Fragments of Hope 2025 Summary report for Research Permit renewal 0013-25

Continued active restoration of critically endangered Caribbean coral species with a focus on acroporids

Abstract/Summary

Lisa Carne and Fragments of Hope (FoH) have been conducting active reef replenishment in Southern Belize since 2006, and in Turneffe Atoll Marine Reserve (TAMR) and South Water Caye Marine Reserve (SWCMR) since 2016. While trial replenishment work began in HCMR in 2011, it was revitalized in 2020 and 2022-2025. This report summarizes work completed in 2025.

Outplanting was voluntarily suspended in 2024 but was resumed in 2025 in smaller numbers than prior to 2024, in caution. A total of 4,131 acroporids were outplanted in seven different locations across Belize.

Mortality of both wild and outplanted acroporids from the 2024 bleaching was as high as >90% in many of the southern sites. FoH did identify survivors/more resilient genets and continued restocking 10 nursery tables at nine sites in seven locations with four different *Acropora cervicornis* genets (46 ropes) and one *A. prolifera* genet (14 ropes).

Belize was on bleaching 'watch' as early as March 2025, again in May, reached Alert Level 2 by August and remained on Alert Level 2 until November 2025. Bleaching surveys were conducted every month January-November (~182 surveys for 2025) and uploaded to the AGRRA website. Bleaching levels in 2025 were less than 2024, but still persistently higher than other years. Much of 2025 was spent re-mapping donor corals and finding new corals to continue adding to the genetic diversity at nurseries and outplant sites. Many corals were re-genotyped (re-sampled) as were "new corals" for genetic analysis (in 2026).

Stony Coral Tissue Loss Disease was observed at Laughing Bird Caye National Park (LBCNP) in May 2025. FoH made six treatment trips May-November, treating ~85 corals (a few of the pillar corals were treated multiple times). All but two of the wild pillar (*Dendrogyra cylindrus*) corals at LBCNP succumbed to the disease. A healthy large fragment was moved to the LBCNP table nursery, and the shallowest pillar coral responded to multiple treatments. The majority of the other affected and treated corals were Symmetrical brain (*Pseudodiploria strigosa*) corals, and a few star corals (*Orbicella spp*).

Spawning monitoring was conducted at South Water Caye August 2025 with spawning from both outplanted and wild acroporids observed on Day's Six and Seven After the Full Moon.

Twenty-one diver-based mosaics were conducted nationwide. Two new plots were added: one in Northern Belize (Coral Gardens) and one in southern Belize (South Water Caye channel). FoH now has three camera set ups to acquire images, and three Metashape licenses to process images. Additionally, a new FoH hire, Mercedes Requena as Marine Research technician, has allowed FoH to finally begin to catch up on the backlog of annotating diver-based mosaics.

Drone ortho-mosaics were conducted at LBCNP, several inner cayes and *A. cervicornis* patch reefs near Placencia, and several sites in TAMR, including a new (to FoH) acroporid stand near Caye Bokel, originally reported by a fisher via the Ecomar "Belize Barrier Reef Watch" program.

In March 2025, a coral ID and bleaching/disease monitoring workshop was held in Placencia with 11 participants including local guides, students, Fisheries and Coastal Zone personnel.

FoH conducted a number of site visits with funders, partners and the media including but not limited to the Caribbean Regional Fisheries Mechanism (CRFM) and the Duchess of Edinburgh. FoH also participated in webinars and was highlighted in an International Science Council policy brief. FoH held its 12th Annual General Meeting (hybrid) in Placencia, November 2025.

Introduction/Background

The Caribbean acroporids were listed as critically endangered (one step away from extinct in the wild) on the IUCN Red List in 2008. Their loss in abundance has been estimated at over 98% in recent decades (Aronson et al. 2008). They are keystone reef species since they are the fastest-growing, main reef-building, branching corals that provide shoreline protection and habitat for hundreds of other marine species. Reef replenishment efforts with acroporids began at LBCNP in 2006 and to date over 92,000 nursery grown corals (all three *Acropora* taxa) have been outplanted in over one hectare of shallow fringing, degraded reef at LBCNP. Using photomosaics, we have shown increases in live coral cover of over 35% in less than five years (2010-2015) at LBCNP (Carne et al. 2016). Efforts expanded to South Silk Caye (in GSSCMR) and Moho Caye (unprotected, control site) in 2015. Expansion to SWCMR and TAMR began

in 2016 under MCCAP. Inclusion of an additional near shore control site (False Caye) began in 2017 under MAR Fund.

In 2024, the IUCN announced over 40% of the world's corals face extinction[1], and several of the Caribbean's previously common corals are now on the Red List due to Stony Coral Tissue Loss Disease (SCTLD), bleaching and disease events.

In May 2025, the World Meteorological Organization issued a press release stating temperatures are not expected to drop in the next five years[2]. In late 2025, Florida announced their acroporids are functionally extinct[3] due to bleaching events, and 160 scientists from 87 institutions in 23 countries declared coral reefs passed their tipping point[4].

Coral replenishment efforts have become increasingly accepted as a management tool (Rinkevich 2014), but many questions still remain, which we continue to address via this program: 1) does MPA status have an effect on the success of the outplanted corals? 2) what is the desired number/density of outplants per plot/site that will achieve self-replication (increases through growth and asexual fragmentation, without adding additional corals)? 3) are there acroporid-associated biodiversity changes that accompany replenishment efforts? 4) *can we still replenish genetically diverse, sexually functional acroporid stands?*

LBCNP is one of the oldest and most extensive restoration sites in the Caribbean and Western Atlantic and is widely considered the best example of true reef restoration. However, much replenished coral mortality occurred at LBCNP in 2024, with new questions arising about future priority sites that need to be collectively addressed and identified. To this end, FoH is collaborating on Belize's National Reef Resilience Plan to develop short, mid and long-term goals. FoH's work and funding will continue in all sites through 2026. FoH is pursuing additional funding options/sources, as always.

In mid-2025, funding from the 2023 CORDAP approved project, "Building the tools for scientific population management of critically endangered coral species in Belize as a

[1] IUCN 2024 press release
[2] https://wmo.int/news/media-centre/global-climate-predictions-show-temperatures-expected-remain-or-near-record-levels-coming-5-years
[3] https://www.science.org/doi/10.1126/science.adx7825
[4] https://www.stockholmresilience.org/research/research-stories/2025-10-13-world-reaches-first-climate-tipping-point---widespread-mortality-of-coral-reefs.html

model for other restoration programs" finally arrived[5]. This project seeks first to collate years of FoH data to create a predictive model or tool, to better decide which corals to outplant, and where. Other funding sources were from WWF, F5 Tech Grant, Summit Foundation, Strong Coasts CoPe, The Belize Fund, the McPZ Foundation, plus private donors have supported various activities reported here.

Objective

Continued objectives under the newest grant from BFSF and other entities include:

1. Enhance coral biodiversity on reefs across Belize through replenishment of resilient coral genets from endangered species
2. Quantify effects of local environment, genotype, and acclimation capacity from outplanted corals

Continued objectives also include:

3. Conduct coral spawning monitoring
4. Collaborate with the National Coral Reef Monitoring Group to carry out reef monitoring for bleaching across Belize's reef systems

The older objective "to increase coral cover by 10% at each targeted site, needs to be amended due to the severe bleaching events.

Methods

Methods remain the same as in the 2024 summary report.

Results

Capacity building

A five-day workshop was held in Placencia in March 2025, fully subsidized by FoH's Belize Fund grant. The focus, as agreed with Belize Fund, shifted to coral ID and learning the proper swim bar methodology for bleaching surveys the Belize NCRMN has endorsed to use for almost two decades. The 11 Belizean participants included eight tour guides, one fisheries staff, one student/NGO intern and one Belizean journalist who

[5]https://cordap.org/dipl-team-member/developing-tools-for-coral-population-management-in-belize

is contracted to write an article on the workshop for MongaBay. There were four female and seven male participants (Figure 1). The attendance sheet is in Annex I.

Bleaching, Temperature and Mortality Data 2025

Bleaching surveys were conducted January-November in 2025 (~16 sites/month in southern Belize, and six sites in TAMR October 2025). Because there was still significant bleaching in 2025, but not as severe as 2024, color codes needed to be updated on the national maps (Figures 2a-b) to indicate the difference in severity. While bleaching usually peaks in Belize during October, it was observed year-round in 2025. Sites surveyed were primarily in LBCNP, GSSCMR, and near shore Placencia that FoH has been monitoring for many years; 2024 was still the most severe to date (Figure 2c). FoH has been monitoring several sites in SWCMR since 2017, and that historical October data 2017-2025 is shown in Figure 2d, again illustrating 2024 bleaching levels were the most severe to date. However, bleaching remained persistent throughout the months surveyed in 2025 January-November for southern Belize sites (Figures 2e-f).

Some bleaching surveys were conducted in TAMR in mid October 2025, and Figure 2g illustrates October bleaching levels from 2021-2025, reflecting the same results/pattern that 2024 bleaching levels were the most extreme to date.

The only 2025 temperature data collected in 2025 is from Tobacco Caye (SWCMR) (June 2024-2025, Figure 3) and Black Bird Caye (October 2024-2025 TAMR). The other loggers at multiple sites will be retrieved in 2026, and all raw data (2007-2025) housed here.

Stony Coral Tissue Loss Disease (SCTLD) and other mortality post 2024 bleaching

SCTLD was first reported in Northern Belize in 2019, spread to South Water Caye Marine Reserve by 2021, then rapidly spread south along the Main Barrier Reef through 2023. FoH was trained in the recommended treatment at the time, and actively treated hundreds of corals 2021-2023. There were very few active lesions observed in 2024 and the inner cayes, west of the main barrier reef including Laughing Bird Caye National Park remained unaffected until May 2025. In fact, through mid-April 2025 there were no active lesions at Laughing Bird. However, this disease rapidly kills corals, and the critically endangered pillar coral is one of the most susceptible species. FoH still has the treatment and the day after the disease was observed (May 20, 2025), treated three different corals species and moved one unaffected pillar coral fragment to the table nursery (Figures 4a-b). FoH also monitored the pillar corals at Moho Caye (healthy), and the two other sites with any living pillar corals (Caye Caulker and Wil Baur Flats) have been checked and remain healthy, as of late 2025. A map of the few remaining living pillar corals is in Figure 4c. The Moho colonies are still unaffected, and because

so few pillar corals are left, two small satellite colonies from the larger coral at Moho Caye were translocated to Will Baur Flats June 13, 2025 (Figure 4d). They were placed on the reef near the wild colonies there and are currently thriving.

Since May 2025, FoH made a total of six treatment trips to LBCNP, where SCTLD quickly spread, as observed in other reef sites in previous years. Although multiple treatments were made on the pillar corals, only two survived: the fragment in the nursery and the shallow pillar coral (Figures 4e-f). Other affected species were primarily the *P. strigosa*, and few *Orbicella spp.*

The coral mortality in southern Belize from the 2024 bleaching event was far more extreme than post-2023. One way to assess the loss of staghorn is via diver-based mosaics. At Moho Caye, three plots (~100m^2) were established in 2015 and monitored this way prior to outplanting, and nearly every year since. Only outplanted staghorn (not elkhorn) were in these plots and no corals were added after initial outplanting, to track the natural growth over time. Figure 5a shows increases in coral cover every year, even post 2023 bleaching, but post -2024 bleaching all the outplanted corals died, and even some wild ones, reducing the live coral cover to <5%.

Another way to assess mortality is counting the individual elkhorn colonies where possible: at Laughing Bird Caye there were too many to assess this way, but the original 2006 transplanted colonies could be tracked: they survived the 2023 bleaching event but not a single one survived the 2024 bleaching event. At South Silk Caye, post 2023 there were 358 Elkhorn colonies (February 2024) most of them outplanted. Post-2024 there are no living wild colonies and only 14 living outplanted colonies at South Silk Caye (Figure 5b, 2025).

However, there are > 60 living elkhorn colonies at Middle Silk Caye. At Moho Caye there were 498 *A. palmata* colonies; post 2023 16% mortality (mostly micro frags), but post 2024 is 73% mortality. None of the original 2006 *A. palmata* transplants at LBCNP survived the 2024 bleaching event, but many others did, including the 2023 outplants sourced from the “inner cayes” near Placencia; see *A. palmata* donor map (partially complete) Figure 6a.

The general pattern for survivors is that the donor corals were sourced near-shore versus offshore, meaning they may be more thermally tolerant as decades of temperature (both satellite and in situ) data shows near shore Placencia waters to be hotter than the offshore sites.

Outplanting 2025

Because the WMO press release in May 2025 stated no abatement for rising sea temperatures, and because there are enough surviving *A. palmata* outplants-some with partial mortality but most sourced from the inner cayes have little to no partial mortality, FoH decided not to wait and to continue outplanting but primarily with the near shore sourced donors. Figure 7 is a table showing the amount of each taxa outplanted and

where, in 2025. Figures 7a-b are examples of the near shore sourced *A. palmatas* that survived both 2023 & 2024 bleaching events; one from 2023 outplanted at Middle Silks Caye and one from 2025 outplanted at Moho Caye.

Re-stocking nurseries with resilient survivors:

Since January 2025, FoH has moved/re-propagated 133 fragments of the hybrid, *Acropora prolifera* on 14 ropes to four different nursery locations, including Caye Caulker in Northern Belize (Figure 8a). Four different genets of winning staghorn (*A. cervicornis*), have been moved to seven different nursery locations (486 frags on 46 ropes). Importantly, a "new" staghorn patch in Gladden Spit and the Silk Cayes Marine Reserve was identified to FoH by our local chairman, fisher and tour guide, in 2024. This patch was monitored and much of it survived the 2024 bleaching event, and so was recently added (40 fragments, on four ropes) to the Silk Caye nursery tables. Not only is this a "new" genet to add to our nurseries, but it is one exception to the near shore survivors' pattern, as it is 25 miles offshore on the back reef. Another 'winning' staghorn was identified near Harvest Caye and moved to Whipray & LBCNP nurseries. Survival rates have been high with one exception: at Bacalar Chico Marine Reserve almost all of the staghorn placed there in May 2025 died by November 2025.

Total Linear Extension (TLE) is conducted on the *A. cervicornis* genets to compare growth rates both between genets, and locations. Figure 8c confirms that faster growing southern Belize sourced genets also grow fast in northern Belize nursery locations.

Spawning 2025

In August, FoH had a fruitful coral spawning monitoring trip to South Water Caye Marine Reserve. A catamaran was provided by Belize Sailing from Aug 9-17th, which allowed for 7 nights of spawning monitoring. With at least 6 persons in the water, the team was able to split into 2 groups, to monitor different areas ensuring observation of both elkhorn and staghorn. There were only a couple healthy staghorn colonies to observe on the north side of the channel, while on the southside of the channel several elkhorn colonies could be observed in a small area. Spawning was observed of staghorn Aug 15th and of elkhorn Aug 16th, though we suspect the elkhorn spawning peaked after our monitoring window, possibly the night of the 17th based on the observation that most colonies only spawned from small portions of their surface. The observations have been shared with AGRRA, so data from Belize can be represented in regional reporting.

Diver Based and Drone Mosaics

All 19 diver-based mosaic plots were repeated in 2025. Two new plots were added: one at Coral Gardens (unprotected) between HCMR & CCMR. The purpose of this new plot is to track how long the dead *A. cervicornis* retain their structure, before eroding. The other new plot is small, in the SWC channel. FoH plans to translocate a number of non-acroporids (species and genets) to this site in 2026 and track their survival over time.

All the processed and annotated diver mosaics (including an Excel tracking the progress of annotating years of backlogged data) are here. FoH is currently primarily looking change in total coral cover over time, but other colleagues and future plans include a deeper dive into this long-term data that is separated by coral species, some other benthic invertebrates, algae, and substrate type. A long term (2015-2025) example from Moho Caye (Figure 5a) illustrates the rapid mortality post 2024. Another example from the channel at Tobacco Caye (2018-2025) is shown in Figure 9. In this case, there was originally a small increase in coral cover from outplanting, but SCTLD reached this site in 2021 and the gradual decrease in coral cover are mostly from SCTLD. Predation on the acroproids was also quite high, even before the bleaching events (2023-2024). Because the annotation protocol lays random points across the plots, FoH will begin to look at the plots using a software called “Taglab” to track individual coral colonies, especially outplanted *A. palmata,* over time.

All 2025 drone orthomosaic products are housed here, with the exception of the LBCNP orthomosaics which are LBCNP 2019-2025 drone. It does not appear very easy to identify dead from living corals from the drone, with the exception of *A. palmata* in the shallows.

Fig. 1. Participants and instructors in the workshop: “Coral ID and Monitoring for Bleaching & Disease in Belize, in Relation to Reef Restoration Future Strategies” March 17-21, 2025 in Placencia. Not shown is Nicole Leslie who had to leave early on the last day.

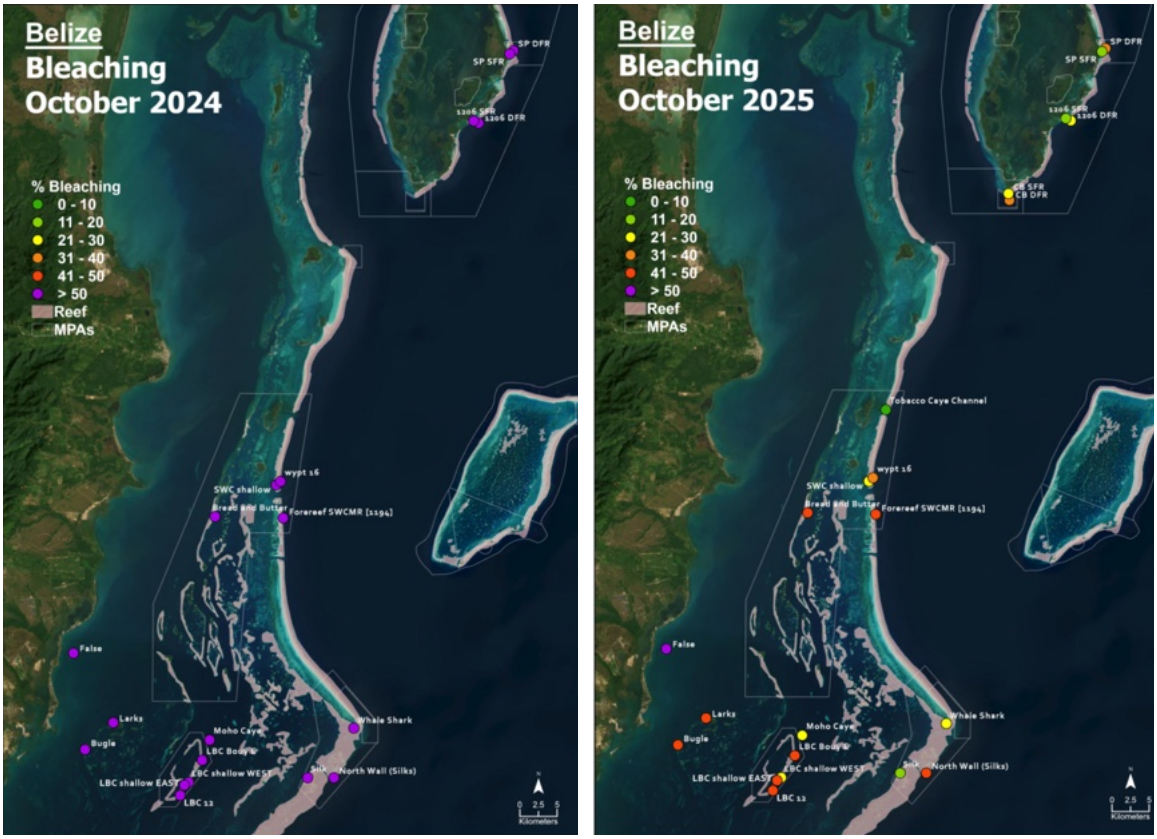
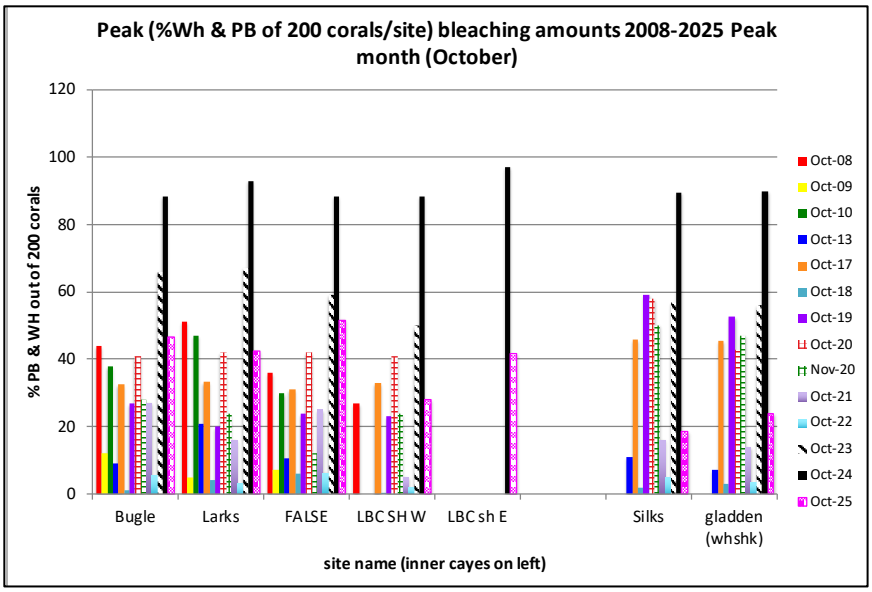


Fig. 2a-b. Comparing the severity of bleaching in October 2024 with October 2025. All surveyed sites had >50% bleaching of 200 corals surveyed in 2024, versus a more varied pattern in 2025.



Figs. 2c. Bleaching surveys conducted in and near LBCNP and GSSCMR by FoH 2008-2025, October data only, in southern Belize.

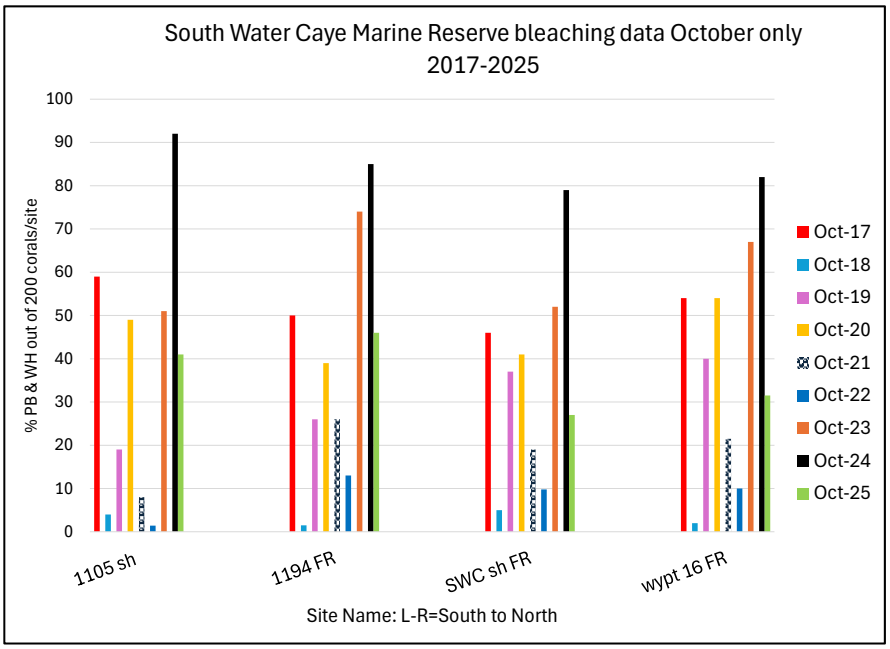


Fig. 2d. Comparing peak (usually October) bleaching levels at four sites (two fore reef 40-60ft, one shallow fore reef and back reef site-1105) 2017-2025 in SWCMR.

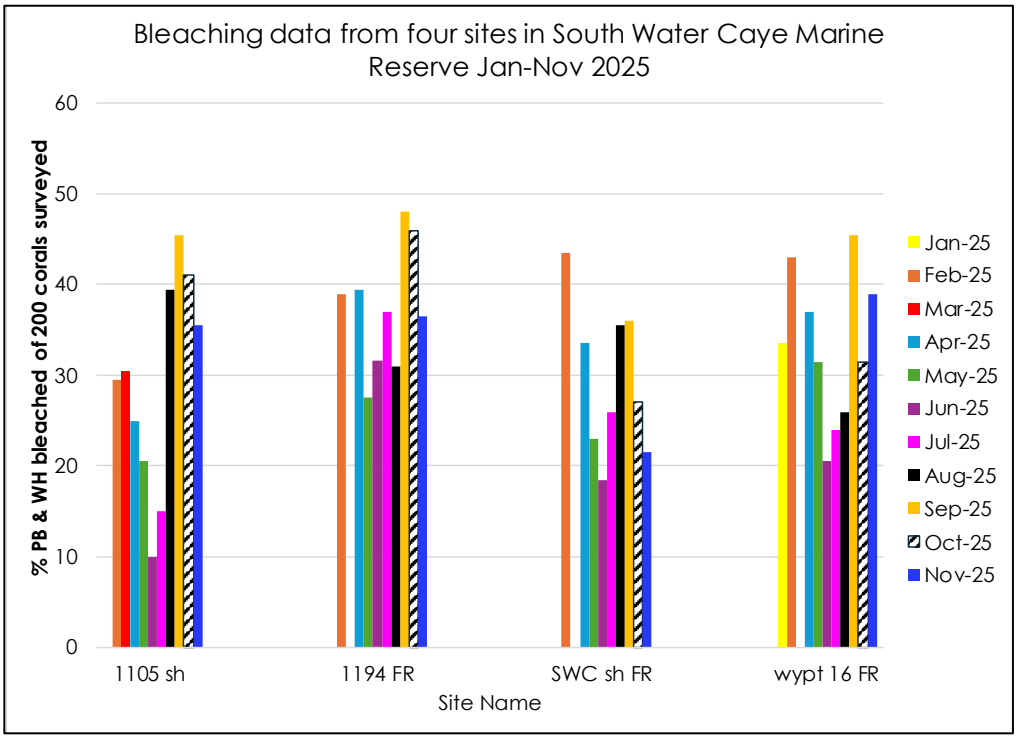


Fig. 2e. The 2025 monthly surveys conducted by FoH at four sites in SWCMR January-November.

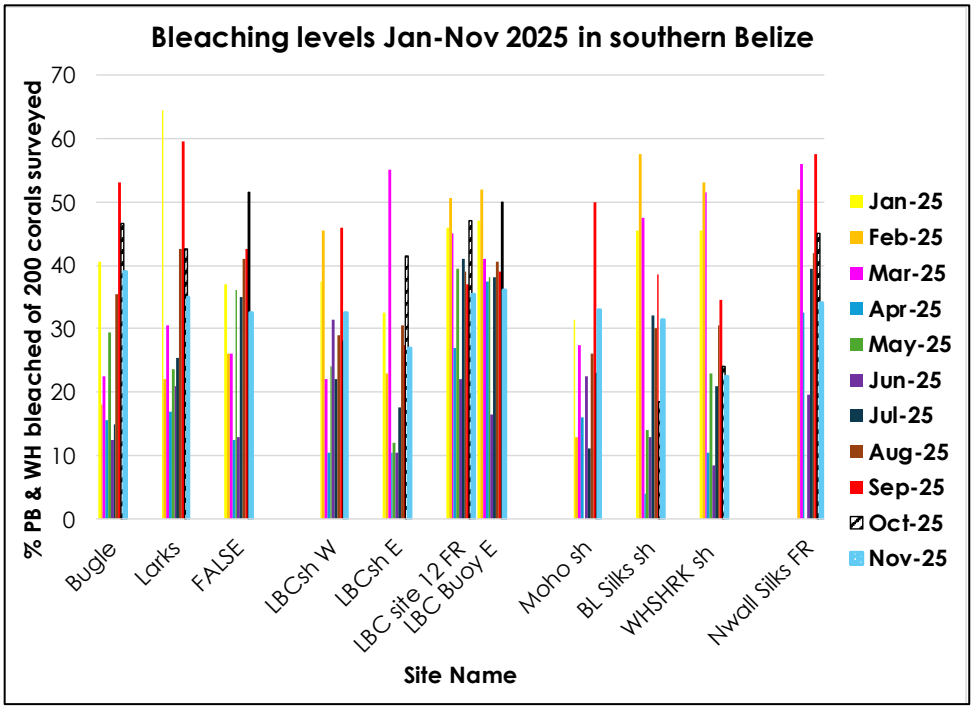


Fig 2f. The 2025 monthly surveys conducted by FoH at 11 sites in southern Belize, January-November

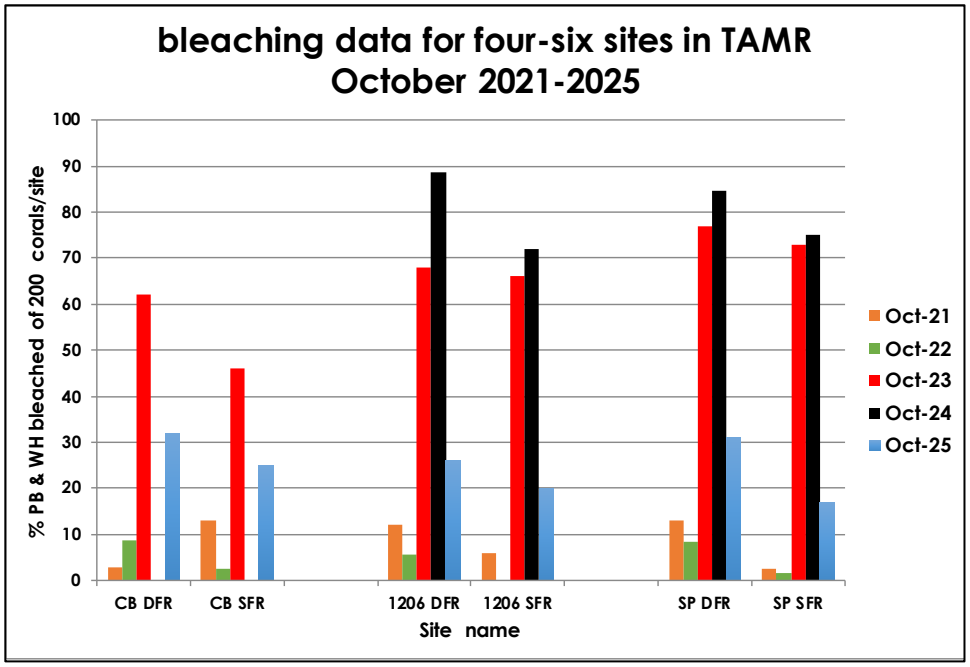


Fig. 2g. Bleaching data during October 2021-2025 reflecting the most severe bleaching in 2024. Site names and coordinates are from the University of Belize.

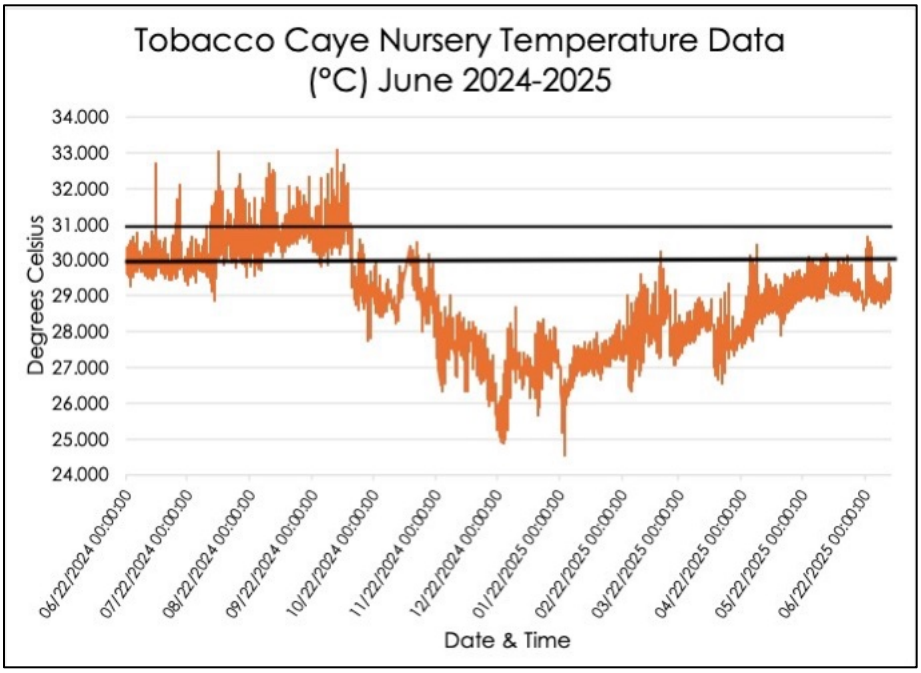
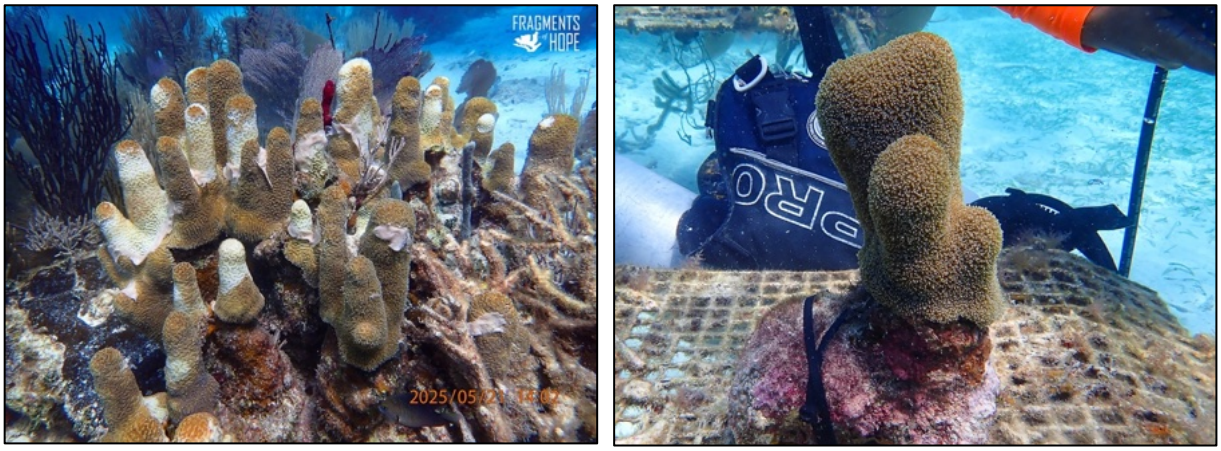
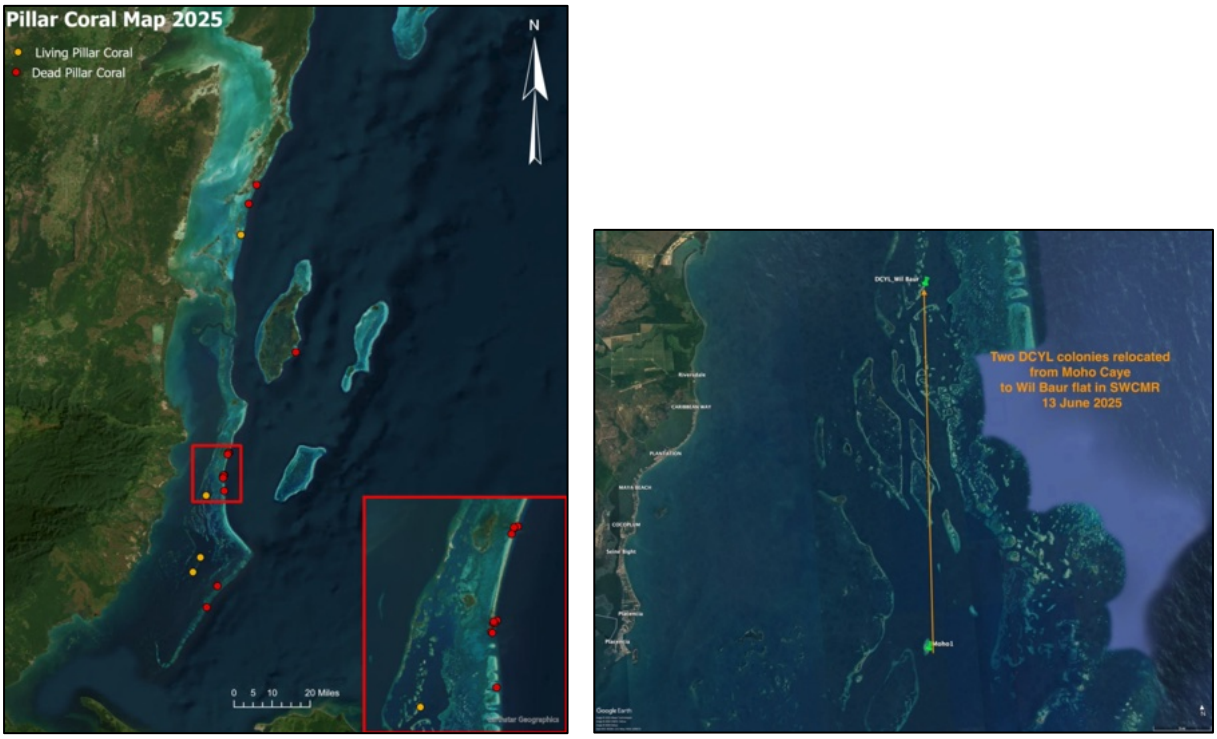


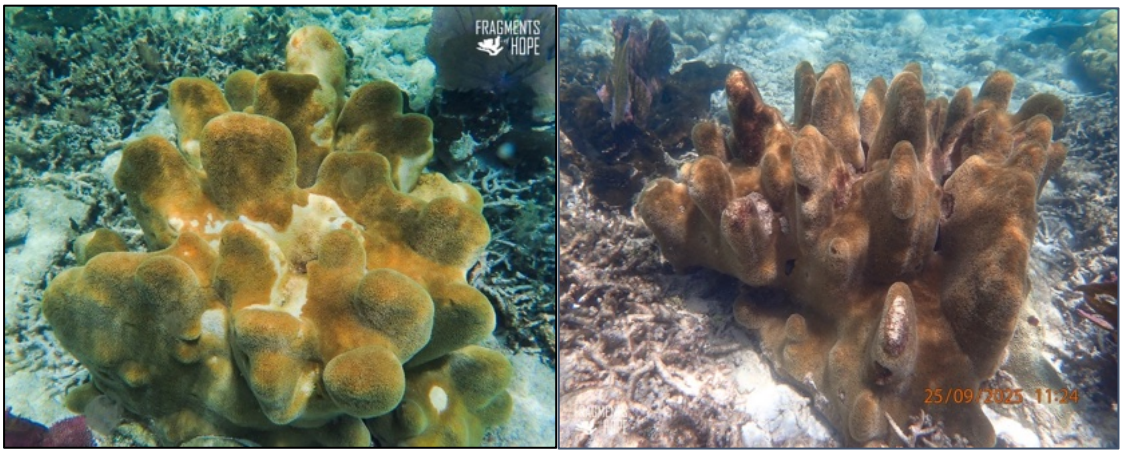
Fig. 3. Temperature data from near the shallow table nursery at Tobacco Caye, in SWCMR, June 2024-2025, illustrating the vast difference in temperature between years.



Figs. 4a-b. During 2021-23 the Belize Fisheries Department amended SCTLD protocols to not treat any coral with >50% mortality, however with so few pilar corals remaining the FoH team still treated what they could (L) and relocated an unaffected fragment to the table nursery at Laughing Bird Caye National Park (R).



Figs. 4c-d. The map on the left is the few remaining living pillar corals in Belize. FoH has heard anecdotally of a few other, but not received any coordinates or verification. On the right is the illustration of the two healthy small pillar corals relocated from Moho Caye to Wil Baur flats.



Figs. 4e-f. The shallow pillar coral at Laughing Bird Caye National Park on 4Aug25 (L) with active SCTLD lesions, and on 25Sep25 after several treatments (R) where it appears the infection is a least temporarily abated. This coral received additional treatment in November, 2025.

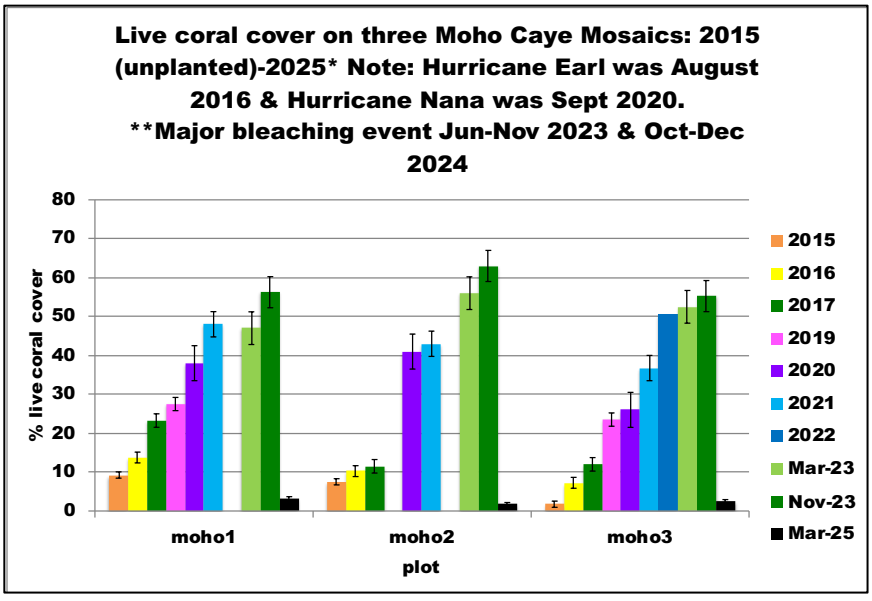


Fig. 5a. This graph shows the percent coral cover in three replenished plots at Moho Caye and illustrates yearly increases until after 2024 bleaching, when live coral cover was reduced to <5%.

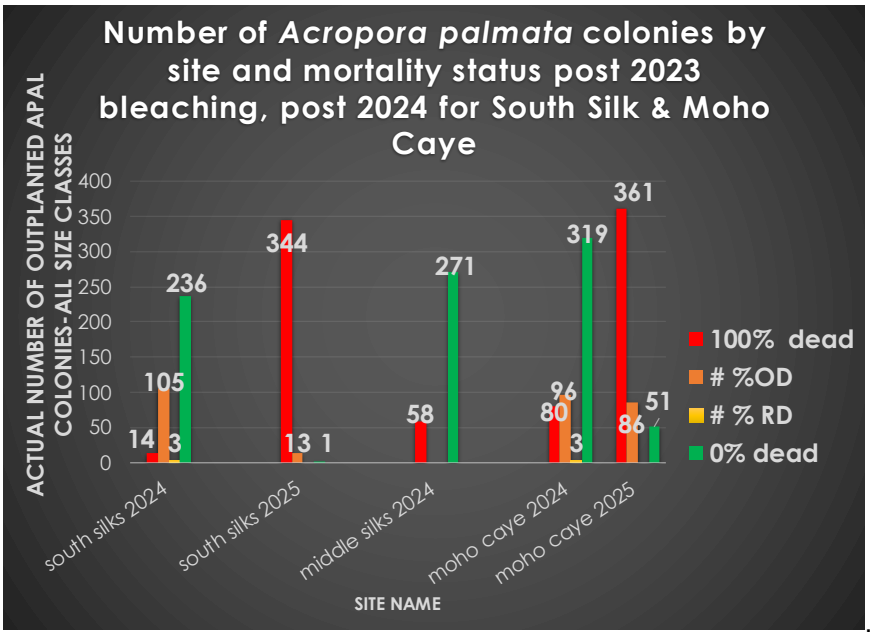


Fig. 5b. Actual colony counts of *A. palmata* (on the Y-axis) reflecting the graphic difference post-2023 and post-2024. At south silks post 2024 was only 4% survival compared to post 2023 was 96% (all wild *A. palmata* there dead post 2024). At Moho Caye post-2024 was 33% survival compared to post 2023 was 84%.

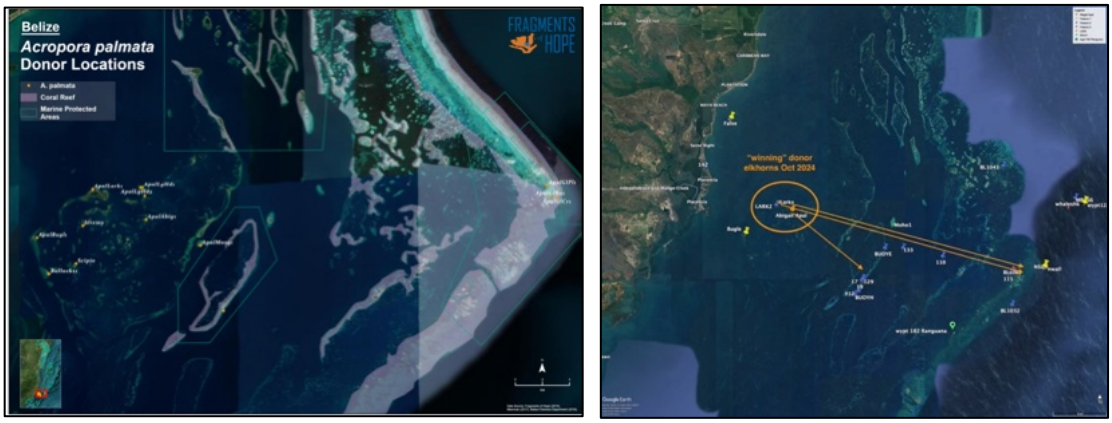


Fig. 6a-b. On the left is a draft map of many of the post-2024 *A. palmata* survivors (winners), that FoH is micro-fragmenting and moving to off shore sites including LBCNP, Moho and Silks cayes.

SITES	TAXA outplanted 2025						TOTAL 2025	totals
	ACER	APAL	APRO	MCAV	OFAV	DCLY		
LBCNP	172	240					412	92,808
south silk caye GSSCMR							0	16,329
Middle SILK caye GSSCMR		498	1858				2,356	2,966
MOHO		343					343	24,874
FALSE							0	8,845
SWC	757						757	8,415
TOBACCO CAYE							0	11,840
BLACK BIRD CAYE							0	6,429
CALABASH CAYE (& nearby, new site)							0	4,887
Mexico rocks	23						23	1,023
HCMR by nursery	63						63	360
HCMR Hol Chan							0	329
Caye Caulker plot 1							0	267
caye caulker shark ray							0	133
Caye caulker by tables			177				177	2,745
SUB totals	1015	1081	2035					
TOTAL							**4,131**	**182,250**

Fig. 7. Table with number of outplanted fragments by taxa and location for 2025.

Figs. 7a-b. Example of winning near-shore sourced *A. palmata* outplant at Middle Silk~ 2 years on the reef, no partial mortality (L). Example of winning near-shore sourced *A. palmata* outplant at Moho Caye ~ 6months on the reef.

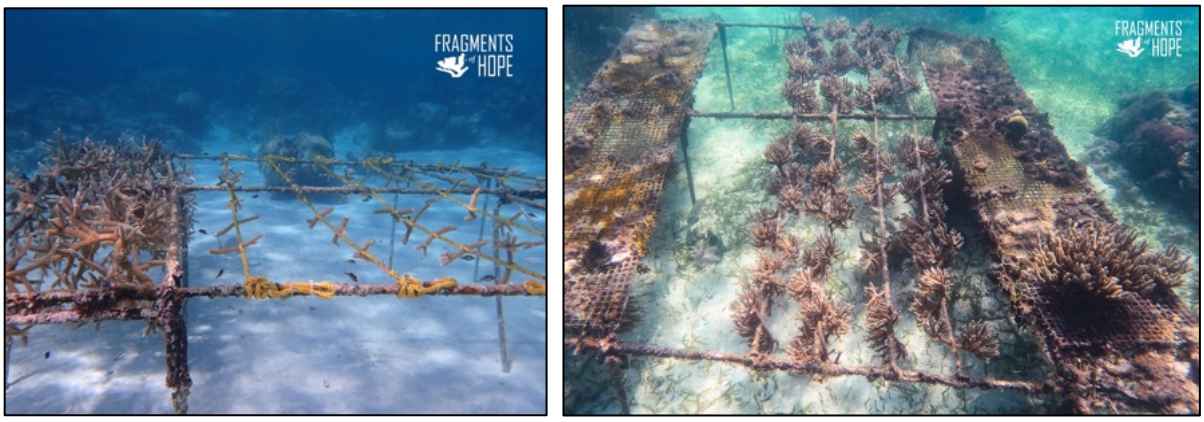


Fig. 8a-b. Example of southern *A. cervicornis* sourced genet thriving in Caye Caulker nursery (L) and *A. prolifera* genet thriving in Whiray Caye nursery (R).

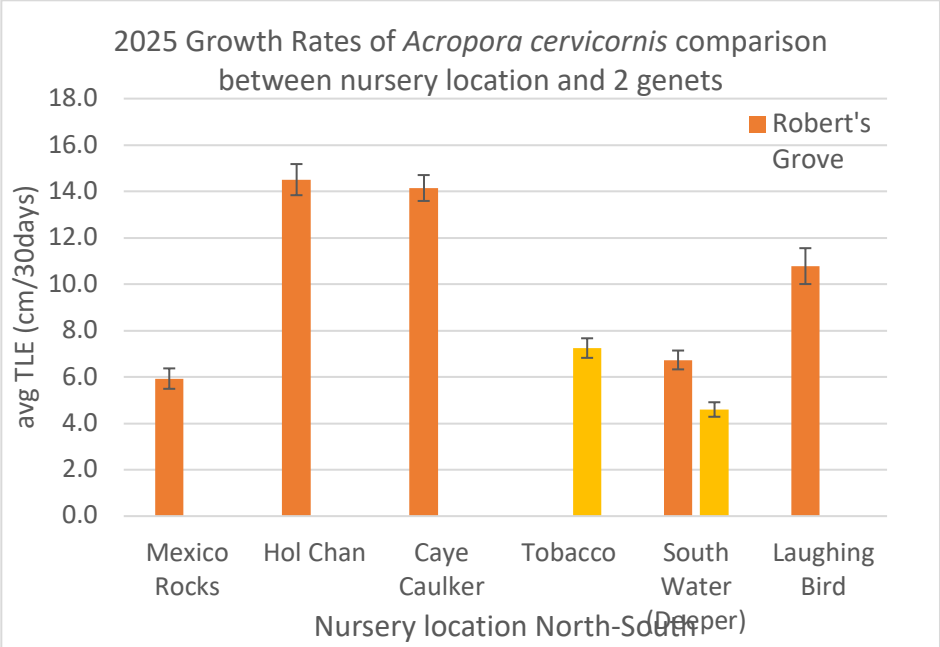


Fig. 8c. Comparing two *A. cervicornis* genets' growth rates at different nursery locations: both are sourced from southern Belize. The preliminary higher growth rates in northern Belize may reflect 1) the shallow nursery depth and 2) the older aged fragments (the more they grow, the more branches form and grow).

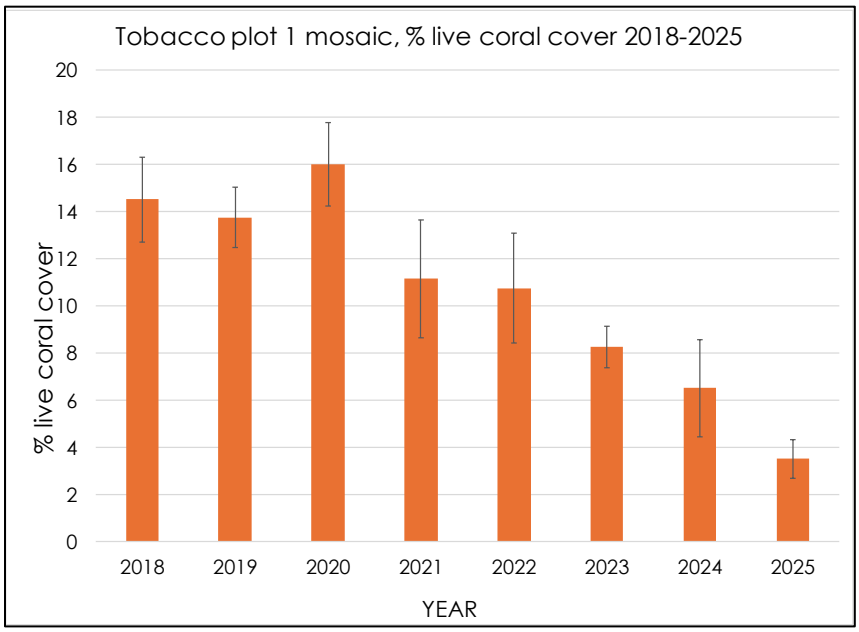


Fig. 9. Total live coral cover annotated from the diver-based mosaics at Tobacco Caye plot 1 (in the channel), 2018-2025.

Discussion, Recommendations & Future Plans

The combined mortality from bleaching events and SCTLD has set back the replenishment work by over a decade, reducing live coral in many areas to <5%. FoH was unsure any outplanting would occur in 2025; yet over 4,000 fragments were outplanted and many survivors mapped. Under the approved CORDAP grant, FoH has hired a part -time GIS technician to create a GIS database. It is much work to collate > 10 years' worth of data, the end goal being a sort of predictive tool and/or population management program for endangered coral species. FoH remains committed to also working with the NCRMN and others to create the National Reef Resilience Plan in 2026. This will include community discussions about narrowing down the numbers and locations of targeted replenishment sites.

With such uncertain and rapidly changing environmental and political conditions regarding fossil fuels, we must be ready to employ adaptative management changes and hopefully begin to address the local impacts to coral reefs, collectively.

Annexes I-: Reports from:

- Annex I: Attendance Sheet for March 2025 workshop.
- Annex II: SCTLD treatment Excel spreadsheet.
- Annex III: Spawning data sheet 2025 (Excel file)
- Annex IV: Student Linden Cheek summary report
- Annex V: Student Claudia Baron Aguilar summary report

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