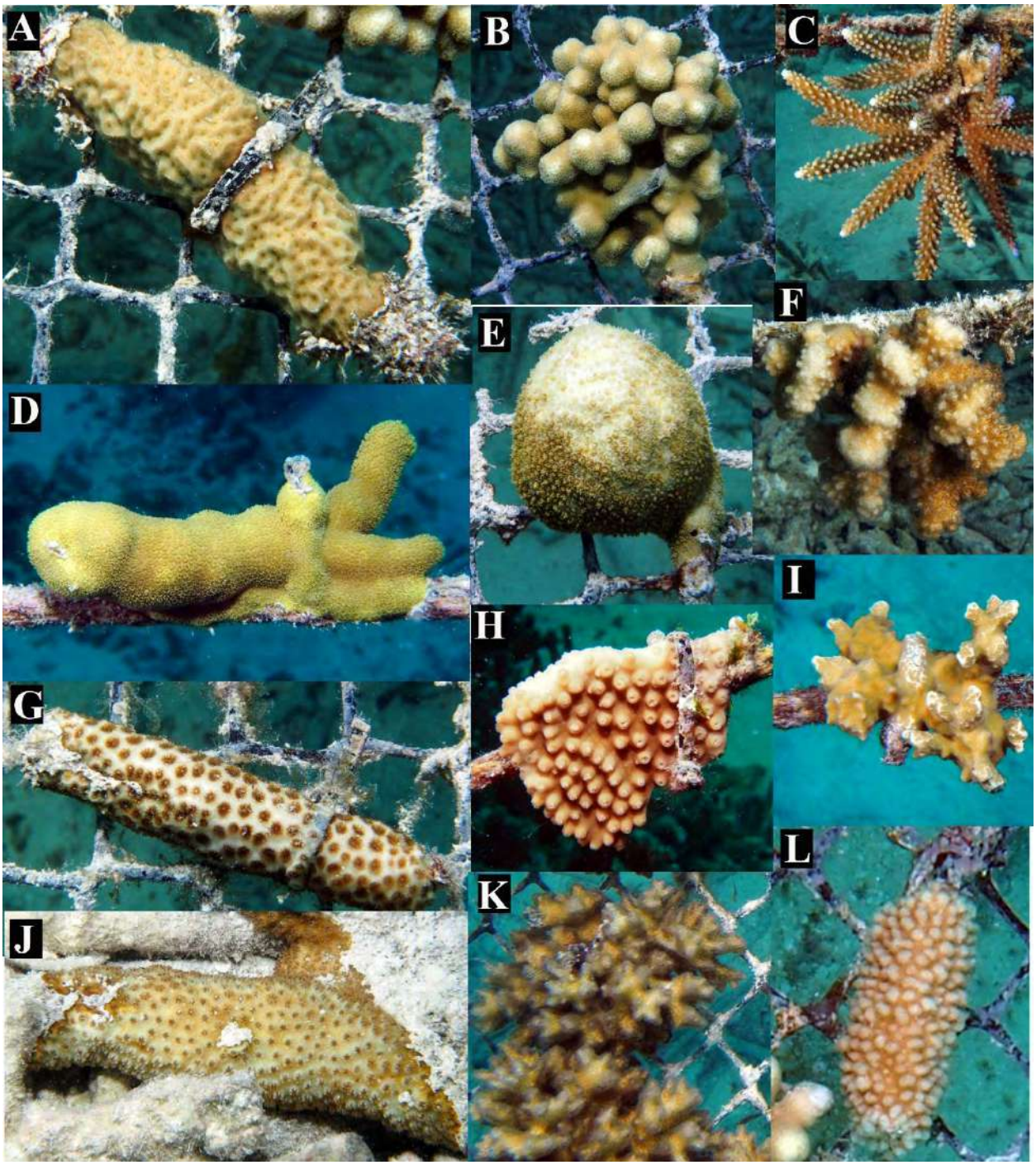

Fig. 3. Examples of the types of corals that are being grown in the nurseries. A. *Psammocora profundacella* B. *Porites* sp. C. *Acropora formosa* D. *Porites cylindrica* E. *Porites lobata* F. *Pocillopora verrucosa* G. *Leptastrea purpurea* H. *Turbinaria mesenterina* I. *Porites rus* J. *Cyphastrea serailia* K. *Pocillopora damicornis* L. *Hydnophora microconos*

Growth and Survival: A total of 2,327 fragments were attached to 59 ropes within five nursery areas at Dhigu and Kihavah. Most (96%) were still alive after four months. A small number (3%) had fallen off of the ropes and 1% died. A total of 1573 fragments were attached to 18 tables at size sites in Dhigu and Kihavah. These showed a mean survival of 87%, with 199 fragments dying between October 2016 and March 2017. All of the tables showed very high survival except for two tables at Kuta Giri and two at Veli Fore Reef, with losses attributed to snail predation and overgrowth by tunicates and algae.

All of the branching and tabular species of *Acropora* showed very rapid growth rates, with fragments increasing 2-5 fold over three months. Digitate acroporids and some of the thicker branched species grew more slowly, but they still increased substantially. The other taxa of corals fused to the ropes/cable ties and show some growth, but these corals tend to grow only a few cm per year.

Fig. 4. Two different species of *Acropora* at Plates nursery photographed in November 2016 and again in February 2017. *Acropora millepora* (left) and *A. formosa* (right). All corals at Plates nursery were small recruits and juveniles, 1-3 cm in length, attached to rubble that were salvaged from a sand extraction area.

Maintenance and Monitoring: Thorough maintenance was undertaken at all other sites which involved cleaning off accumulated sediment, removal of algae and cyanobacteria from attached to ropes and tables using a scrub brush, wire brush and toothbrush, removal of coral-eating snails from corals (at two sites), and removal of tunicates and sponges from tables (at three sites). Coral growth and survival was measured at all sites and fragments were photo-documented. All dead fragments were removed. One nursery (Marina/Naladhu) was abandoned in March 2017 after a severe storm overturned and broke all of the tables and an abnormally high prevalence of coral-eating snails continues to plague the site.

Fig. 5. Coral Reef CPR scientist, Georgia Coward removing encrusting and filamentous algae from the ropes at AKH House Reef using a wire brush.

Coral Loss: Loss of all corals established in August 2016 at one nursery on a fore reef location off Marina/Naladhu due to severe weather in February 2017. The unusually strong waves overturned, shattered and removed the coral nursery tables, and also caused massive damage to surrounding reef. Large boulder 2-3 m diameter were fractured and overturned and the bottom was covered with rubble. Similar extreme wave action has not been observed at this site since 2010.

Fig. 6. Overturned table without mesh (left) and a shattered boulder coral (right) at Marina Nursery Area

Assistance and Limitations: The local marine biologist at Kihavah has routinely cleaned the ropes and tables, removing sediment, algae and encrusting invertebrates. At Dhigu, no maintenance was undertaken at any of the sites between visits by Coral Reef CPR Scientists. While the dive staff all noted that the nursery tables had been overturned by storm waves at two outer sites, no effort was made to turn the frames back over. Several of the nursery areas were being affected by coral-eating snails (*Drupella*) and overgrowth by tunicates, cyanobacteria and filamentous algae.

A total of 26 fragments attached to tables were infested with 133 snails, and numerous adjacent fragments had been eaten. The snails negatively affect the survival of the fragments, and this could be avoided if the ropes and corals were inspected every few weeks and cleaned.

Nearshore areas on South Malé Atoll also had crown of thorns starfish, including juveniles that were moving into shallow sandy and rubble areas close to the resort. Without removal these have the potential to damage coral nurseries and are posing a risk to guests that swim and wade in the lagoon. Coral Reef CPR collected 16 starfish from shallow areas off Marina, Naladhu, Dhigu and Veli during March 2017.

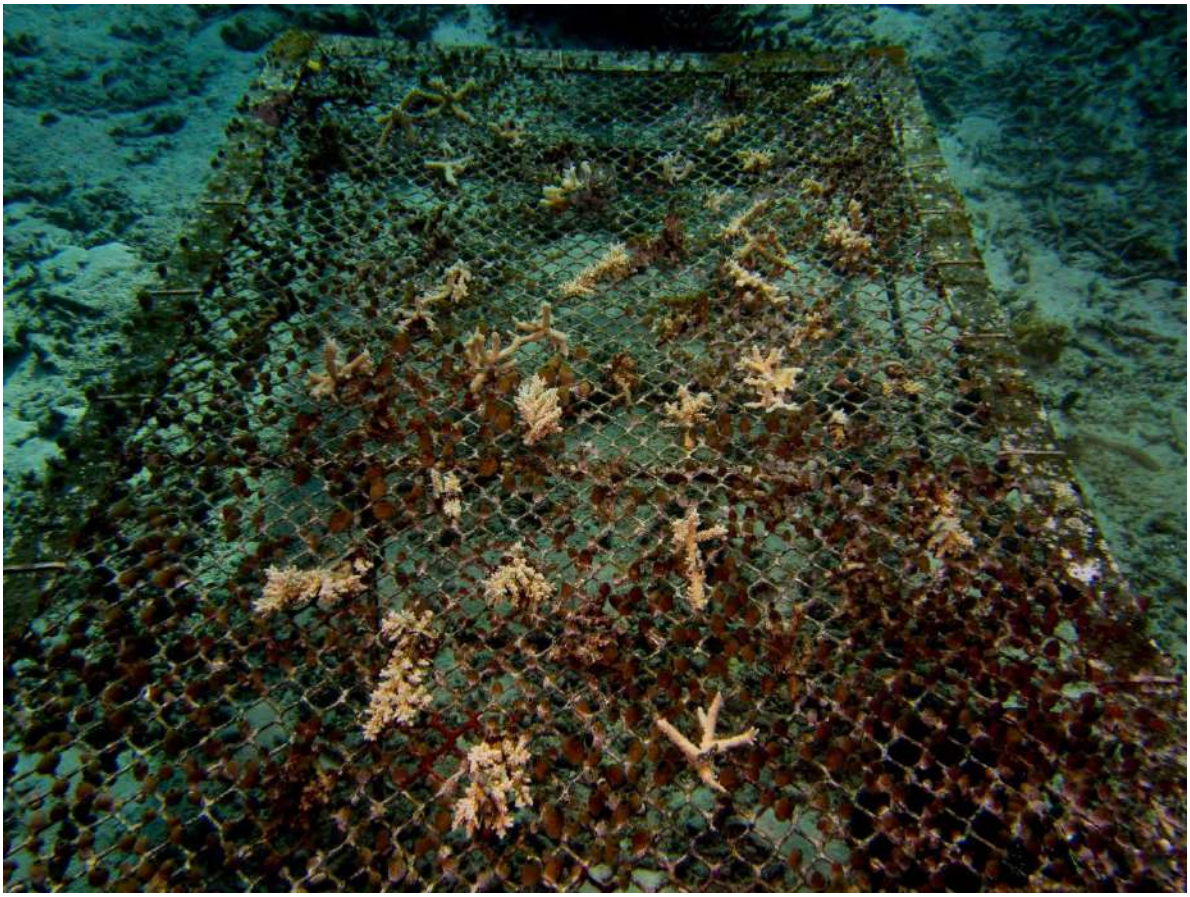

Fig. 7. A coral table at Kuda Giri covered in tunicates.

Methods

Coral nursery areas included 6 original sites at Dhigu and 2 original sites at Kihavah with one new site established on each atoll in March 2017. One site (Marina) was abandoned in March 2017.

Fig. 8. Coral nurseries at Dhigu. 1. Veli Water Villas (WV), 2. Dhigu House Reef (HR), 3. Kuda Giri, 4. Veli Fore Reef (FR), 5. Marina (abandoned), 6. Dhigu Advanced Snorkel Area (Adv Sn), 7. Aquabar (new in March 2017).

Fig.9. Coral nurseries at Kihavah. 1. Plates, 2. AKH House Reef, 3. SEA restaurant.

All corals were sourced from locations and colonies that would have died if left on site. This included sand extraction sites, colonies being eaten by crown of thorns starfish and coral eating snails, corals with disease, and broken, detached fragments that were being buried by sand, deposited at the base of the reef or were rolling around on the bottom. Corals were transported from the collection site to the nursery area in buckets kept submerged in the water. Coral fragments were cut into small branches (2-8 cm) with coral clippers and attached to ropes/plastic mesh with cable ties

Fig. 10. Sand extraction site where corals were sourced for nurseries (left) and a close-up of a coral attached to rubble at the sand mining site (right).

For all new ropes that were established in February/March 2017 at Veli, Dhigu deep snorkel area, Plates and SEA, fragments were brought to shore for use in coral gardening demonstrations. Visitors at both resorts were shown how to attach the corals and they had the opportunity to make coral ropes. After completing the ropes, they were immediately transported to the nursery site. The additional handling time and aerial exposure was expected to stress the corals to some extent, and some mortality is expected, but efforts were made to keep the corals underwater in buckets. All new ropes were attached to metal "staples" inserted into the sand and suspended 1-2 m off the seafloor.

Tables and ropes must be cleaned every two-four weeks to ensure coral survival. Cleaning involves shaking the ropes to dislodge sediment, carefully searching each fragment for snails and removing the snails, removing any fragments that become infected with disease, detaching algae and encrusting invertebrates from fragments, and removing sediment and invertebrates from the ropes and mesh with a toothbrush and scrub brush. When brushing the table, care must be taken to avoid abrading the coral.

Survival of coral fragments

Table 1. Rates of survival of coral fragments attached to ropes

Site	No. frames	No. ropes	No. corals/rope	Live	Dead	Missing	Survival
Dhigu HR	3	15	30-41	529	1	5	99%
Veli WV	1	4	6-39	141	2	6	95%
Adv Sn	5	7	28-37	231	3	2	98%
Plates	5	13	38-49	556	1	24	96%
AKH House	5	20	31-50	771	14	41	93%
Total	19	59		2228	21	78	96%

Table 2. Rates of survival of coral fragments attached to mesh tables

Site	No. tables	No. corals/table	Live	Dead	Missing	Survival
Dhigu HR	4	93-102	390	24	0	94%
Veli FR	4	58-71	208	58	0	78%
Veli WV	2	50-100	132	18	0	88%
Adv Sn	2	107-113	220	1	0	99.5%
Kuda Giri	4	58-94	198	96	0	67%
Plates	2	107-112	219	2	6	96%
Total	18		1367	199	6	87%

Coral fragments secured to ropes in October 2016 exhibited 96% survival after 5 months, with <1% of the fragments dying and 3% that fell off the ropes and were lost. Coral fragments attached to tables exhibited a lower mean survival (87%) with a higher proportion of the fragments dying (12.6%) and very low numbers of lost fragments.

Mortality on the tables was observed primarily at Veli fore reef and Kuda Giri.

At Veli fore reef, fragment death was attributed to a high incidence of snail (*Drupella*) predation and the overturning of two of the four tables due to an unusual period of high wave exposure in February. If routine maintenance was conducted at the site, the snails could have been removed preventing loss and partial mortality to the fragments. Furthermore, the tables should have been flipped back over after the storm, instead of being left upside down for close to a month (until Coral Reef CPR scientists arrived).

At Kuda Giri, two of the shallow tables established in August were heavily colonized by an encrusting tunicate which settled on the mesh and coral fragments. No maintenance was conducted at this site following the visit by Coral Reef CPR scientists in October. During March, Coral Reef CPR removed all of the tunicates using a toothbrush on the coral fragments and a scrub brush on the mesh tables. The two tables were also relocated slightly deeper (7 m) to try to reduce the settlement of these pest species. With regular

cleaning of the tables, additional loss due to overgrowth by algae, cyanobacteria and encrusting invertebrates could be avoided.

At Veli water villas the mesh on one of the tables was detached from the table and all the cable ties were broken due to a snorkeler standing on the table. The mesh was reattached and the table was relocated slightly deeper.

Expansion of Nursery Areas

During the February/March 2017 HARP visit, Coral Reef CPR established two new coral nursery areas and added nine additional ropes to three existing nurseries.

Table 3. Number of ropes and coral fragments added to coral nurseries on South Malé Atoll and Baa Atoll.

Location	Site	No ropes	No corals
BAA	SEA	5	293
South Malé	Aquabar	20	1312
South Malé	Veli WV	2	109
South Malé	Adv Sn	5	144
BAA	Plates	2	56
	Total	34	1914

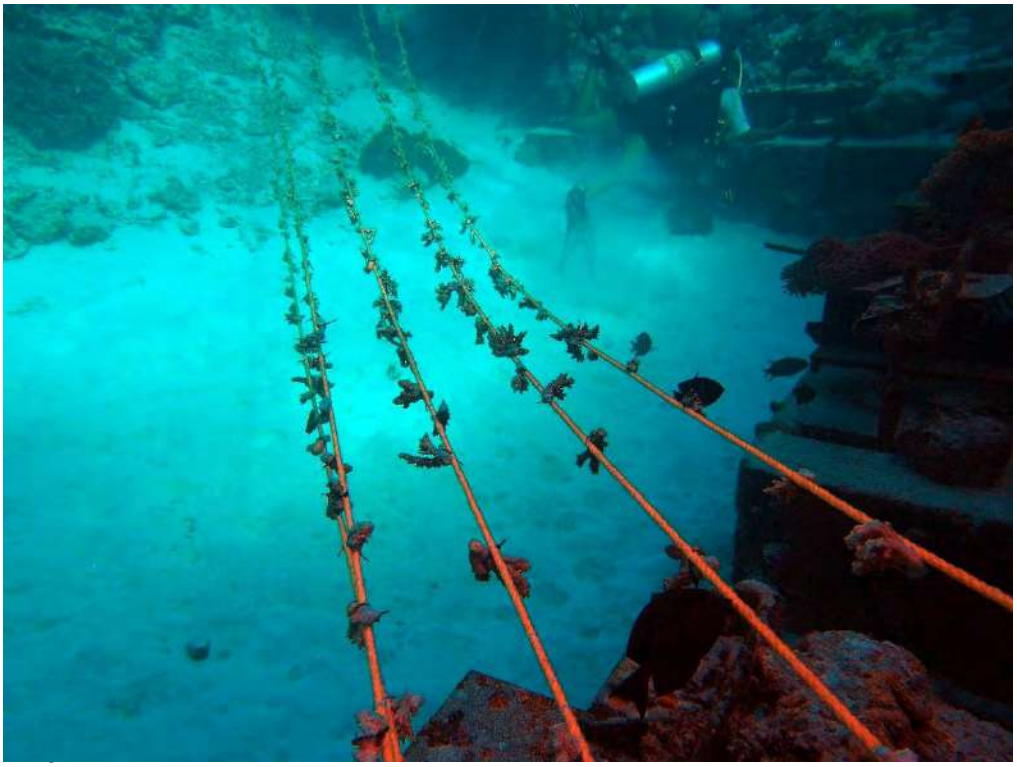

Fig. 11. Coral nursery at SEA restaurant.

Education

Coral Reef CPR presented two educational seminars to guests at Kihavah and two at Dhigu, reaching a total of 32 guests. We also set up an educational display at the weekly cocktail reception with videos and live specimens, reaching 48 families. Guests also learned about our coral gardening efforts and worked with Coral Reef CPR to make coral nursery ropes, attaching fragments to the new ropes placed at SEA, Plates, veli water villas and advanced snorkel area off the Dhigu water villas. A total of 17 families/couples participated in the coral nursery efforts. They had extremely positive feedback, with several stating it was the highlight of their trip.

Fig. 12. A family assisting Coral Reef CPR scientists in attaching coral fragments to a rope at Kihavah.

Coral Reef CPR participated in an educational day with a new school from Malé City. We presented a seminar on the importance of their coral reefs, their threats and how we can conserve them for the future generations. Students then attached coral fragments to a new, 10m coral rope which was later placed at Veli water villas.

Fig. 13. High school students from Kalaafaanu School, Malé participating in a coral reef workshop. The students and teachers attached coral fragments to a rope that was deployed at Veli water villas.

Recommendations

- Regular (fortnightly) maintenance is required on each of the nursery areas between Coral Reef CPR visits. Ropes, fragments and mesh can all easily be cleaned using a toothbrush. A larger brush can be used to scrub the mesh (avoiding contact with fragments) on the tables. This will remove all algae, sponges, tunicates etc. and will increase survival and growth rates hugely.
- Continued guest involvement between Coral Reef CPR visits to raise awareness on coral reefs conservation, the nurseries and the HARP program is required.
- Coral Reef CPR scientists will conduct another thorough clean and maintenance effort in July, replacing any dead fragments and continuing to expand the nurseries. Coral reef CPR will continue to remove COTS and coral-eating snails.
- Routine snorkel surveys should be undertaken around Marina, in the reef flat between Marina and Naladhu, near the Advanced Snorkel Area and around the water villas at Veli to search for and remove crown of thorns starfish. Their common occurrence and small individual sizes of starfish noted during the March 2017 period indicates 1) a new generation of starfish is emerging from the shallow rubble areas surrounding the resort; 2) starfish are moving through the area in search of food and may come into very shallow areas off the shore, causing a potential guest injury; and 3) there is the potential for a secondary outbreak, as the starfish we are frequently seeing are between 6 months- 2 years old. Diligent efforts to control the starfish now are critical to ensure recovery of the reefs damaged by the 2016 bleaching event.
- Efforts to eradicate starfish from Stage Reef should be undertaken, as we observed over 75 starfish in this area during March.

Fig. 14. A juvenile COTS, 25 mm diameter, collected at Veli Water Villas (left) and a sub-adult (14 cm) at Marina jetty.

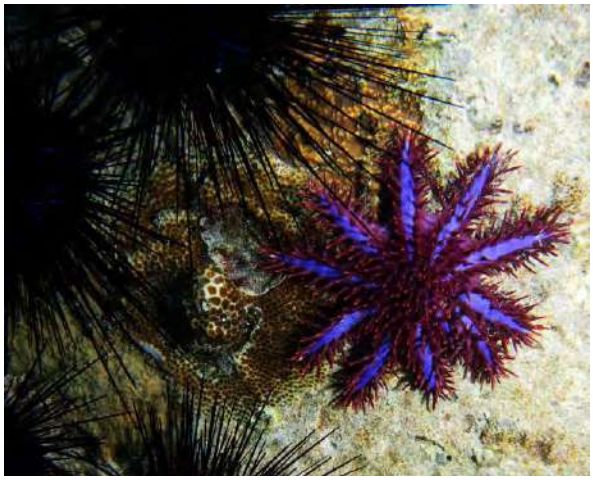

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Fig. 15. The Marine Biologist at Anantara Kihavah, Talya Davidoff (right) with Coral Reef CPR scientists on the last day of the HARP mission.

Fig. 16. Paula Berenguer, one of the Marine Biologists at Anantara Dhigu removing COTS from Stage Reef in August, 2016. This reef is currently infested with COTS and the few acroporids, *Pocillopora, Porites* and *Goniastrea* that survived the 2016 bleaching event are being quickly killed by the starfish. Additional efforts to control COTS are key to saving these reefs.