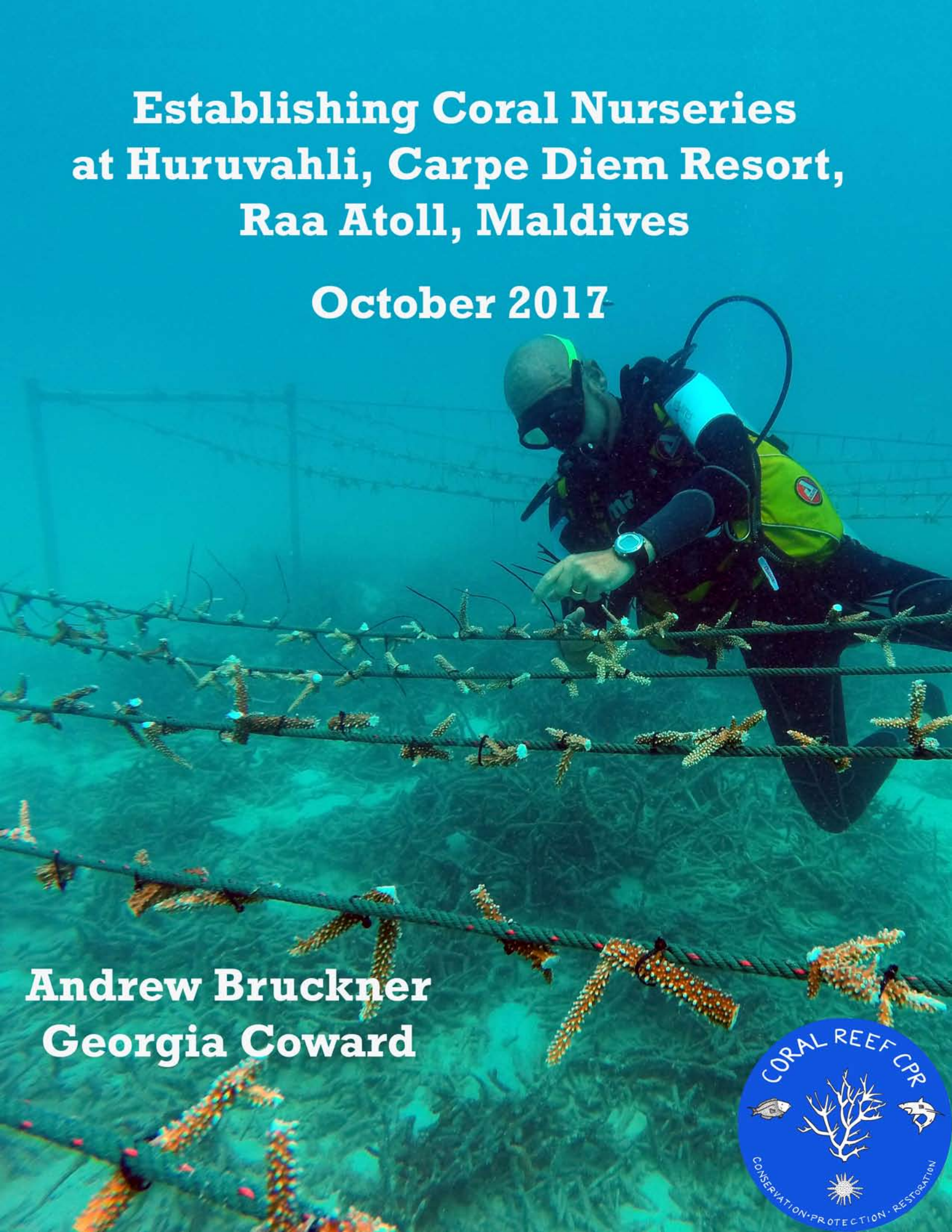
Establishing Coral Nurseries at Huruvahli, Carpe Diem Resort, Raa Atoll, Maldives

October 2017



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CORAL REEF CPR
CONSERVATION · PROTECTION · RESTORATION

Acknowledgements

Within a four week period, we were able to successfully install three large coral nurseries within the lagoon directly off Huruvahli Island. These nurseries now contain 15 nursery frmaes, each with 5-6 ropes and a total of 3,451 corals. This was a huge effort requiring field assistance from Igino (Dive team leader for the resort). We are grateful for the time Igino dedicated to this project, helping install the frames, attach corals to the ropes and conduct the initial maintenance, as well as his hard work filling SCUBA tanks for our use. Special thanks to HoHo de Farouq who assisted with all logistics. We are grateful for the field transportation provided by the small boat operators, especially Ahmed, who brought us to collection sites at a neighboring island, and also transported us out to the nursery sites whenever the boat was available. This reduced our challenging long distance swims by about half and saved considerable time. Thanks to Socrates for his organizational help and assistance with accommodations and meals and all the useful discussions on our proposed coral conservation work. We are especially grateful for the support of this project provided by Amir Mansoor and Agnes Van Linden.

One of our boat operators, Ahmed from Innamaadhoo

EXECUTIVE SUMMARY

Between October 28-November 19, 2017 Coral Reef CPR scientists installed three coral nurseries within the lagoon immediately adjacent to Huruvahli Island. These nurseries now contain a total of 3,451 corals, all in the genus Acropora. The nurseries are suspended off the bottom by 1.5-2 m, with corals attached to 10 mm braided nylon line using cable ties. The ropes are attached to a metal (2 inch pipe) frame that is inserted into the sand. Two of the nurseries were placed in a rubble field, while the third is adjacent to a patch reef in clean sand. All of the corals used in the nurseries consist of small fragments (2-8 cm length) that were rescued from lagoonal habitats surrounding Huruvahli Island, the lagoon adjacent to Kuda Villingilli, and around the supply jetty prior to its construction.

All of the corals used in the nursery were rescued colonies that would have otherwise died. They included 1) branches that had broken off larger colonies and were sitting in the sand; 2) small recruits that settled onto unstable rubble; 3) branches removed from colonies that were being eaten by corallivorous snails (Drupella) or coral eating starfish (Culcita); 4) colonies with white syndrome and black band disease; 5) corals located within the channel where dredging and sand extraction was being undertaken; and 6 juvenile corals that had settled on rock substrates in the direct construction path of the supply jetty. Branches were transported underwater, except for corals collected at Kuda Villingilli, which were transported in large buckets covered by a damp towel to minimize light exposure with frequent flushing to keep water cool.

At each nursery, the coral branches were further subdivided using coral clippers, and attached to ropes using small cable ties. Individual ropes containing single species whenever possible. A total of 16 species of Acropora were used in the nursery, including staghorn coral, digitate acroporids, bushy acroporids and table acroporids. This included all representative species found within these lagoons.

After completion of the nurseries an initial maintenance was undertaken and Igino and Farouq were provided training in necessary maintenance. It is our hope that they continue to clean these nurseries a minimum of every two weeks to maximize growth and survival.

One of the nursery frames with attached corals

RECOMMENDATIONS

A coral nursery is like a vegetable garden. It needs care to grow and survive. Routine maintenance and inspection of ropes should be done a minimum of once every two weeks.

- The ropes will become covered in sediment, especially after periods of rough water. This can be shaken off the rope and should be done weekly.
- Algae often gets trapped on the rope and branches, and algae will also settle onto the rope and dead portions of the corals. It is important to brush the algae off the rope using a toothbrush, but never touch the coral with the toothbrush. Algae on the skeletons can be picked off by hand
- Invertebrates often settle on the rope and corals, including mussels, tunicates, worms and sponges. These should be removed immediately as they can smother the corals. If sponges invade a fragment, you should remove this fragment and dispose of it, because it will spread to other fragments.
- Fragments should be carefully searched for coral eating snails. If there are fragments with white spots, this is an indication that a snail is eating the tissue. These can be tiny (<1 cm), but cause continued damage. These should be collected and removed from the site
- Occasionally fragments become diseased, especially because we rescued fragments that were already stressed. These should be removed from the ropes, as the disease can spread to neighboring fragments
- Once the fragments achieve a large size (about 1 year) it is possible to take small clippings from the fragments and attach them to new ropes
- Large corals can be outplanted onto reef habitats after 12-18 months. Staghorn corals will grow the fastest, while some of the digitate corals will take longer. Outplanting requires cementing the corals onto the reef substrate. Maintenance is critical as these are suddenly vulnerable to coral eating snails, cushion starfish, fish and other animals.

A disease spread through one rope within two days of planting, killing numerous staghorn fragments in a row. These were removed and replaced.

BACKGROUND

Between 2015 and 2016, coral reefs experienced the largest loss of corals on record as a result of an unprecedented global coral bleaching event that affected 80% of the world's reefs. In the Maldives, shallow reefs dominated by staghorn, digitate, and table acroporids sustained losses of 80-99%. Other slow growing boulder corals also bleached, although most recovered within partial tissue loss. The loss of the acroporids has negative ramifications for reefs, as these corals provide much of the habitat used by fishes and they are the species that the tourists view when snorkeling and diving.

On much of the Huruvahli Reef System the boulder corals survived the coral bleaching event, and only the branching, digitate and table acroporids died.

Fortunately, Coral Reef CPR has developed a novel technique to rescue corals and grow these into larger colonies for use in restoration aimed at speeding up the recovery of the corals that are most important for these reefs but most vulnerable to climate change and other stressors. Over the last year, we have established coral nurseries on two atolls. During the initial phase, we 1) tested different cultivation systems in an attempt to maximize growth and survival of coral fragments, 2) identified best practices to collect fragments for use in nurseries, 3) evaluated growth and survival of multiple species of Acropora in different environments and 4) tested approaches to outplant nursery-grown

corals onto degraded reefs. While we still use different methods, we found that the rope nurseries suspended off the bottom offer the most suitable conditions for coral growth and survival, and we have begun to produce many of these types of nurseries. Prior to the start of this project, our nurseries contained over 9,000 corals, with survival of over 95% after one year, and many have increased in size by 30-50X and are ready for transplanting to surrounding reefs.

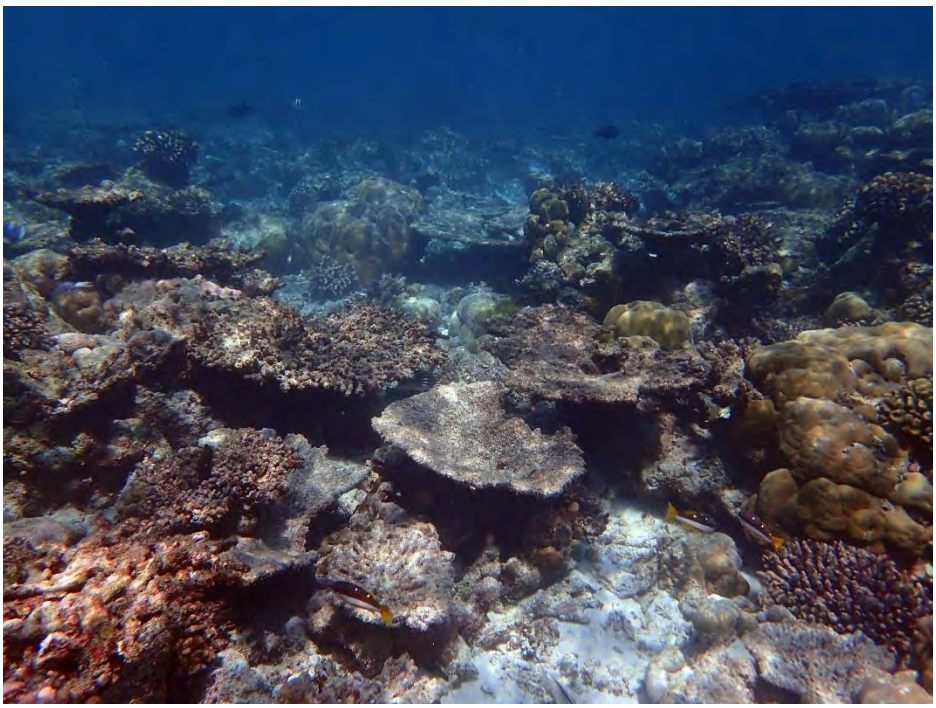
One of our largest challenges has been finding suitable locations to establish nurseries, as the environmental conditions vary between islands. While we can set up successful nurseries on the outer reef, these tend to show slower growth and run the risk of damage during periods of rough sea. We can also grow corals in very shallow (<1 m) water close to shore, but these are likely to be affected by intolerable high water temperatures and high UV radiation during extreme calm periods. Our best choice for nurseries is within sand/rubble channels adjacent to the island (including artificial channels that resulted from the construction of the island, or shallow protected lagoonal habitats.

We also have to select sites with few natural predators and minimal land-based stressors (sewage discharge, industrial waste, high boat traffic and anchoring etc.). We prefer rope nurseries as these are elevated off the bottom making access by coral eating snails and starfish unlikely, increasing water flow, and reducing potential for burial by sand.

A storm broke one of our tables on an outer fore reef, and a crown of thorns starfish (COTS) moved in and ate the corals growing on the plastic mesh

Another **challenge we've had on outer sites** is an infestation of tunicates and other encrusting invertebrates on our ropes and corals. As long as there is routine maintenance, these can be removed before causing harm.

Carpe Diem Resort property provides a unique and ideal location for coral nurseries. The island is surrounded by a reef system and this reef extends around a central lagoon. This lagoon is protected from waves and currents seen on the outer reef, and it is shallow (3-7 m depth), making it an ideal location for coral nurseries. As long as the discharge of grey water, sewage and boat fuels remains low or absent, this environment should support thriving coral nurseries. Furthermore, the lagoon (and adjacent lagoonal area at Kuda Villingilli) are bleaching refuges, as many species of Acropora survived within the lagoon. Acropora was formerly common on the outer exposed reef systems, but over 85% of the acroporids died in these areas during the 2016 bleaching event, and the only remaining colonies of these species are found on the deeper part of the fore reef slope and at the base of the reef.



Some parts of the shallow fore reef at Hurvahli was once dominated by *Acropora,* and now only the *Porites* colonies remain.

METHODS

Three locations varying distance from the island were chosen for the establishment of nurseries. We selected rubble fields for two, as this would reduce the amount of reflection of UV off the bottom, and if corals break off the ropes they are likely to fall into the rubble and continue growing. One of our nurseries is also in a clean, sandy area. It was selected to be adjacent to a very large submerged patch reef, as this could offer guests a unique diving experience combining a natural reef with a coral nursery. Further, our intention was to use these corals initially to restore the adjacent patch reef, making a healthy coral garden for guest enjoyment. All nurseries were marked with a float.

Location of coral nurseries at Huruvahli, Raa Atoll. The imagery used is pre-construction and does not show resort.

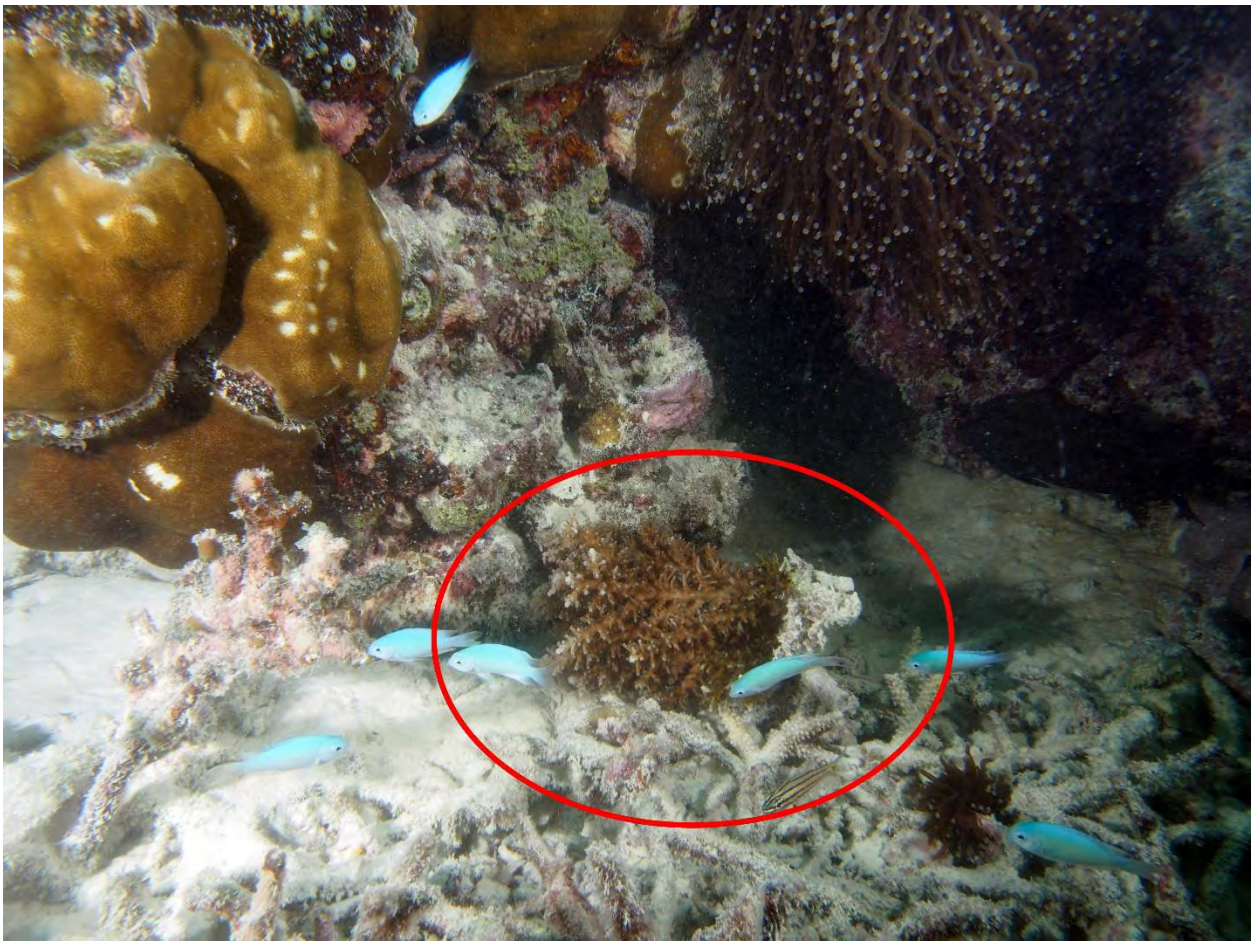
Each nursery contained four to five sets of nursery frames (four at the nearshore nursery) with 5-6 ropes per frame. The metal frames consisted of two 2m pipe connected by a horizontal 1.5 pipe at the top (forming a "staple") with a support bar across the base. The staples were pounded manually into the substrate a minimum of 0.5 m and nylon ropes were extended between each pair of staples. The ropes were 5-6 m in length and each held 33-63 corals. Differences in numbers were due to the size of the fragment and the species.

After installing the frames, we searched the surrounding lagoonal area for corals. Fragments were placed into large plastic buckets and transported underwater to the nursery site. At the nursery, one of us used coral clippers to separate the corals into individual branches, 2-8 cm long. This person then handed the fragments, one at a time to the other two divers to attach to the ropes using cable ties. All cable ties were pre-inserted into the rope on land to facilitate attachment of coral. After all of the ropes on one frame were filled with coral, one diver cut the cable tie ends, so that it was flush with the fragment. A second diver had to ensure each fragment was securely attached to the rope. After completing an entire nursery, every fragment was photographed to have a baseline of its size and shape for future monitoring. A temperature meter was also placed at the nurseries to obtain long-term water temperature data.

Two divers attaching coral fragments to the ropes.

A completed nursery frame consisting of staghorn coral. All of the corals are attached, but the cable ties have not been clipped.

Igino is clipping the cable ties.



One of the corals collected for use in the nursery. All of the fragments collected in the lagoon had naturally broken off an attached colony (as seen above), or were being eaten by corallivorous snails, buried by sand, on unstable rubble, or affected by disease.

One of the corals that was rescued from the site where the supply jetty was constructed. We removed all the small digitate and branching acroporid corals in the vicinity of the excavators to avoid their mortality.

Table 1. Corals at Nursery 1

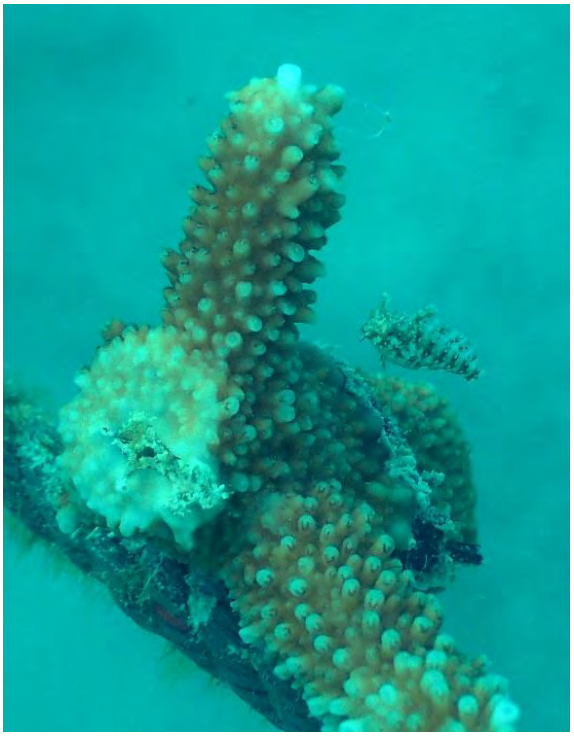
Frame	Tag #	Rope	No corals
1	177	1	54
1		2	41
1		3	43
1		4	50
1		5	53
1		6	50
2	561	7	57
2		8	55
2		9	44
2		10	42
2		11	54
2		12	50
3	572	13	45
3		14	53
3		15	57
3		16	53
3		17	52
4	563	18	46
4		19	41
4		20	42
4		21	44
4		22	44
TOTAL			1070

The coral fragments showed rapid growth beginning to accrete new tissue and skeleton over the cable ties within two weeks

Section of a frame showing fragments of staghorn coral (*A. muricata*). This species has nearly disappeared from reefs in Raa Atoll following the 2016 bleaching event.

Table 2. Corals at nursery 2.

Frame	Tag #	Rope	No corals
5	570	23	56
5		24	33
5		25	35
5		26	37
5		27	51
6	567	28	46
6		29	37
6		30	36
6		31	58
6		32	56
7	566	33	54
7		34	53
7		35	42
7		36	39
7		37	39
8	568	38	55
8		39	40
8		40	52
8		41	51
8		42	52
9	569	43	55
9		44	47
9		45	41
9		46	40
9		47	49
TOTAL			1154



The nurseries were also colonized by juvenile fishes within a matter of days and we expect the fish community to continue to grow

Table 3. Corals at nursery 3

Frame	Tag #	Rope	No corals
10	574	48	52
10		49	48
10		50	51
10		51	49
10		52	57
11	573	53	63
11		54	60
11		55	58
11		56	59
11		57	61
12	564	58	45
12		59	47
12		60	48
12		61	47
12		62	38
13	565	63	43
13		64	45
13		65	45
13		66	50
13		67	45
14	562	68	45
14		69	45
14		70	40
14		71	42
14		72	44
TOTAL			1227

Photoplate (opposite page): Examples of fifteen species of the Acropora fragments within the coral nursery (left to right, top to bottom). *Acropora millepora, A. loripes, A. granulosa, A gemmifera A. divaricata, A. tenuis, A. muricata, A. samoensis, A. grandis, A humilis, A. echinata, A. latistella, A. straita, A. nobilis, A. aculeus*