Reef Monitoring and Restoration in Palm Beach County

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Final Report

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Management Summary

This project has resulted in a prioritized list of reef restoration sites for three main reef-building coral species (*Colpophyllia natans, Montrastraea cavernosa,* and *Diploria labyrinthiformis*) in Palm Beach County. While outplant sites have historically been chosen based on local conditions such as depth, stony coral diversity, and the presence or absence of predators, the sites in this study were chosen based on recently modeled coral connectivity coupled with local conditions. This should result in strategically restored areas where currents facilitate larvae dispersal to a greater number of surrounding reefs, therefore expanding the benefits to the wider ecosystem (Frys et al. 2020). We hope that the state's forthcoming Restoration Plan follows a similar approach, resulting in a list of prioritized outplant sites that have been confirmed by recent field surveys.

The two successful outplanting efforts that took place this season show that with the right coordination and leadership, outplanting in 50-60 ft. of water on Palm Beach County's linear outer reef can be done, even with less experienced divers and intimidating field conditions. We encourage restoration practitioners to build off the success of this project by continuing to outplant stony corals offshore of Palm Beach County. Such projects will allow scientists to continue refining restoration techniques, overcome issues such as tissue loss caused by predation, and finally, increase stony coral diversity on the local reef.

Derelict fishing gear made up the majority of the debris collected during reef cleanup dives conducted as part of this project. While there is no realistic way to prevent local stakeholders from leaving such debris (e.g., monofilament, rope, nets, etc.) on the reef, we encourage management agencies to consider sponsoring more frequent community dive cleanups. Such events help stakeholders connect to the marine environment, elevate awareness of the issue within the coastal community, and ultimately result in safer reefs. Additionally, targeted outreach regarding the effectiveness of biodegradable fishing gear and proper fishing practices applicable to South Florida could go a long way within the region. We recommend looking into an ambassador program where conservation-minded fishing leaders are given products to test and share with local audiences via social media.

Executive Summary

Scientists from Palm Beach County Department of Environmental Resources Management (PBC ERM) reviewed data from past reef surveys and overlaid the results with species connectivity data to identify and map potential outplant sites for three stony coral species (*Colpophyllia natans, Montrastraea cavernosa,* and *Diploria labyrinthiformis*). The team then surveyed eleven potential sites and ranked each one by order of priority based on site conditions coupled with their potential to serve as a source site or a reef where coral larvae originate and disperse from. Three sites were selected as high-priority outplanting sites, six were selected as medium-priority, and two were labeled low-priority.

PBC ERM scientists then partnered with The Reef Institute to train a team of divers and outplant stony corals to two sites using two-part epoxy. In January, the team outplanted 31 *C. natans* and 16 *D. labyrinthformis* corals to a 50 ft. site offshore of Lake Worth Beach. At this site, divers observed 89.6% survivorship both 13 days and 36 days after outplanting. In May, the team outplanted 9 *C. natans* and 24 *M. cavernosa* corals to a second 50 ft. site also in the Lake Worth Beach area. Here, divers observed 96.9% survivorship one week after outplanting with two *C. natans* corals showing signs of heavy predation and five *M. cavernosa* corals slightly paling.

In addition to the restoration efforts mentioned above, PBC ERM worked with local dive shops to identify natural reef sites in need of a cleanup. Divers completed 30 to 60-minute cleanups at eight reef sites. On each dive, stretches of monofilament, rope, or braided fishing line were delicately removed without causing further damage to the reef. These findings, along with the anchor damage observed across six of the potential restoration sites further demonstrate the effects that human stakeholders can have on the reef and highlight the need for more effective protections.

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List of Acronyms

DEP	Florida Department of Environmental Protection
DRM	Disturbance Response Monitoring
FWRI	Florida Fish and Wildlife Research Institute
PBC ERM	Palm Beach County Department of Environmental Resources Management
SAL	Special Activity License
SCTLD	Stony Coral Tissue Loss Disease
SECREMP	Southeast Florida Coral Reef Evaluation and Monitoring Project
TNC	The Nature Conservancy
TRI	The Reef Institute

1. BACKGROUND

Florida's Coral Reef is currently experiencing a multi-year disease-related mortality event that has resulted in massive die-offs in multiple coral species. Approximately 21 species of coral, including both Endangered Species Act-listed and primary reef-building species, have displayed tissue loss lesions, which often result in whole colony mortality. First observed near Virginia Key in late 2014, the disease has since spread throughout the Caribbean.

While coral diseases have always threatened coral reef ecosystems, the geographic range, duration, rapid progression, number of species affected, and high rate of mortality made this event unique. Within the Kristin Jacobs Coral Reef Ecosystem Conservation Area, the outbreak reduced the abundance of stony corals by at least 30% and caused the loss of 60% of their live tissue between 2012 and 2016 (Walton et al., 2018). Coral bleaching events, overfishing, eutrophication, and physical damage by hurricanes, further threaten local reefs that the population relies on for coastal protection, wildlife habitat, food, and recreation. To combat the disease outbreak and preserve the genetic diversity of Florida's Coral Reef, coral "rescue" efforts began in 2018 to collect and propagate healthy and disease-resilient corals for later outplanting on Florida's Coral Reef. By May of 2024, roughly 2,300 colonies of 20 different species had been collected from 97 reef sites (Florida Fish and Wildlife Conservation Commission, 2024).

In the wake of the disease outbreak and with a second consecutive summer of record high water temperatures expected for 2024, maximizing the effects of every restoration project is vital. Thanks to fine-scale (100 m) biophysical connectivity models available for all of Florida's Coral Reef, it is now possible to identify reefs where currents facilitate the dispersal of the embryos/larvae produced by outplanted corals, therefore replenishing reefs beyond that immediate site (Frys et al., 2020).

For this project, PBC ERM scientists utilized the results of such models to inform the selection of potential restoration sites for three stony coral species (*C. natans, M. cavernosa,* and *D. labyrinthiformis*). PBC ERM scientists then surveyed each site to inspect field conditions (e.g., coral species diversity, presence or absence of grazers, disease, etc.), prioritized sites for outplanting, refined procedures for conducting restoration work in challenging local conditions, removed anthropogenic debris from local reef sites, and outplanted corals to Florida's Coral Reef with TRI.

2. TASKS AND OUTCOMES

2.1. Task 1: Prioritize restoration sites by analyzing current research and surveying specific reef sites

In 2022, PBC ERM outplanted to a reef site that was chosen by FWRI staff and based solely on DRM survey observations. For future outplanting efforts, PBC ERM staff wanted baseline information to select sites that would be most successful and beneficial to the wider ecosystem. To identify such sites, staff reviewed data from past DRM and SECREMP reef surveys, overlaid physical survey data with the results of species connectivity models, identified potential outplant sites, and completed field surveys.

While PBC ERM was working on Task 1 of this project, staff at TNC began working with local reef managers to identify priority restoration areas along all of Florida's Coral Reef for the state's Coral Restoration Plan. However, the results of this plan would not be finalized until late 2024. To align with the state's plan and prevent further delay of restoration efforts, PBC ERM acquired the raw hydrodynamic modeling results TNC was using to inform their work and began studying the modeled connectivity of Florida's stony coral species within Palm Beach County. This data was supplied to TNC by Dr. Joana Figueiredo's lab.

2.1.1. Methods

To get started with the analysis, TNC shared ArcGIS shapefiles that could be used to study larval source and sink potential for six stony coral species (*C. natans, M. cavernosa, D. labyrinthiformis*, *Acropora cervicornis, Orbicella faveolata,* and *Pseudodiploria strigosa*) along Florida's Coral Reef. Of those species, PBC ERM prioritized the identification of outplant sites for *C. natans, M. cavernosa,* and *D. labyrinthiformis*. These are three species that naturally exist in Palm Beach County and that TRI had ready for offshore transplantation.

To begin the mapping process, PBC ERM clipped each shapefile to Palm Beach County's boundary. Next, staff symbolized each section of reef by source potential for that particular species with a color ramp. PBC ERM staff then reviewed the DRM data from 2021 and 2023 and reviewed SECREMP data from 2012 to 2022 to glean information on the presence and health of those three species in Palm Beach County. Once identified, all sites where the three species were observed in good health were added to a map and considered in relation to that species' source potential.

To eliminate the possibility of outplanting corals in an area with minimal source potential, only DRM and SECREMP sites that overlapped with reefs earning a high source score (e.g., a score of 1.2 or higher) greater remained on the map. Reefs with lower scores corresponded to reefs at the northernmost extent of Palm Beach County where depths would be restoration-prohibitive and downstream benefits would be minimal. PBC ERM staff then added shapefiles representing areas to avoid when outplanting. These included SECREMP stations where outplanted corals would skew annual monitoring data, reefs within 500 ft. of a wastewater outfall, and reefs within one nautical mile of an inlet. Sand borrow areas were also considered, but were removed from the maps after a quick analysis showed that each permitted borrow area was sufficiently buffered from the natural reef (i.e., borrow areas are more than 1,000 ft. from the natural reef).

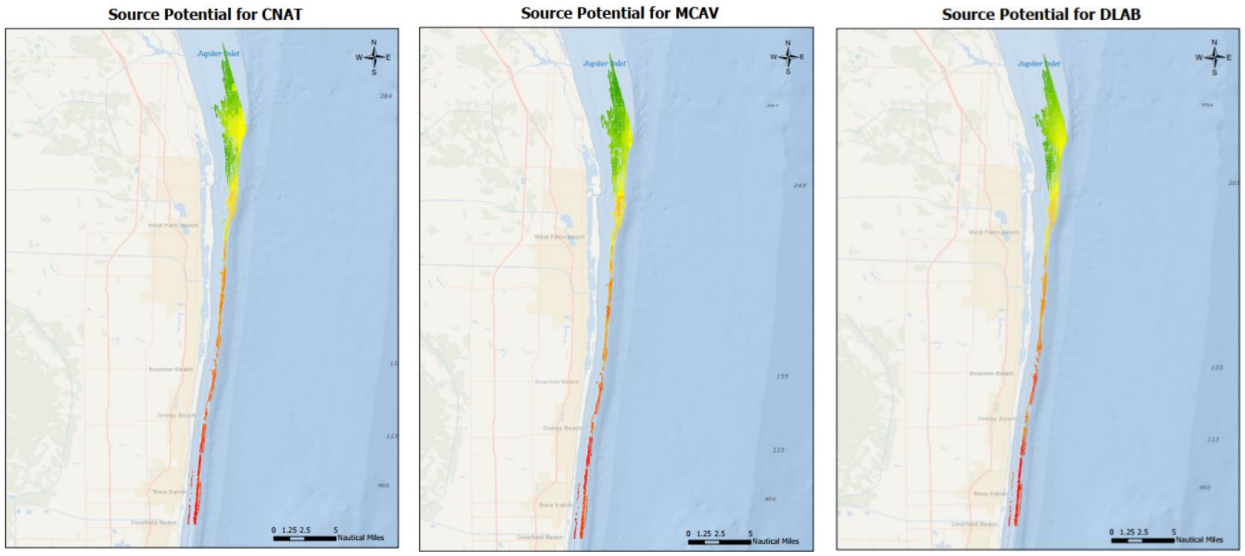

Figure 1 Maps created to study C. natans, M. cavernosa, and D. labyrinthiformis larval source potential of Palm Beach County reefs. In these maps, source scores are symbolized by a red to green color ramp showing high to low source scores, respectively.

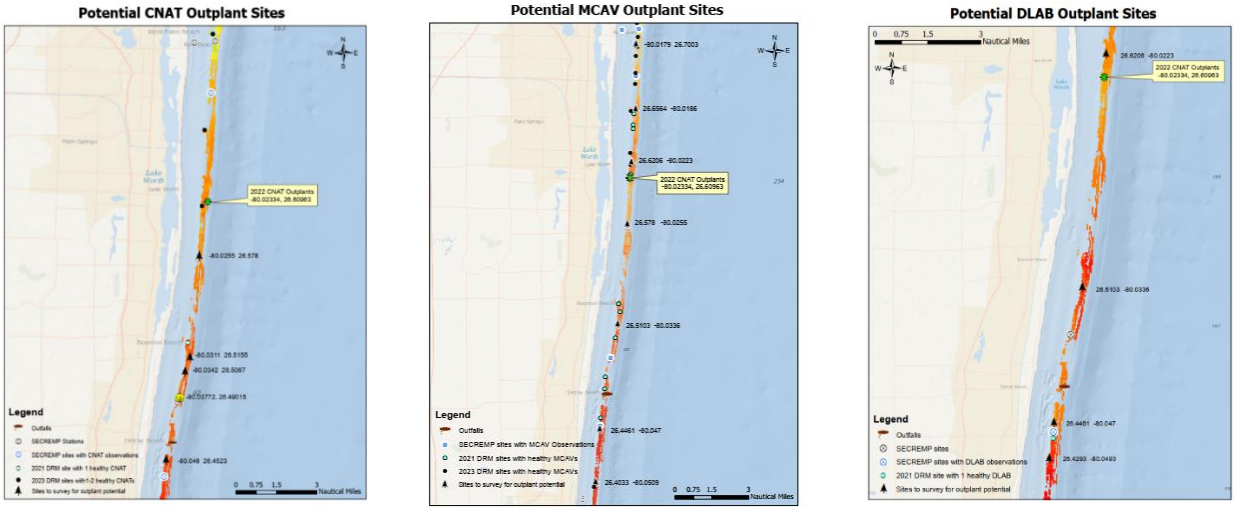

Figure 2 Maps created to identify potential outplant sites for C. natans, M. cavernosa, and D. labyrinthiformis corals based on modeled source potential, past observations, and avoidance areas.

Once 12 potential restoration sites were mapped offshore of Palm Beach County, PBC ERM divers geared up to complete 30-minute roving diver surveys at each site. During each survey, trained diver pairs collected data on site depth and field conditions, availability of hardbottom space, stony coral species diversity, presence or absence of grazers, abundance of *Palythoa caribaeorum* or other encrusting organisms, and evidence of disease or predation on wild corals. Divers also recorded data on the presence of marine debris and evidence of anchor damage.

2.1.2. Results

PBC ERM divers completed surveys at 11 total reef sites. This included 10 of the 12 previously mapped sites and one that the team identified in the field (CNEWB) to replace two failed surveys (CBOY1 and CBOY2). Upon arrival, one failed site (CBOY1) was more than 60 ft. deep, which is beyond the maximum depth for outplanting, and the other (CBOY2) was occupied by recreational fishing vessels each time divers attempted the survey.

All 11 Task 1 dive surveys took place between January 11 and April 18. Data from these surveys indicate that divers observed an average of 22.45 corals representing between five and 13 stony coral species per site. In total, divers recorded 247 coral colonies representing 19 species. Of those 19 species, *M. cavernosa* was observed most often (n=73), followed by *Siderastrea siderea* (n=38) and *Porites astreoides* (n=28). *Agaricia humilis*, *Agaricia lamarcki*, *Mycetophyllia lamarckiana*, and *Scolymia cubensis* were each observed only once.

Disease was not observed at any survey sites. However, *Xestospongia muta* damage was observed at six, sedimentation was observed at four, and either *P. caribaeorum*, *Erythropodium caribaeorum*, or algal overgrowth was observed at seven survey sites. Based on these results, three sites were selected as high-priority outplanting sites, six were selected as medium-priority, and two were labeled low-priority.

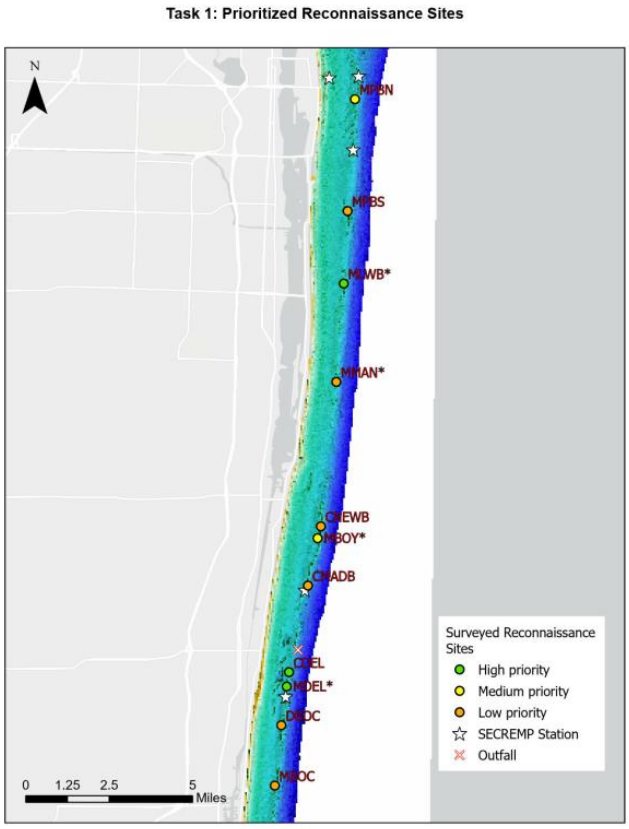

Figure 3 Map of sites surveyed for outplant potential and prioritized for outplanting based on survey results.

2.2. **Task 2: Lead dive efforts to outplant 30-60 framework-building corals to at least two natural reef areas**

On January 4, 2024, PBC ERM hosted a two-hour meeting to train TRI and PBC divers on outplanting procedures. PBC ERM then led two shorter training events the afternoon before two separate outplanting efforts. Both outplanting events took place offshore of Lake Worth Beach, were conducted in partnership with TRI, and were delayed until January 2024 due to the increased water temperatures experienced in the summer and fall of 2023.

The first outplanting event occurred on January 31, 2024 at Site A (26.60963 N, 80.02334 W). This site was selected by FWRI staff for a PBC ERM – TRI outplanting project in 2022, was already included in TRI's Special ActivityLicense (SAL), and had proven to be a safe home for outplanted *C. natans* corals. At Site A, divers outplanted 31 *C. natans* corals and 16 *D. labyrinthiformis* corals to the reef using two-part epoxy manufactured by All-Fix.

The second event took place on May 8, 2024 at Site B (26.62084 N, 80.02250 W). This site was identified as a high priority outplant location for *C. natans* and *M. cavernosa* corals through Task 1 of this project and was added to TRI's SAL on May 7, 2024. At Site B, divers placed 9 *C. natans* corals and 24 *M. cavernosa* corals using two-part epoxy manufactured by Magic Sculpt.

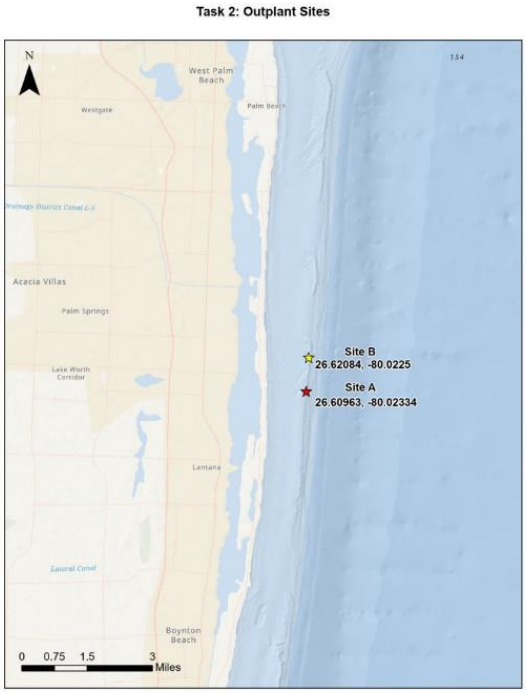

Figure 4 Map showing where corals were outplanted on January 31, 2024 (Site A) and May 8, 2024 (Site B).

Both events took place via a chartered dive vessel. The 46 ft. chartered vessel afforded the team ample space for dive gear and allowed multiple videographers to join and document outplanting efforts. On both days, only four trained divers were involved in handling corals or affixing them to the reef. Details on the exact outplanting procedures followed by this team are included in Appendix A.

2.3. **Task 3: Complete follow-up monitoring on outplant sites**

As the state-issued SAL holder, TRI is committed to monitoring each outplant site one week, one, three, six, nine, and twelve months after outplanting takes place. To assist in these efforts, PBC ERM completed three monitoring events for TRI.

2.3.1. Methods

During each monitoring event, one diver collected the following information for each individual coral: location along a set transect; percent live tissue; predation type and percentage; disease type and percentage; bleaching type and percentage; and presence or absence of algal competition. That same diver also captured photographs of each coral with a ruler in view for later size calculations using Image J software. The second diver used a wire brush to remove sediment and algae from each coral tile and set up a photosynthetically available radiation (PAR) meter to collect water quality and light data for the duration of the dive. Upon completion of each survey, photos were analyzed using Image J software, width and diameter measurements were recorded for each coral, and all monitoring and water quality data was transferred to an Excel spreadsheet.

2.3.2. Results

At both sites, staff from TRI collected the initial outplanting data for each coral. PBC ERM staff then performed the one-week surveys for both sites and the one-month survey for Site A. Results from these surveys reveal 89.6% and 96.9% survivorship of corals at Site A and Site B, respectively.

At Site A, 47 healthy stony corals were outplanted on January 31. By February 13, 42 corals remained. This included one *C. natans* coral that had to be re-epoxied to the reef and two *D. labryrinthiformis* corals that were paling. Two *C. natans* coral tiles were missing from the reef completely, one *D. labryrinthiformis* coral was missing from a tile, and two *C. Natans* corals showed 100% recent mortality. By March 7, 42 corals remained with the same two *D. labryrinthiformis* corals paling, two *C. natans* tiles missing completely, one *C. natans* coral missing from a tile, two *C. natans* showing 100% mortality, and one *D. labryrinthiformis* showing 90% recent mortality.

At Site B, 33 healthy stony corals were outplanted on May 8. By May 17, 32 healthy corals remained with one *C. natans* coral missing from a tile. Predation impacts were minimal at this site with only two large *C. natans* corals exhibiting greater than 10% recent mortality by predation.

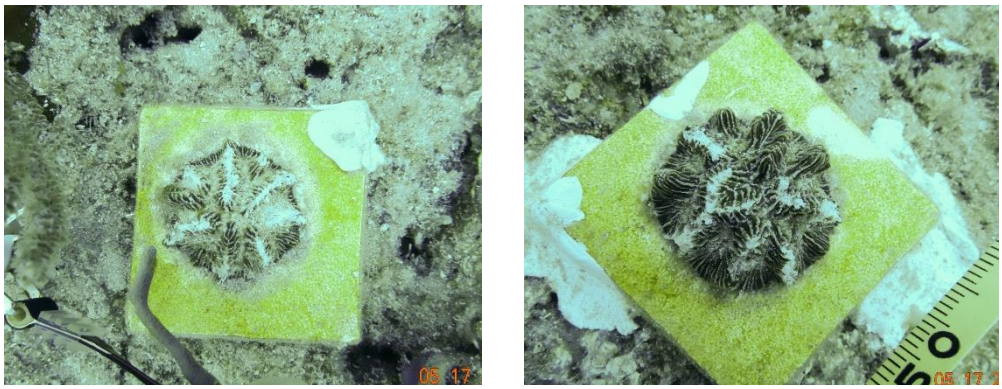

Figure 5 Images from May 17 of two C. natans corals exhibiting heavy predation at Site B.

2.4. **Task 4: Thoroughly clean up at least five natural reef sites**

PBC ERM divers conducted reef cleanups at eight natural reef sites offshore of Palm Beach County. Four sites were identified by local Palm Beach County dive operators (Moray Bend, Delray Ledge, Horseshoe Reef, Paul's Reef), two were selected by PBC ERM divers (Breaker's Reef and the reef surrounding a *Madracis auretenra* patch in Boynton Beach), and two were included after Task 1 surveys revealed excessive debris in the area (DBOC and MPBS). Upon descent to each site, between two and four divers surveyed the reef for debris and carefully removed anthropogenic items for 30 to 60 minutes, covering between 200 and 2000 m^2 depending on the current velocity. Although a 30-minute cleanup was completed at Breaker's Reef, current velocities prevented divers from safely removing all of the derelict fishing gear found there. PBC ERM divers intend to return to Breakers Reef during the summer of 2024.

Monofilament was carefully removed from the reef at all eight sites, hooks were removed from six, lead weights or wire leaders were removed from four, and braided fishing line was removed from three. Between 25 and 100 ft. of natural (e.g., jute or manila) rope was collected from three sites, one of which was still entangled with floats. The least common items found were a single lobster net and a single pair of plastic sunglasses.

Table 1 Reef cleanup data.

Dive Date	Site name	Latitude	Longitude	Materials Collected
9/6/2023	Moray Bend	26.3342	-80.0582	monofilament, hooks, weights, plastic, aluminum cans
9/6/2023	Delray Ledge	26.46506	-80.04428	25 ft. rope, monofilament, hooks, braided line, wire, leaders
9/11/2023	Breaker's Ledge	26.71442	-80.01705	monofilament, weights, and hooks
9/18/2023	Horseshoe Reef	26.6259	-80.0229	monofilament, braided line, hooks, wire, plastic
9/18/2023	Paul's Reef	26.65272	-80.02082	monofilament, braided line, hooks, wire, leaders, aluminum
10/19/2023	Madracis Boynton	26.49015	-80.03772	30 ft. rope, plastic cup lid, monofilament, hand net, trap material, strapping
2/13/2024	DBOC site	26.4293	-80.0493	100 ft. rope with floats, sunglasses, monofilament
3/21/2024	MPBS site	26.652	-80.0206	>100 ft. monofilament, lead weights, two circle hooks

3. CITATIONS

Florida Fish and Wildlife Conservation Commission (2024, March 22) *Coral Rescue - Coral Monitoring Dashboard*. Myfwc.com. Retrieved May 22, 2024, from https://myfwc.maps.arcgis.com/apps/dashboards/eba7dc2cabc64f60819e6d4b084d94cd

Frys C, Saint-Amand A, Le Hénaff M, Figueiredo J, Kuba A, Walker B, Lambrechts J, Vallaeys V, Vincent D, Hanert E (2020) Fine-scale coral connectivity pathways in the Florida reef tract: implications for conservation and restoration. Front Mar Sci 7:312

Walton CJ, Hayes NK, Gilliam DS (2018) Impacts of a regional, multi-year, multi-species coral disease outbreak in Southeast Florida. Front. Mar. Sci., 5, 323

4. APPENDIX A

Outplanting Procedure:

Site Setup

On the first dive of any outplanting effort, divers will work together to lay out the new outplant plot as shown in Figure 1 below. They'll do this by laying out one 4.5 m transect, turning 90° to lay out a 1.5m transect, turning 90° to lay out another 4.5m transect, and turning 90°to lay out one last 1.5m transect to make a rectangle.

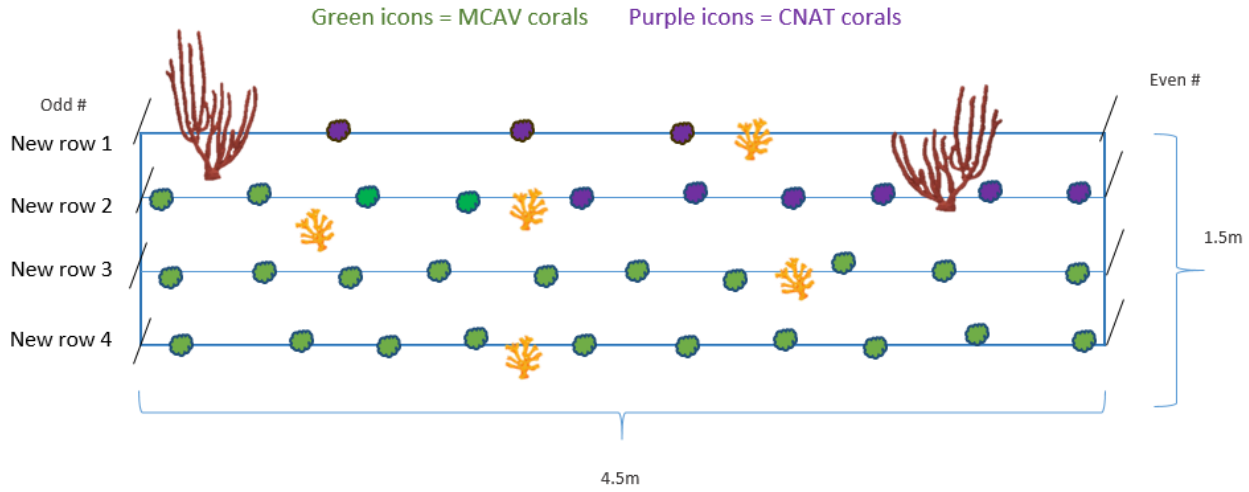

Figure 1. Sample May 8 MCAV/CNAT outplant plot with ideal coral species placement. In this image, blue lines represent new transect tapes that will need to be laid out.

Divers will then use the NEMO Hammer drill to insert 10" ground nails into the substrate at the start and end of every row. If the substrate proves too dense after 10 minutes of trial with the drill, divers will pack up the nails/drill, and instead utilize 3.5" masonry nails OR epoxy to attach bright tags to the beginning and end of each row. This will signify the site boundaries and make it easier to monitor in the future.

Once site setup is complete OR divers have to surface for more air, each diver will ascend with gear that is no longer needed (i.e., NEMO drill). This dive will not exceed 45 minutes.

Outplanting:

On the second dive, all divers will descend together and work together to outplant corals (assuming site setup is complete). Corals will be transported to the reef on weighted trays in laundry baskets, and will be outplanted every 50 cm along each transect as shown in Figure 1. Corals can be placed at the immediate beginning of each row (0cm), and the absolute end (4.5m), but need to be within the plot boundaries and along/under the transect tape if possible while avoiding benthic organisms such as coral, sponge, palythoa, and excessive macroalgae. Areas with excessive sediment or depressions must also be avoided. If the area is crowded with other benthic organisms, move horizontally along the transect until a space can be cleared.

See page 3 for more detail on outplanting procedures.

Outplant protocol specifics:

CORAL TRANSPORT

Corals will be carried in modified laundry baskets or crates and will be superglued down to a tray or placed in bags if the superglue fails upon transport to the site. They will be sitting upon a variety of small nursery tiles.

SUPPLY TRANSPORT

Aside from the NEMO hammer drill, all supplies will be transported to the outplant site in two or three total clamshell bags. Epoxy will be in four Ziploc bags each with two baseball-sized balls of 2-part epoxy (one baseball of each part). The team will also try to prepare one or two large hamburger-sized epoxy balls topside immediately prior to outplanting. This would occur between Dives 1 and 2.

- Clamshell #1 will be transported to the site on Dive 1 along with the NEMO hammer drill.
- Clamshell #2 will be transported to the site on Dive 2.

Clamshell #1
6 transects (KA taking 4)
10 nails of each type in a Ziploc
2 claw hammers
2 chisels
2 wire brushes
2 Ziploc bags of epoxy
10 row tags
1 site marker/tag
4 extra drill bits

Clamshell #2
2 claw hammers
2 mallets
2 chisels
2 wire brushes
2 Ziploc bags of epoxy
One blank slate
One slate with one datasheet
One plastic ruler
One camera

CLEARING CORAL SITES

To epoxy each coral, buddy pairs will claim a transect to work on and select a location (one every 50 cm) for their coral. Using the backside of a hammer, the wire brush, and a chisel, each diver will clear a palm-sized area on the reef of any biota and brush away loose sediment. They will also flatten the area a bit to prepare it for epoxy application, being careful to remove loose sediment after knocking down minor (<1 in.) nooks or crannies in the limestone. See below for example of a cleared outplant area.

Ideally before everyone begins outplanting on their assigned transect, one diver will mix enough epoxy for the group to pinch from and use for several coral locations. This

might also take place on the boat immediately prior to Dive #2. Mixing too much epoxy at one time can lead to poorly mixed material, so it will be a fine balance.

APPLYING EPOXY

Once an outplant spot is clean, the diver that cleaned the spot should immediately place epoxy on the intended outplant location before swimming away. If epoxy isn't pre-prepared, that diver should take a pinch from one ball of epoxy and a pinch from another ball of epoxy, and mix them together until they are a consistent color and texture. The resulting ball of mixed epoxy should only be placed on the reef once it is fully mixed and is large enough to cover the entire base of the tile, ooze into any remaining crevices in the reef, and wrap the tile edges in a smooth fashion. Before moving on to the next location 50cm away, ensure the epoxy is sufficiently anchored to the substrate and will not drift away. The cleaning diver should do this until all 10 corals spaces are cleaned and marked with epoxy along a transect.

At the same time, the buddy diver will be using a chisel to carefully "pop" a coral tile loose from the weighted tray for outplanting.

PLANTING CORALS

In the final step, the same diver will swim the selected coral over to the cleared site, and "squish" the coral tile down onto the epoxy. When pushing the tile down on the epoxy, divers must be careful to only touch the edges of the tile. If you can't avoid touching the coral, use equal pressure along each edge that is handled and only push enough to solidify that it's in the epoxy. Lastly, smooth the epoxy around the tile with your fingers, and try to wiggle it slightly to ensure its holding. Finally, smooth the epoxy over one more time and move on the next location 50 cm down the transect!

Divers will work in pairs this way to complete all transects until 45 corals are outplanted. After completing one full transect, the buddy pair is welcome to switch roles.

*Using too little epoxy or mixing it improperly can lead to failure to harden and hold the coral, which makes it easier for them to come loose or be ripped off the reef by predators. Using too much epoxy can potentially attract predators (they are fiercely curious when they first happen upon the site). This extra epoxy can also result in the coral coming loose if it unintentionally spreads into sand More epoxy = more time and air consumption, so we'll work wisely.

DATA COLLECTION

After all corals are firmly attached to the reef or as soon as one diver finishes their transect and confirms that everyone will be done on time, one diver will collect data on the location of each coral along the transects while also taking photographs and recording photo numbers.