Holistic Approach to Reef Protection (HARP)

Establishment of Coral Nurseries

at Dhigu (South Malé Atoll), Maldives

Field Report

October/November 2016

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HARP
HOLISTIC APPROACH TO REEF PROTECTION

ANANTARA
HOTELS · RESORTS · SPAS

CORAL REEF CPR
CONSERVATION · PROTECTION · RESTORATION

AQUAFANATICS

Executive Summary

Coral Reef CPR team members (Dr Andrew Bruckner and Georgia Coward) and two volunteers from the Mai Khao Marine Turtle Foundation (Katie Bimson and Tipwimon Rattanawongwan) completed the next phase of the HARP Program. Efforts included 1) monitoring of coral survival within existing nurseries and maintenance to remove dead fragments, algae, snails and encrusting invertebrates; 2) removal of crown of thorns starfish; 3) assessment of densities of coral eating snails and partial removal from three locations; 4) quantification of coral survival and damselfish populations in Veli Lagoon; 5) expansion of coral nurseries at four sites; and 6) creation of one new coral nursery.

A total of 977 fragments attached to 10 tables (at five sites) and three ropes (at one site) in August, 2016 were assessed in November, 2016. These exhibited a mean survival of 80%, with Dhigu House Reef showing highest survival overall (97%). The fragments attached showed considerable amounts of new growth in the first two months, overgrowing the plastic cable ties and developing new branches. Mortality was due primarily to predation by coral-eating snails. Overgrowth by encrusting invertebrates was noted at Kuda Giri, while several ropes at Veli Lagoon were unknowingly placed in water that was too shallow and fragments were exposed to air during low tide. The highest number of coral-eating snails were observed on tables at Marina/Naladhu, followed by Veli Lagoon and Veli Channel Reef. Mortality could have been reduced if routine (weekly to bi-monthly) maintenance of the nurseries was undertaken.

Maintenance at nursery sites completed in November, 2016 included 1) collection and removal of crown of thorns starfish (COTS) and *Drupella* gastropods from the surrounding habitat; 2) removal of coral-eating *Drupella* snails; 3) cleaning and detachment of sessile organisms (algae, mussels, tunicates and sponges) from fragments; 3) cleaning of sediment from tables (primarily at Dhigu House Reef); and 4) removal of dead fragments from tables and ropes. A total of 37 COTS were removed from Veli Channel Reef; COTS were not seen anywhere else. Snails (1,070) were removed from 47 corals at the five nursery sites.

Nurseries were increased in size at four of the five locations. Two additional tables, each with approximately 100 fragments, were placed at each of the outer sites. One new rope nursery with three ropes and 119 fragments was installed at Veli Lagoon. Three rope nurseries, each with five ropes and a total of 750 fragments were installed at Dhigu House Reef. A new site, the Advanced Snorkel Area adjacent to the Dhigu Water Villas was also established. This site now has two tables (200 fragments) and five rope nurseries, with a total of 11 ropes and approximately 550 fragments. Multiple species of *Acropora* were placed at each nursery site, along with ropes containing *Pocillopora* and *Porites* at Dhigu House Reef.

Acknowledgements

The HARP Program relies on the donations provided by the guests through Dollars for Deeds and the matching funding provided by Minor Hotel Group. Coral Reef CPR scientists that participated in the project to date are unpaid volunteers and have been assisted by two volunteers from the turtle foundation.

Implementation of HARP would not be possible without the assistance of the staff from Anantara Dhigu and Veli Resorts. We are especially grateful for the dedicated efforts of the engineering department. They obtained all the necessary supplies, painstakingly welded together tables and "staples" for use in the coral nurseries, and assisted in deploying the materials to the nurseries.

Fig. 1. Engineering Department staff

Mohamed Yamany assisted with logistics, helped with organization and attendance at the first Maldives Marine Science Symposium, and provided us with field assistance in removing snails.

Fig. 2. (Left) Mr Yamany Mohamed, Training Director and our volunteers at the Marine Science Symposium. (Right) Members in the Explorers Training Program helping us to remove coral-eating snails from the lagoon at Veli Resort.

Rizan Afeef was instrumental in ensuring we had logistical and boat support and helped organize many other aspects of the HARP Program. Special thanks to Coetzer Deysel for supporting the HARP Program through Dollars for Deeds, providing lodging and meals and engaging staff and visitors through Guest Cocktail Hours, seminars and meetings. Gaudéric Harang gained direct experience in coral gardening, assisting in the field with the set-up of a coral nursery, and assisting with logistical aspects. We are grateful for the support provided by Aiman Mohamed. Special thanks to the Marina Dive Centre Manager, Mohamed and all his crew for their field assistance in deploying the hardware and helping install the angle iron staples into the substrate. Silver Sands also was instrumental in providing SCUBA support for the project.

Introduction

In response to the catastrophic losses of corals on reefs surrounding Anantara Dhigu and Veli, and the complete mortality of the "*adopt a coral*" rebar frames in lagoonal habitats near the resort, Coral Reef CPR initiated a coral gardening initiative as part of the Holistic Approach to Reef Protection (HARP) Program. This effort consists of several phases, beginning with the establishment of coral nurseries in different habitats near the resort, progressive expansion of the coral nurseries, and the subsequent transplantation of the corals onto degraded reefs. Over subsequent visits, the nurseries will be expanded into new areas, enlarged, and additional species will be added. The intent is to begin outplanting corals onto reefs within 18 months, while continuing to propagate the corals within the nurseries. It is expected to become self-sustaining, with no additional need to supplement with new coral fragments from reefs as small clippings can be taken from the nursery-grown corals to produce 2nd, 3rd, 4th and future generations. The nurseries will, however continue to require routine maintenance to clean the ropes/tables and remove algae, colonizing invertebrates and coral predators.

The project introduces two novel coral mariculture techniques to the Maldives, growing of corals on plastic mesh-covered tables and on ropes suspended in the water column. A third design, floating PVC "trees" will be introduced in 2017. We use these techniques for two main reasons, 1) these are designed to avoid some of the problems associated with the metal rebar frames (listed below) and 2) because our ultimate goal is different to these frames; to grow corals to transplant for reef restoration.

1 Metal frames have a limited lifespan as they eventually rust once the epoxy/sand coating wears away. For both the ropes and plastic mesh tables, the corals are only in contact with the plastic/nylon and coral readily overgrows plastic.
2 It is not possible to remove the corals from the frames once the fragments have fused and grown into larger colonies. Corals can be easily removed from both the ropes and plastic mesh without injury for reef transplantation.
3 Metal frames are placed on the substrate, close to the bottom, allowing potential burial, smothering, and easy access by coral eating starfish (crown of thorns starfish, *Acanthaster*) and snails, *Drupella*). The ropes are easier to clean than the metal frames and snails/starfish cannot climb onto them.

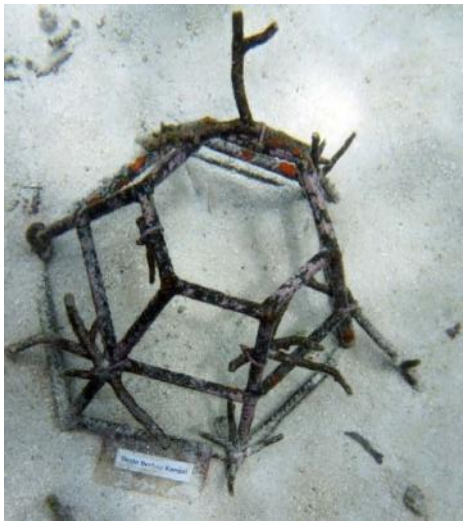

Fig. 3. Example of a metal frame deployed at Veli Lagoon in October 2016. All of the small fragments died, the frame is rusting and it is being buried by sediment.

Because of the widespread devastation from the 2016 El Niño, all coral nursery projects are being undertaken in a manner that does not disturb remaining attached adult colonies. The dominant type of coral, *Acropora* (staghorn, digitate and tabular growth forms) sustained 80-95% mortality throughout the Maldives, with small pockets remaining in certain bleaching refuges. The remaining corals must not be disturbed, as these are critical brood stock essential to rebuild and restore the reef systems. When growing these (and other) corals, extreme care must be taken not to damage source reefs. Coral Reef CPR addresses this in three ways:

1. A major source of corals used in our nurseries are broken fragments that have been detached from adult colonies by human (snorkeler/diver) contact, waves and currents and bioerosion. These are collected from the reef slope and sandy bottoms and are likely to die if left in place, as they are unattached, often partially buried, and are one of the main targets of coral-eating snails
2. Coral fragments are removed from colonies with disease (white syndrome) and with high densities of coral eating snails, as these will otherwise die
3. Corals are collected from areas with ongoing development projects such as dredging sites, channel excavation, sand extraction and reclamation and nearshore areas in vicinity of filling, shoreline expansion and land reclamation.

Fig. 4. A group of broken corals that accumulated on a rubble/sand slope. Several of these are starting to die, but were salvaged for use in one of our nurseries.

One of the consequences of this approach is that the corals used in the nurseries are already stressed and may have areas of partial mortality, and a portion of these are expected to die. However, this is minimized by removing all coral eating snails and diseased tissue from the fragment before introducing into the nursery. Furthermore, corals are never removed from the water. They are transported in buckets of seawater, either underwater using lift bags, or on boats containing large plastic buckets filled with

seawater. They are immediately brought to the nursery site, fragmented and attached to the ropes or mesh with cable ties.

The corals are likely to exhibit superior survival to future temperature perturbations, as they are fragments that survived the 2016 bleaching event and either did not bleach, or bleached and produced fluorescent pigments that shielded them from damaging ultraviolet radiation.

Whenever possible, we attempt to place the corals in nurseries that are at the same depth as the source of the colonies using fragments from similar habitats/environments. In several locations this was not possible, as the only sources of fragments were on the deeper part of the reef slope and at the base of the reef. We expect many of these to bleach, however most should recover as the nurseries were initially established during cool water periods. Even by transplanting fragments from between similar depths, we have observed bleaching because they are moved from dark, algal covered substrates to white sandy areas where there is much more reflection of light. Severe bleaching is caused by the combination of higher water temperatures and higher than normal UV radiation, while corals can also bleach when exposed to a sudden increase in light (or temperature).

Dhigu Nurseries

We initially established small nurseries in five locations in July/August: Veli Channel Reef, Marina/Naladhu outer reef, Dhigu House Reef, Kuda Giri, and Veli lagoon (near the water villas).

Fig. 5. Locations of coral nurseries. Site 1-5 were established in August and site 6 was added in November 2016.

In locations 2-4, we placed two tables and attached 90-100 corals to each table. In Veli Lagoon (site 1), we were unable to find many broken fragments as this reef sustained 99.8% mortality. Thus, two tables

with 113 and 67 fragments, and an additional three short ropes, each with 14-18 fragments were established in July. The survivorship of the fragments was assessed in November (Table 1). All dead fragments were removed and survivors were carefully searched for coral eating snails.

Site Name	Tag #	Live	Dead	Total Fragments	% Live
Veli Lagoon	T232	104	9	113	92.04
Veli Lagoon	R217	12	2	14	85.71
Veli Lagoon	T221	26	41	67	38.81
Veli Lagoon	R208	6	10*	16	37.50
Veli Lagoon	R250	13	5*	18	72.22
		161	**52**	**228**	
Kuda Giri	T210	72	26	98	73.47
Kuda Giri	T207	97	20	117	82.91
		169	**46**	**215**	
Dhigu House Reef	T226	95	5	100	95
Dhigu House Reef	T230	98	1	99	98.99
		193	**6**	**199**	
Veli Channel Reef	T202	70	32	102	68.63
Veli Channel Reef	T246	85	5	90	94.44
		155	**37**	**192**	
Marina	no tag	49	23	72	68.06
Marina	no tag	53	18	71	74.65
		102	**41**	**143**	
All sites		**780**	**182**	**977**	**79.84**

Table 1. Numbers of coral fragments placed in each nursery and their survival. Fifteen fragments in Veli Lagoon, attached to ropes (see asterisk), died due to aerial exposure during spring tides.

During October/November, we added two additional tables to the nurseries at Dhigu House Reef, Veli Channel Reef, and Kuda Giri. We also set up a single rope nursery at Veli lagoon with three ropes suspended between two metal frames, and three sets of ropes at Dhigu House Reef, each with five ropes. We established a new nursery at the Advanced Snorkel Area off the water villas on Dhigu (site 6; Fig.). This site contains five rope nurseries, each with five ropes, and two tables. Each of the ropes is 5 m long and contains 30-40 coral fragments, and the new tables each contain approximately 100 fragments.

1. Veli Lagoon

This reef was dominated by a single species of staghorn coral, with extensive thickets surrounding the water villas on both sides and coral extending into the lagoon near the pontoon channel. The area is shallow and coral colonies were 20-160 cm tall, extending to the water's surface.

Fig. 6. Aerial shot showing the existing location of the (dead) staghorn coral patches at Veli Lagoon (dark blotches within the sand) and locations of our coral nurseries and remaining live coral. A rope and table are located next to the jetty (1). Another table set up in August (2) and three ropes established in November (3) are in a deeper part of the lagoon. Eight damselfish territories, each with living staghorn coral are located near 4.

Most of the coral (>99.8%) died during the bleaching event. Two small patches (5 m X 1 m diameter) of surviving branches were found under the water villas. These consisted of scattered 5-20 cm branches intermixed among dead coral skeletons. There were also a few isolated branches at the perimeter of the stands that were fully bleached but live. In both patches, and on the perimeter, there were high numbers of coral-eating snails aggregated on living tissue. The colonies had notable tissue-denuded white skeletal areas. There were also 12 small colonies (5-25 cm diameter/height, with corals having 1-5 branches) located at the perimeter, spread over an area of about 100 m. These were the only healthy, fully pigmented corals remaining in the population. Each of these was located within a damselfish territory.

Fig. 7. The only remaining healthy staghorn coral at Veli Lagoon is found within damselfish territories. We strongly recommend that these colonies are not used for "adopt a coral" frames, as they are critical to the recovery of this site.

Fig. 8. The coral in Veli Lagoon provides a critical nursery habitat that supports over 150 species of reef fishes. The dead colonies are still largely intact, and provide habitat for many of these fish, but as they break down this role will diminish. There is also a few fish that are only found within live stands of this coral, such as the coral goby (right). This fish was once common here, but only a single remaining individual (pictured here) was found in November.

Using staff, volunteers and members of Anantara's Explorers Program, we removed all of the coral eating snails we could find during August. Small branches were clipped from the ends of colonies located within the two patches, equivalent to about 50% of the remaining colonies. These were fragmented into 2-8 cm branches, and attached to two tables and short ropes suspended between the pilings of the water villas in July.

Fig. 9. Anantara's Explorer Program members are helping improve the health of the Veli Lagoon by removing damaging coral-eating snails.

In November, we carefully searched the area for additional snails, removing an additional 44 snails from two of the small patches of staghorn coral, one of the "adopt a coral" frames deployed in October 2016, and two tables. Survivorship and growth of fragments attached to ropes and tables was assessed. The rope and table placed near the pontoon dock exhibited very high survival (>90%), although several colonies were being consumed by coral eating snails. The second table had over 12 snails actively preying on fragments and 62% and many corals (62%) had already been eaten. All of the corals placed on ropes that remained submerged survived and were actively growing, while 15 coral fragments exposed to the air during low tide died.

Fig. 10. One of the branches attached to a metal "adopt a coral" frame in Veli Lagoon in October 2016. The coral bleached and was being attached by *Drupella* snails. Also note the rust on the frame. We removed these snails.

Fig. 11. The coral table at Veli Lagoon near the pontoon dock showing very high survivorship.

Fig 12. Close-up of a fragment attached to a rope in August 2016. This fragment has already produced 12 new branches.

One new rope nursery at 2 m depth was established in November. It had three lines, each five meters in length, with 38-41 very small (2-8 cm) fragments (total=119) attached to them.

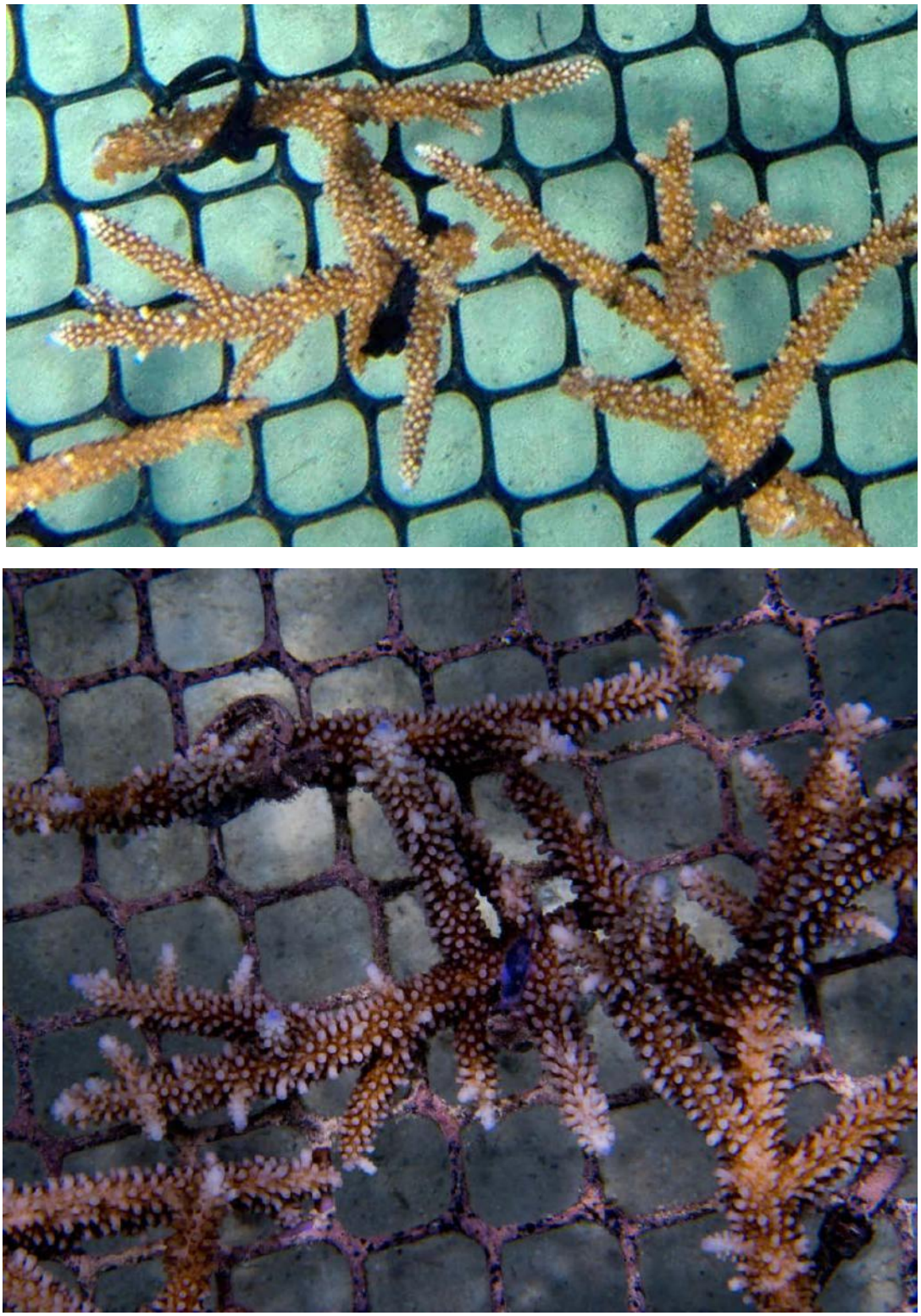

Fig. 13. Several coral branches attached to mesh tables at Veli Lagoon. The top image shows the original fragments in August and the bottom is the same corals with considerable new growth (dozens of small, white branches) and darker pigmentation.

2. Dhigu House Reef

This is a shallow protected location within the lagoon that provided a refuge from the 2016 bleaching event. Mortality of less than 30% of the colonies was recorded. Notably, a lot of the branching and digitate acroporids survived. We attribute higher survival to the unusually murky conditions found here, reducing the penetration of damaging UV radiation. This area is ideal for coral nurseries because of the shallow depths, extensive sand habitats and calm conditions.

Fragments at this reef showed the highest survival overall, with over 95% of the 200 fragments attached to the two tables remaining after two months.

Fig. 14. One of the tables at Dhigu House Reef two months after it was set up.

We added two additional tables (100 fragments each) and three rope nurseries, each with five sets of ropes and approximately 30 fragments. On one of the rope nurseries we included two additional taxa of corals (*Pocillopora*, *Porites*).

We also collected additional broken coral branches from this site for use at the Advanced Snorkel Area nursery.

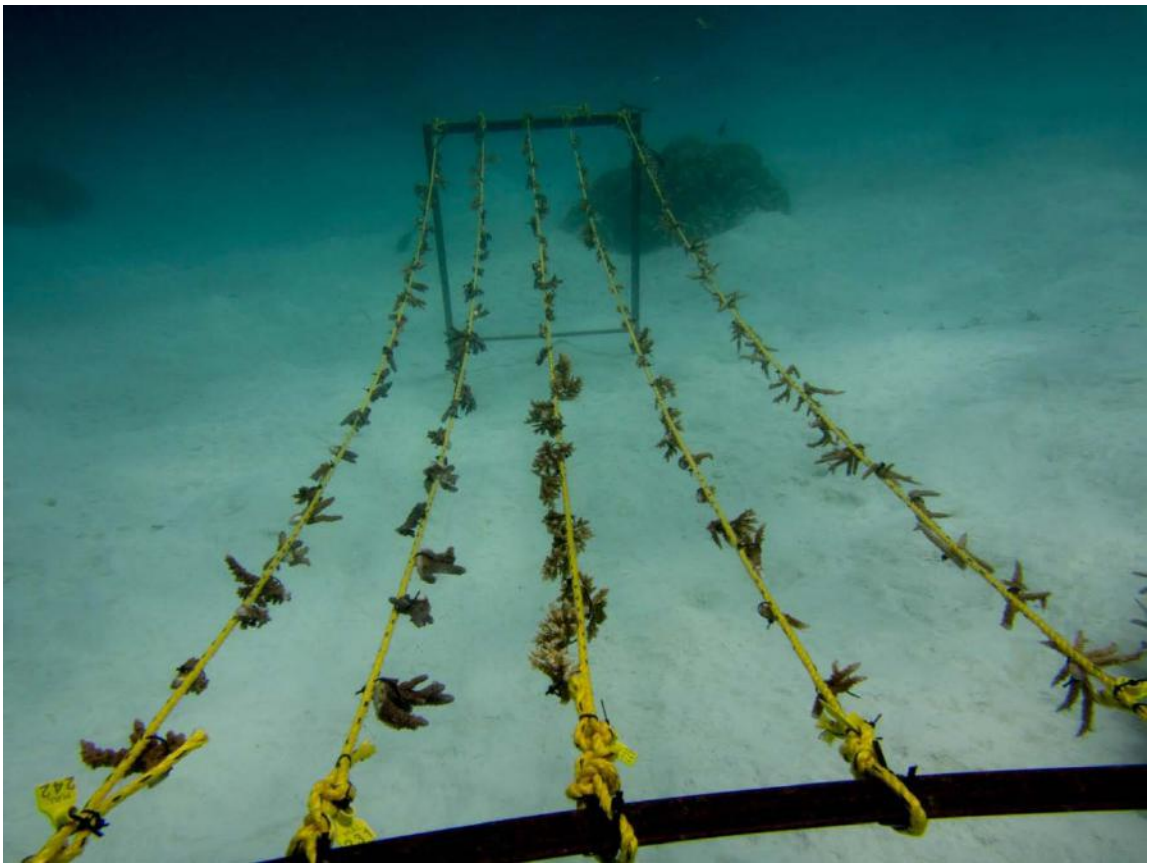

Fig. 15. One of the rope nurseries at Dhigu House Reef.

Fig. 16. Gaudéric Harang, Resident Manager at Anantara Dhigu assisted in attaching corals to the ropes at Dhigu House Reef.

3. Kuda Giri

Kuda Giri is a submerged patch reef located within the lagoon. The top of the reef has a relatively flat terrace, 2-3 m deep. This slopes steeply to 25+ m, forming a vertical wall with overhangs and small caves in some areas, and a sand slope in others. Bleaching impacts on this reef were slightly higher than Dhigu House Reef, but less than all other locations examined in South Malé. Numerous *Acropora* colonies remained on the reef slope, including high numbers of broken fragments.

Two tables established in July (4-5 m depth) exhibited 73-83% survival with mortality attributed to *Drupella* predation, bleaching, and overgrowth by encrusting sponges and tunicates. Fragments collected on the reef slope were transplanted to tables that were at a slightly shallower depth, in sand, increasing their exposure to light. As a result many of the fragments bleached, although most eventually regained their pigmentation as water temperatures cooled.

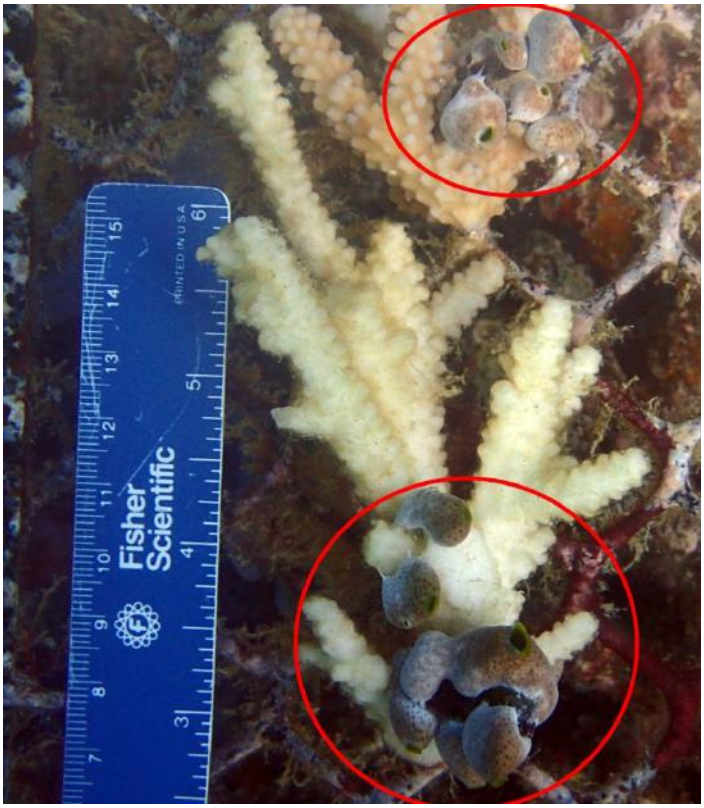

Fig. 17. Close-up of two branches of *Acropora* attached to tables in August. The lower branch recently died, while the upper branch is still living. Both are being overgrown by tunicates (red circles).

Two additional tables were established on this reef, located below the existing tables (6-7 m depth). Approximately 100 fragments, consisting of 7 species of *Acropora*, were attached to each table.

Fig. 18. Close-up of one of the tables established at Kuda Giri in October, 2016.

4. Veli Channel Reef

This reef has a shallow terrace, several hundred meters wide (1-5 m depth) and a reef slope extending to about 20 m depth. Below this depth the reef becomes sand. The majority of the corals in shallow water died. There was moderate survival on the reef slope, and high numbers of surviving broken fragments. The reef now has a moderate density of coral eating snails and a surviving population of crown of thorns starfish.

Transects at 5-10 m were completed to estimate the density of snails and the food preferences. Snails were identified on many of the surviving coral taxa including: *Acropora, Pocillopora, Porites, Montipora, Astreopora, Favites, Favia* and *Cyphastrea*. It was unusual to find them on *Porites*, as these boulder corals are not a preferred species of *Drupella*; instead, they usually support populations of *Coralliophila*, another type of coral-eating snail that tends to cause less damage.

Fig. 19. *Drupella* gastopods completely consumed a digitate acroporid colony and are now feeding on *Porites*.

Hydnophora, *Goniastrea*, *Platygyra*, *Galaxea* and *Leptoria* and also occurred within transects, but these were not infested with snails. Low numbers of crown of thorns starfish were also identified within the vicinity of the tables. A total of 37 COTS were removed.

The two tables established in July exhibited highly variable survivorship. Over 94% of the corals were still living on one table, while the other lost approximately 31% of the colonies and five colonies were being consumed by *Drupella* gastropods (which were removed).

Fig. 20. All corals used at Veli Channel Reef were detached, broken fragments and branches from colonies infested with coral eating snails. These were collected on the reef slope and transported to shallower depths to attach to nursery tables. To minimize stress, corals were transported in plastic boxes, and never removed from the water.

Two new tables were established on this reef at a shallower depth (5-6 m, on the reef terrace at the edge of the slope). Approximately 200 fragments were attached to the tables.

5. Marina/Naladhu

This reef is a fore reef community on the outside of the atoll directly off the islands of Marina and Naladhu. It has a shallow, 100-200m reef terrace that gently slopes from 2-8 m, leading to a steeper reef slope. The top was dominated by table corals intermixed with cauliflower coral and lower numbers of other species. The community on the reef slope contained a higher diversity of branching, table, encrusting and boulder corals. The majority of the coral died during the bleaching event and remaining corals were being rapidly consumed by coral eating snails.

Transects conducted at this site indicate a much higher prevalence of *Drupella* than all other nursery areas, and a much lower number of surviving corals than other sites (except for Veli Lagoon). Over 60% of the surviving corals located within 200 m^2 of the tables were infested by snails, with up to 250 snails on an individual colony. Most of the snails were found on *Pocillopora*, followed by *Porites*.

Two tables were placed at this site in August, each with approximately 70 fragments of branching and table acroporids. Fewer fragments were attached due to the rarity of the coral and very few surviving coral fragments on the reef slope and reef terrace. In November, these tables were covered with snails, and many fragments had been recently eaten; no maintenance had been done at this site since it was first established.

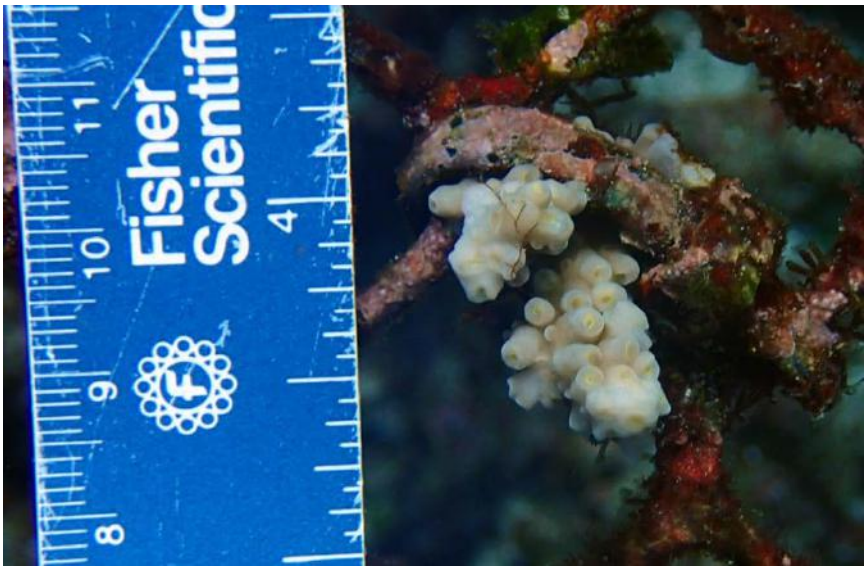

Fig. 21. Because there was so little coral remaining at Marina, we had to use much smaller fragments on our tables. Even though some fragments were only about two cm in length, they showed high survival unless they were eaten by snails or colonized by algae. The fragment here is healthy and showing new growth.

The tables lost 25 and 32% of the corals primarily due to snail predation, wioth additional stress from algal overgrowth. All dead fragments were removed and remaining fragments were carefully examined to identify and remove snails. Because so few *Acropora* remain on this reef, and the unsustainably high abundance of *Drupella*, no additional coral fragments were placed onto tables at this site. If conditions improve at this site, and the snail population is reduced, we will place additional fragments on the nursery tables at a later date.

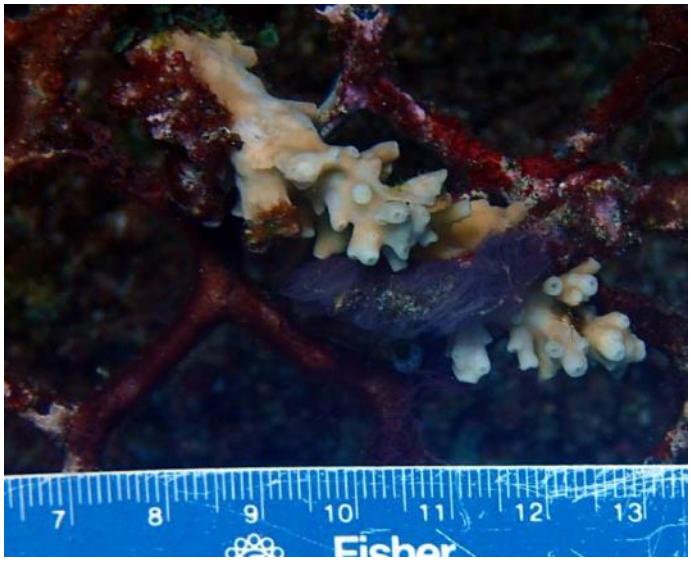

Fig. 22. The Marina nursery is the only area where nursery tables became completely encrusted with algae and cyanobacteria. This fragment has been partially overgrown by red algae and a thick filamentous mat of cyanobacteria overlies the fragment.

6. Advanced snorkel area

This is a deeper (3-4 m), natural "channel" within the lagoon, extending from the outermost villa toward the Aquabar. It is sand bottom with a few isolated large *Porites* bommies. A considerable amount of coral (mostly branching *Acropora*, the same species as in Veli Lagoon) was transplanted here several years ago but it sustained 100% mortality. There were small patches of surviving boulder corals (*Porites*).

Two coral tables and five rope nurseries, each with 2 ropes were installed at this site. Fragments were collected at Dhigu House Reef and transported in water in plastic buckets to the site.

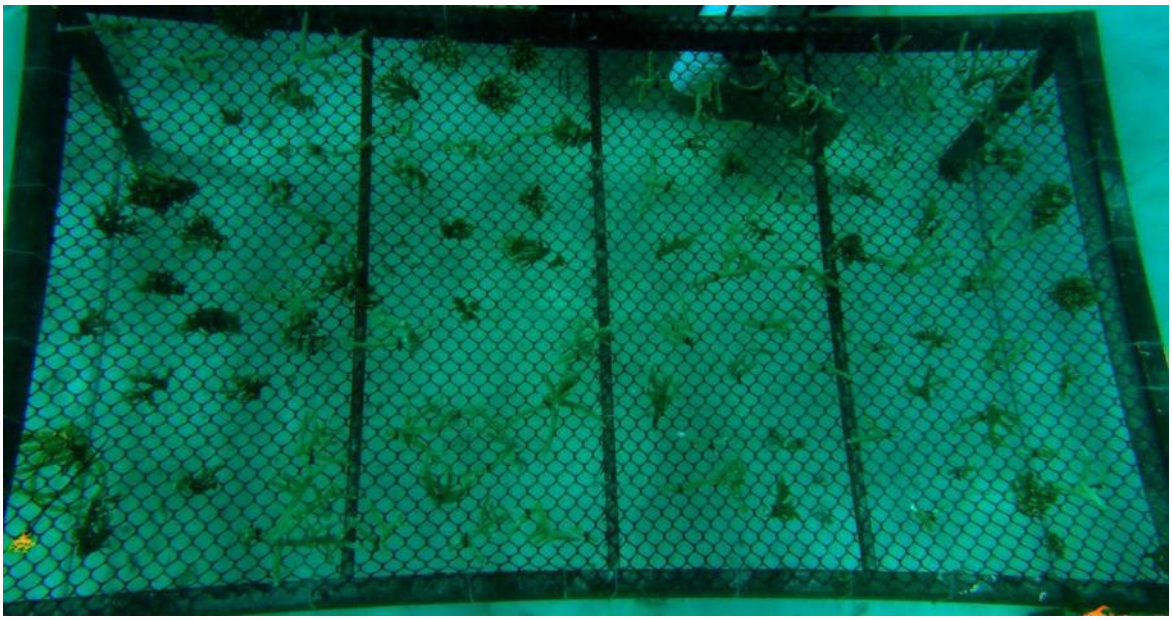

Fig. 23. One of the tables at the Advanced Snorkel Area.

Fig. 24. Rope nurseries at the Advanced Snorkel Area were placed in the vicinity of the dead staghorn coral colonies. The advantage of this is that any fragments that fall off the line are likely to land on coral skeletons and survive, whereas they would die if they landed on the sand.

Fig. 25. Close-up of the ropes with attached branches of staghorn coral.

Coral eating snails (*Drupella*)

The sizes of the *Drupella* removed from 47 corals were measured using calipers. These corals had 2-206 snails on each one (mean= 22.8, SD= 33.2). Snails found on massive corals were significantly larger than those found on branching corals, although branching corals exhibited a bimodal size structure (Fig. 25).

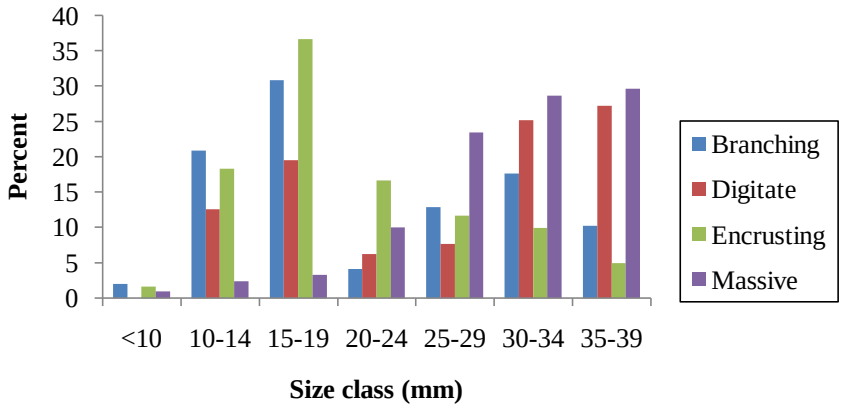

Fig. 26. Size structure of snails collected from the nursery areas at Dhigu.

Recommendations

- Regular maintenance (once/2 weeks) should be conducted at each nursery area to remove coral predators (COTS, *Drupella*) and excess sediment/algae by gently shaking rope, or mesh. This is a quick and straightforward procedure, but will have a huge impact on survivorship and growth of fragments. If more time permits, attached invertebrates, such as mussels and tunicates, should be carefully removed from fragments.
- Improved awareness raising to snorkeling and diving guests on appropriate in-water behavior, including not stepping on corals. It is critical that we do everything possible to protect these remaining corals as they will be vital in reseeding the reefs.
- Any new "*adopt a coral*" frames should only use broken coral fragments, with no collection of attached colonies as the few remaining corals are critical to the recovery of these reefs.
- Local and staff divers and snorkelers should organize routine COTS removal trips to eliminate the remaining population between our visits. The highest remaining numbers of the COTS are on Stage and Raaebundi.
- The dive operators should attempt to collect *Drupella* gastropods when they find infested corals. Snails could be collected from at least one coral while leading each dive trip - the dive instructor could point these out to the guest, remove them, and then show them to them after the dive and explain why they removed them.
- Guests could be offered the possibility to contribute to reef conservation during their dives and snorkel trips through collection of snails and/or COTS. Those that are interested in undertaking this could be easily trained to remove these animals in a safe way. To highlight their involvement, they could receive a simple certificate of recognition.
- Efforts should be made by staff to educate guests on the reef conservation initiatives Anantara is undertaking through the HARP Program, as this could help diminish negative feedback on the degraded state of many coral reefs, and it would provide an opportunity to explain the 2016 bleaching event and put it in context with losses experienced on reefs worldwide.