Pillar Coral Restoration and Strengthening the Level of Protection for Critical Reef Ecosystems in the North East Tobago UNESCO Man and the Biosphere Reserve

Final Technical Report

Pillar coral colony present in Booby Reef, documented on 14 September 2021

Submission: 18 July 2022

Funded by:

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Executive Summary

Activities for this project were initiated in May 2021, beginning with the Natural National Heritage Site (NNHS) Nomination component. The NNHS technical dossiers for selected islets and reefs in North East Tobago were prepared through a combination of stakeholder consultations and literature review. It was then reviewed by both the Director of the Environment for the Tobago House of Assembly (DoE, THA) and stakeholders and subsequently edited. The DoE, THA submitted the dossiers in September 2021 to the National Trust of Trinidad and Tobago (NTTT) for deliberation and listing as a Natural National Heritage Site. No decision has yet been made, however, there are assurances that the NTTT are actively discussing its merit. Once the sites are listed, the UNESCO Man and the Biosphere (MaB) maps will be updated to include the islets and reefs as "core zones" to the biosphere reserve. The maps will be submitted to the Department of Land Management of the Tobago House of Assembly for approval and inclusion and then to the UNESCO MaB Office in Paris.

Pillar coral survey activities began in September 2021 to coincide with its spawning period, following literature review and consultations with relevant stakeholders. Seventeen sites were identified however, of which 13 were surveyed in ten dive events (six North East and five South West), of which three (one North East and two South West) successfully yielded colonies which were sampled for sex determination. An additional colony was identified outside of the survey dives at one of the South West (SW) Tobago sites (Culloden). Overall, **eight colonies were documented from four sites in Tobago**. The pillar corals in SW Tobago were bleached at the time of survey, delaying transplantation as the risk of mortality increased with any additional stress. Overall, **64** fragments from Booby Reef and Plymouth colonies were transplanted in June 2022 and monitoring is ongoing.

The ERIC is collaborating with The University of the West Indies, Department of Life Sciences (UWI, DLS) to determine the sex of the colonies using deep sequencing. There were delays at the university in completing the sequencing in time for the project deadline, however, the activity is presently underway. A bonus outcome from this collaboration will be the genotyping of the corals, which can benefit both local and regional pillar coral conservation efforts.

Presentations on this project's activities were made to two secondary schools. These sessions were welcomed by both teachers and students, who were especially interested in the pillar coral conservation efforts. Social media posts on the pillar coral activities and school outreach sessions were also published on the ERIC's Facebook page. Two press releases are presently awaiting publication in the local daily newspapers and a scientific manuscript on the distribution and genetics of pillar corals in Tobago is in progress.

Several challenges were encountered particularly in the implementation of the pillar coral conservation component of this project, including COVID-19 pandemic restrictions, loss of human resource, inclement weather, poor water conditions and loss of boat services. However, the ERIC is committed to seeing through the completion of the outstanding deliverables beyond the project's deadline.

The ERIC received 50% payment in September 2021, with the second half the funds due upon submission of the final report.

Summary of Activities

Table 1. Summary of activities for the project period 2021-2022

Overall Goal: Regionally replicable coral restoration and improved legal protection of vulnerable reefs in the North East Tobago UNESCO Man and the Biosphere Reserve contribute to the reduction of coastal risks and adaptation to climate change.	
Sub Goal 1: *The extirpation of coastal, reef-building IUCN (VU), EDGE top-listed Pillar corals in North East Tobago UNESCO Man and the Biosphere Reserve is prevented leading to increased densities and coastal risk reduction.*	
Output	**Summary**
1.1. Documentation of the status and distribution of pillar corals in Tobago, with a focus on North East Tobago UNESCO Man and the Biosphere Reserve	• A literature review on the pillar coral biology, ecology, reproduction, conservation and distribution was completed (see Appendix 1). • Five local dive tour operators (5 active, 1 retired), the Department of Marine Resources and Fisheries of the Tobago House of Assembly (DMRF, THA) and Dr. Anjani Ganase of the Institute of Marine Affairs were consulted on their knowledge of pillar coral distribution in Tobago's reefs. • From both the literature review and the consultations, a total of 18 potential sites were identified (see Appendix 2). • Three community-based field technicians (CBFTs) received a one-day training in the underwater visual census method and specimen collection in September 2021. In May 2022, two out of the three CBFTs were re-trained while one new CBFT was trained (see Appendix 3). • Ten survey dive events were completed – six in North East (NE) Tobago and four in South West (SW) Tobago (see Appendix 2 for map of locations and Appendix 4 for images). The dive log for these surveys have been integrated into the datasheet (see Appendix 5). • Invitation was extended to the DMRF, THA to participate in the surveys. Fisheries Officer Mr. Kirwin Sampson accompanied the team for surveys in SW Tobago and in Speyside. • Also participating occasionally in the surveys were ERIC's Dive Operations Manager and a MSc. Student from the IMBRSea programme (Europe). For four of the dives in Speyside in May 2022, a community-based divemaster familiar with the dive sites was contracted to participate in the surveys as a guide was needed. • Seven colonies from three sites were documented during the surveys: *Booby – 1, Buccoo – 1, Plymouth – 5.*
	• Mr. Kirwin Sampson of DMRF, THA surveyed Culloden on 01 July with the Institute of Marine Affairs and successfully found a pillar coral colony, bringing the number of documented colonies to **eight from four sites**. Arrangements will be made with him to collect data and samples for sex determination during his next visit to the site.

	• Survey data has been entered into a .csv file for the creation of a map (see Appendix 5). • The pillar coral samples are presently being deep sequenced by a MSc. student from The University of the West Indies, Department of Life Sciences (UWI, DLS) for sex determination as the DNA has already been extracted. They are presently under the supervision of Prof. Adesh Ramsubhag and Dr. Ryan S. Mohammed, one of the ERIC's directors. • The data from this will be included in the scientific manuscript's second draft which will be sent to SPAW-RAC, post-project deadline.
1.2. Colony fragments transplanted at sites of the opposite sex to supplement existing colonies to support future sexual reproduction, monitored monthly for 6 months	• Four community-based field technicians received a one-day training in pillar coral transplantation in June 2022 (see Appendix 6). • All SW Tobago colonies were bleached at the time of the survey in September 2021 (see Appendix 5). It was believed that it was prudent that the colonies should not be harvested at that time since it was unlikely that they would survive the additional stress of fragmentation and transportation to a new site. • It was also decided that direct transplantation might be more beneficial to the fragments, to minimise stress from handling and multiple site transfers with transplantation to a nursery. • Additionally, larger fragments of a minimum width of 6cm were made, to increase the coral's survival. It was believed that microfragmentation may not be suitable for direct transplantation of such a sensitive species. • Fragments from the Booby Reef colony were harvested and directly transplanted at a prepared area in Booby Reef, close to the colony on 02 June 2022 (see Appendix 7). This activity served the following purposes: 1. Gaining practical experience in harvesting and fragmenting from a massive coral species as well as experimenting with epoxy for attaching to substrate. 2. Trial run and planning for harvest and transplantation from the SW Tobago colonies. 3. Creation of a separate colony to improve the species' resilience within the reef. • Fragments were collected only from the Plymouth colonies in SW Tobago on 17 June 2022. At the time of harvesting in Buccoo, the tide was lower than forecasted, making boat entry into the barrier reef unsafe and difficult. Fragments were taken from four Plymouth colonies (see Appendix 7).
	• A total of **64 fragments** were transplanted (Booby – 18, Plymouth – 46). • Two monitoring events were completed by the team following the transplantation with no mortality documented among fragments (Appendix 8). A few fragments were dislodged but easily reattached to the substrate using Portland cement.

	• Monitoring will continue monthly using a modified reef survey method. Light maintenance may be done as needed to ensure that colonies continue to thrive. As monitoring continues, updates on the health of the transplants will be posted on the ERIC's social media pages.

Sub Goal 2: *Coastal risks for vulnerable communities in the North East Tobago UNESCO Man and the Biosphere Reserve are reduced and climate change resilience improved by an increased level of legal protection, significantly supporting biodiversity and ecological integrity of fragile reef ecosystems.*	
Output	**Summary**
1. Provision of all relevant and necessary documentation to list North East Tobago's islets (4) and selected, high priority reef sections as "properties of interest" under the National Trust of Trinidad and Tobago Act	• Two technical dossiers, one for islets and the other for reefs, were completed and submitted to the Director of Environment to distribute to relevant stakeholders for review and comments. • The dossiers were also submitted to SPAW-RAC for review. • Due to national COVID-19 regulations which continued to restrict gatherings, no stakeholder meetings were conducted. In lieu of this, stakeholders were consulted over the phone for their expertise, knowledge and input. • All feedback received were considered and any necessary edits were completed. • The technical dossiers have since been re-submitted to the Director of Environment. He has submitted the documents to the National Trust of Trinidad and Tobago (NTTT) whose Landmarks Committee is presently deliberating the sites' inclusion as heritage sites and grade classification. Informal communication has indicated that the islets were accepted in late June and is due to be listed. • Informal communication has indicated that the islets were accepted in late June by the committee and is due to be listed. A formal, public announcement is yet to be made.
2. Provision of documentation and maps to the Department of Land Management of the Tobago House of Assembly to upgrade the selected islets and reefs to "core zones" within the North East Tobago UNESCO Man and the Biosphere Reserve as well as submitting the revised maps to the UNESCO Man and the Biosphere Office in Paris.	• Draft maps have been prepared but will only be finalised pending the decision of the NTTT (see Appendix 9).

Sub- Goal 3: *Disseminated project information and lessons learnt leads to local and regional action to reduce coastal risks*	
Output	**Summary**
3. Intelligible project information and funder visibility disseminated to local and regional stakeholders	• Three social media posts highlighting the activities related to the pillar corals and the secondary schools' outreach, were published (see Appendix 10). Future posts are planned to provide updates on the transplanted pillar corals as well as the declaration of the islets and reefs as Natural National Heritage Sites (NNHS). SPAW-RAC and Carib-Coast will be tagged on these publications. • Two press releases have been drafted and are awaiting publication in the local daily newspapers (See Appendix 11). Once published, the articles will be shared on social media with SPAW-RAC and Carib-Coast tagged as they both acknowledge the funders. • If the islets and reefs are declared as NNHS before publication, the article will be updated to reflect this • Presentations were made to Speyside High School and Roxborough Secondary School to students ranging from ages 11 to 15 years. ERIC staff and interns talked to the students about the importance of NE Tobago Man and the Biosphere Reserve, its islets and reefs. They then learned about ERIC's coral restoration programme, with emphasis on pillar corals. • For Speyside High School, a total of 35 students (17 females, 18 males) were present while at Roxborough Secondary School, 17 students were present (13 males and four females). • A draft manuscript is being prepared documenting the distribution of the pillar corals in Tobago and the sex and genetic analyses of these colonies for submission to a journal for review.

Challenges and Actions Taken

During the project, various challenges were encountered which affected the implementation of various project activities, particularly for the pillar coral component, as summarised below.

Table 2. Summary of challenges encountered during the project and actions taken to address each.

Problem	Impact	Action(s)
COVID-19 pandemic - ERIC	The project unfortunately took place during the COVID-19 pandemic. The Government of Trinidad and Tobago instituted work restrictions and vaccination mandates while case numbers were rising, which affected the delivery of our work, particularly those that required assembly in groups. To protect primary staff, the ERIC implemented mandatory vaccination as part of its COVID-19 policy, however, a few technicians were reluctant to accept the vaccine. As per the ERIC's dive safety policy, all dives are accompanied by at least a Divemaster. For much of 2021, the pandemic prevented hiring of a Dive Operations Manager, while the organisation's primary Divemaster and Head Field Technician was incapacitated due to prolonged illness, further affecting dive surveys. Additionally, the restrictions delayed other simultaneous projects and deadlines, resulting in work overload for the implementing staff.	- Surveys were conducted with minimal staff possible while adopting masking and social distancing practices. - Vaccination moratorium period was granted to the technicians to allow for time to receive the vaccine unless they were medically unable to do so. - COVID-19 rapid tests kits were made available for interim testing. - Divemasters familiar with the dive sites were contracted to lead dives in the absence of a Dive Operations Manager and primary Divemaster. - Activities were scheduled based on deadlines and immediate organisational needs.
COVID-19 pandemic – The UWI, DLS	Similarly, our collaborators at The UWI, DLS were also affected as access to campus and labs were significantly restricted. The lab also needed to await the completion of all surveys before running the sequences due to the practicality and cost of using the reagents and kits	- Pillar coral samples were consolidated with staghorn coral samples from another project to increase the practicality of running the sequencing.
Human resource	Two Dive Operations Managers left at crucial stages of the project's implementation, derailing activities and further straining staff as deliverables needed to be re-aligned and human resources re-assigned.	- Hiring of new staff was prioritised to reduce the strain on remaining implementing staff

Problem	Impact	Action(s)
Thermal stress to corals	The original workplan scheduled coral harvesting and transplantation to occur immediately after the surveys. However, thermal stress to the colonies prevented timely delivery of activity in 2021.	- A monitoring dive followed by transplantation was re-scheduled for 2022 when water temperatures were cooler and sea conditions were stable.
"Acts of God" and uncontrollable events	Inclement weather and poor sea conditions disrupted survey, transplantation and monitoring dives on several occasions, particularly with earlier-than-normal onset of the rainy season. Further compounding the issue was the loss of boat transport service from the ERIC's regular service provider for one month, towards the end of the project.	- Weather forecasts and models were monitored frequently to schedule and re-schedule in-water activities, as needed. - Another boat capable of transporting dive gear was hired to push completion of the project. However, this came at a much higher cost to the project as prices for boat transport services were increased due to the rising cost of fuel.

Future Work

Pillar Coral Component

Monitoring of transplanted colonies'

ERIC will continue to monitor the health and growth of the transplanted fragments in Booby Reef. Considering that the monitoring plan was not implemented as proposed, ERIC will continue to provide updates to the funder. The funder will also be tagged in subsequent social media publications.

Transplantation from Buccoo Reef's colonies

It is yet to be decided whether it is possible to harvest from Buccoo Reef's colonies, post-project. This decision may be influenced by the results from the sexing of colonies by The UWI, DLS. If the results indicate that Buccoo Reef's colonies are of the opposite sex to those in Plymouth and Booby, then the ERIC will harvest fragments for transplantation into Booby Reef.

Arrangements will be made with the DMRF, THA to collect data and specimen from the Culloden colony, for sexing and inclusion in the scientific manuscript. Like Buccoo Reef's colonies, the decision to harvest fragments for transplantation in NE Tobago will depend on the results of the sequencing (see Figure 1).

Should transplantation occur from these colonies, the activity will be published on the ERIC's Facebook page, tagging SPAW-RAC and Carib-Coast.

Sex determination of colonies

Post-project deadline, the results of the sex determination will be included in the scientific manuscript. A report prepared by The UWI, DLS will also be submitted to the funder. A complementary result to the sequencing carried out by The UWI, DLS which was not a project deliverable is the genotyping of the pillar

coral colonies. This can potentially benefit local and regional conservation efforts as linkages and relatedness to other colonies in the Caribbean can inform transplantation efforts to build resilience within the species in different geographic locations.

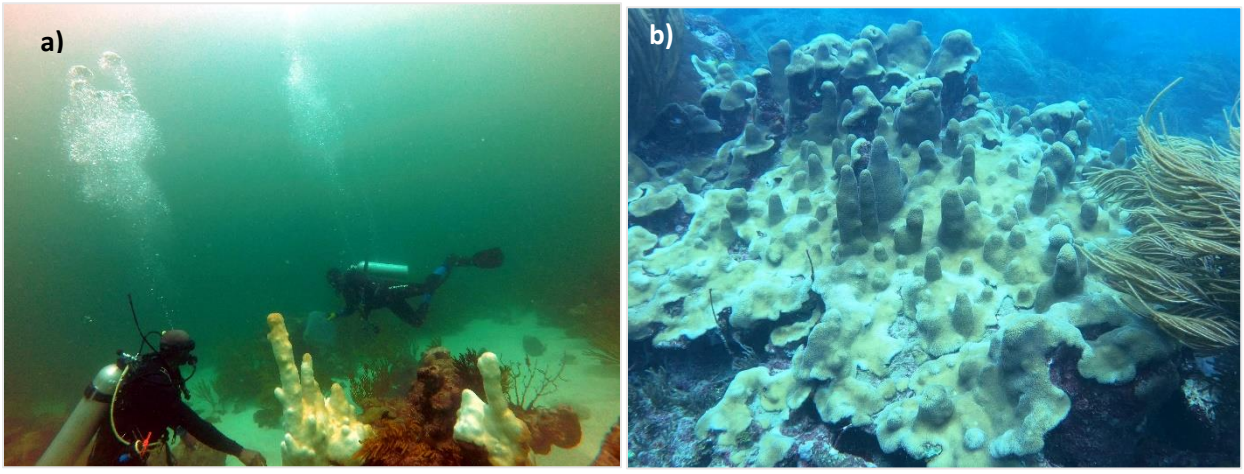

Figure 1. Bleached/ paling colonies at a) Buccoo Reef, documented on 27 September 2021 and b) Culloden colony found outside of the survey dives by Kirwin Sampson of DMRF on 01 July 2022.

Natural National Heritage Nomination Component

The technical dossiers, which were shared with the SPAW RAC Office, are presently before the Landmarks Committee of the National Trust of Trinidad and Tobago for deliberation (Figure 2 and Figure 3). Discussions was temporarily stalled due to the Trust's recent office relocation and preparation for its upcoming Annual General Meeting (AGM) and further delayed due to the need to immediately deal with additional government-related business. The Landmarks Committee have resumed discussions on the inclusion of the natural sites.

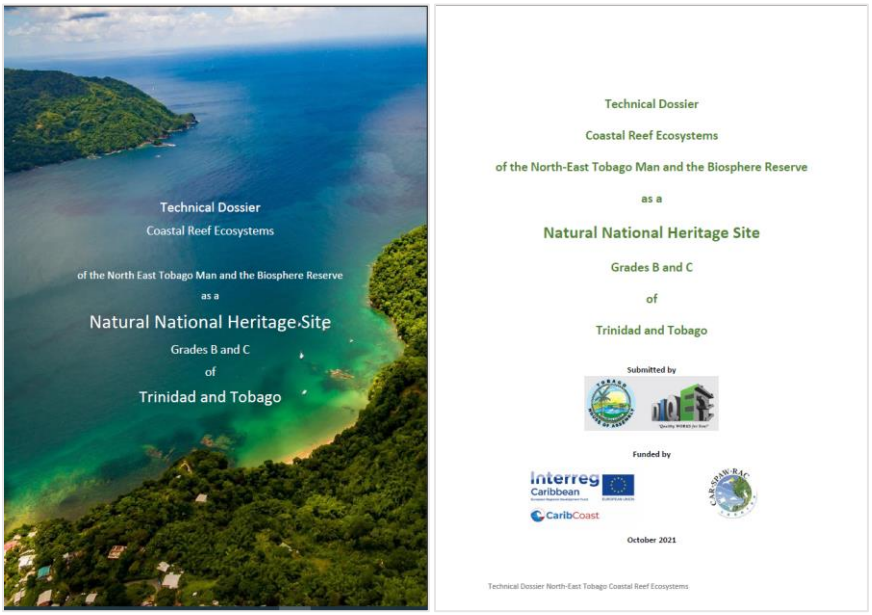

Figure 2. Cover and first pages of the technical dossier for reefs

Figure 3. Cover and first pages of the technical dossier for islets

Once the listing process is complete, the draft map of the North East Tobago UNESCO Man and the Biosphere Reserve (see Appendix XX) will be finalised for submission to the Department of Land Management of the Tobago House of Assembly and then the UNESCO MaB Office in Paris. The funder will be notified of the outcome.

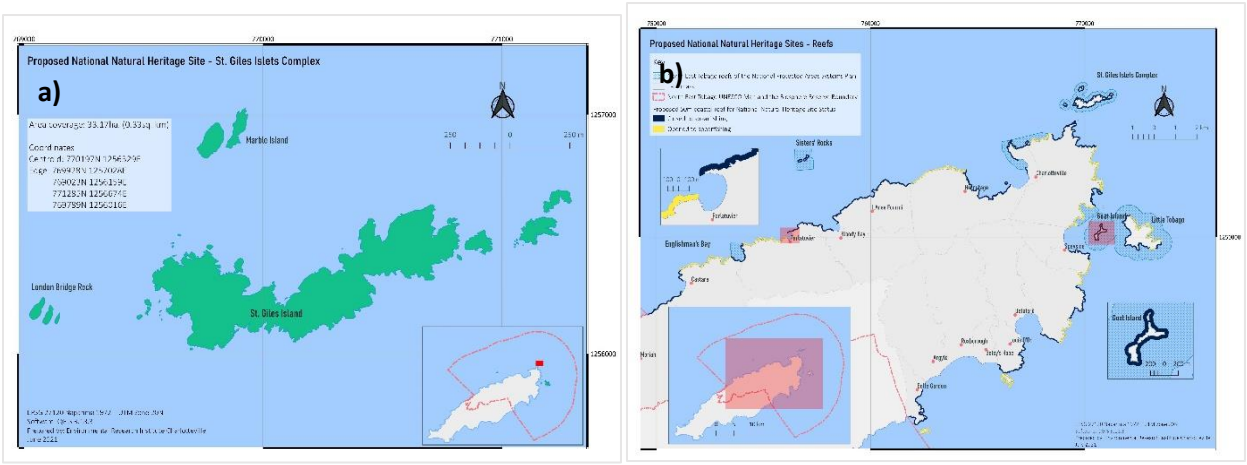

Figure 4. Maps developed for consideration by the National Trust of Trinidad and Tobago; a) St. Giles Islets Complex, one of four islets nominated and respectively mapped and b) proposed reef area

Project Administration

Dossier brief and school outreach

The production of the brief for teachers and relevant government offices and presentations to schools awaits the decision of the NTTT and finalisation of the maps.

Media outreach

The two anticipated press releases awaiting publication in the local daily newspapers will highlight:

- Conservation activities for the pillar corals; and
- The importance of islets and reefs within in the UNESCO MaB.

Once published, the online version of the articles will be shared on the ERIC's Facebook page, tagging the funder.

Scientific manuscript

A first draft on the distribution of the pillar corals in Tobago is in progress. The component on the genetics and sex determination will be written in collaboration with The UWI, DLS. This will be subsequently submitted to a selected journal for review and hopefully acceptance. A copy of the draft and final article will be submitted to the funder. SPAW-RAC and the INTERREG Carib-Coast will be acknowledged in the scientific article as the funders for the data collection.

Appendices

Appendix 1 – Pillar coral literature review

Biology and Reproduction

Pillar corals (*Dendrogyra cylindrus*) are the only species of its genus, and is a member of the family Meandrinidae, a relatively small family consisting of seven genera. Colonies take on a columnar growth-form starting as an encrusting base from which cylindrical columns grow, reaching heights of 2m (Vernon 2000). Young colonies are usually encrusting with incipient columns. The grey-brown tentacles are extended during the day, giving the colony a furry appearance (Vernon 2000). When retracted, the meandroid valleys are visible (Vernon 2000).

Pillar corals reproduce similarly to other scleractinian (hard) corals, using two mechanisms: asexual and sexual reproduction. During asexual reproduction corals clone themselves using fragmentation, and in sexual reproduction, they release gametes to fertilize in the water column and eventually land as larva on the substrate to begin a new colony. Pillar corals are gonochoric (though there has been evidence of hermaphroditic colonies (K. L. Neely et al. 2018)) meaning the colonies are either all-male or all-female, and when they sexually reproduce these colonies must be close enough for the gametes to reach each other to create a viable larva.

Though clonal propagation can be useful for maintaining colony and population size (Chan et al. 2019), sexually reproduction is important as it increases genetic diversity and resilience of corals (Chan et al. 2019; Marhaver, Vermeij, and Medina 2015). Pillar corals, like other hard corals, release their gametes into the water just after sunset around once a year, and the males release slightly before the females, increasing the chances that eggs will be fertilized (Marhaver, Vermeij, and Medina 2015).However, very few juvenile pillar corals have been found in surveys of the Caribbean, indicating a lack of reproductive success (Marhaver, Vermeij, and Medina 2015).

Pillar coral growth rates may range between 8mm – 20mm/year depending on the location of the colony ((Bernal-Sotelo, Acosta, and Cortés 2019; Hudson and Goodwin 1997; Hughes 1987)

Habitat and Ecology

Pillar corals are ecologically important as they are reef-building corals that create structure and habitat for marine life and specific recreationally and commercially important species (González-Gamboa, Santos-Martínez, and Herrera-Martínez 2019) as well as provide an underwater barrier that decreases wave energy and protects shoreline communities (Pienkowski 2020). They are usually found on flat or gently sloping sheltered back reefs and fore reefs at average depths ranging from 5-15m, though they can successfully thrive at depths of 25m, once the water is clear (Goreau and Wells 1967). They grow in reefs with sandy substrate and consolidated coral rubble with several encrusting organisms such as gorgonians, sponges and other coral species (Bernal-Sotelo, Acosta, and Cortés 2019; Acosta and Acevedo 2006). While pillars are resistant to strong wave action, they are susceptible to bioerosion at their bases which may cause toppling of pillars. This mechanism allows colonies to expand its range as new pillars may emerge from fallen columns (Bernal-Sotelo, Acosta, and Cortés 2019).

No specific studies have been done on faunal communities associated with pillar corals, there is evidence that the fish species composition within a reef is linked to coral species, whereby specific coral species support distinctive fish communities (Komyakova, Jones, and Munday 2018).

Conservation

Many institutions have already identified pillar corals as animals of high conservation priority (Jones et al. 2021). It has been declared threatened under the United States' Endangered Species Act and vulnerable according to the IUCN Red List (Jones et al. 2021; Aronson et al. 2008). The species is considered an Evolutionarily Distinct and Globally Endangered (EDGE) species under the EDGE of Existence programme by the Zoological Society of London. This means that they are morphologically and genetically unique with very few close relatives and are also significantly threatened in the absence of conservation action. Conservation attention towards pillar corals is considered to be very low.

Studies conducted in Southeast Florida have found that pillar corals are highly susceptible to diseases such as Stony Coral Tissue Loss Disease (SCTLD) and thermal stress (Karen L. Neely et al. 2021). As a result, they are essentially functionally extinct in this region, which was once the northernmost range of their distribution (Karen L. Neely et al. 2021; Jones et al. 2021). Further, Jones *et al.* (2021) found that 97% of the monitored colonies were dead three years into their project and completely dead by June 2020. This population was decimated at an alarmingly high rate. Understanding how disease prevalence and thermal stress is affecting the Caribbean's coral populations proves to be an urgent conservation issue.

Research conducted into the minor and chronic sources of mortality for *Dendrogyra cylindrus* colonies along the Florida Reef Tract found that damselfish gardens and nests, predation by the corallivorous snail *Coralliophila abbreviata*, competition with other benthic organisms and physical damage from abrasion or burial, exert stress on pillar coral colonies. Additionally, numerous diseases were observed on such as black band disease, white plague syndromes, stony coral tissue disease (SCTLD) and an unidentified disease having similar traits to the yellow band disease. This was observed in 2014, at 8 sites in the Upper Keys during cooler water periods (Karen L. Neely et. al 2021).

SCTLD has now been documented as far south as St. Lucia, as of 09 August 2020 (Pienkowski 2020), since its documentation in 2014 in Florida. Pillar corals has shown to be highly susceptible to infection, with death being likely within a few weeks (Alvarez-Filip et al. 2022). In fact, the genetically distinct Florida colony is now extirpated from the wild and exists only in captivity (Alvarez-Filip et al. 2022). It is likely one of the main vectors for the spread of the disease are vessels that would have taken ballast water from sites where disease is present (Dahlgren et al. 2021). Within the reefs, the disease may spread among colonies by organisms feeding on infected corals such as butterflyfishes (Dahlgren et al. 2021).

In the west of the reef complex of Old Providence, numerous stressors have been recognized as the cause of declining pillar coral population. Increased nutrient loading has led to an increase in cyanobacteria and macroalgae (Puyana et. al. 2015). Over a ten-year period, the accumulation of cyanobacteria resulted in a habitat change and has affected the tissues of the species. This result supports the findings of Ford et al. (2018), who discovered that cyanobacterial mats have spread to many reefs worldwide and are playing a significant role in the decline of the ecosystem. Furthermore, it was discovered that the reproductive biology of pillar corals, which involves asynchronous spawning and rapid embryonic development can account for the lack of recruitment by limiting dispersal and interpopulation crossbreeding.

Various institutions have worked with techniques to increase pillar coral recruitment and to restore the species. These include in-situ and ex-situ growth of coral microfragments which are then transplanted to new reef sites or reefs historically known for pillar coral presence. The fragmentation method involves collecting fragments from donor colonies and growing them in nurseries either in marine habitats with ideal conditions for coral growth or growing in incubators whereby conditions for coral growth are optimised and controlled. Microfragmentation has been found to increase the speed of coral growth as the polyps channel energy towards rapid spatial expansion to increase survival chances which competing with other nearby encrusting organisms, including other hard coral species (Page, Muller, and Vaughan 2018). Fragments are later transplanted into reefs in arrays, where they grow until their edges meet and fuse to form a larger colony . This strategy enables slow-growing fragments to occupy a larger surface area in a shorter timeframe than it typically would if fragments are left to grow on its own. However, this strategy is only successful on fragments from the same colony. The main challenge of microfragmentation is the vulnerability of small fragments to fish predation (Page, Muller, and Vaughan 2018; Koval et al. 2020).

Lab-based propagation of embryos have also been experimented with, considering the poor larval recruitment rates in natural habitats (Marhaver, Vermeij, and Medina 2015). This involves collecting gametes during spawning events and sexually fertilising them under laboratory conditions. The developed larvae are allowed to settle on substrate and grow for several months until the small colonies are large enough to seed into reefs (Marhaver, Vermeij, and Medina 2015). The reason for low larval recruitment in the wild is still unknown as success rates are still low even in reefs with dense populations of pillar corals, such as in Curaçao (Marhaver, Vermeij, and Medina 2015)

Distribution

Pillar corals are found only in the Caribbean, occupying a distribution range from Florida in the north, Central America, through to the southern Caribbean where they are present in reefs in Colombia, Venezuela, the Netherland Antilles and Tobago (Kabay 2016). Its abundance is uncommon to rare, with the largest populations likely in the Florida Reef Tract and Curaçao (K. L. Neely et al. 2018; Marhaver, Vermeij, and Medina 2015; Kabay 2016).

In Trinidad and Tobago, the species has been documented only in the island of Tobago. Various reports have identified pillar coral presence in reefs in Plymouth (Mallela, Parkinson, and Day 2010), Buccoo(Alemu I and Lum Kong, n.d.). Professor Julian Kenny photo-documented pillar corals in Mt. Irvine between 1975 and 1977. Reef surveys conducted by Coral Cay Conservation identified pillar corals in several their transect sites, namely in Charlotteville, Goat Island, Little Tobago, Speyside, Great River Shoal, Castara and Arnos Vale (van Bochove and McVee 2012).

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Appendix 2 – Location of survey sites

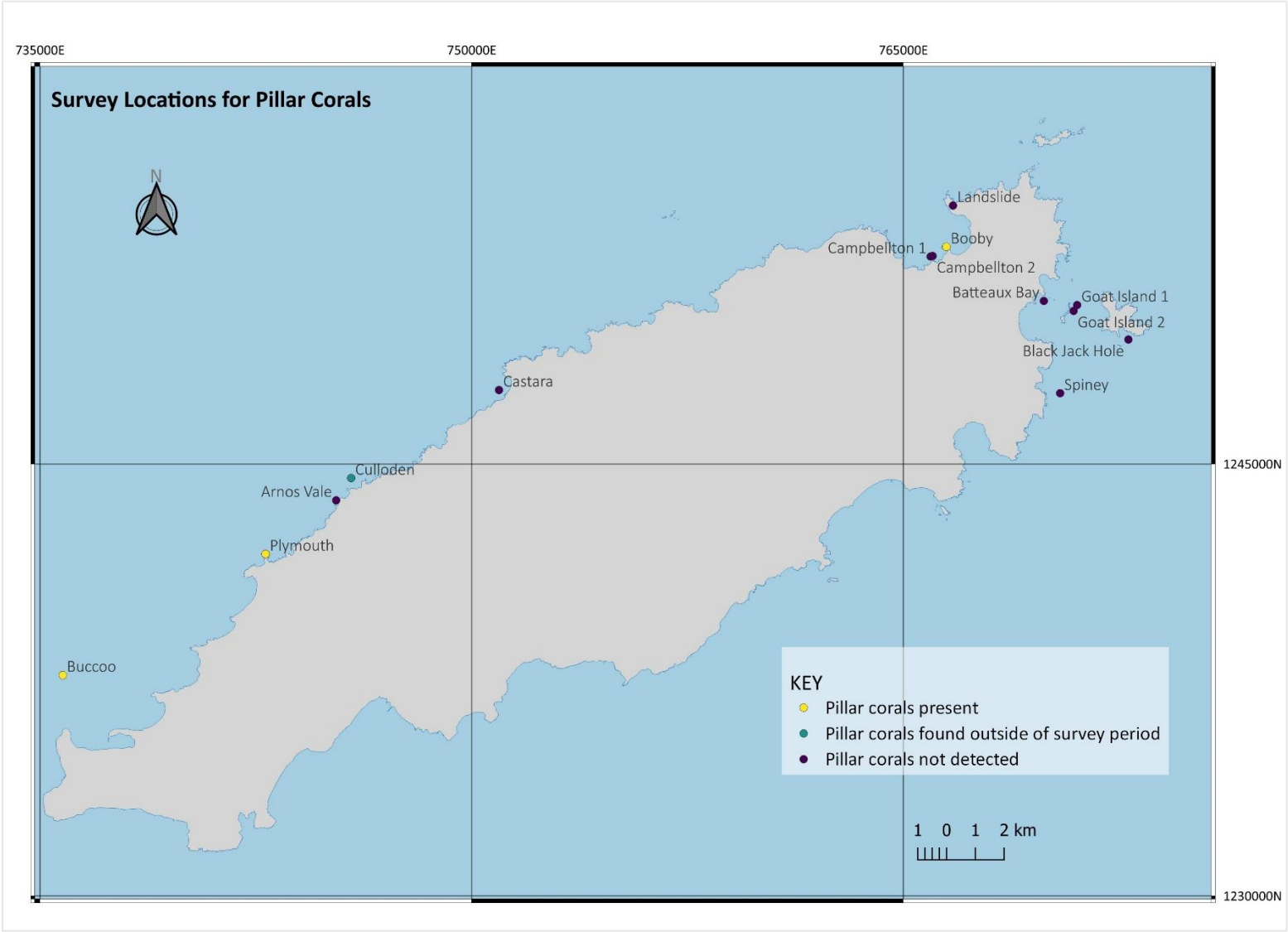


Figure 5. Location of survey sites and positive detection of pilar corals (Dendrogyra cylindrus)

Appendix 3 – Pillar coral survey training

Figure 6. a-b) Land review of survey method with CBFTs and boat captain

Figure 7. a-c) Sample of training slides

Appendix 4 – Pillar Coral Datasheet

Commonly shaded rows represent replicate samples taken from a single colony. The table includes all survey dive events. In summary, 13 sites were surveyed over 10 days.

Id	Date	Site	Northing	Westing	Depth (m)	Temp (°C)	DC present	MaxL (m)	MaxW (m)	MaxH (m)	Condition	Genetic Sample No.	Survey Team	Comments
1	2021-09-14	Booby	11°19.234'	60°33.512'	6.7	28	N	n/a	n/a	n/a	n/a	none	LF, KM, KeS	Dive 1
2	2021-09-14	Booby	11°19.234'	60°33.512'	5.5	29	Y	7.16	1.69	2.1	healthy	B01A1	LF, KM, KeS	older portions of colony (base) completely dead, live tissue at upper portions of pillars
3	2021-09-14	Booby	11°19.234'	60°33.512'	5.5	29	Y	7.16	1.69	2.1	healthy	B01A2	LF, KM, KeS	older portions of colony (base) completely dead, live tissue at upper portions of pillars
4	2021-09-14	Booby	11°19.234'	60°33.512'	5.5	29	Y	7.16	1.69	2.1	healthy	B01A3	LF, KM, KeS	older portions of colony (base) completely dead, live tissue at upper portions of pillars
5	2021-09-14	Booby	11°19.234'	60°33.512'	5.5	29	Y	7.16	1.69	2.1	healthy	B01A4	LF, KM, KeS	older portions of colony (base) completely dead, live tissue at upper portions of pillars
6	2021-09-24	Goat Island	11°18.222'	60°31.074'	5.4	29.4	N	n/a	n/a	n/a	n/a	none	LF, KM, KeS	no comment
7	2021-09-24	Goat Island	11°18.117'	60°31.025'	4.6	30	N	n/a	n/a	n/a	n/a	none	LF, KM, KeS	no comment
8	2021-09-27	Buccoo	11°11.167'	60°50.085'	8.4	29.2	N	n/a	n/a	n/a	n/a	none	LF, KE, KM, KiS	Dive 1, surface temperature 30deg
9	2021-09-27	Buccoo	11°11.299'	60°50.443'	9.5	29.2	Y	1.17	1.48	0.97	bleached	BU01A1	LF, KE, KM, KiS	surface temperature 30deg
10	2021-09-27	Buccoo	11°11.299'	60°50.443'	9.5	29.2	Y	1.17	1.48	0.97	bleached	BU01A2	LF, KE, KM, KiS	surface temperature 30deg
11	2021-09-27	Buccoo	11°11.299'	60°50.443'	9.5	29.2	Y	1.17	1.48	0.97	bleached	BU01A3	LF, KE, KM, KiS	surface temperature 30deg
12	2021-09-27	Buccoo	11°11.299'	60°50.443'	9.5	29.2	Y	1.17	1.48	0.97	bleached	BU01A4	LF, KE, KM, KiS	surface temperature 30deg
13	2021-09-27	Buccoo	11°11.299'	60°50.443'	9.5	29.2	Y	1.17	1.48	0.97	bleached	BU01A5	LF, KE, KM, KiS	surface temperature 30deg
14	2021-09-27	Buccoo	11°11.299'	60°50.443'	9.5	29.2	Y	1.17	1.48	0.97	bleached	BU01A6	LF, KE, KM, KiS	surface temperature 30deg
15	2021-09-28	Plymouth	11°13.578'	60°46.507'	6.7	28.2	N	n/a	n/a	n/a	n/a	none	LF, KE, KM, KiS	Dive 1, surface temperature 30deg
16	2021-09-28	Plymouth	11°13.553'	60°46.555'	5.1	28.2	Y	0.92	0.51	0.14	bleached	PL01A1	LF, KE, KM, KiS	surface temperature 30deg
17	2021-09-28	Plymouth	11°13.553'	60°46.555'	5.1	28.2	Y	0.92	0.51	0.14	bleached	PL01A2	LF, KE, KM, KiS	surface temperature 30deg
18	2021-09-28	Plymouth	11°13.553'	60°46.555'	5.2	28.2	Y	0.88	0.67	0.95	bleached	PL03A1	LF, KE, KM, KiS	surface temperature 30deg
19	2021-09-28	Plymouth	11°13.553'	60°46.555'	5.2	28.2	Y	0.88	0.67	0.95	bleached	PL03A2	LF, KE, KM, KiS	surface temperature 30deg
20	2021-09-28	Plymouth	11°13.553'	60°46.555'	5.2	28.2	Y	0.88	0.67	0.95	bleached	PL03A3	LF, KE, KM, KiS	surface temperature 30deg
21	2021-09-28	Plymouth	11°13.553'	60°46.555'	5.2	28.2	Y	0.88	0.67	0.95	bleached	PL03A4	LF, KE, KM, KiS	surface temperature 30deg
22	2021-09-28	Plymouth	11°13.553'	60°46.555'	5.2	28.2	Y	0.88	0.67	0.95	bleached	PL03A5	LF, KE, KM, KiS	surface temperature 30deg
23	2021-09-28	Plymouth	11°13.553'	60°46.555'	5.6	28.2	Y	1.32	1.16	0.45	bleached	PL04A1	LF, KE, KM, KiS	surface temperature 30deg
24	2021-09-28	Plymouth	11°13.553'	60°46.555'	5.6	28.2	Y	1.32	1.16	0.45	bleached	PL04A2	LF, KE, KM, KiS	surface temperature 30deg

Id	Date	Site	Northing	Westing	Depth (m)	Temp (°C)	DC present	MaxL (m)	MaxW (m)	MaxH (m)	Condition	Genetic Sample No.	Survey Team	Comments
25	2021-09-28	Plymouth	11°13.553'	60°46.555'	5.6	28.2	Y	1.32	1.16	0.45	bleached	PL04A3	LF, KE, KM, KiS	surface temperature 30deg
26	2021-09-28	Plymouth	11°13.553'	60°46.555'	5.6	28.2	Y	1.32	1.16	0.45	bleached	PL04A4	LF, KE, KM, KiS	surface temperature 30deg
27	2021-09-28	Plymouth	11°13.553'	60°46.555'	5.6	28.2	Y	1.32	1.16	0.45	bleached	PL04A5	LF, KE, KM, KiS	surface temperature 30deg
28	2021-09-28	Plymouth	11°13.553'	60°46.555'	6.3	28.2	Y	2.53	1.59	0.57	bleached	PL02B1	LF, KE, KM, KiS	surface temperature 30deg
29	2021-09-28	Plymouth	11°13.553'	60°46.555'	6.3	28.2	Y	2.53	1.59	0.57	bleached	PL02B2	LF, KE, KM, KiS	surface temperature 30deg
30	2021-09-28	Plymouth	11°13.553'	60°46.555'	6.3	28.2	Y	2.53	1.59	0.57	bleached	PL02B3	LF, KE, KM, KiS	surface temperature 30deg
31	2021-09-28	Plymouth	11°13.553'	60°46.555'	6.3	28.2	Y	2.53	1.59	0.57	bleached	PL02B4	LF, KE, KM, KiS	surface temperature 30deg
32	2021-09-28	Plymouth	11°13.553'	60°46.555'	6.3	28.2	Y	2.53	1.59	0.57	bleached	PL02B5	LF, KE, KM, KiS	surface temperature 30deg
33	2021-09-28	Plymouth	11°13.553'	60°46.555'	8.0	28.2	Y	8.75	8.55	0.9	bleached	PL02A1	LF, KE, KM, KiS	surface temperature 30deg
34	2021-09-28	Plymouth	11°13.553'	60°46.555'	8.0	28.2	Y	8.75	8.55	0.9	bleached	PL02A2	LF, KE, KM, KiS	surface temperature 30deg
35	2021-09-28	Plymouth	11°13.553'	60°46.555'	8.0	28.2	Y	8.75	8.55	0.9	bleached	PL02A3	LF, KE, KM, KiS	surface temperature 30deg
36	2021-09-28	Plymouth	11°13.553'	60°46.555'	8.0	28.2	Y	8.75	8.55	0.9	bleached	PL02A4	LF, KE, KM, KiS	surface temperature 30deg
37	2021-09-28	Plymouth	11°13.553'	60°46.555'	8.0	28.2	Y	8.75	8.55	0.9	bleached	PL02A5	LF, KE, KM, KiS	surface temperature 30deg
38	2021-10-01	Culloden	11°14.970'	60°44.910'	8.5	n/a	N	n/a	n/a	n/a	n/a	none	LF, KE, KM, KiS	no comment
39	2021-10-01	Culloden	11°14.970'	60°44.910'	9.8	n/a	N	n/a	n/a	n/a	n/a	none	LF, KE, KM, KiS	no comment
40	2022-01-23	Campbellton	11°19.054'	60°33.814'	10.0	n/a	N	n/a	n/a	n/a	n/a	none	LF, AK, SR	no comment
41	2022-01-23	Campbellton	11°19.064'	60°33.775'	9.5	n/a	N	n/a	n/a	n/a	n/a	none	LF, AK, SR	no comment
42	2022-01-25	Landslide	11°20.010'	60°33.378'	5.0	n/a	N	n/a	n/a	n/a	n/a	none	LF, AK, SR	no comment
43	2022-01-25	Landslide	11°20.010'	60°33.378'	7.1	n/a	N	n/a	n/a	n/a	n/a	none	LF, AK, SR	no comment
44	2022-05-06	Castara	11°14.970'	60°44.910'	12.0	n/a	N	n/a	n/a	n/a	n/a	none	LF, KE, ED, KiS	no comment
45	2022-05-06	Arnos Vale	11°14.553'	60°45.200'	9.8	n/a	N	n/a	n/a	n/a	n/a	none	LF, KE, ED, KiS	no comment
46	2022-05-10	Goat Island	11°18.007'	60°31.093'	7.6	n/a	N	n/a	n/a	n/a	n/a	none	KE, SS, KM, KiS, RC	no comment
47	2022-05-10	Black Jack Hole	11°17.459'	60°30.052'	8.5	n/a	N	n/a	n/a	n/a	n/a	none	KE, SS, KM, KiS, RC	no comment
48	2022-05-11	Batteaux Bay	11°18.200'	60°31.660'	7.6	n/a	N	n/a	n/a	n/a	n/a	none	KE, SS, KM, KiS, RC	no comment
49	2022-05-11	Spiney	11°16.460'	60°31.364'	6.5	n/a	N	n/a	n/a	n/a	n/a	none	KE, SS, KM, KiS, RC	no comment
50	2022-07-01	Culloden	11°14.970'	60°44.910'	tbd	tbd	Y	tbd	tbd	tbd	tbd	tbd	KiS, IMA	identified by K. Sampson (DMRF, THA) during surveys with IMA; not ERIC dives

Appendix 5 – Survey dive images

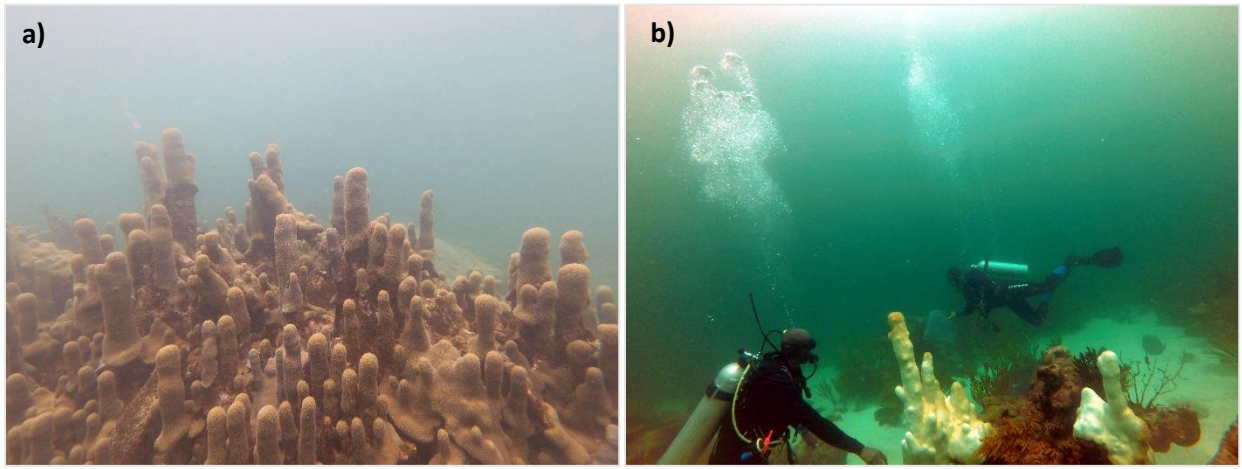


Figure 8. Colonies in a) Booby Reef, and b) Buccoo Reef

Figure 9. Pillar coral colonies being a-b) measured and c) sampled for sex determination in Plymouth

Appendix 6 – Pillar coral harvesting and transplantation training

Figure 10. a-d) CBFTs practicing with the use of two-part marine epoxy to attach coral fragments to substrate

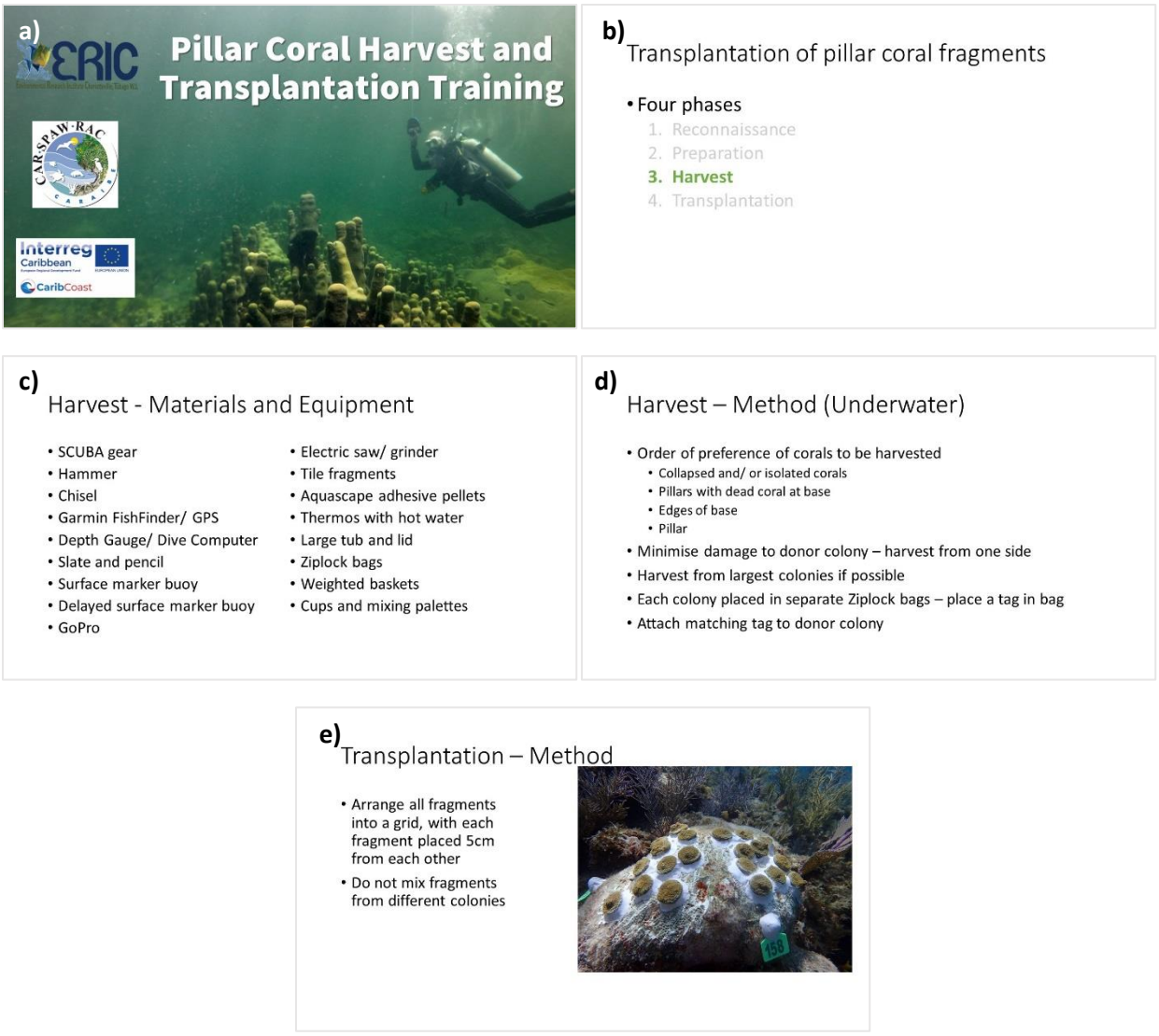
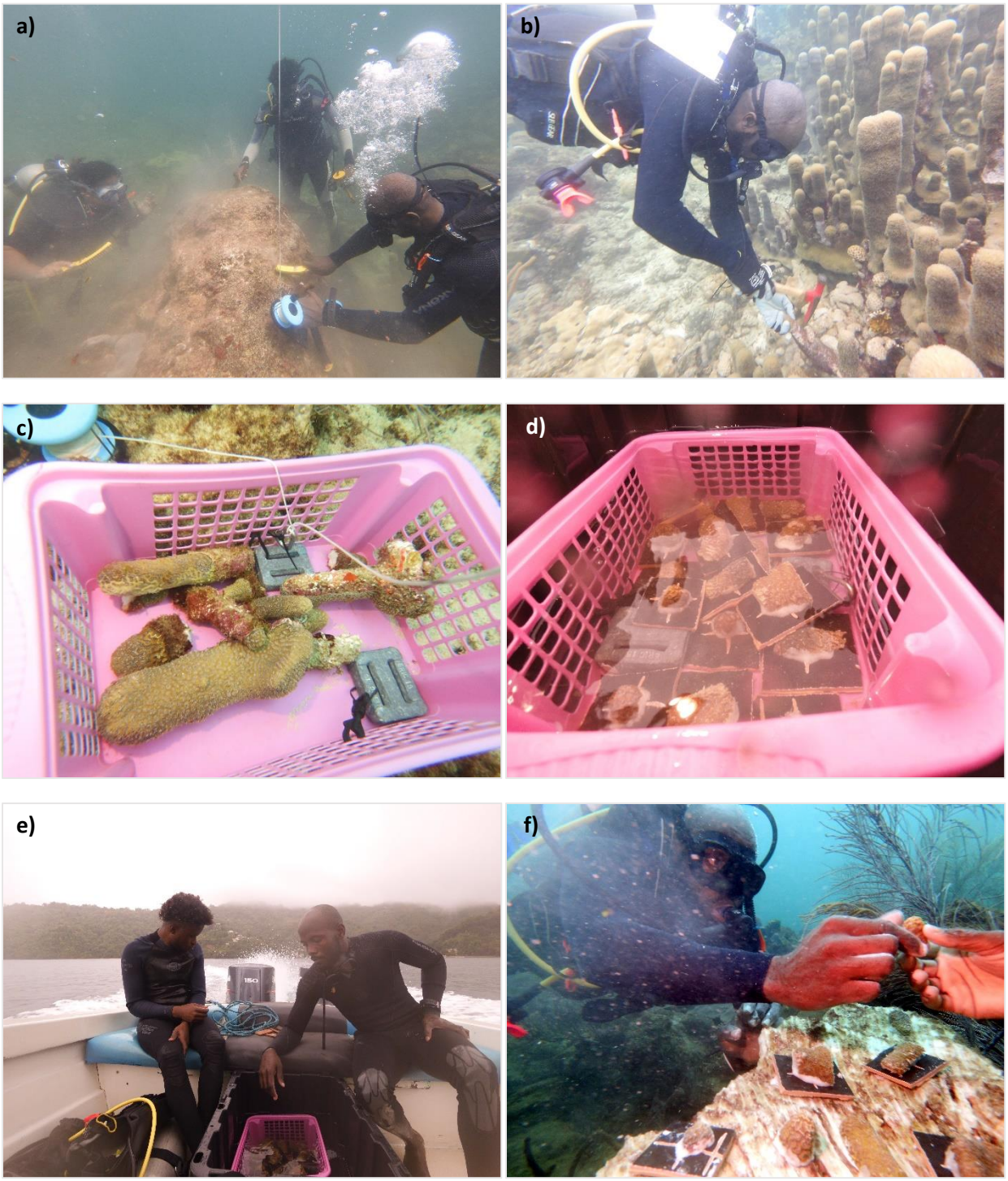


Figure 11. a-e) Sample slides from harvest and transplantation training workshop

Appendix 7 – Pillar coral harvesting and transplantation images



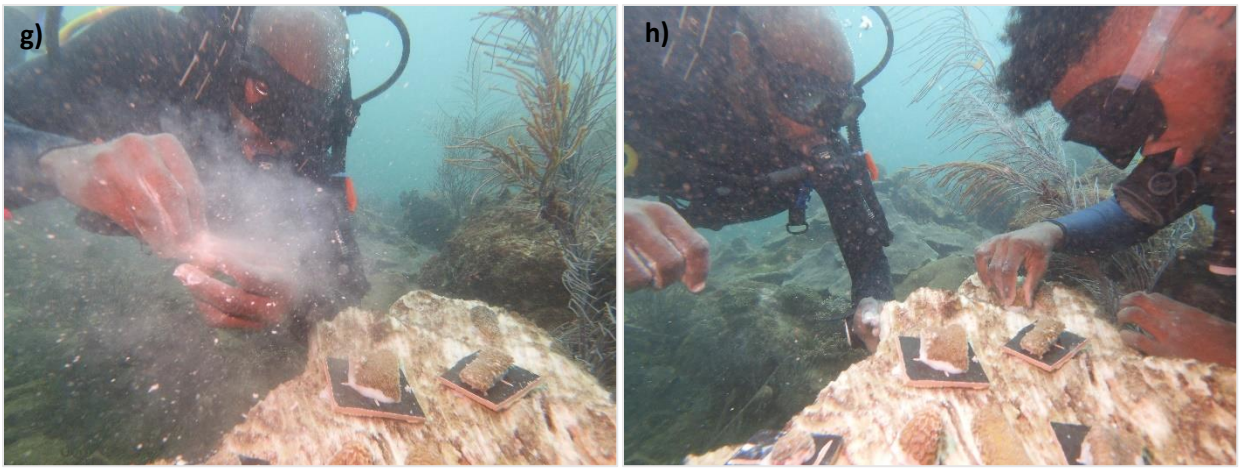
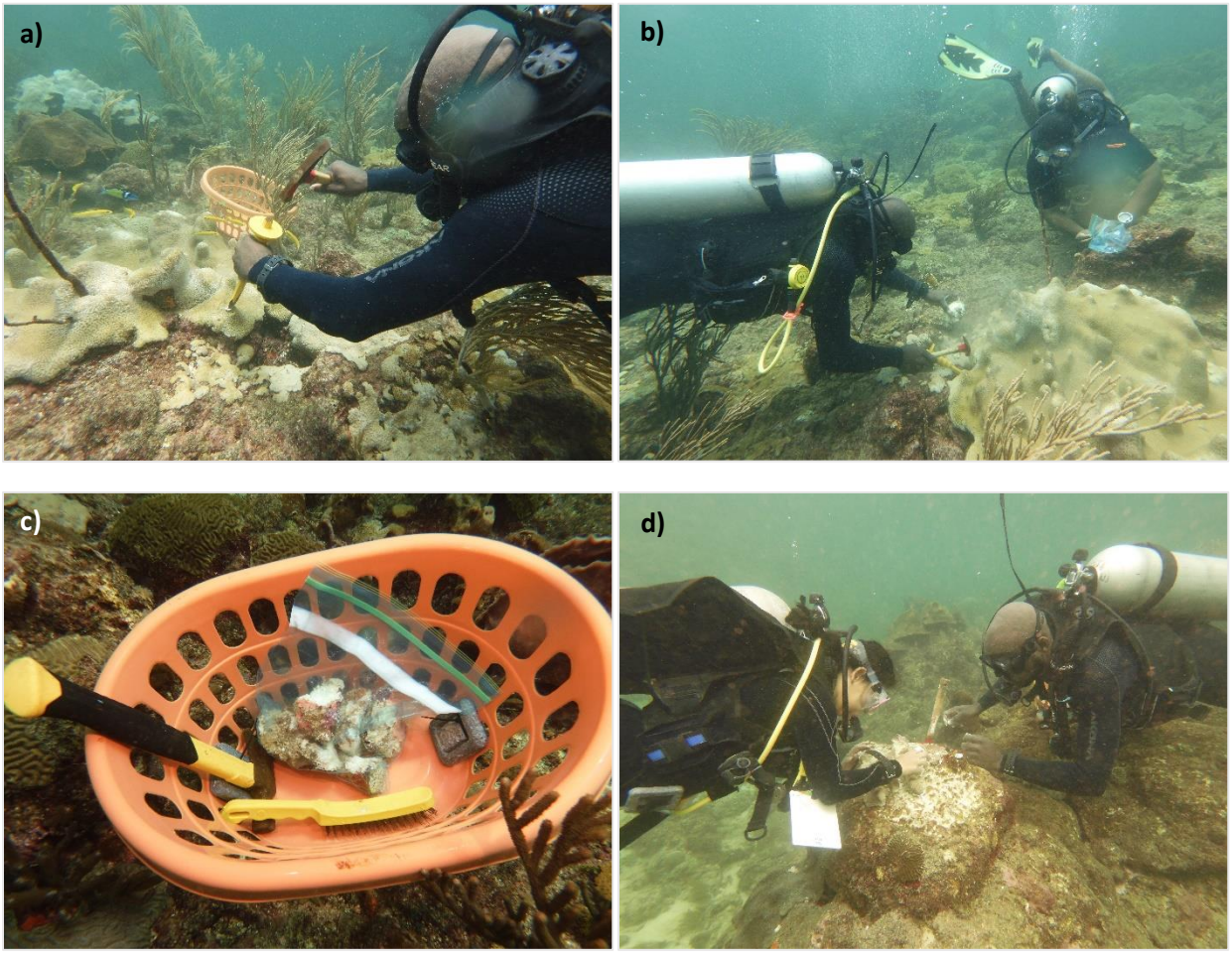


Figure 12. Stages of transplantation of Booby colony fragments in Booby Reef: a) preparing substrate for fragments, b) harvesting from donor colony, c) fragments collected for further fragmentation, d) fragments attached to tiles, e) transportation of fragments to transplantation site, f-h) attachment of fragments to substrate.



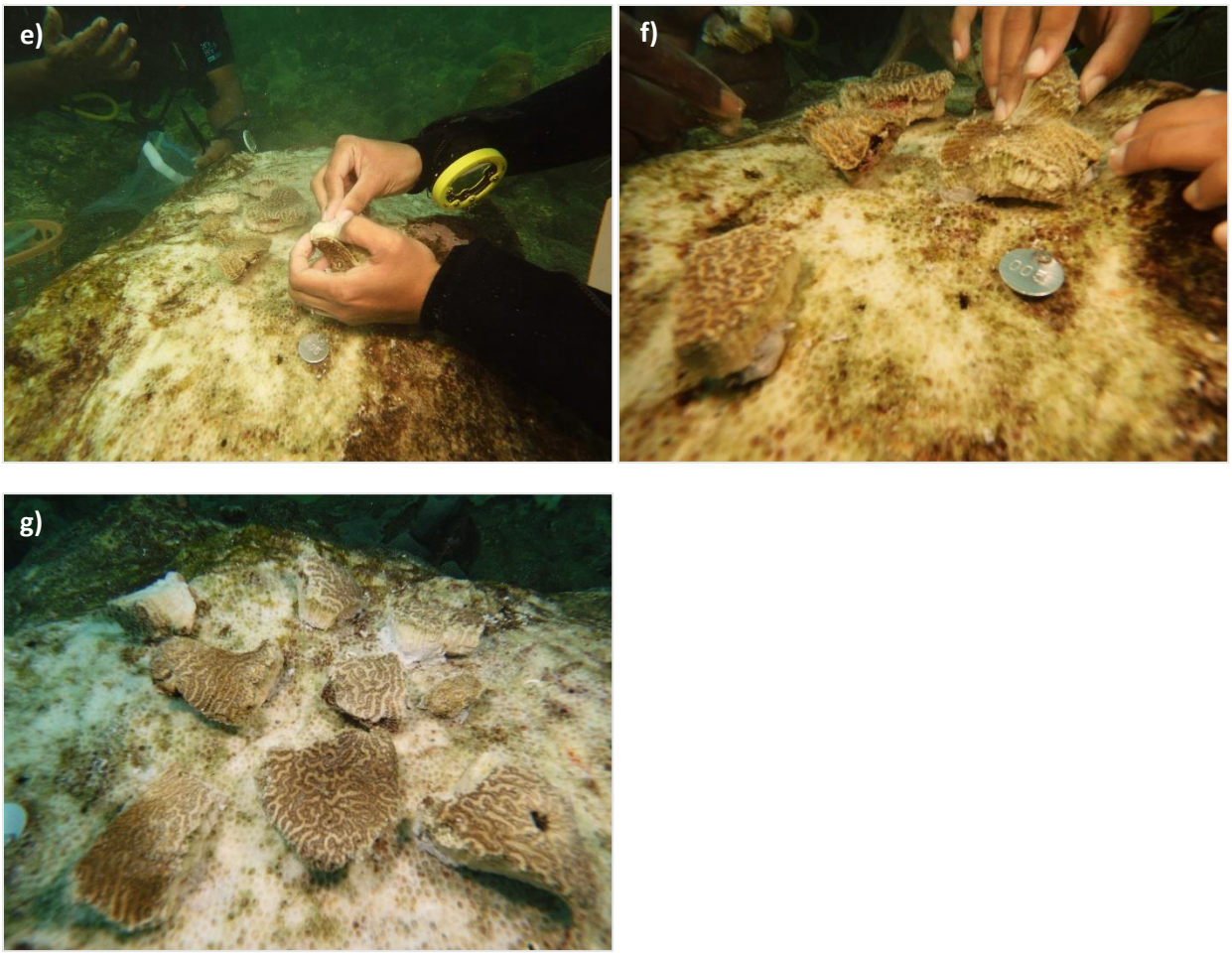


Figure 13. Stages of transplantation of Plymouth colony fragments to Booby Reef: a-c) harvesting from donor colony, d-g) transplanting in Booby Reef

Appendix 8 – Pillar coral transplant monitoring images

Figure 14. Fragments one week post-transplantation

Appendix 9 – Draft North East Tobago UNESCO Man and the Biosphere Reserve Zonation Map

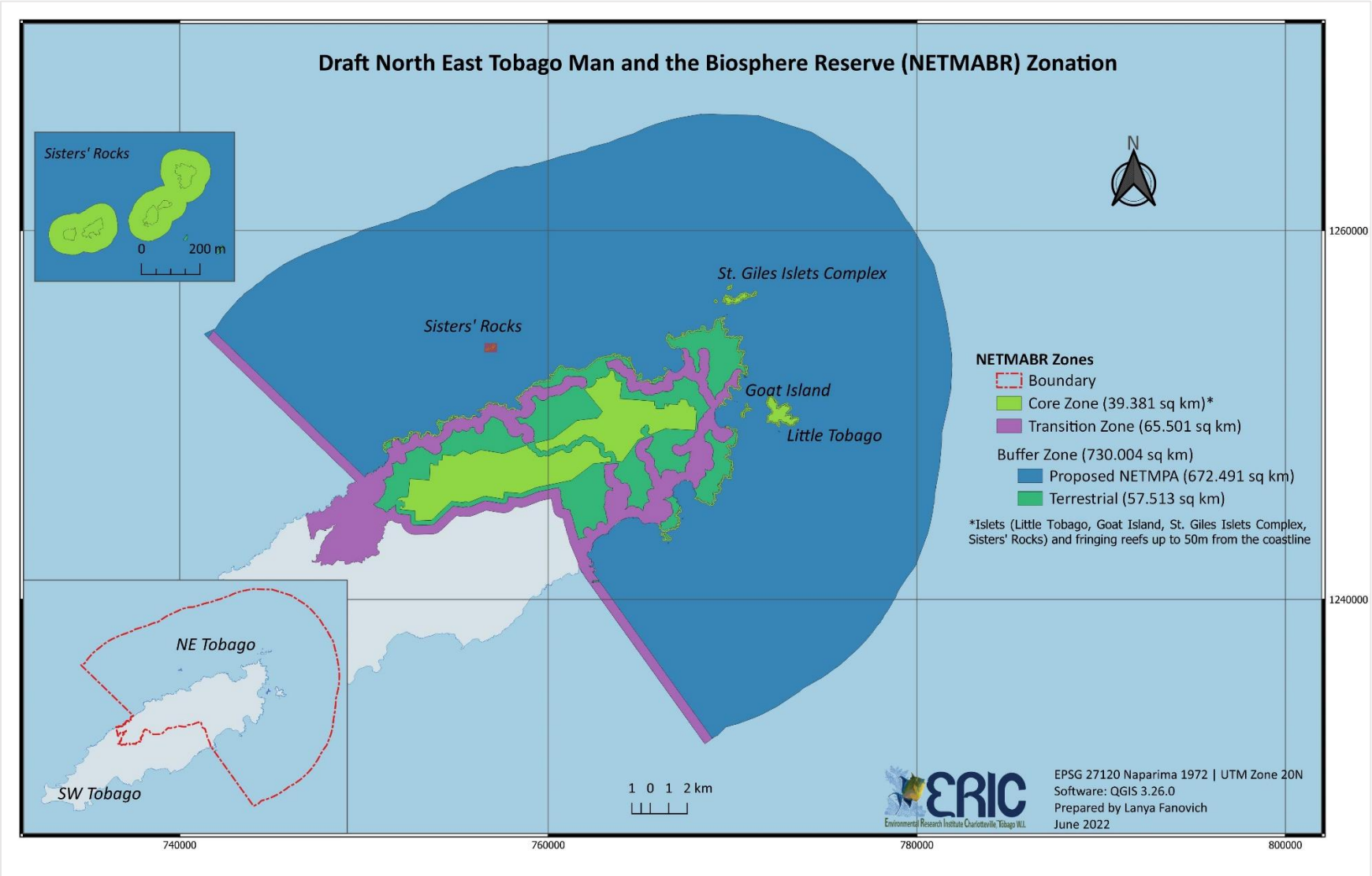
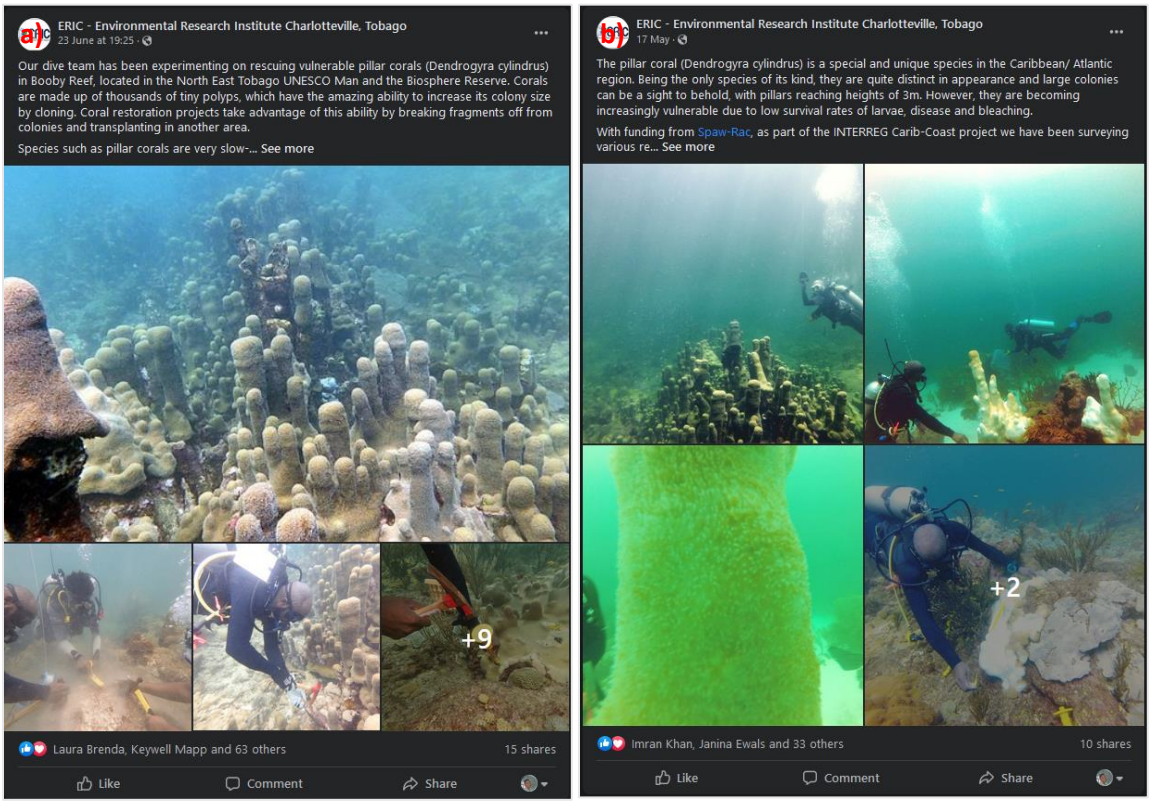


Figure 15. Draft map of the NETMABR to be submitted upon listing of islets and reefs as Natural National Heritage Sites

Appendix 10 – Social media posts



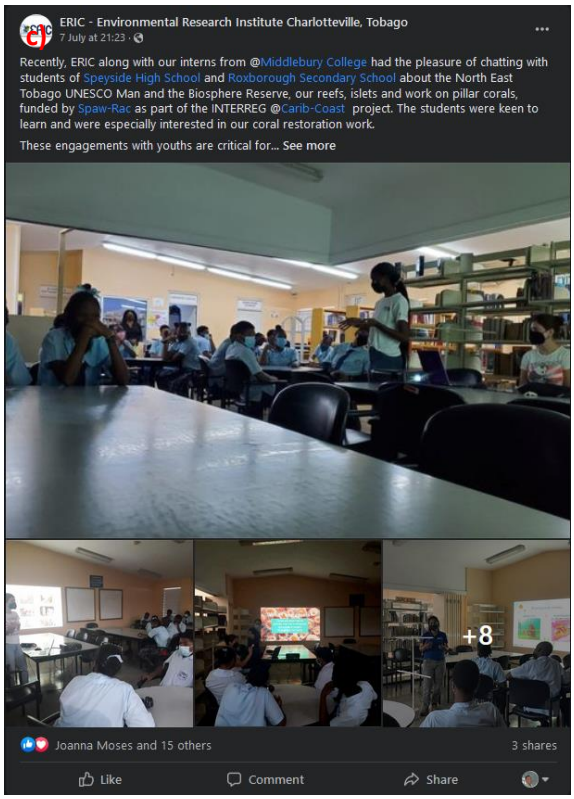


Figure 16. Facebook posts made on a) 17 May, b) 23 June, and c) 07 July 2022

Appendix 11 – Draft press releases

Saving our Pillar Corals

On a sunny day in Northeast Tobago, Kimron Eastman, a Community-Based Field Technician (CBFT) at the Environmental Research Institute Charlotteville (ERIC), expertly scraped clear a patch of rock to attach a small coral, 8m below the sea surface. Around him at that very same spot many years ago, there was a vibrant, colourful reef with several coral species. Now, there are mainly rocks.

Corals are tiny marine animals that form the foundation for our coastal reefs. They provide habitat for the fish and marine creatures that support our diets, livelihoods, and attract tourists. Additionally, they act as underwater breakers that decrease wave strength, protecting our shoreline communities. Some species even produce compounds that can be extracted in laboratories to produce medicines to potentially treat illnesses like cancer. Unfortunately, over the past few decades, corals have not been thriving as they once did.

One species of coral that is suffering in Tobago and in the wider Caribbean is the pillar coral (*Dendrogyra cylindrus*). They are unique in appearance with very few closely related species and grow into cylindrical towers emerging from a single fixed base, reaching up to 2m in height – hence its name! They are not abundant in the Caribbean and even less so in Tobago, which makes sightings of this species in our reefs even more special. They are a slow-growing species, growing at a rate of 8mm to 20mm (less than ¾ inch) per year. While pillar corals are important "reef-builders" like most coral species, they are especially vulnerable to bleaching and disease. Most coral species can sexually reproduce by releasing both male and female gametes during spawning periods, which then after fertilisation, form larvae that settles on rock surfaces. Pillar coral colonies are either fully male or female, which makes reproduction difficult for isolated colonies. For more than 30 years, there has been no new pillar corals via sexual reproduction in the wild. This is detrimental to the existence of the species as progressively warmer sea temperatures increases the likelihood and frequency of bleaching events and as new diseases emerge and rapidly spread.

Recognising these challenges, the ERIC, based in Charlotteville, Tobago, embarked on a pilot exercise to preserve pillar corals in Tobago with funding from the Specially Protected Areas and Wildlife Regional Activity Centre (SPAW-RAC) as part of the INTERREG Carib-Coast project. With the assistance of trained CBFTs from within the communities of northeast Tobago, fisheries officers from the Department of Marine Resources and Fisheries in the Tobago House of Assembly and divemasters and dive instructors familiar with several reefs in Tobago, surveys were conducted across several sites to assess the distribution, population size and health of pillar corals between September 2021 and May 2022. Most of the surveys yielded disappointment among team members as each dive failed to detect colonies, further highlighting the rarity of pillar corals in Tobago. Even more alarming, the few colonies found in September in southwest Tobago showed signs of bleaching!

In June 2022, the corals were revisited where luckily, they have recovered from the heat stress experienced in 2021. However, with each year presenting elevated record-breaking temperatures and the high likelihood of annual bleaching, the future is uncertain for pillar corals. With this, fragments were harvested for transplantation in Charlotteville, where the largest colony presently exists and was

unaffected by the bleaching events. The process of fragmentation takes advantage of the cloning ability of corals to establish new colonies at different sites. Coral restoration practitioners also discovered that fragments grow at a faster rate than larger pieces and that fragments of the same colony will fuse together as they grow. With this knowledge, ERIC's CBFTs transplanted clusters of pillar coral fragments into Charlotteville reefs, in the hope that they will eventually grow into large, sexually mature colonies that may one day be able to reproduce and give rise to new generations of pillar corals.

There is also interest in determining the sex of each pillar coral colony, which can give an idea of the reproductive potential for the recruitment of new colonies in Tobago's reefs. With this information, donor colonies can be strategically harvested for transplantation into other reefs that present the ideal environment and conditions for pillar coral growth.

Welldon Mapp, ERIC's Head CBFT, shared: "restoring pillar corals is a bit sad because here we have a hard coral species which is not frequently seen and has to also cope with the challenges of low reproductive capacity and ability to adapt in the face of climate change." Restoring and preserving pillar corals in Tobago will be challenging with so many odds stacked against it, from its biology to changing environments and shifting climate. However, these activities and continued monitoring are just first small steps towards reef conservation in Tobago. It is thanks to SPAW-RAC that ERIC can begin this initiative.

IMAGES

Charlotteville's pillar coral, the largest colony found in Tobago's during ERIC's surveys.

ERIC's Community-Based Field Technician, Kimron Eastman measuring a bleached pillar coral in September 2021.

Delicately attaching pillar coral fragments to a cleaned rock surface

Harvested pillar coral awaiting further fragmentation before transplantation into the reef.

Close-up of the surface of a pillar coral, with its fully tentacles extended, giving the species its hairy appearance.

Islet and Reefs of North East Tobago: Natural National Treasures

The landscape of the North East Tobago is shrouded in rich green hues as forested mountains and valleys surround the clusters of buildings that form the various communities. This is what most people are witnesses to when entering the Man and the Biosphere Reserve. However, as you cast your eyes to the horizon beyond the coastline, there are ecosystems silently proffering their own, uniquely rich and beautiful vistas to anyone willing to take an adventure to explore them.

Hugging our coastlines, hidden beneath the sea, Tobago's coral reefs are an ecosystem of remarkable natural beauty, ecological and economic importance. They teem with diverse life, home to thousands of marine species including at least 85 species of corals, over 500 reef and commercially important fish species and hundreds of species of other invertebrates including crabs, sea slugs, and brittle stars, making it almost as biodiverse as the Main Ridge Forest Reserve.

The islets of North East Tobago hosts a different forest ecosystem than the Main Ridge Forest Reserve. Antillean tropical dry forests dominate the landscape of Little Tobago, with large aroids (related to anthuriums), silver thatch palms and the gumbo limbo tree (locally called naked indian tree), easily identified by it colourful peeling bark. These plants are home to reptiles, sea and land birds and invertebrates. Strolling through the underbrush are soldier crabs, most often using abandoned Caribbean top shells (locally called whelks) and returning to the shoreline to either swap for larger shells or to breed. Red-footed boobies and red-billed tropicbirds reside while the forests act as a nursery for laughing gulls each year before departing with the adults around November each year.

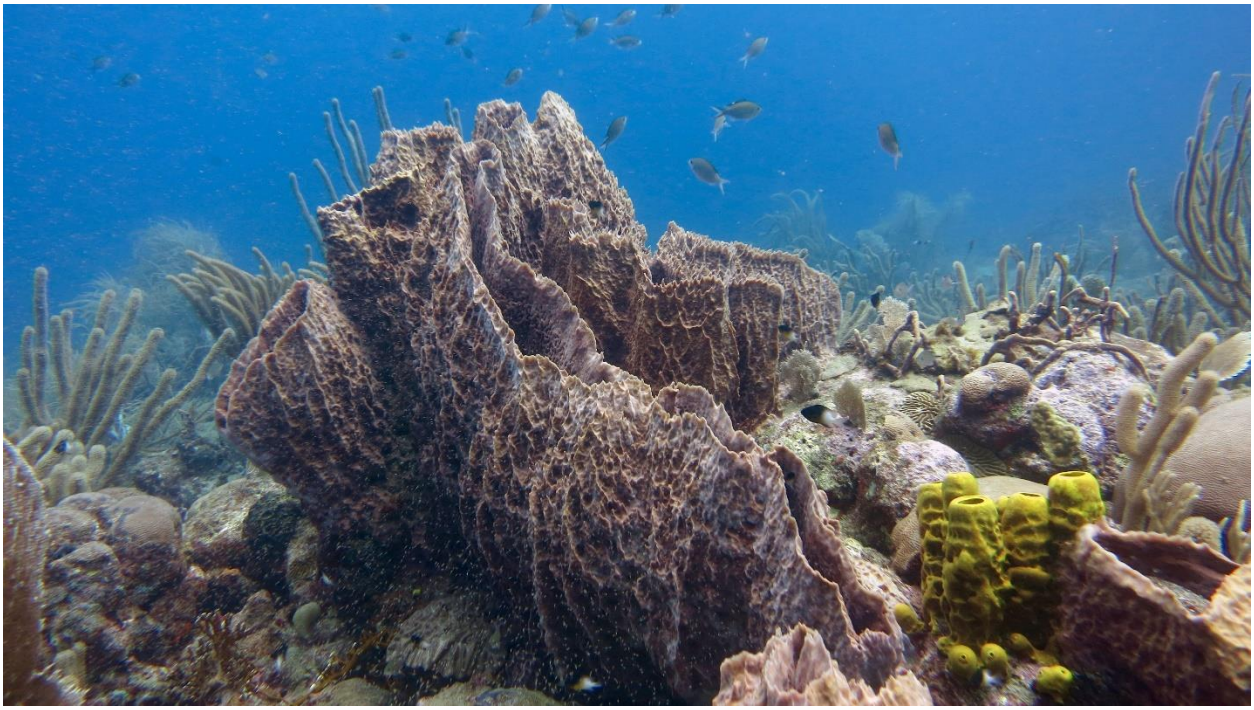
The other islets include Goat Island, the St. Giles Islet Complex and Sisters' Rocks. Covered with cacti and shrubs tolerant to the harsh marine environment, they provide roosts and homes for several resident and migratory birds. One of the largest populations of magnificent frigatebirds breed at St. Giles Island, with impressive displays by males during the breeding season. Due to the diversity and significance of the St. Giles Islets Complex and Little Tobago as seabird habitat, they were designated as bird and wildlife sanctuaries by the Government of Trinidad and Tobago.

As different as reef and islets ecosystems may be from each other, they both share a close connection to each other. Seabirds nesting and roosting on the islets feed on pelagic fishes including those found in reefs. In turn, the faeces from these birds not only provide nutrients for vegetation growth on the islets, but also nutrients for the reefs. Some studies such as one conducted in the Chagos Archipelago, an island of Mauritius in the Indian Ocean, provide evidence of a close connectivity between healthy seabird populations and coral reef productivity. Fishermen also share a close relationship with seabirds as they use the birds' flocking over an area as a cue for the presence of a school of fish. The islets and reefs together also reduce wave energy from the open ocean as it approaches mainland Tobago, therefore sheltering the island's coastlines from severe erosion.

Apart from the ecology of these natural treasures, they are all backed by a colourful history, spanning as far back as pre-colonial times. Evidence of occupation of Little Tobago by the First Peoples have been found, with population records during the British colonisation. Many wars were fought either among the islets or for the islets. Little Tobago once hosted a cotton plantation which was eventually abandoned. Even more famously, Little Tobago was once home to the introduced greater bird of paradise which failed to thrive due to neglect and later perished with the passage of Hurricane Flora.

Both reefs and islets are important to Tobago's tourism industry. SCUBA divers, birders, naturalists and people who generally enjoy the outdoors are drawn to the attractions provided by both. However, they both face numerous threats from over-exploitation of natural resources, pollution, climate change, invasive species and diseases. Reefs have been significantly impacted over the past few decades, while the islets have remained resilient, though this can easily change without proper management and protection.

The Environmental Research Institute Charlotteville (ERIC) is one such organisation that has been working over the years to advocate for sustainable development in North East Tobago to carefully manage the reefs and islets. Collating information on these ecosystems' biogeography, ecology, geology, climate, culture, history, threats, services and stakeholders is an important step towards informing management plans. Funding from the Specially Protected Areas and Wildlife Regional Activity Centre (SPAW-RAC) as part of the INTERREG Carib-Coast project has allowed the institute to begin this process. Improving understanding and knowledge of North East Tobago's reefs and islets while working closely with community stakeholders and management authorities such as the various departments of the Tobago of Assembly (Department of Marine Resources and Fisheries, Department of Environment and Department of Natural Resources and Forestry), the Institute of Marine Affairs, the Environmental Management Authority and the National Trust of Trinidad and Tobago, can enable the implementation of regulations that will protect both these environments and the livelihoods of persons who depend on them. Achieving sustainability for North East Tobago and ensuring that everyone can experience the beauty and treasures of reefs and islets require close collaboration and cooperation from all.



Reef in North East Tobago with a diversity of sponges, hard corals and soft corals.

Goat Island (foreground) and Little Tobago (background) located in Speyside Tobago

Magnificent frigatebirds during the breeding season among St. Giles Island foliage. The males are easily distinguished by their bright red gular sacs which they inflate to attract females, identified by white breasts.

Soldier crab in Little Tobago's forest

Fishermen casting their net over a school of fish for bait in reefs in Charlotteville

Appendix 12 – School outreach

Speyside High School





Roxborough Secondary School


New Books


New Books


New Books