

WWF technical Report

PART 1: GENERAL NARRATIVE REPORT

Project Title:	Facilitating coral reef resilience to climate-driven bleaching incidence through bioengineering as a means of lesson-learning: A continuation
Project Number:	DW50
Reporting Period:	July 25-Dec 15, 2019: Report 4 Summary of work to date
Organization Submitting Report	Fragments of Hope

Citation suggestion: Carne, L. (2019). Facilitating coral reef resilience to climate-driven bleaching incidence through bioengineering as a means of lesson-learning: A continuation. Technical Report 4. DW50. Fragments of Hope and the World Wildlife Fund.

Project Overview. During hurricane season (June 1-November 30) no coral outplanting is planned/conducted but regular monitoring of nurseries and outplants continues. This year the Stony Coral Tissue Loss Disease (SCTLD) was reported in northern Belize and much time was committed to national and regional meetings designed to develop an action plan for response to SCTLD. Dr. Claire Paris from the University of Miami had previously developed an acroporid coral larvae dispersal model using hydrodynamic models for Mesoamerica. Given that SCTLD is thought to be water bourn, and with input from models used in the US Virgin Islands to predict the spread of SCTLD, Dr. Paris and her colleagues created such a model for Belize at Fragment’s of Hope request. With input from regional partners, from Florida, Mexico and the US Virgin Island, a number of treatments for SCTLD were tried in Bacalar Chico, with the most recent recommendation being the use of antibiotics in a special paste applied semi-regularly. Unlike other regions affected, Belize has no land based nurseries for any emergency rescue options, so instead the use of in water nurseries will be trialled, with one-two of the most susceptible coral species targeted (e.g. *Dendrogyra cylindrus* and/or *Monstastrea cavernosa*) in partnership with the Smithsonian Institution. Fortunately, acroporids remain unaffected by SCTLD. Besides the SCTLD crisis, 2019 has been the most severe bleaching event for Belize to date, this year marked not only by the severity, but the lateness of the onset, and the length of the event: as of December 15 bleaching is still severe on outer and deeper reefs. For this reason, coral outplanting is delayed until full recovery of the 2019 bleaching event is in evidence, even though many shallow acroporids are showing resistance and/or resilience. During the last report period the annual photo-mosaics were conducted at Laughing Bird Caye National Park and sent to Dr. Arthur Gleason for processing. Dr. Steve Schill, Lead Scientist for the Nature Conservancy, Caribbean Division, came to Belize and trained FoH members on the use of drones for shallow coral reef mapping and has committed to assist FoH with processing those mosaics for another twelve months. Lisa Carne’s abstract entitled “Challenges in evaluating reef restoration success: how long do we need? Lessons learned in Belize the past decade” was accepted as an oral presentation to the ICRS 2020 conference in Bremen, Germany under the theme “Interventions and

restoration'. Local stakeholder updates were shared at FoH's 6th AGM in Placencia in August, and again at a week of meetings in Belize City during October that also included regional stakeholders. The final days of these meetings were the Second Biennial Mesoamerican Reef Restoration Meetings, and Lisa Carne was re-elected as the Belize representative on the Executive Committee.

Progresses on each activity are listed in Section 3 below in numerical order (Activity #2-9), while Project Successes (Section 2) are listed in chronological order.

Project Successes. Fragments of Hope (FoH) shared their photo-mosaics results to date in online webinar on the subject July 25, hosted by The Nature Conservancy and was featured in the Caribbean Culture & Lifestyle magazine, shared on the local Maya Island airlines and in most hotel rooms, <https://caribbeanlifestyle.com/a-race-to-save-the-reef/>. FoH was also featured on Swiss Radio by journalist Max Bohnel in September¹. Ms. Nicole Craig represented FoH in Australia at the Commonwealth Blue Charter Reef Restoration meeting in July, and again in New York City at the United Nations Climate Summit on "Solutions for Implementing Gender-Responsive Climate Action" in September². FoH helped MAR Fund to organize the Second Biennial Mesoamerican Reef Restoration Network meeting in Belize City October 9-10 and was featured on the local channel 5 news:

<https://edition.channel5belize.com/archives/192259> and <https://www.youtube.com/watch?v=KhrKfS9uRBU>.

Following the October meetings in Belize City, FoH hosted Dr. Dave Gulko from the Hawai'i State Government and Dr. Johanna Calle from Iberostar Resorts (in Mexico and the Dominican Republic) at Laughing Bird Caye National Park (LBCNP). Channel 5 interviewed both visitors at LBCNP where they each declared it the best restoration site they had ever seen.

Dr. Gulko's edited video is here: <https://www.youtube.com/watch?v=bqYJ3pcDya0>

Dr. Calle's unedited footage (in Spanish & English) is here:

https://drive.google.com/open?id=1q6AHDjQQY2SfdB7wg_uY3bj1Vdwjq3Fr

The abstract entitled "Challenges in evaluating reef restoration success: how long do we need?

Lessons learned in Belize the past decade" was accepted as an oral presentation to the ICRS

2020 conference in Bremen under the theme "Interventions and restoration" and in the

Session: How can interventions and restoration help coral reefs survive the next few decades?

Many of these project successes have been highlighted on social media and shared in in monthly

articles in the local Placencia *Breeze*. FoH received a small amount of funds from Vulcan/Allan

to create in water rescue nurseries for *D. cylindrus* in partnership with Dr. Valerie Paul at the

Smithsonian Institution. FoH has also received several generous donations from the private

sector, and has been contacted by several other journalists, many from Germany, since the

feature on the ARD/TV news station.

¹ <https://oe1.orf.at/player/live>

² Aired on facebook live:

<https://www.facebook.com/GEFSmallGrantsProgramme/videos/515586912540066/UzpfSTExNjgzMTQ0NjI6MTAyMTg1Njc4MzA2MDQ4MzA/>

3) Progress on Activities and related financial issues.

Activity #2. Maintenance of over 16 nurseries in southern Belize continues, with regular cleaning and reinforcement of structures. Sadly, almost all of the acroporids at the newest, near shore site False Caye (see map Fig. 3) did not survive the 2019 bleaching event, with two staghorn (Figures 1a-b) and one hybrid genet (Figure 6a) an exception; these will continue to be monitored and propagated for their resilience. While there was some partial bleaching on acroporids at the LBCNP and Whipray nursery, there were no mortalities from bleaching, and most of the LBCNP acroporids have recovered as of December 15, 2019. Notably there was minimal to no bleaching on the acroporids in the Silks and Moho Caye (Figure 1c) nurseries, both several years older than the False Caye nurseries.



Figs. 1a-b. Nurseries at False Caye Oct 22, 2019 (L) and November 25, 2019 (R).



Fig. 1c. Table nursery at Moho Caye, no evidence of bleaching or partial mortality, picture taken December 15, 2019. These staghorn genets were sourced from Silks and Hatchet (Ray) Caye, on the outer reef, and placed in May 2019.

Activity #4 & #6. Bleaching: Monitoring of nurseries and outplants has an emphasis on bleaching during hurricane season, and Figure 2a shows the level of bleaching in October 2017-2019 because October was historically the peak bleaching month in Belize, until this year. Figure 2b includes historical data back to 2008, to reflect that the outer reef sites (right hand side of X-axis) were more severely affected than the near shore sites; the longer data set for the near shore sites (left hand side of X-axis) also illustrates a decreasing rate of bleaching over time, suggesting local adaptation and increasing temperature tolerance. Figure 2c includes 2019 survey data through December (for some sites) to reflect that, for some sites, bleaching was worse in November than October and remains high for the outer reef sites surveyed in December. Figure 3 is a map for reference to inner (near shore)/outer reef sites (illustrating October 2019 results only).

FoH has large sets of *in situ* temperature data-in some sites up to ten years, which makes it difficult to illustrate all the data at once. Figures 4a-e are a sample of some this data from multiple sites comparing different years and/or different locations in the same year. Besides the southern Belize sites, FoH also has multiple years of *in situ* data sets from Turneffe Atoll Marine Reserve and South Water Caye Marine Reserve. Although some requested data sets have been shared with NOAA and other partners, FoH is still actively seeking external collaborators to better organize and illustrate all this data. The prevalent trend, across all sites is the marked difference in 2019 versus other years by up 1-2 degrees Celsius in October-explaining how the bleaching data for many sites was worse in November than October and lasting longer. Each graph is captioned with details. The partial recent mortality observed in 2019 is higher than previous years (Figures 5, 5a-d).

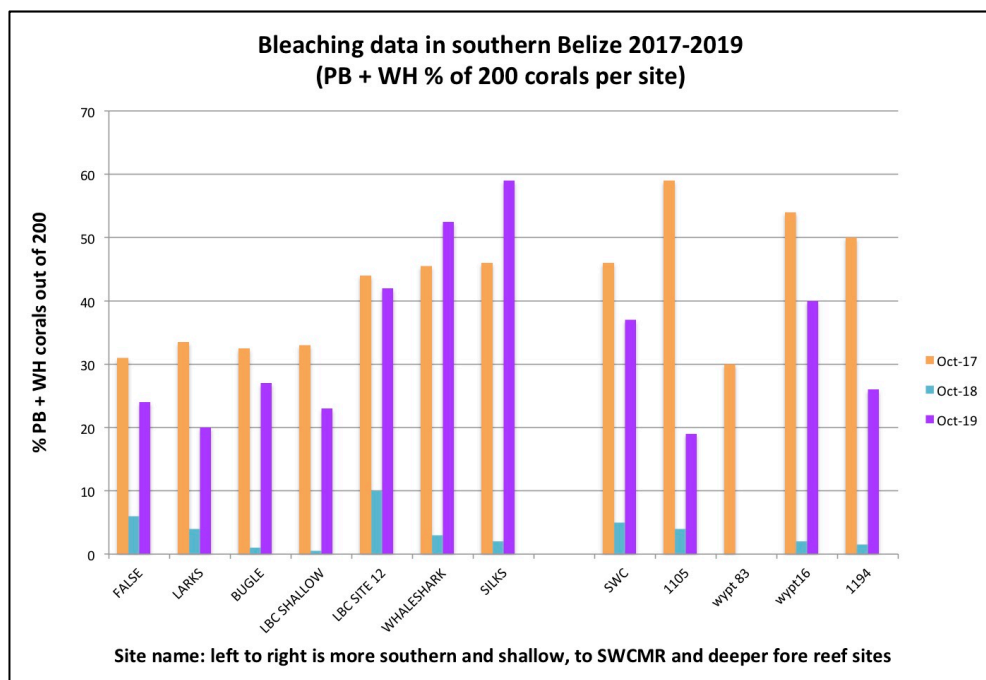


Fig. 2a. Comparing bleaching rates in October 2017-2019 at multiple sites in southern Belize. All are shallow except LBC12, wypt 16 and 1994 are ~ 40-50 ft or 12-14m depth. The percentage of bleaching (Y-axis) is based on 200 corals per site surveyed.

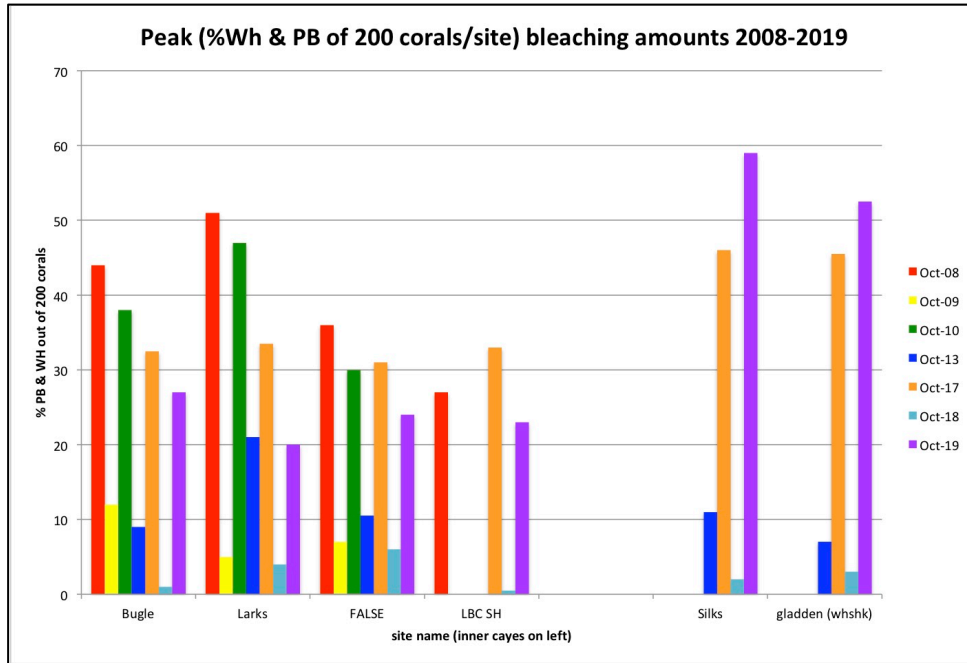


Fig. 2b. Historical bleaching data in October 2008-2019 (where available) for shallow sites in southern Belize. On the left (X-axis) are the near-shore sites compared to the off shore sites on right side

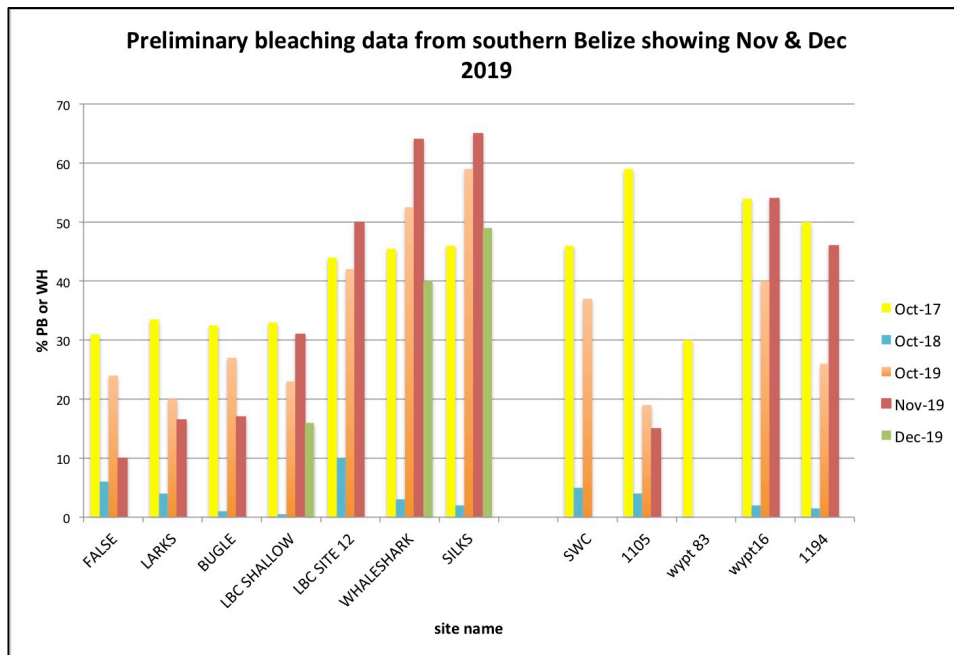


Fig. 2c. This chart is the same as Figure 2a but includes November and December 2019 data where available. On the deeper and outer reef sites (LBC site12, wpyt 16, 1194, whale shark, silks) bleaching levels increased in November over October, and at the outer reef shallow sites, whaleshark and silks bleaching levels remain severe (>40%) up to mid- December 2019.

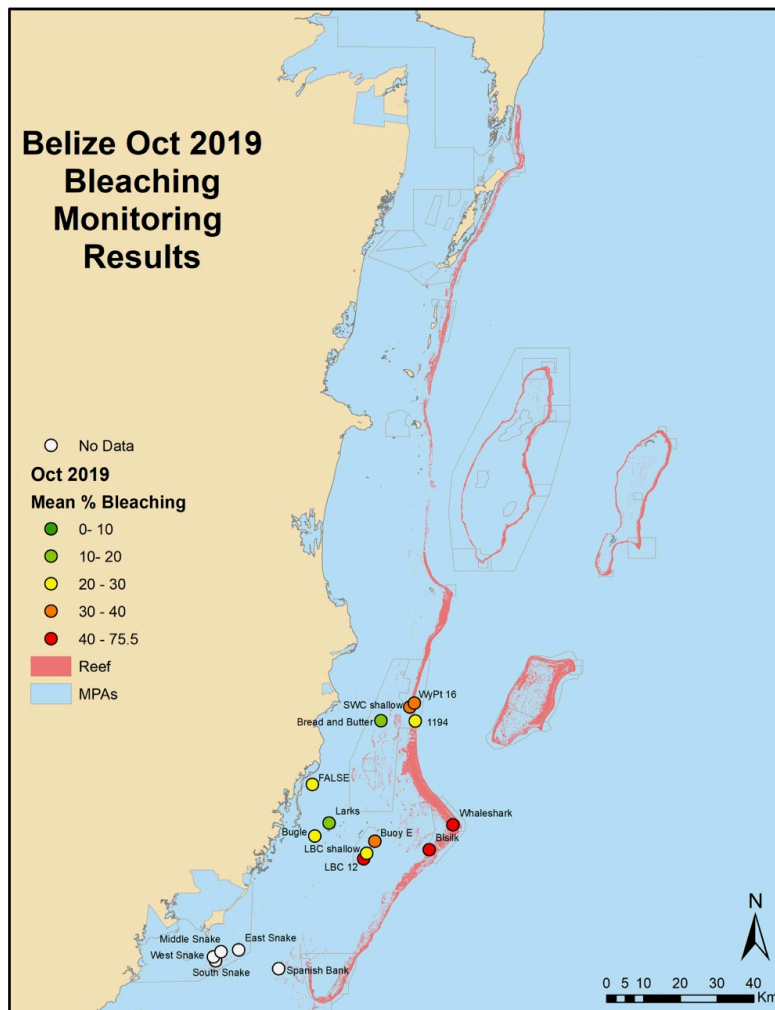


Fig. 3. Map created/donated by Lynnette Roth to match formats used in 2008.

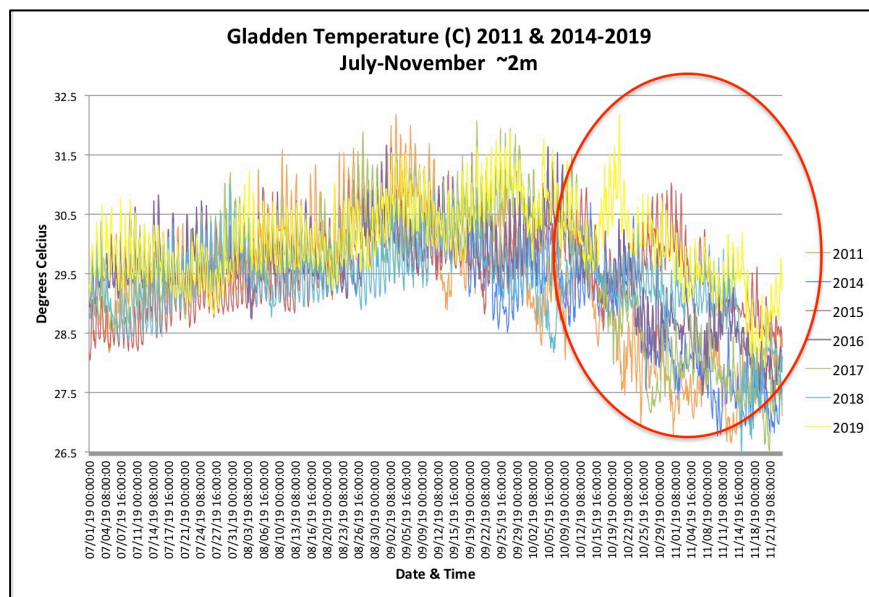


Fig. 4a. Comparing temperature at Gladden (degrees Celsius on the Y-axis) in 2011 and 2014-2019, July-early November. With multiple years of data it can be difficult illustrate differences; in this graph 2019 is bright yellow and October-November is circled as clearly several degrees warmer than previous years. Gladden=the whaleshark site on the map in Fig. 3.

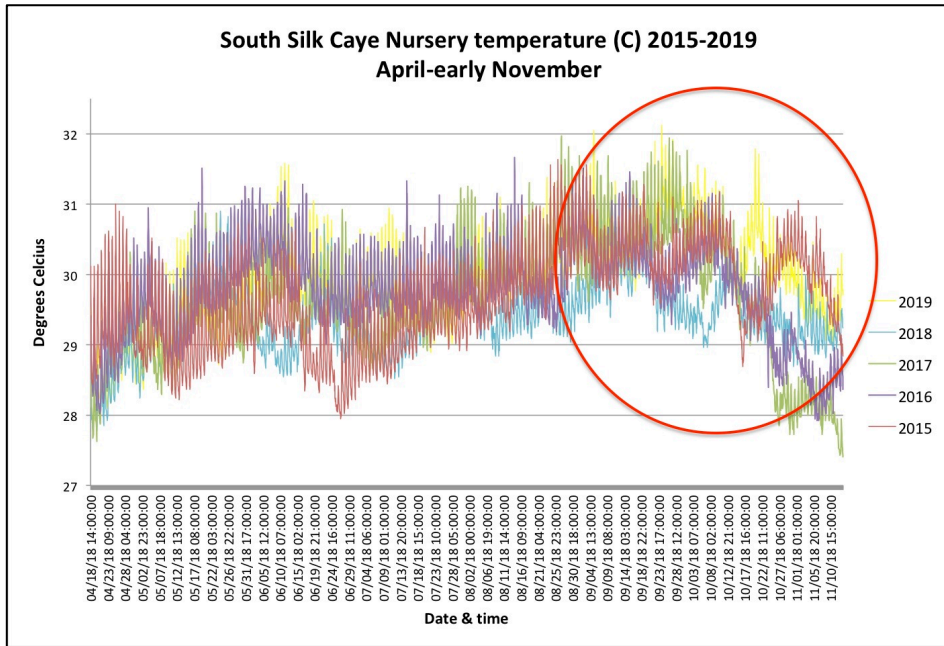


Fig. 4b. Comparing temperature at Silks (on map in Fig. 3) 2015-2019, April- early November. Here 2019 is bright yellow and with a brief exception in 2015 (also seen in Fig 4a) temperatures are considerably higher in 2019 Oct-Nov.

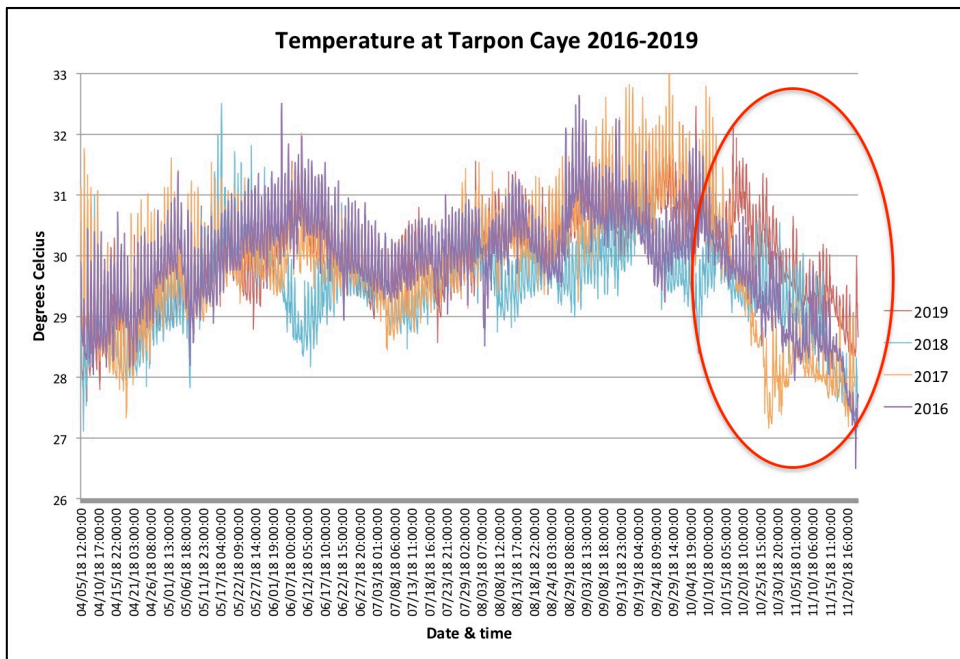


Fig. 4c. Moving west from locations Figs 4a-b, Tarpon Caye is not on the map in Fig 3 (no bleaching surveys there) but an A-frame has been on site since 2009-and FoH has temperature data that long, but for simplicity only 2016-2019 shown here-2019 data is red in this graph and again several degrees higher than previous years. The temperature itself is consistently higher at Tarpon than on the outer reef sites (note Y-axis scale is 33C versus 32C in previous graphs) yet none of the acroporids on this site ever bleached in 2019 (an A-frame still remains and lots of surrounding *A. cervicornis*).

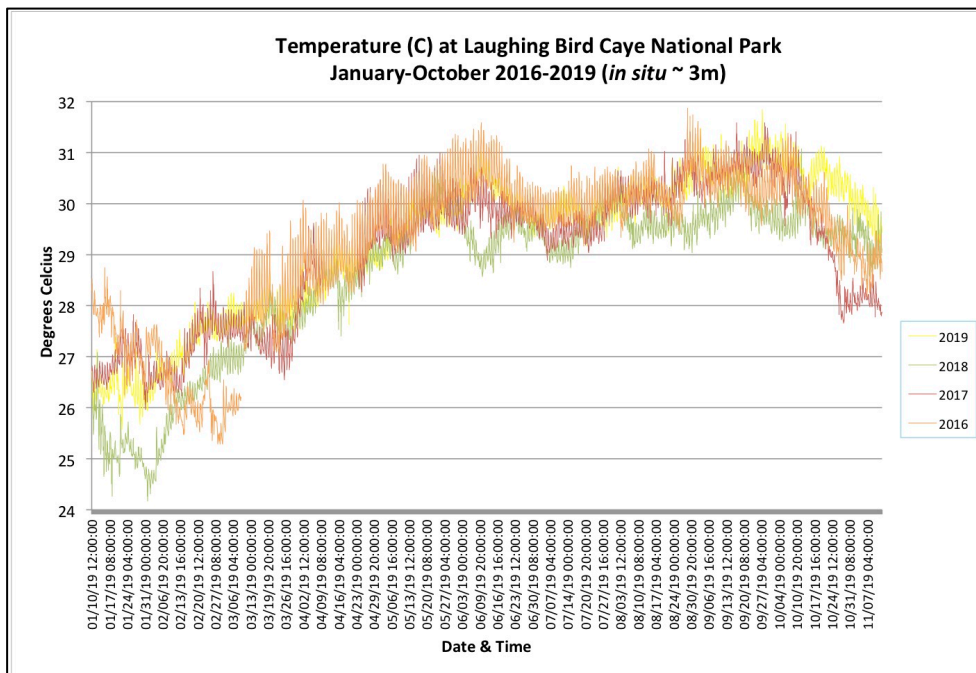


Fig. 4d. LBCNP is another site where > 10 years of temperature data exist; here again only 2016-2019 is shown and 2019 is in bright yellow, not circled but showing the same trend of much higher temperatures later in the year than previous years. The logger is located on the west side of LBCNP.

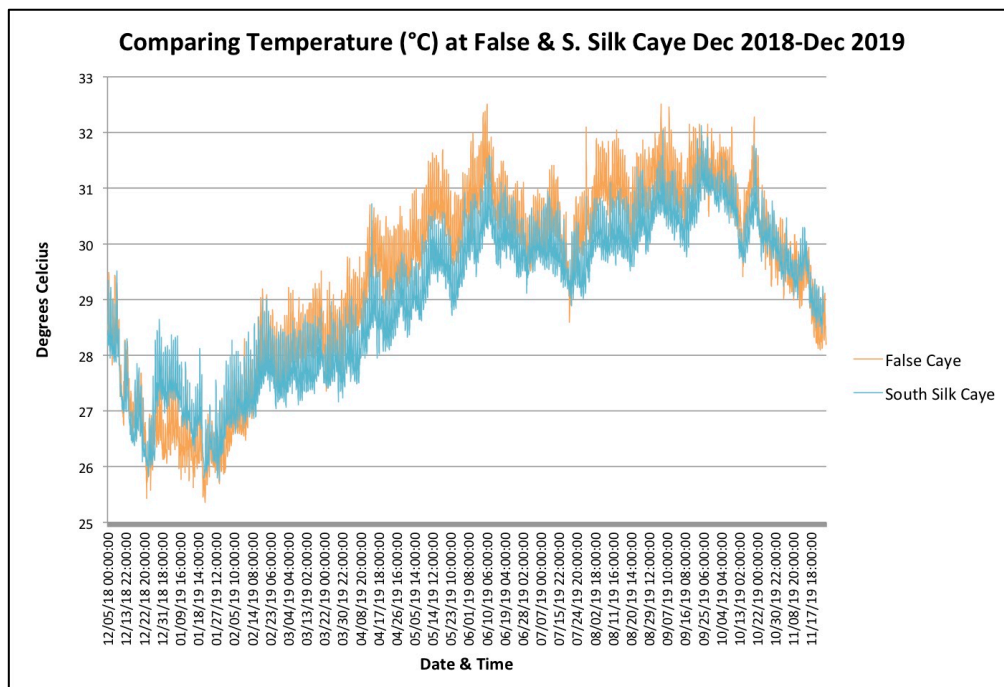


Fig. 4e. This graph compares temperature data for one year (2019) at two extreme locations, Silks on the outer reef (blue line) and False Caye near shore (orange line). The locations are shown on the map in Fig.3 and also, the bleaching data was worse at Silks (offshore) than at False (near shore) despite the higher temperatures near-shore. This supports FoH's long term hypothesis (and the foundation of much of our work) that corals in these near shore sites have a higher temperature tolerance or evidence of adaptation compared to the outer reef sites, The acroporid mortality here is likely because the transplanted corals only had ~ one year or less on site (in nurseries and outplanted), but makes the existence of the few survivors even more impressive (Fig.6a).

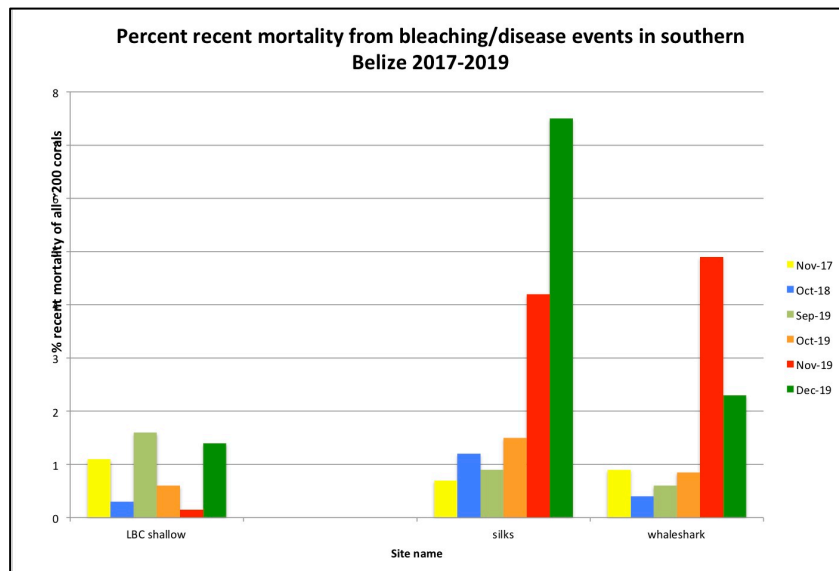
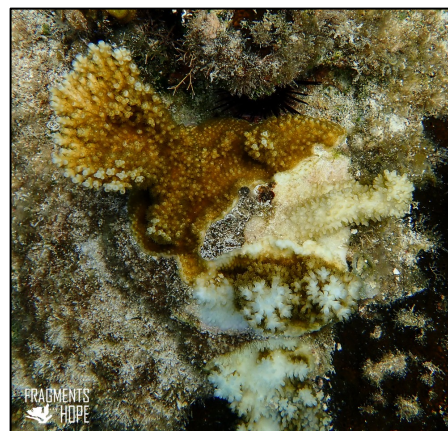


Fig. 5. Comparing recent mortality rates across two years, where available, ‘normally’ less than 2% of 200 corals surveyed each site, but dramatically increasing in Nov-Dec 2019, specifically for the outer reef sites.



Figs 5a-b. *Agaricia tenuifolia* at Silks late November 2019 ‘wholly’ bleached and with recent partial mortality, compared to nursery grown outplanted *A. cervicornis* (R) not bleaching at all.



Figs. 5c-d. On the left is *Colpophyllia natans*, partially bleaching showing some recovery but also partial recent mortality (center) and on the right is *A. palmata* outplants showing different genets’ responses to this year’s temperatures-some un affected, some dead, some bleached but not yet dead. Both photos from Silks late November 2019.

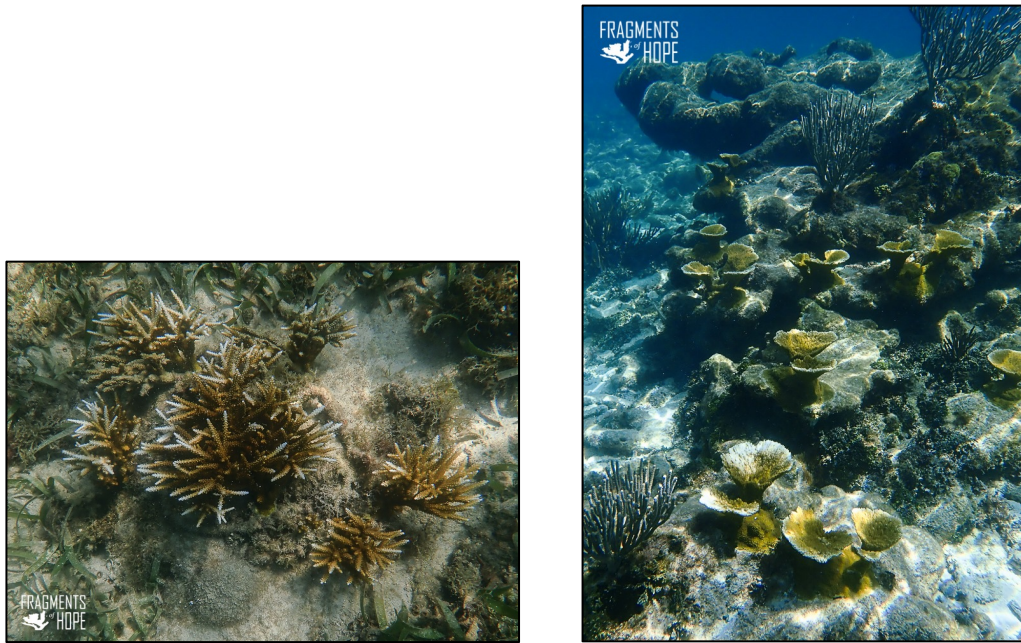


Fig. 6a-b. Examples of resilient shallow water acroporids outplanted at False Caye (L) and LBCNP (R).

Photo-mosaics & mapping:

The annual photo mosaics were completed for the six LBCNP sites and Dr. Arthur Gleason has received the files and begun processing, an example is in Figure 7, but they are not shared yet for annotation (next report period). Shallow reef mapping using a Phantom4Pro drone was conducted at replenished sites LBCNP, Moho, & Silks Caye; these are very large files when processed, an example of the processed mosaics for LBCNP using Pix4D software licensed to Dr. Schill is here:

<https://cloud.pix4d.com/pro/project/525410/map?shareToken=f126854d-62c9-4d36-b227-4588f48882f8>

FoH also mapped natural acroporid stands (donor sites) such as Dale’s Reef, Cramp Caye, Loggerhead Patch, Crawl Caye—mostly known *A. cervicornis* stands FoH had identified previously but had been unable to quantify. A bonus was the discovery of a large patch of *A. prolifera* when mapping a known patch for *A. cervicornis*, at Loggerhead Patch, calculated at >50m² using ArcMap to trace the polygon shown in Figures 8c. Figure 8a is a reduced image of the entire Loggerhead patch drone mosaic with the known *A. cervicornis* patches in the lower part of the mosaics (the skiff was parked there) and circled in green, and the new/unknown *A. prolifera* patch circled in red (top of image). Figure 8b illustrates just how different the *A. cervicornis* patches look in a drone mosaics, compared to diver-based mosaics (again circled in green). Figures 8c-d show the *A. prolifera* patch from the air (drone mosaic) and ground-truthed, in the water.

Annotating the drone mosaics is a steeper learning curve than the diver-based mosaics, as the corals and all benthic organisms, look very different from above.

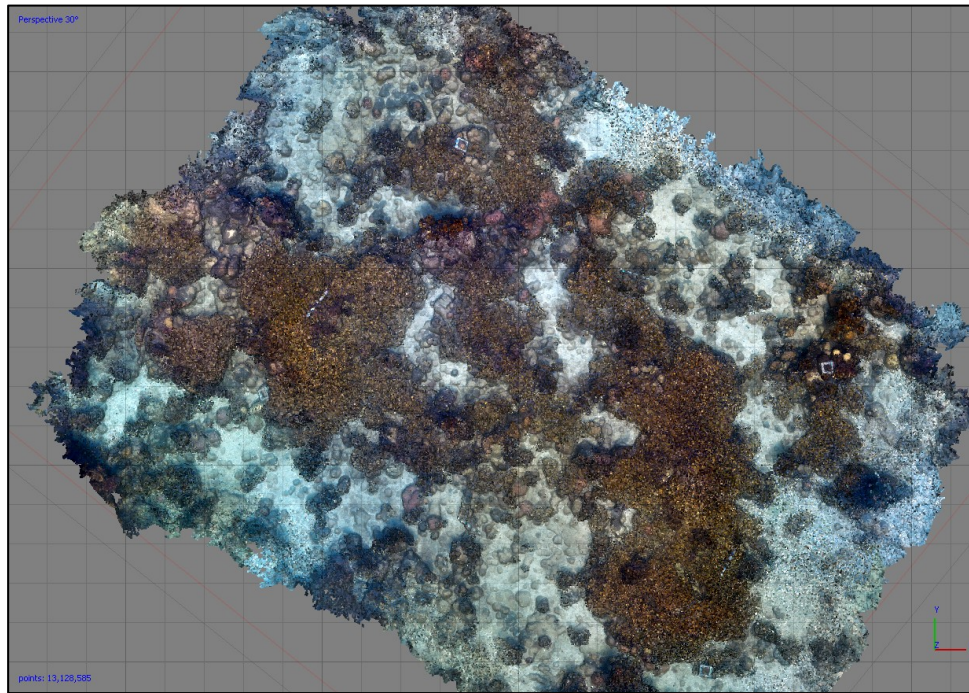


Fig. 7. Example of processed diver based photo mosaic (sub-site 9) at LBCNP 2019. This is a reduced version shared by Dr. Gleason to obtain geo-referencing. You can see the quadrats (top right) and now meter sticks, used for calibration since the staghorn patches have become so thick/continuous on many sites.

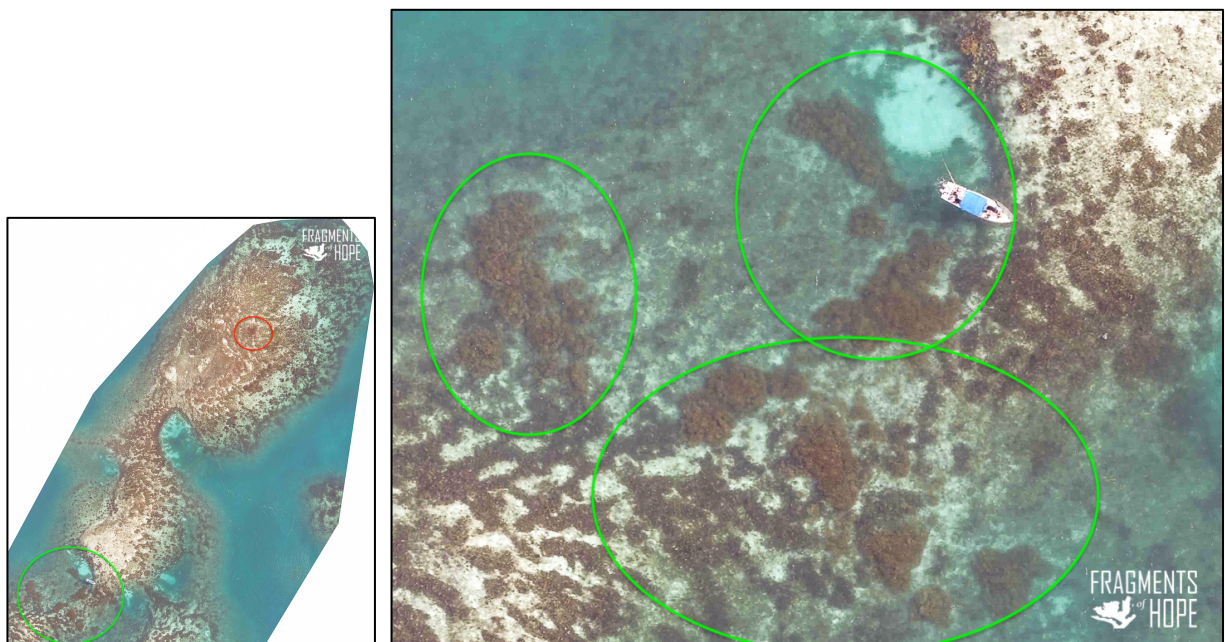
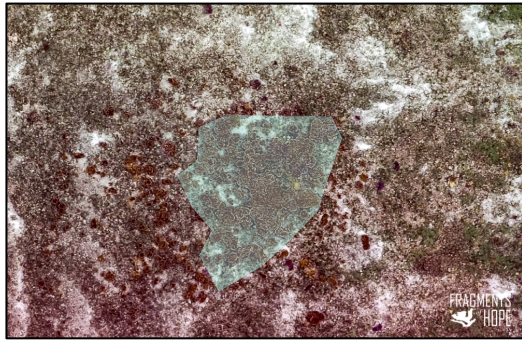


Fig. 8a-b. Part of the processed (Pix4D) mosaic at Loggerhead patch using a drone-in the top right red outline is a large (>50m²) patch of *A. prolifera*. The green circles are the *A. cervicornis* stands. Arc-Map is necessary to outline and quantify the identified acroporid stands.



Figs. 8c-d. The polygon laid over the *A. prolifera* patch (circled in red in Fig. 8a) and calculated at 50m², on the left. On the right, what the *A. prolifera* patch really looks like, ground truthed.

Activity #7 Recruits and training. In this report period FoH reconnected with Amir Neal who first began with FoH in 2014. New recruits in this time frame include Natasha Gibson and Andres Fletes (Placencia tour guides), and there are many others that have reached out for training including Ken Williams, a dive master on the Aggressor, Max Canelo (Placencia tour guide), members of the San Pedro Tour Operators Association, the Hol Chan Marine Reserve, ECOMAR based in Belize City, and the Coastal Zone Management and Authority Institute (CZMAI) for Goff's Caye. While we did not formally budget for training in 2020 under the WWF contract, FoH is considering how to offer this training again in early 2020.

Activity #8. Reporting/record progress & findings. This is the 4th report for WWF since July 2018. FoH also gave three separate talks in Belize City in October 2019: one on the work in southern Belize, one on the work nationwide, and one on the recent exchange trip with Belize & Mexico restoration practitioners (June 2019) to local and regional stakeholders. FoH also shared results of the photo-mosaics in an online webinar dedicated to that that method, and an abstract for ICERS 2020 summarizing the work to date has been accepted.

4) **Problems and Constraints.** Besides the STCLD and bleaching event this year, other constraints relate to the mapping. While FoH had private funds to purchase a drone, and bring Dr. Steve Schill to Belize for a week of training, FoH does not have the hardware or software to either process the drone mosaics or annotate them. Similar to the diver based mosaics, FoH cannot process them but can (potentially) annotate them. Dr. Schill has committed to helping FoH process the drone mosaics, in-kind, but ARC-MAP or GIS software is needed to annotate (map out and measure the acroporids). Although Dr. Schill went through these steps with FoH, there are several, and even recognizing how the corals look from these images is very different than in the diver based mosaics. FoH began to do this with a 'donated' student license for Arc-

Map but the system crashed with subsequent software updates. FoH lacks the ideal processor and amount of memory (hardware) to even run some of the necessary software. FoH is waiting to see if Dr. Schill and/or ESRI can provide a free or discounted license, or if Q-GIS (open sourced) may be sufficient, and/or, if CZMAI can commit to assisting FoH with the mapping in 2020. Ideally a grad student (or more) could be identified for assistance, and FoH did send out a request to UCSD's call for proposals for undergrads & grad students, but have heard nothing back yet, except students had over 500 project choices. Because of this software setback, FoH has yet to map the drone mosaics images already processed, and is still seeking collaboration/assistance with this activity.

5) **Unexpected effects.** Since the airing of FoH's work on the German public TV news channel mid-2019, FoH continues to receive requests from (mostly) German journalists and film crews.

6) **Learning and Sharing.** FoH hosted Dr. Steve Schill in late July/Early August to learn how to program and 'fly' drone 'missions' for shallow reef mapping. FoH invited the Belize Fisheries Department who sent two representatives for the final two days, Tyrell Reyes, Manager at the Sapodilla Cayes Marine Reserve, and Ali Cansino, Manager for Caye Caulker Marine Reserve. Both Mr. Reyes and Mr. Cansino had previously attended FoH's reef replenishment training. Mr. Reyes participated in FoH's Belize portion of the Mexico/Belize exchange (September 2018) and Mr Cansino participated in the Mexico portion of the exchange (June 2019). See also "Project Successes", Activity #8 and below, "Communications /Stories"

7) **Adaptive Management.** Since Stony Coral Tissue Loss Disease (SCTLD) has been reported in Bacalar Chico (June 2019) FoH has worked with HRI and BFD to take the lead on response. Now, with funding from Vulcan/Allan FoH will work in partnership with the Smithsonian to set up in water nurseries for *D. cylindrus* and maybe *M. cavernosa*. The Smithsonian will look at the corals' micro-biome layer and samples will also be sent to Dr. Iliana Baums for genetic analysis. FoH has delayed outplanting due to the severe bleaching event this year, and added on extra bleaching survey months.

8) **Communications/ Stories.** The FoH full time Outreach Officer, has submitted updates in each monthly publication of the Placencia Breeze, which is distributed peninsula wide with hard

copies (free) and posted online via their Face Book page³ and on a website⁴ as well. FoH was featured briefly on the local Channel 5 news show, and they filmed more footage in person at LBCNP in October 2019, not realized as yet. FoH was featured in a two-page spread in the Belize edition of Caribbean Culture & Lifestyle magazine. FoH also shared their results from the photo-mosaics as a case study in the webinar on photo-mosaics hosted by CRC/TNC on July 25, 2019⁵. FoH recently opened Instagram and Twitter accounts/pages, and these audiences are also growing.

9) **Challenges.** See Section 5 **Problems and Constraints.** Due to the extreme bleaching event this year, outplanting will not occur until recovery signs are satisfactory-perhaps by mid-late January 2020. Besides the constraints listed with drone mapping, and even though the FoH team is now trained to fly their own ‘missions’ /mosaics, the conditions for underwater mapping with drones are very unique: it cannot be raining nor too choppy, and to avoid glare on the surface the flight times need to be before 8:30-9am and/or after 4pm. This makes flying the drone in sites far from Placencia more challenging. Other challenges include lack of nationwide coordinated bleaching/SCTLD surveys, sharing of information, and repetitive meetings on these issues without taking action.

10) **Overall Assessment of Progress.**

Despite the set backs with SCTLD and the severe bleaching event in 2019, FoH is still on track to begin replenishment activities in early 2020.

Report completed by:	
Name	Lisa Carne
Position/ Title	Executive Director/Founder
Organisation	Fragments of Hope
Date	31 December 2019

³ <https://www.facebook.com/ThePlacenciaBreeze/>

⁵ <https://reefresilience.org/photomosaics-as-a-tool-for-monitoring-coral-restoration-success/>