Transforming a degraded reef: The Aquabar Snorkel Trail

before

Dhigu, South Malé Atoll

March 2017

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after

EXECUTIVE SUMMARY

During March 2017, Coral Reef CPR created a snorkel trail and large coral nursery off Dhigufinolhu Island (Anantara Dhigu Resort & Spa) between Aquabar and Sea Fire Salt Restaurant. The project involved the removal of all existing metal "adopt a coral frames" and other trash located in the deep channel, creation of a natural coral rubble framework, transplantation of corals, soft corals, colonial anemones, false corals, sea anemones and giant clams onto the framework, attachment of the corals to the framework using non-toxic underwater epoxy, and the creation of an associated coral nursery. The snorkel trail is 33. 5 m long and 1-2 m wide, along with a large damselfish algal garden, and a midwater rope nursery containing 1,312 coral fragments of *Acropora* attached to 20 ropes. A total of 415 scleractinian corals, 23 sea anemones, 7 leather coral colonies, 3 soft corals and five giant clams were transplanted to the snorkel trail. Branching corals and anemones were brought in with their associated anemonefish, chromis, and humbugs. All the corals and other organisms used in this trail were rescued, and would otherwise have died.

Fig. 1. The new Aquabar Snorkel Trail photographed from Sea Fire and Salt Restaurant.

These corals and other invertebrates were collected from non-reefal habitats, areas undergoing sand extraction, reef flat communities that were exposed at low tide and lagoonal patch reefs. The corals and anemones were likely to die if they had not been salvaged, as they included specimens that were partially buried by sand, corals infested with coral-eating snails or affected by disease, detached colonies that were rolling around on the bottom and were abraded, and corals that were being overgrown by fleshy algae.

Upon completion of the restoration, a total of 46 species of corals (843 individuals) and 59 species of fish could be found on the snorkel trail. Corals included very large boulder corals (*Porites, Lobophyllia, Pavona, Goniopora*) up to 50 kg in weight, branching corals, table corals and submassive corals, including numerous large branches of staghorn coral. Staghorn coral branches were also transplanted into the damselfish algal gardens among the dead staghorn skeletons and thick mats of algae to test the survivorship of corals inside and outside of damselfish territories. In addition to the resident damselfishes, humbugs and anemonefish, a large proportion of the fishes were juveniles that use this habitat as nursery areas, along with visiting schools of predatory species and herbivores, moray eels, and sting rays.

Fig. 2. The start of the snorkel trail, in 2 m water depth.

The coral nursery consisted of twenty 9-10 meter long ropes suspended between metal "staples" with 50-75 small coral branches attached to each rope using cable ties. Twelve species of *Acropora* were placed into the nursery. All of the coral branches were collected within the lagoon from sand extraction sites, fields of staghorn rubble, and from dead branching and boulder coral skeletons, and only included small branches, 2-5 cm in length that were injured, diseased, affected by coral-eating snails, being buried, or in shallow water exposed at low tide.

Acknowledgements

Coral Reef CPR received assistance from engineering, the launch section, hotel staff and management and the dive center for various aspects of this work. Engineering fabricated the metal staples used in the nursery and made descriptive signs for the snorkel trail, and provided the nylon rope used for the coral frames. The launch section provided a small boat ("whaler") and a driver that assisted in collecting and transporting the dead coral skeletons and rubble used to create the framework of the snorkel trail. Hotel staff and management assisted in the removal of the metal "adopt a coral" frames from the beach. Gauderic Harang also helped with the coral nursery by pounding the metal "staples" into the sand. Aquafanatics provided SCUBA tanks, and transported these daily by small boat from the dive center to the arrival jetty. The hotel staff also helped transport dive gear and tanks between Aquabar and the arrival jetty using a luggage buggy. A lot of hard labor went into the creation of the snorkel trail, and it couldn't have been accomplished without the assistance described above. We are also grateful for the support provided by the General Manager, Coetzer Deysel, who recognized the need for an easily accessible educational snorkel trail at Anantara Dhigu.

Fig. 3. The new Aquabar snorkel trail.

Background

The east side of Dhigufinolhu Island (Anantara Dhigu Resort & Spa) fronts an extensive shallow (0-1.5 m depth) sand flat approximately 400,000 square meters in area that extends from the beach near Aquabar to the reef flat, 400-800 meters eastwards. Adjacent to the island, beginning north of the Spa and continuing almost to the water villas is a narrow channel, 2-8 m deep. This is man-made, resulting from the annual excavation of sand to replenish the neighboring beaches. This channel experiences high tidal flow that alternates in direction. Water flow affects the turbidity of the channel, with visibility dropping on a daily basis from 20-30 m to a few meters in the deeper parts of the channel. The bottom is mostly sand, with patches of dead coral, rubble and a few scattered living corals present in February 2017. All of the coral skeletons and living corals were transplanted into the site several years ago, and over 100 "adopt a coral" rebar frames were placed on the site. Until April, 2016 a considerable amount of the coral was living, and frames had attached branching corals that were 20-100% live, intermixed with dense turf algae and macroalgae.

This reef system became severely bleached in April, 2016, and by May 99% of the corals attached to the frames had died, and 90% of the other transplanted corals had also died. The metal frames were rusting and were covered in thick filamentous algae and cyanobacteria. The primary survivors consisted of a small "ring" of coral located in the deepest part of the channel, seaward of Sea Fire, Salt restaurant. Many of the corals were also being buried by sand and most of the reef fish had disappeared.

In March, 2017 Coral Reef CPR conducted a restoration of the reef system, and established a large coral nursery. All of the trash and rusting metal frames were removed, skeletons of coral and rubble were placed on the sand to create a reef framework, and corals were planted on top of this framework.

Fig. 4. Location of the Aquabar snorkel trail and coral nursery.

Restoration Approach

The restoration of the undersea habitat in front of Aquabar and Sea Fire Salt Restaurant involved ten main components.

- Initially, all of the dead coral skeletons attached to the metal frames were removed, collected together and placed in a large pile at the southern end of the restoration site. The rusting frames were then removed from the water. Many had been partially buried and were encrusted with dense filamentous algae and large fronds of cyanobacteria.

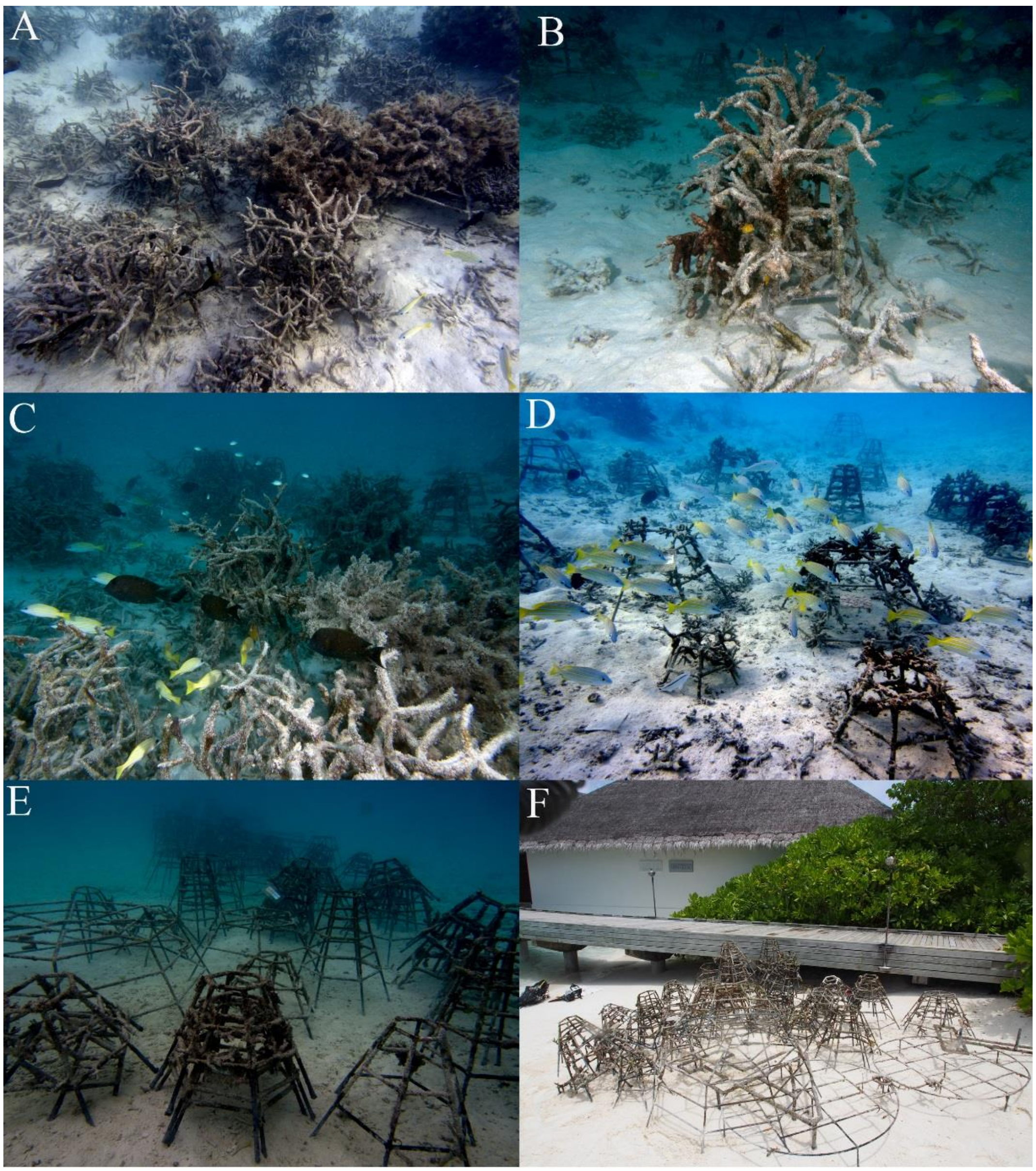


Fig. 5. Adopt a coral frames at Aquabar. A-D. Rusting frames in place, covered with dead skeletons and algae. E-F. All coral was removed from the frames, which were carried into shallow water and onto the beach for disposal.

- Concurrently, all of the trash (clothing, footwear, plastic bottles, bags, kitchen items, chairs, a trash can, buckets, signs from the metal frames, and other debris) was collected and disposed of on shore. The existing coral skeletons and few remaining live corals were carefully searched for coral-eating pest species including (*Drupella*) snails and (*Acanthaster*) crown of thorns starfish and these were removed along with the fleshy algae and cyanobacteria.

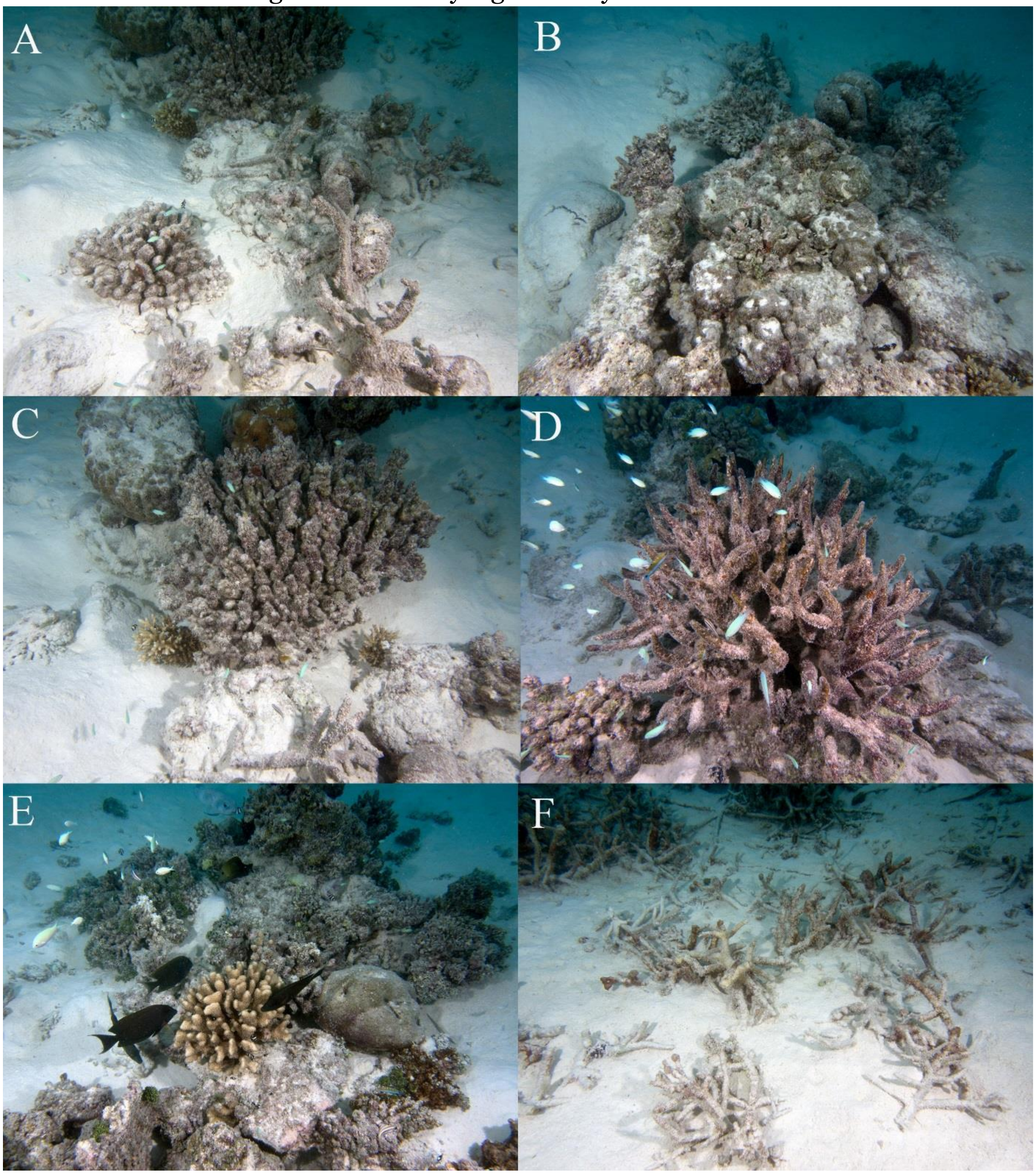


Fig. 6. Habitat at Aquabar prior to restoration. Over 95% of the coral was dead; scattered living corals (primarily small *Pocillopora* (E), small *Acropora* (C) were still living, but most coral was dead, buried and/or covered in algae.

- Numerous boat loads of coral rubble, including dead boulder corals, table corals, plates and other coral skeletons were collected from the reef flat, channels and other areas adjacent to the reef and brought into the site. The rubble was placed on top of the sand and the existing dead coral skeletons in a long, meandering path that was 1-2 m wide and extended north/south for 35 m. This was the framework for the snorkel trail.

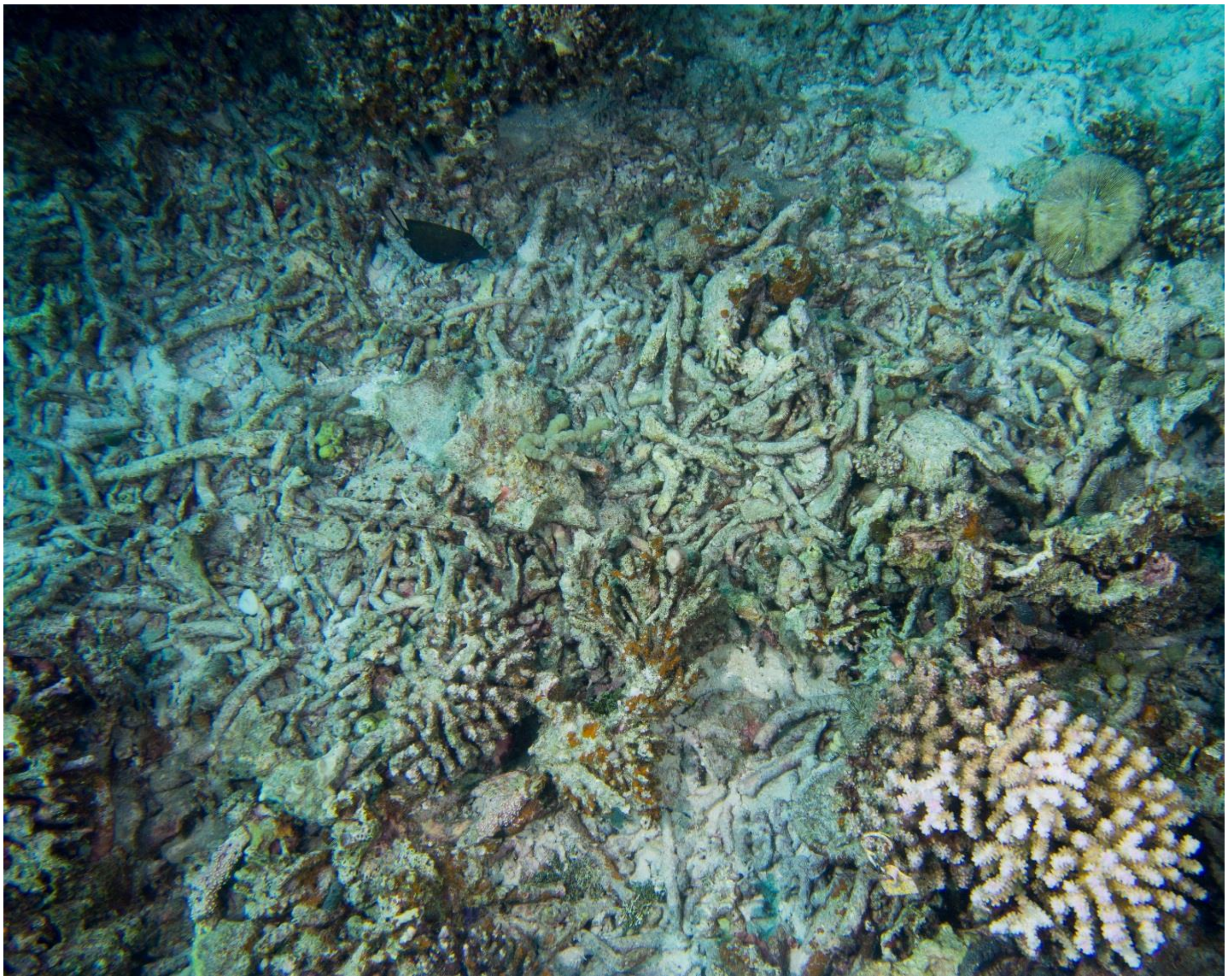


Fig. 7. Rubble was collected from sandy areas, rubble fields and lagoonal reefs and used to create a framework for the snorkel trail. The rubble provided substrate that was elevated off the surrounding sandy bottom. A combination of skeletons of staghorn coral, table corals, boulder corals, plating corals and thick branches were used.

- The surrounding habitats were searched for corals, anemones, soft corals, giant clams and other benthic invertebrates that were likely to die. These were collected, transported to the restoration site and placed on top of the rubble framework. All of the living organisms were transported underwater, using lift bags for the larger organisms, or placed into buckets containing sea water. Aerial exposure of corals was avoided.

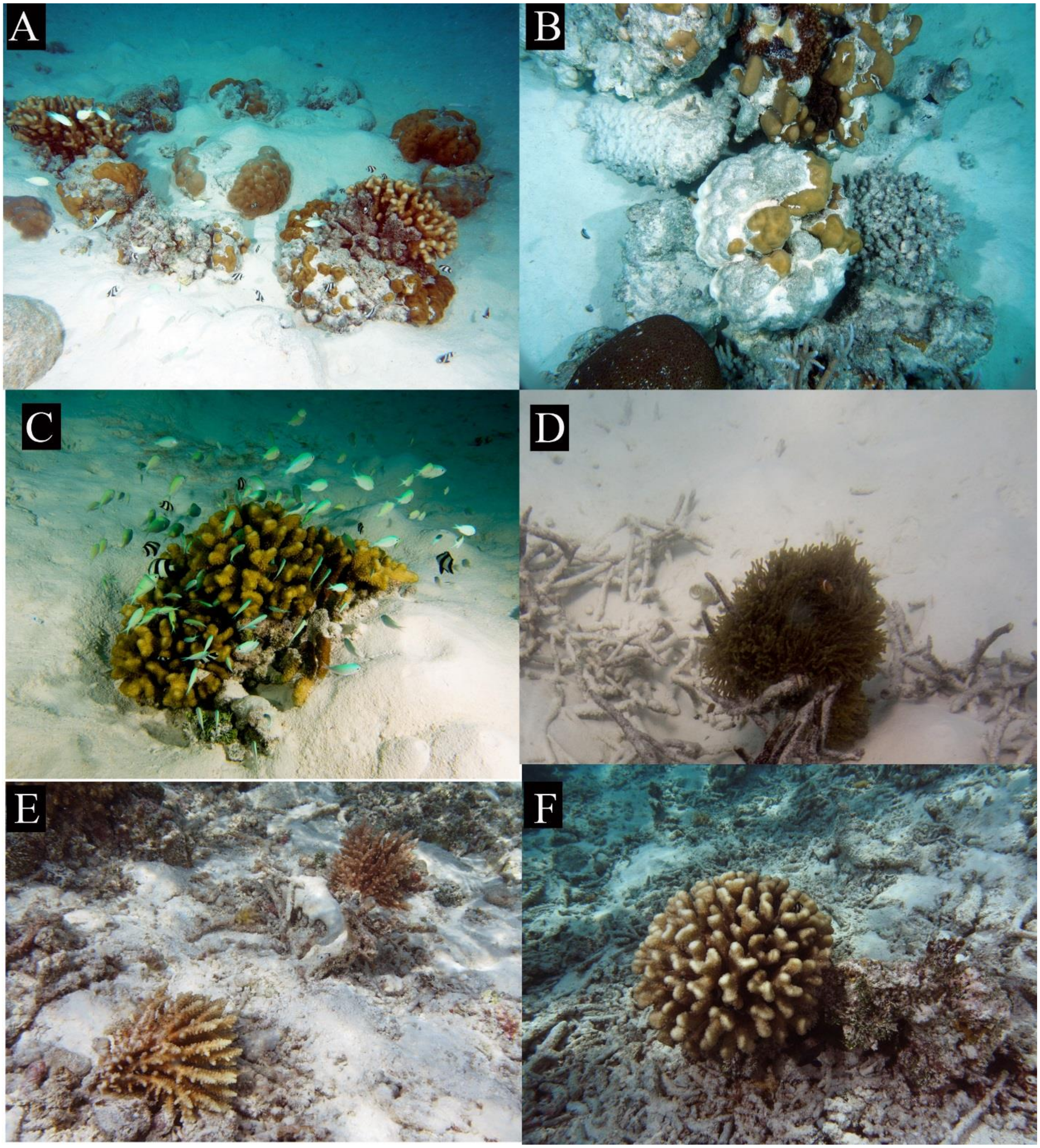


Fig. 8. Examples of corals collected and placed on the Aquabar Snorkel Trail. A. Partially buried corals located in sandy lagoonal areas were salvaged. B. Several Porites colonies that were extracted from the sand and are in place on the snorkel trail. All of the white skeleton was formerly under the sand. C. A *Pocillopora* colony with an assemblage of humbugs and chromis that was located in a deeper channel in the lagoon. The coral was being smothered by sand; no other corals were surviving in the vicinity. D. The magnificent anemones and their associated clownfish were collected from patches of dead staghorn coral rubble. E. Broken and detached corals were found within rubble and dead coral areas. F. A large *Pocillopora* colony located on the reef flat among rubble and sand.

- All of the corals and other organisms were carefully examined and any pest species (crown of thorns starfish and coral-eating snails) were removed.

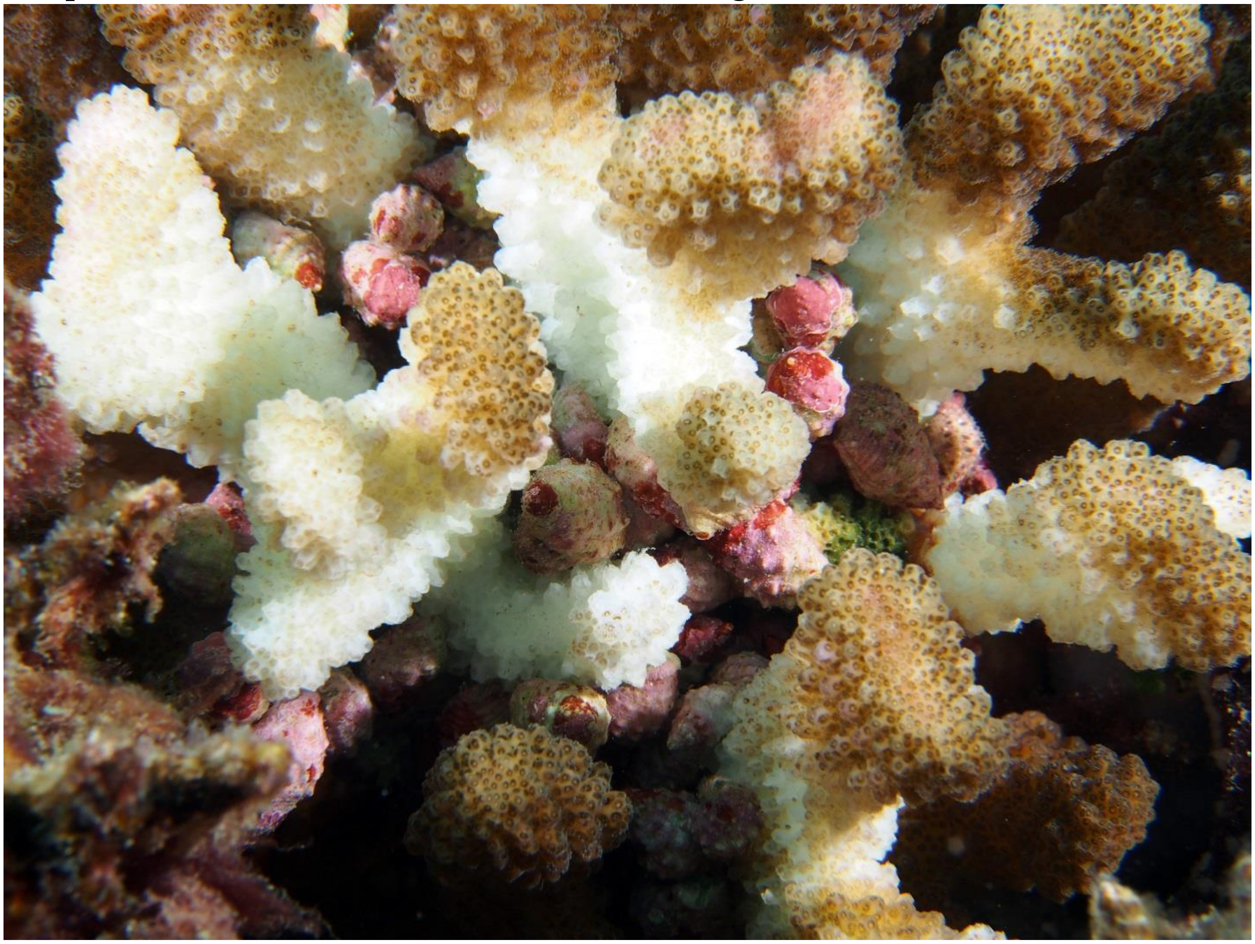


Fig. 8. A colony of *Pocillopora verrucosa* infested with *Drupella* snails. The snails have eaten the bases of the coral branches and only the branch tips remain living. This coral was collected, all snails were removed, and placed in the snorkel trail.

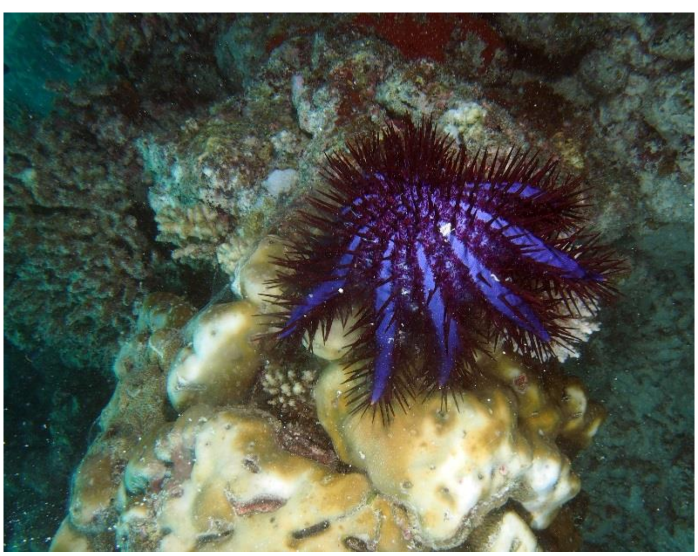


Fig. 9. The lagoon, including patch reefs, advanced snorkel area, and rubble habitats around Veli and Dhigu water villas were searched for crown of thorns starfish and these were removed. A total of 14 starfish were found in shallow lagoonal areas off Dhigufinolhu Island. If left in the lagoon, they are likely to travel to the snorkel trail in search of food.

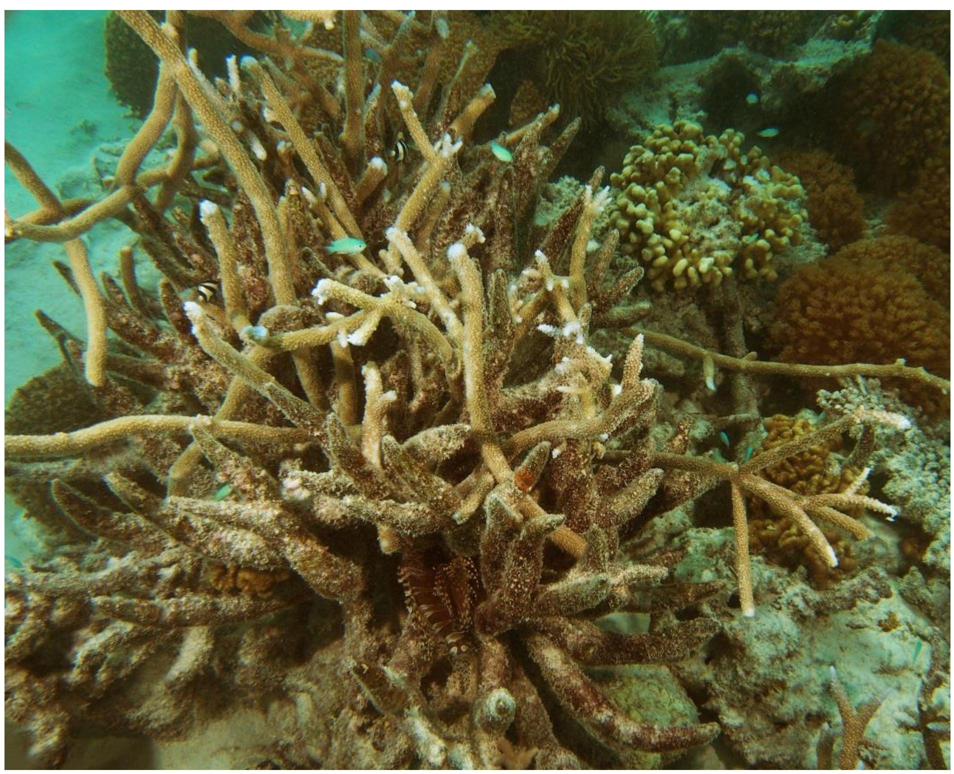
- All of the dead staghorn coral skeletons removed from the frames were piled up around damselfish territories to create high-relief habitat and a damselfish algal garden. Living branches of staghorn coral were attached to the skeletons to test their survival.

Fig. 10. Damselfish algal gardens created from dead staghorn skeletons removed from the metal frames. This structure provides habitat for resting schools of blue-striped snapper (top). Thirty branches of living staghorn coral were attached to dead skeletons using cable ties to evaluate growth and survival (bottom).

- The corals and other invertebrates were distributed among the rubble to create the snorkel trail. Similar species were placed together to form breeding clusters. Small branches, plates, and boulders were secured in place using non-toxic underwater epoxy.

Fig. 11. A cluster of free living *Goniopora stokesi* placed along the snorkel trail to mimic their natural distribution and enhance reproductive success.

Fig. 12. Branches of staghorn coral were cemented to dead coral skeletons using non-toxic underwater epoxy.



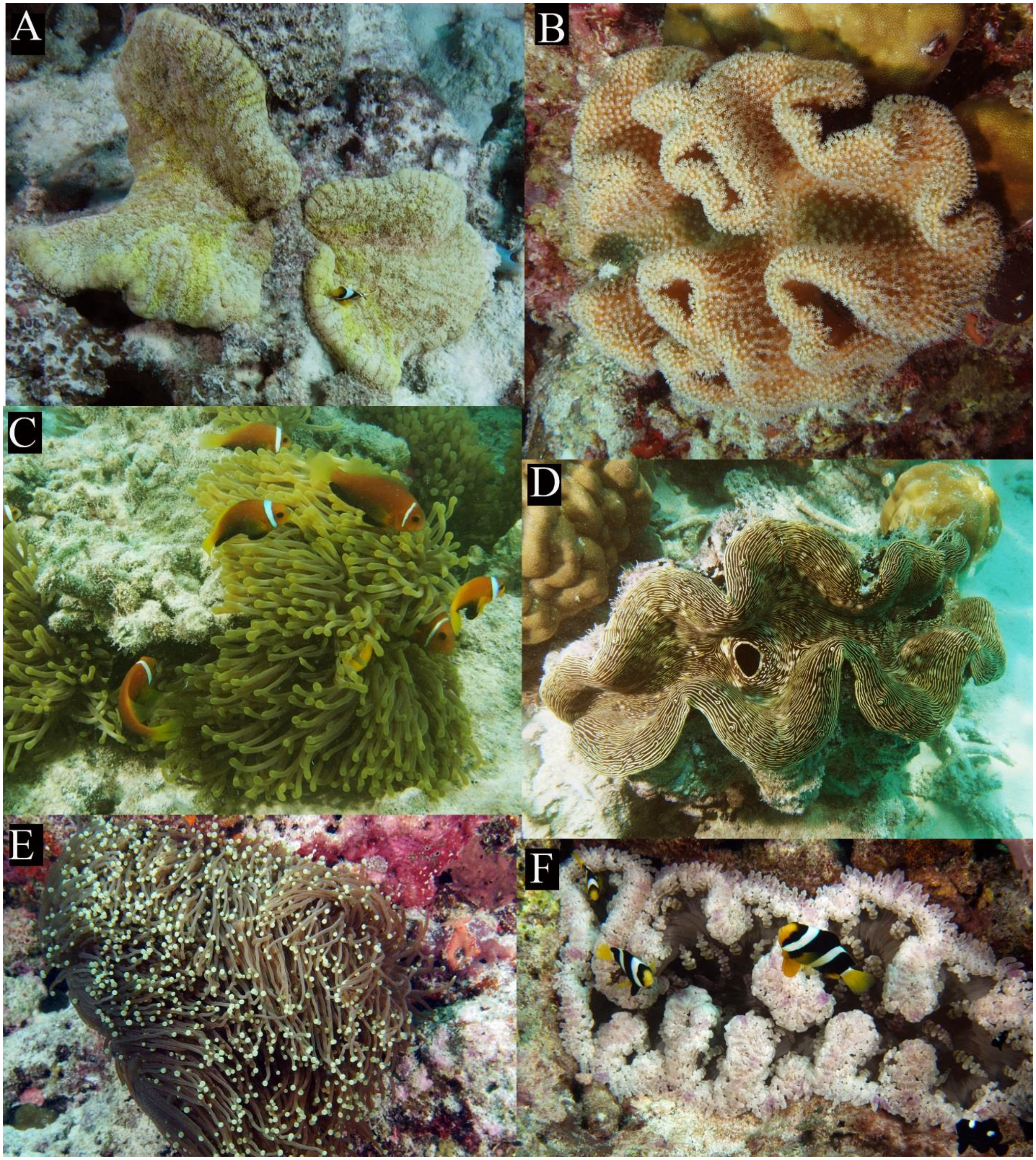


Fig. 13. Images of some of the invertebrates and fish found along the Aquabar Snorkel Trail. A. *Stichodatcyla gigantea* with Clark's anemonefish B. *Sarcophyton* leather coral C. *Heteractis magnifica* sea anemone with Maldivian endemic clownfish D. Giant clam E. *Euphyllia glabrescens* stony coral F. Clark's anemonefish among a sea anemone.

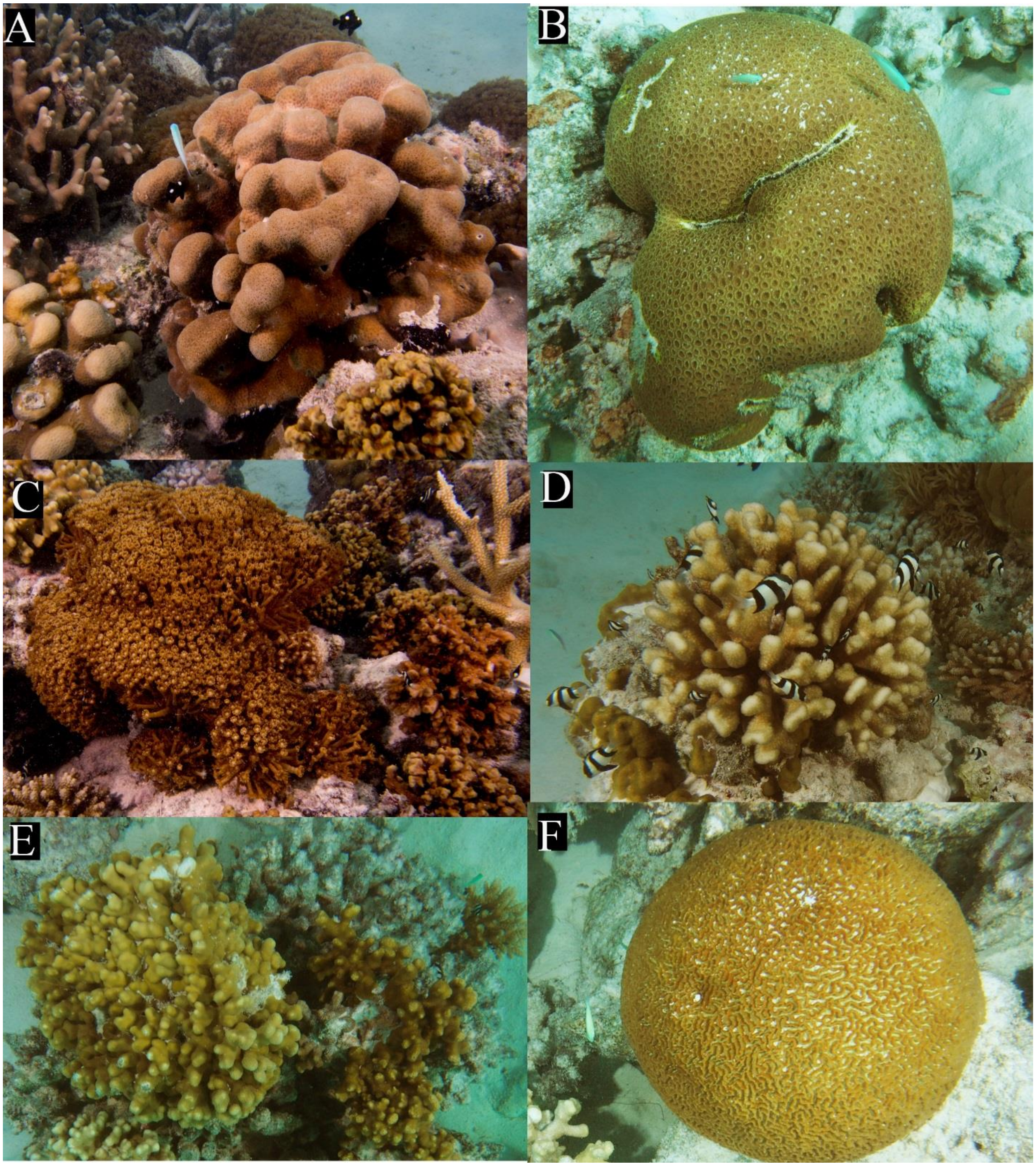


Fig. 14. Respresentative stony corals located on the Aquabar Snorkel Trail. A. *Psammocora digitata*. B. *Favia favus* star coral. C. *Goniopora lobata* flowerpot coral. D. *Pocillopora meandrina* cauliflower coral with humbug dascyllus. E. *Porites cylindrica* finger coral. F. *Platygyra daedalea* brain coral.

- Informative signs were inserted into the sediment along the snorkel trail to mark 1) damselfish algal lawn, 2. beginning of the snorkel trail, 3. clownfish and anemone patches, and 4. coral nursery.

Fig. 15. One of the wooden signs at the Aquabar Snorkel Trail.

- Eight large (1.5 m wide by 2 m tall), heavy metal "staples" were pounded into the sand in pairs, each staple separated by 10 m. Nylon ropes (5 per pair of staples; 20 total) were extended between the staples and secured with knots and cable ties. Small cable ties were inserted through the braids in the rope (50-75 per rope). This was the framework for the coral nursery.

Fig. 16. Steel angle iron "staples" were inserted inot the sand in pairs, each separated by 10 m (right) and five nylon ropes were secured between the staples (left).

- Small branches of *Acropora* were brought to the coral nursery and attached to the ropes using the cable ties. The cable ties were secured to the fragment and rope, and the ends of the cable ties were cut off.

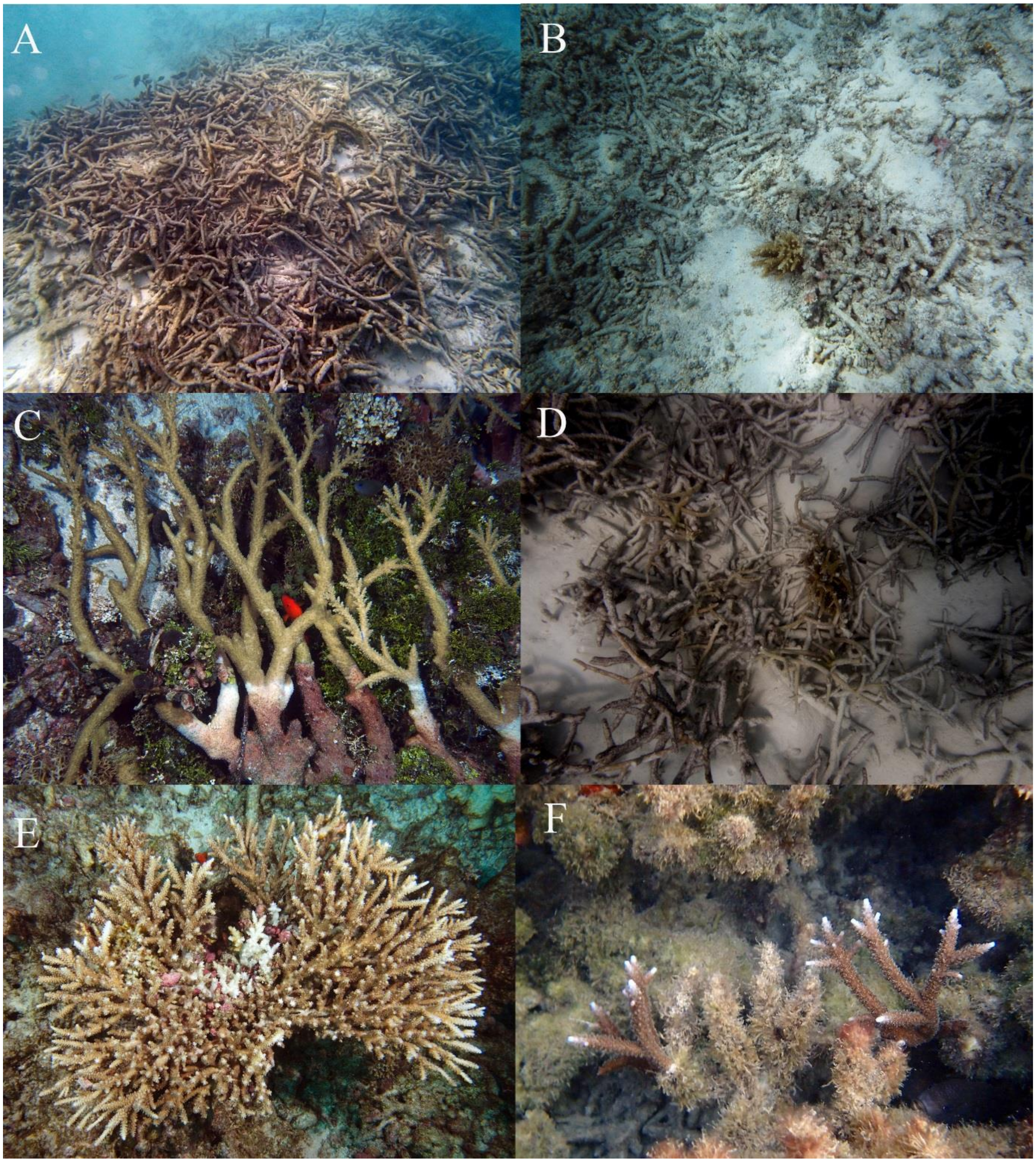


Fig. 17. Examples of the collection sites and corals used in the coral nursery. A. A sand extraction site with piles of dead staghorn coral rubble. Recruits and juvenile colonies settle on the rubble, but they have a very short lifespan as they are overturned and buried during the process of sand extraction. B. An unstable rubble field with a small *Acropora* colony. C. Colony of *Acropora* with white syndrome. If left alone, the disease will progress up the branch tip, killing the coral. The branch ends are clipped from the colony. D. Staghorn branches living among a largely dead staghorn thicket. E. A large table coral that is infested with *Drupella* snails. The snails are all removed and small branch ends are collected. Most of the colony is left in place, to allow it to regrow. F. *Acropora grandis* branches being smothered by thick turf algae. The branch ends are removed for use in the nursery.

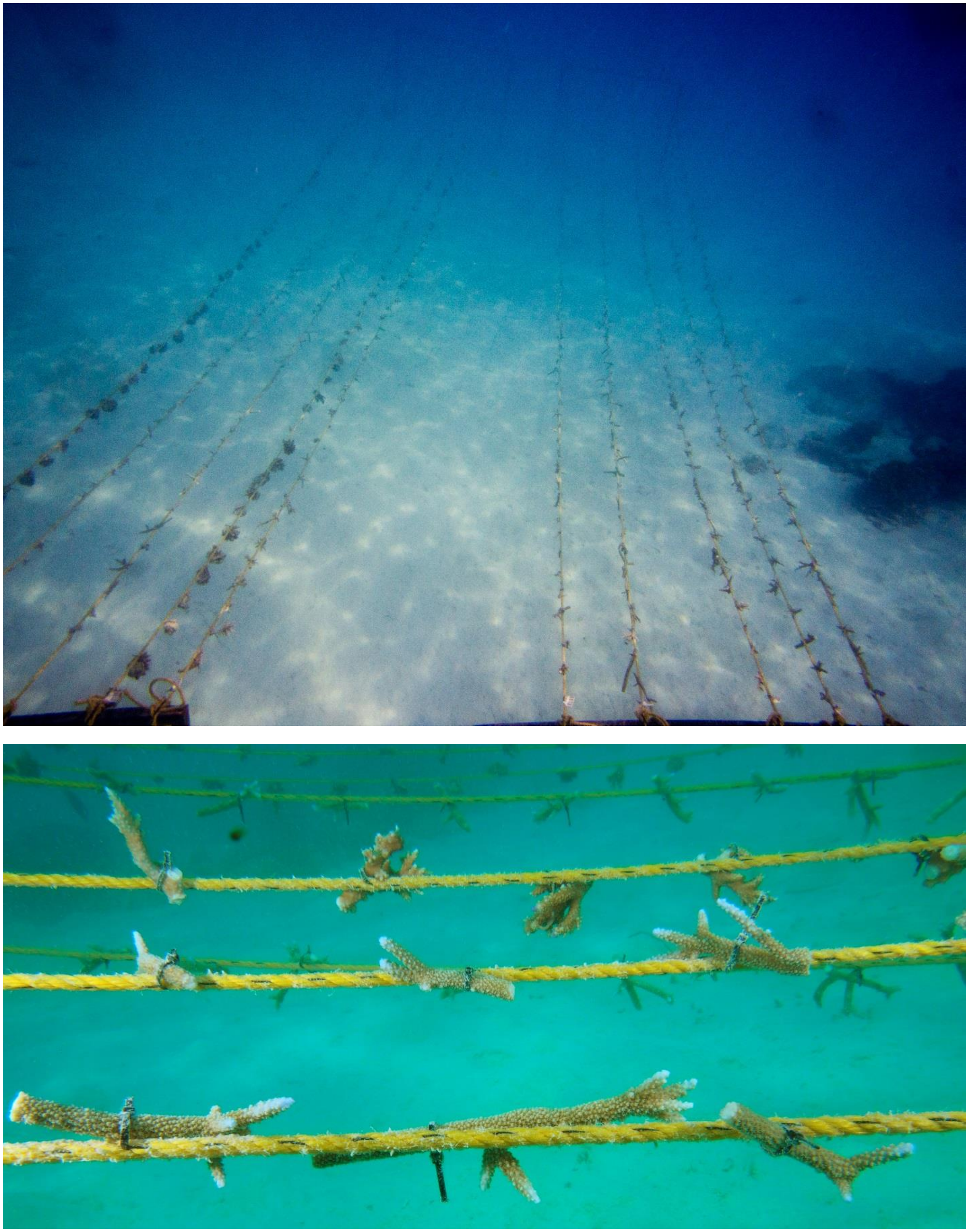


Fig. 18. Two of the rope nurseries (top). Each contains five 10 m long ropes with 50-75 coral fragments per rope. Close-up of a section of the ropes showing the attached fragments (bottom). Twelve species of *Acropora* were attached to ropes.

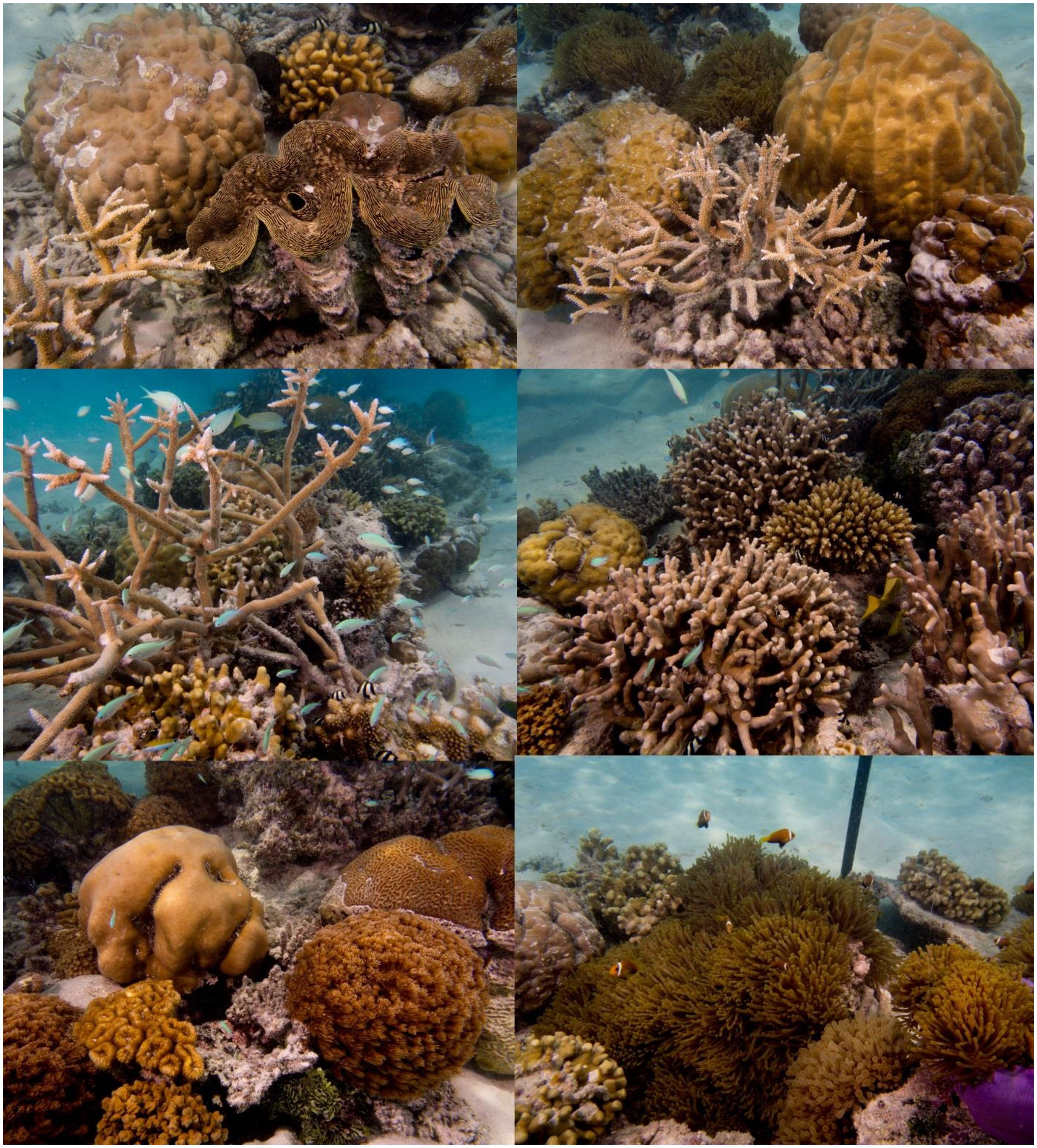


Fig. 19. Scenes from the Aquabar Snorkel Trail.

The new snorkel trail and coral nursery

Importance of the work

The HARP Program has demonstrated that it is possible to restore a dying coral reef which has attracted a diverse assemblage of reef fish. The new snorkel trail was created solely using corals that were rescued and would otherwise die. The corals were 1) being buried by sand, 2) removed from sites where sand extraction was occurring, 3) salvaged from very shallow water where they would have bleached and died due to aerial exposure at low tide, 4) detached corals that were rolling around on the reef, covered in abrasions and being smothered by sand and algae, and 5) collected from sites with high numbers of coral eating snails and starfish (crown of thorns starfish). Many of the corals were infested with coral predators, and these were removed, saving the corals from inevitable death. In addition to salvaging the corals, we removed numerous crown of thorns starfish that were progressively moving close to shore in search of food (putting the guests at risk of injury from the venomous spines).

To make the base of our reef we used the dead coral rubble that formed after the bleaching event in 2016. This is basically recycling dead corals to form the base of our brand new reef-this creates a natural structure.

In addition to the snorkel trail, we created the largest rope nursery in the Maldives which contains more coral fragments than any other nurseries we have established around Dhigu to date. There are over 1,300 small coral fragments attached to ropes that will grow up over the next 18 months into small "bushes". Once large enough, these corals will be used to expand the size of the snorkel trail, creating a larger reef that supports a more diverse fish community. This will be a continual process, where we will replace the coral nursery fragments after the larger coral bushes we grew are transplanted on to the reef.

Benefits to the environment

Shallow nearshore lagoonal areas are critical nursery areas for reef fish. Fish require the structure of corals for protection, shelter, habitat, behavioural processes (e.g., cleaning) and food. Without structure, fish (including stingrays and juvenile sharks) will leave the area and local extinctions of species becomes highly likely.

This location in front of Aquabar formerly had a lot of branching coral, but 99% died in April/May 2016. The structure created by these corals was now crumbling and the few surviving corals were being buried by sand. All of the dead skeletons were being smothered by fleshy algae, which was preventing natural recovery of the site. In addition, there were about 100 metal "adopt a coral" frames placed throughout the site. All of the coral that had been attached to these frames had died, and the frames were rusting. The iron from the metal frames is very bad for tropical reef systems, as it promotes the growth of seaweed and inhibits settlement and survival of baby corals.

Our coral nursery consists of small branches of *Acropora* coral which is the most diverse type of coral found in the Maldives and most important because it forms large bushes, trees and tables that provide high relief habitat for other species. This coral was the most abundant coral in the Maldives but it suffered >90% mortality throughout the Maldives during the bleaching event in April/May 2016. All of the corals we used were rescued and would otherwise have died. They include juvenile colonies attached to rubble in areas where dredging and sand extraction occurs, as well as broken branches that were detached by snorkelers, divers and strong wave action from larger colonies, and corals that were dying due to coral-eating snails and coral disease. We take very small clippings and attach them to ropes suspended in the water column (much like clippings removing from plants). The nursery creates new habitat that attracts fish, and it also maximizes survival and growth, as the fragments are elevated off the sea floor preventing burial and being eaten by coral predators.

The new snorkel trail and coral nursery provide much needed habitat and structure for the fish and invertebrates in the area. Within just a few days, over a 1,000 fish of 60 species had moved into the reef. A cleaning station established at the beginning of the trail which is now visited by a school of batfish, dart fish, unicornfish and other species every day!

Benefits for guests

Provides an easily accessible snorkel site that is close to shore and in shallow water, hence it is suitable for all swimming abilities and ages. This new reef trail illustrates what a healthy, complex coral reef should look like. This is the only location around the resort that now contains a high amount of living coral, as other options for snorkelling (Veli water villas, advanced snorkel area and snorkel island) were badly damaged by the bleaching in 2016 and less than 1% of the bottom now has living coral. It also contains more living coral than any snorkel site that can be accessed by boat within 15-20 minutes from the resort. This also highlights the CSR initiative of Anantara and their passion to improve the environment surrounding the resort.

Prior to the restoration, the site looked like a graveyard of coral skeletons littered with trash and rusting metal frames. It was very unattractive and not natural.

Environmental dangers we face with bleaching / dying of corals and why we need to continue this work

The Maldives lost up to 90% of the branching, table and foliaceous corals and 20-50% of the boulder corals during the April/May mass bleaching event. This is the second time in the history of the Maldives that this has occurred (the first was in 1998). It took over 10 years for the reefs to recovery from the 1998 event, and some locations still had not recovered. Natural recovery relies on a successful coral spawning event, with baby corals settling onto damaged reefs and growing up to adults. Corals grow very slowly (boulder corals grow about 1 cm per year, while branching and table corals grow 6-20 cm per year), so natural recovery, if there are sources of baby corals will take a decade or more depending on the type of coral. Coral spawning occurs once per year

(February/March in the Maldives), but alarmingly there was no spawning during 2017. Also, because so much coral was lost, the few remaining corals are critical for the recovery of these reefs, but these are under attack by crown of thorns starfish and snails.

The HARP Program is working to eliminate these predators, to save the remaining corals. These corals are the strongest corals found on the reefs, as they were able to withstand bleaching in 2016 and therefore are more likely to survive future bleaching events. Without continued support for this effort, we will lose the corals that are most critical to the persistence of these reefs.

Furthermore, we are collecting and growing corals that are slowly dying and are subject to great stress due to human activities (e.g. dredging and sand extraction). Our coral nurseries and restored reefs are being produced without damaging intact corals or healthy reefs.

Table 1. Snorkel trail facts and figures

Reef length	33.5 m
Number of corals transplanted	415
Approximate number of coral species	46
Approximate number of fish species	60
Approximate number of fish on the reef	900
Number of corals in nursery	1312