Restoring the underwater habitat at SEA Restaurant Anantara, Kihavah

Phase II

July/August, 2017

Andrew Bruckner
Georgia Coward

EXECUTIVE SUMMARY

Coral Reef CPR scientists completed Phase II of the SEA Restaurant restoration between July and Aug 23, 2017. The restoration involved six aspects: 1) Creation of rubble reef framework behind and above grid at SEA and stabilization of metal grid; 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 reef on slope adjacent to metal grid; 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 of the coral nursery ropes and creation of a new coral nursery adjacent to the wine cellar.

Fig. 1. The view out of the window on the right side. The grid is completely covered with coral and a living reef now extends up the reef slope behind the grid.

An initial evaluation of Phase I efforts in July 2017 reveal that the project has been highly successful, with minimal loss of corals (<2%) and a dramatic increase in the fish communities present at the site. Some coral mortality was noted, primarily due to corallivores and algal gardening effects of resident damselfish. Corallivores observed included: coral eating snails (*Drupella*) that had aggregated on 7 branching *Pocillopora* and *Acropora* colonies, and were rapidly consuming the tissues; and 8 cushion starfish (Culcita) that were feeding on *Pocillopora*. The territorial damselfish (*Microspathodon chrysurus)* had created algal lawns on several *Porites* colonies. One giant clam was also

eaten. The snails and cushion starfish were removed and the dead/damaged corals were replaced. In total 12 out of 680 transplanted organisms were replaced (1.8%). Additional corals were also placed onto the metal grid off the left side to completely cover this structure.

Fig. 2. The cement platform in front of the windows was restored in Feb. 2017. The corals have shown very high survivorship and this is now a thriving reef community.

A major component of the restoration included the stabilization of the metal grid and the construction of a reef framework between the grid and the reef slope. The structural supports holding the grid had rusted and the frame was collapsing. Hundreds of large pieces of coral skeletons were piled between the frame and the reef slope to make a continuous reef framework extending from the window to the top of the reef slope at 1.5 m depth. Additional metal stabilization bars were secured under the grid.

Corals, soft corals, leather corals, sponges, anemones and giant clams were collected from surrounding habitats and translocated to the degraded reef slope off the left side of the restaurant. All organisms were detached, broken, overturned and/or dislodged corals that had been transported to sand channels and the base of the reef. This included boulder corals (Porites) with dimensions of up to 1 m x 1m (150-200 kg), large colonies of leather corals that were being buried by sand, and clumps of staghorn corals,

with a total diversity of 37 different species. A total of 340 corals and other benthic organisms (10-200 cm diameter) were used to restore a section of reef that extended 5 m from the seafloor to the shallow reef flat and 8 m in length from the edge of the grid, seaward 8 m from the drop-off. A total of 47 square meters of reef habitat was restored, with resulting living coral cover of >85%.

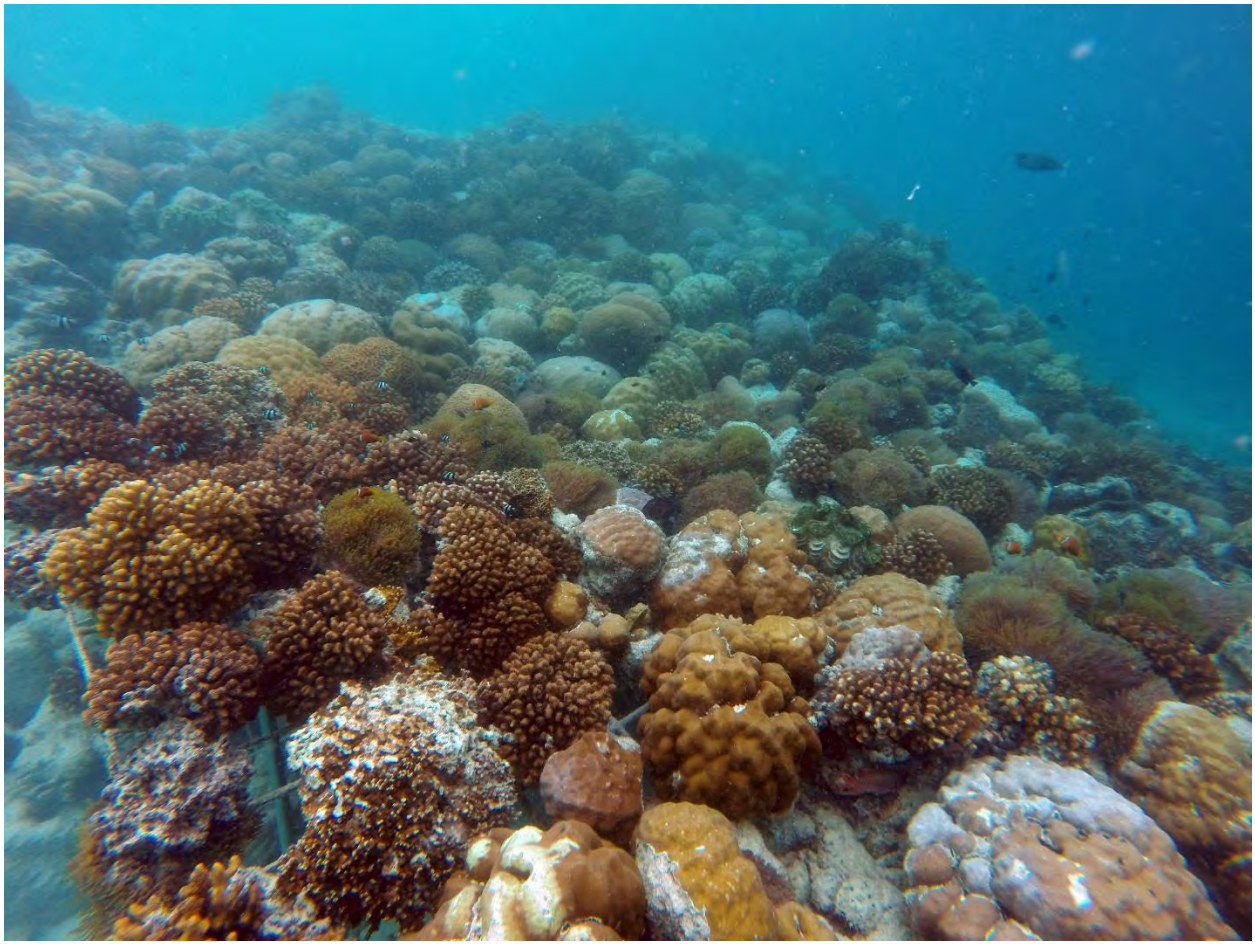
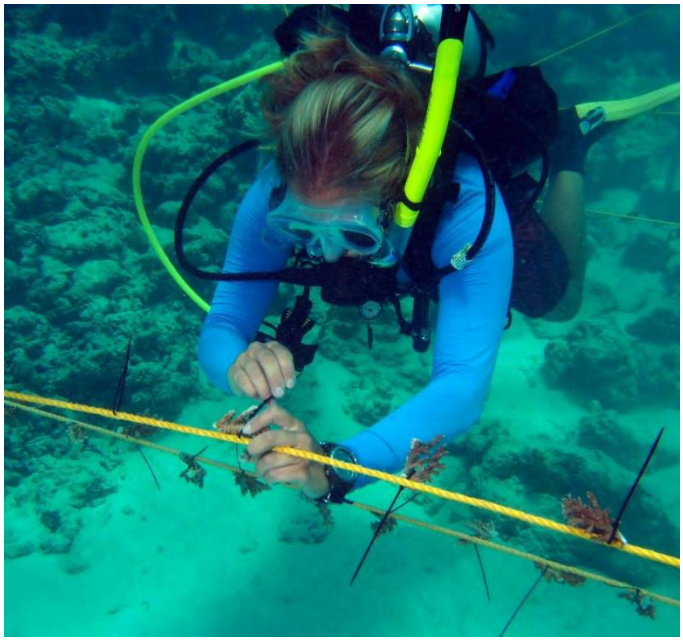


Fig. 3. The grid and restored reef. The area now has >85% living coral cover and it forms a continuous reef system that extends upward from the grid to the reef flat at 1.5 m and seaward towards the drop-off.

Efforts were made to reduce potential for future coral loss due to coral predators through removal of cushion starfish (*Culcita*). Extensive searches of the reef between the supply jetty and Plates restaurant was made to locate Culcita. The team covered the entire reef flat from the shoreline to the reef slope, and the reef slope from 3-15 m depth A total of 387 cushion starfish were removed.

The coral nursery was repaired, with reattachment of ropes to a more stable structure on the barge/restaurant; dead fragments were removed and new fragments were added to replace the missing corals. A new nursery was created on the opposite (right) side of the restaurant. Five ropes were extended across the sand flat between the wine cellar and



the reef slope and 255 coral fragments were attached to these ropes. The corals will be grown for 18 months, and then used for further restoration of the surrounding habitat.

Fig. 4. Elements Dive Center Marine Biologist is attaching coral fragments to a rope within the new nursery at SEA.

Restoration of the habitat surrounding SEA was undertaken using a non-destructive, non-damaging approach with a focus on corals and other benthic organisms that are threatened and/or dying due to sediment burial, detachment and breakage, accumulation in sand channels, predation and disease. The restoration offers both ecological and human benefits. New, healthy habitat was created to provide refuge for other animals. It also serves to concentrate organisms that reproduce primarily through spawning, thereby increasing the likelihood of successful fertilization. A healthy reef community showcases the diversity and vibrancy of Maldivian coral reefs and offers guests the opportunity to understand and appreciate these reefs without getting wet. It also serves to increase awareness of the vulnerable state of reefs and tangible actions that can be taken to help them survive and thrive.

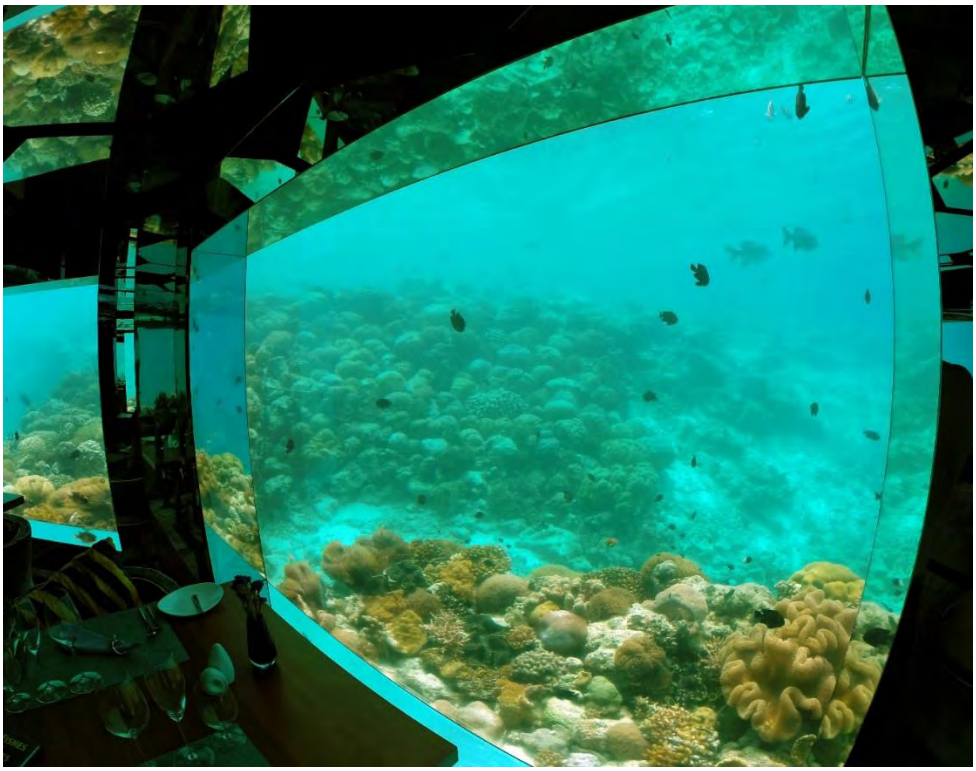


Fig. 5. View of restored habitat from the inside of SEA. The platform next to the window in the foreground was restored in February 2017 and a new reef visible in the distance was constructed in July/August 2017.

Introduction

SEA Restaurant is part of *SEA. FIRE. SALT.* a signature overwater and underwater dining experience located underwater, adjacent to Kihavah House Reef at Anantara Kihavah Villas, Baa Atoll, Maldives. The specifics of the structure were described in a previous report detailing Phase I of the restoration. The location of the restaurant is unusual for the Maldives, being the only structure that is not in a lagoonal habitat. Rather, the restaurant is located on a shallow terrace, sandwiched between a sloping reef on either side, and positioned within 3 m of the drop-off.

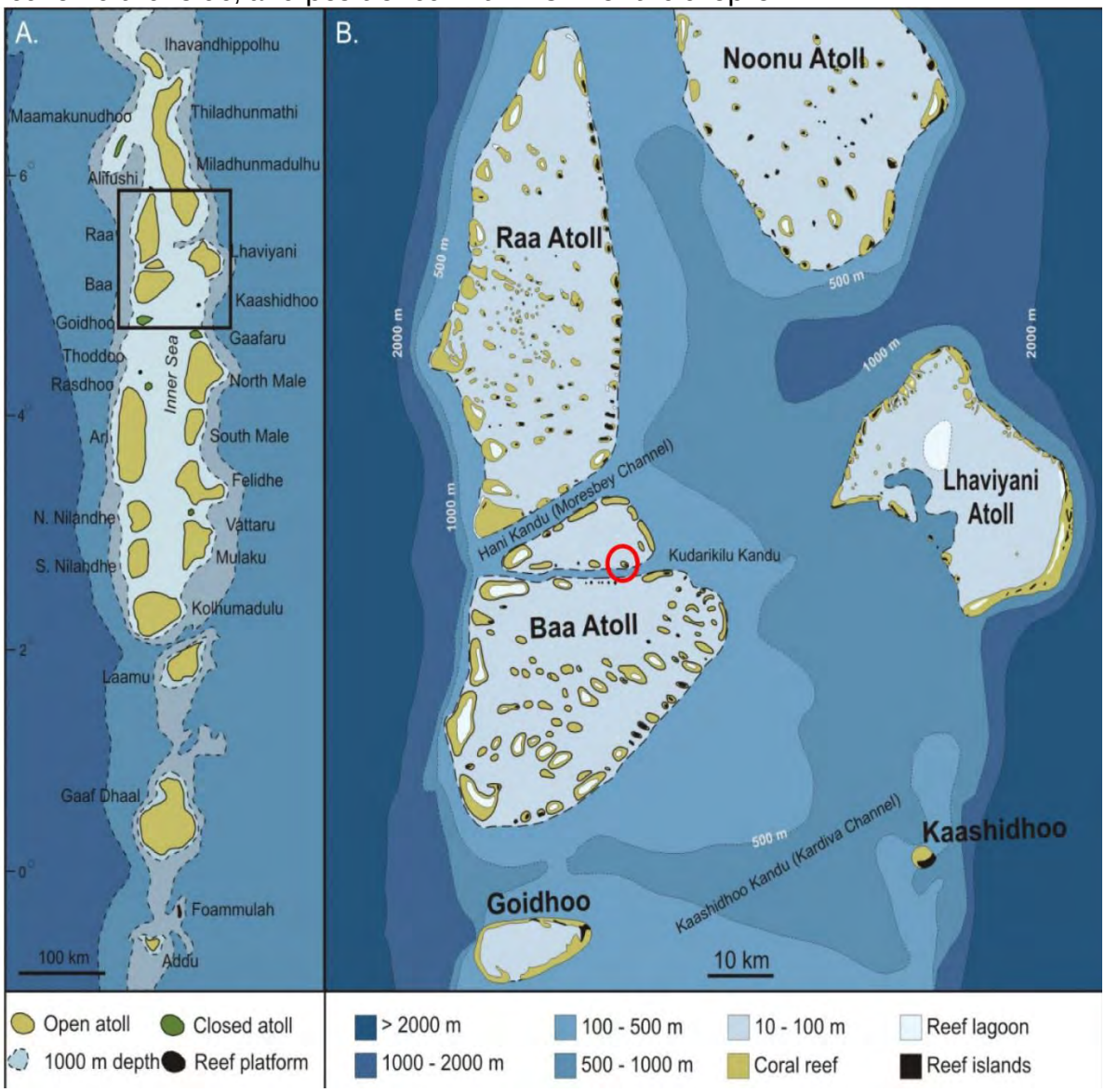


Fig. 6. Map of Baa Atoll showing the location of Kihavah and the geomorphology of the atoll and surrounding environment.

Fig. 7. Google Earth image from 2017 showing an aerial view of Anantara Kihavah Villas. SEA Restaurant is located within the red circle.

The restaurant faces south, towards the Kudarikilu Kandu channel. This narrow channel separates the northern and southern "sub-atolls" that make up Baa Atoll. This channel has depths of up to 256 m and is characterized by strong currents and tidal flow. As a result, the underwater restaurant provides a unique opportunity to view pelagic fishes such as sharks, tuna, and trevally, along with diverse fore reef community inhabitants.

During 2016, reefs throughout the Maldives experienced an unprecedented bleaching event that had catastrophic impacts on shallow reefs. Habitats surrounding SEA were badly damaged, with severe impacts to coral communities on the platform surrounding the restaurant and on the adjacent reef slope. A large number of metal "adopt a coral" frames had been placed on the platform and on the surrounding reef platform. These had hundreds of attached corals and coral fragments that sustained 99% mortality. As part of Phase I, all of these frames were removed, as they were rusting and covered in fleshy algae. Phase I focused on restoration of the coral reef community located on the platform adjacent to the windows, with additional efforts to cover the exposed metal grid off the left side of the restaurant. After completion of this phase, the natural reef surrounding the restaurant remained badly degraded with <1% living coral. At the time of completion of Phase I, the proposed strategy was to completely rehabilitate the reef environments surrounding the restaurant as a series of consecutive projects. Phase II, discussed here, focused on the creation of a thriving reef adjacent to the grid on the left side of the restaurant through transplantation of corals and other benthic animals onto the reef slope which contained <1% living organisms at the start of the project.

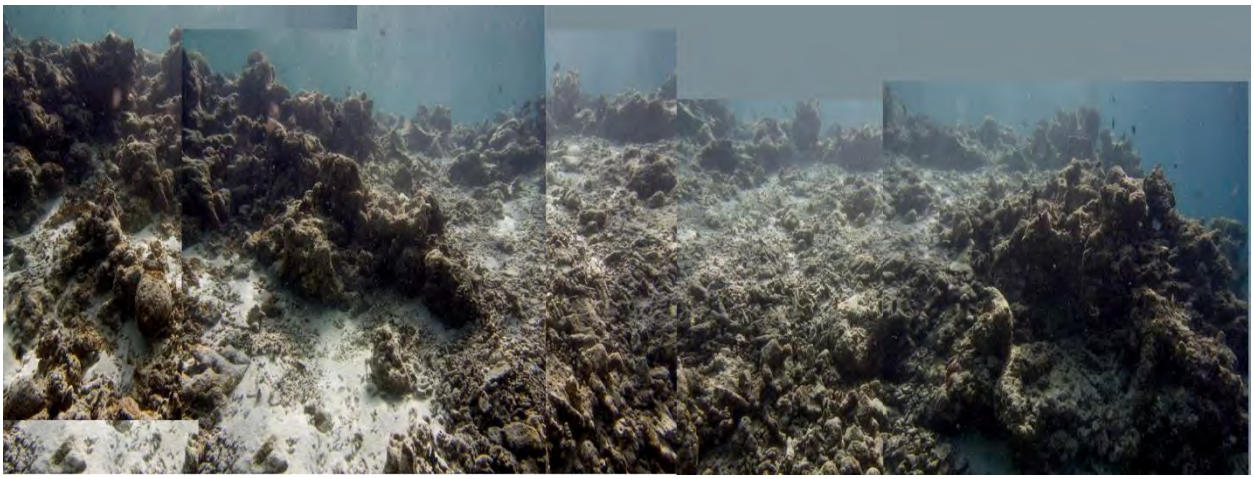


Fig. 8. A mosaic showing the reef slope off the right side of the restaurant, adjacent to the grid, prior to the restoration.

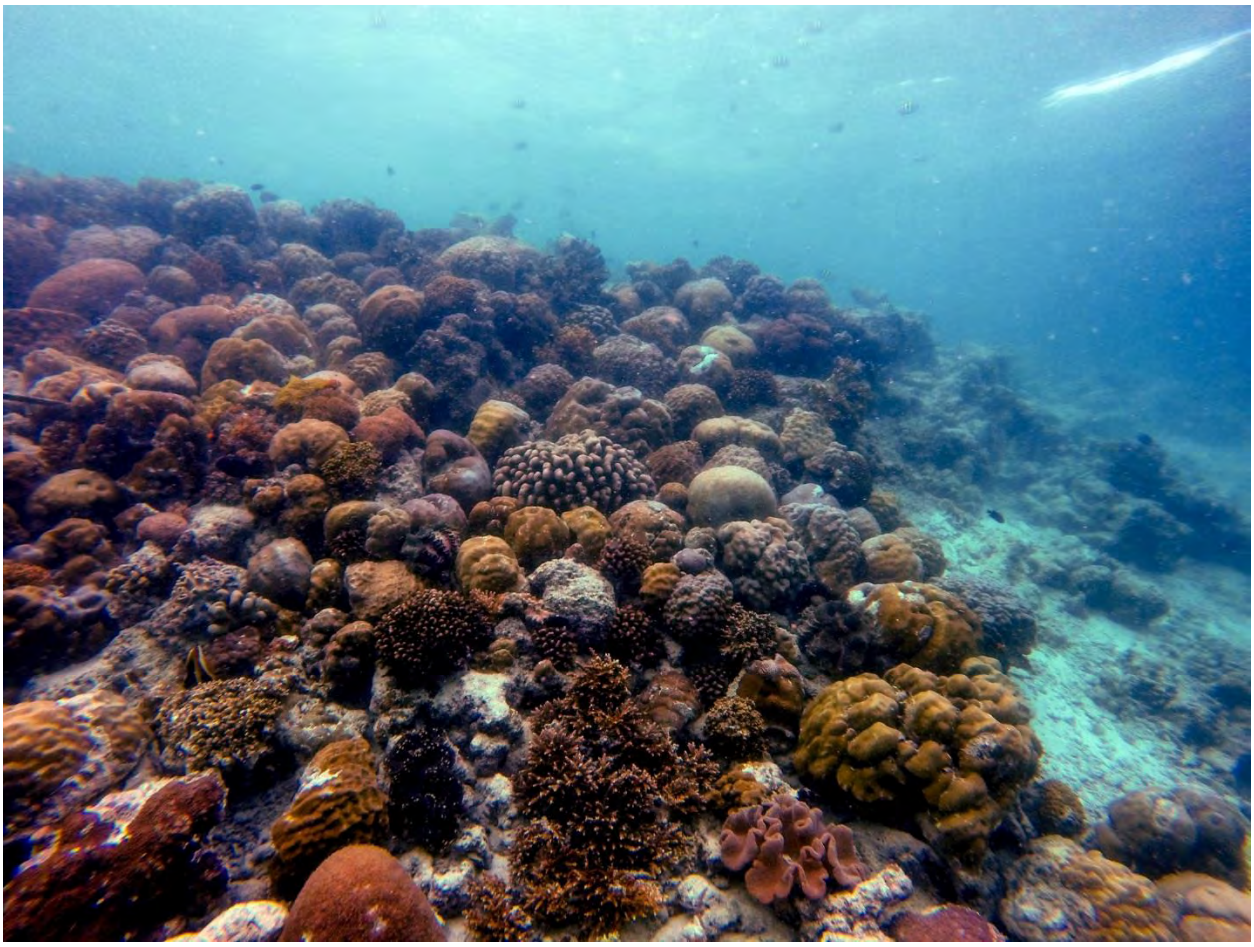


Fig. 9. The right side of the restored reef, showing the same section of reef slope after the restoration.

Phase II

1. Creation of a reef framework

At the start of Phase II, there was a large gap between the end of the metal grid and the natural reef slope. The grid supports had rusted away, and the grid was beginning to collapse. The engineering department made steel stabilizing bars that were secured beneath the grid and surrounded by coral boulders at their base. Large dead coral boulders and pieces of rubble were collected from the reef flat adjacent to the reef slope and deposited in the large gap between the grid and the reef slope. The area was completely filled in, resulting in a natural reef slope that was continuous from the grid to the shallow reef terrace. The rubble further stabilized the grid, and it resulted in a "cave" underneath the grid that provided refuge for the large resident grouper.

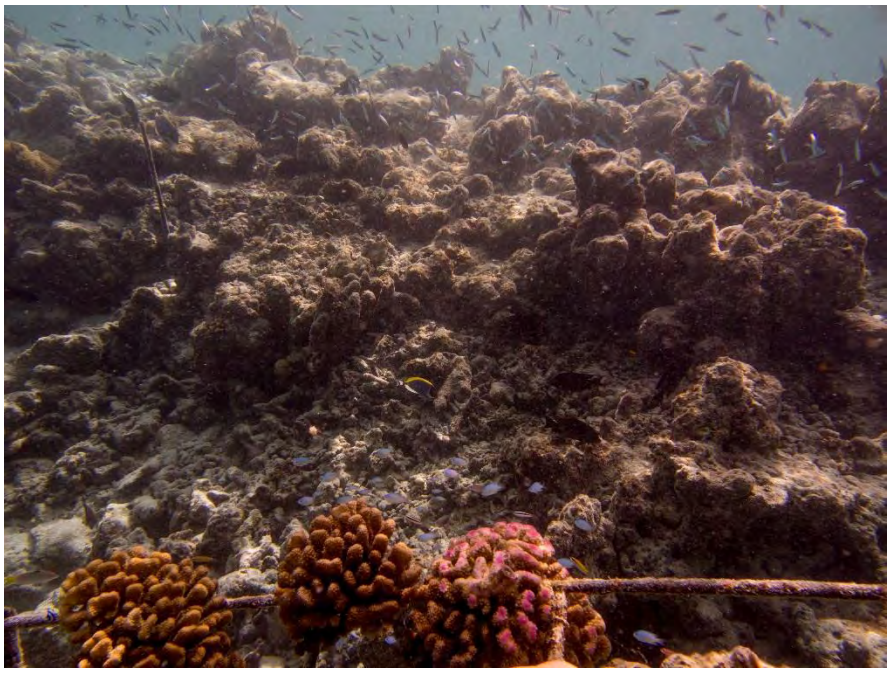


Fig. 10. The reef slope adjacent to the top of the grid was devoid of life and there was a large gap between the grid and the reef substrate (top). This was filled in with large coral boulders (bottom)

2. Sourcing of living corals and other benthic organisms

Extensive search was undertaken in the reef habitat and adjacent sand/rubble slope and platform for organisms that were suitable for use in the restoration. Any detached/loose/broken boulder corals that were freely rolling around the substrate were transported using lift bags to the restoration site. Other detached organisms and organisms being buried by sediment were also collected and transported underwater in large plastic tubs to the site. Branching corals included specimens that were infested with coral eating snails, branches that had partly died and were covered in algae, colonies under attack by cushion stars, and detached fragments that had accumulated in no-reef environments. Organisms were collected from an extensive area, beginning adjacent to the shoreline, extending across the entire reef platform and on the reef slope to 20 m depth. The search area extended from the arrival jetty to the spa.

Fig. 11. Large boulders, up to 200 kg were relocated to the restoration site using lift bags.

3. Maintenance of the shelf platform and grid

All corals were carefully examined for signs of partial or complete mortality, along with recent signs of tissue loss. Any corals with coral eating snails were removed to detach and collect the snails. The surviving colonies were either placed back on the grid, or

used as a source of fragments for the coral nursery. Completely dead corals that had died since February 2017 due to cushion starfish predation, damselfish algal lawns or other causes were removed. The resulting gaps in the created reef were filled in with new corals and other organisms. Additional corals were also placed at the perimeter of the windows to fill additional spaces where the cement platform and/or the stabilizing plates and bolts were visible.

Fig. 12. A cushion starfish (*Culcita*) that had hidden under a coral at the base of the grid. The two small white coral skeletons (in red circles) were eaten by this starfish the previous evening. The reef was carefully searched for coral predators to prevent additional loss.

4. Construction of a reef

All benthic organisms were transported to the restoration site and secured to the bottom with rubble and other colonies such that they were stable and would not move due to surge, currents or waves. For colonies with partial mortality, the living areas were positioned such that they face towards the windows. Corals were placed such that they recreated a natural reef slope. The dominant organism transplanted into the site was the boulder coral *Porites lobata*, with other corals placed in between and around these

colonies. Organisms were placed in such a way that they mimicked a natural reef. The shallowest part on the top was dominated by leather corals intermixed with cauliflower coral (*Pocillopora*) and a suite of massive corals. Branching acroporids were placed in large aggregations toward the base of the slope to represent a natural coral thicket. Organisms were placed as close to their natural depth, with organisms collected from shallow water placed near the top of the slope and the deeper organisms placed at the base. Overall 309 large corals, leather corals, sea anemones and other benthic organisms were used to build a reef that was 47 square meters, extending linearly 8 m and vertically from 6 m to 1.5 m depth a total of 5-6 m. The reef is a continuous extension of the metal grid, but it also extends down the slope to the sand platform on the seaward edge of the grid.

Fig. 13. Large colonies of *Lobophyton* spp., a leather coral, that prefers shallow water was placed on the top of the restored reef adjacent to the reef flat.

Fig. 14. Another beautiful leather coral that expands its polyps during periods of high flow, and retracts its polyps at slack tide is *Sarcophyton*. This species forms colonies that can be up to 1 m in diameter. Select colonies were placed on the reef slope and also on the grid.

Table 1. Total number of benthic organisms transplanted into the restoration site.

Organism	Genus	Count
Stony (scleractinian) corals		
Porites lobata	Boulder coral	176
Porites rus	Plate and pillar coral	4
Diploastrea heliopora	Volcano coral	3
Goniastrea	Lesser star coral (2 species)	5
Goniopora	Daisy coral (2 species)	4
Leptastrea	Purple crust coral	1
Pocillopora	Cauliflower coral (2 species)	41
Gardineroseris planulata	Honeycomb coral	1
Symphyllia	Large ridged brain coral	12
Lobophyllia	Lobe brain coral	6
Platygyra	Brain coral	4
Pavona clavus	Club coral	4
Physogyra lichtensteini	Pineapple coral	7
Psammocora contigua	Branched sandpaper coral	3
Favia	Moonstone coral	2
Favites	Star coral	4
Astreopora myriophthalma	Volcano coral	1
Acropora	Multiple species of staghorn coral and table corals	16
Leather Corals		
Sarcophyton	Dead man's fingers	9
Lobophyton	Flower coral	24
Cladiella	Color changing coral	1
Sea Anemone		
Heteractis	Magnificent sea anemone and anemone fish	10
Giant Clam		
Tridacna/Hippopopus	Two free living species of giant clams	2
Total		340

Fig. 15. Examples of the diversity of corals within the newly restored reef.

5. Removal of cushion stars

Cushion starfish (*Culcita* spp.) are coral predators that feed on new recruits, juvenile colonies and larger colonies in the genus *Acropora* and *Pocillopora*. These starfish appear to aggregate among the corals transplanted to SEA Restaurant and they have been observed consuming entire *Pocillopora* colonies. During the initial phase of the restoration in February, 2017 a total of 87 cushion stars were removed from the reef habitat around SEA and the adjacent sections of reef. During July, 2017, larger scale searches for *Culcita* were undertaken on the reef slope and the shallow reef flat extending from the supply jetty to just past the arrival jetty, off Plates Restaurant. A total of 386 cushion starfish were removed.

Fig. 16. The first collection of cushion stars from the reef slope next to SEA restaurant yielded 78 starfish. Another 300+ were removed from surrounding areas.

6. SEA Coral Nurseries

Five ropes were placed on the left side in February 2017 and 243 *Acropora* fragments were secured to the ropes using cable ties. These ropes extended from the wine cellar window to the grid. They were attached to a metal frame placed on the platform near the window which was detached and deposited in the sand during a period of rough weather in May 2017. In July, the ropes were re-secured to the stabilizing plates on the frame of the barge. A total of 9 fragments had been buried by sand. These were replaced and additional fragments were secured, with a total of 253 fragments in July 2017.

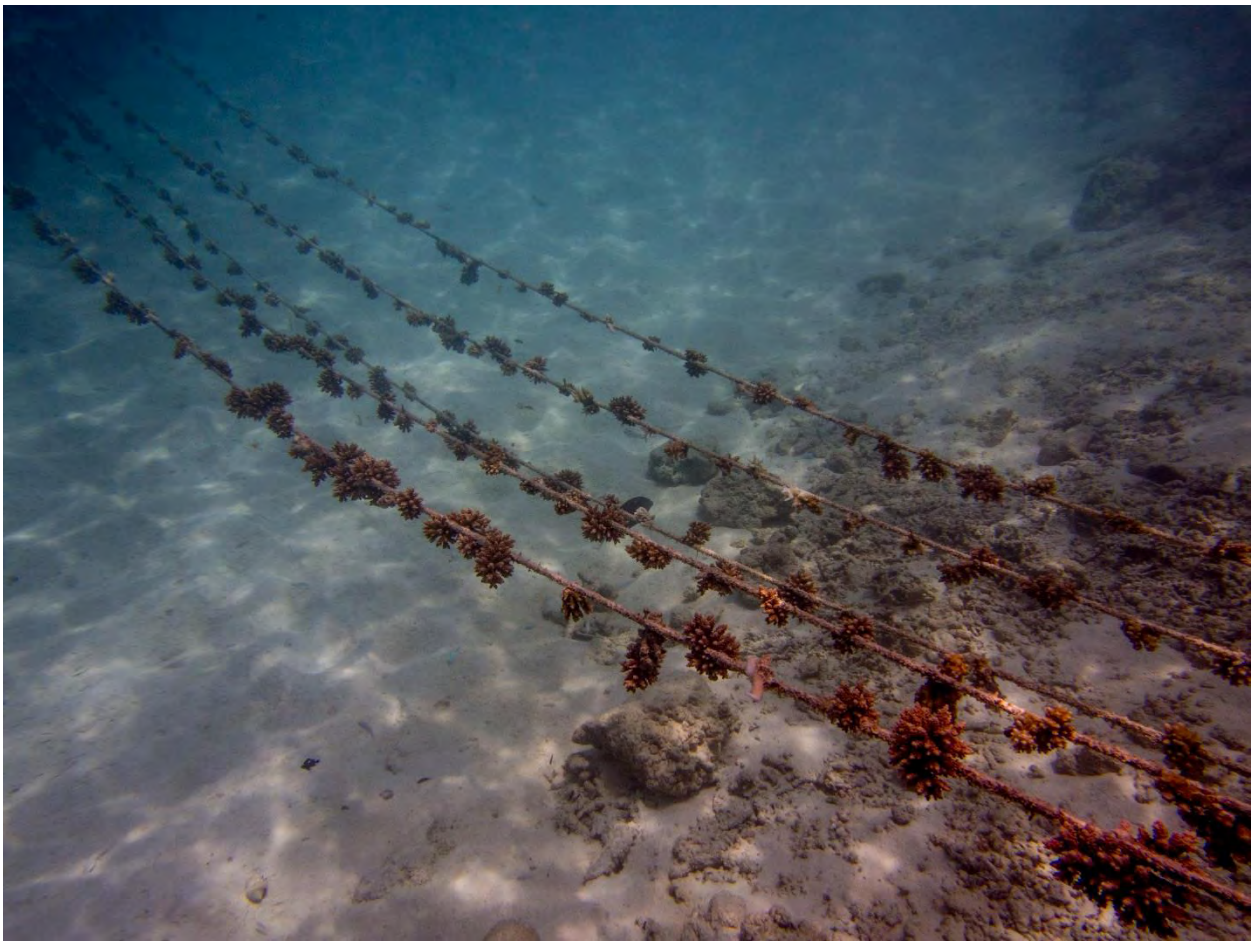


Fig. 17. Original nursery created at SEA in February 2017 showing considerable growth to fragments.

In August 2017, five new ropes were placed on the right side of the restaurant, extending from the barge platform near the wine cellar window to the reef slope. The ropes were secured on two inch metal tubes inserted into the substrate. Acropora fragments collected from the reef slope at 3-8 m depth between the arrival jetty and SEA were attached to four of the ropes. *Acropora* recruits (and attached coral rubble pieces) collected near Plates nursery at 3-4 m depth were secured to the fifth rope to evaluate survival. A total of 255 fragments were attached to these ropes.

Fig. 18. A portion of two of the new ropes at the nursery at SEA (left). On one rope we attached a number of *Echinopora* fragments (above). This is a very rare coral that sustained high mortality in 2016. Only two colonies are known to occur at Kihavah.

Conclusion and recommendations

The efforts to rehabilitate the reef environment around the windows at SEA and create a new, thriving reef in the surrounding habitat has promoted a large influx of other reef organisms, especially motile fish and invertebrates by providing refuge and feeding areas. It also has the added benefit of concentrating organisms such that the potential of successful reproduction during the annual spawning period is maximized, which has greater benefits for surrounding reefs and is likely to contribute to a faster recovery from the 2016 bleaching event. The restoration project has also resulted in the removal of unattractive and dangerous human trash, including rusting metal frames and it has stabilized the habitat. This project has the greatest benefit for guests, by offering a glimpse of what a natural reef in the Maldives should look like when unaffected by human impacts and climate change. It showcases the diversity of the Maldives by including representatives of all common benthic organisms found within the reef

systems of the Maldives, but offers the benefit of housing these animals in a defined area.

- Additional phases of the project should be undertaken to complete the restoration of the habitat. This includes: 1) the deep area at the edge of the drop-off, visible from the windows on the left side; 2) the slope on the left side; 3) continuation of the reef created in July along the slope towards the seaward edge; 4) the sand platform between the wine cellar and the drop-off.
- Stabilization and covering of the sand flat with coral rubble followed by the planting of corals in this rubble will improve the visibility of the area by reducing resuspension of sediment.
- Transplantation of Acropora corals grown in the nursery onto the rubble would create a natural Acropora reef.
- 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.
- 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.

Acknowledgments

Coral Reef CPR would like to thank the hard-working staff at Anantara Kihavah Villas for all of their support and interest during the project. A special thank you to Liezl and Christine (Sales and Marketing) for assistance in organizing project logistics. Thank you to Elements Dive Centre for their help, and equipment. We are also very grateful for the enthusiasm and hard work from Flora Blackett, the Resident Marine Biologist, during the project, and to Sonja Müller for joining us on her day off! Finally, a big thank you to the General Manager, Dylan Counsel, for his ongoing support and dedication to restoring and protecting this critical habitat.