Port of Miami *Acropora cervicornis* Relocation Report

Final Report

Prepared by NOAA National Marine Fisheries Service

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Introduction

Between October 26 and November 8, 2014, a NOAA team consisting of personnel from NOAA (Restoration Center, Habitat Conservation, Southeast Fisheries Science Center, Atlantic Oceanographic and Meteorological Laboratory, and NOAA Corps) along with partners from the University of Miami mobilized to rescue *Acropora cervicornis* colonies, which are listed as threatened under the Endangered Species Act, located along the Inner Reef[1] that were being impacted by sedimentation believed to be a result of dredging operations associated with expansion of the Federal Channel that leads into Miami Harbor. Dive operations at the site were challenging given the difficult logistics with on-going dredge operations, low visibility, tug and scow traffic associated with the spider barge, fluctuating tidal currents, and commercial shipping in the area; but through careful planning, coordination, and execution, the project was safely and successfully completed.

Background

During the summer of 2014, southeast Florida experienced a regional thermal event and subsequent coral bleaching (affecting multiple species) that lasted through at least September 10, 2014. In addition, the Florida Department of Environmental Protection (FDEP) issued a letter (dated August 18, 2014) to the Jacksonville District of the United States Army Corps of Engineers (USACE) warning the USACE of possible violations related to the Miami Harbor Phase III Federal Channel Expansion Project. In particular, FDEP reported elevated sedimentation levels along channel-side reef habitats, with up to 14 centimeters of standing sediment in some locations. Notably, over 200 colonies of *A. cervicornis* were known to exist along the Inner Reef in this area. USACE agreed to initiate a monitoring effort composed of 25 corals north-of-channel and 25 corals south-of-channel (50 corals within 150 meters of the channel), in addition to 50 corals located at a reference site. NOAA and USACE participated in teleconferences regarding the fate of these corals[2] and the status of the corals monitored in August, September, and October. Based on a review of the *Acropora cervicornis* survey information from the October monitoring event, NOAA concluded the sediment impacts, particularly on the north side of the channel[3], are persistent and distinguishable from the coral bleaching and stress in the surrounding population. By October the acute temperature stress had resolved and the monitoring provided a means to distinguish between sediment and heat stress/bleaching. Sediment stress was predominant among north-of-channel colonies and both stressors were evident in the south-of-channel colonies.

NOAA determined the known *A. cervicornis* colonies, in particular the corals located north of the channel, were at high risk of mortality unless an immediate coral relocation effort was effectuated. As a result the NOAA's National Marine Fisheries Service and the USACE entered into an Economy Act agreement to relocate the corals to a coral nursery, monitor the health of the relocated corals, conduct best husbandry practices, and ultimately transplant back to the reef if conditions are determined to be suitable. The costs associated with the relocation project and the coral nurseries will be reimbursed through an Economy Act Agreement between USACE and NOAA's National Marine Fisheries Service.

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1 The term *Inner Reef* is used to describe habitats characterized in Walker (2009) as colonized coral reef, hardbottom - linear reef and colonized coral reef, hardbottom - ridge shallow.

2 Unless specified use of the term *corals* is used interchangeably with *Acropora cervicornis,* for the purpose of this report.

3 The current direction is predominantly north in this area.

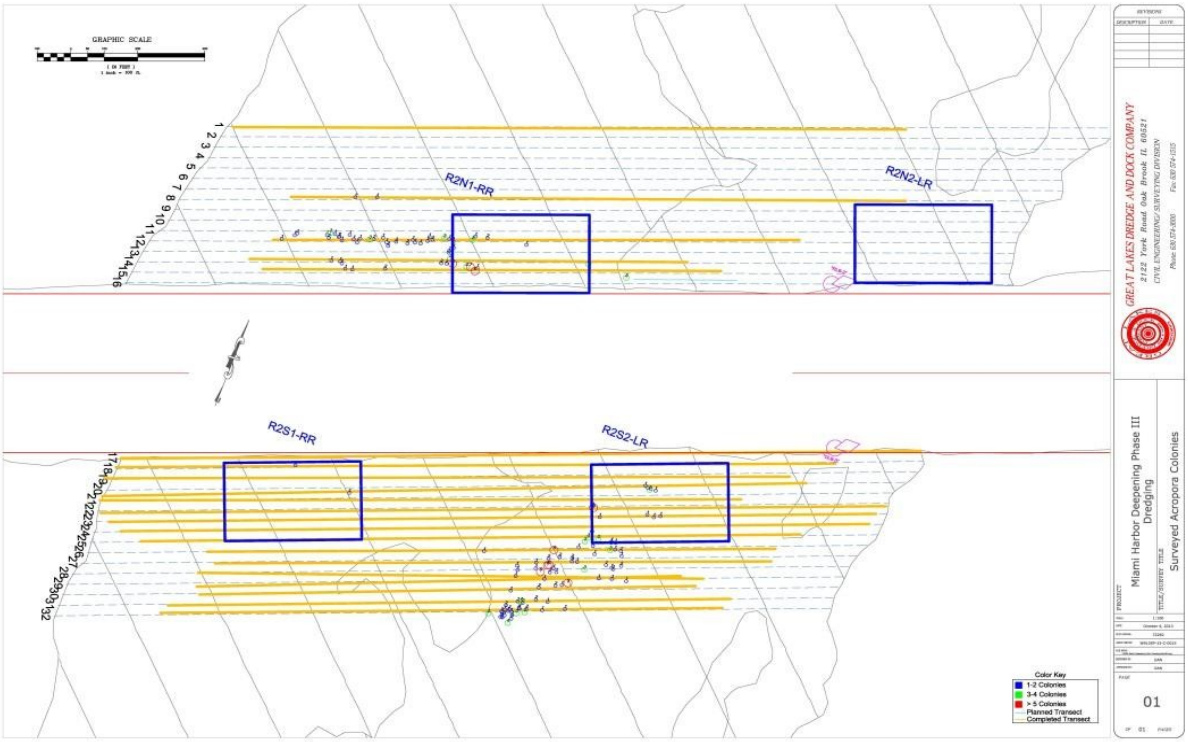


Figure 1: Location of *A. cervicornis* colonies on Inner Reef within 150 m to the north and south of Federal Channel. Yellow lines represent completed transects.

Methods

USACE provided maps developed by its contractors showing locations of 239 *A. cervicornis* colonies that were within 150 meters to the north and south of the Port of Miami entrance channel on the Inner Reef in October 2013 (Figure 1). The location of 50 mapped corals that were being monitored by USACE north and south of the channel was also provided to NOAA. Based on comparison of the data and post-fieldwork communication with USACE, it was determined that the 50 monitored corals were not a subset of the corals mapped in October 2013, however there was some overlap with an additional 25 corals that were tagged (numbers 26-50), but not monitored. Based on this, NOAA estimates the range of corals within mapped areas to be between 283 and 290 corals, however for the purposes of this report we are using 284 corals as the estimate of how many corals were within search areas.

The south side of the channel appeared to be more thoroughly surveyed according to the provided map data. The same map data exhibited large gaps in areas north of the channel in the Inner Reef section (Figure 2). Using the data provided by the USACE, NOAA identified seven search areas covering 3.3 acres where colonies of *A. cervicornis* had been observed (Figure 2). Areas 1-3 were located to the south of the channel and Areas 4-7 were located to the north of the channel. Corals located within 100 feet of the channel were excluded from the search areas and assumed to have been previously relocated as required by the NOAA Biological Opinion (dated September 8, 2011).

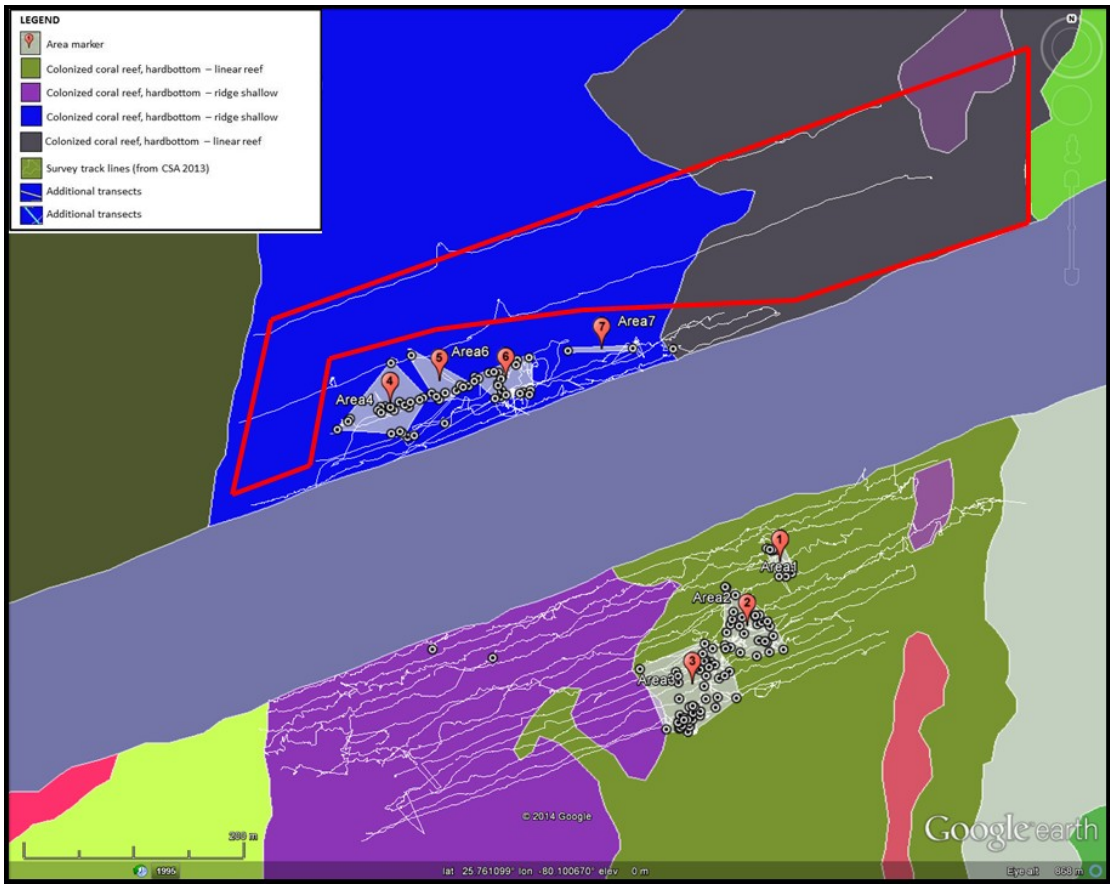


Figure 2: The seven search areas identified by NOAA where *A. cervicornis* had been observed on the north and south sides of the Federal Channel. The orange markers show the center of each area. The red polygon in reef habitat to the north of the channel depicts areas with limited prior survey effort.

Maps of each individual area were printed on waterproof "Never Tear" paper so that divers could use them while underwater to locate the corals under low visibility conditions (Appendix 1). While working within a site, a temporary anchor with a line attached to a floating polyform buoy was placed in the center of each search area according to the coordinates. Because of the low visibility and congested overhead conditions at the site with considerable boat traffic and tug and barge movement, divers were directed to only descend and ascend to the surface on that line. Once on the bottom, divers attached transect lines to the anchor chain and then conducted searches using the maps as a reference for the location of *A. cervicornis* colonies in each area. Search methods (circle searches, radial searches, etc.) varied depending on visibility and bottom contours.

Whenever a diver located a colony of *A. cervicornis*, a coral biologist would collect data on the health of the colony prior to removing any tissue, including noting the tag number if the coral had been previously tagged for monitoring. The amount of tissue removed from each colony was recorded. If tissue was not collected, the reason it was left behind was also recorded. Only intact healthy tissue was harvested. Any areas of dead skeleton, sections of tissue that had come in contact with bottom sediments, or margins with active tissue loss were not collected and were trimmed away from the collected colonies or fragments and left *in situ*.

Results

Of the estimated 284 colonies of *A. cervicornis* that were identified on maps supplied by the USACE, the NOAA team was able to locate 205 colonies or tags. This represents 72% of the colonies previously identified. Tissue was collected from 157 of the 205 colonies located (77%). No tissue was removed from the other 48 colonies (23%) because the colonies were either dead, did not have enough live healthy tissue to remove, or only a tag was found (i.e., the colony was missing). Missing colonies were only able to be identified as such if a monitoring tag was located and there was no colony in the area.

Of the 205 tags or colonies that were located, 138 colonies (67%) were showing some sign of stress. This included recent tissue mortality, bleaching, burial by sedimentation, disease, death, etc. Table 1 shows the data for the different stress classifications. A colony was given a score of 0 or 1 if it was displaying symptoms of a particular stress. A colony was given a score of 0 or 1 for the Total Stress Index if it was showing one or more signs of stress in any of the other categories. It is important to note that the sum of the total number of colonies and percentages for each category will equal more than the Total Stress Index since an individual colony may exhibit multiple symptoms. For example, the colony that was tagged as #22, located approximately 46 m north of the channel within search area #4, was noted to be dead and to display burial/sediment (Figure 3). The coral associated with tag #57, located approximately 31 m south of the channel within search area #1, was reported as missing during the October monitoring, and is located near a dead colony (Figure 3). The coral nearby tag #57 was located during the relocation work, and was subsequently labelled as both dead and burial/sediment as well.

Table 1: The total number of colonies and the percent of the colonies located (n=205) showing signs of stress.

	Recent Mortality	**Bleaching**	**Dead**	**Disease**	**Burial/ Sediment**	**Missing**	***Lyngbya* Overgrowth**	***Desmapsamma anchorata* overgrowth**	**Predation**	**Total Stress Index**
Total # of colonies	106	5	37	12	28	5	30	14	2	138
% of colonies located (n = 205)	52%	2%	18 %	6%	14%	2%	15%	7%	1%	67 %

Figure 3: Colonies of *A. cervicornis* that had been tagged for monitoring [tag #22 (left)]. Tag #57 (right)] associated with a missing colony with a nearby dead coral as a result of burial by sediment.

Figure 4: Photo of *A. cervicornis* fragments on PVC trees in the coral nursery off Key Biscayne where they will be allowed to recover until dredge operations finish at the Port of Miami and sedimentation issues are no longer a concern.

The colonies were relocated to the coral nurseries off Key Biscayne run by partners from the University of Miami. These corals were used to generate 1,059 fragments (average 10 cm diameter) in the nursery after dead portions were trimmed away, and the fragments were prepped for nursery hanging (Figure 4). There, they will be allowed to recover until dredge operations finish at the Port of Miami and sedimentation issues are no longer a concern. The corals can then either be transplanted back onto the reef where they originated or used as broodstock in the nursery to propagate more corals for future restoration.

Discussion

NOAA successfully located 72% of the previously mapped *A. cervicornis* colonies at the Port of Miami site, even given the difficult logistics at the site with the low visibility, cutterhead dredge, spider barge, tugs, scows, and commercial shipping. Independent of these complications, the dive window to conduct underwater surveys at the site is limited to the period of slack tide when there is little current, usually no more than 60 minutes per tide cycle. Each day, the NOAA team would attempt to work in the areas with the greatest number of corals, but decisions on which sites were safe to dive were dependent on the dredge operations which were working on the Inner Reef section during the relocation project. This made it difficult to impossible to safely work in certain areas on different days, and approximately half the dives had to be aborted because of the tugs and scows movement associated with the dredging project which compromised diver safety. At times, dredge operations also limited how far divers could perform searches within each area. Table 2 lists the number of colonies that were eventually located in each area and compares that to the number of colonies that had been previously surveyed in each area during October, 2013 including the estimated number of corals remaining in each site and the percent of potentially present colonies that were located. Before the dredging commenced, 38 colonies of *A. cervicornis* that were within 100 feet of both sides of the channel were removed and transplanted by USACE contractors. Between the original 38 transplants and the colonies identified during this relocation effort (205 total), 86% of the colonies that were originally surveyed in October, 2013 may have been relocated and/or accounted for.

Table 2: Number of colonies removed from each area compared to number of colonies that had been previously surveyed in October, 2013 including the 38 colonies that had been removed prior to dredging operations.

Area	Total # of Colonies Located	Previous COE Surveys	Potential Corals Remaining	% complete
1	10	16	7	63%
2	53	55	2	96%
3	63	109	46	58%
4	29	34	5	85%
5	7	12	5	58%
6	39	53	19	74%
7	0	4	4	0%
Additional North Surveys	4	N/A	N/A	N/A
Total	**205**	**284**	**88**	**72%**
Total plus the 38 corals relocated prior to dredging	243	284	46	86%

As mentioned previously, the north side of the Federal Channel was not surveyed thoroughly during the original assessment in October, 2013 (Figure 2). The NOAA team attempted 2 dives in the unsurveyed areas to the north of the channel (Figure 5) to try and determine if there were additional colonies of *A. cervicornis* in the northern area. As shown in Table 2, four colonies of *A. cervicornis* were found during these dives, but these surveys were extremely limited and could not be considered thorough because visibility was reduced to 5 feet during the first survey (N1) as a result of extreme turbidity and conflict with dredging operations, and the second survey (N2) had to be cut short before completing even half of the circle search due to tugs working with the scows alongside the spider barge. The first survey (N1) did provide better insight into the extent of sedimentation effects. Spatial distribution would suggest the source of sedimentation was local, and active coral sloughing of sediment would suggest recent and ongoing impacts. At 200 meters north of the channel, there was no change in observations on the effects the sedimentation was having on the corals (i.e., multiple centimeters of fine and clay-like standing sediments, recent mortality, sediment dusting of sessile reef organisms with fine and clay-like material, and associated mortality) demonstrating that the sediment accumulation was continuous and sedimentation effects continued beyond 200 meters to the north of the channel.

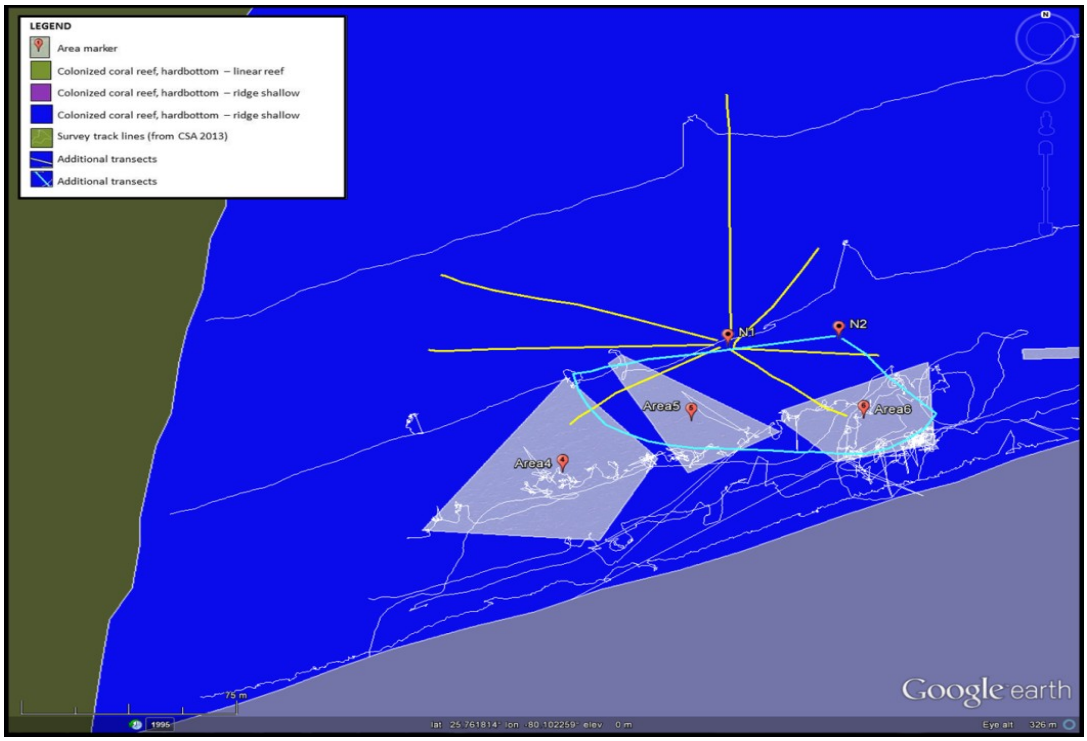


Figure 5: Location of additional transects [N1 (yellow lines) and N2 (blue line)] to the north of Federal Channel. The white lines are the survey tracks during the original surveys conducted by Continental Shelf Associates, Inc. for the USACE.

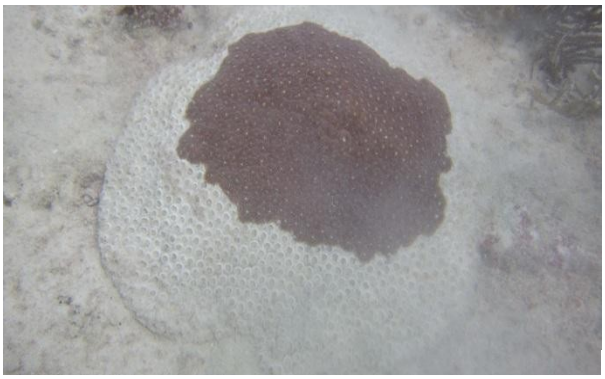
Description of Surrounding Resident Environment and Conditions

Divers reported observations of severe sediment impacts on the Inner Reef located north and south of the Federal Channel. Observed sedimentation impacts included, but are not limited to coral mortality, burial by sediment, accumulation of fine and clay-like sediment on the coral tissue forcing the corals to expend energy to remove the sediment either through polyp distension, tentacular action and/or mucus production. Examples of this can be seen in Figure 6. NOAA's observation of mortality above does not represent the total mortality, even of colonies surveyed. NOAA's observations are consistent with well documented, easily observable stress reactions to recent sedimentation on corals (Hubbard and Pocock, 1972; Erftemeijer et al., 2012; Pollock et al., 2014). There are additional stress factors related to sedimentation that are not so easily measured or discernable from background levels including reduced fecundity, productivity, growth and photosynthesis; and increases in algae, bleaching and susceptibility to disease (Erftemeijer et al., 2012; Flores et al., 2012). Coral mortality associated with the sedimentation on Inner Reef from the ongoing turbidity/sedimentation event varied from complete tissue mortality or colonies that exhibited a distinct concentric ring of mortality around the base of the colony (Figures 6 and 7). Some colonies were unable to keep up with sediment removal, resulting in an accumulation of sediments around the lower portions of the colony resulting in smothering and eventually tissue mortality. Notably the stony coral species documented to have this pattern of mortality include, but are not limited to, *Colpophyllia natans, Montastraea cavernosa, Dichocoenia stokesi, Porites astreoides, P. furcata, Meandrina meandrites, Diploria strigosa, D. labyrinthiformis, Solenastrea bournoni, Stephanocoenia intersepta,* and *Siderastrea siderea*. One reference dive was completed on October 29, 2014, at a reef located near the coral nursery, referred to as Emerald Reef. While bleaching was observed at Emerald

Reef, the distinct pattern of mortality (i.e., concentric ring of mortality around the base of the colony) observed on Inner Reef adjacent to Federal Channel during dredging operations was not seen at Emerald Reef nor was the fine and clay-like material observed. It will be easier to detect sediment impacts with a high degree of confidence in the immediate short-term. As time goes by, the dead portions of the colony could be colonized by algae and it will become more difficult to determine sediment impacts.

Future efforts to examine the extent of impacts at the Port of Miami from sedimentation should not be limited to comparisons of the extent of bleaching at impact versus reference sites, they should also include examination of the pattern and causation of the mortality of coral colonies. While corals can recover from bleaching, they cannot recover if the bleached portions of the colonies are buried in sediment. Furthermore, chronic exposure to sediment plumes and suspension of sediment can result in elevated disease outbreaks and other forms of compromised coral health (Pollock et al. 2014).

Figure 6: Accumulation of sediment on corals (and resultant partial mortality of basal portions of the colonies) in areas adjacent to the dredging. The colony of *Montastraea cavernosa* on the top left has its tentacles out and is actively producing mucus to remove the sediment. This sediment then accumulates on the lower section of the colonies causing mortality.

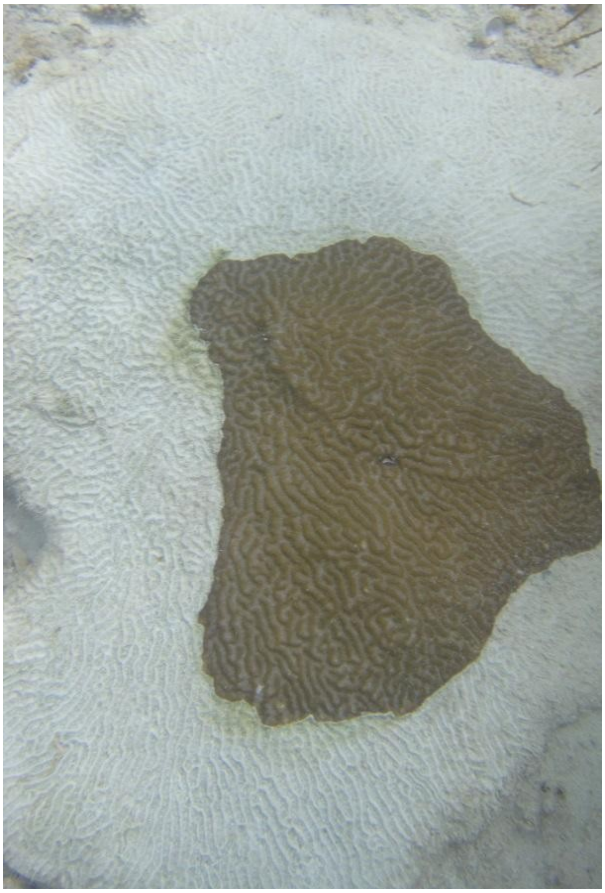
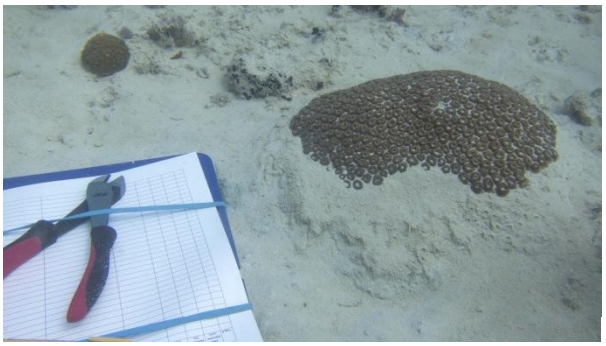
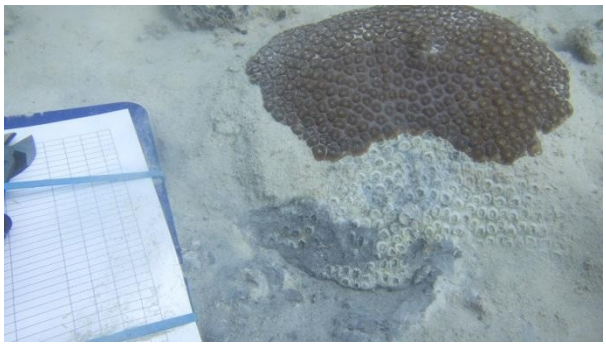




Figure 7: Coral colonies before (left photos) and after (right photos) divers cleared sediment from the corals showing accumulation and recent mortality (exposed white skeleton) along the lower portions of the colonies as a result of accumulation of fine and clay-like material (sedimentation)

References

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Pollock F.J., Lamb J.B., Field S.N., Heron S.F., Schaffelke B., Shedrawi, G., Bourne, D.G., Willis B.C. 2014. Sediment and Turbidity Associated with Offshore Dredging Increase Coral Disease Prevalence on Nearby Reefs. PLoS ONE 9(7): e102498. doi:10.1371/journal.pone.0102498

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Appendix 1: Maps of search areas used by divers to locate *A. cervicornis* colonies.

Using the data provided by the USACE, NOAA identified seven search areas covering 3.3 acres where colonies of *A. cervicornis* had been observed. Areas 1-3 were located to the south of the channel and Areas 4-7 were located to the north of the channel. Figures 1-7 below are the maps used by divers to locate colonies of *A. cervicornis* during the relocation work. The circles on each map represent colonies of *A. cervicornis*. The white numbers (#1-25 and #51-75) represent colonies that had been previously tagged for monitoring. The orange markers show the location of where the temporary anchor and surface buoys were deployed. The scale for each map is located in the bottom left corner. The white lines are the survey tracks during the original surveys conducted by Continental Shelf Associates, Inc. for the USACE.

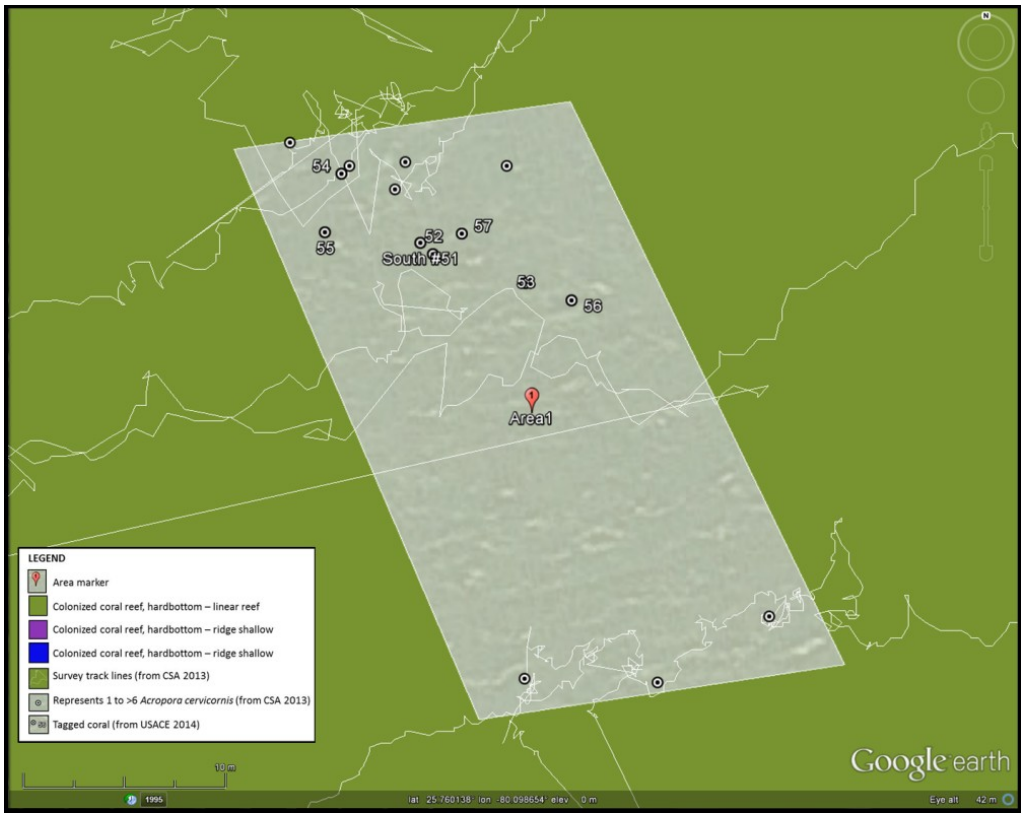

Figure 1: Map of area 1

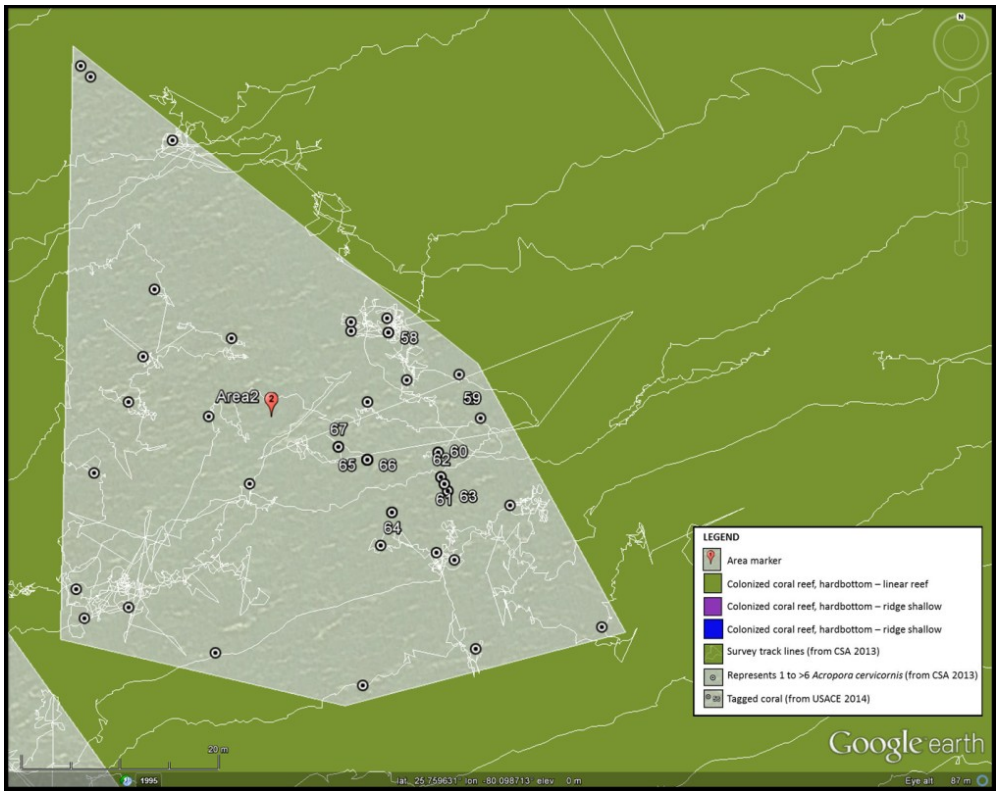

Figure 2: Map of area 2

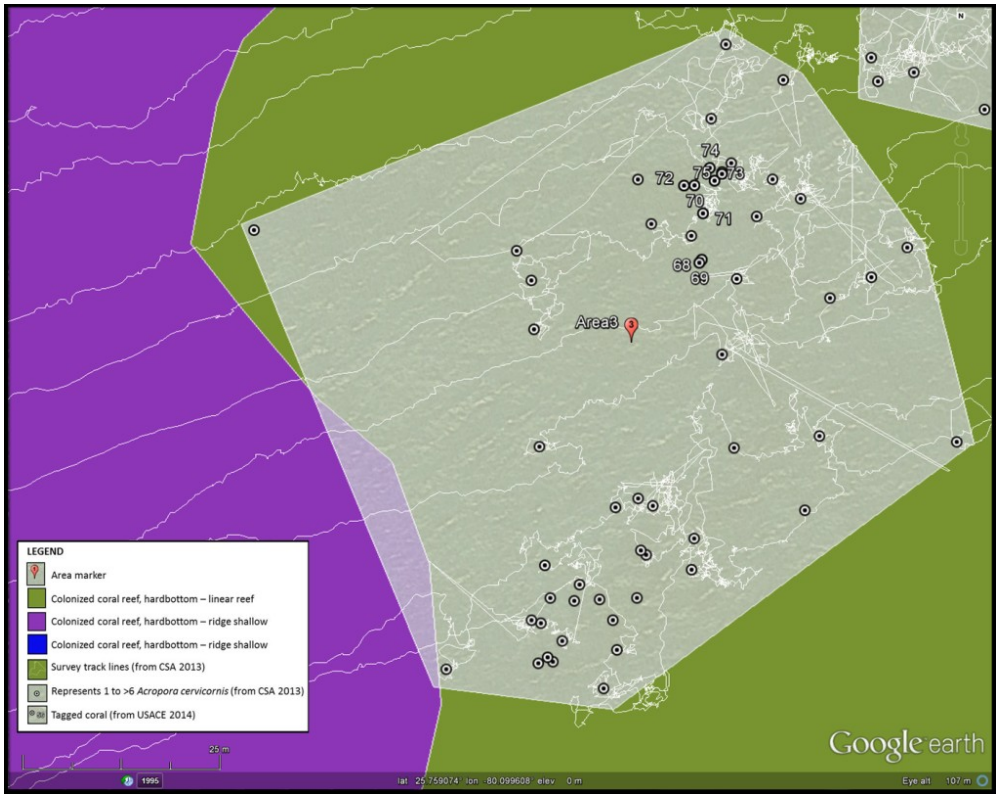

Figure 3: Map of area 3

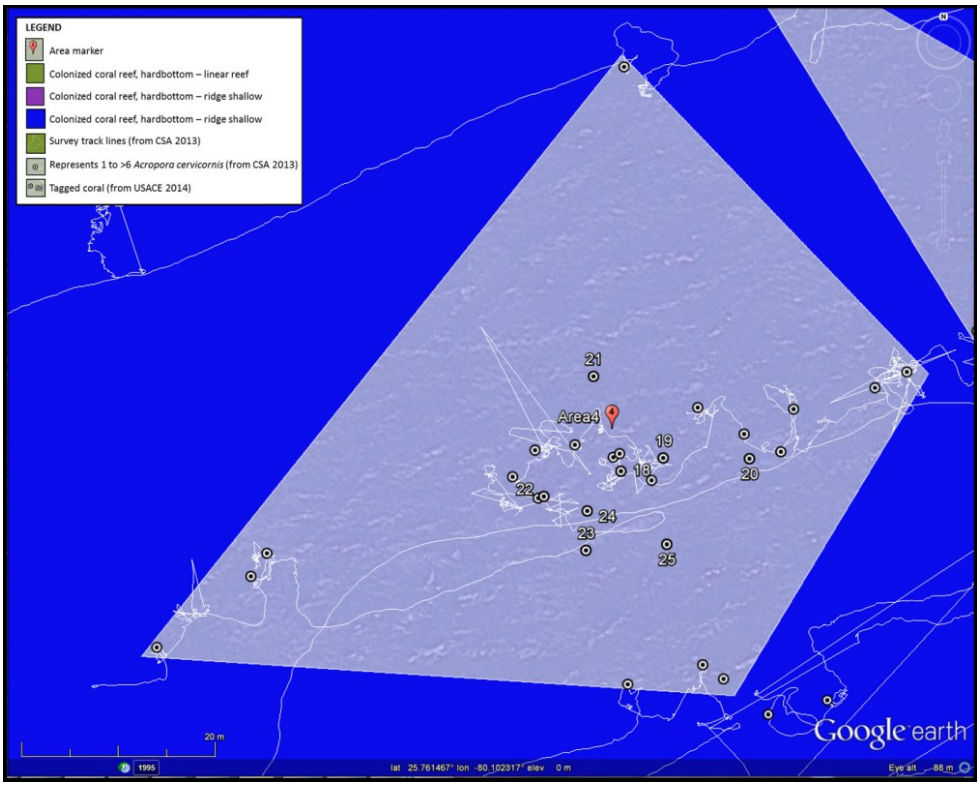

Figure 4: Map of area 4 – note that one coral located at the southern tip of the polygon was determined to be within the 100 foot relocation area and removed from the accounting in Table 2

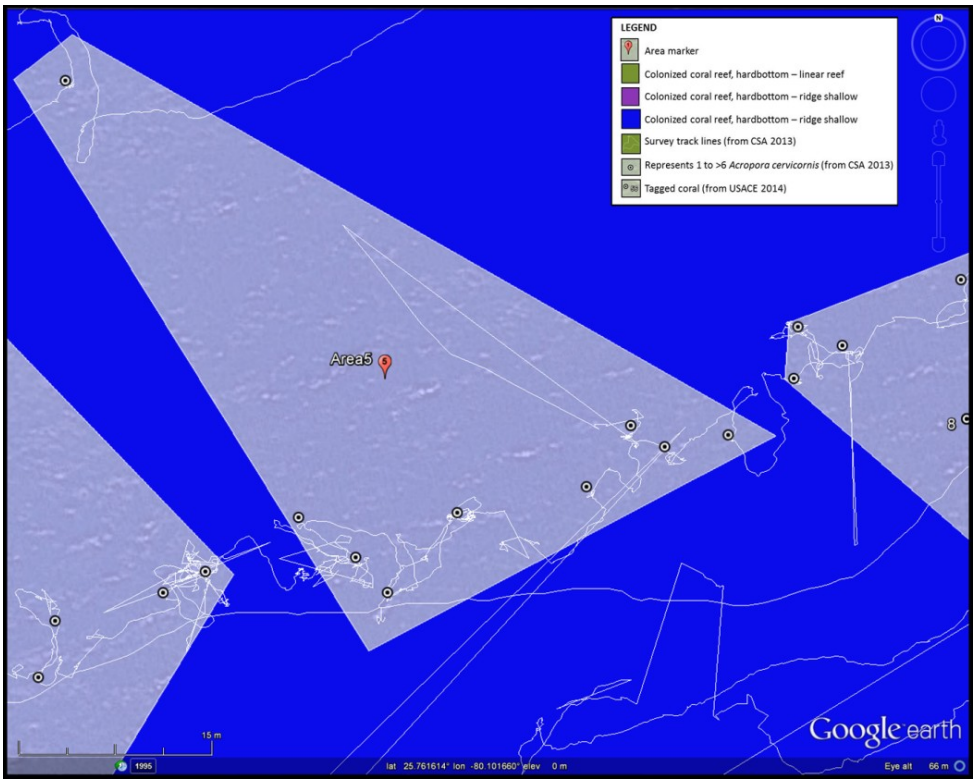

Figure 5: Map of area 5

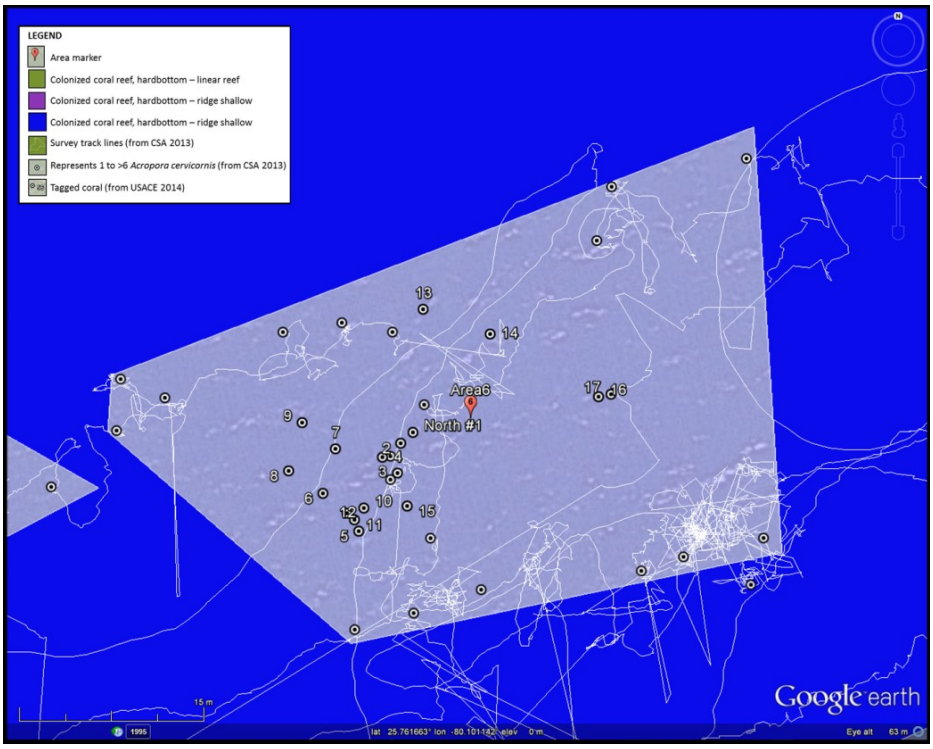

Figure 6: Map of area 6 – note that 5 corals located along the southern edge of the polygon were determined to be within the 100 foot relocation area and removed from the accounting in Table 2

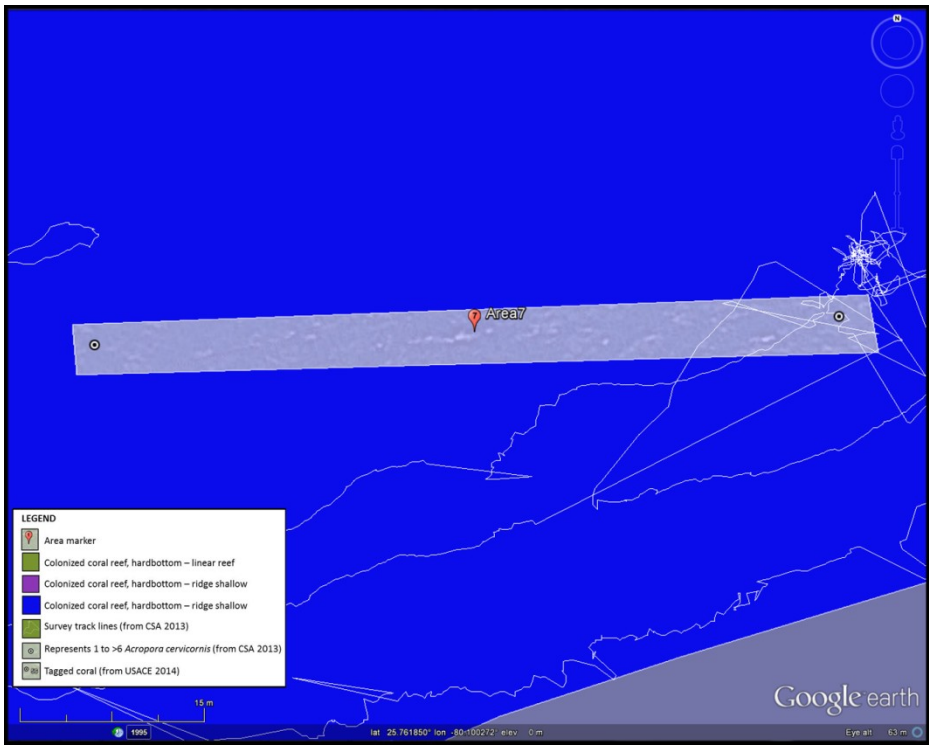

Figure 7: Map of area 7