

HOLISTIC APPROACH TO REEF PROTECTION

CORAL NURSERIES at Anantara Kihavah and Anantara Dhigu

Field Report
July/August 2017



EXECUTIVE SUMMARY

Coral Reef CPR continued our Holistic Approach to Reef Protection (HARP) Program initiatives at Anantara Dhigu, South Malé Atoll and Anantara Kihavah Villas, Baa Atoll between July 16 – August 23, 2017. The project focused on the assessment and maintenance of coral nurseries established in October 2016 and February 2017, along with maintenance of the Aquabar Snorkel Trail, continued eradication of coral reef predators, expansion of coral nurseries, a pilot outplanting of nursery grown corals, and education. Rates of survival and growth were documented at all nursery sites, and a thorough cleaning of all ropes was undertaken to remove colonizing and competing algae and invertebrates. All of our rope nurseries have shown remarkable survival (>95%) and unprecedented growth.

New ropes were added to both nurseries at Kihavah (Plates and Jetty) and an additional nursery containing five ropes was installed at SEA. A new rope was also added at the advanced snorkel area off Dhigu water villas, and two additional frames with six ropes (three each) were installed at the nursery in Veli lagoon near the water villas. The nurseries now contain over 6,000 corals, all of which were initially established with coral fragments that were 2-5 cm in length.



Fig. 1. Attaching coral fragment to a nursery rope at Anantara Kihavah House Reef

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One rope within the Veli Coral Nursery with fragments attached in October 2016 showed unexpected dramatic growth: fragments increased in size from single 3-5 cm branches to 25-30 cm bushes. Due to the large size and substantial weight of these nursery-grown corals, the first outplanting was undertaken. These corals were transplanted to the coral

skeleton framework at Veli, adjacent to the nursery, in 2 m depth. We will assess their survival and subsequent propagation over time to determine best practices for future outplanting.

As a key part of the HARP Program, we continued our educational seminars and outreach efforts. A coral reef seminar and hands-on coral nursery demonstration was presented to a Malé high school during their visit to Anantara Dhigu. Several guest, staff and VIP/media presentations were also undertaken at Anantara Kihavah Villas.

Concerns and Recommendations

Coral reef pest species remain problematic on many Maldivian reefs. While recovery of certain badly damaged reefs has begun in many locations, unnaturally high numbers of coral eating snails (*Drupella*) are found on many fore reef locations and some lagoonal sites, especially off Marina and Veli (see Bruckner et al. 2017). An infestation of cushion starfish (*Culcita*) has also been noted throughout our survey sites in the Maldives, and densities of up to 1-3 starfish per square meter occur on many reefs. Both cause excessive damage to the small, newly settled and juvenile branching corals (*Pocillopora* and *Acropora*), and the snails are also feeding on the few remaining acroporid and pocilloporid colonies that survived the coral bleaching. Because of the high numbers of these predators and voracious feeding behaviors, they are likely to delay the recovery of these reefs unless simple steps are taken to control these pests. As part of our HARP activities, we removed several hundred snails from the reef surrounding SEA restaurant (Kihavah), Aquabar snorkel trail (Dhigu) and Veli fore reef. Cushion starfish (386) were also removed from the house reef at Kihavah.



Fig. 2. A fragment of *Acropora* from the Veli Fore Reef coral nursery that has almost been completely eaten by coral eating snails (*Drupella*). Three snails are visible on the left side. The only remaining live tissue is the brown patch on the top left.



Fig. 3. An outbreak of crown of thorns starfish is advancing along the fore reef between Veli and Dhigu House reef in an area that contains a high abundance of *Acropora* species that are rare elsewhere, due to the catastrophic mortality during the 2016 bleaching event. These starfish have also moved along Veli Fore reef and were seen feeding on the coral fragments remaining on the broken coral tables.

An outbreak of crown of thorns starfish was observed on the reef system between Veli and Dhigu House reef. This is alarming, as this reef was a refuge for many of the species of *Acropora* that died on all surrounding reefs during the 2016 bleaching event, including the only known remaining population of table acroporids in this area. The COTS are consuming the acroporids, along with Pocillopora, various plating coral species and the boulder corals (*Porites*) that form the framework of these reefs. They are progressing from the Veli side of the reef towards Dhigu, and once they consume all the coral on this reef they will invade Dhigu House reef and possibly move into the lagoon near the resort. It is critical that dive staff of Aquafanatics dedicate several dives to removing these starfish or the entire reef will be lost, and these starfish will move into guest areas and become a safety concern.



Fig. 4. A fragment of *Acropora* at Kuda Giri that attached to the plastic mesh and was showing extensive growth. A high number of tunicates settled on the mesh and corals, and are overgrowing the fragments. Losses from tunicates could be easily avoided if routine maintenance was undertaken at the nurseries.

Due to a lack of recommended maintenance of nurseries at Anantara Dhigu between Coral Reef CPR visits, we were forced to abandon one of the nurseries (Kuda Giri), as the coral tables were heavily infested with colonial tunicates and coral-eating snails, and these were smothering coral fragments and eating their tissue. The surviving corals were removed from the tables and planted on the reef, and the tables were removed from the reef and discarded. While we are fortunate that other nurseries have exhibited much less colonization and overgrowth by other organisms, the absence of routine maintenance of nurseries between our visits present the largest limitation to the success of the coral gardening initiatives. One option is to hire a team (2) of Maldivian divers to conduct routine maintenance. The requirements of the divers are minimal, and Coral Reef CPR could conduct all training necessary. A second alternative is to support an intern program, whereby a team (2) of foreign students are recruited to assist with the project. They would stay on site in staff accommodations and could work full time on the project, with emphasis on monitoring and maintenance of the nurseries and corals that are outplanted onto the reefs.

Introduction

Coral reefs worldwide are undergoing a global crisis due to human and natural stressors. Between 2014-2016, coral reefs worldwide experienced periods of unprecedented high water temperatures which led to mass coral bleaching. This global event affected 70% of **the world's reefs and resulted in very high mortality in most locations**. Throughout the Maldives, water temperatures exceeded their normal maximum between March-June **2016, and severe bleaching was documented from just below the water's surface to depths of 35-40 m (and possibly deeper)**. By August 2016, between 60-95% of the corals on these reefs had died, with the greatest losses recorded on the branching and table corals in the genus *Acropora*. Fortunately, many of the massive boulder corals recovered from the bleaching and mortality was less among these taxa. Nevertheless, the acroporids were the dominant corals found in the Maldives, especially in shallow water and these are the most important habitat forming species that is utilized by reef fish and motile invertebrates.

In addition to large losses sustained during the bleaching event, reefs in the Maldives have experienced a prolonged outbreak of crown of thorns starfish. The starfish caused extensive damage in 2015-2016 on three atolls (North and South Malé Atoll and Ari Atoll) along with localized damage in other atolls. The starfish disappeared during the bleaching event (presumably moving into deeper, cooler water), but they have reemerged and are eating the few surviving corals (both the important acroporid species as well as the massive boulder corals) and are attacking juvenile and newly settled coral recruits. Their continued pressure could delay recovery of these reefs. Furthermore, in some locations these losses are being compounded by impacts from unsustainable development, creation of artificial islands, and growing fishing pressure.

Due to the losses of the key branching and table coral species, and the ongoing threats to the reefs, Coral Reef CPR has focused their HARP Program on coral gardening with intent of producing corals to rehabilitate degraded reefs and speed up recovery of reefs damaged by bleaching. We introduced a novel method to the Maldives, growing corals on ropes **suspended in the water column as an alternative to the metal "adopt a coral" frames**. This approach avoids problems with the metal frames (rusting, access to the corals by COTS and coral eating snails, sand burial etc.); it speeds up growth rates of the corals by elevating them into the water flow (higher nutrients and oxygen); and it allows easy removal of nursery reared corals once they reach a suitable size.

Our main focus has been on *Acropora* because of their pivotal role on these reefs and the fact that the losses among this genus was greater than any other coral. We also emphasize the collection of corals in as low an impact as possible, avoiding the removal of large attached colonies, and focusing on corals that have naturally broken, are affected by disease and predators, are being buried by sand, and are located in construction/sand extraction areas.

We first tested our nursery approach in August 2016, attaching corals primarily to nylon mesh on elevated tables. In October 2016 we switched to rope nurseries, although we

still have several mesh tables at both Dhigu and Kihavah. All corals used in our nurseries are small (2-8 cm length) when first attached to the rope/mesh. They are secured with a cable tie and allowed to grow for 12-18 months.



Fig. 5. Typical fragment size when first attached to a rope. This fragment is a juvenile coral that settled on rubble within a site affected by sand extraction.

Nursery progress

1. Location and size of nurseries

Coral nurseries currently exist in three locations near Anantara Kihavah (supply jetty, Plates and SEA) and four locations at Anantara Dhigu (Advanced snorkel area; Aquabar; Veli; Dhigu House Reef).

Kihavah, Baa Atoll

Supply Jetty

In October 2016, five frames were inserted between 5-15 m depth, each with 4 five meter long ropes and 30-50 corals per rope, with a total of 771 fragments. Two additional ropes were added to the shallow nursery frame in July, 2017. One rope contains 39 juvenile corals that were collected in the lagoon near the sand extraction site at Plates. A second rope contains 30 fragments of a foliaceous *Echinopora* coral. This is now an extremely rare coral, with only two colonies identified to date at Kihavah.

Corals at this nursery have shown highly variable survival and growth rates, with highest survival and greatest growth on the shallow ropes (>95%). A disease (white syndrome) affected three of the ropes at 14 and 12 m depth. A filamentous red algae has also settled on the corals and the ropes, causing partial mortality to a number of fragments. This site is also affected by the greatest amount of water flow, and a number of fragments have become detached and lost from the ropes (5.3%). In August 2017, the nursery contained 754 corals.

Plates

In October 2016, five frames and two tables were placed at the nursery site off Plates. The tables each contained approximately 100 corals and the frames each consisted of 2-3 five meter ropes with 30-40 corals. Additional ropes were added in February 2017. In July 2017, two new ropes were added with 79 fragments. This nursery now contains 841 fragments.

The coral recruits and juveniles collected from the rubble field adjacent to the nursery at Plates have shown exceptional growth, and fragments are 5-10X larger than when first planted on ropes in October 2016. Fragments that were translocated from the fore reef are also growing, but at a slower rate.



Fig. 6. A fragment at Plates nursery when first attached to ropes in October 2016, and the same coral in August 2017.

Unusually, this nursery has a very high rate of algal colonization and growth with tables and ropes becoming completely engulfed in fleshy red algae and cyanobacteria within a two week period following a cleaning. Coral Reef CPR, with assistance of Elements Marine Biologist, cleaned this nursery once a week over the eight week mission in August. By removing as much of the rubble base the living coral is attached to when first attaching the corals to the ropes, overgrowth of the fragments is reduced, however the ropes still need bi-monthly cleaning. The tables acquired a film of cyanobacteria on the mesh. After an initial removal of this, it was determined that this is best left on the mesh, as the removal re-suspends and propagates the cyanobacteria. Nevertheless, the fleshy algae that settles on the table and among the corals needs to be removed.

SEA

One nursery containing five ropes was established in February 2017. The frame holding the ropes was detached and ropes were lying in sand in July, 2017. The ropes were reattached, dead fragments were removed and a small number of new fragments were added. Four fragments were completely bleached in July, but had begun to regain pigmentation by mid-August. The ropes now contain 253 fragments.

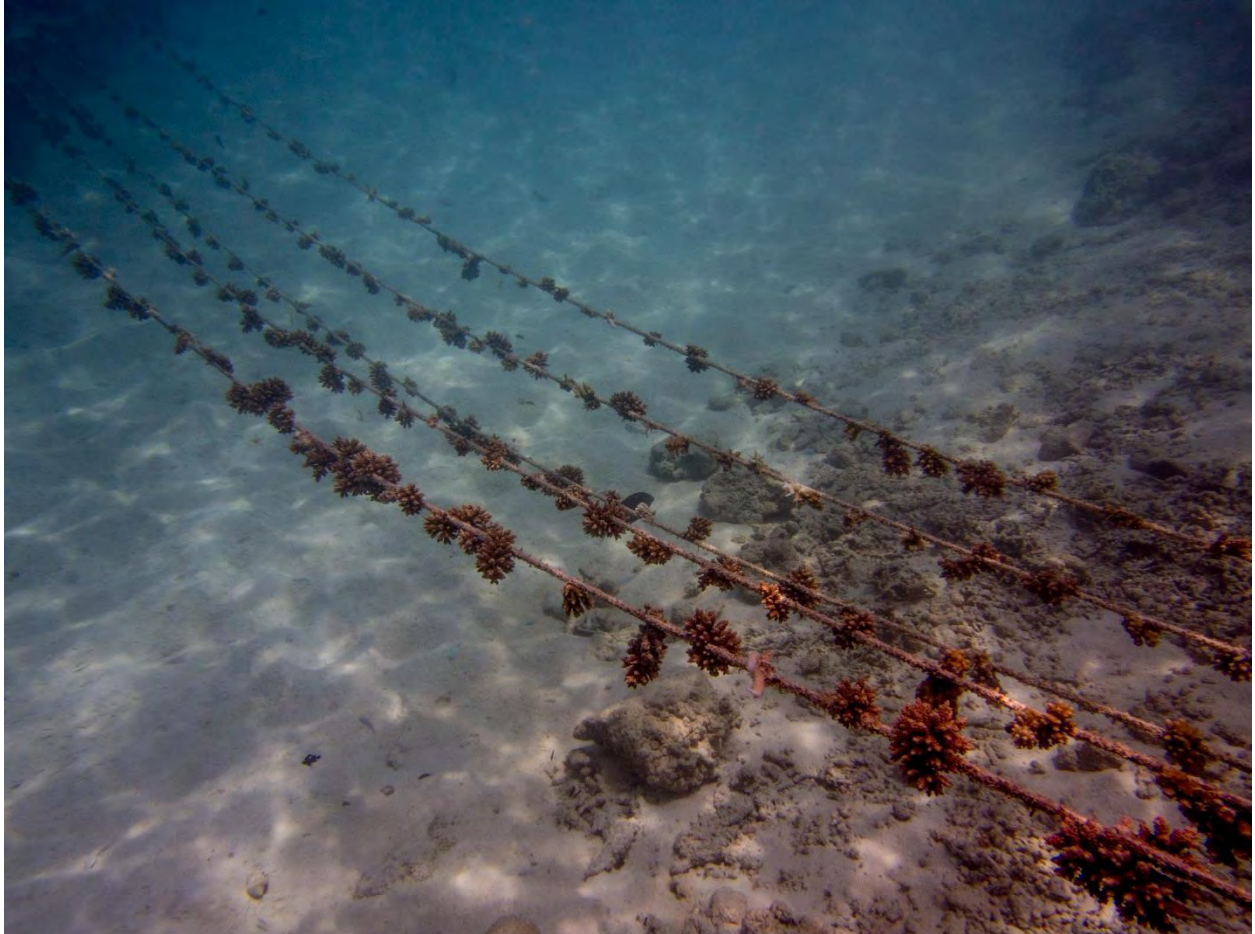


Fig. 7. The coral nursery on the left side of SEA restaurant near the wine cellar. The nursery was established in February 2017 and corals are showing rapid growth.

In August 2017, a second nursery, on the opposite side of the restaurant was installed. This contains five ropes on two frames with 255 fragments. All of the fragments are from the adjacent reef system except one rope. This rope contains 10 *Echinopora* fragments and 20 fragments collected at Plates. The nursery now contains 508 corals.

Because of the bright white sand at this nursery, bleaching of fragments placed at the nursery is expected. However, the corals are highly likely to acclimate to the conditions.

Dhigu, South Malé Atoll

Advanced Snorkel Area

In October 2016, a coral nursery containing five frames with a total of 7 ropes and 231 coral fragments and two tables with 219 corals was created. Five additional ropes and 144 fragments were added to this nursery in February, 2017. Two new ropes with 78 fragments were added in August 2017. In total, three fragments died between February and August and one fragment was lost. There are currently 683 corals with a 99.5% net survival of coral at this nursery.



Fig. 8. One of the mesh tables at the Advanced Snorkel Area coral nursery. The top photo shows the table when first established in October 2016 and the same table in August 2017 (bottom image).

Coral have shown variable growth rates, with staghorn-type corals showing the greatest growth. These corals are 3-5x larger than they were in February. All other corals have also grown, but more slowly. A small number of *Pocillopora* colonies were also attached to ropes. These have also shown growth, but much slower; fragments are now 1.5-3x larger than when first attached.

Veli

A pilot nursery consisting of a single mesh table and a series of short ropes extended between the cement pillars of the water villa was established in August 2016. Several of the ropes were abandoned, as these were exposed to air during very low tides. The table near the jetty has done extremely well, with the fragments growing from 2-5 cm single branches to a dense thicket of coral that completely covers the mesh and is 15-20 cm tall. The mesh was detached in May 2017 due to the weight and then re-secured. This table was 100% live in August 2017 and now supports a large population of humbugs (damselfish).

A second table and a frame with ropes was added in October 2016. The table was placed near one of the water villas in shallow water. Due to the scarcity of the staghorn coral found at this site, only 32 fragments were attached. Unfortunately snorkelers stood on this table and broke the mesh; 16 fragments were detached and lost. The mesh was reattached and the table was moved slightly deeper, closer to the rope nursery in February 2017. An additional 13 fragments were attached to this table in August 2017.



Fig. 9. The coral table near Veli jetty in August 2016 (left) when first set up and the same table in August 2017 (top of next page). Every fragment on this table has survived and has grown substantially. The table is now serving as a nursery habitat for juvenile humbugs and other fishes.



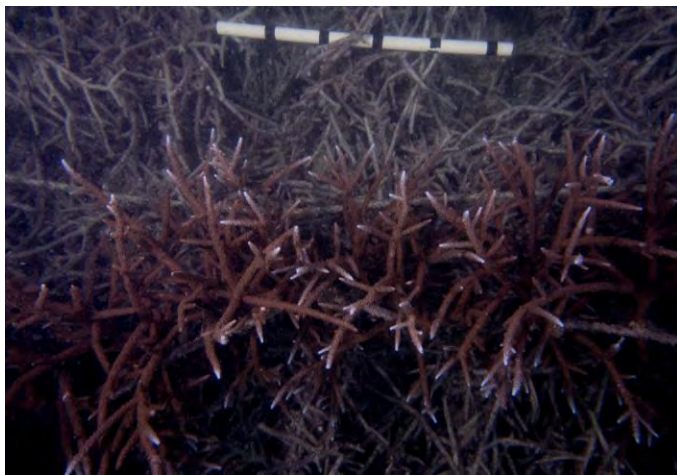
A metal frame with three ropes was installed in the deeper part of the lagoon in October 2016. An additional rope was attached to this in February 2017. A long rope, containing staghorn fragments collected at Dhigu House reef, was also placed near this frame in February. The fragments from Veli showed extraordinary growth on these ropes, with some colonies growing into large bushes, 20-30 cm diameter. The fragments imported from Dhigu House reef all survived and are growing, albeit a slower rate.

Fig. 10. A portion of one of the rope nurseries at Veli Lagoon in October 2017 (bottom left) and the same set of ropes in August 2017 (right).





Fig. 11. A rope nursery at Veli Lagoon. The fragments on these ropes were salvaged from the few remnant colonies that survived the bleaching event. These colonies were under attack by coral-eating snails. Over 125 snails were removed from the corals and the surrounding reef and surviving branch ends were attached to the ropes. This nursery has shown 100% survival.



One of the three ropes was removed from the frame and the corals were transplanted onto the reef, adjacent to the nursery. As a test, these were left attached to the rope and placed on top of dead coral framework (dead staghorn branches).

Fig. 12. Half of the colonies from one rope at Veli Lagoon were very large (25-30 cm diameter) and were weighing the rope down. As a pilot experiment, these were removed from the nursery and planted on top of the dead reef framework. This reef formerly consisted of 99% staghorn coral, many of the corals were 1-2 m in length, and new colonies naturally settled and grew on the dead skeletons of old corals.

Two additional frames were installed in this area in August 2017. These contain six ropes and 350 fragments. The majority of these corals were collected at Dhigu House Reef to test whether they will survive in a shallower environment and can be used to restore the reef surrounding the water villas.

Dhigu House Reef

Dhigu House Reef coral nursery contains four tables, two placed on the reef in August 2016 and two in October 2016. There are also three frames, each with five ropes that were installed in October 2016. This nursery contained 879 corals in October 2016. In August 2017, there were 841 corals; a total of 38 corals had died and one was missing. Total survival was 95.7%.



Fig. 13. One of the rope nurseries at Dhigu House reef in October 2016 (top left) and in August 2017 (bottom left).



Aquabar

Four frames, each with 5 ropes (9 m long) were installed in February 2017. The nursery contained 1312 fragments. The nursery has done extremely well. We had 100% survival at this site and all fragments are showing rapid growth.

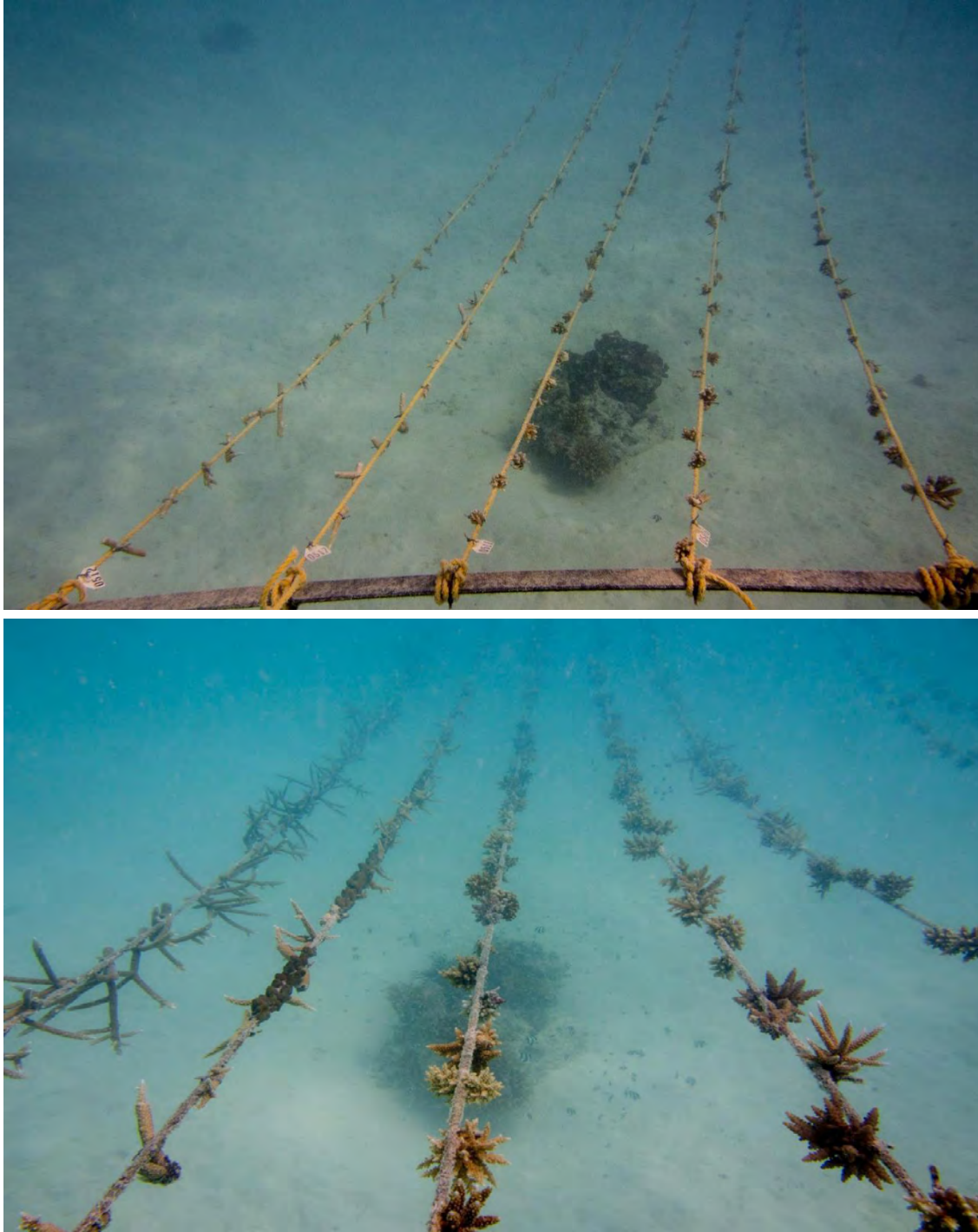


Fig. 14. One of the nursery frames at Aquabar, Dhigu established in February 2017 (top) and the same ropes in August 2017 (bottom).

Table 1. Rates of survival of coral fragments attached to ropes between February 2017 and August 2017

Site	Date	No. ropes	Orig. No. corals	Live 2/17	Live 8/17	Dead	Missing	Survival
Dhigu HR	10/16	15	529	523	506	7	10	95.6%
Veli WV	10/16	4	141	133	133	0	0	100%
Veli WV	2/17	2		109	109	0	0	100%
Veli WV	8/17	6			350			
Adv Sn	10/16	7	231	226	221	3	2	98%
Adv Sn	2/17	5		144	137	2	5	95%
Adv Sn	8/17	1			87			
Aquabar	2/17	20		1312	1312	0	0	100%
Plates	10/16	13	556	531	500	17	14	94.1%
Plates	2/17	2		56	50	2	4	89.2%
Plates	8/17	2			79			
AKH House	10/16	20	771	715	685	21	9	93%
AKH House	8/17	2			69			
SEA	2/17	5		243	253	6		97.5%
SEA	8/17	5			255			
Total		108	2228	3992	4749	57	44	97.5%

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

Site	No. tables	Live 10/16	Live 2/17	Live 8/17	Survival
Dhigu HR	4	390	366	335	91.5%
Veli FR	4	208	150	90	***
Veli WV	2	132	114	114	100%
Veli WV				13	
Adv Sn	2	220	219	212	96.3%
Kuda Giri	4	198	102	64	***
Plates	2	219	211	212	96.8%
Total	18	1367	1162	1040	

*** Fragments were removed from the table and attached to the reef.

Education

Coral reef CPR continued our evening seminars and educational workshops for Maldivian High School students. We presented an overview of coral reef ecology, health, threats, and conservation actions, with emphasis on the status and changes observed to Maldivian reef over the last few years to a group of 28 high school students and teachers on Marina. Our intention was to help them understand the impacts of climate change on the Maldives, and recent losses of corals due to the catastrophic 2016 bleaching event. We then highlighted the CSR initiatives undertaken by Coral Reef CPR at Anantara, and discussed coral gardening approaches. At the end of the presentation, the students assisted with a coral nursery rope, attaching coral fragments to the rope and planting the rope at the Advanced Snorkel Area Coral Nursery.



Fig. 15. Students from attaching corals to a nursery rope.

We have also started a dessert and cocktail hour at SEA restaurant where guests have the opportunity to learn about Maldivian reef, some of the unusual animals found there and their unique behaviors by viewing the natural, restored reef surrounding the underwater restaurant.

Challenges and lessons learned

One small nursery on the fore reef off Marina was abandoned in February, 2017. The nursery, consisting of two tables, each with 100 corals, was destroyed by a strong storm in February 2017 that dislodged and overturned the tables and broke the metal frames. The surviving fragments were attached to the reef and the broken metal tables were removed and discarded. The nursery at Veli was also damaged by the storm. The tables were temporarily repaired, but high numbers of snails had invaded the corals at the time the frames were overturned. These were completely removed, and the tables were re-secured. In July 2017, three of the four frames were broken, two were overturned and two were lying on the reef substrate. Additional snails infested the corals and subsequently consumed 40% of the fragments remaining coral fragments. A total of 180 snails were collected and discarded. The surviving corals were attached to the reef and the metal tables were removed and discarded.



Fig. 16. One of the tables at Veli Fore reef that was destroyed by storm waves.

The nursery at Kuda Giri contained four tables and 400 corals. These tables were heavily colonized by encrusting tunicates. Coral Reef CPR cleaned these tables in February 2017, and asked for assistance with routine maintenance of the tables (monthly cleaning) to prevent the tunicates from overgrowing the corals. However, no maintenance was done, and many of the corals were overgrown and had died by August 2017. All of the surviving corals were removed and placed on the reef and the metal tables were taken out of the water and discarded.



Fig. 17. Coral tables at Kuda Giri with dense colonization of cyanobacteria and tunicates. These pest species were killing the corals and can be prevented through routine cleaning.

With routine maintenance, the broken and overturned tables would not have remained on the bottom. They could have been overturned and repaired. It is normal to periodically lose nurseries when they are placed in high exposure outer reef sites. However, the benefits of growing corals on these sites is that they will be acclimated to the site and exhibit high survival when transplanted from the nursery to the surrounding reef. By monitoring storm activity and visiting the site immediately following a storm, it is possible to repair any damage and salvage corals from the nurseries, as these type of storms are infrequent.

Furthermore, coral-eating snails can easily be removed from affected corals through monthly maintenance; efforts to remove snails from surrounding corals should also be undertaken, as these have consumed >99% of the branching pocilloporids (cauliflower coral) and acroporids on both Marina and Veli fore reef, and the snails are now aggregating on the few remaining slow-growing boulder corals (*Porites*). Both reefs have shown no recovery and no new recruitment, suggesting these reefs may take a decade or more to show positive signs of recovery.



Fig. 18. The fore reef community at Veli has <1% living coral cover. Shown here is the rebar marking one of our permanent monitoring stations. All of the corals are dead and covered in algae. There has been no new recruitment.

It is normal to have algae and encrusting invertebrates settle on the ropes and mesh (and any uncolonized substrate such as the metal frames). These grow faster than the corals and can overgrow and outcompete them when left unmanaged. However, through routine maintenance (every two weeks to monthly), the competing organisms can be kept under control and will have minimal impacts on the corals. Unfortunately, because Coral Reef CPR scientists are not on site, and there is no maintenance conducted at Dhigu sites, Kuda Giri does not present a feasible location for a coral nursery at this time.

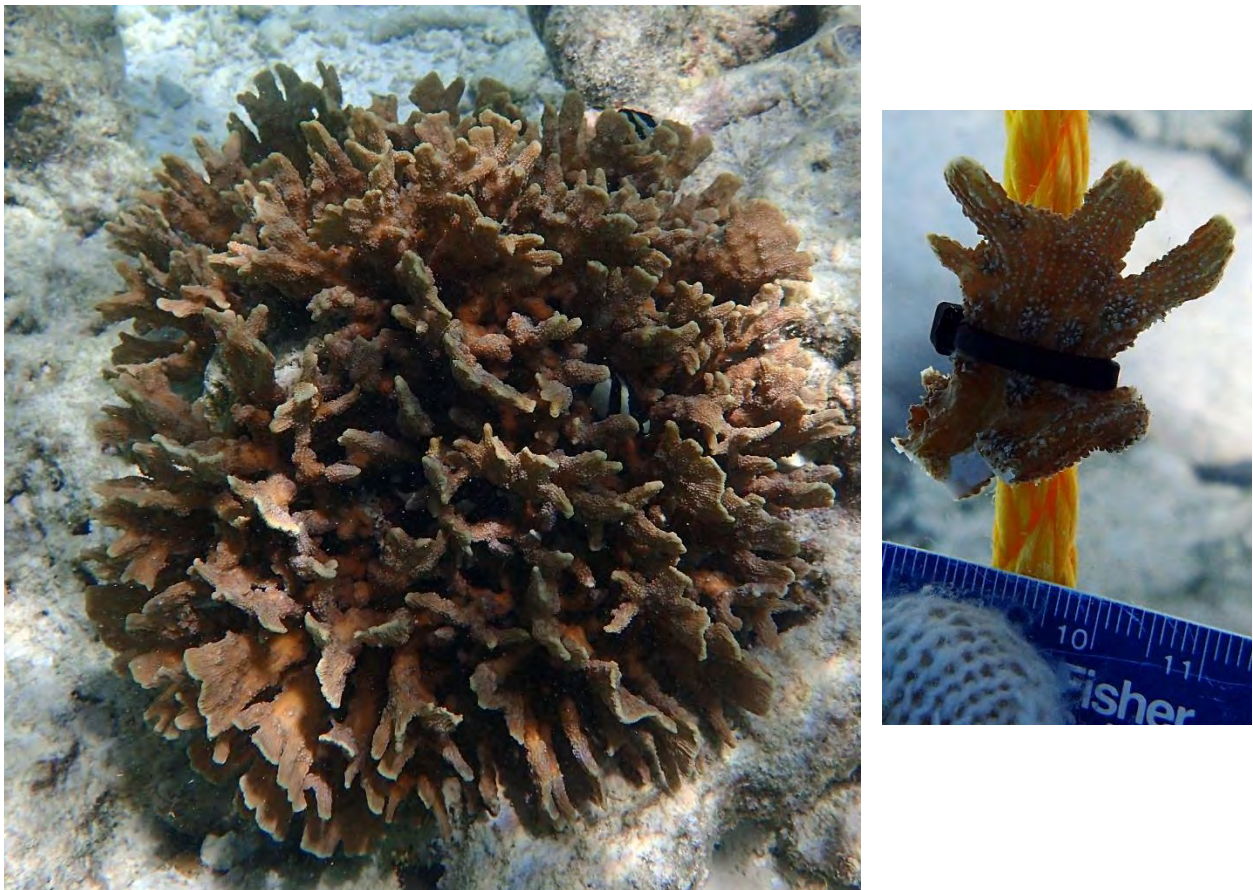


Fig. 19. We identified two colonies of a foliaceous *Echinopora* at Kihavah. One is found near the supply jetty and the second is located on the reef flat near SEA (left). We conducted an experiment to determine whether it is feasible to grow this coral from small branches, and attached fragments to the nursery at the Supply Jetty and also at SEA (right)

Acknowledgements

We would like to thank the staff at both Anantara Dhigu and Anantara Kihavah Villas for their support and interest in the ongoing HARP initiatives. A special mention to Launch and Engineering departments for their continued help and enthusiasm. The team fabricated additional frames for use at Veli, transported our gear from Marina to Veli and Dhigu, and provided boat support to outer reefs. A particular thank you to Rizan Afeef, Mohamed Yamany, Liezl Lising, Coetzer Deysel and Dylan Counsel. Aquafanatics provided tanks, transported us to Dhigu House Reef and provided equipment when necessary. We are most appreciative of the support provided by Elements Dive Centre and are grateful for their ongoing interest in coral nursery techniques and assisting with routine maintenance. Their resident marine biologist, Flora Blackett, went out of her way to help us each day during our site visit, and was an invaluable help with the nursery maintenance. She even gave up her free time to help clean nurseries, and she showed a keen interest in understanding the CSR initiatives and in educating the guests on their importance. Her enthusiasm is invaluable.