# Suitable sites for coral nurseries and outplanting (SWCMR and TAMR)



### Technical Report I

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#### Citation:

Carne, L. (2020). Repopulate reefs within replenishment zones of Turneffe Atoll Marine Reserve and South Water Caye Marine Reserve with temperature resilient coral varieties. Scope suitable nursery and outplanting areas (Task 2). MCCAP/SER/05. Fragments of Hope, The World Bank and The Adaptation Fund



## **Executive Summary**

This report on identified suitable areas for coral nurseries and outplanting sites is one of four technical reports required under the MCCAP sub-project entitled "Repopulate reefs within replenishment zones of Turneffe Atoll Marine Reserve (TAMR) and South Water Caye Marine Reserve (SWCMR) with temperature resilient coral varieties" (Contract Number: MCCAP/SER/o5 and ID number: P131408-BZ/C-2). The objective of this consultancy is to support the implementation and expansion of propagation and restoration practices in TAMR and SWCMR in Belize. Identification of suitable sites for both coral nurseries and planned replenished (outplanted) sites is listed as Task 2.10, and this report also serves as a deliverable for Task 3.14: Technical Report on established coral nurseries. The methods and work plan were outlined in the approved Inception Report. This report describes the site selection criteria used to identify appropriate sites for both coral nurseries established in TAMR, and SWCMR, respectively (12 total). Included here are the maps and coordinates for the identified coral outplant sites in each MPA (SWCMR n=seven, TAMR n=six).



CONTENTS	
Executive Summary	i
Introduction/Background/Project Justification	5
Methods and related completed tasks to date:	8
Literature review	7
Community Consultations	9
Site Selection Criteria	14
Table II. Nursery and outplant criteria	20
Results: Nursery and outplant sites identified, SWCMR and TAMR	6
Tables III & IV. Coordinates of nursery and outplant locations	21
Conclusions & Recommendations	22
References	24

## Introduction/Background/Project Justification

Climate change is believed by the majority of marine scientists to be the most serious threat to corals and their ecosystems today (Aronson and Precht 2006; Baird et al. 2009; Hoegh-Guldberg and Bruno 2010; Lesser 2011), with global warming causing increased severity and frequency of bleaching and coral mortality (Hoegh-Guldberg et al. 2007). Coral reefs are generally recognized as the most vulnerable of the planet's ecosystems to the impacts of climate change (Donner et al. 2005). An estimated 19% of the world's coral reefs have been lost and a further 35% are seriously threatened (Wilkinson and Souter 2008), and one-third of all reef-building corals are considered to be at risk of extinction (Carpenter et al. 2008). Some authors estimate 60% of all live corals could be lost by 2030 and state that current management practices must undergo radical changes to become effective (Hughes et al. 2003).

Widespread coral loss due to thermal stress and mass bleaching has already occurred (Hoegh-Guldberg et al. 2007) and Caribbean reefs are particularly impacted, with lower coral cover presently than at any time in geological history (Greenstein et al. 1998). The Caribbean as a whole has lost an average of 40% of its absolute live coral cover since the late 1970's (Gardner et al. 2003) and most of this is accounted for by the wide-spread loss of two Caribbean acroporids, *Acropora cervicornis* (Lamarck 1816) and *A. palmata* (Lamarck 1816), whose mass mortality is attributed to hurricanes, bleaching and disease (Aronson and Precht 2001; Bruckner 2003). These two species are the fastest growing, main reef building species in the Caribbean, previously dominating both the shallow and intermediate depths; their combined abundance has been reduced by more than 95% Caribbean-wide and they were placed on the IUCN's Red List in 2008 as Critically Endangered, one step away from Extinction in the Wild (Aronson et al. 2008).

In Belize, coral reefs were valued for their ecosystem services (shoreline protection, nursery habitat and aesthetic/tourism value) at over US\$370million/year (Cooper et al. 2008). The national average coral cover is currently just 15%, yet both Turneffe Atoll and South Water Caye Marine Reserve are labeled as "poor" with coral cover between 5-9% (Kramer et al. 2015).

The most widely recognized climate change adaptation option for coral reefs is to increase coral reef health through the management of local stresses such as pollution, sedimentation, and overfishing (Buddemeier et al. 2004). But with ongoing work at Laughing Bird Caye National Park (LBCNP) in southern Belize since 2006, an additional option has been explored and now validated: the identification and propagation of bleaching resistant and/or resilient corals, their cultivation into second/third generation fragments, followed by transplantation to reefs where thermal stress has decimated coral cover (Carne 2008, 2011; Bowden-Kerby and Carne 2012). Restoration techniques have recently become more accepted as conservation tools in recognition of such rapid and continued reef degradation (Jaap 2000; Rinkevich 2005; Baums 2008; Baums et al. 2010; Lirman et al. 2010; Johnson et al. 2011; Young et al. 2012; Rinkevich 2014).

Belize, under the leadership of the Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development with fiduciary management assistance from the Protected Areas Conservation Trust (PACT) as the National Implementing Entity (NIE) and the World Bank as Multilateral Implementing Entity (MIE), is responsible for the implementation of the Marine Conservation and Climate Change Adaptation Project (MCCAP) in the coastal areas of Belize. The Project Implementing Agency Group (PIAG) housed within the Fisheries Department and staffed by full-time and part-time consultants is responsible for the coordinating MCCAP implementation. The PIAG consists of a Project Coordinator (PC), a Senior Technical Officer (STO), Administrative Officer, staff from Fisheries Department, and fiduciary staff of PACT.

MCCAP is a five-year project designed to implement a priority ecosystem-based marine conservation and climate adaptation measures to strengthen the climate resilience of the Belize Barrier Reef System and its productive marine resources. Specifically, the project will support:

- Improvement of the reef's protection regime including an expansion and enforcement of the Marine Protected Areas (MPAs) and Replenishment (no-take) Zones in strategically selected locations to strengthen climate resilience,
- ii. Promotion of sustainable alternative livelihoods for affected users of the reef, and

iii. Building local capacity and raising awareness regarding the overall health of the reef ecosystem and the climate resilience of coral reefs.

MCCAP will benefit three Marine Protected Areas (MPAs), namely, the Corozal Bay Wildlife Sanctuary (CBWS), the Turneffe Atoll Marine Reserve (TAMR), and the South Water Caye Marine Reserve (SWCMR). These MPAs are fished by fishermen mainly from 12 coastal communities, namely: 1) Consejo Village, 2) Corozal Town, 3) Copper Bank Village, 4) Chunox Village, 5) Sarteneja Village, 6) Belize City, 7) Dangriga Town, 8) Hopkins Village, 9) Sittee River Village, 10) Riversdale Village, 11) Seine Bight Village, and 12) Placencia Village.

The Belize Marine Conservation and Climate Adaptation Project (MCCAP) has developed a programme to conduct pilot investments into repopulating reefs within replenishment zones of Turneffe Atoll Marine Reserve (TAMR) and South Water Caye Marine Reserve (SWCMR) with temperature resilient coral varieties to support climate change adaptation measures that will improve the resilience of the reef. MCCAP contracted Fragments of Hope, Ltd., to implement the reef restoration activities in TAMR and SWCMR (Sub-Component 1.2.3), and by extension to expand the reef restoration programme in Belize. With financing from the Adaptation Fund, these activities will also compliment other tasks under Component 1, such as field verification of spatial mapping activities via ground-truthing and carrying out stakeholder consultations (Sub-Component 1.2.1), and biological and water quality (temperature) monitoring of strategic and control sites (Sub-Component 1.2.2). Additionally, Fragments of Hope will add to the project outcomes under Component 3, Raising Awareness and Building Local Capacity through Project Information Dissemination (Sub-Component 3.2.3) and Community Training Events (Sub-Component 3.2.4).

Fragments of Hope has increased live coral cover at LBCNP from just 6% to over 35% by outplanting nursery-reared acroporids from 2010-2016 in ~ one hectare of degraded reef, and is an international example of effective reef ecosystem restoration. Fragments of Hope has established replicable methodologies for mapping, genetics, outplanting and most importantly, created quantifiable success indicators for evaluating the replenishment process. This technical report addresses the site selection process and locations for coral nurseries and outplanting sites established to date in SWCMR and TAMR.

## Methods:

#### Literature review

Although listed as a completed Task (1.3) and multiple peer-reviewed articles were shared it the approved Inception Report, literature review is an on-going activity, especially essential as coral restoration becomes more widely accepted. Summarized here are a few recent publications on the work in Southern Belize, and several new, other peer-reviewed articles validating the work and highlighting future gaps/needs.

Selected participants from the 2016 International Coral Reef Symposium (ICRS) in Hawaii were invited to submit full, peer-reviewed papers, and a summary of the restoration work at Laughing Bird Caye National Park (LBCNP) to date was accepted (Carne *et al.* 2016) and is posted on the ICRS website<sup>1</sup>. Additionally, Ms. Carne was invited by the editor for an article submission to Reef Encounter, and a brief description (with photos) on the nursery-grown, outplanted acroporids spawning events (2015-2016) at LBCNP was published in the December 2016 edition (Carne and Baums 2016) p. 42, available online<sup>2</sup>.

Other relevant, new publications describe dating (the age) of acropora stands in Belize using genetics, which included samples from southern Belize (Baums *et al.* 2016) and northern Belize (Baums *et al.* 2017), and mapping large stands of acropora in Belize with satellite imagery (Greer *et al.* 2016). Lirman and Shopmeyer (2016) and Schopmeyer (*et al.* 2017) published on the validation of *Acropora* restoration efforts. Lirman and Shopmeyer are considered Caribbean acroporid restoration experts, and evaluated LBCNP in 2014 and declared it even then, as "one of the best examples of successful large-scale reef restoration in the Caribbean" (cited in Inception Report). Lirman and Drury (2017) also published on the need for intraspecific diversity, further validating our genetic component. Work in Belize was also included in the thesis dissertation on long-term survival (*A. palmata*) by Garfield (2016)<sup>3</sup>.

<sup>&</sup>lt;sup>1</sup> http://coralreefs.org/wp-content/uploads/2016/12/Session-42-B-2-Carne-ICRS-clean-and-final-ATB1.pdf

<sup>&</sup>lt;sup>2</sup> http://coralreefs.org/wp-content/uploads/2014/03/Reef-Encounter-Dec-2016-LoRes.pdf

<sup>&</sup>lt;sup>3</sup> https://search.proquest.com/openview/oaf18e8594e8d7653675d9d64d5ba178/1?pq-origsite=gscholar&cbl=1875o&diss=y

One of the gaps highlighted for reef restoration work is both costs and socio-economic benefits. An article on all marine coastal restoration efforts (mangroves, seagrasses, corals, etc.) highlighted the paucity of economic information on reef restoration (Bayraktarov *et al.* 2016), which prompted a reply from coral restoration expert Dr. Buki Rinkevich and a rebuttal from the co-authors. Full citations for these articles and letters are provided in the references section at the end of this report.

#### Community consultations

Task 2 is "identification of reefs suitable for nurseries set-up and out-planting", with the first step being community consultations (**Task 2.5a/b**). These are to inform stakeholders from each MPA of past reef replenishment work in Belize and the current project's scope, but also to engage and invite stakeholders to participate in the project via the training course, and further, to gain their anecdotal information on where the targeted corals exist (See Annex II for maps<sup>4</sup>), and recommended nursery and outplant site locations, given the site selection criteria (shared at each consult, in the Inception Report p. 21, in the manual available for download from fragmentsofhope.org and again in this report p. 12). Stakeholders are identified as anyone in the tourism industry, fishers, NGO partners relevant to each respective MPA, the Fisheries Department staff, and interested community members inclusive of students, teachers, etc. Table I summarizes the locations, number and type (e.g. fisher, guide, NGO staff) of participants. Detailed description of each consultation follows:

<sup>&</sup>lt;sup>4</sup> Maps were copied/sourced from <u>The Cruising Guide to Belize & Mexico</u>, by Captain Freya Rauscher.

Community Consulted, MPA, Date	Participants (organizations, individuals, schools, etc.)	Total number Attendees	Number male/female
Dangriga, SWCMR, 11 October 2016	Fishers, resorts, tour guides, students, educators, Fisheries Dept.	26	15 /11
South Water Caye, SWCMR, 16 October 2016	Fishers, resorts, tour guides, educators, Fisheries Dept.	18	10/8
Hopkins, SWCMR, 20 October 2016	Tour guides, fishers, community members, MCAPP, Fisheries Dept.	35	24/11
San Pedro, TAMR, 1 February 2017	Tour guides, fishers, Hol Chan MR staff, community members, tourists	24	17 /7
Chunox, TAMR, 16 February 2017	Fishers, MCAAP, Belize Audubon Society	25	21/4
Belize City, TAMR, 26 July 2017	Fishers, tour guides, MCAPP, TASA, MAR Fund, CCCCC, Fisheries Dept.	21	13/8
Placencia, SWCMR, 31 Aug 2017	Fishers, tour guides, local NGO's, tourists & community members	52	30/22

 Table I. List of community consultations conducted October 2016-August 2017<sup>5</sup>.

**SWCMR**: Three community consultations were held for SWCMR stakeholders: In Dangriga on 11 October 2016, on South Water Caye 13 October 2016 and in Hopkins Village 20 October 2016. Targeted participants are identified through the Belize Tourism Industry Association (BTIA for resorts, hotels, dive shops, etc.), local tour guide associations (for individual tour guides), the Belize Fisheries Department (for fisher cooperatives and associations and individuals), and to some extent, local schools (high school and tertiary level). Invitations are sent via direct phone calls and texts, e-mail, the use of social media (Facebook pages) and local television and radio announcements. Details of each consultation are shared below; they represent Task 2.5a and were completed on time. The attendance sheets for each consultation are shared in Annex I. Each consultation followed the same format, with

<sup>&</sup>lt;sup>5</sup> See also final report on Education and Dissemination.

an approximately 45 minute presentation, time for questions and answers, sharing videos, and an interactive session with printed map of the MPA (see Fig. 1b) for anecdotal identification of coral locations, and potential nursery and outplant site locations, followed by light refreshments and informal discussions.

Dangriga, 11Oct16, venue Mars Place, 5-8pm (Fig. 1a). There were 21 participants, with seven females and 14 males. Individual tour guides and students attended, as well as representatives from the tourism industry (Yok Ha and Blue Marlin Resort, Island and Southern Adventures and Chaleanor Hotel). Fishers were represented by several members of the Wabafu group and a Fisheries Officer from the Belize Fisheries Department was also in attendance. Reefkeeper is an educational program on Tobacco Caye and a representative attended. Other community members identified themselves as cooks or carpenter or left that section (organization) blank. Five FoH members were in attendance to answer questions; the discussion was lively and supportive and 18 of the 21 participants expressed interest in the training program (attendance sheet in Annex I, p. 1).

South Water Caye, 13Oct16, Blue Marlin Resort, 10am-12pm (Fig. 1b). This consult was held specifically targeting the many residents on SWC and Tobacco Caye; the Smithsonian group from Carrie Bow Caye were also invited but had other commitments. There were 15 participants (four females and 11 males) from the tourism industry on SWC (Blue Marlin Resort, IZE, Bamboo) and on Tobacco Caye (Jean's Place). There were four representatives from the Belize Fisheries Department and one from the Belize Coast Guard. One woman from the Belize Conservation Foundation, and educational institute, traveled all the way from the Cayo District (western Belize) to attend. She was especially engaged and introduced the discussion of current Belize curricula in the schools, and the need to include more information on marine ecosystems. In general, the participants were excited and eager to have reef replenishment activities begin in their areas, and offered support (including use of some facilities and staff). The attendance sheet is shared in Annex I, p. 2.

Hopkins Village, 20 Oct16, the Holy Cross primary school, 7-9pm (Figs. 1c-d). This consultation was organized and scheduled by the Stann Creek Tour Guide Association, and held after their general meeting. There were at least 31 participants (six females and 25 males, Annex I, p. 3-4). Besides the

individual tour guides, there were also students, two expat community members, and three separate resorts/ tour operators represented. The Belize Fisheries Department and Dr. Sandra Grant, MCCAP Project Coordinator also attended. Discussions were directed and supportive, and 16 participants signed up for the training course. Because this was the third and final (for now) consultation, and scoping activities had previously occurred (next section), discussion centered on the agreement of the initial nursery locations: near South Water Caye, potentially at Carrie Bow Caye, and in the south side of the Tobacco Caye channel. Initial outplant locations discussed were: the north and south side of the channel between South Water and Carrie Bow Caye, and the north and south side of Tobacco Caye Channel (Figs. 10-11).

Anecdotally, many guides are already familiar with the nurseries/locations and we have received feedback and some monitoring photos already. These initial community consultations had three successful outcomes: 1) Spreading awareness of the program, 2) making and gaining contacts for future training events and program participation, and 3) anecdotal mapping of coral populations (e.g. staghorn at the "fourth cut" in SWCMR and staghorn locations on the west side of TAMR) and input on nursery locations.





Fig. 1a-b. Dangriga consult, 11 Oct16 and SWC consult, 13 Oct16-map on the wall on the right.





Fig. 1c-d. Hopkins consult, 20 Oct16.





Fig. 2a-b. San Pedro invite and San Pedro consult, 1 Feb 17.





Fig. 2c-d. Chunox consult, 16 Feb17 and using the map for locating coral locations.





**Fig. 3a-b.** Cement lobster shade near Placencia placed over 10 years ago; all natural recruitment. Crabs and lobsters utilize the shades. Note *A. cervicornis* rubble in both photos, there is wild, natural coral nearby.

## Site Selection Criteria

Site selection criteria are similar for both acroporid nurseries and outplant sites for depth (2-5m) and water quality (clarity, good flow). Both locations should be practical logistically speaking, for ease of access and affordability (considering high fuel costs for regular, consistent monitoring). Outplant sites should be chosen first, so that the nursery sites are located nearby: although corals can be transported safely up to two hours or more away, again for maximized efficiency on outplanting days, proximity of nurseries to outplant sites should be close. Key differences in site selection criteria for nurseries are protection from wave action/storms for the structures and suspended corals on ropes, and nearby permanent presence on cayes to deter interference or theft (of steel and/or temperature loggers). These criteria are not vital for outplanting, but presence of reef fish/ algaegrazing fish is crucial for both sites, to minimize algae and other potential fouling organisms (E.g. angel fish eat hydroids and some sponges). For this reason, locations within MPAs are ideal for both nurseries and outplants.

For targeted outplanting, sites should have evidence of living or recently dead acroporids, and presence of *Diadema* (long spiny urchins), as urchins also control algae, be 'clean' (no macro-algae), have solid, substrate for outplanting the corals, and presence of crustose coralline algae (CCA), itself a preferred substrate for coral recruitment. These criteria (see Table I) are also shared in the approved Inception Report (p. 20-22) and detailed in The Coral Reef Replenishment Training Manual (p. 2-3, 13), available for downloading from the website, fragmentsofhope.org.<sup>6</sup> Figures 4-6 illustrate these criteria.

<sup>&</sup>lt;sup>6</sup> http://fragmentsofhope.org/technical-documents/



**Fig. 4a-b**. Table nurseries at Black Bird caye (TAMR) and Tobacco Caye (SWCMR) L-R. Regardless of depth, nurseries need protection behind the reef, ideally behind large coral heads (seen in the back ground of each photo). Each photo is taken facing windward; tables are set up so the ropes hang perpendicular to the wave flow, so they are not knocked side to side.



**Fig. 5a-b**. Acropora palmata dead reef (L) and A. cervicornis dead reef (R). Parrot fish, whose presence are key site selection criteria for outplanting sites, are pictured on the left.



**Fig. 6a-b.** *Diadema* (long spine urchin) are key algae grazers, making a 'clean' substrate for crustose coralline algae (the pink/lavender in photo), which in turn promotes stony coral recruitment. On the left is an ideal flat, sturdy, surface for outplanting corals (low 'turf' algae is scrubbed first, not the same as macro-algae).

## Results: Sites identified, SWCMR and TAMR

Outplanting sites in SWCMR were chosen based on site selection criteria plus input from stakeholders. In SWCMR the channels (both sides) south of Tobacco and south of South Water Caye are heavily frequented for snorkeling. These shallow reefs have been impacted physically from storms, and previous bleaching events. Although acroporids are present, in most areas the dead corals outnumber the living. These chosen outplant sites are within the Replenishment Zone. In TAMR, targeting specific users is more diffcult, because of the size and relative remoteness of the atoll. The few resorts there market to divers and/or fishers; therefore far less snorkelers visit these reefs than in SWCMR, with the exception of students at Calabash Caye, because the University of Belize's field station is located there. The shallow forereef at Calabash was also recently heavily affected by Hurricane Earl (August 2016), so this is one chosen outplant site. The other is at Black Bird Caye, just north of the resort there, located within the Replenishment Zone. Shallow fore reef/reef crest sites are chosen not only because this is the normal habitat and depth for acroporids, but because shallow reefs dissipate the majority of wave energy (Beck et al. 2014) thus living shallow reefs provide the most shoreline protection. So replenishment efforts are focused here for three main reasons: contribution to the tourism industry (aesthetic and socio-economic value), shoreline protection, and increased biodiversity (increased genetic diversity of remnant acroporid poputions and increased

amounts and diversity of acroporid-associated fauna such as fish, crabs, lobsters and other invertebrates).

Six table nurseries were installed in each MPA, in proximity to the chosen outplant sites, and there are seven identified outplanting plots in SWCMR, six in TAMR, plus a number of suitable outplanting areas outside and nearby the identified outplanting areas.



**Fig. 7a-b.** SWCMR nursery (green) and outplant (pink) sites shown near South Water and Tobacco Caye, respectively. Not shown at SWC are outplant plots 2 &3 which are just adjacent to the SWC Tables 1-3 (top).



Figs. 7c-d. The shallow fore reef at SWC (SWCMR); recovering A. palmata (L), and at Tobacco Caye (R).



**Fig. 8a.** TAMR nursery tables n=3, (green) and outplant sites n=5, (pink) located near Black Bird Caye in the replenishment zone.



Fig. 8b-c. Details of nursery and outplant site selected at Black Bird Caye (TAMR) inside Replenishment Zone.



**Fig. 9a.** TAMR nursery tables, n=3 (green) and outplant sites (pink) near Calabash Caye. Not shown are outplant sites adjacent to CCT<sub>2</sub>.





**Figs. 9b-c.** Details of nursery and outplant sites selected at Calabash Caye (TAMR). Located inside MPA but not inside Replenishment Zone, however all other site selection criteria is met, inclusive of stakeholder input (UB's Research station located here).

Table II. Site selection criteria for coral nurseries and outplant sites.

Nursery site selection criteria	Outplant site selection criteria
<ul> <li>Accessibility (fuel considerations)</li> </ul>	<ul> <li>Accessibility (logistics for long-term monitoring)</li> </ul>
<ul> <li>Optimal depth 2-5m</li> </ul>	<ul> <li>Evidence of acroporids (dead and/or alive)</li> </ul>
<ul> <li>Clear, good water quality and flow (presence of healthy corals)</li> </ul>	<ul> <li>Clear, good water quality and flow (presence of healthy corals)</li> </ul>
<ul> <li>Protection from high surge (leeward side of cayes, nestled amongst large coral heads)</li> </ul>	Low macro-algae cover
<ul> <li>Sand and/or rubble substrate or sparse seagrass and sand (test with probe and mallet)</li> </ul>	Crustose coralline cover
<ul> <li>Permanent residents on caye or nearby</li> </ul>	Presence of <i>Diadema antillarum</i>
<ul> <li>MPA status/protection</li> </ul>	<ul> <li>Presence of parrotfish/surgeon fish</li> </ul>
<ul> <li>Permission /endorsement from managers/co-managers if in MPA</li> </ul>	<ul> <li>Solid/fixed substrate (not rubble-can use domes on rubble)</li> </ul>
<ul> <li>Stakeholder support</li> </ul>	<ul> <li>No-Take (replenishment) zone status)</li> </ul>
Proximity to out-plant site and cross reference with out-plant site selection criteria	Since larvae dispersal maps were completed, these will be used with the above criteria, for strategically located replenished outplant sites to promote natural reef regeneration.

MPA	Table number	<u>Depth</u>	<u>Latitude</u>	<u>Longitude</u>
SWCMR	SWC T1-3	3m	16.81139	-88.08246
SWCMR	TBC T1-3	2-4M	16.88923	-88.06466
TAMR	BBC T1-3	2-5M	17.31848	-87.79353
TAMR	CC T1	3m	17.27881	-87.80927
TAMR	CC T <sub>2</sub>	3m	17.27835	-87.80929
TAMR	RHT1	5m	17.26931	-87.81626

Table III. GPS coordinates (Datum=WGS84,) for coral nurseries established.

Table IV. GPS coordinates (Datum=WGS84,) for coral outplant sites established.

MPA	<u>Plot number</u>	<u>Depth</u>	<u>Reef type</u>	Latitude	<u>Longitude</u>
SWCMR	SWCı	2-5M	Fore reef	16.48698	-88.04790
SWCMR	SWC2-3	2-4M	Back reef	16.88923	-88.06466
SWCMR	SWC4	4m	Channel	16.8110	-88.08126
SWCMR	TBC1	3m	Channel	16.89588	-88.06238
SWCMR	TBC2	3m	Channel	16.89033	-88.06462
SWCMR	TBC3	2-3M	Fore reef	16.89673	-88.05973
TAMR	BBC 1	2-5M	Reef crest	17.31781	-87.79266
TAMR	BBC2	1M	Reef crest	17.31791	-87.79295
TAMR	BBC3	4-5m	Fore reef	17.31803	-87.79236
TAMR	BBC4	2M	Back reef	17.31799	-87.79340
TAMR	BBC5	2M	Back Reef	17.31925	-87.79328
TAMR	CC1	3-4m	Fore Reef	17.27860	-87.80641

## Conclusions & Recommendations

Specific to SWCMR:

 Continued restoration can and should occur, with suitable outplant sites sourced in front of both Tobacco and South Water Caye, and both sides of the channels south of each caye. The established nursery sites would work well for continued replenishment work. Continued efforts should focus on adding additional acroporid genets of each taxa (already mapped and sourced).

Specific to TAMR:

TAMR is so large, that continued stakeholder consultations should occur to decide what the primary replenishment goals are: endangered species recovery, increased biodiversity, shoreline protection, added value for tourism, or all of the above (in SWCMR the chosen sites meet all of the above goals). In TAMR for example Calabash Caye is not in the replenishment zones, yet because of proximity to UB and TASA field stations nursery and outplant sites were chosen there. Fragments of Hope will hold a final stakeholder consultation in Belize City in 2020, but suggest that TASA be engaged for future replenishment plans since there are several new tourism establishments in TAMR, and TASA has a second field station in the northern part of the atoll, making additional sites more readily accessible from their station. Mapping in TAMR needs to continue.

Reef restoration has become globally and regionally popular lately; a recent publication identified 362 case studies in 56 countries (Boström-Einarsson et al. 2020), many of which were spearheaded by the tourism industry, with individual dive shops or "citizen science" groups wanting to capitalize on the recent headlines about dying reefs and climate change. Therefore many of these projects set up coral nurseries first, without considering outplant/restoration sites and goals, so our first basic recommendation is:

• Always choose the outplant sites and restoration goals first, using the site selection criteria listed in Table II, so that nursery sites can then be identified in close proximity to the chosen outplant sites.

Another common criticism for restoration efforts is that it can never be done to an appropriate scale, and Fragments of Hope has always recognized that the entire reef tract cannot be restored, and thus developed the site selection criteria listed in Table II. Through this project, an additional, crucial, selection criteria has been added, that of the coral larvae dispersal models created by Dr. Claire Paris

at the University of Miami, specific to acroporids in Belize using our mapping and spawning data. These reports were shared as a separate deliverable, and key generalizations can be made from her reports such as:

• South/Central Belize reefs offers more connectivity than for example, the Sapadillo Cayes Marine Reserve in the far south, in terms of potential to re-seed Belize's reef with coral larvae from replenished sites.

In 2018 the only other Research Permit for restoration, outside of Fragments of Hope, was given to the San Pedro Tour Operators without any oversight or standardized methods. The Belize Fisheries Department has since engaged the National Coral Reef Monitoring Network (NCRMN) to update and revise the National Reef Restoration Policy (Annex II) and this occurred in a meeting February 2020 (final revisions still pending). Recommendations specific to Belize from that meeting include the following:

- All requested new restoration efforts/projects have a Belizean marine scientist and local organization involved;
- All requested new restoration efforts/projects be approved by the NCRMN and use the established best practices developed in Belize, and include local capacity building;
- The use of non-Belizean, citizen science 'volunteers' is not recommended.

Finally, as there are few peer-reviewed publications from the work in Belize, despite the many years of data collected, another specific recommendation is that:

• These project technical reports, once approved (and including Dr. Paris' larvae dispersal modeling) be made public, available as PDF downloads on the Fragments of Hope website as 'grey literature' for reference.

Fragments of Hope is a member of the Coral Restoration Consortium (CRC) and regularly provides data to the monitoring working groups, and the case study working group, and is also a member of the Mesoamerican Reef Restoration Network, but even within these two groups standardization of vocabulary (e.g. what constitutes a restoration 'site') and monitoring methods are still lacking. Making these progress/funder/technical reports freely available will contribute to accepted best practices for reef restoration in Belize and the region.

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