



Restoring coral reef habitat around
Anantara Dhigu and Anantara Veli,
South Male Atoll, Maldives

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EXECUTIVE SUMMARY

Between Feb 17-23, 2019, Coral Reef CPR completed the next phase of coral nursery and coral restoration work, as part of the Holistic Approach to Reef Protection (HARP) program. All of the work was undertaken within the shallow lagoonal and reefal habitats surrounding Anantara Dhigu and Anantara Veli, in South Malé Atoll, Maldives. The nursery (1-4) and restoration locations (1, 2, 4) are shown below. The field activities focused on four aspects: 1) outplanting of nursery-grown corals onto degraded reefs at Veli, Aquabar, Advanced Snorkel area and Dhigu House Reef; 2) nursery maintenance; 3) expansion of coral nurseries through addition of new fragments to coral ropes and coral tables; and 4) maintenance and expansion of the Aquabar snorkel trail.

Dhigu

A. Aquabar

The Aquabar Snorkel trail was expanded in width, with addition eight mature coral ropes removed from the two deep frames at the Aquabar nursery. These corals were placed onto a dead coral framework built from coral rubble collected at the Advanced Snorkel Area. The new reef structure was built on the right and left side of the trail.

B. Advanced Snorkel Area nursery

The majority of the corals were removed from this nursery during Nov 2018 by the onsite marine biologists. These were planted into a very shallow area within the Advanced Snorkel Area. Staghorn coral, the primary type of coral transplanted from the nursery is a species that does not occur naturally in this habitat and it has sustained over 50% mortality. Most remaining staghorn corals are bleached and show signs of continuing tissue loss attributed primarily to farming damselfish, although two crown of thorns starfish that were feeding on the coral were removed and coral eating snails (n=58) were also collected. Other growth forms (digitate, bushy) of *Acropora* transplanted to this reef have exhibited higher rates of survival. Two remaining ropes on the nursery frame were transplanted to a large coral bommie adjacent to the nursery in 7 m depth. The nursery was reestablished, and 13 new ropes containing 485 fragments were installed.

C. Dhigu House reef

Eight mature coral ropes were removed from three nursery frames and transplanted to the reef. One new restoration plot was established at 7 m north of the nursery and two plots were located in 6 m depth southwest of the nursery frames.

Veli

Nursery-reared staghorn corals from four tables and nine ropes were transplanted to five areas surrounding the water villas. The restored area now includes eight discrete thickets of staghorn coral, covering a total of 193 square meters. In addition, 477 staghorn fragments were attached to five tables and 370 fragments were attached to nine ropes; all coral were branches from second generation colonies that had broken off the colonies and were rescued from sandy areas around the nursery. Corals planted during the prior mission, in April 2018 exhibited over 95% survival and colonies showed substantial growth, increasing in height by 10-30 cm.

Letter from the Director

Since the 2016 coral bleaching event, Coral Reef CPR has successfully rescued coral fragments that survived the bleaching and prevented further loss of corals succumbing to coral predators, construction, sand extraction and breakage by inexperienced snorkelers and divers. We removed garbage and pest species from reef habitats, including a major effort to remove the failed metal rebar frames used in “adopt a coral” programs. We experimented with various nursery and outplant techniques, including coral trees, suspended ropes, growing corals on blocks and tables, and rebar frames and also experimented with different depths and habitats for our nurseries. The ropes were found to be the optimal technique to grow corals, as they prevent access by coral predators, they receive more water flow and less sedimentation and contact with harmful algae. The corals on the ropes have grown at rates that exceed that reported for wild corals, with differences depending on habitat and depth. The tables also work well in sheltered lagoonal environments, but these were abandoned from outer reefs near Marina and Veli due to physical damage following a storm and excessive predation from coral eating snails. They were also abandoned at Kudi Giri, as they were overgrown by tunicates (which could have been prevented if there was ongoing maintenance).

The most feasible approach for nurseries is to establish them close to the restoration site, as the corals will be acclimated to local conditions and the labor required to move the corals is minimal.

Our nurseries have offered substantial benefits to reef-associated fish and invertebrates, as they provided habitat and structure for juvenile species in areas devoid of any structure.

Our restoration efforts have focused on three highly visible and accessible sites, two snorkel areas just off the beach (Aquabar) and around the water villas (Veli) in two areas that sustained over 98% mortality during the 2016 bleaching event. The Aquabar Snorkel Trail is now the most diverse shallow reef system in the Maldives, containing over 50 species of corals and 100 species of fish, along with many other soft corals, anemones, sponges, giant clams and other invertebrates. Both of these offer educational opportunities and they provide critical habitat for reef-associated species.

During return visits in 2019-2020, Coral Reef CPR proposes to further expand the nurseries, add new species to the nurseries, establish two new nurseries, and begin focusing restoration efforts on new locations, including the degraded reef off Snorkel Island. For this to be successful, there is a need for better maintenance of nurseries and restoration areas during intervals between Coral Reef CPR visits, as all the efforts undertaken can be lost relatively quickly if coral eating snails, crown of thorns starfish and other pests species are not removed, and nurseries are not properly cleaned and repaired when needed.

Andy Bruckner, March 2019

ACKNOWLEDGEMENTS

The work undertaken by Coral Reef CPR could not have been accomplished without the support of Anantara Dhigu Resort, Anantara Veli Resort and Aquafanatics. During the current mission, Anantara's Engineering team provided rope, floats and other supplies needed for nursery expansion. Anantara's Launch section for use of a small boat and a captain to collect coral rubble for use in expansion of the Aquabar Snorkel Trail. SCUBA support (tanks, BC and regulator) was provided by Aquafanatics. I would like to acknowledge Lisa Jacobsson, along with her staff for their efforts to photo-document and publicize this CSR initiative through Minor Hotels and associated social media sites. Special thanks to Adrian Stoppe, Matteo Lingua and John Roberts, who have all continued to support the HAPR program and the work undertaken by Coral Reef CPR.



Andy Bruckner, Coral Reef CPR Director is measuring the height of nursery-grown staghorn corals outplanted in shallow water, near the water villas at Veli.

BACKGROUND

Coral Reef CPR has partnered with Anantara Resorts in the Maldives since 2015 with coral conservation efforts targeted at addressing impacts from crown of thorns starfish, coral-eating snails and coral bleaching. Following a large scale removal of crown of thorns starfish surrounding Anantara Veli and Anantara Dhigu, we established permanent sites to document the extent and severity of the coral bleaching event. This event was associated with abnormally high sea water temperatures during the most severe, multi-year El Niño ever documented. It resulted in losses of 80-95% of the keystone corals in the genus *Acropora*. These were formerly the dominant corals in the Maldives, with living cover that exceeded 50-80% in many locations. These corals are responsible for much of the reef growth in the area and they are the most important species utilized by reef fishes and invertebrate for nesting, feeding, resting and refuge habitat. Between March-May 2016, sea water temperatures climbed to 32-35° C. Concurrently, there was an extended period of doldrum-like conditions with no wind, calm seas and an absence of cloud cover and precipitation. Corals began to bleach in early April, and in some areas they sustained 90-98% mortality within a month.



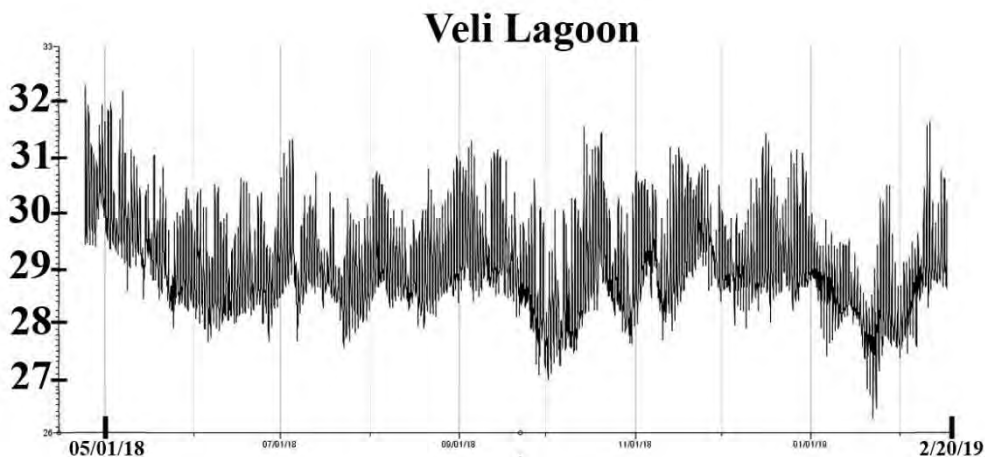
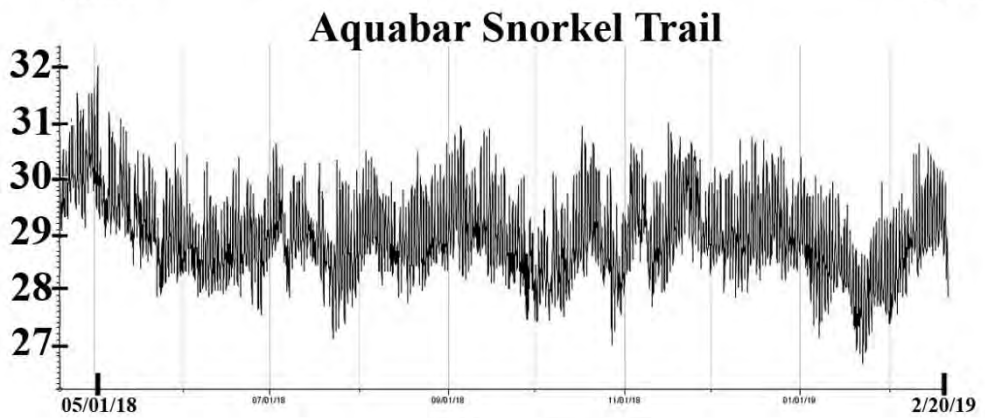
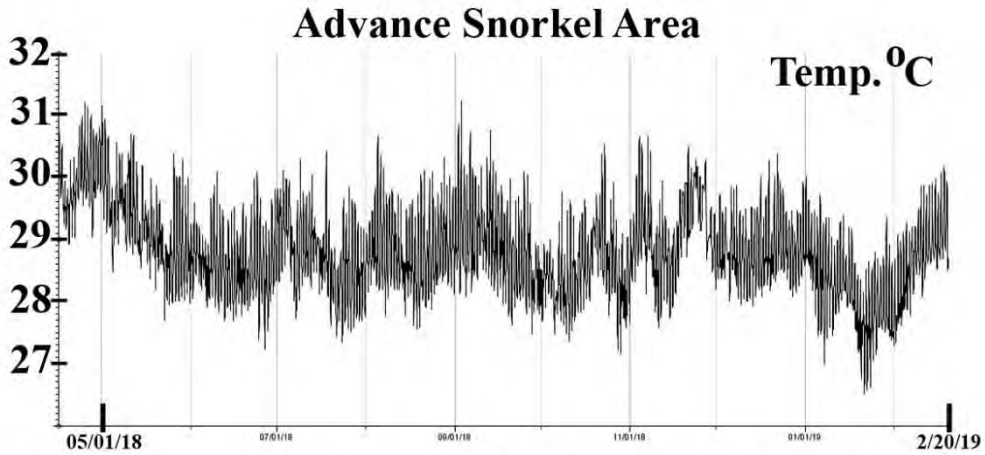
Location of coral nursery and restoration locations at Anantara Dhigu and Anantara Veli.

Coral Nursery and Restoration work at Anantara Dhigu and Anantara Veli, February 2019

In response to the catastrophic losses of coral observed throughout the Maldives, Coral Reef CPR established the Holistic Approach to Reef Protection (HARP) program in partnership with Anantara Resorts and Minor Hotels as an important Corporate Social Responsibility (CSR) initiative targeted at coral reef conservation and restoration. We established coral nurseries around Anantara resorts in South Male Atoll and Baa Atoll, and have been using nursery-reared corals to rehabilitate degraded reef habitats. Our efforts were unique to the Maldives for several reasons, and in recent years a number of other resorts in the Maldives have adopted these practices:

1. All of the corals we use in our nurseries and restoration projects are sourced from locations where they would otherwise die. This includes corals that are in rubble/sandy areas that are being buried; coral fragments removed from diseased corals; corals rescued from coral predators including coral-eating snails and starfish; corals that have become detached and have rolled down the reef slope into sand patches, channels and at the base of the reef; and corals rescued from construction sites, sand extraction and burial areas, and other development areas. We never remove a whole, intact, attached coral colony from the reef.
2. We have abandoned the use of metal rebar frames. These are still widely used in the Maldives, but have been shown to be deleterious to coral health. First, they are placed directly on the bottom and are readily accessible to coral predators like starfish. Second, the corals can never be removed from the frames once they are attached, so restoration of a reef required deploying artificial man-made structures. Third, coral does not like metal, especially when it starts to rust. Fourth, the breakdown of these frames leads to the release of iron into the surrounding water. Iron is a limiting nutrient in tropical areas that promotes the growth of harmful algae and seaweeds. In our first phases of restoration, we removed all metal frames from Veli, Aquabar, and Kihavah. All of these were rusting, all coral was dead, and they were covered in fleshy seaweed.
3. We grow our corals primarily on horizontal ropes suspended 1-2 m off the seafloor in shallow sandy and rubble areas. This maximizes coral growth rates, as they are exposed to higher flow, less sedimentation and are excluded from harmful effects of coral predators.
4. We outplant corals onto degraded reefs as an entire unit instead of planting corals one at a time. By placing multiple ropes and/or mesh tables with mature corals onto a reef we increase survival, and can create a new thriving reef much more quickly. By planting a very high number of corals at once into a site, the existing predators on these reefs have much less impact than that seen when individual colonies are outplanted. This also greatly reduces the amount of labor required to outplant corals.
5. We traditionally used nylon braided rope because that was the most readily available product in the Maldives. During the present mission we began switching to braided hemp, a natural alternative that will biodegrade relatively quickly once planted on the reef.
6. Our nurseries are established close to the restoration site, as this increases likelihood of survival when outplanted as the corals are acclimated to local conditions. It also reduces labor to transport corals to the restoration site.
7. Our main focus has been on branching, digitate and tabular acroporid corals (e.g. staghorn, finger and table coral) but we have experimented with many other species. We have had survival on our ropes of 80-95%, and growth rates that exceed that published in the literature.

Environmental conditions since the 2016 bleaching event have returned to normal and sea water temperatures have been stable, at or below the normal temperatures. In early 2019 we entered another El Niño period, and the Maldives is currently under an alert for bleaching during April/May. We have replaced all temperature meters and will continue to monitor this event.



Water temperatures at the Advanced Snorkel Area nursery, Aquabar snorkel trail and Veli lagoon between April 2018-February 2019. Temperatures remained at or below normal for 2018.

[Coral Nursery and Restoration work at Anantara Dhigu and Anantara Veli, February 2019](#)

ACTIVITIES AND OUTCOMES

Veli

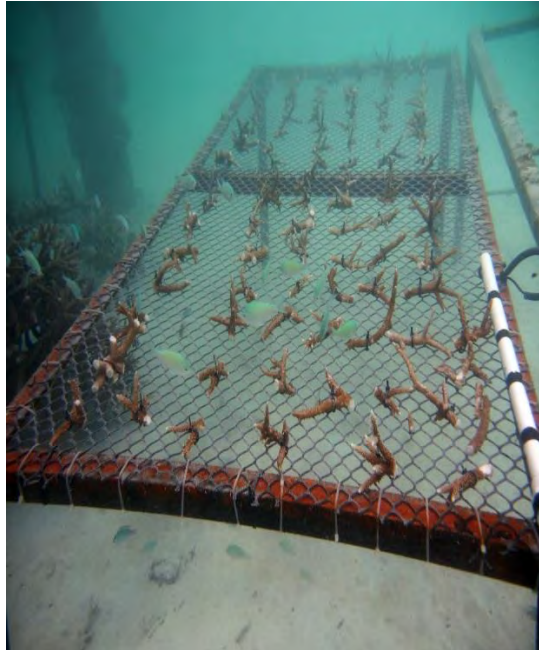
The shallow lagoonal reef surrounding the water villas at Veli was formerly constructed by tall (50-200 cm) densely branched stands of staghorn coral forming a “forest” that supported over 100 species of juvenile reef fish and many larger schooling fish. Over a month long period in April 2016, the reef bleached and >98% of the corals died. Coral Reef CPR salvaged small, surviving branch ends, most which were under attack by coral-eating snails, and planted the pilot nurseries in August 2016. These were expanded in October 2016, February 2017, August 2017 and April 2018 using 2nd, 3rd and 4th generation fragments from the nursery, and rescued fragments salvaged from surrounding areas. The first outplanting of nursery-reared corals in Veli Lagoon began occurred during April 2018, with corals taken from nurseries at Veli and near Aquabar on Dhigu. Corals were relocated to one deeper slope, adjacent to the nursery frames, and two shallow areas next to the water villas. These corals exhibited 100% survival and have increased in height by 20-30 cm.



Location of coral nurseries and restoration sites at Veli. 1) four coral tables and one rope; 2) three frames with 9 coral ropes and 1 table; 3) two restoration plots established in Feb 2019 4) large restoration area established in April 2018 and expanded during 2019; 5) restored habitat adjacent to the dock using corals from the nursery tables; and 6) two areas between the water villas with restored corals planted in April 2018.

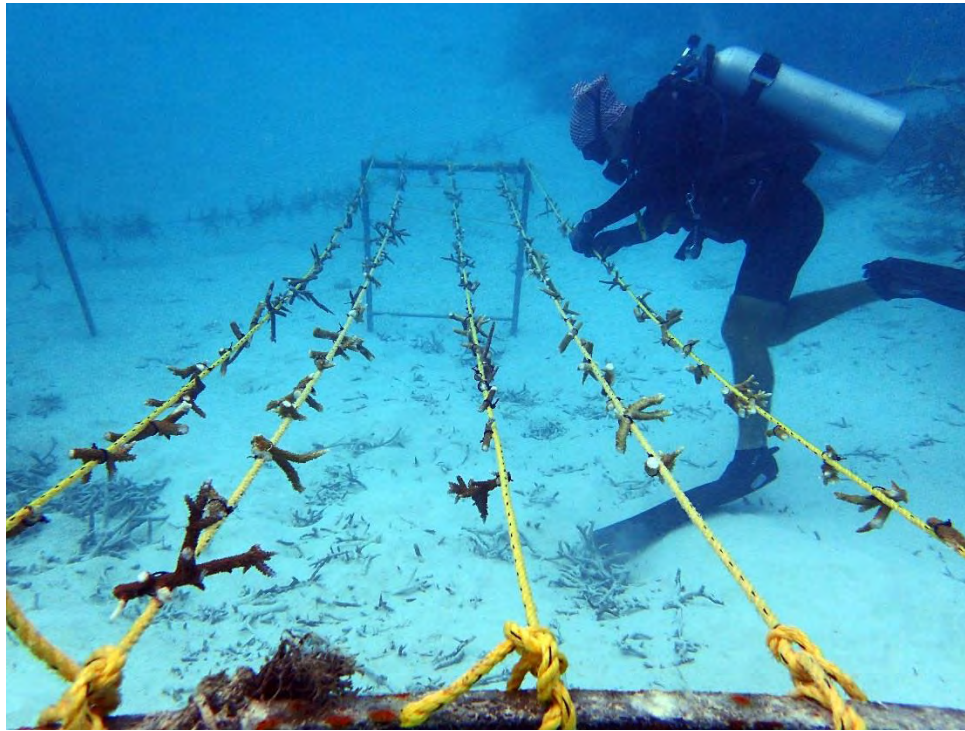
During the fall and winter of 2018 there was considerable sand movement and burial of staghorn skeletons surrounding the water villas on the right side and much of this area is no longer habitable for fish or coral. The left side, adjacent to the nurseries, still includes deeper areas suitable for the growth of corals.

Four tables established near the dock in April 2018 were fully mature and these were transplanted to a shallow area adjacent to the walkway (visible from the pier). Mesh was replaced and new fragments were attached. Corals from a fifth table, located near the nursery ropes, were also used to recreate a small patch of coral within the lagoon.

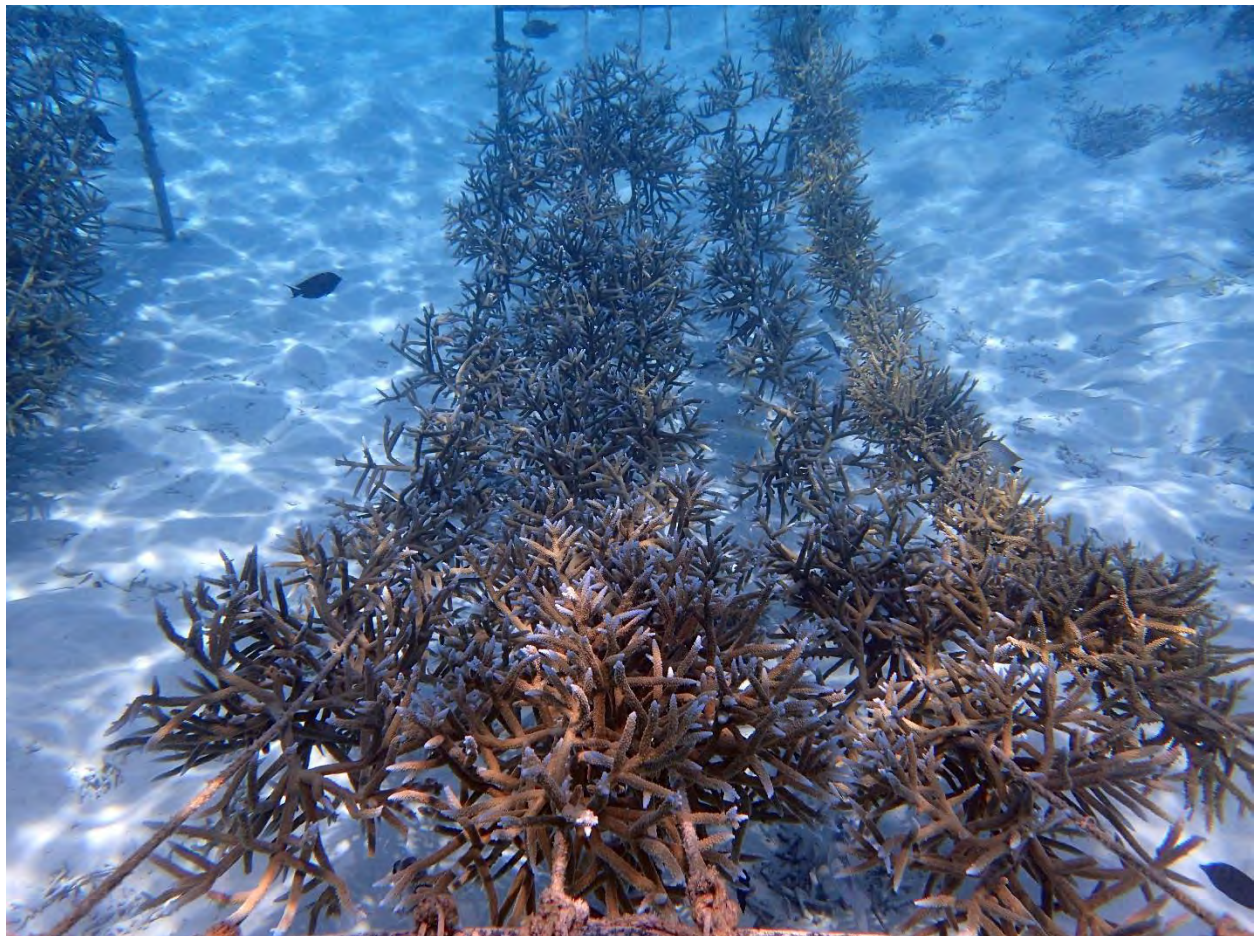


Coral table near the dock established in April 2018 (left) and in Feb 2019 prior to outplanting (right).

Mature ropes from three frames (n=12) were transplanted onto the adjacent dead coral framework to continue expansion of the reef. A total of 9 new ropes were placed on these frames (3 ropes per frame) using two species of staghorn coral. All fragments used on these ropes had naturally broken off the transplanted ropes and were rescued from the sand.



One nursery frame at the Veli nursery established in April 2018 (left) and the same frame in Feb 2019 (bottom). This frame exhibited 100% survival and the corals increased from 2-8 cm branches to bushy colonies, 30-40 cm diameter and height. All of the ropes on this frame were transplanted to the reef.



Coral Nursery and Restoration work at Anantara Dhigu and Anantara Veli, February 2019



Moving a rope from the Veli Nursery (left) to a degraded rubble field (top right). In many areas on Veli, the dead coral skeleton framework has now collapsed. Corals are planted onto the rubble to keep them off the sand. The same area from above is shown with coral ropes transplanted in Feb 2019 (bottom).



Coral Nursery and Restoration work at Anantara Dhigu and Anantara Veli, February 2019



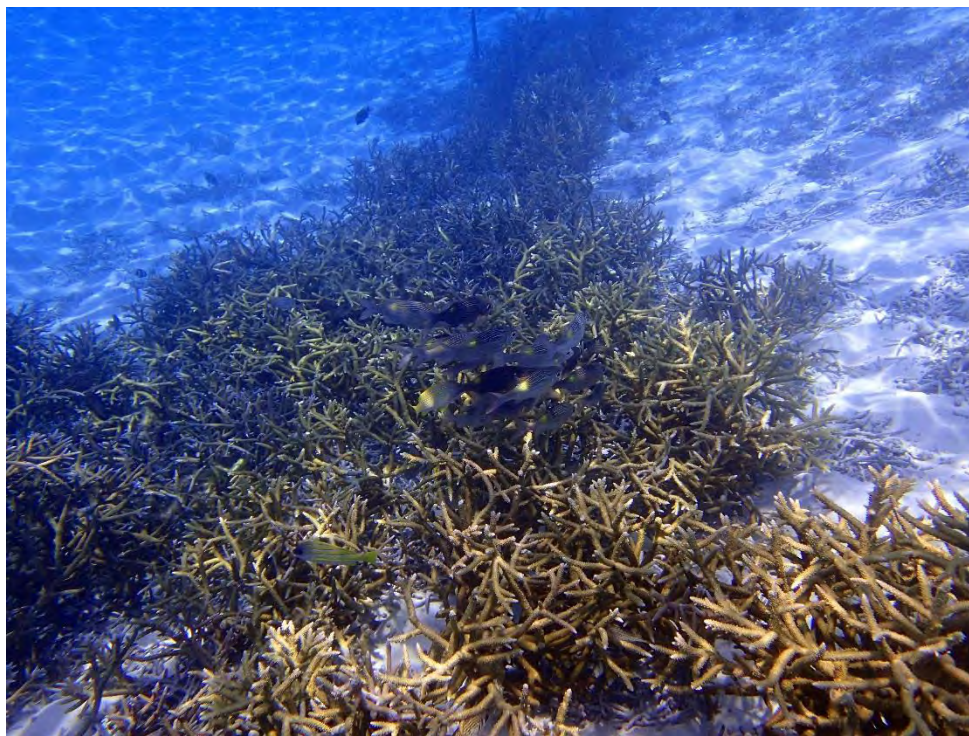
Restored areas at Veli Lagoon (yellow) and nursery areas (red).

Table 1. Total area (in square meters) of each restoration plot. The locations are shown in the figure above.

Location	Area
1	41.1
2	46.1
3	25.6
4	21.5
5	8.1
6	3.5
7	5.2
8	5.2
Total	193



Staghorn corals are the fastest growing corals within our nurseries, with 10-15 cm linear growth rates per year. Original coral fragment in April, 2018 (top left) and the same coral in Feb 2019 after 10 months (right).



One of the restored areas within the Veli Lagoon after 10 months. Over 95% of the coral has survived and it has increase in height by 20-40 cm. Some mortality of branch ends has occurred recently due to the movement of farmer fish (*Stegastes punctatus* damselfish) from dead coral patches near the water villas on the right that were buried by sand.

Dhigu



Location of nursery and restoration areas near Dhigu Island. 1. Dhigu House Reef; 2. Advanced Snorkel Area nursery and restoration site; 3. Aquabar Nursery; 4. Aquabar Snorkel Trail.

Advanced Snorkel Area nursery and restoration site

A coral nursery was first established in the deeper channel next to the Dhigu Water villas in October 2016, with additional ropes added in February and August 2017. The coral fragments have shown high survival and rapid growth rates, slightly higher than Dhigu House reef nursery and slightly lower than Aquabar nursery. While many of the corals were ready to transplant in April 2018, no corals were outplanted from this nursery due to time constraints.

During November, 2018 the Marine Biologists from Aquafanatics transplanted both coral tables and all of the ropes from the nursery frames (with exception of two ropes) to the shallow eastern edge of the Advanced Snorkel Area. Unfortunately, the majority of the species within this nursery (staghorn type corals) do not naturally occur in the habitat where they were relocated and they experienced very high rates of mortality. In addition, there was a lot of recent mortality and the survivors are continuing to decline due to an infestation of farming damselfish, snail predation and crown of thorns. Two crown of thorns were actively feeding on the outplanted corals and they were removed.

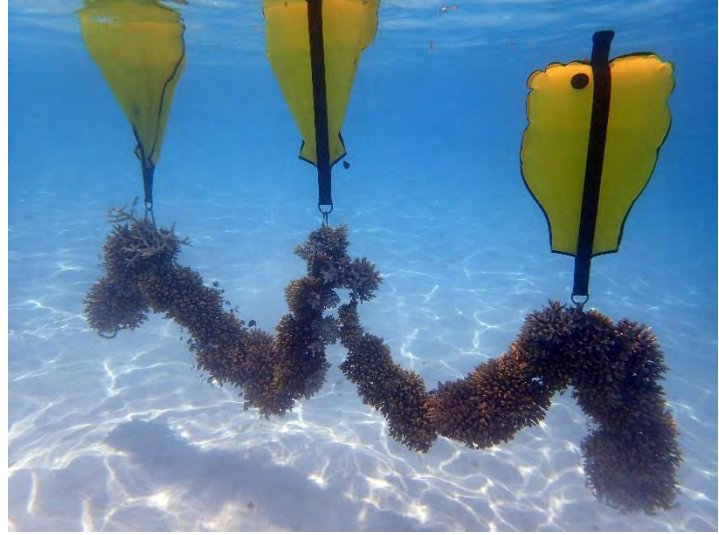


A large staghorn coral rope at the Advanced Snorkel Area outplanted in Nov. 2018. Over half of the coral has been killed by damselfish (top). A crown of thorns starfish under an outplanted coral rope. All of the white coral was eaten by this starfish in the last 24 hours.

Coral Nursery and Restoration work at Anantara Dhigu and Anantara Veli, February 2019



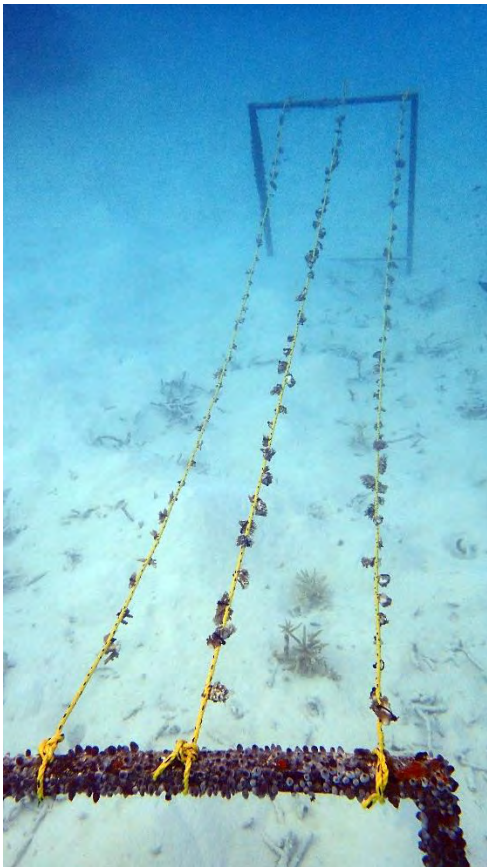
Close-up of a coral killed by *Stegastes planifrons* damselfish. The damselfish is on the right, guarding its territory (top). A rope with digitate acroporids (bottom). These are the typical species that inhabit this environment, and they have survived transplantation from the nursery.



Moving a coral rope from the nursery (top two images) to a coral bommie (bottom).

In February 2019, we transplanted the two remaining ropes on the nursery frame to a large coral bommie adjacent to the nursery, in 7 m depth. The bommie was formerly completely dead and has been transformed into a flourishing reef.

We also restocked the nursery, installing 13 new ropes containing 485 fragments.



Installing new ropes at the coral nursery (top, bottom left) and restored coral bommie (right).

Coral Nursery and Restoration work at Anantara Dhigu and Anantara Veli, February 2019

Aquabar nursery

The nursery at Aquabar was established in February 2017. There are four nursery frames each with 5 ropes. The ropes are 12 m in length (most other ropes at the other nursery sites are 6 m). This site has shown the most rapid rates of growth and over 98% survival for both first and second generation corals over 10-18 month periods. In April 2018, ten ropes from two of the four frames were transplanted to the Aquabar snorkel trail and Veli Lagoonal reef and 10 new ropes were added to these frames. In Nov. 2018, the Marine Biologists from Aquafanatics added 3 new ropes to the deep frames.



Location of the Aquabar Snorkel Trail and Aquabar Nursery. The trail is visible in Google earth imagery from 2019.

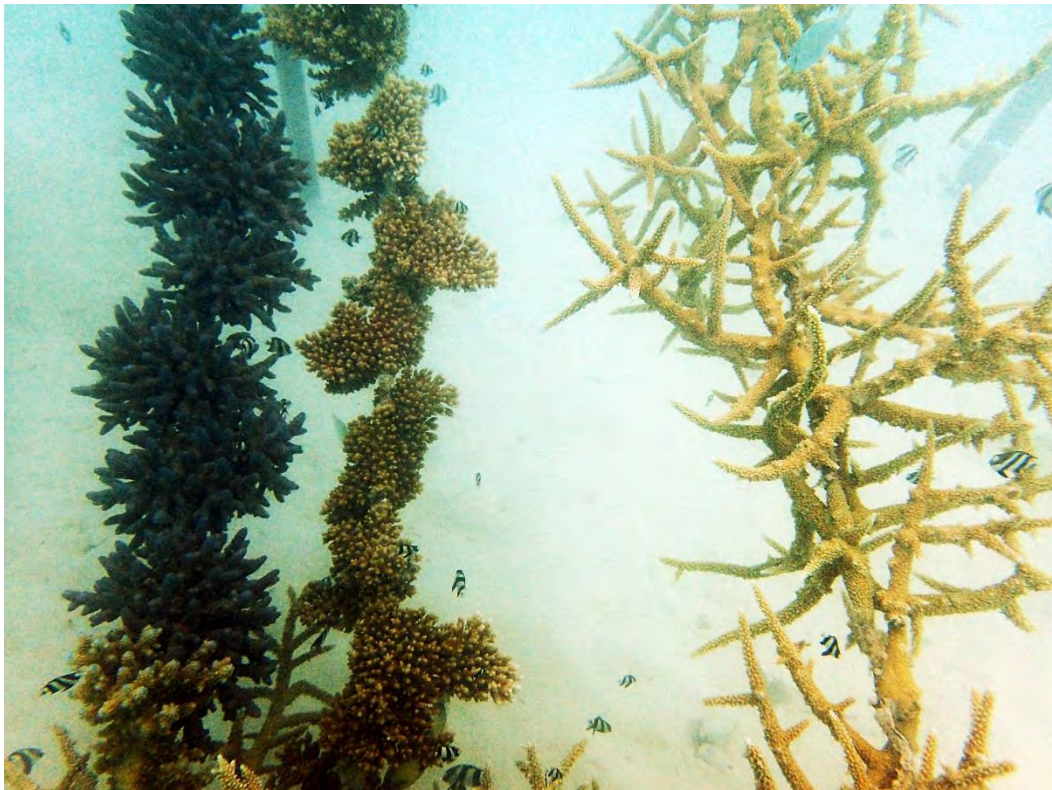
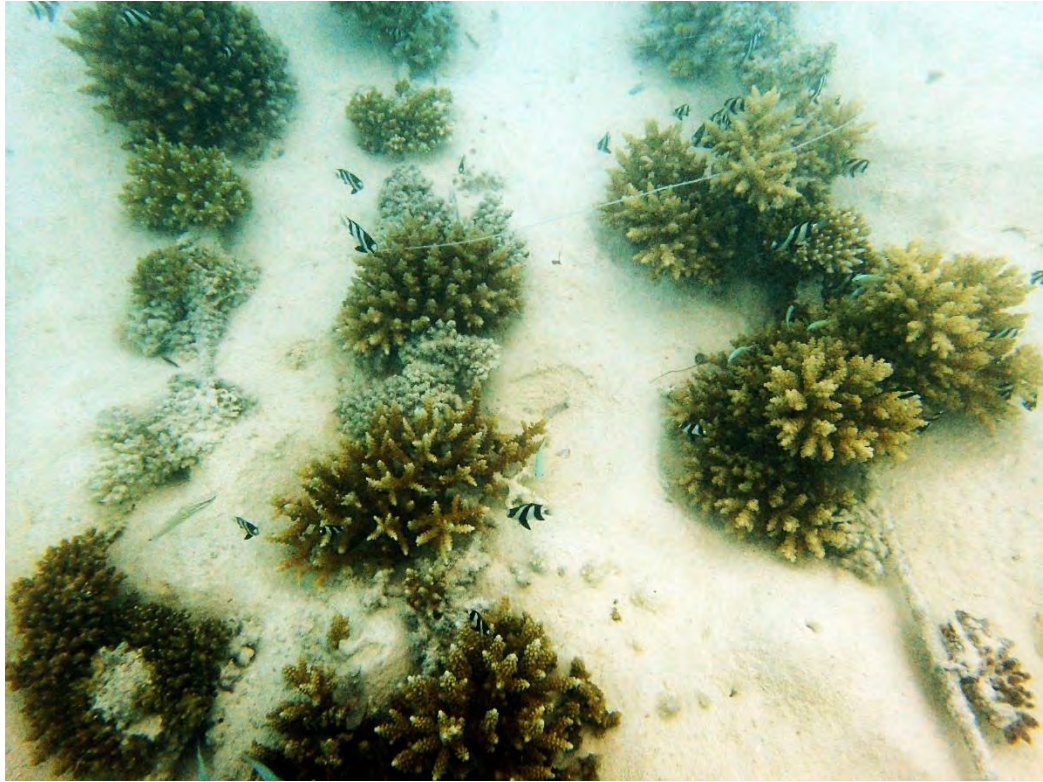
In February, 2019, the nursery was cleaned. Ropes added in April 2018 showed 99% survival and corals have grown substantially. The coral fragments attached to ropes placed on the deeper frames (established in August 2017; not transplanted in April 2018 due to restrictions on time) had grown into 30-50 cm colonies and these were extremely heavy, and sitting in the sand. All of the corals were still living, with exception of the bases of the colonies that became buried by sand. The ten ropes were transplanted to the Aquabar Snorkel trail. No new ropes were added to this nursery.



Coral ropes on deep nursery at Aquabar in April 2018. Corals are 8 months old.



Portion of a rope in Feb 2019, prior to outplanting.



Portions of two ropes outplanted onto the Aquabar Snorkel Trail. The center of the top rope was sitting in the sand and the bases of the corals had died, but the corals were still alive.

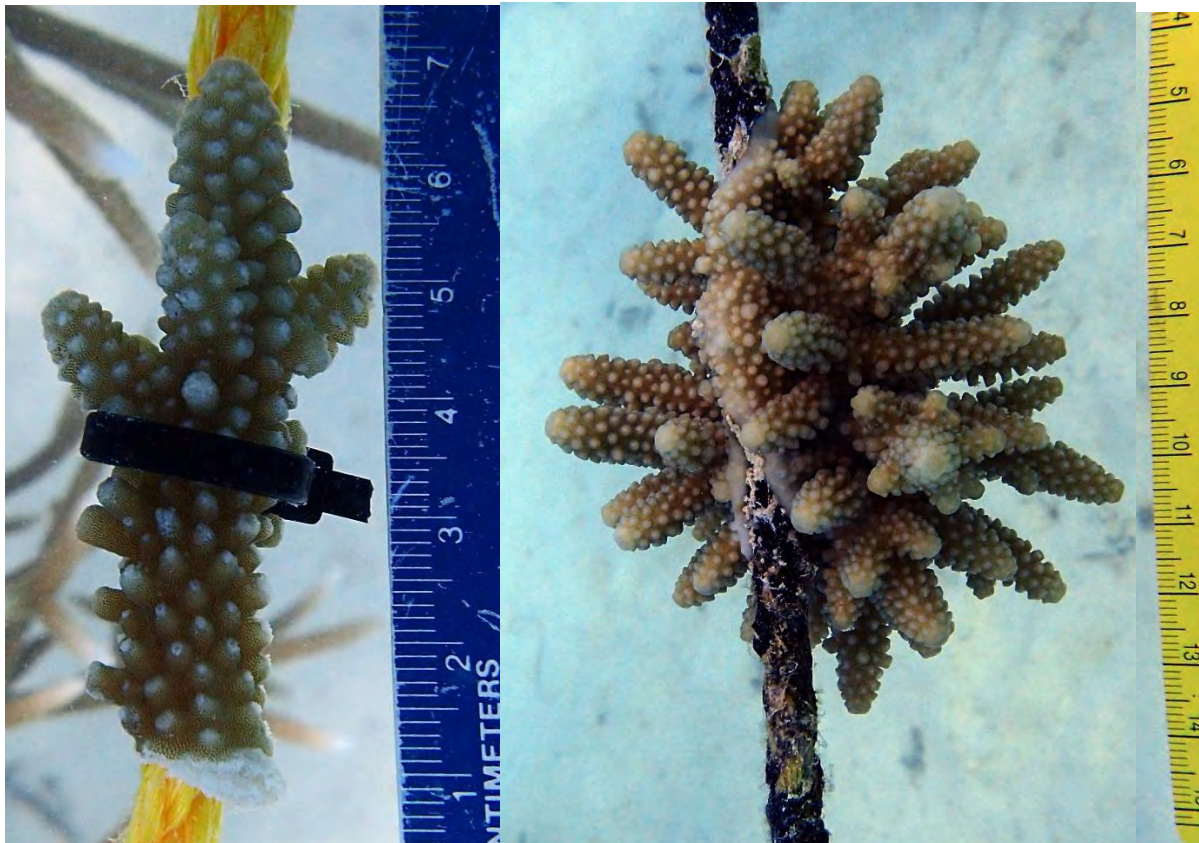


Shallow nursery frames at Aquabar. Corals were placed on these ropes in April 2018.

Coral Nursery and Restoration work at Anantara Dhigu and Anantara Veli, February 2019



Shallow nursery frame showing one rope prior to harvest and five new ropes in April 2018



Growth of a digitate *Acropora* between April 2018 and February 2019.

Coral Nursery and Restoration work at Anantara Dhigu and Anantara Veli, February 2019

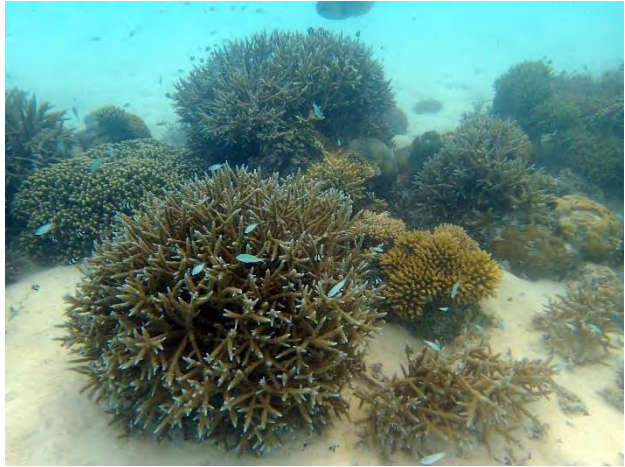
Aquabar Snorkel Trail

The Aquabar Snorkel Trail was built in stages during Feb 2017, August 2017 and April 2018. A small reef existed at this site prior to the 2016 bleaching event. There were scattered boulder corals and over 100 metal frames. By May 2016 all of the coral died and the metal frames were heavily overgrown by algae. In Feb 2017, Coral Reef CPR scientists removed the metal frames, removed all trash and debris, crown of thorns starfish and fleshy algae. Reef rubble was brought in to create a new platform for corals. An initial reef was constructed in Feb. 2017 atop this reef framework using corals rescued from sand and rubble areas, detached boulder corals, and small nursery grown acroporids from October 2016. The trail was enlarged both in width and length in Aug. 2017 and April 2018, with additional nursery-reared acroporids. The nursery reared acroporids showed unprecedented growth, with colonies increasing in diameter and height by 20-50 cm.

In Feb 2019, additional rubble and dead coral skeletons were brought in to create new substrate on the right and left sides of the trail. Ten coral ropes were transplanted from Aquabar nursery to the snorkel trail. The trail is now 45 m long and up to 10 m wide in the center.



Transporting a rope (top left), new reef framework (top right) and outplanted corals (bottom).



Aquabar Trail in February 2019. All of the branching corals were grown in coral nurseries at the Advanced Snorkel Area and the Aquabar nursery.

Coral Nursery and Restoration work at Anantara Dhigu and Anantara Veli, February 2019



The north end of the trail when first established in April 2018 and the same area in Feb. 2019.

Coral Nursery and Restoration work at Anantara Dhigu and Anantara Veli, February 2019

Dhigu House Reef

Dhigu House Reef is a protected lagoonal reef with the deepest coral nursery (8.8 m; 27 feet) that includes four nursery frames and four coral tables. This nursery contains additional *Acropora* species not found in the shallow nurseries, as well as other slower growing coral species (*Turbinaria*, *Porites rus*, *Porites cylindrica*, *Pocillopora*, *Echinopora*). The main nursery area is a sand patch surrounded by reef framework and large *Porites lobata* colonies, along with large coral heads colonized by numerous branching, plating and encrusting corals. This reef showed moderately high survival of acroporids (>40%), but there are still large rubble patches devoid of living corals and corals within several areas (*Acropora* and branching (finger corals) *Porites*).

In April 2018, we moved a selected number of ropes to two adjacent reef areas. These have shown 100% survival and considerable growth. We also replaced the ropes that were transplanted with new ropes.

A restored area at Dhigu House Reef in April 2018 (top) and Feb 2019 (bottom).



In February, 2019 we moved all other mature *Acropora* ropes and one *Pocillopora* ropes to the reef, creating three new restoration plots. Due to time constraints (a single dive) we were unable to make new ropes. The nursery now contains two original ropes with experimental species (mostly *Porites rus* and *Porites columna*) as well as three ropes that were placed into the nursery in April 2018.



Experimental corals at Dhigu House reef have all shown high survival and good growth rates. This is one example of a finger coral (*Porites columna*) during Feb 2017 (top right), Aug 2017 (top left) and Feb 2019 (bottom).

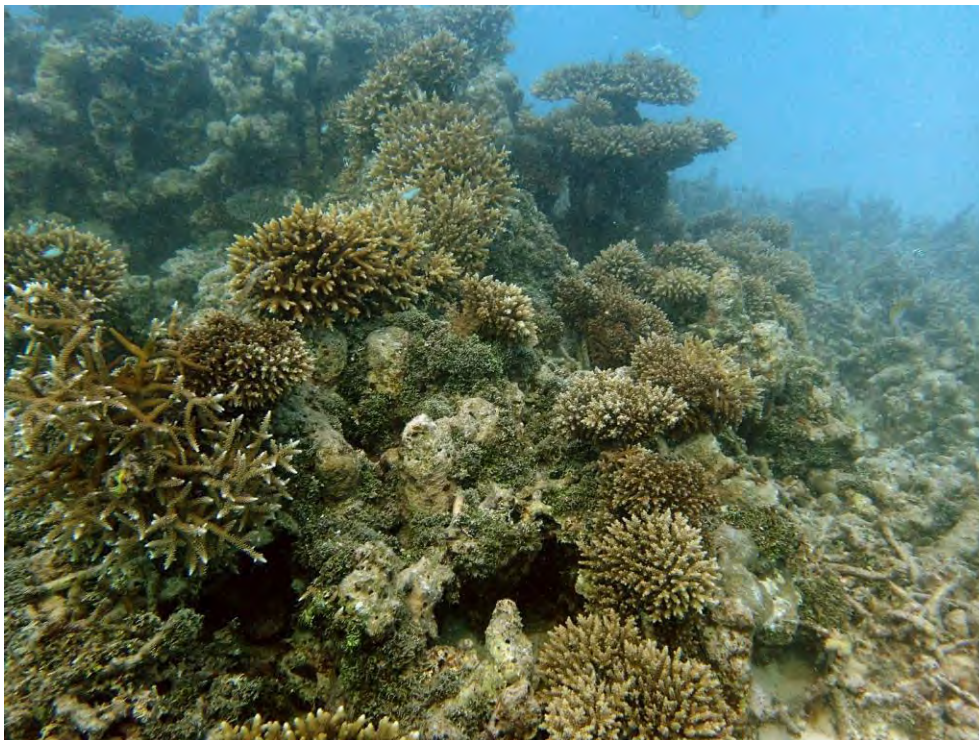


One nursery frame in April 2018 (top) and Feb 2019 (bottom). Two ropes were transplanted to the reef from this frame in April 2018 and one new rope was added. The three remaining older ropes were outplanted onto the reef in Feb. 2019.

Coral Nursery and Restoration work at Anantara Dhigu and Anantara Veli, February 2019



A restored section of the reef completed in April 2018. Corals have shown 100% survival.



A section of reef that was restored in Feb 2019 using nursery-grown corals.

Table 1. Total number of new corals added to the nurseries at Dhigu and Veli, South Male Atoll.

Advanced Snorkel		Veli	
Rope	No corals	Rope	No corals
1	37	1	41
2	42	2	43
3	39	3	42
4	40	4	45
5	27	5	46
6	39	6	50
7	40	7	35
8	39	8	34
9	37	9	34
10	45	Table 1	87
11	32	Table 2	86
12	28	Table 3	103
13	40	Table 4	101
		Table 5	100
	485		847
Grand Total			1332

Recommendations

1. Closely monitor water temperatures during April and May. If bleaching does occur, coral losses could be minimized in the key shallow areas (Aquabar Snorkel Trail, Veli Lagoon) by temporarily placing shade cloth over the Aquabar Snorkel Trail and the coral nursery frames. This is the same material used in the orchid and vegetable gardens.
2. Whenever ropes are transplanted from the nursery to the reef, create the same number of new ropes using branches that break off from the nursery-reared corals curing transport. In November 2018, the Aquafanatics Marine Biologists moved all the ropes from the Advanced Snorkel Area as well as ropes/tables from Veli Lagoon and they never replaced these. Upon arriving in February, nurseries that could have still been producing coral were devoid of ropes/tables. Due to time constraints, we were not able to fully restock the nurseries. Empty frames remain at Aquabar Nursery. Two empty tables and additional ropes can be placed at the Advanced Snorkel Area nursery. Also, because we were only able to get to Dhigu House Reef one time, we transplanted coral ropes to the reef substrate but did not have time to make new ropes.
3. Marine Biologists and Aquafanatics staff should communicate with Coral Reef CPR prior to undertaking any restoration/transplantation efforts. The large losses associated with the corals they outplanted in November at the shallow Advanced Snorkel Area could have been avoided through better placement of these ropes.
4. Time needs to be devoted to maintenance of both the restoration areas and the nurseries. Routine examinations of corals and the surrounding reef should be made to identify and remove coral eating snails and crown of thorns starfish. Frames and ropes need to be periodically cleaned to remove biofouling organisms including algae, molluscs, tunicates and sponges.
5. For any new coral ropes placed into the nursery, use braided hemp rope instead of the yellow nylon line as this is more environmentally friendly.
6. Existing ropes and tables need to be inspected at least monthly to tighten ropes, repair broken mesh, and prop ropes up off the substrate if the corals begin to touch sand.

