Restoring the underwater habitat at SEA Restaurant Anantara Kihavah

Phase III
November, 2017

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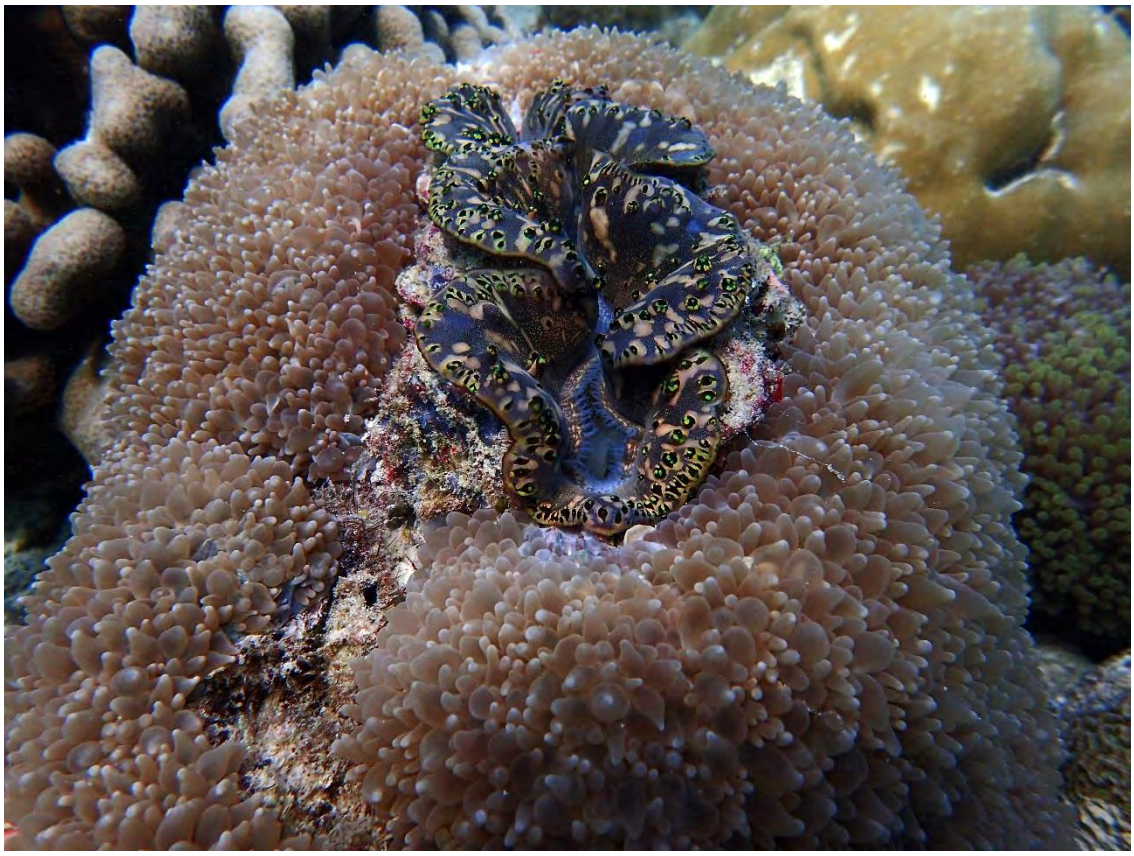
CORAL REEF CPR
CONSERVATION · PROTECTION · RESTORATION

Acknowledgements

During the Phase III restoration at SEA Restaurant, we built a new reef off the right side of the restaurant, adjacent to the drop-off. This was the most challenging effort completed here to date, as we transformed a completely barren sand/rubble habitat to a thriving reef that is much larger in area than any previous efforts. Because we rely on corals and other animals that are broken, detached and overturned, thereby minimizing damage to the reef, we have had to swim further from the restaurant in search of the corals. Concurrently, access to the restoration site was more difficult, as a major construction of a new over water bar was underway and the dive buggy used to transport gear was broken. During previous phases, we had a lot of assistance with the staff of Elements. While several dive masters did provide assistance when available, the marine biologist was only able to help early in the mission due to a severe injury. Nevertheless, the restoration was extremely successful.

We are grateful to the support provided by Elements, including SCUBA gear and especially the in-water assistance by Flora Blackett (the resident Marine Biologist), Sonja Müller, and Marsha. Special thanks to Liezl and Christine (Sales and Marketing) for assistance in organizing project logistics. We are also grateful for the support provided by the General Manager, Dylan Counsel, and his continued dedication to the conservation and restoration of marine habitats surrounding Anantara Kihavah.

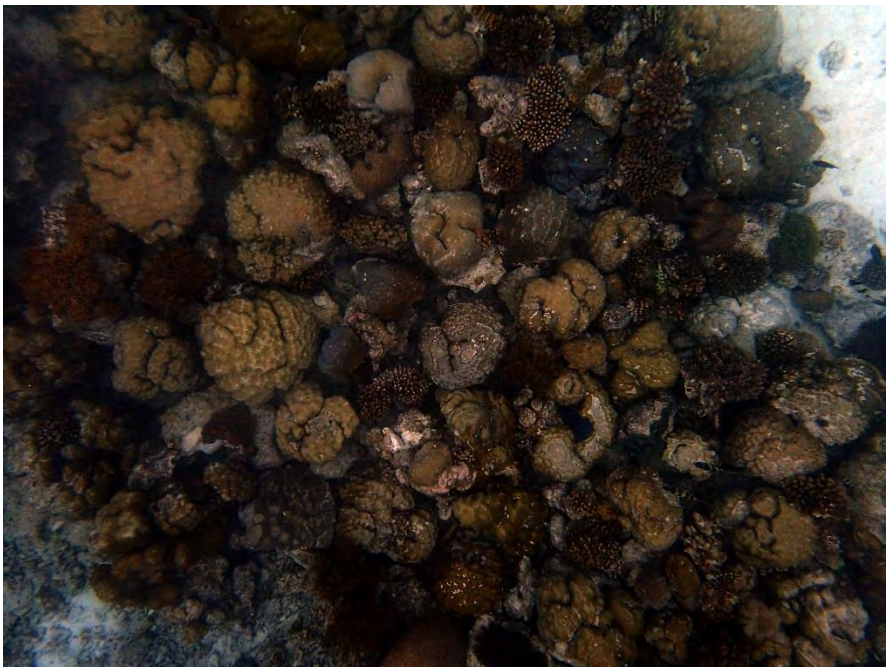


One of the more unusual corals (pineapple coral; *Physogyra*) and a giant clam transplanted onto the new reef

Executive Summary

Coral Reef CPR scientists completed Phase III of the SEA Restaurant restoration between November 18 and December 12, 2017. The restoration involved six aspects: 1) Creation of a reef framework on the sand adjacent to the drop-off; 2) sourcing of corals, sponges, anemones, soft corals and other invertebrates and relocation to SEA: 3) maintenance of shelf area through removal of predatory snails and starfish, removal of any dead corals, replacement of dead corals and filling of empty spaces with new corals; 4) construction of a new reef on the east side of the restaurant; 5) removal of coral-eating cushion starfish (*Culcita* spp.) from the reef slope, reef terrace and shallow back reef environment surrounding the resort; and 6) maintenance and expansion of the coral nursery ropes on the east and west side of the restaurant.

Over the three week effort we were able to create a diverse, vibrant reef system on the west side of the restaurant, maintain and fill out the two areas constructed in February and August, remove coral-eating snails and starfish, and expand the coral nurseries near the wine cellar windows. The reef system has attracted a diverse fish community as well as lobsters, crabs, sea urchins and other motile invertebrates. There are now several endangered species that inhabit the reef system around SEA including a giant (1.3 m) camouflage grouper, stingrays, nurse shark, and a hawksbill turtle, and numerous pelagic species.



A section of the new reef photographed from above

The outcomes include:

- 77 square meters of new, thriving reef habitat was created
- 308 stony corals, 39 leather corals, anemones and soft corals, and 5 giant clams were used to create the reef
- 55 species of stony corals, 15 species of anemones, false corals, blue coral and leather corals, 4 species of bivalves and 2 sponges are now found around SEA
- 665 coral eating cushion starfish were removed
- 1066 coral fragments are being grown in the SEA nursery, including 484 new fragments added in December 2017.

Introduction

SEA Restaurant is part of *SEA. FIRE. SALT.* is a signature overwater and underwater dining experience located underwater, adjacent to Kihavah House Reef at Anantara Kihavah Villas, Baa Atoll, Maldives. The restaurant faces south, towards the Kudarikilu Kandu channel. This narrow channel separates the northern and southern "sub-atolls" that make up Baa Atoll.

The restaurant sits on a sand terrace at 5-6 m depth, sandwiched between the fringing reef system that surrounds Anantara Kihavah. In order to place the restaurant at this site, a wide channel was excavated into the main reef system, removing reef rock from the landward edge of the reef flat to the reef slope, covering an area of about 30 m wide by 40 m long. On either side of the restaurant the reef flat now slopes to the sand substrate; this slope runs perpendicular to the main reef system, and consists predominantly of large boulders. There was no living coral on the reef slope on either side of the restaurant prior to undertaking the restoration. On the seaward edge of the restaurant, facing south, the natural reef starts about 3 m from the windows, forming a wall that slopes to 50-60 m. The top of this wall is primarily hard bottom (dead limestone coral skeletons) closest to the drop, and rubble and sand extending towards the restaurant.

During Phase I, we restored the reef system adjacent to the windows, on the platform surrounding the restaurant. We removed all the existing rebar "adopt a coral" frames that were on the platform and in the surrounding reef, as all the corals attached to these had died and the frames were covered in algae and rusting. We also removed the dead coral skeletons from the platform and translocated living corals, anemones, and other invertebrates, positioning them around the windows to create a natural reef system. We also transplanted new corals onto the metal grid that extends from the window on the east side towards the reef slope. A total of 489 stony corals (43 species), 129 anemones (four species), 41 soft/leather corals (6species), and 21 giant clams were used in this phase. Most of the corals were small to medium sized (15-30 cm diameter).

During Phase II, we built a new reef system on the slope adjacent to the metal grid. We built up a reef framework so that the corals on the grid would form a continuous reef system extending to the reef flat at 2 m depth. The reef extends along the slope to the north and south a total distance of 8 m, covering an area of 47 square meters. A total of 340 stony corals, leather corals, anemones and soft corals (37 species) were transplanted onto this reef including a predominance of large boulder corals that were 30-100 cm diameter and up to 100 kg.

During Phase III we created a new reef system off the west side of the restaurant, at the edge of the drop-off, at 5-6 m depth (Fig. 1). This report summarizes the activities undertaken during Phase III.

Fig. 1. Location of the three Phases of the coral restoration projects undertaken at SEA restaurant.

Phase III

1. Creation of a reef framework

The area restored during phase three was a low-relief terrace located between the west side of the restaurant, the seaward facing drop off and the shallow reef slope. Much of the habitat was a flat terrace composed of sand and loose rubble, with the only hardground areas located within 1 m of the drop-off. The terrace sloped slightly downward away from the restaurant, as you move towards the reef slope. Prior to transplantation of corals into this area, we needed to stabilize the sand/rubble and build up the terrace so that it formed a very gradual slope as you moved away from the restaurant. The goal was to provide a platform for the corals, so they would not be buried by moving sand, and to improve the viewing by placing corals closer to the substrate nearest the restaurant, and higher up at the far end of the newly created reef.

To stabilize and build up the terrace, we transported large dead coral colonies to the site and fit them together such that they formed a continuous substrate that slopes upward

toward the back of the restoration site and forms a continuous reef that extends up the reef slope. These were predominantly long dead pieces of flat coral rubble and boulders that were 1-2 m diameter, with smaller skeletal pieces fitted into the spaces between the large pieces.

2. Sourcing living corals and other benthic organisms

The surrounding reef flat, reef slope, sand channels and base of the reef was carefully searched to identify detached corals and other organisms that were suitable for use in the restoration. Efforts were made to select animals from depths that were similar to the restoration site. Initially, only the large boulders were moved using straps and lift bags. These boulder corals were up to 200 kg and 1.5 m diameter and were significantly larger than anything moved during Phase I and Phase II. After a large number of these had been collected, small organisms were also transported using large plastic tubs. In all cases, the animals were maintained underwater, and corals were transported in such a way that we avoided any additional injuries and abrasions. Because the areas closed to the restaurant had been previously examined, and most of the detached corals had already been removed, we had to swim a greater distance to find suitable organism that could be collected without causing damage to the reef. All of the corals were placed at the site and later rearranged to create the new reef.

Moving a 100 kg boulder coral (*Porites lobata*) using a lift bag.

3. Maintenance of the shelf area and adjacent restored reef

As in Phase II, we conducted routine maintenance of all areas around the windows of the restaurant and the new reef created on the east side. One of the most significant challenges has been the continued invasion of coral predators, including coral eating snails (*Drupella*) and the cushion starfish (*Culcita*). These animals have continued to target branching corals, especially cauliflower coral (*Pocillopora*) and staghorn coral (*Acropora*). We lost 5-6 colonies between the August and October trips due to snails, which can be avoided if routine maintenance is undertaken. Another ongoing issue is the presence of damselfish that occupy territories and create algal lawns. A high number of

these were present on the platform prior to Phase I, and these have continued to kill corals within their territories. A third issue that has not been previously noted was the occurrence of bleaching on a small number of corals. Bleaching only affected a few corals on the right side (near the gird; east side). One likely cause of this is the discharge of cement into the water during the construction of the observatory. Cement is a known toxin that is extremely damaging to corals. We witnessed a considerable amount of cement that spilled into the water, and a number of corals that were recently killed in the water below the observatory. This may also have been associated with the unusual calm conditions and extreme low tides during the super moon, as this is likely to have resulted in increased penetration of UV radiation. Our temperature meters indicate that sea water temperatures throughout 2017 have been normal or slightly cooler than normal.

A large boulder coral (*Porites*) that bleached in early December, during the coolest time of year

All animals that had died were removed and the spaces created by moving corals were filled with new corals. In addition, we collected over 400 snails from the area and dozens of cushion starfish (see below).

4. Construction of a new reef

Large boulder corals (*Porites lobata*) that were collected from surrounding reefs were distributed throughout the restoration site and positioned such that they were upright and stabilized among the reef framework so that they would not be moved by surge, currents and waves. Additional rubble was then deposited between the corals to further stabilize the area and provide an elevated substrate to place other branching, smaller massive, plating and foliaceous corals, anemones, leather corals, soft corals and other species. Individual species were placed in aggregations to minimize competition among organisms and enhance the likelihood that they successfully reproduce. One side of the reef had a concentration of leather corals; a large patch of branching cauliflower corals (*Pocillopora*) was assembled on the back side of the reef at the base of the slope. Other animals were positioned between massive corals, such that the living tissue of different species was not in contact. Whenever possible, associated fish (damselfish, clownfish, humbugs, chromis) were transported to the site with their ghost coral or sea anemone.

The western end of the new reef, adjacent to the reef slope (furthest from the restaurant windows). The reef was extended to the reef slope and built up so that it forms a continuous reef system. The top right shows a small part of the patch of cauliflower corals laced near the base of the slope. A large clump of leather corals are visible in the lower right.

Over the duration of Phase III, 77 square meters of new reef was created. This reef contained 308 stony corals, 39 leather corals, anemones and soft corals, and 5 giant clams when completed.

Reef fish, such as the Maldives anemonefish shown here (above), were transported with their coral and anemone hosts. Corals were planted in patches to increase reproductive potential, such as the *Pocillopora* placed on the reef slope (lower left).

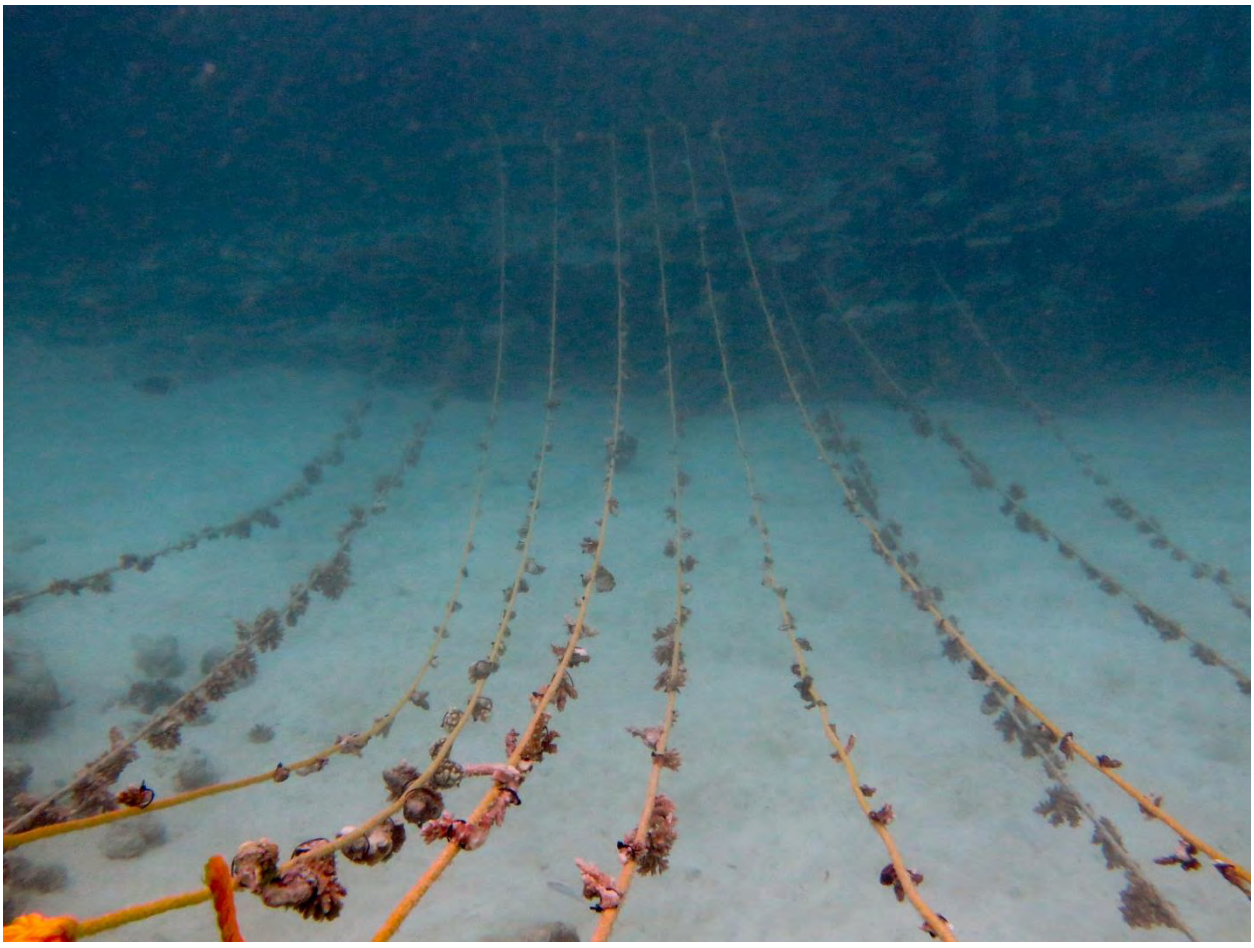
5. Removal of coral-eating cushion starfish (*Culcita* spp.)

In February, 2017 we observed an abnormal density of cushion starfish on the reefs surrounding Anantara. These are reported to occur naturally at a density of about 1 animal per 500 square meters. Because these animals eat coral, and they prefer juvenile corals of the two types of branching corals that were most damaged by the 2016 bleaching event (*Acropora* and *Pocillopora*), there are concerns that these animals could affect the recovery of the reefs following bleaching if their populations are too high. Our initial surveys revealed densities of 5-10 starfish per 100 square meters (approx. 50 times higher than normal) and we observed an abnormally high number of white, recently eaten juvenile corals on this reef system, we began to remove the starfish. During February, we focused our efforts on the habitats surrounding SEA restaurant, mainly because we had lost several corals that were transplanted onto the ledge adjacent to the restaurants windows that had been eaten. In August, we conducted the first ever large scale removal effort, collecting 387 starfish. During our reconnaissance surveys of the restoration sites in November, we identified an additional 22 starfish around the restaurant and many more on adjacent reefs. Over the three week mission we removed an additional 278 starfish, bringing our total to 665!

Cushion starfish (*Culcita*) near SEA that had eaten two juvenile Acropora colonies (white corals to the right of the starfish) over the last 24 hours. These corals are the most important species on these reefs and are critical for the recovery following the bleaching event.

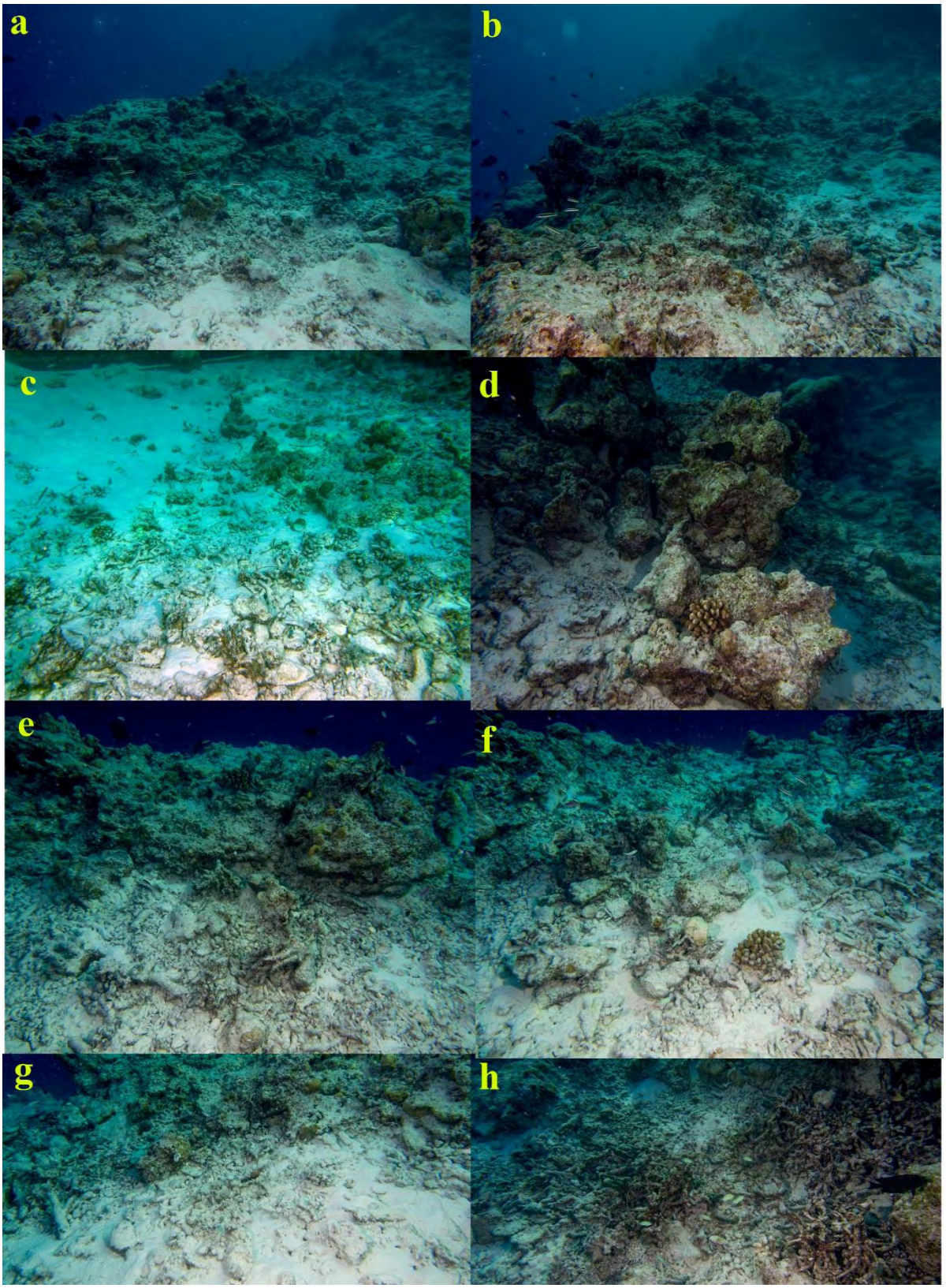
6. Maintenance and expansion of the coral nursery ropes

The ropes installed at SEA in February 2017 on the eastern side of the wine cellar and the second set of ropes placed on the western side have done extremely well with over 98% survival and considerable new growth. These ropes have remained free of algae, but are periodically covered in sediment during periods of rough weather. The majority of the corals attached to the ropes are in the genus Acropora. All of the coral fragments attached in February came from the areas surrounding the restaurant. In August, we experimented with fragments collected near the Plates nursery, and also added a new, very unique and rare coral (*Echinopora*; two colonies exist in Kihavah). All of these have survived incredibly well and have shown substantial new growth. In November, we added four new frames, two on the east side and two on the west. A total of 24 ropes containing 30-40 corals each were placed on these frames. All of the ropes were made on shore during a VIP trip. There are currently 1066 corals growing in this nursery.

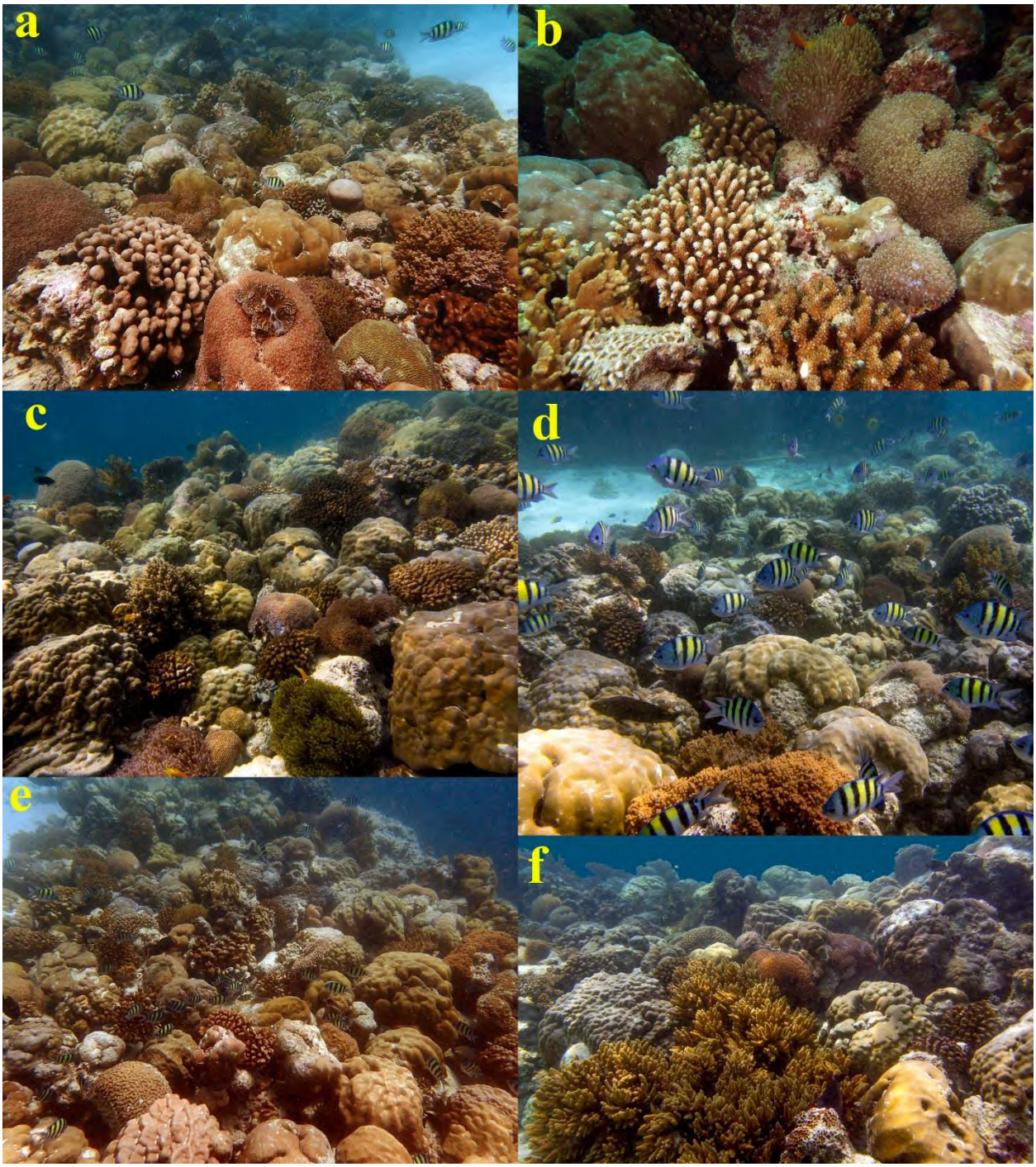


New ropes were added to two frames on each side of the wine cellar (24 ropes total).

Original coral nursery ropes when set up in February 2017 (top) and in December 2017 (bottom).



BEFORE: Habitat condition of the area targeted for restoration during Phase III, photographed in October, 2017.



AFTER: Scenes of the new reef created off the west side of the undersea restaurant. a. looking towards the sand flat from the edge of the drop-off; b. several of the different species; digitate *Acropora* and *Pocillopora* in foreground and pineapple coral (*Physogyra*), boulder coral (*Porites*) and magnificent anemone (*Heteractis*) in the background; c. looking from the sandflat (the window is behind me) toward the reef slope; d. facing towards SEA. A narrow sand channel separates SEA from the new reef; e. A distance shot of the new reef; and f. a patch of leather corals at the northern end.

Angelfish and butterflyfish were among the first species to colonize the new reef. a. longfin bannerfish (*Heniochus acuminatus*); b eclipse butterflyfish (*Chaetodon bennetti*); c. emperor angelfish (*Pomacanthus imperator*); d. regal angelfish (*Pygoplites diacanthus*); e. longnose butterflyfish (*Forcipiger flavissimus*); f. triangular butterflyfish (*Chaetodon triangulum*); g. Indian redfin butterflyfish (*Chaetodon trifasciatus*); h. spot nape butterflyfish (*Chaetodon oxycephalus*).

Table 1. Corals and other animals transplanted to the newly created reef during Phase III.

Organism	Genus	Count
Stony (scleractinian) corals		
Porites lobata	Boulder coral	126
Porites rus	Plate and pillar coral	4
Diploastrea heliopora	Volcano coral	4
Goniastrea	Lesser star coral (2 species)	3
Goniopora	Daisy coral (2 species)	16
Leptastrea	Purple crust coral	5
Pocillopora	Cauliflower coral (2 species)	76
Gardineroseris planulata	Honeycomb coral	1
Symphyllia	Large ridged brain coral	6
Lobophyllia	Lobe brain coral	1
Platygyra	Brain coral	3
Pavona	Club coral	6
Physogyra lichtensteini	Pineapple coral	13
Psammocora contigua	Branched sandpaper coral	11
Favia	Moonstone coral	2
Favites	Star coral	2
Astreopora myriophthalma	Volcano coral	5
Acropora	Multiple species of staghorn coral and table corals	15
Galaxea	Galaxy coral	3
Cyphastrea	Smallcup star coral	3
Montipora	Rice coral	2
Leptoria	Fine brain coral	1
Leather Corals		
Sarcophyton	Dead man's fingers	7
Lobophyton	Flower coral	3
Cladiella	Color changing coral	2
Other leather corals		15
Dendronepthya	soft coral	6
Sea Anemone		
Heteractis	Magnificent sea anemone and anemone fish	6
Giant Clam		
Tridacna/Hippopopus	Two free living species of giant clams	5
Total		352

RECOMMENDATIONS

- Maintenance of the restored reef and nursery area is critical to ensure long-term survival. Efforts should focus on removal of pest species (snails and cushion starfish), removal of any corals that succumb to disease, and cleaning of the nursery ropes to eliminate algae and colonizing invertebrates.
- Additional phases of the project should be undertaken to complete the restoration of the habitat. This includes: 1) the sand flat adjacent to the restaurant; 2) the slope on the left side; 3) continuation of the reef created in July on the east side, along the slope towards the seaward edge;
- The sand platform on either side of the restaurant should be covered with large boulders and rubble to stabilize the sediment, and acroporid corals should be planted on this. This would improve visibility and provide excellent reef habitat.
- The reef community present at SEA should be promoted both in house and in publications and social media, as SEA is a very unusual restaurant (the only one in the Maldives adjacent to the open ocean), and it is the only one with a thriving coral reef. Guests, especially those that do not want to snorkel/dive have an opportunity to view a natural reef and appreciate the beauty, diversity and natural behaviors of the unique animals found here.
- Anantara should support the development of color imagery, pamphlets and booklets on the life contained here, for display in villas and at the restaurant.

Appendix I. Inventory of invertebrates transplanted to SEA

Group	Species	Common name
Ahermatypic corals	*Tubastrea micranthus*	Green tube coral
Ahermatypic corals	*Tubastrea coccinea*	Orange tube coral
Alcyonaria	*Heliopora coerulea*	Blue coral
Alcyonaria	*Sinularia brassica*	Brassy leather coral
Alcyonaria	*Cladiella spp.*	Color changing leather coral
Alcyonaria	*Clathria spp.*	Gorgonian
Alcyonaria	*Sarcophyton spp. 2*	Long polyp leather coral
Alcyonaria	*Sarcophyton spp. 1*	Mushroom leather coral
Alcyonaria	*Lobophytum spp.*	Ridged leather coral
Alcyonaria	*Dendronephthya spp.*	Soft coral
Antipathidae	*Stichopathes spp.*	Whip coral
Corallimorph	*Amplexidiscus fenestrafer*	False coral
Hermatypic corals	*Acanthastrea echinata*	Moon Coral
Hermatypic corals	*Acropora hemprichii*	Boulder coral
Hermatypic corals	*Acropora divaricata*	Interlocking branched table acroporid
Hermatypic corals	*Acropora humilis*	digitate acroporid
Hermatypic corals	*Acropora aculeus*	Bushy table coral
Hermatypic corals	*Acropora tenuis*	Bushy acroporid
Hermatypic corals	*Acropora anthoseris*	Branched acropora
Hermatypic corals	*Alveopora gigas*	flowerpot coral
Hermatypic corals	*Astreopora myriophthalma*	volcano coral
Hermatypic corals	*Coscinarea monile*	Sand paper coral
Hermatypic corals	*Cyphastrea seralia*	Small polyp star coral
Hermatypic corals	*Diploastrea heliopora*	Volcano coral
Hermatypic corals	*Echinopora forskaliana*	Bermuda coral
Hermatypic corals	*Euphyllia glaberescens*	Hammer coral
Hermatypic corals	*Favia favus*	Moonstone coral
Hermatypic corals	*Favia speciosa*	Moonstone coral
Hermatypic corals	*Favia helianthoiides*	Moonstone coral
Hermatypic corals	*Favites abdita*	Star coral
Hermatypic corals	*Favites complenata*	Star coral
Hermatypic corals	*Favites pentagona*	Star coral
Hermatypic corals	*Fungia spp*	Mushroom coral
Hermatypic corals	*Galaxea fasicularis*	Galaxy coral
Hermatypic corals	*Gardineroseris planulata*	Pineapple coral
Hermatypic corals	*Goniastrea edwardsi*	Lesser star coral
Hermatypic corals	*Goniastrea edwardsi*	Lesser star coral
Hermatypic corals	*Goniastrea pectinata*	Lesser star coral
Hermatypic corals	*Goniopora columna*	Daisy coral
Hermatypic corals	*Goniopora lobata*	Lobate daisy coral
Hermatypic corals	*Hydnophora microconus*	Velvet coral
Hermatypic corals	*Leptastrea purpurea*	Purple crust coral
Hermatypic corals	*Leptastrea transversa*	Spotted crust coral
Hermatypic corals	*Leptoria phyrigia*	Brain coral
Hermatypic corals	*Lobophyllia corymbosa*	Lobed brain coral
Hermatypic corals	*Montastrea curta*	True star coral
Hermatypic corals	*Merulina ampliata*	Ruffled lettuce coral
Hermatypic corals	*Montipora tuberculosa*	Rice coral
Hermatypic corals	*Oulophylia bennetta*	Boulder brain coral
Hermatypic corals	*Pavona clavus*	Club coral
Hermatypic corals	*Pavona maldivensis*	Maldive coral
Hermatypic corals	*Pavona varians*	Rough crust coral
Hermatypic corals	*Physogyra lichtensteini*	Pineapple coral

Group	Species	Common name
Hermatypic corals	*Platygyra daedalea*	Brain coral
Hermatypic corals	*Platygyra lamellina*	Brain coral
Hermatypic corals	*Plesiastrea versipora*	Small knob coral
Hermatypic corals	*Pocillopora verricosa*	Cauliflower coral
Hermatypic corals	*Pocillopora meandrina*	Smiling cauliflower coral
Hermatypic corals	*Pocillopora damicornis*	Thin finger cauliflower coral
Hermatypic corals	*Porites lobata*	Boulder (pore) coral
Hermatypic corals	*Porites rus*	Plate and pillar coral
Hermatypic corals	*Psammocora digitata*	Branched sandpaper coral
Hermatypic corals	*Symphyllia recta*	Symphony coral
Hermatypic corals	*Symphyllia radians*	Symphony coral
Hermatypic corals	*Turbinaria mesenterina*	Pagoda coral
Sea anemone	*Heteractis magnifica*	Magnificent anemone
Sea anemone	*Stichodactyla mertensii*	Merten's anemone
Sea anemone	*Heteractis aurora*	Beaded sea anemone
Zoanthid	*Palythoa caesia*	Colonial anemone
Giant clam	Tridacna deresa	Giant clam
Giant clam	Tridacna squamosa	Giant clam
Giant clam	Tridacna crocea	Burrowing clam
bivalve	*Atrina*	Pen shell

14 species of anemones, soft corals, false corals, leather corals

55 species of stony corals

4 bivalves

2 sponges