Fruit Farm Creek Restoration Project

MONITORING REPORT 2020

Prepared for
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BACKGROUND

The Goodland Fruit Farm Creek Mangrove System is located near the southwest boundary of Rookery Bay National Estuarine Research Reserve on Marco Island. Most of Marco Island was developed as part of the Deltona Settlement Agreement of 1964, which allowed the island to become a residential area and tourist attraction. Fruit Farm Creek was excluded from development and forms the southwestern border of the Ten Thousand Island National Wildlife Refuge. Prior to 1964, Marco Island, the largest island within the refuge, consisted largely of mangrove swamps. Widespread development and dredge and fill operations destroyed most of the mangrove swamps and created the current landscape of canals, waterfront homes and businesses. Vestiges of the original mangrove swamp, now referred to as the Fruit Farm Creek area, are still viable near Goodland and consists of approximately 1036 hectares (ha) located on the southeast corner of Marco Island, west of Goodland, of which 259 ha is zoned for future development (Collier County Planning Department Land Use Map, 2000).

Prior to 1938, this mangrove system was primarily a black mangrove (*Avicennia germinans*) basin. Urban encroachment adjacent to the Fruit Farm Creek mangrove forest disrupted the natural tidal flow, causing water impoundment, which ultimately resulted in mangrove mortality. Changes to the natural hydrology occurred first in 1938 when State Road 92 (C.R. 92) was built and more recently when the road to Horr's Island was built as an access for a residential development, Key Marco. These roads bisected the original mangrove forest causing tidal flow to be diminished in areas farthest from the Gulf of Mexico tributaries. Mangroves on the east side of the road to Horr's Island and to the south and north of C.R. 92 were visibly stressed after periods of heavy rains in 1992 and were dead by 1995. Since 1992, prior to restoration activities, there had been no successful revegetation in the die-off areas and standing water was present for long periods throughout the year (Figure 1). Without restoration, these areas could not recover on their own, as the Fruit Farm Creek die-off areas have slowly increased over time.

Development and roadway construction adjacent to the black mangrove basin system likely altered the natural drainage patterns within the mangrove forest, which caused an accumulation of surface water within the mangroves adjacent to the development. In 1995, the black mangrove pneumatophores (finger-like root systems) were completely submerged by high surface water levels that were present for months at a time, resulting in large-scale mangrove die-offs (hereafter referred to as the Fruit Farm Creek Die-offs (FFCD)). Pre-restoration the hydrology of FFCD was altered extensively, resulting in extended hydroperiods, along with higher surface water and groundwater levels (Figure 2). The impact of increased surface water levels and water retention further reduced the soils and "drowned" any mangroves that attempted to become established in the die-off areas. Periods of extended flooding encroached into the edges of the die-off, blocking aeration paths to pneumatophores, effectively killing the trees and causing further die-off expansion (Worley, 2005).

Prior to restoration, these die-offs had no signs of sustainable mangrove reestablishment. The ecology of the areas deteriorated as fish and invertebrates movements into and out of the area became very restricted, and the export of detrital material to the adjacent estuary was reduced. The area has become an island of the dead and dying as the natural ecology has been compromised to the extent that intervention was and still is necessary to return this area to a healthy ecosystem.

Figure 2: Surface Water Level Fluctuations within Living Mangrove Forest (Top Graph) vs a Die-off Area (Bottom Graph).

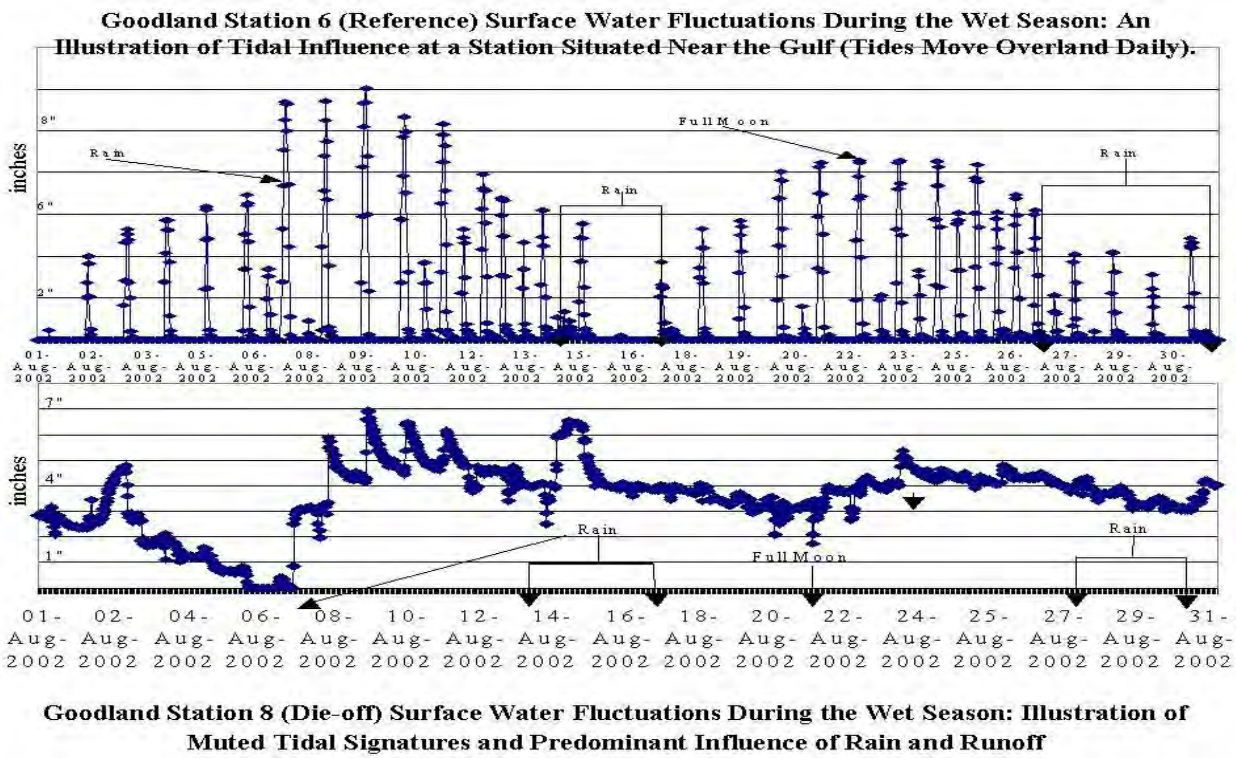

Figure 2, illustrates the visible differences where surface water levels in the adjacent living mangrove forest (top graph) displays an obvious daily tidal signature where surface tidal waters enter the forest and then subsequently drain out leaving the forest floor dry. Whereas, in the die-off area (bottom graph) tidal signatures are muted and water is impounded within the die-off area almost the entire month at levels higher than mangrove pneumatophores (aerial root system necessary for gas exchange in black mangroves). Without this gaseous exchange to and from the atmosphere the tree can die. Water impoundment also prevents seedling establishment.

Beginning in 1996, the Conservancy and Rookery Bay began to raise the alarm in an attempt to gain interest in restoring the area. In 2010, a team of scientists from various organizations including the Conservancy of Southwest Florida, Coastal Ecology Group, Rookery Bay National Estuary Reserve, City of Marco, Collier County, and local residents, formed a partnership to develop and implement a restoration program within the die-off areas. The goal of this cadre of organizations was to develop and implement a restoration program within the three die-off areas that were present at that time. Since resources were limited, it was decided to address these die-offs in stages beginning with the smaller die-off north of C.R. 92, which was designated as Phase 1a. The partners accomplished the following:

- Collated all existing historical information on the targeted restoration area.
- Developed a restoration plan based upon historical information, current topographic data, bathymetric data, and hydrologic modeling.
- Restoration alternatives were evaluated, the preferred alternative was selected, and permit drawings prepared (Figure 3).
- A Joint Environmental Resource Permit (ERP) and Federal Dredge and Fill permits were prepared and acquired from the South Florida Water Management District (SFWMD Permit No. 11-03308-P) and the United States Army Corp of Engineers (USACOE Permit No. SAJ-2011-00336-IP-MD) in coordination with the U.S. National Marine Fisheries Service (NMFS).
- Phase 1a construction plan was completed. A total of 275 linear feet of tidal channels that connected the die-off area to a functioning tidal creek was constructed to drain out impounded fresh water and re-establish tidal flushing within the die-off area (Figure 3) (Appendix 1).
- In 2012 an environmental review and assessment was initiated; monitoring has continued for 8 years in Phase 1a.
- Plans were developed for Phase 1b and Phase 2 of the restoration and are ready for implementation once funding is available (Figure 3). Cost of these phases will be significantly higher due to the need to install culverts under C.R. 92 and the large amount of acreage of dead mangroves that need restoration.
- Baseline pre-restoration monitoring within Phase 1b and 2 was completed and will recommence once funding is more likely.
- In the last 3 years, restoration plans for Phase 1b and Phase 2 have been updated and permits for the restoration renewed.

Previously, the group has been unsuccessful in obtaining funding necessary to begin the larger restoration project (Phase 1b and Phase 2), despite numerous valiant attempts. New avenues of funding are continually investigated. In March 2020, it was announced that funding for the next phase of the restoration had been secured through the RESTORE ACT. It is expected that funding will be available for Phase 1b beginning in 2021. In the meantime, we began to re-initiate baseline monitoring in this area, finalize permitting and construction plans, and the work has been sent out to bid. The only uncertainty is the affect that the COVID19 pandemic will have on this project, but it is our hope that in the spring of 2021 construction will commence.

OBJECTIVES

The Conservancy of Southwest Florida has committed its science division to performing all of the floral and faunal monitoring required to assess the success of the restoration activities employed at the FFCD. This data is subsequently used to adaptively manage the restoration moving forward. Using these techniques the restoration plans can and have been adjusted in response to environmental outcomes. Comparisons of pre and post-restoration vegetation and wildlife within the project area are used to evaluate restoration success (if any). General forest health and wildlife usage is used to gauge restoration success. The objective of this report is to summarize the state of the Phase 1a restoration from September 2012 through February 2020.

Monitoring efforts include an evaluation of the existing mangrove, epibenthic, and aquatic faunal communities in a living mangrove forest adjacent to the die-off (reference areas) and the restoration area (die-off areas). In this manner, success of the restoration project can be gauged overtime. As restoration will occur in phases, this assessment report evaluates the restoration progress within the Phase 1a area of the Restoration Project located between Steven's Landing and C.R. 92. Additionally, this assessment report also delineates baseline data being collected within the Phase 1b area of the Restoration area located between Key Marco and C.R. 92A that leads to the town of Goodland.

MATERIALS AND METHODS

Plot Preparation

Four 5 m x 5 m (25 m²) fixed square mangrove monitoring plots were established in 2012, two restoration plots within the Phase 1a die-off area and two reference plots within the adjacent mangrove forest on the north side of C.R. 92, next to the Phase 1a restoration (die-off) area (Figure 4). In 2014, six additional mangrove monitoring plots were established on the south side of C.R. 92 (Phase 1b). At that time, three of the six plots were located in the major Phase 1b die-off area and three plots in the adjacent healthier mangrove forested areas south of C.R. 92 (Figure 5). In 2015, the Conservancy extended the existing hand-dug channels in the Phase 1a die-off, north of C.R. 92, and an additional restoration (die-off) Plot 3D was installed to monitor any subsequent effects (Figure 6).

Six aquatic faunal sampling sites were also established in 2012, four within the Phase 1a die-off area north of C.R. 92 and two within the tidal creek near the Phase 1a die-off area. An additional six aquatic faunal monitoring sites were established in 2014 on the south side of C.R. 92, within the Phase 1b die-off area and nearby tidal creeks (Figure 7).

In 2012, efforts were made to ensure the reference plots had similar floristic characteristics to the die-off area prior to the forest collapse. Since historically these die-off areas were populated with primarily black mangroves, steps were taken to insure reference plots were primarily populated with black mangrove trees. The plots were installed in a haphazard stratified manner with half in lower and half in higher elevation areas based upon best professional judgment of local topography. Corners of each plot were permanently marked with numbered PVC pipes and a photo point was established at one of the corners.

Mangrove Assessment

A Global Positioning System (GPS) was used to determine the position of the center point of each plot. Distance and bearing of each mangrove tree and sapling are measured in relation to a known reference point to determine the exact location of each tree within each plot. All trees within each plot equal to or greater than 150 cm in height are identified to species, tagged, measured (DBH – Diameter at Breast Height (1.4 m)), and visually classified for condition. Tree height is estimated, but not included in tree morphometric measurements, since DBH is a better indicator of dry weight than stem height (Smith and Whelan, 2006). Additionally, each tree is visually classified by condition as having minimal stress (relatively healthy), stressed, very stressed (dying) or dead. For purposes of this study, a sapling is defined as an established seedling of at least 50 cm tall. Saplings are identified to species, tagged, measured (height) and visually classified for condition.

Canopy cover estimates are generated based on an evaluation of cover data collected at 17 established sample points within each 5-meter square plot using a GRS densiometer. Sample points are placed at equidistant radii emanating from the center sample point of each plot. This method of cover sampling is accurate, objective and repeatable (Stumpf, 1993). A quantitative measurement of percent ground cover by plant species is estimated within four haphazardly placed 1 m^2 quadrats within the larger plot. Additionally, photographs from an established photo station are taken at each plot to visually document any changes in the floristic characterization overtime.

Epibenthos Assessment

Sampling for epibenthic invertebrates (primarily terrestrial mollusks and crabs) coincides with mangrove assessments at each of the established plots described above for vegetation sampling. Epibenthic species are evaluated at the same four haphazardly positioned 1 m^2 quadrats used to assess percent ground cover. Live epibenthic invertebrates are identified to the lowest taxonomic unit possible and counted within each 1 m^2 quadrat. In the event that an invertebrate cannot be identified in the field, the specimen is collected and preserved for later identification by a qualified individual. All crab burrows present in each of the 1 m^2 quadrats within each of the plots are also enumerated.

Aquatic Faunal Assessment

Two reference (tidal sites where mangroves were relatively healthy in 2012) and four restoration aquatic sampling sites in the die-off areas, in each of the Phase 1a and 1b study areas are being monitored, near or in shallow tidal tributaries where water levels are sufficient for trap deployment. Four clear, plastic traps (Breder, 1960) are set in shallow water (< 50 cm; actual depth recorded) at each sampling site and retrieved after a 1-2-hour soak time (Sargent and Carlson, 1987). Captured fish are identified to the lowest possible taxonomic level. Fish that cannot be identified in the field are preserved in 10% formalin and returned to the laboratory for positive identification. The first 30 fish of a given species are measured (total length) and the remainder enumerated. With the exception of voucher specimens, all fish are released alive at the site. Water conditions (temperature and salinity) and weather conditions are recorded during each sampling event using a handheld YSI (Yellow Springs Instrument) Model 85 meter and a Kestral 3000 weather meter respectively. In 2012, attempts were made to use seines and cast nets in the main tidal channel on the north side of C.R. 92 to augment fish captures since Breder traps are biased toward the smaller fish classes. Unfortunately, the die-off and adjacent mangrove reference areas are too littered with objects that snagged the nets, preventing accurate use of these two methods and thus were subsequently discontinued.

During fish trap deployment, aquatic invertebrate samples are collected from each of the six sites in the reference and restoration areas in the Phase 1a and Phase 1b study areas using a 30 cm x 30 cm 1,400 micron mesh D-frame dipnet. Multiple sweeps are performed in vegetation and benthic substrates until no additional taxa are observed during 3 successive sweeps (typically represents the asymptote of the taxa accumulation curve). Dipnet samples are field-sorted using forceps, eyedroppers and sorting pans. Aquatic invertebrates are placed in 80% ethanol and returned to the lab for identification. Samples are sorted under a Meiji (Santa Clara, CA) EMZ-8TR stereo microscope (magnification 7X - 90X using 10X – 20X eyepieces). Aquatic invertebrates are identified to the lowest taxonomic level using keys available through FDEP Bureau of Laboratories (http://www.floridadep.org/labs/cgi-bin/sbio/keys.asp) as well as Merritt, et al., (2008) and other available resources.

Data Analysis

Documented measurements and observations recorded during assessment periods are used to make comparisons between reference and restoration areas pre and post-restoration. The floristic dataset is used to calculate the following baseline parameters: number of individual trees and saplings, tree relative and absolute density of species, mean DBH, total basal area, mean basal area, absolute and relative dominance, tree condition, and canopy and ground coverage. Vegetative data is summarized by plot and by type (reference or restoration area). Subsequent assessments overtime will allow for evaluation of overall tree and sapling recruitment and mortality rates, which will help indicate whether the restoration is successful.

The epibenthic dataset is being used to assess the soil overtime based upon what types of organisms are utilizing the substrate (number of individuals by species by plot, and crab hole density by plot and by plot type). The aquatic faunal dataset is being used to assess species richness and abundance overtime and is based upon the total number of individuals.

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RESULTS PHASE 1a MANGROVE RESTORATION

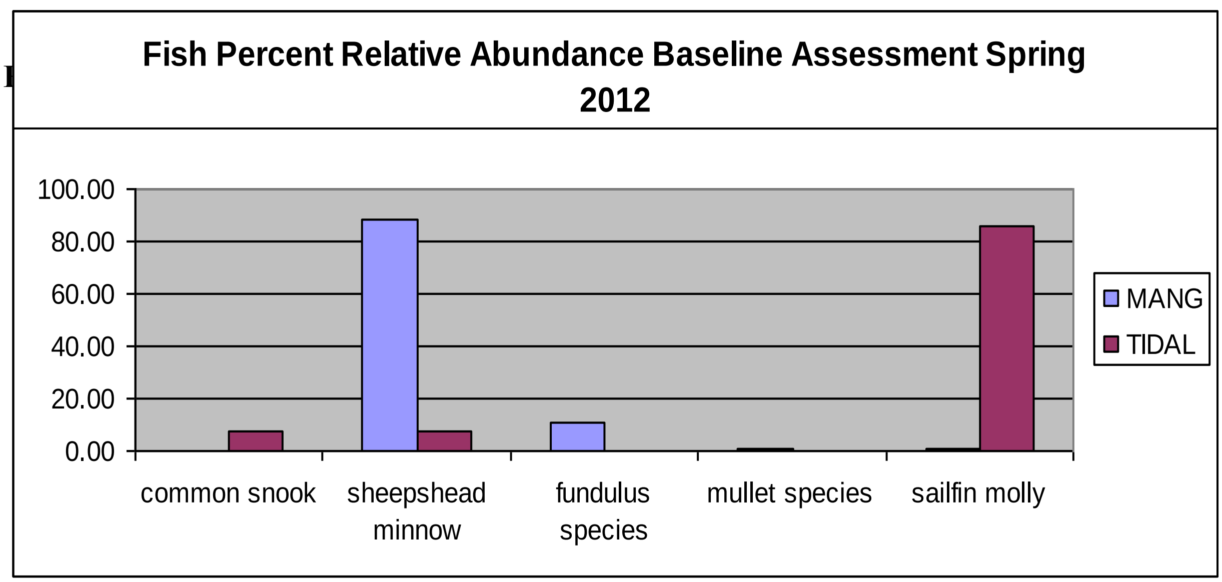
A total of 17 separate monitoring assessments were conducted from February 2012 to February 2020 to evaluate the restoration efforts within the Phase 1a die-off to the north of C.R. 92 near Stevens Landing (Appendices 2 & 3). Plots 1D, 2D and 3D are located in the die-off area in the Phase 1a restoration project area and plots 3A and 4A are located in an adjacent primarily healthy mangrove reference forest (Figures 4 & 6).

Pre-Restoration Baseline Assessment February through April 2012

No living mangrove trees or saplings existed within plots 1D and 2D during the baseline pre-restoration assessment that occurred in February of 2012 (Tables 1 and 2). Canopy cover was also non-existent. There were a total of 12 dead black mangrove trees still standing in plot 1D, while 10 dead black mangrove trees were still standing in plot 2D. Ground cover was sparse in the die-off (restoration) plots and only plot 1D had minimal vegetative cover, saltwort (*Batis maritima*).

A total of 48 trees (47 black mangroves and 1 red mangrove (*Rhizophora mangle L.*)) were evaluated during February of 2012 within the Phase 1a reference plots during the baseline assessment pre-restoration. Reference plot 3A was a monoculture of 31 black mangrove trees. Four of these trees were very stressed, 14 trees were stressed, and the remaining 13 trees exhibited minimal signs of stress. Reference plot 4A consisted of sixteen black mangrove and one red mangrove trees. Four black mangrove and one red mangrove trees were stressed, while the remaining twelve black mangrove trees exhibited minimal signs of stress (Table 1). Percent canopy cover was 82.35% in reference plot 3A, where only 3 black mangrove saplings (2 stressed and 1 very stressed (>50 cm)) were present (Table 2). Ground cover consisted entirely of black mangroves, primarily seedlings (<50 cm) in the four 1 m^2 quadrats. Percent canopy cover was 58.8% in reference plot 4A. Nine saplings consisting of 7 black mangroves (3 were stressed; 4 relatively healthy) and 2 red mangroves (one of which was stressed and one that was relatively healthy) were found within plot 4A (Table 2). Ground cover consisted primarily of black mangrove seedlings (<50 cm), with a few red and white mangrove (*Laguncularia racemosa*) seedlings (<50 cm) in the four 1 m^2 quadrats during the baseline assessment pre-restoration.

Pre-restoration a total of 268 fish were collected in breder traps at reference (tidal) and restoration (die-off) sites (Figure 8). Four species of fish were caught within the 4 mangrove die-off sites, with sheepshead minnows (*Cyprinodon variegates*) dominating the assemblage during this baseline assessment. Whereas 4 different species of fish were caught within the 2 tidal reference sites, with sailfin molly (*Poecilis latipinna*) dominating the fish assemblage. Larger sized fish included a mullet (*Mugil sp.*) and a common snook (*Centropomis undecimalis*) were caught in the die-off and tidal areas respectively, during the spring of 2012 (Appendix 4). Aquatic invertebrates that were found during dipnetting sessions within the 4 mangrove die-off sites consisted primarily of water boatman *(Trichocorixa reticulate)* as these invertebrates encompassed 78% of the species netted. Whereas, ladder horn snails (*Cerithidea scalariformes*) and coffee bean snails (*Melampus coffeus*) were the dominant assemblages (55% and 30% respectively), within the reference tidal sites (Appendix 4).



Pre-restoration no crab holes were found within the four 1 m^2 quadrats surveyed within each of the die-off plots (1D or 2D). A total of 81 and 59 crab holes were surveyed within the quadrats in reference plots 3A and 4A respectively, during the baseline assessment. At reference plot 3A, ribbed mussels (*Geukensia demissa*) dominated, comprising an estimated 85% of the invertebrates present in the quadrats sampled. Whereas, 99% of the invertebrate assemblage found within the quadrats at plot 4A were coffee bean snails during the baseline assessment pre-restoration.

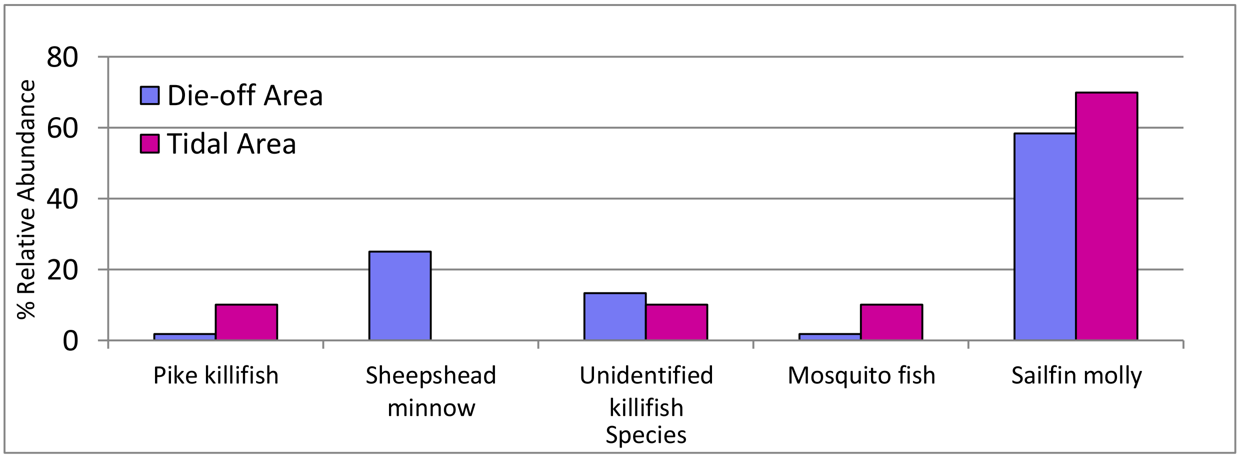
Post-Restoration Time Zero September 2012

In September of 2012, (restoration time zero), there were no living trees within the two die-off plots 1D and 2D (Table 1) and canopy cover was non-existent. Ground cover was sparse in the die-off (restoration) plots. Plot 1D had 1 black mangrove sapling (>50 cm tall) (Table 2) and both die-off plots had some mangrove seedlings (<50 cm tall) that were attempting to establish themselves. Saltwort was also present in plot 1D.

The same 48 trees that were evaluated during the pre-construction baseline assessment in February of 2012 were reassessed within the adjacent mangrove forest or reference plots in September of 2012. One black mangrove tree in plot 3A that was categorized as very stressed pre-construction, died between February and September of 2012. The remaining 30 black mangrove trees consisted of 17 trees categorized as stressed, 3 as very stressed and the remaining 10 trees exhibited minimal signs of stress. Reference plot 4A still had 17 mangrove trees, which consisted of 4 black mangroves and 1 red mangrove that were categorized as stressed and the remaining 12 black mangrove trees exhibited minimal signs of stress (Table 1). Percent canopy cover was 65% and 59% in reference plots 3A and 4A respectively. Reference plot 3A had 2 stressed black mangrove saplings (> 50 cm) remaining within the plot, as one of the saplings died between February and September of 2012 (Table 2). Ground cover consisted of 113 black mangrove and 2 red mangrove seedlings (<50 cm); and 4 black mangrove trees in the four 1 m^2 quadrats within reference plot 3A. In reference plot 4A, 9 saplings (>50 cm) were present consisting of 7 black mangroves and 2 red mangroves (Table 2). Ground cover in plot 4A consisted of 88 black mangrove and one red mangrove seedling (<50 cm), along with 4 black mangrove trees within the four 1 m^2 quadrats during the time zero assessment post-restoration.

In September of 2012, (time zero post-construction), a total of 70 fish were collected in breder traps at reference (tidal) and restoration (die-off) sites. Five species of fish were caught within the 4 mangrove die-off sampling sites. Sailfin mollies (58%) and sheepshead minnows (25%) dominated this assemblage. Four different species of fish were caught within the 2 tidal sampling sites, and sailfin molly dominated this assemblage at 70%. Larger sized fish included a gulf killifish (*Fundulus grandis*) and a pike killifish (*Belonesox belizanus*), both caught in the tidal area during the fall of 2012 (Figure 9 & Appendix 4).

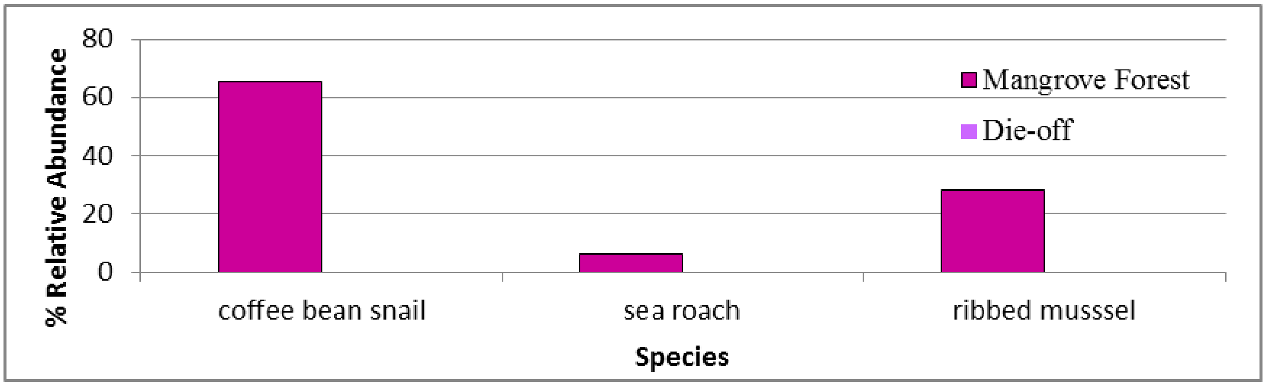
Figure 9: Phase 1a Fish Relative Abundance September 2012



Very few aquatic invertebrates, (primarily ladder horn snails), were found within the 4 mangrove die-off sites. Post-restoration coffee bean snails and ladder horn snails were the dominant assemblages found in the reference tidal sites.

No crab holes or insect assemblages were found within the four 1 m^2 quadrats surveyed post-restoration at plots 1D or 2D during the time zero sampling in September of 2012. A total of 91 and 64 crab holes were surveyed within the quadrats at reference plots 3A and 4A respectively. In the fall of 2012, coffee bean snails comprised an estimated 55% of the invertebrates present in the quadrats sampled at reference plot 3A. The remaining invertebrate assemblage within these quadrats consisted of 39% ribbed mussels and 6% of sea roaches during the time zero assessment. Within plot 4A, 94% of the invertebrate assemblages found within the quadrats were coffee bean snails. The remaining 6% of this assemblage consisted of sea roaches (Figure 10).

Figure 10: Phase 1a Terrestrial Invertebrate Relative Abundance Determined within the 1 m^2 Quadrats in September 2012



1 Year Post-Restoration September 2013

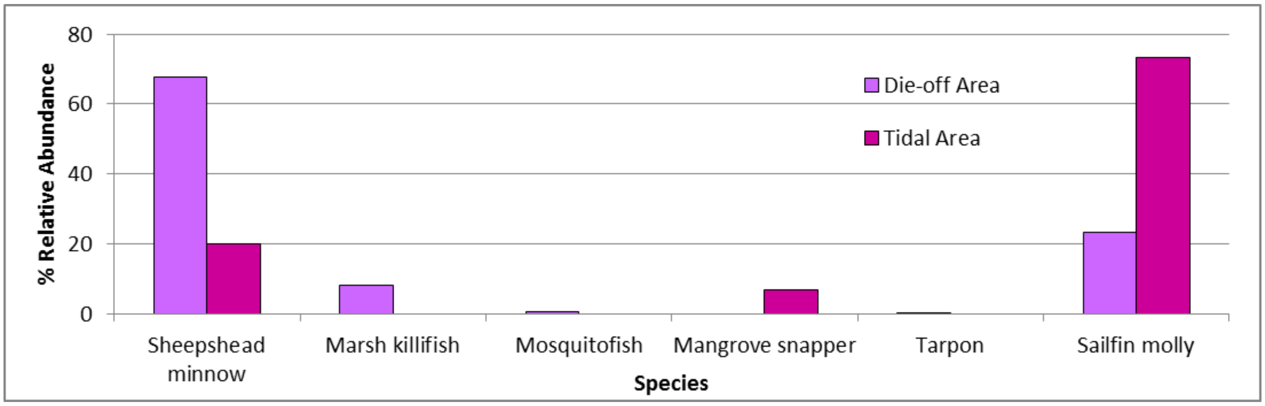
In September of 2013, there were no living trees within the two die-off plots 1D and 2D (Table 1), and canopy cover was still non-existent. Ground cover was sparse in the die-off (restoration) plots. Plot 1D had 14 black mangrove saplings (>50 cm tall) (Table 2) and both die-off plots had some mangrove seedlings (<50 cm tall) that were attempting to establish themselves. Saltwort was present in both die-off plots 1D and 2D during September 2013.

Forty-seven of the original 48 mangroves (1 tree died in the fall of 2012) that were evaluated during the pre-construction baseline assessment (February of 2012) were reassessed within the adjacent mangrove forest or reference plots post-restoration in September of 2013. In reference plot 3A, 30 black mangrove trees remain, consisting of 22 trees categorized as stressed, 2 very stressed, and the remaining 6 trees exhibited minimal signs of stress. Reference plot 4A still had 17 mangrove trees, consisting of 5 stressed black mangroves, one stressed red mangrove. The remaining 11 black mangrove trees exhibited minimal signs of stress (Table 1). Percent canopy cover was estimated at 82% and 59% in reference plots 3A and 4A respectively. Reference plot 3A had only 1 stressed black mangrove sapling (>50 cm) remaining within the plot as one of the saplings died between September 2012 and September of 2013 (Table 2). Ground cover consisted of 9 black mangrove, 72 white mangrove and 2 red mangrove seedlings (<50 cm); and 7 black mangrove trees within the four 1 m^2 quadrats within reference plot 3A. Reference plot 4A had a total of 16 saplings (>50 cm) consisting of 10 black mangrove (2 were still stressed and 1 died and the remaining 7 were relatively healthy; 4 red mangrove (one of which was still stressed and 3 relatively healthy), and two relatively healthy white mangrove saplings (Table 2). Ground cover consisted of 78 black mangrove and two red mangrove seedlings (<50 cm); 3 black mangrove and 2 red mangrove saplings (>50 cm and <150 cm tall); and 4 black mangrove trees within the four 1 m^2 quadrats during the one-year assessment post-restoration in plot 4A.

In September of 2013, (one year post-construction), 368 fish were collected in breder traps at reference (tidal) and restoration (die-off) sites. Five species of fish were caught within the 4 mangrove die-off sites. Sheepshead minnow (68%) and sailfin molly (23%) dominated the assemblage during this assessment one year post-restoration. Three different species of fish were caught within the 2 reference tidal sites. The dominant fish species were sailfin molly (73%) and sheepshead minnows (20%) during the fall of 2013 post-restoration (Figure 11).

Very few aquatic invertebrates, (<25 individual aquatic insects/site), primarily water boatman were found during the dipnetting sessions within the 4 mangrove die-off sites. One year post-restoration, *Rheumatobates vegatus* (water striders), coffee bean snails, and sea roaches were the dominant assemblages found in the reference tidal sites.

Figure 11: Phase 1a Fish Relative Abundance September 2013



One year post-restoration, crabs began to utilize parts of the die-off. Six and 57 crab holes were counted in the four 1 m^2 quadrats in plots 1D and 2D, respectively. Insect assemblages also began to utilize the die-off area. Plot 1D was dominated by sea roaches and grass ceriths (*Bittiolum varium)* within the quadrats surveyed 1 year post-restoration at plot 1D. Whereas 100% of the insects found in the quadrats in plot 2D were grass ceriths. Twenty-one and three crab holes found within the four 1m^2 quadrats in reference plots 3A and 4A respectively. In the fall of 2013, coffee bean snails comprised an estimated 90% of the invertebrates present in the quadrats sampled at reference plot 3A. The remaining invertebrate assemblages surveyed within the quadrats in plot 3A included ribbed mussels, mangrove mud crabs (Ocypodidae (Ucides); Grapsidae; and Gecarcinidae), fiddler crabs (*Uca minar)* and sea roaches. In plot 4A, the dominant invertebrate assemblage found within the quadrats, were coffee bean snails during the one year post-restoration assessment in reference plot 4A (Figure 12 & Appendix 4).

Figure 12: Phase 1a Terrestrial Invertebrate Relative Abundance Determined within the 1 m^2 Quadrats in September 2013

2 Years Post-Restoration September 2014

In September of 2014, data collected two years post-restoration revealed that there were no living trees within the two die-off plots (Table 1). Canopy cover was still non-existent. Ground cover had increased in the die-off (restoration) plots. Plot 1D had 28 black mangroves and 4 white mangrove saplings (>50 cm tall) and plot 2D had 22 black mangrove, 3 red mangrove and 30 white mangrove saplings (Table 2). Additionally both die-off plots had mangrove seedlings (<50 cm tall) that were establishing themselves. Saltwort and mangrove seedlings were covering an estimated 65% and 25% of the restoration die-off plots 1D and 2D during September 2014.

Forty-seven mangroves trees in September of 2014 were reassessed within the adjacent mangrove forest or reference plots. Plot 3A consisted of 30 black mangrove trees of which 21 trees were categorized as stressed, 3 were very stressed, and the remaining 6 trees exhibited minimal signs of stress. Reference plot 4A had 17 mangrove trees, which consisted of six stressed black mangroves; one stressed red mangrove; and the remaining 10 black mangroves exhibited minimal signs of stress (Table 1). Percent canopy cover was 41% and 35% in reference plots 3A and 4A respectively. Reference plot 3A had no mangrove saplings (>50 cm) remaining within the plot as the remaining sapling died between September 2013 and September of 2014 (Table 2). Ground cover consisted of 81 black mangrove and 4 red mangrove seedlings (<50 cm); and 4 black mangrove trees within the four 1 m^2 quadrats within reference plot 3A. In reference plot 4A, 15 saplings (>50 cm) consisting of 9 black mangroves, 4 red mangroves, and two white mangrove saplings were recorded (Table 2). Ground cover within the four 1 m^2 quadrats consisted of 60 black mangrove and 2 red mangrove seedlings (<50 cm); and 5 black mangrove and 3 red mangrove saplings (50 cm and < 150 cm) during the two-year assessment post-restoration in plot 4A.

In September of 2014, (two years post-construction), a total of 333 fish were collected in breder traps at the reference (tidal) and restoration (die-off) sites. Six species of fish were caught within the 4 mangrove die-off sampling sites. Sheepshead minnows (33%), sailfin molly (30%), and diamond killifish (*Adinia xenica*) (25%) were the dominant assemblages during the two year post-restoration assessment in the die-off restoration sites. Six different species of fish were caught within the 2 tidal reference sampling sites. The dominant fish species were sailfin molly (54%) and gulf killifish (36%) during the fall of 2014 post-restoration (Figure 13). As far as aquatic invertebrates, water boatman dominated the restoration (die-off) sites and shore bugs (*Saldidae*), *Pentacora sphacelata*, and *Enochrus reflexipennis* were dominant in the tidal reference sites.

Crabs and other invertebrates were still utilizing parts of the die-off restoration area. A total of 2 and 41 crab holes were counted in the four 1 m^2 quadrats in plots 1D and 2D respectively. Ninety percent of the insect assemblages were grass ceriths within the quadrats surveyed post-restoration at plot 1D. Whereas grass ceriths or ladder horn snails comprised 89% and mangrove periwinkles, (*Littoraria angulifera,)* 7% within plot 2D during this assessment (Appendix 4). A total of 88 and 1 crab holes were found within the quadrats in reference plots 3A and 4A respectively. In the fall of 2014, coffee bean snails comprised an estimated 89% of the invertebrates present in the quadrats sampled at reference plot 3A. Within plot 4A, 83% of the invertebrate assemblage found within the 4 quadrats, were coffee bean snails, during the two year post-restoration assessment (Figure 14).

Figure 13: Phase 1a Fish Relative Abundance September 2014

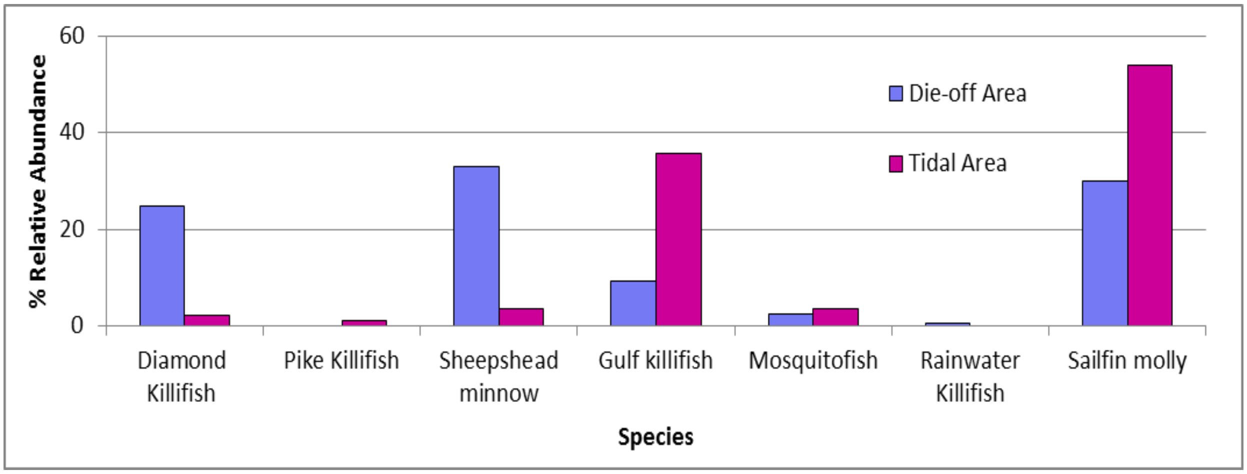
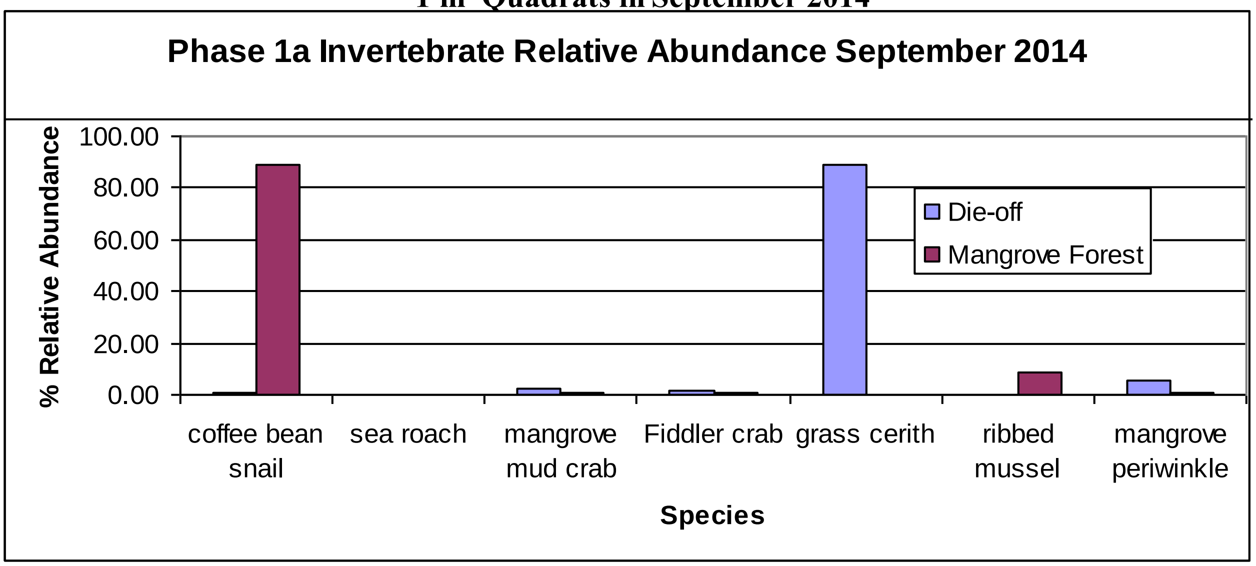


Figure 14: Phase 1a Terrestrial Invertebrate Relative Abundance Determined within the 1 m^2 Quadrats in September 2014



<u>3 Years Post-Restoration September 2015</u>

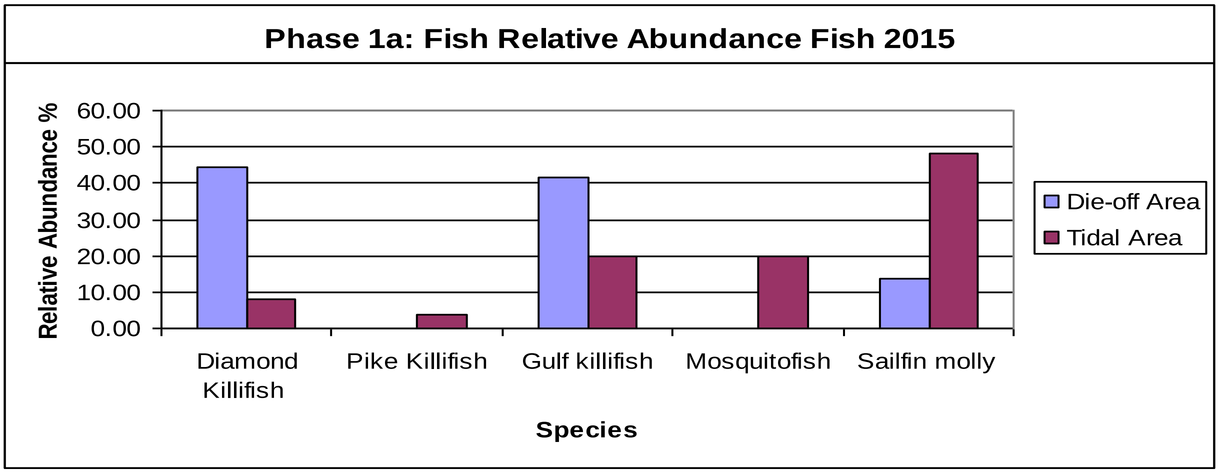
In September of 2015, data collected three years post-restoration revealed that a total of 33 mangroves had attained sufficient height to qualify as trees within the two die-off plots 1D and 2D (Table 1). Plot 1D had 5 black mangrove saplings that became trees and plot 2D had 8 black mangrove, 1 red mangrove and 19 white mangrove saplings that grew into trees (>150cm tall). Canopy cover was still non-existent. Ground cover had increased in the die-off (restoration) plots. Plot 1D had 82 black mangrove (1 of which died), 5 red mangrove and 39 white mangrove saplings (>50 cm tall) and plot 2D had 46 black mangrove (1 of which was stressed), 22 red mangrove and 30 white mangrove saplings (Table 2). Within the four 1 m^2 quadrats, ground cover was comprised of 9 white mangrove, 16 black mangrove and 1 red mangrove saplings (between 50 – 150 cm tall); and 14 white mangrove, 2 red mangrove and 27 black mangrove seedlings (<50 cm) within restoration plot 1D. Whereas ground cover, within the four 1 m^2 quadrats, within plot 2D was comprised of 59 black mangrove, 36 red mangrove, and 55 white mangrove seedlings (<50 cm); 27 black mangrove, 1 red mangrove and 5 white mangrove saplings (between 50 – 150 cm tall); and 1 white mangrove tree (>150 cm tall). Saltwort and mangrove seedling recruitment has increased since September of 2014, covering an estimated 94% and 80% of the restoration die-off plots 1D and 2D respectively during September 2015.

Forty-eight mangrove trees were evaluated in September of 2015 within the two adjacent mangrove forest or reference plots. In reference plot 3A, there were 30 black mangrove trees consisting of 13 stressed, 12 very stressed, and 5 mangrove trees exhibiting minimal signs of stress. Reference plot 4A had 18 mangrove trees comprised of 8 stressed black mangroves, 2 very stressed black mangroves, 1 very stressed red mangrove, and the remaining 7 black mangrove trees exhibited minimal signs of stress (of which 1 of the 7 attained tree status this year) (Table 1). Percent canopy cover was 71% and 65% in reference plots 3A and 4A respectively. Reference plot 3A had no mangrove saplings (>50 cm) within the plot as no recruitment occurred during this past year (Table 2). Ground cover consisted of 28 black mangrove and 1 red mangrove seedlings (<50 cm); and 6 black mangrove trees (>150 cm) in the four 1 m^2 quadrats sampled within reference plot 3A. In reference plot 4A, 17 saplings (>50 cm) consisting of 11 black mangroves; 4 red mangroves; and two white mangrove saplings were recorded (Table 2). Ground cover within the four 1 m^2 quadrats in reference plot 4A consisted of 39 black mangrove and 1 red mangrove seedlings (<50 cm); 1 red mangrove and 1 black mangrove saplings (between 50 – 150 cm tall); and 2 black mangrove trees (>150 cm). Mangrove seedling recruitment covered an estimated 16% and 21% of the ground in reference plots 3A and 4A respectively during September 2015.

In March of 2015, plot 3D was completely barren prior to hand-dug channel extensions (Appendix 5). By December 2015, two black mangrove saplings (>50 cm) were established within plot 3D (Table 2). Canopy cover was non-existent. Ground cover was comprised of 3 white and 5 black mangrove seedlings (<50 cm); and 1 black mangrove sapling (between 50 – 150 cm tall) within the four 1 m^2 quadrats. Mangrove seedling recruitment covered an estimated 7% of the ground in restoration plot 3D during December 2015. A total of 31 invertebrates were observed within the 4 one meter squared quadrats, where 94% were grass ceriths and the remainder were water striders.

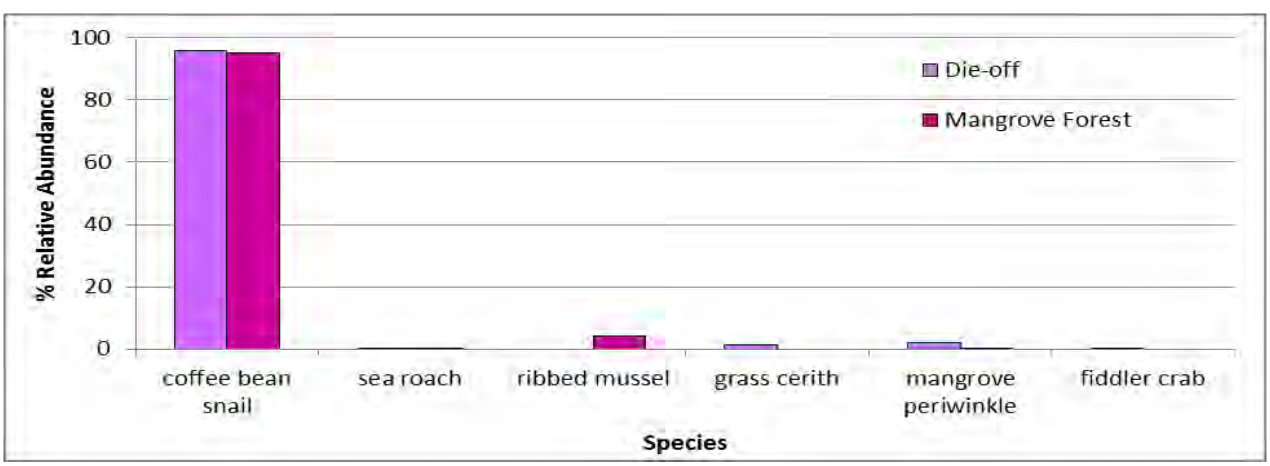
In September of 2015, (three years post-construction), a total of 61 fish were collected in breder traps at reference (tidal) and restoration (die-off) sites. Three species of fish were caught within the 4 mangrove die-off sites. Diamond killifish (44%) and gulf killifish (42%) were the dominant assemblages in the die-off restoration sites. Five different species of fish were caught within the 2 tidal reference sites. The dominant fish species were sailfin molly (48%), gulf killifish (20%), and mosquitofish (*Gambusia holbrooki*) (20%) during the fall of 2015 post-restoration (Figure 15). As far as aquatic invertebrates, *Enochrus reflexipennis* dominated the restoration (die-off) sites and sea roaches and water striders were dominant in the tidal reference sites.

Figure 15: Phase 1a Fish Relative Abundance September 2015



Sixty-five crab holes were enumerated within the four 1 m^2 quadrats within plot 2D. Plot 1D had no visible crab holes. This was likely in part due to its lower topography. This plot was underwater during sampling, (due to higher than normal tides), likely accounting for the lack of discernable crab holes. The same high tides were also likely responsible for the lower than expected number of crab holes discerned in the reference plots 3A and 4A (14 and 9 crab holes respectively). There was a substantial uptick in the numbers of invertebrates found within the restoration plots. A total of 260 and 568 individual invertebrates comprised of four species were found in the quadrats surveyed in plots 1D and 2D, respectively (mean density of 65 and 142 individuals per square meter respectively). Coffee bean snails dominated the invertebrate assemblages at restoration plots 1D and 2D and reference plot 3A in the four 1 m^2 quadrats (Figure 16). Plot 4A was completely under high tidal waters during this period and no invertebrates could be discerned.

Figure 16: Phase 1a Terrestrial Invertebrate Relative Abundance Determined within the 1 m^2 Quadrats in September 2015



4 Years Post-Restoration September 2016

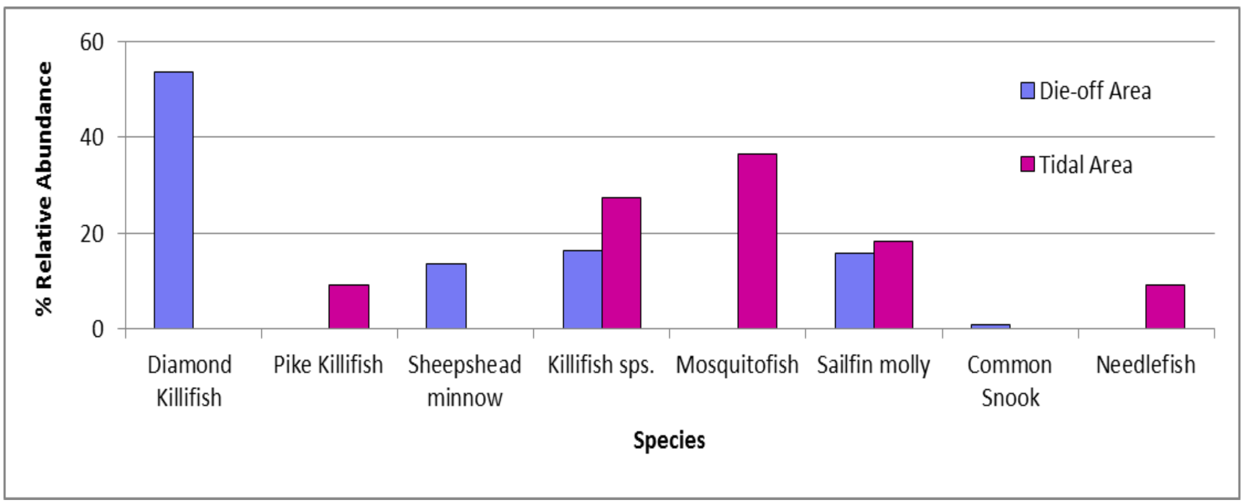
In September of 2016, data collected four years post-restoration revealed that a total of 108 mangrove saplings/seedlings had attained sufficient height to qualify as trees (>150cm tall) within the two die-off plots 1D and 2D. Together these plots had a total of 141 trees. Thirty-eight of the 43 trees, of which 27 black mangrove, 2 red mangrove and 9 white mangrove saplings became trees during the past year. The 5 trees that were existing prior to this assessment were black mangrove trees. Seventy of the 98 trees that resided within plot 2D, of which 27 black mangrove, 15 red mangrove, and 28 white mangrove saplings became trees during the past year. Twenty-eight trees were existing prior to this assessment consisting of 8 black mangrove, 1 red mangrove and 19 white mangroves (Table 1). Canopy cover has increased from non-existent to 5.9 % in plot 1D and to 35.3% in plot 2D. Plot 1D had 115 black mangrove, 11 red mangrove, and 89 white mangrove saplings (>50 cm tall) and plot 2D had 37 black mangrove, 48 red mangrove, and 23 white mangrove saplings of which 1 died within each species (Table 2).

Ground cover had increased in the die-off (restoration) plots. Seven white mangrove, 36 black mangrove, and 4 red mangrove seedlings (<50 cm); 50 white mangrove, 5 red mangrove, and 71 black mangrove saplings (between 50 – 150 cm tall); and 3 white mangrove, 1 red mangrove, and 12 black mangrove trees (>150 cm tall) were found within the four 1 m^2 quadrats sampled within restoration plot 1D. Whereas ground cover, within the four 1 m^2 quadrats within plot 2D, was comprised of 41 black mangrove, 44 red mangrove, and 26 white mangrove seedlings (<50 cm); 16 black mangrove, 32 red mangrove, and 9 white mangrove saplings (between 50 – 150 cm tall); and 12 black mangrove, 8 red mangrove, and 18 white mangrove trees (>150 cm tall). Additionally, both die-off plots had numerous mangrove seedlings (<50 cm tall) that were attempting to establish themselves. Saltwort decreased as mangrove seedling and sapling recruitment increased covering an estimated 79% and 88% of the restoration die-off plots 1D and 2D respectively.

Forty-seven mangrove trees were evaluated in September of 2016 within the two adjacent mangrove forest or reference plots. In reference plot 3A, 28 black mangrove trees remain consisting of 17 stressed, 6 very stressed, 5 trees exhibiting minimal signs of stress. Two black mangrove trees died since the last assessment. Reference plot 4A had 17 mangrove trees comprised of 7 stressed; 1 very stressed; 8 relatively healthy black mangrove trees; along with 1 relatively healthy red mangrove tree. One black mangrove tree died since September 2015 (Table 1). Percent canopy cover was 88% and 65% in reference plots 3A and 4A respectively. No saplings (>50 cm), resided within reference plot 3A and reference plot 4A had 22 saplings consisting of 17 black mangrove, 3 red mangrove and 2 white mangrove saplings (>50 cm) (Table 2). Ground cover consisted of 6 black mangrove, 3 red mangrove, and 1 white mangrove seedlings (<50 cm); and 8 black mangrove trees (>150 cm tall) in the four 1 m^2 quadrats sampled within reference plot 3A. Plot 3A also had sea anemones living within the plot, indicative of extreme inundation over an extended period. Ground cover within the four 1 m^2 quadrats in reference plot 4A consisted of 69 black mangrove and 5 red mangrove seedlings (<50 cm); 4 black mangrove and 1 white mangrove saplings (between 50 – 150 cm tall); and 2 black mangrove and 1 red mangrove trees (>150 cm). Ground cover was estimated at 5% and 23% of the ground in reference plots 3A and 4A respectively during September 2016.

In September of 2016, plot 3D had a total of 18 established mangrove saplings (>50 cm). Fifteen of these were black mangroves of which 13 were newly recruited. The remaining were 3 white newly recruited mangrove saplings (Table 2). Canopy cover was non-existent. Ground cover was comprised 4 black and 3 white mangrove saplings (between 50 – 150 cm tall) in the four 1 m^2 quadrats and mangrove seedlings covered an estimated 11% of the ground in restoration plot 3D. In September of 2016, (four years post-construction), a total of 261 fish were collected in breder traps at reference (tidal) and restoration (die-off) sites. Five species of fish were caught within the 4 mangrove die-off sites. Diamond killifish (54%) was the dominant assemblage in the die-off restoration sites. Five different species of fish were caught within the 2 tidal reference sampling sites and the dominant fish species were mosquitofish (36%) and killifish (27%). A new species, needlefish (*Strongylura sps*.) was found in the tidal area during the fall of 2016 post-restoration (Figure 17 and Appendix 4).

Figure 17: Phase 1a Fish Relative Abundance September 2016

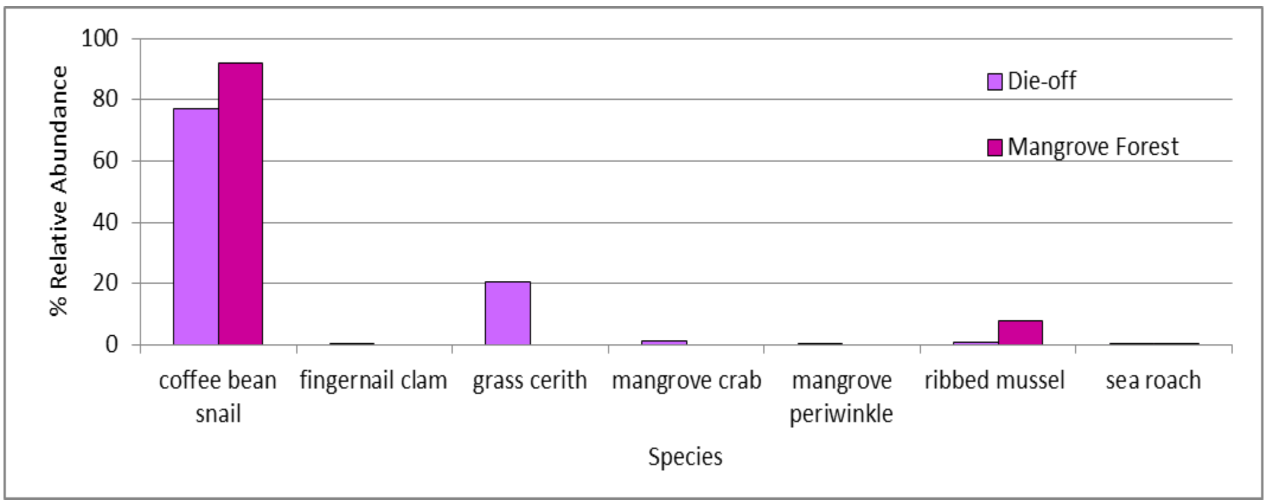


Fifteen and 77 crab holes were enumerated within the four 1 m^2 quadrats within plot 1D and plot 2D respectively. This was indicative that crabs are utilizing the die-off restoration area. The lower topography within the vicinity of plot 1D and more frequent inundation likely accounted for the lesser number of crab holes found within this area of the die-off. Plot 3D had no evidence of crab immigration. High water levels in plots 3A and 4A prevented enumeration of crab holes within the reference plots. A total of 864 individual invertebrates comprised of seven species were found in the quadrats surveyed in plots 1D and 2D with a mean density of 108 individuals per square meter. This was a major change from pre-restoration and initial post-restoration sampling when there was less diversity within the invertebrate assemblage in the restoration plots. Sixty-eight percent of the invertebrate assemblages consisted of coffee bean snails; 29.1% grass ceriths; 0.8% mangrove mud crab; 0.7 % ribbed mussel; 0.7% sea roach; 0.5% fingernail clam (*Muscluium species*); and 0.2% mangrove periwinkles within the quadrats surveyed post-restoration at plot 1D. Similarly, coffee bean snails made up the dominant assemblage (97%) followed by 1.5% mangrove mud crab; 1.1% grass ceriths; and 0.4% ribbed mussel in plot 2D

(Figure 18). Grass ceriths or ladder horn snails dominated the assemblage (94.8%) followed by 5.2% coffee bean snails within plot 3D. There was less diversity in plot 3D, which only recently had access to tidal flushing and is still primarily bare ground.

A total of 275 individual terrestrial invertebrates comprised of three species were found in the 1 m^2 reference quadrats surveyed in plots 3A and 4A with a mean density of 34 individuals per square meter. Coffee bean snails comprised the bulk of the invertebrate assemblage, (an estimated 92% of the invertebrates present in the quadrats sampled at reference plot 3A). The invertebrate assemblage within plot 4A consisted of 50% coffee bean snail and 50% sea roach (Figure 18). This plot was once again flooded during the sampling period causing difficulty in discerning terrestrial invertebrates within the four quadrats.

Figure 18: Phase 1a Terrestrial Invertebrate Relative Abundance Determined within the 1 m^2 Quadrats in September 2016



There has been a dramatic shift in the aquatic invertebrate species collected in dipnets within the restoration area of the Phase 1a mangrove die-off area. Pre-restoration only 8 species of aquatic invertebrates were found of which water boatman dominated the assemblage. As the die-off area began to recover there was a dramatic decrease in abundance of water boatman captured and a dramatic increase in aquatic invertebrate species diversity. Post-restoration, 50 aquatic invertebrate species (42 more that found during pre-restoration) were documented in the Phase 1a die-off area overtime as the area began to show indications of recovery.

5 Years Post-Restoration October 2017

On September 10, 2017, Hurricane Irma impacted Florida and the study area. This hurricane was an extremely powerful and catastrophic Cape Verde-type hurricane. It was the strongest storm recorded (in terms of maximum sustained winds) in the Atlantic since 2005, when Hurricane Wilma hit Florida. Hurricane Irma made initial landfall in Florida at Cudjoe Key as a Category 4 hurricane, and thereafter at Marco Island with gusts up to 130 mph. Marco Island (near where our study area is located), Everglades City, Chokoloskee and the Ten Thousand Islands were the hardest hit areas. Mangroves in these areas took a beating, thereby protecting inland residential areas. Hurricane Irma impacted the study area, which was reflected in the results of this assessment.

In October of 2017, data collected five years post-restoration revealed that a total of 98 mangrove saplings and 8 seedlings had attained a height to qualify as trees within the two die-off plots 1D and 2D since the September 2016 assessment. A total of 247 trees were evaluated within plots 1D and 2D. As of October of 2017, there were a total of 123 trees in plot 1D consisting of 53 black mangrove, 9 red mangrove, and 61 white mangroves trees. Plot 2D had a total of 44 black mangrove, 22 red mangrove, and 58 white mangroves (124 living trees) (Table 1). Sapling numbers decreased slightly in plot 1D and increased within plot 2D in comparison to sapling numbers present in September of 2016. Plot 1D had 116 black mangrove (of which 1 died), 10 red mangrove (of which 1 died), and 56 white mangrove saplings (>50 cm tall) (of which 1 died). Plot 2D had 63 black mangrove, 93 red mangrove, and 29 white mangrove saplings remaining within the entire plot. Four black mangrove, five red mangrove, and two white mangrove saplings died (Table 2). Plot 1D canopy coverage increased to 11.8%, double the percentage since last year. Canopy cover remained stable at 35.3% in plot 2D.

The ground cover recorded within the four 1 m^2 quadrats in plot 1D consisted of 27 white mangrove, 25 black mangrove, and 5 red mangrove seedlings (<50 cm); 23 white mangrove, 4 red mangrove, and 37 black mangrove saplings (between 50 – 150 cm tall); and 15 white mangrove, 5 red mangrove, and 16 black mangrove trees (>150 cm tall). Whereas ground cover, within the four 1 m^2 quadrats, within plot 2D consisted of 9 black mangrove, 19 red mangrove, and 6 white seedlings (<50 cm); 7 black mangrove, 26 red mangrove, and 5 white mangrove saplings (between 50 – 150 cm tall); and 5 black mangrove, 2 red mangrove, and 14 white mangrove trees (>150 cm tall). In October of 2017, vegetative coverage was estimated to encompass 64% and 38% of the restoration die-off plots 1D and 2D respectively.

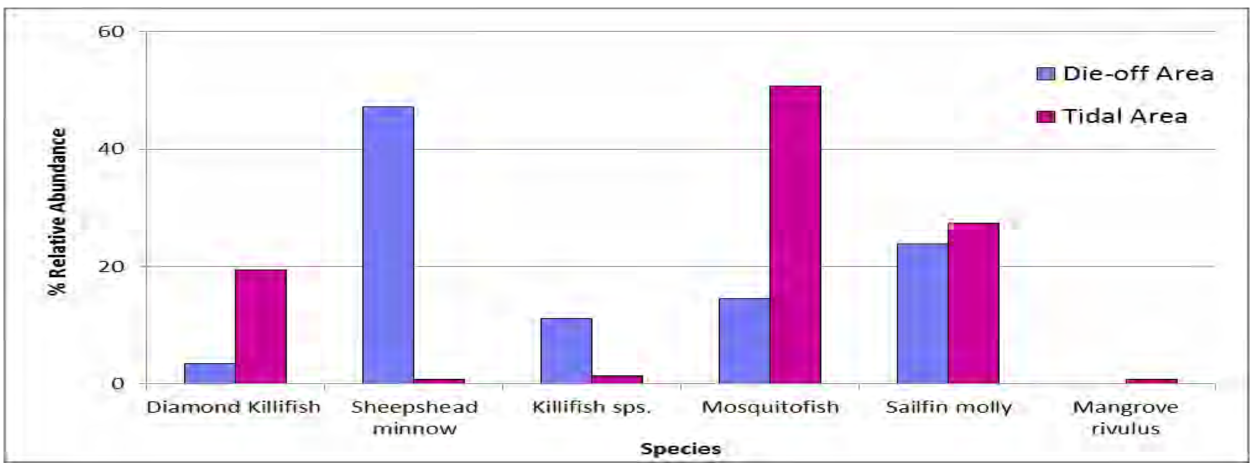
Plot 3D had a total of 18 saplings, comprised of 15 black mangrove and 3 white mangrove saplings (>50 cm) in October of 2017 (Table 2). Canopy cover was non-existent. Ground cover was comprised of 6 black mangrove and 1 white mangrove saplings; and 2 white mangrove seedlings (50 – 150 cm tall) within the four 1 m^2 quadrats. Mangrove seedlings covered an estimated 4% of the ground in restoration plot 3D during October of 2017.

Forty-seven mangrove trees were evaluated in October of 2017 within the two adjacent mangrove forest or reference plots. In reference plot 3A, 26 trees remain consisting of 3 stressed, and 23 very stressed black mangrove trees. Two black mangrove trees died and no new mangrove trees were recruited. Reference plot 4A had 19 living trees comprised of 4 stressed and 12 very stressed black mangroves; along with 1 stressed and 2 very stressed red mangroves. No mangrove trees died or were recruited in reference plot 4 (Table 1). Reference plot 3A had no mangrove saplings (>50 cm). In reference plot 4A, 35 saplings (>50 cm) consisting of 27 black mangrove, 5 red mangrove, and 3 white mangrove saplings were recorded (Table 2). Percent canopy cover decreased significantly in comparison to coverage in September 2016, primarily as a result of Hurricane Irma. Canopy cover was reduced to 11.8% and 29.4% in reference plots 3A and 4A respectively.

Ground cover consisted of 34 black mangrove, 4 red mangrove, and 18 white mangrove seedlings (<50 cm); and 8 black mangrove trees (>150 cm tall) in the four 1 m^2 quadrats sampled within reference plot 3A. Ground cover within the four 1 m^2 quadrats in reference plot 4A consisted of 28 black mangrove, 3 red mangrove, and 1 white mangrove seedlings (<50 cm); 7 black mangrove and 1 white mangrove sapling (between 50 – 150 cm tall); and 3 black mangrove trees (>150 cm). In October of 2017, vegetative ground cover was estimated to cover 1% and 16% of reference plots 3A and 4A respectively.

In October of 2017, five years post-construction, a total of 529 fish were collected in breder traps at reference (tidal) and restoration (die-off) sites. Five species of fish were caught within the 4 mangrove die-off sites. Sheepshead minnow (47%) was the dominant assemblage in the die-off restoration sites. Six different species of fish were caught within the 2 tidal reference sites and the dominant fish species was mosquitofish at 51% of the assemblage (Figure 19).

Figure 19: Phase 1a Fish Percent Relative Abundance 5 Years Post-Restoration

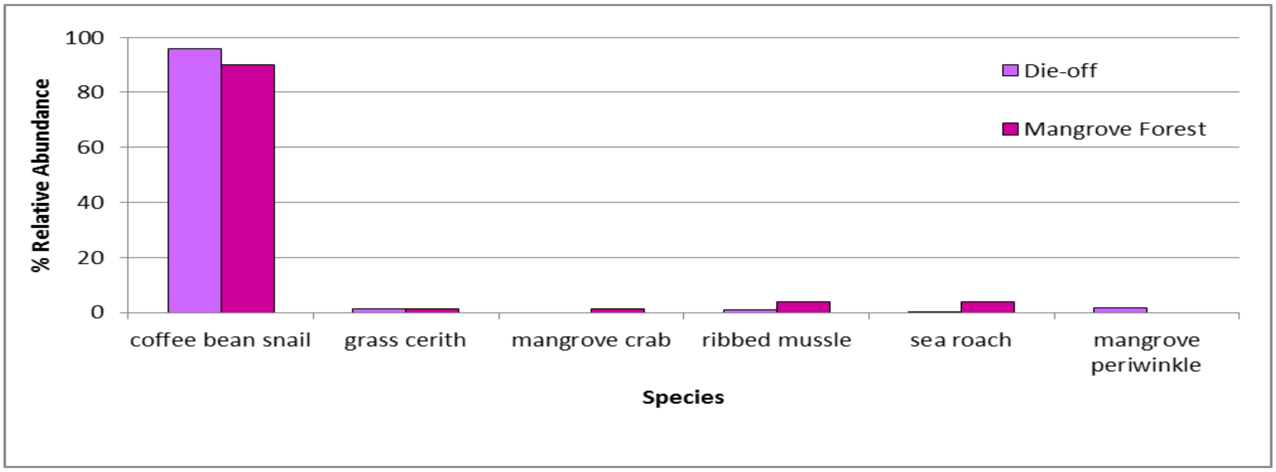


High water levels were present throughout the reference and restoration sites limiting visibility, likely accounting for diminishing numbers of both crab holes and ground dwelling invertebrates. Eleven crab holes were enumerated within the four 1 m^2 quadrats within plot 1D, while none could be discerned in restoration plot 2D. Only 1 crab hole was enumerated within the four 1 m^2 quadrats in reference plot 3A and no crab holes were seen within the four 1 m^2 quadrats in reference plot 4A. Plot 3D had 1 crab hole, the first time evidence of crab immigration was discovered in this die-off plot.

A total of 528 individual invertebrates comprised of five species were found in the four quadrats surveyed in plots 1D and 2D with a mean density of 66 individuals per square meter. Coffee bean snails were the dominant assemblage with plots 1D and 2D. Plot 3D had a total of 318 individual invertebrates comprised of two species within the 4 quadrats surveyed. Grass ceriths dominated this assemblage (99.7%), followed by a single Florida marsh clam (*Cyrenella floridana*), which made up the remaining 0.3% of the invertebrate assemblage found within plot 3D. This was the first instance where a Florida marsh clam was found within the study area (Figure 20).

In the fall of 2017, a total of 81 individual invertebrates comprised of five species were found in the 1 m^2 reference quadrats surveyed in plots 3A and 4A, (mean density of 10 individuals/m^2). An estimated 91% of the invertebrates present in the four quadrats sampled at reference plot 3A were coffee bean snails. The invertebrate assemblage within plot 4A consisted of 50% coffee bean snails, 25% sea roaches; and 25% mangrove mud crabs within the four 1m^2 quadrats (Figure 20). These reference plots were flooded causing difficulty in discerning invertebrates within the four quadrats. The decline in the number of individuals enumerated in the reference areas may be due to the effects of high water levels in combination with disturbance from Hurricane Irma. As far as aquatic invertebrates, ladder horn snail dominated the restoration (die-off) sites and coffee bean snails were dominant in the tidal reference sites.

Figure 20: Phase 1a Invertebrate Relative Abundance Determined within the 1 m^2 Quadrats in October 2017



65 Months Post-Restoration January 2018

In 2018, Hurricane Irma impacts were still affecting the results and are likely to continue to affect the condition of the reference forest, in particular, for many years. In January of 2018, data collected approximately 5 1/2 years since the pre-restoration baseline assessment revealed that a total of 11 mangrove saplings and 2 seedlings had attained a height to qualify as trees within the two die-off plots 1D and 2D since the October 2017 post-hurricane Irma assessment. A total of 259 trees were evaluated within plots 1D and 2D. As of January of 2018, there were a total of 131 living trees in plot 1D consisting of 53 black mangrove, 10 red mangrove, and 68 white mangroves trees. Plot 2D had a total of 45 black mangrove, 23 red mangrove, and 60 white mangroves (128 living trees) (Table 1). Sapling numbers increased within plots 1D and Plot 2D in comparison to sapling numbers present in October of 2017. Plot 1D had 145 black mangrove (of which 4 died), 13 red mangrove, and 69 white mangrove saplings (>50 cm tall and <150 cm tall) (of which 2 white mangrove saplings died). Plot 2D had 76 black mangrove (of which 10 died), 129 red mangrove (of which 4 died), and 36 white mangrove saplings (of which 4 died) (Table 2). Mangrove sapling recruitment increased in plots 1D and 2D, while tree recruitment has decreased since October of 2017. Plot 1D canopy coverage increased to 17.7%, approximately 6% more than last year. Canopy cover decreased to 23.5% in plot 2D, likely still attributed to Hurricane Irma.

The ground cover within the four 1 m^2 quadrats within plot 1D was comprised of 10 white mangrove, 5 black mangrove, and 1 red mangrove seedlings (<50 cm); 12 white mangrove, 5 red mangrove, and 22 black mangrove saplings (between 50 – 150 cm tall); and 6 white mangrove and 8 black mangrove trees (>150 cm tall) within the four 1 m^2 quadrats. Whereas ground cover, within the four 1 m^2 quadrats within plot 2D were comprised of 11 black mangrove, 22 red mangrove, and 5 white mangrove seedlings (<50 cm); 7 black mangrove, 11 red mangrove, and 2 white mangrove saplings (between 50 – 150 cm tall); and 6 black mangrove and 15 white mangrove trees (>150 cm tall). Saltwort has slowly disappeared. Vegetative covering was estimated 25% and 16%, decreasing since October of 2017 within the restoration die-off plots 1D and 2D respectively.

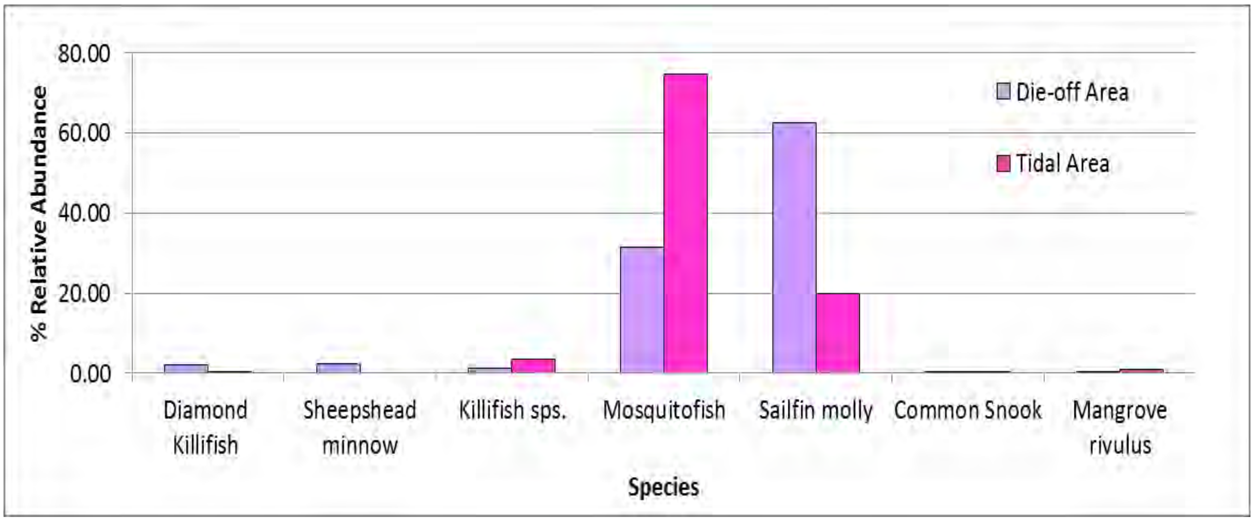
Plot 3D had a total of 20 saplings, comprised of 17 black mangrove and 3 white mangrove saplings between 50 – 150 cm tall) in January of 2018 (Table 2). Canopy cover was non-existent. Ground cover was comprised of 6 black mangrove and 1 white mangrove saplings and 1 black mangrove seedling (<50 cm) within the four 1 m^2 quadrats sampled. Additionally, saltwort was present, albeit sparse. Mangrove seedlings covered an estimated 13.8% of restoration plot 3D during January of 2018.

Forty-five mangrove trees were evaluated in January of 2018 within the two adjacent mangrove forest or reference plots. In reference plot 3A, 25 black mangrove trees remain. One black mangrove tree died and no new mangrove trees were recruited. Reference plot 4A had 17 living trees comprised of 14 black mangroves and 3 red mangrove trees. Two black mangrove trees died or none were recruited in reference plot 4A (Table 1). Reference plot 3A had no mangrove saplings (>50 cm). In reference plot 4A, 28 living saplings (>50 cm) consisting of 22 black mangrove, 5 red mangrove, and 1 white mangrove saplings that remain (Table 2). Five black mangrove and 2 white mangrove saplings (>50 cm) died since the last assessment in reference plot 4A. Percent canopy cover increased significantly in comparison to coverage in October 2017 within Plot 3A and stayed constant within plot 4A (35.3% and 29.4% in reference plots 3A and 4A respectively).

Ground cover was comprised of 6 black mangrove and 7 red mangrove seedlings (<50 cm) and 5 black mangrove trees (>150 cm tall) within the four 1 m^2 quadrats sampled within reference plot 3A. Ground cover within the four 1 m^2 quadrats sampled within reference plot 4A consisted of 9 black mangrove and 1 red mangrove seedlings; 3 black mangrove and 1 red mangrove saplings (between 50 – 150 cm tall); and 1 black mangrove tree. Ground cover was estimated at 12.5% and 4.3% of reference plots 3A and 4A respectively during January of 2018.

In February of 2018, a total of 1019 fish were collected in breder traps at reference (tidal) and restoration (die-off) sites. Seven species of fish were caught within the 4 mangrove die-off sites. Sailfin molly (63%) was the dominant assemblage in the die-off restoration sites. Six different species of fish were caught within the 2 tidal reference sites and the dominant fish species was mosquitofish comprising at 75% of the assemblage (Figure 21).

Figure 21: Phase 1a Fish Percent Relative Abundance 65 Months Post-Restoration



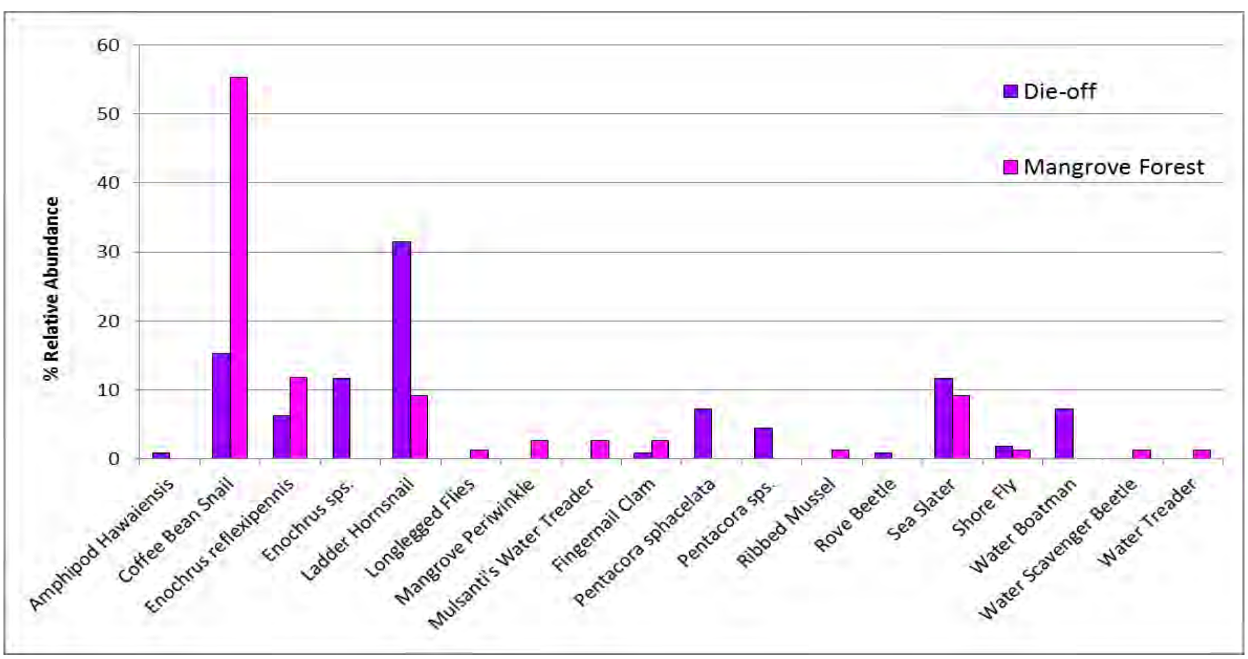
Nineteen and twenty-seven crab holes were enumerated within the four 1 m^2 quadrats within the restoration plots 1D and 2D respectively. A total of 34 crab holes were enumerated within the four 1 m^2 quadrats at plot 3A. No crab holes could be seen within the four 1 m^2 quadrats in reference plot 4A. Fine silt was present throughout plot 4A, which limited the ability to discern crab holes and is likely the reason for diminishing numbers. No crab holes were observed within the four 1 m^2 quadrats at plot 3D.

In January of 2018, a total of 847 individual invertebrates comprised of five species were found in the quadrats surveyed in restoration plots 1D and 2D, mean density of 106 individuals per square meter. Coffee bean snails dominated the assemblages at both of these restoration plots. There were a total of 447 grass ceriths within the four 1 m^2 quadrats surveyed in plot 3D (Figure 22). A total of 512 individual invertebrates comprised of four species were found in the 1 m^2 reference quadrats surveyed in plots 3A and 4A, mean density of 64 individuals per square meter. Coffee bean snails comprised the bulk of the invertebrate assemblage present in the 1 m^2 quadrats sampled at reference plots 3A and 4A. Fine silt was present throughout plot 4A. This may have limited visibility to discern invertebrates (Figure 22).

Figure 22: Phase 1a Invertebrate Relative Abundance Determined within the 1 m^2 Quadrats in February 2018

There were 12 different species of aquatic invertebrates sampled in both the mangrove die-off restoration and the mangrove tidal reference areas. Relative abundances ranged from 0.9% to 31.5% in the die-off restoration area and ladder horn snails were the dominant species. In the mangrove tidal reference areas relative abundance ranged from 1.3% to 55.3% and coffee bean snails were the dominant species (Figure 23).

Figure 23: Relative Abundance of Aquatic Invertebrates Sampled in April of 2018 67 Months Post-Restoration in the Phase 1a Study Area



77 Months Post-Restoration January 2019

Hurricane Irma was still impacting the reference area. The more mature trees are for the most part stressed or very stressed and are likely to be more susceptible to delayed mortality in subsequent years.

In January of 2019, data collected six and one-half years post-restoration revealed that a total of 56 mangrove saplings and 2 seedlings had attained a height to qualify as trees within the two die-off plots 1D and 2D since the January 2018 assessment. A total of 317 trees were evaluated within plots 1D and 2D. As of January of 2019, there were a total of 165 living trees in plot 1D consisting of 72 black mangrove, 10 red mangrove, and 83 white mangroves trees. Six mangrove trees died in plot 1D consisting of 3 black mangroves and 3 white mangroves. Plot 2D had a total of 52 black mangroves, 29 red mangroves, and 59 white mangroves (140 living trees). Six mangrove trees died in plot 2D consisting of 1 black mangrove and 5 white mangroves (Table 1). Sapling numbers decreased in plots 1D and 2D in comparison to sapling numbers present in January of 2018. Plot 1D had 136 black mangrove (of which 12 died), 15 red mangrove and 59 white mangrove saplings (>50 cm tall) (of which 6 died). Plot 2D had 48 black mangrove, 127 red mangrove, and 27 white mangrove saplings remaining within the entire plot. Twelve black mangrove, three red mangrove, and three white mangrove saplings died (Table 2). Plot 1D canopy coverage increased to 29.4 %, at least double the percentage since last year. Canopy cover increased to 76.5% in plot 2D, at least a threefold increase since last year.

The ground cover within the four 1 m^2 quadrats within plot 1D was comprised of 27 black mangrove, 26 white mangrove, and 1 red mangrove seedlings (<50 cm); and 24 black mangrove, 6 white mangrove, and 4 red mangrove saplings (between 50 – 150 cm tall); and 19 white mangrove, 15 black mangrove and 8 red mangrove trees (>150 cm tall) within the four 1 m^2 quadrats. Whereas ground cover, within the four 1 m^2 quadrats within plot 2D were comprised of 19 black mangrove, 11 red mangrove, and 10 white mangrove seedlings (<50 cm); 8 red mangrove, 3 black mangrove, and 1 white mangrove saplings (between 50 – 150 cm tall); and 11 black mangrove, 8 white mangrove and 3 red mangrove trees (>150 cm tall). Vegetative covering was estimated 47.5% and 19%, increasing since January of 2018 within the restoration die-off plots 1D and 2D respectively.

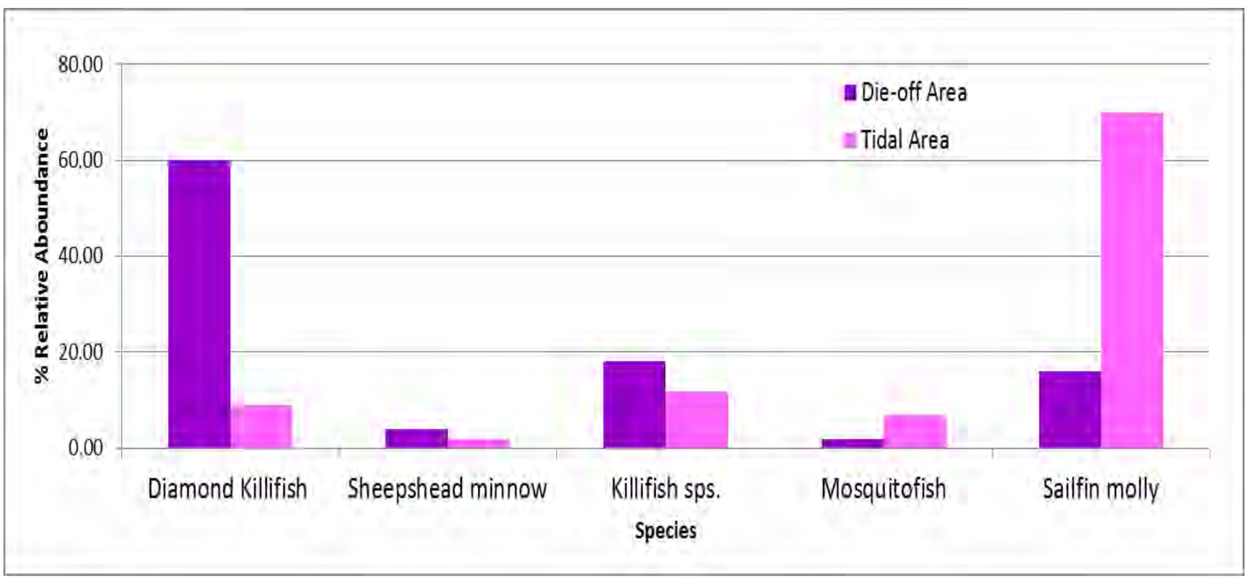
Plot 3D had 20 established saplings, of which 1 black mangrove sapling was recruited into the plot and excluding the 1 black mangrove that became a tree since the last assessment. (Table 2). Canopy cover was non-existent. Ground cover was comprised of 5 black mangrove and 5 red mangrove saplings and 13 black mangrove seedlings (<50 cm) within the four 1 m^2 quadrats sampled. Mangrove seedlings covered an estimated 22% of restoration plot 3D during January of 2019, increasing slightly since the last assessment. Percent canopy cover continued to increase in comparison to coverage in January of 2018 within plot 3A and increased slightly within plot 4A (52.9% and 35.3% in reference plots 3A and 4A respectively).

Forty-two mangrove trees were evaluated in January of 2019 within the two adjacent mangrove forest or reference plots. In reference plot 3A, 25 black mangrove trees remain. No mangrove trees died and no new mangrove trees were recruited. Reference plot 4A had 13 living trees comprised of 10 black mangrove and 3 red mangrove trees. Four black mangrove trees died and no mangrove trees were recruited in reference plot 4A (Table 1). Reference plot 3A had no mangrove saplings (>50 cm). In reference plot 4A, 38 saplings (>50 cm) consisting of 21 black mangrove, 16 red mangrove, and 1 white mangrove saplings remain and 9 black mangrove saplings died (Table 2).

Ground cover was comprised of 107 black mangrove and 6 red mangrove seedlings (<50 cm) and 2 white mangrove seedlings (<50 cm tall); and 5 black mangrove trees within the four 1 m^2 quadrats sampled within reference plot 3A. Ground cover within the four 1 m^2 quadrats sampled within reference plot 4A consisted of 6 red mangrove seedlings; 5 red mangrove and 4 black mangrove saplings (between 50 – 150 cm tall); and 3 black mangrove and 2 red mangrove trees. Ground cover was estimated at 15.6% and 32.5% of reference plots 3A and 4A respectively during February of 2019, an increase since the last assessment.

In March of 2019, (78 months post-restoration), a total of 251 fish were collected in breder traps at reference (tidal) and restoration (die-off) sites. Five species of fish were caught within the 4 mangrove die-off sites. Diamond killifish (60%) was the dominant assemblage in the die-off restoration sites. Six different species of fish were caught within the 2 tidal reference sites and the dominant fish species was mosquitofish at 51% of the assemblage. The same five species of fish were caught within the 2 tidal reference sites, albeit the composition differed. The dominant fish species was sailfin molly (70%) (Figure 24).

Figure 24: Phase 1a Fish Percent Relative Abundance 78 Months Post-Restoration

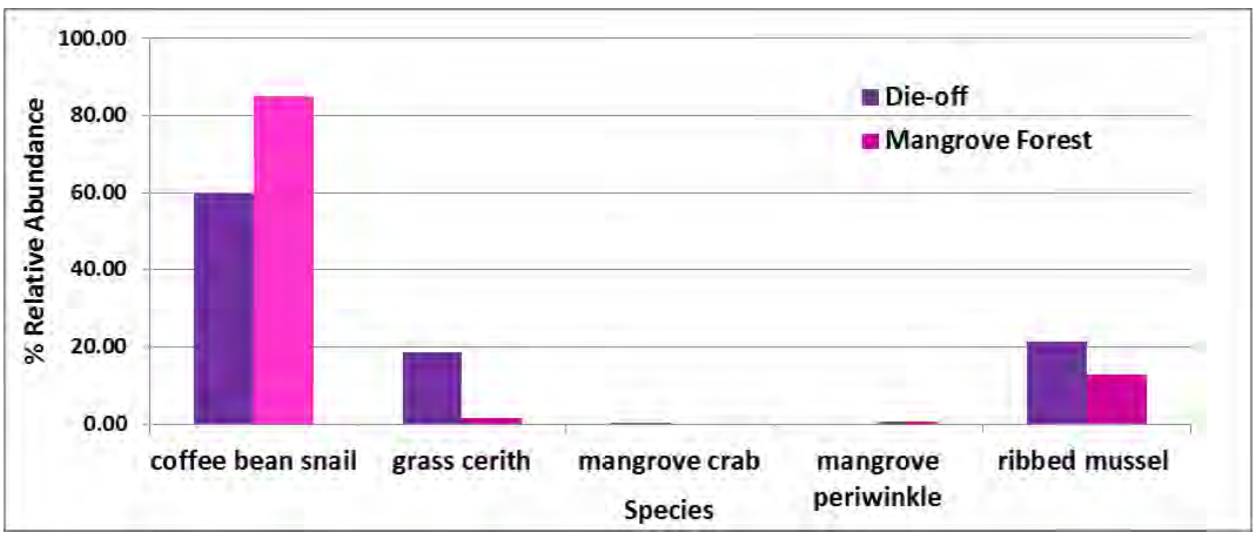


Fifty-three and sixty-six crab holes were enumerated within the four 1 m^2 quadrats within the restoration plots 1D and 2D respectively. A total of 104 crab holes were enumerated within the four 1 m^2 quadrats at plot 3A. Whereas, only fourteen crab holes could be discerned within the four 1 m^2 quadrats in reference plot 4A due to surface water inundation. Eighty-seven crab holes were observed within the four 1 m^2 quadrats at plot 3D.

A total of 699 individual invertebrates comprised of four species were found in the quadrats surveyed in plots 1D and 2D with a mean density of 87.4 individuals per square meter. This is still a positive change from pre-restoration and initial post-restoration sampling when there were fewer observed invertebrates and diminished species diversity within the restoration plots. The dominant invertebrate assemblage were coffee bean snails (72.6%) within the quadrats surveyed post-restoration at plots 1D, whereas, ribbed mussels made up the dominant assemblage (65.3%) in plot 2D. There were a total of 166 individual invertebrates within the four 1 m^2 quadrats surveyed in plot 3D. The dominant assemblage was comprised of grass ceriths (92.8%) (Figure 25).

In February of 2020, a total of 201 individual invertebrates comprised of four species were found in the 1 m^2 reference quadrats surveyed in plots 3A and 4A, mean density of 25 individuals per square meter. Coffee bean snails comprised the bulk of the invertebrate assemblage (70.8%) in the 1 m^2 quadrats sampled at reference plot 3A. Coffee bean snails (96.4%) within the 1 m^2 quadrats sampled at reference Plot 4A dominated the invertebrate assemblage (Figure 25).

Figure 25: Phase 1a Invertebrate Relative Abundance Determined within the 1 m^2 Quadrats in January 2019



RESULTS 89 MONTHS POST-RESTORATION 2020

Hurricane Irma impacts in combination with increased inundation periods is likely still affecting the mangroves and will likely affect the condition of the reference forest in particular for many years to come, as post-hurricane related tree mortality can last for many years. Everham and Brokaw (1996) predicted that it could take over five years for mortality rates to return to base-line conditions following a severe storm. However, Worley and Payton (2013) documented that hurricane effects could be felt within the forest for much longer.

Unfortunately, the spring fish and aquatic invertebrate sampling could not be completed this year as the optimum period for these sampling efforts occurred during the March – April 2020 period when the pandemic precluded close contact between staff that was needed to complete these sampling regimes.

Data collected approximately seven and a half years post-restoration and 8 years since the baseline assessment revealed that since January of 2019, 47 mangrove saplings and 2 seedlings had attained sufficient height to qualify as trees within the two die-off plots 1D and 2D. Overall, the restoration plots (1D and 2D) had a total of 354 trees that were evaluated, of which 10 mangrove trees died.

In February of 2020, 201 trees were living within in plot 1D. Of these trees, 11 black mangrove, 5 red mangrove and 25 white mangrove saplings and 1 black mangrove and 1 white mangrove seedling attained tree height since January of 2019. One of the original black mangrove trees and 6 of the original white mangrove trees died since the previous assessment. Eighty-three black mangrove trees remain living in plot 1D, of which 7 were stressed and 76 were relatively healthy. Fifteen relatively healthy red mangrove trees remain living in plot 1D. One hundred and three white mangrove trees remain living in plot 1D, of which 9 were stressed, 1 very stressed and 93 were relatively healthy (Tables 1 and 3). Plot 1D canopy coverage increased to 41.2%, an approximate 11.8% increase in coverage since February of 2019.

Plot 2D had 1 black mangrove, 4 red mangrove, and 1 white mangrove saplings that grew into trees and 2 black mangrove and 1 white mangrove trees died since the February of 2019 assessment. Fifty-one black mangrove trees remain living, of which 24 were relatively healthy, 22 were stressed, and 5 was classified as very stressed. Thirty-three red mangrove trees remain consisting of 30 relatively healthy and three stressed trees within plot 2D. No red mangrove trees died during the period between January of 2019 and February of 2020. A total of 59 white mangrove trees remain since the last assessment. Forty-one white mangrove trees were relatively healthy, 15 were stressed, and 3 was classified as very stressed. As of February of 2020 there were a total of 143 living trees in plot 2D (Tables 1 and 3). Canopy cover has slightly decreased since January of 2020 to 70.6% in February of 2020 a decrease of 5.9 percentage points in canopy coverage in plot 2D.

Sapling numbers decreased within plots 1D and 2D in comparison to sapling numbers present within the plots in January of 2019. In February of 2020, of the 132 black mangrove saplings (>50 cm tall), assessed within plot 1D, 7 died, 22 were stressed, 2 were very stressed, and 101 were relatively healthy. Twelve red mangrove saplings were assessed, of which 1 died, 1 was stressed and 10 were relatively healthy. Plot 1D also had 37 white mangrove saplings that were assessed of which 6 died, 10 were stressed, and 21 were relatively healthy. In February of 2020, 50 black mangrove saplings (> 50 cm tall) were assessed in plot 2D. Thirty-seven black mangrove saplings died, 1 was very stressed, 5 were stressed and 7 were relatively healthy. Of the 131 red mangrove saplings assessed, 47 died, 2 were very stressed, 10 were stressed, and 72 were relatively healthy. Twenty-six white mangrove saplings were assessed within plot 2D of which 21 died, 1 was very stressed, 1 was stressed, and 3 were relatively healthy (Tables 2 and 3).

The ground cover within the four 1 m^2 quadrats within plot 1D was comprised of 7 black mangrove and 8 white mangrove seedlings (<50 cm); and 14 black mangrove and 4 white mangrove saplings (between 50 – 150 cm tall); and 10 white mangrove and 13 black mangrove trees (>150 cm tall) within the four 1 m^2 quadrats. Whereas ground cover, within the four 1 m^2 quadrats within plot 2D was comprised of 1 black mangrove and 1 red mangrove seedlings (<50 cm); 13 red mangrove and 1 black mangrove saplings (between 50 – 150 cm tall); and 13 black mangrove, 1 white mangrove and 2 red mangrove trees (>150 cm tall). Saltwort is still absent. Plot 1D had a very slight increase in recruitment of mangrove saplings (+3 saplings) and mangrove trees (+3 trees) than occurred in 2019. Plot 2D had a very slight decrease in sapling recruitment (-4 saplings) and tree recruitment decreased (-12 trees) than occurred in 2019. Vegetative covering was estimated 51.3% and 36.3%, increasing since January of 2019 within the restoration die-off plots 1D and 2D respectively. Increase in ground cover could be due to hurricane recovery and/or an artifact of where the squares were randomly placed in relation to last year (Table 4).

Thirty-eight mangrove trees were evaluated in February of 2020 within the two adjacent mangrove forest or reference plots. Plot 3A is an example of a tree monoculture, as all of the trees within this plot are comprised of one single species, in this case black mangroves. However, sapling recruitment has signaled a potential shift, since new saplings consisted of both black mangroves and red mangroves. This could be an artifact of the increased hydroperiod present in this area more recently. No black mangrove trees died and no new mangrove trees were recruited since the last assessment in reference plot 3A. Twenty-five black mangrove trees remain consisting of 19 stressed and 6 very stressed mangroves. No mangrove trees were recruited between this assessment and January of 2019 within plot 4A and 1 red mangrove trees died. There were 12 living mangrove trees still present within plot 4A in February of 2020. Five black mangrove trees were stressed and 5 were very stressed. Additionally, plot 4A had 2 relatively healthy red mangrove trees within its boundaries (Tables 1 and 3).

Reference plot 3A recruited 4 mangrove saplings within the plot consisting of 1 black mangrove and 3 red relatively healthy mangrove saplings since the last assessment. One red mangrove sapling (>50 cm) died since the last assessment in reference plot 4A. Forty-six saplings remain within this plot consisting of 23 relatively healthy black mangrove saplings; 22 relatively healthy red mangrove saplings; and 1 relatively healthy white mangrove sapling (Tables 2 and 3). Percent canopy cover was slightly less in comparison to coverage in January of 2019 within plot 3A and was nonexistent in plot 4A (47.1% and 0% respectively).

In February of 2020, ground cover was comprised of 79 black mangrove and 5 red mangrove seedlings (<50 cm) and 7 black mangrove trees within the four 1 m^2 quadrats sampled within reference plot 3A. Ground cover within the four 1 m^2 quadrats sampled within reference plot 4A consisted of 1 red mangrove and 5 black mangrove seedlings; 3 red mangrove and 4 black mangrove saplings (between 50 – 150 cm tall); and 4 black mangrove trees. Ground cover was estimated at 23.8% and 37.5% of reference plots 3A and 4A respectively increasing since the last assessment (Table 4).

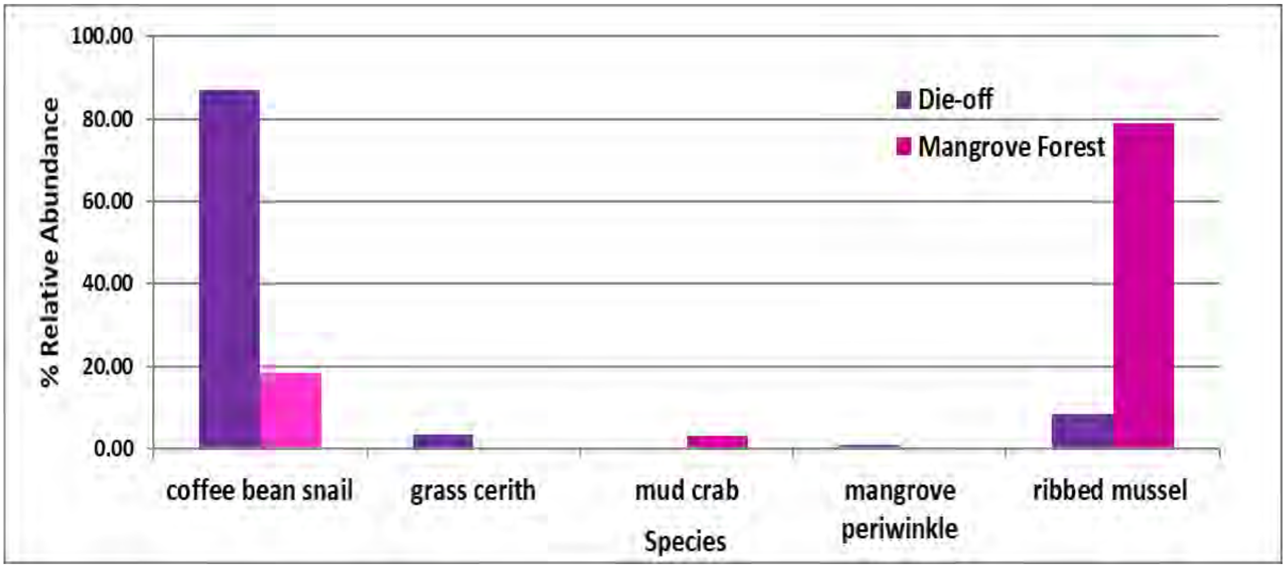
Plot 3D recruited 12 new black mangrove trees and 1 established black mangrove tree, all of which are relatively healthy since the last assessment. In February of 2020, there were a total of eight black mangrove saplings (50 – 150 cm tall) of which 7 were relatively healthy and 1 was stressed. Also present within this plot were 3 white mangrove saplings consisting of 1 relatively healthy, 1 stressed and 1 very stressed white mangroves. (Table 2). Canopy cover is still non-existent. Ground cover was comprised of 4 black mangrove trees; 5 black mangrove and 1 white mangrove saplings; and 9 black mangrove seedlings (<50 cm) within the four 1 m^2 quadrats sampled. Saltwort covered around 1/3 of the plot during this assessment. Mangrove seedlings covered an estimated 36.3% of restoration plot 3D during February of 2020, increasing since the last assessment (Table 4).

Sixty-eight and twenty-six crab holes were enumerated within the four 1 m^2 quadrats within the restoration plots 1D and 2D respectively. Only sixteen, six and eight crab holes were enumerated within the four 1 m^2 quadrats at plot 3A, 4A and 3D respectively. There was difficulty discerning crab holes within the reference plots due to surface water inundation, which interfered with visibility (Table 5).

A total of 225 individual invertebrates comprised of four species were found in the quadrats surveyed in plots 1D and 2D with a mean density of 28.3 individuals per square meter. This is still a positive change from pre-restoration sampling when there were fewer observed invertebrates and diminished species diversity within the restoration plots. However, the density was less than in 2019. The invertebrate assemblage consisted of approximately 92.5% coffee bean snails; 4% grass cerith; 2.5% ribbed mussel and 1% mangrove periwinkles within the quadrats surveyed post-restoration at plot 1D. Whereas, ribbed mussels made up the dominant assemblage at 58.3% followed by 41.7% coffee bean snails in plot 2D. There were a total of 23 individual invertebrates within the four 1 m^2 quadrats surveyed in plot 3D. This assemblage was comprised of 65.2% grass ceriths and 34.8% coffee bean snails (Table 6 and Figure 26).

In February of 2020, a total of 33 individual invertebrates comprised of four species were found in the 1 m^2 reference quadrats surveyed in plots 3A and 4A, mean density of 4.13 individuals per square meter. Ribbed mussels comprised the bulk of the invertebrate assemblage at an estimated 81.3% followed by 18.8% coffee bean snails present in the 1 m^2 quadrats sampled at reference plot 3A. The invertebrate assemblage within plot 4A consisted of only 1 individual mangrove mud crab that made up 100% of the assemblage during the 89th month assessment (Table 6 and Figure 26).

Figure 26: Phase 1a Invertebrate Relative Abundance Determined within the 1 m^2 Quadrats in February of 2020



RESULTS PHASE 1b DIE-OFF PRE-RESTORATION

Pre-restoration baseline assessments were performed in the Phase 1b die-off area in anticipation of restoration activities. Six mangrove monitoring plots were established in 2014 within the Phase 1b die-off to the south of C.R. 92 near Key Marco to discern baseline vegetative and epibenthic conditions along with aquatic faunal determinations for use in evaluating mangrove forest health and any ecological change post-restoration. Plots G2D, G10D, and G14D were located in the die-off area in the Phase 1b restoration project area and plots G4A, G7A, and G12A were originally located in an adjacent primarily healthy mangrove reference forest (Figures 5 and 7). Aquatic faunal data was collected for 2 years from 2014 through 2016, establishing a statistically valid dataset delineating baseline or pre-restoration conditions for later post-restoration comparison. Beginning in 2020, aquatic faunal sampling was reprised in anticipation of restoration beginning in the late spring of 2021. Mangrove and epibenthic monitoring continues on an annual basis.

In 2020, data collected reaffirmed that there were no living trees within these three die-off restoration plots and canopy and ground cover remain non-existent (Appendix 6). Crab holes and epibenthic species were not present within the three die-off plots, although water boatman and *Corixidae sps*. were prevalent throughout the Phase 1b die-off restoration area. Pre-restoration aquatic sampling occurred between 2014 through 2016. During this time a total of 14 aquatic invertebrate species were identified within the die-off area of the Phase 1b restoration site. The dominant species were water boatman (similar to pre-restoration results of the Phase 1a die-off site prior to restoration), followed by *Corixidae sps*. and no see-ums (*Ceratopogonidae*) (Figure 27). The Phase 1b reference tidal sites had a higher diversity of aquatic invertebrates, of which coffee bean snails, upside-down jellyfish (*Cassiopea sps.*), and ladder horn snails were more prevalent (Figure 28). Aquatic invertebrate sampling began again in August of 2020 in anticipation of restoration efforts being initiated in the spring of 2021 and are awaiting identification.

Figure 27: Normalized Abundance of Aquatic Invertebrates in the Phase 1b Restoration Die-off Area Pre-Restoration

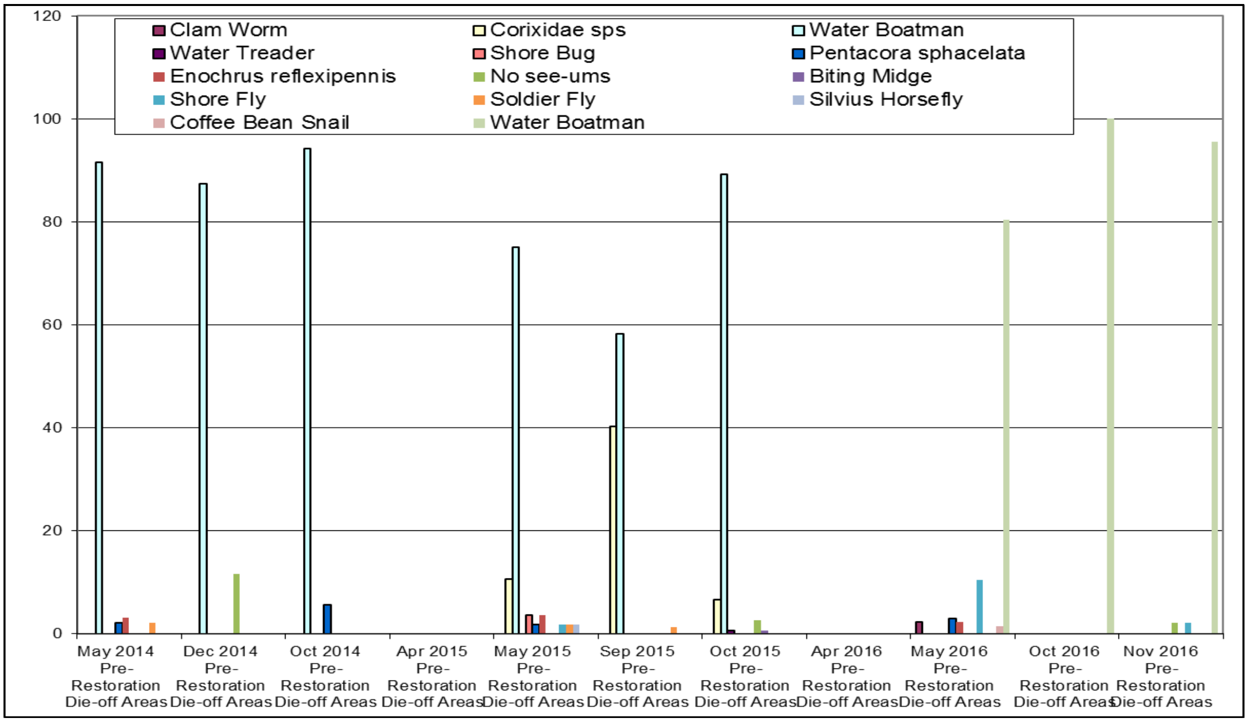
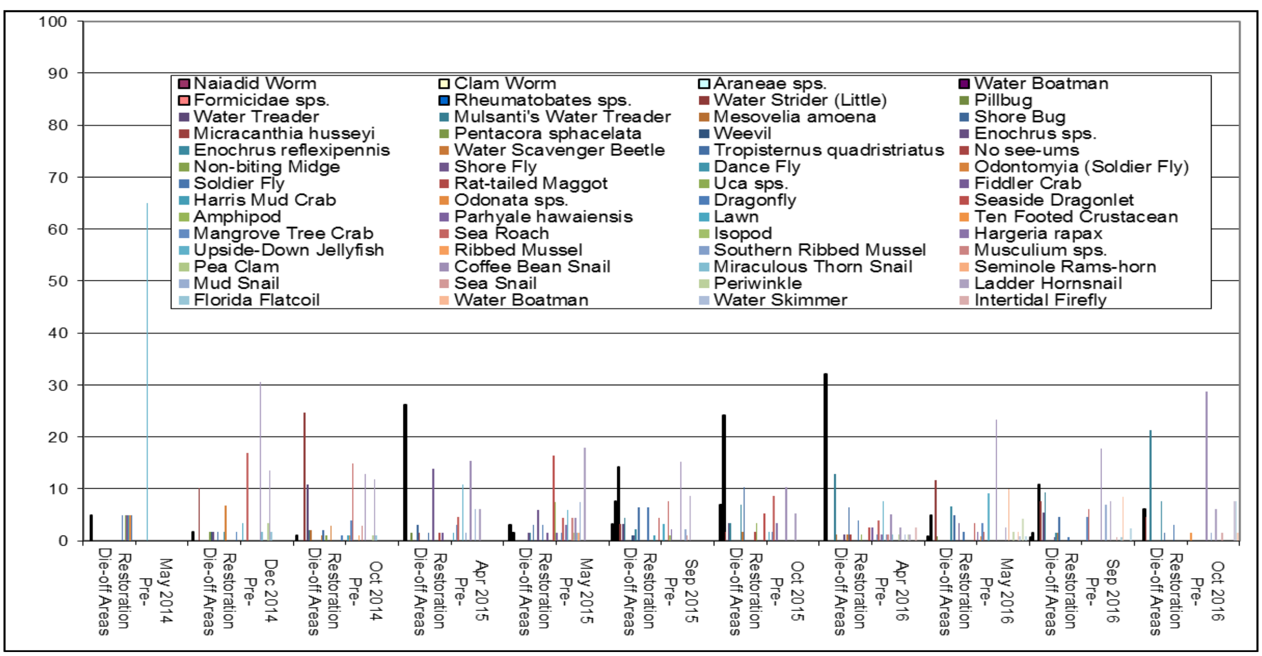


Figure 28: Normalized Abundance of Aquatic Invertebrates in the Phase 1b Reference Tidal Area Pre-Restoration



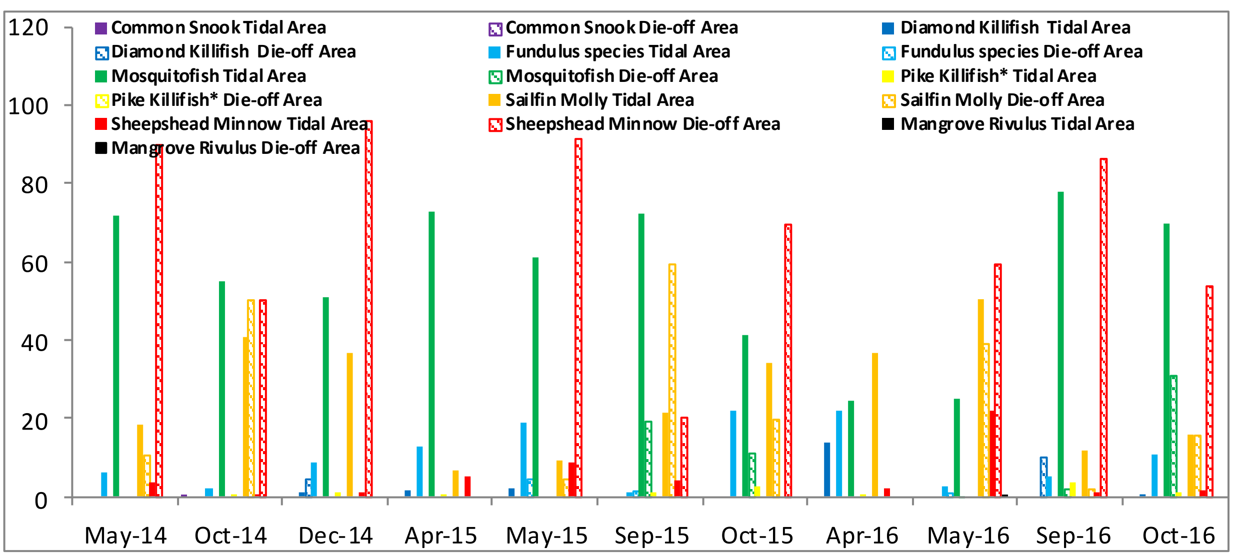
Only 18 mangrove trees were assessed in 2020 within what was once a relatively healthy reference mangrove forest adjacent to Phase 1b die-off area. Neither plots G4A nor G7A should be considered reference sites since the die-off has slowly penetrated these areas overtime. Plot G4A is on the edge of the die-off area and was established as a transitional plot between the die-off area and the adjacent mangrove forest. However, overtime the die-off has expanded into this area. Only 1 black very stressed mangrove tree remains within this plot. No saplings were recruited this year. At present, there are no saplings within plot G4A (Table 7). Two black mangrove trees were assessed within plot G7A of which 1 died and 1 was very stressed and dying. There has been no sapling recruitment within plot G7A, which remains waterlogged and is being absorbed into die-off area (Table 7). A total of 15 mangrove trees were assessed within reference plot G12A, consisting 2 red relatively healthy mangrove trees; 6 black mangrove and 6 red stressed mangrove trees; while 1 black mangrove tree died. Within the confines of reference plot G12A, 43 saplings were assessed in February of 2020 consisting of 1 black newly recruited mangrove sapling and 42 red mangrove saplings, 21 of which are newly recruited. Of the 43 saplings, 11 are stressed (of which 1 was a black mangrove and 10 were red mangrove saplings) and 32 are relative healthy red mangrove saplings. No saplings have died since the last assessment within plot G12A (Table 7). In 2020, percent canopy cover dramatically decreased in comparison to the 2018 assessment and continues to decrease in comparison to the 2019 assessment (0%, and 94%) in reference plots G4A, and G7A respectively) (Table 7). It was hoped that this decline was due to the lingering effects of Hurricane Irma. However, continued deterioration is indicative that water impoundment is enabling die-off expansion into this area. Plot G12A had a percent canopy cover of 59%, and could still be indicative of a slow post-hurricane forest recovery or the spread of mangrove deterioration into this area. The number of trees and established saplings and seedlings decreased particularly in reference plots G4A and G7A, which lost 80% and 94% of their trees respectively between 2014 and 2020. In 2018, losses were due to Hurricane Irma along with deteriorating conditions. These plots have become more transitional in nature overtime and are slowly being absorbed into the die-off. Water inundation has increased overtime and the tree losses in plot G7A were primarily a result of Hurricane Irma and exacerbated by waterlogging during this assessment period. Only 1 very stressed black mangrove tree remains in plot G4 and 1 very stressed black mangrove trees remain in plot G7A. Similar to plot G7A during the 2018 and 2019 assessments, plot G4A suffered a catastrophic loss in its understory as all of the established seedlings succumbed during this period. Neither of these plots had any propagule recruitment and conditions continue to rapidly deteriorating due to extended hydroperiods. Plot G12A, on the other hand has lost 18% of its trees since 2014 and 1 black mangrove tree died from lingering effects of Hurricane Irma. The remaining 12 out of 14 trees are primarily stressed from the hurricane, but none of the 21 red mangrove saplings that were present last year died and 21 new red saplings and 1 new black mangrove sapling were recruited this year.

There were no crab holes or invertebrates found within the four 1 m^2 quadrats within the Phase 1b restoration plots (Tables 8 & 9). Plot G4A was devoid of crab holes within the 4 quadrats in 2020 (Table 8) and invertebrates found within the 1 m^2 quadrats consisted solely of 1 grass cerith (Table 9). Ground cover consisted only of one black mangrove seedling (< 50 cm tall) in the four 1 m^2 quadrats sampled within plot G4A. Some algae ≤5% covered the ground in plot G4A within each of the four 1 m^2 quadrats (Table 10). Plot G7A had 4 crab holes (Table 8) and only 10 grass ceriths were enumerated within the four 1 m^2 quadrats (Table 9). Ground cover consisted of only

1 black mangrove tree in the four 1 m^2 quadrats sampled within reference plot G7A (Table 10). Thirty-nine crab holes were present within the four 1 m^2 quadrats within plot G12A and 34 invertebrates were enumerated consisting of 29 coffee bean snails, 3 ribbed mussels and 2 mangrove periwinkles (Tables 8 and 9). Ground cover within the four 1 m^2 quadrats in reference plot G12A consisted of 15 black mangrove seedlings and 5 red mangrove seedlings (<50 cm tall), 6 red mangrove and 1 black mangrove saplings (> 50 cm and <150 cm tall), and 1 red mangrove tree (>150 cm tall) (Table 10). Ground cover was estimated at 0.1%, 6.3% and 19.5% within reference plots G4A, G7A and G12A respectively during January of 2020 (Table 10). Reference plots are still exhibiting signs of water stress as the die-off continues to expand into some of the transition and reference areas. Plots G4A and G7A are particularly vulnerable to becoming part of the encroaching die-off as indicated by the strong odor of reduced soils in their vicinity. Additionally, Hurricane Irma is still affected all of the plots in this area, further stressing the system.

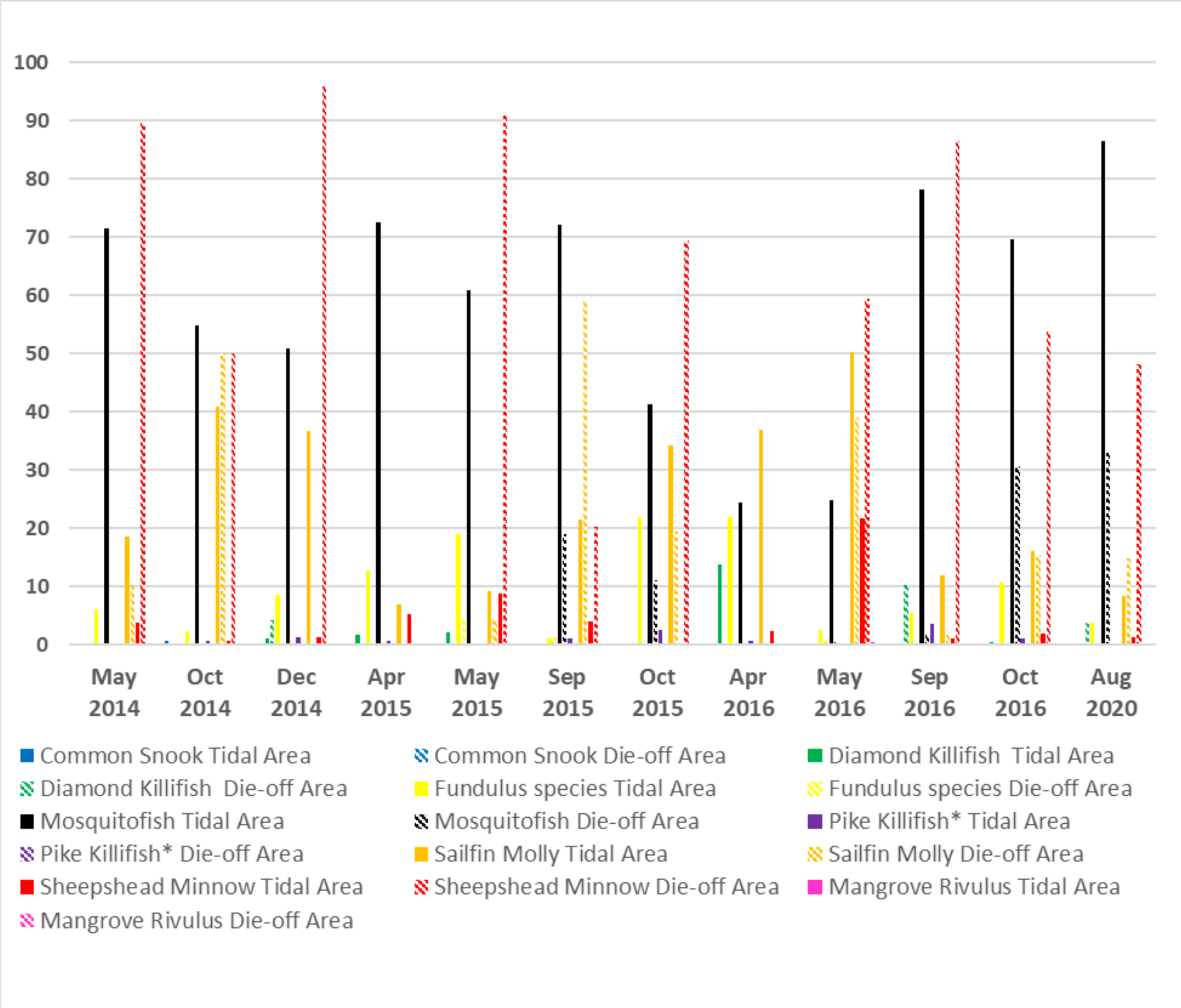
The baseline pre-restoration aquatic invertebrate and fish assessments in Phase 1b area were suspended in 2016 since enough information has been gathered to ascertain baseline population statistics pre-restoration or until the restoration becomes a reality. During the aquatic assessment in October 2016, a total of 3 species were captured within the mangrove die-off sampling sites, with sheepshead minnow dominating the assemblage. Mosquitofish and sailfin molly were also caught within the Phase 1b die-off area, but only as occasional visitors. A total of 7 fish species were collected in the Phase 1b tidal reference sites and the dominant assemblage consisted of mosquitofish. In addition, sailfin molly and *fundulus* species were captured within the reference tidal areas in moderate numbers, whereas sheepshead minnows, diamond killifish, and pike killifish seemed to be only occasional visitors to the reference areas. As anticipated, the tidal areas had more diversity than the die-off areas (Figure 29).

Figure 29: Fish Relative Abundance Pre-Restoration Phase 1b 2014-2016



In 2020, fish sampling resumed in anticipation of restoration commencement in the spring of 2021. In August 2020, a total of 4 species were captured within the mangrove die-off sampling sites, with sheepshead minnow closely followed by mosquitofish dominating the assemblage. Sailfin molly and diamond killifish were also caught within the Phase 1b die-off area, but only as occasional visitors. A total of 4 fish species were collected in the Phase 1b tidal reference sites and the dominant assemblage consisted of mosquitofish. In addition, sailfin molly and *fundulus* species and sheepshead minnows were captured within the reference tidal areas and seemed to be only occasional visitors to the reference areas. Over the years the tidal areas had more diversity than the die-off areas (Figure 30).

Figure 30: Fish Relative Abundance Pre-Restoration Phase 1b Overtime



DISCUSSION

Black mangrove die-offs that are situated near roads and development are usually the result of rapid environmental alterations (Jimenez and Lugo, 1985). Unfortunately, this is not an unusual event in mangrove systems that are adjacent to anthropogenic activities. The chief cause of a die-off in these cases, including the Fruit Farm Creek mangrove die-off, is the result of altered hydrology. Normal hydrologic flow was and still is altered by diversion of stormwater runoff into the mangrove system after Key Marco, Stevens Landings, C.R. 92, and the road to Horr's Island (Key Marco) were built next to and even bisected the mangrove forests. The placement of structural impediments (roads and buildings) interfered with tidal flushing and both surface and groundwater flow was compromised. Urban encroachment adjacent to estuarine areas often interrupts the natural tidal flow by preventing tides from entering and exiting the adjacent estuary (Menon, et. al., 2000). This causes water impoundment that can result in mangrove die-offs, similar to the Fruit Farm Creek mangrove die-off.

Hurricane Irma

This assessment was performed approximately 3 years since Hurricane Irma hit the study area. Initial impacts of the hurricane were documented in October of 2017, approximately one month after Hurricane Irma. Both the mangrove stands within the restoration and reference areas both north and south of C.R. 92 were adversely impacted. As expected, defoliation and branch loss were the most visible changes to the mangrove areas, along with the death of more mature trees. However, individual tree recovery will determine the forests viability long-term, since mangrove trees often take years to decades to recover or succumb to injuries following a hurricane like Irma. The path to forest recovery after a hurricane is dependent upon the severity of the storm damage and localized resource availability. Severe hurricanes (Category 4 and 5 storms), like Hurricane Irma, tend to produce gaps in forest structure and recovery can take decades.

Larger and taller mangrove trees are usually more susceptible to severe damage and thus suffer higher mortality rates (Baldwin, et. al., 2001, Smith and Robblee, 1994). Data assessments directly following Hurricane Irma suggest that this was the case in Fruit Farm Creek. Hurricane Irma had much more impact on the Phase 1a and Phase 1b reference areas (plots 3A & 4A; plots G4A, G7A and G12A, respectively) than the Phase 1a restoration area (plots 1D, 2D, 3D). The larger more mature mangrove trees present in the reference areas were hit the hardest. The Phase 1a restoration area plots north of C.R. 92 fared much better post-hurricane. These trees and saplings were recently recruited into the die-off area, are young and supple, able to bend instead of break. Plots 1D and 2D have already rebounded but are now stressed by the natural forest evolution of inter and intraspecies competition for resources.

Many of the mature mangrove trees within the study area were killed outright, snapped in half, bent, defoliated, lost branches, or uprooted. This was reflected in the condition of mangroves within reference plots 3A and 4A directly after the hurricane. The majority of these trees were stressed, very stressed, or dying, and two mangroves were killed instantly. Twenty-nine months following Hurricane Irma, tree are continuing to die as a direct or indirect result of the storm, particularly in the reference area. Water inundation has also been a problem in areas of lower elevation, causing mangroves to waterlog. Some of these trees died as their mortality was hastened or exacerbated by Hurricane Irma. Only time will tell the extent of the mortality from Hurricane Irma as mangroves are often susceptible to delayed mortality for decades following a major stressor.

Following Hurricane Irma the tree canopy was opened up dramatically as most of the leaves were stripped from the trees in both the reference and restoration areas. As a result, it was anticipated that mangrove seedling recruitment would begin anew, rejuvenating the mangrove forest. However, to date that has not occurred in the reference area, and the trees and propagules continue to exhibit signs of stress. Mangroves have adapted to handle hurricanes. The forest will be rebuilt overtime, provided there is enough of a time gap between storms, seed sources are available, standing water and inundation is abated, and the soil conditions are able to support new growth.

Mangrove Floristic Characteristics

Mangrove floristic characteristic data collected pre-restoration at the Fruit Farm Creek Phase 1a Mangrove Die-off in February of 2012 served as a baseline to evaluate whether or not the Phase 1a restoration project is a success over time. Prior to restoration efforts, this restoration (die-off) site no longer had no living mangrove trees. During the wet season, the entire die-off area was underwater for months at a time and during the dry season, the ground became overly dried out and cracked. Prior to restoration, only dead mangrove stumps remained in the area that was once a vast black mangrove forest.

To date, post-restoration results in the Phase 1a study die-off area indicate that restoration efforts are yielding positive results (Appendix 2). The construction of tidal channels increased tidal flushing and successfully removed a substantial amount of standing water (Appendix 7). As water levels subsided, the die-off area became suitable for vegetation establishment. Patches of saltwort began to establish within the Phase 1a die-off in areas that had higher topography a few months post-restoration. Saltwort absorbs large quantities of water and is often present as a precursor to mangrove recruitment (Proffitt and Devlin, 2005). This succulent plant flourished in the first years following restoration in southern areas of the die-off area paving the way for subsequent successful mangrove establishment. The recruitment of saltwort into the die-off area supported the hypothesis that if the impounded water is drained off, the die-off area had a good chance of recovery, since the soils when given a proper drainage and tidal flow could support life. Numerous mangrove seedlings became established within two years post-restoration at restoration plots 1D and 2D and many of the saplings attained tree status within these restoration plots within four years post-restoration. Mangroves slowly began to outcompete saltwort species and over time mangroves superseded saltwort as the dominant vegetative species. The southern section of the Phase 1a die-off, despite a slight setback in 2017 by Hurricane Irma, is still exhibiting signs of recovery.

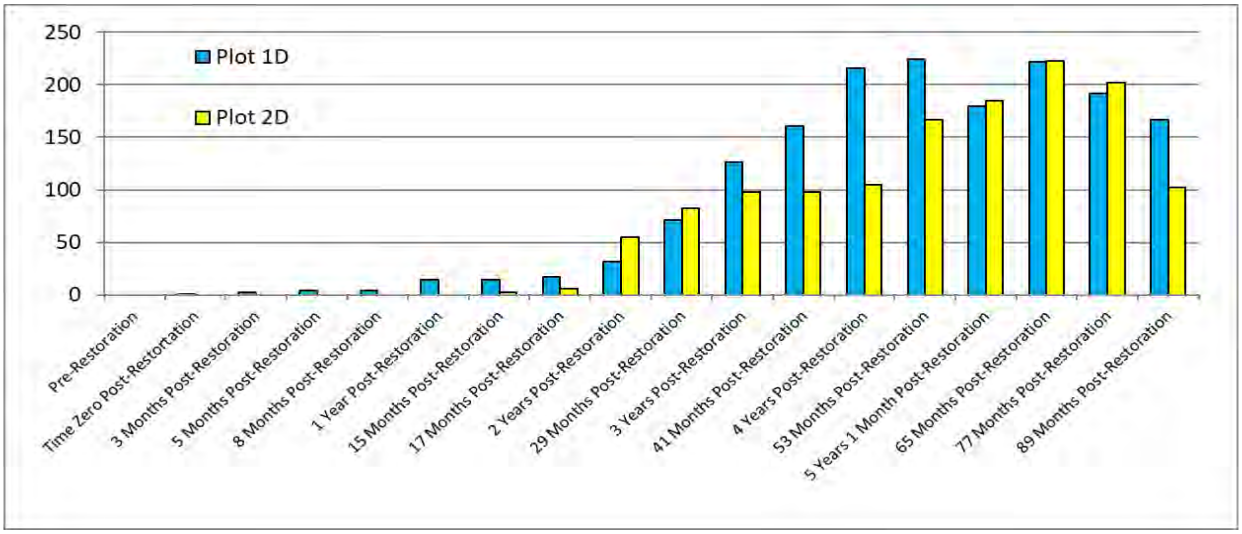
Different areas within the die-off are recovering at different rates. Plot 1D, as expected, had the first signs of mangrove recruitment. Pre-restoration this plot had slightly higher elevation and some established saltwort was present, which likely jump-started the restoration process. These two factors allowed plot 1D to initially begin to show signs of mangrove recovery earlier (within less than a year post-restoration) than plot 2D, which initially began to support sapling establishment 15 months post-restoration. Plot 2D initially recovered more slowly, since this plot had more standing water and was devoid of any vegetation pre-restoration. However, as time passed plot 2D superseded plot 1D due to faster maturity rates, possibly indicative of improved localized conditions, which favored mangrove vigor.

Mangrove sapling recruitment proceeded at a slow but steady rate in plot 1D through the first seventeen months post-restoration. Saplings more than tripled between the 2nd and 3rd year post-restoration and almost doubled between the 3rd and 4th year post-restoration. Recruitment naturally slowed down after the 4th year post-restoration. Sapling numbers were leveling out, since competition for space was now a factor. Five years post-restoration sapling recruitment decreased, reflecting both the impact of Hurricane Irma and resource competition. Sixty-five months post-restoration, plot 1D sapling numbers increased to levels similar to pre-Irma levels and then subsequently declined as saplings grew into trees and competition for space increased. Eighty-nine months post-restoration mangrove tree and sampling recruitment only slightly increased since the last assessment in 2019. This is further indication that competition for resources is favoring the growth of existing trees and the forest recruitment phase is slowing.

Plot 2D initially had a slower rate of recruitment in the early months post-restoration, in comparison to plot 1D. However, between 17 months post restoration and year 2 post-restoration, the recruitment rate rose sharply within plot 2D. The number of established saplings in plot 2D briefly surpassed the number of saplings within plot 1D by the fall of 2014. Recruitment subsequently slowed down between the 2nd and 3rd year post-restoration. Sapling recruitment leveled off between post-restoration years two and four, prior to increasing dramatically between year 4 and 53 months post-restoration. In October of 2017, sapling numbers in plot 2D again briefly surpassed plot 1D, as saplings in this plot were not as affected by Hurricane Irma. Sixty-five months post restoration plots 1D and 2D had similar a number of recruits, but the saplings within plot 1D exhibited more stress than saplings within plot 2D. Sapling numbers, similar to plot 1D, have subsequently declined during the latest assessment as saplings grew into trees and competition for space was high in plot 2D. It is expected that sapling recruitment will decline as the trees grow and outcompete their younger brethren within the restoration area. During this assessment, plot 2D had a very slight decrease sapling recruitment (Table 2 & Figure 31). The plot has likely started to stabilize and is maturing into a mixed mangrove forest barring unforeseen events.

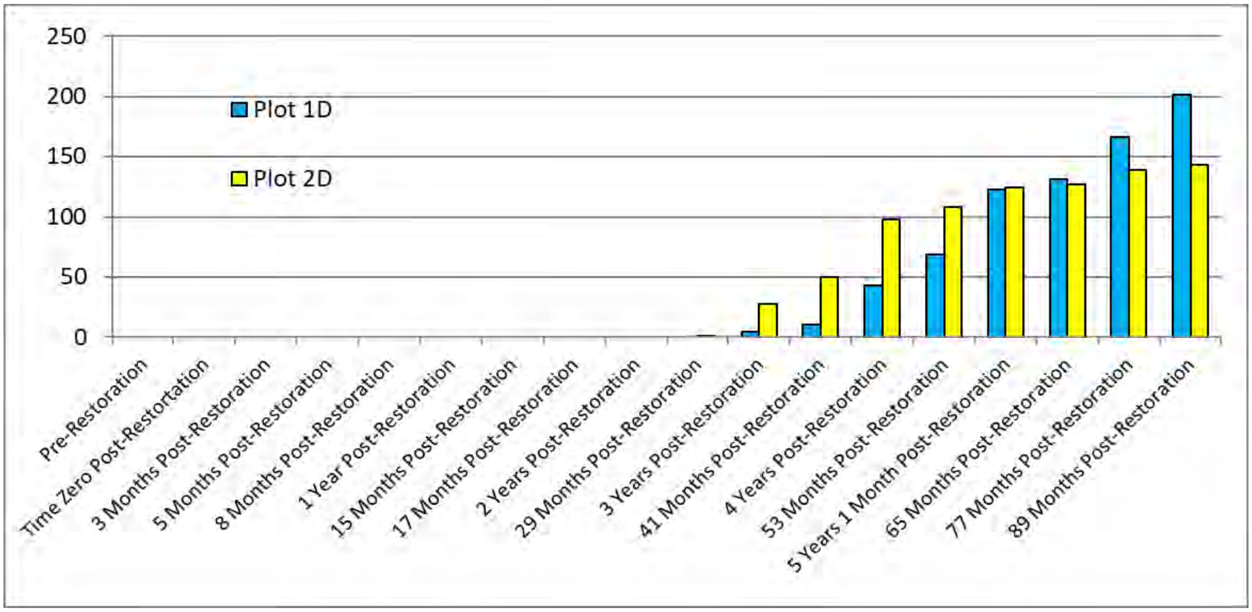
Many saplings became trees beginning in the fall of 2015 within both restoration plots. Plot 1D saplings and seedlings became trees at a steady rate, whereas saplings and seedlings grew into trees more rapidly within plot 2D. During the third year, more saplings attained tree height within plot 2D than in plot 1D. Tree recruitment continued to increase in both plots overtime, albeit plot 2D continued to surpass plot 1D in total number of trees prior to the 65 month assessment. Both die-off plots were recovering, although the mangrove trees with plot 2D were exhibiting more signs of stress than those trees within plot 1D. Seventy-seven months post-restoration, more trees were present within plot 1D than within plot 2D and tree recruitment during this assessment declined. Competition for resources is likely causing an increase in stress within both restoration plots as the larger hardier trees out compete the smaller trees. This is normal forest maturation. Trees are dominating over saplings and seedlings, as competition for space and resources becomes a premium. Barring unforeseen circumstances, as the restoration plots become crowded with trees, real estate will become scarce. The presence of so many mangroves within a small area will cause some of the individual trees and saplings to show signs of stress, due to competition for space and resources. When this occurs, the taller and healthier mangroves will outcompete their siblings and recruitment rates will drop. Sapling and smaller tree mortality will increase, as the larger and the healthier trees will shade out new recruits as the plots mature.

Figure 31: Mangrove Saplings Overtime Phase 1a Die-off



The decline in tree numbers within restoration plots 1D and 2D is likely indicative that an asymptote has been or will be soon be reached. Recruitment tapers off and the forest enters a stage where competition between existing trees for resources becomes the norm as the forest matures to support larger but less numbers of trees (Tables 1 and 3 & Figure 32).

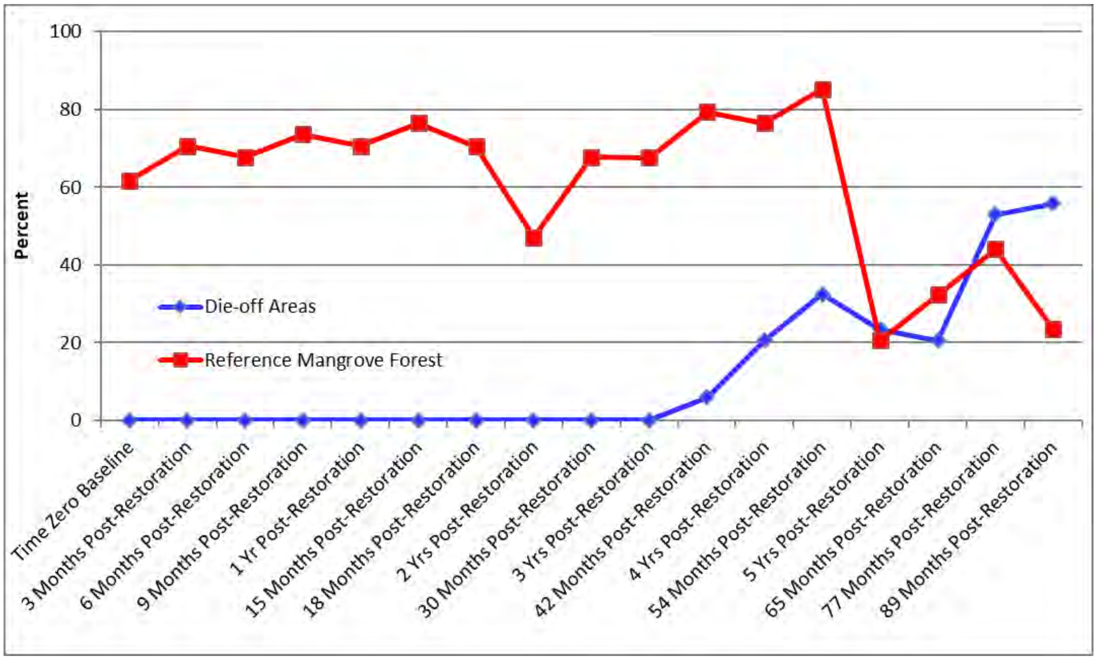
Figure 32: Mangrove Trees Overtime Phase 1a Die-off



The canopy has begun to form in the Phase 1a restoration area and reflects the number of trees that attained a height taller than the observer and the fullness of the tree canopy. The canopy started to form 3½ years post-restoration and peaked briefly in the restoration plots 4½ years post-construction. In 2017, Hurricane Irma defoliated some of the trees re-opening the canopy. Canopy coverage reflected the storms impact on the forest as the mean percentage decreased in the restoration plots. This slight decrease in canopy cover allowed more sunlight to penetrate down toward the forest floor, which favored propagule recruitment. Following Hurricane Irma, the canopy has begun to reform in the restoration area plots faster than at the reference plots. As of this assessment, the canopy in the restoration plots has attained an estimated mean of 55.9% (Figure 33).

Mean canopy coverage in the reference plots was reflective of a more mature mangrove forest and was relatively stable (~60%) for the majority of the time these plots were assessed through February of 2017. In October of 2017, 5 years post-restoration the tree canopy dramatically opened up in the reference area. The older trees were heavily impacted from Hurricane Irma, which almost completely destroyed the tree canopy. There has been some canopy reformation due to tree coppicing post Hurricane Irma. In 2020, percent canopy cover is possibly trying to stabilize within plot 3A. However, plot 4 is further deteriorating as the canopy coverage was practically nonexistent. There is concern regarding whether or not the canopy will be able to reform to pre-hurricane levels as other stress factors could limit response in some areas of the reference forest Overall the mean canopy coverage within restoration area continues to decline since the last assessment (Figure 33). There is even a question now of the utility of this area as a reference forest, although the hurricane was a natural occurrence. The resilience of youth protected the restoration area from much of the destructive force of Hurricane Irma. This was not the case in the reference area where larger trees received the full force of the hurricane and were decimated.

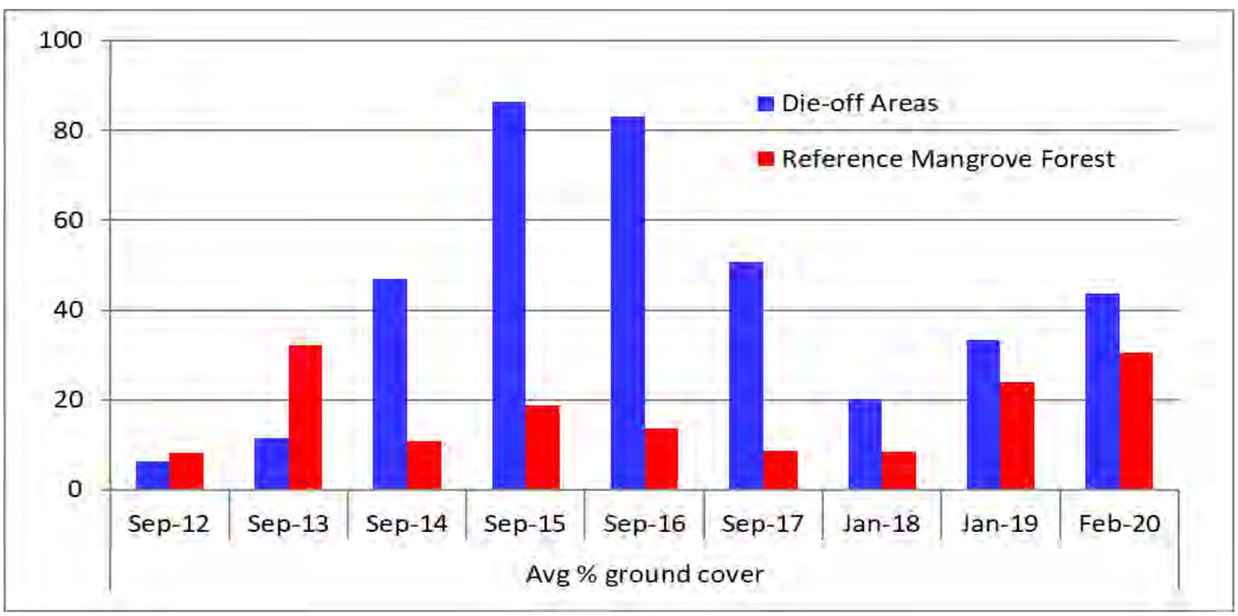
Figure 33: Phase 1a Mean Percent Cover for Restoration and Reference Plots Overtime



Ground Cover

Vegetative ground cover increased overtime in the Phase 1a restoration die-off area as batis and mangrove seedlings become re-established. A sharp increase in percent ground cover began approximately 2 ½ years post-restoration, peaked at approximately 3 years post-restoration, and then slowly receded (typical bell curve). The decrease in ground cover that began 4 years post-restoration is a good indicator that the area is recovering. Vegetative ground cover, as expected, was minimal within the reference areas due to forest maturity until the 2018 assessment when Hurricane Irma decimated the tree canopy allowing sunlight to penetrate the forest floor encouraging vegetative growth. There was an increase in percent ground cover during the last two assessments within both the restoration and reference areas. Ground cover should ultimately decrease as the canopy is formed when seedlings grow into trees (Figure 34). Saltwort has been absent from the restoration plots for approximately 2 years, which is another good indication that the mangrove forest is slowly maturing since saltwort species are generally precursors to mangroves.

Figure 34: Phase 1a Mean Percent Ground Cover in the Restoration and Reference Plots Overtime within each of the 4 Sampled Quadrats



Fish

Areas within the die-off area that fish utilized pre-restoration were poorly oxygenated shallow water pools that exhibited extreme seasonal salinity fluctuations and high temperatures. Some fish species are able to rapidly colonize these types of areas and are better adapted to survive in poor water quality conditions (Trexler, et al., 2003). However many species are incapable of tolerating these extremes and tended to frequent the tidal areas where water quality was improved and subject to less extreme environmental fluctuations. Pre-restoration, fish species that could survive in stagnant water within the die-off areas were capable of air breathing, tolerating low dissolved oxygen levels, extreme salinity fluctuations, high temperatures, and frequent dry down. Pre-restoration sheepshead minnows dominated, accounting for 88% of the assemblage. These fish can survive in stagnant shallow pools and high salinity. They tend to hide in the mud and are able tolerate a wide range temperature present in a die-off area. Forty-two months post-restoration there appeared to be a shift in the fish species assemblage that frequented the die-off areas. Sheepshead minnow abundance began to comprise less of the assemblage. Sixty-six months post-restoration sailfin molly and mosquitofish began to dominate the fish assemblage in the die-off areas. The remaining fish assemblage consisted of killifish, sheepshead minnow, common snook and mangrove rivulus.

Hurricane Irma did impact the fish assemblages within the restoration die-off sites and the reference sites. Tidal surges resulted in siltation and lower dissolved oxygen levels. No significant discernable trends other than physiological constraints, extreme weather and storm surge events seem to be guiding fish occupancy in the die-off and tidal areas of the Phase 1a site. In 2019, seventy-eight months post-restoration, sheepshead minnow and mosquitofish comprised the lower percentages and diamond killifish (60%) and other killifish species (18%) dominated the assemblage in the restoration die-off area. The remaining fish assemblage in the restoration area was comprised of sailfin molly (Figure 35). The shift in dominance overtime is perhaps indicative that hydrologic restoration not only benefits the mangrove forest but the aquatic community as well. There were no significant changes in community structure within the tidal reference areas overtime in the Phase 1a site. (Figure 36). Unfortunately, restrictions imposed by the COVID19 pandemic prevented the annual fish sampling in 2020.

Localized variations in fish community assemblages may be explained by geographic location, season, tidal anomalies, weather patterns, temperature fluctuations, drainage patterns, and minor disturbances from road runoff and other anthropogenic activities. Field observations of fish dispersement during high water events suggest that hydrologic connections often determine fish movements and hence community structure. Fish have preferred ranges and different tolerances to physical water quality parameters, particularly dissolved oxygen, water temperature, and salinity. Levels outside of these ranges can potentially stress the physiological systems of the organism and limit their distribution (Robertson-Bryan, Inc., 2004). Aquatic fauna tend to inhabit areas where their growth, foraging opportunities, and reproductive capabilities are optimum.

Figure 35: Normalized Fish Abundance in the Phase 1a Die-off Restoration Area
***Refers to a non-native fish species**

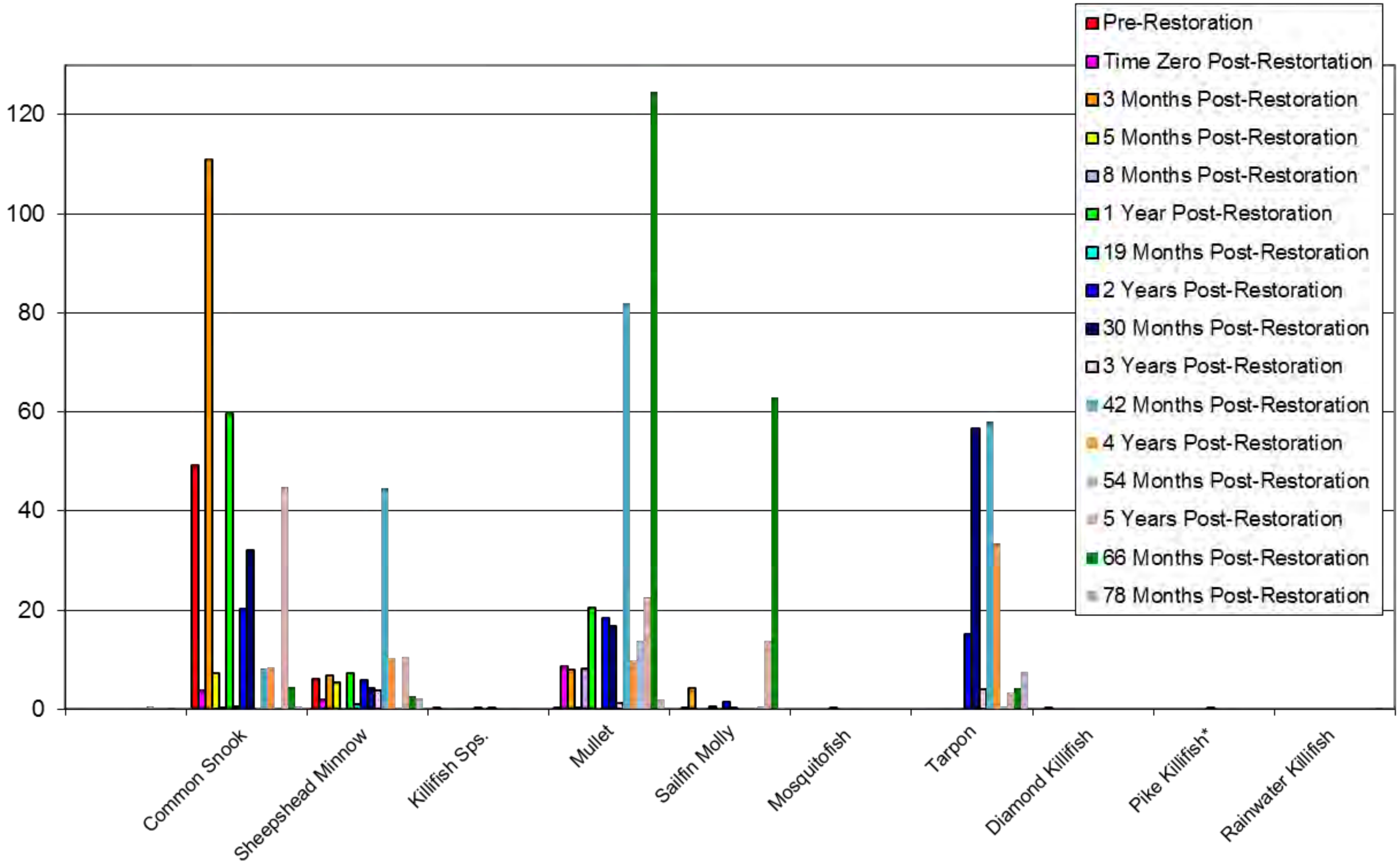
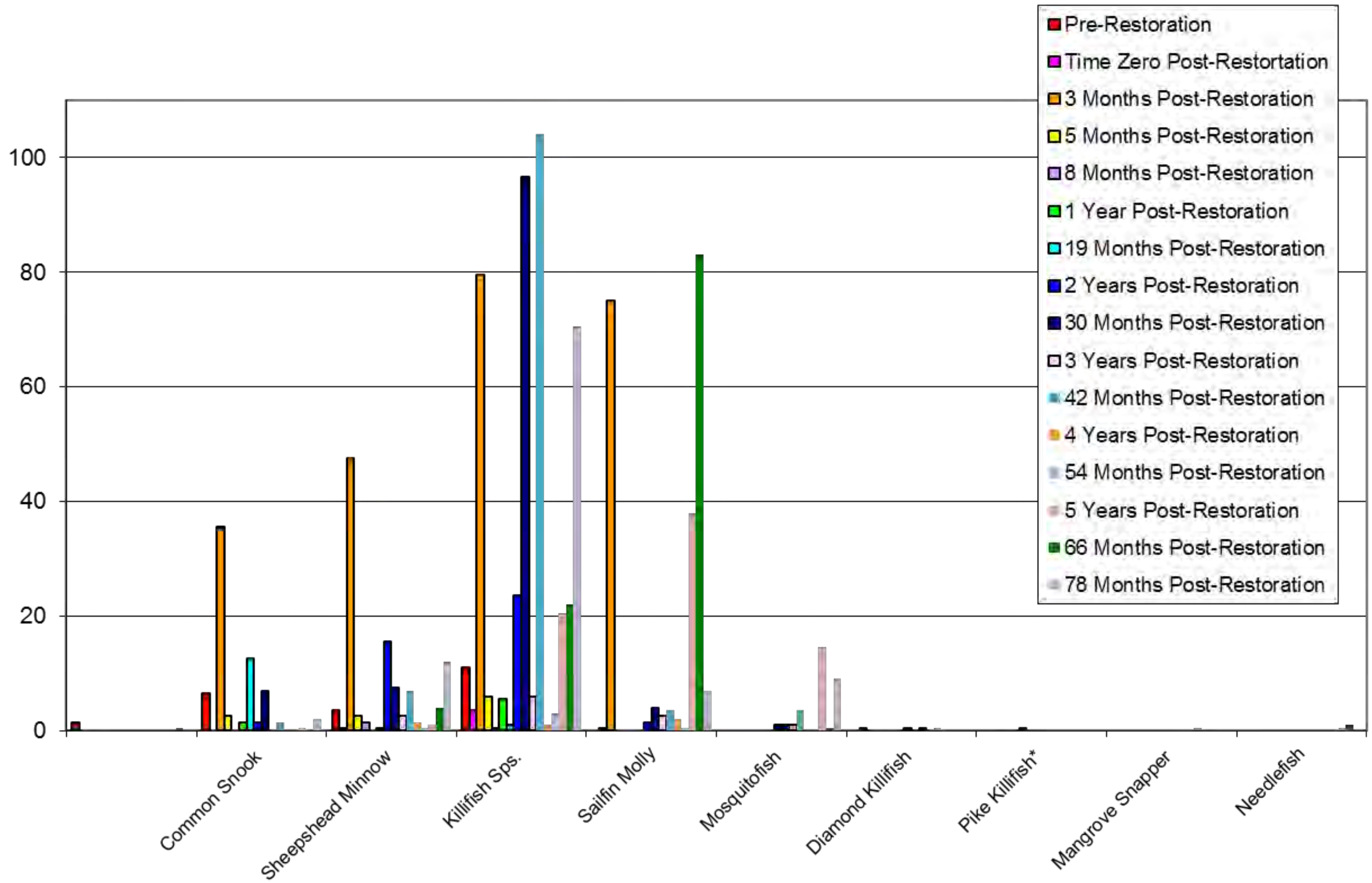


Figure 36: Normalized Fish Abundance in the Phase 1a Tidal Reference Area
***Refers to a non-native fish species**



Terrestrial Invertebrates

Overtime immigration and colonization of terrestrial and marine mulluscs, and other invertebrates such as coffee bean snails, mangrove periwinkles, and grass ceriths has occurred into the Phase 1a die-off restoration area from the adjacent reference mangrove forest (Figures 37 and 38). Compositional changes to the terrestrial invertebrate community occurred in concert with the restoration area becoming vegetated. This is an indication of die-off recovery, since none of these species were present in the die-off plots prior to restoration. Mulluscs provide a variety of essential services to the mangrove ecosystem. They contribute to the food web as predators, herbivores, detritivores and filter feeders. Coffee bean snails entered die-off area once the mangroves had re-established. The presence of these snails is indicative that the tidal flow has been re-established, since these invertebrates feed on the substrate during low tide and migrate up the mangrove stems during high tide to avoid drowning. Although mulluscs can reach a high level of diversity within a mangrove forest (Cannicci, et. al., 2008), very few, such as mangrove periwinkles (often referred to as marine snails), have an obligate association with mangrove systems (Reid, et. al., 2010). Periwinkles are found on the trunks, branches, roots, and foliage of mangroves and other salt tolerant plants where they depend upon the trees for food, shelter, substrate and shade. They feed on mangrove leaf litter, propagules, and algae found on mangrove prop roots. These snails form an important link in the food chain between estuarine flora and crabs, fish and birds, which prey on them. The presence of periwinkles and coffee bean snails within the die-off area is also an indication of mangrove recovery.

Figure 37: Phase 1a Invertebrate Relative Abundance Determined within the 1 m^2 Quadrats Overtime in the Die-off Restoration Areas

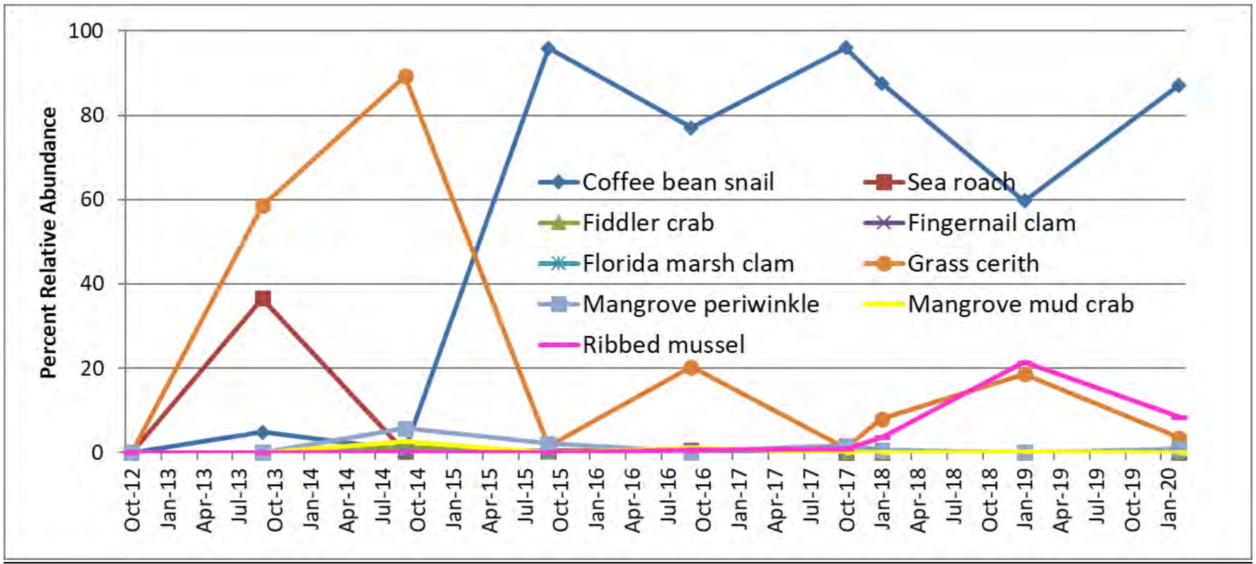
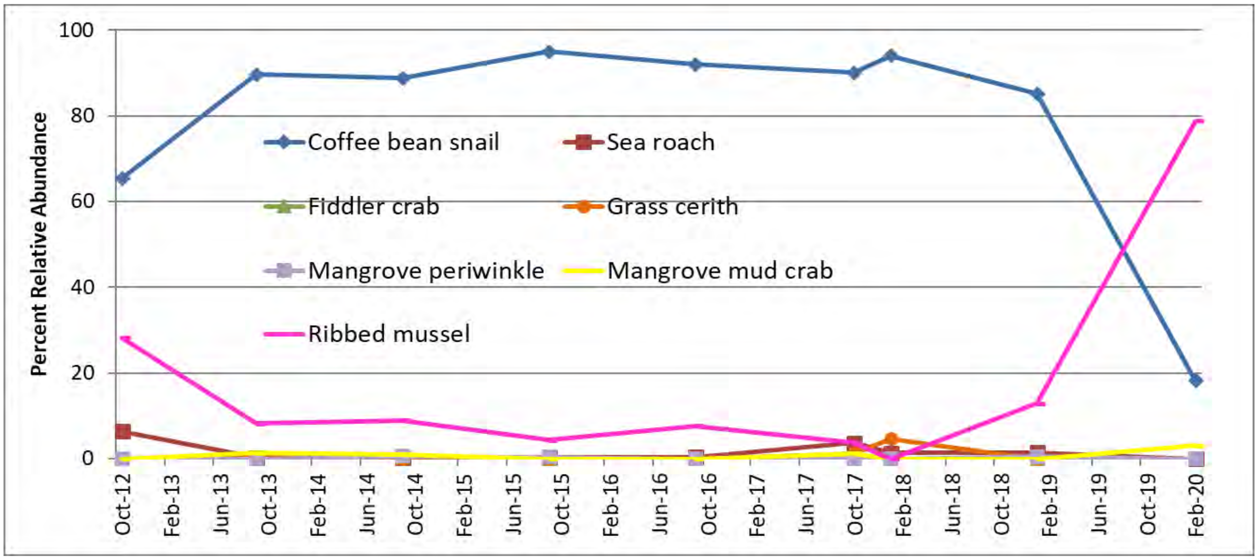


Figure 38: Phase 1a Invertebrate Relative Abundance Determined within the 1 m^2 Quadrats Overtime in the Reference Areas



Aquatic Invertebrates

As mangroves moved into the die-off area, this coincided with a positive correlation of aquatic invertebrate species diversity. This was particularly evident five years post-restoration. Only 8 species of aquatic invertebrates were collected pre-restoration; whereas 19 species were collected 5 years post-restoration. Additionally, there was a shift in the species of aquatic invertebrate assemblage within the restoration area of the Phase 1a mangrove die-off area. Pre-restoration water boatman dominated the Phase 1a die-off area. As tidal connections were re-established and inundation periods decreased and tidal flushing increased, the abundance of water boatman captured decreased up until Hurricane Irma. Ecosystem recovery was demonstrated in the continued reduction in water boatman in the Phase 1a restoration die-off area and the slow increase in other aquatic invertebrate species that are found in healthier mangrove areas. Water boatmen gravitate toward stagnant water that was present in the die-off pre-restoration and their absence in the latter year's post-restoration (pre-hurricane Irma) was encouraging. Hurricane Irma interrupted this trend as higher water levels and extended inundation interrupted recovery (Figure 39). Unfortunately, the COVID pandemic also precluded aquatic invertebrate sampling in 2020 (Figure 40).

The presence of crab holes in a mangrove area is indicative of healthy soil conditions and the absence of these holes, and hence crabs, is indicative of poor soil conditions. Crabs are potentially the most important macrofaunal component of the mangrove forests (Mchenga, et al., 2007 and Cannicci, et al., 2008). Land crabs function as the ecological engineers in mangrove systems, influencing both the physical environment and the plants that live there (Lindquist, et al., 2009 and Cannicci, et al., 2008). They play many roles in mangrove community dynamics and alter the microtopography of the substrate by building mounds. These land crabs influence the physical environment by creating burrows that aerate reduced mangrove soils, while affecting groundwater flow by facilitating exchange of overlying water and the soil (Lindquist, et. al., 2009). Their habit of bioturbation decreases the amounts of ammonium and sulphide in the soil, which allows mangroves the opportunity to increase their productivity (Cannicci, et. al., 2008). Land crabs accelerate decomposition of organic material through grazing on leaf litter. They are considered the primary agent responsible for high leaf litter turnover rates, facilitating the conversion of organic nitrogen to ammonia, providing energy to other organisms (Cannicci, et. al., 2008). Additionally, mangrove crabs often act as ecological filters, impacting community structure by influencing the density, species composition and distribution of tree recruitment, since crabs will differentially consume, damage, and/or bury propagules and seedlings (predator guild pressure on community development). Alternatively, as crabs store leaf litter in burrows and regularly move the soil around through their excavation activities, they may increase local carbon and nutrient resources that may in turn facilitate seedling recruitment (Lindquist, et. al., 2009).

Similar to mangrove seedling recruitment, mangrove crabs slowly entered the Phase 1a restoration die-off area, which was an early indication that the restoration was succeeding. Flooding due to storms and silt overwash as a result of Hurricane Irma, and high tides has precluded accurate crab hole enumeration during the previous two sampling events. However, crab presence rebounded during the later years (Figure 41).

Figure 39: Species Diversity within the Phase 1a Die-off Restoration Area over the Years

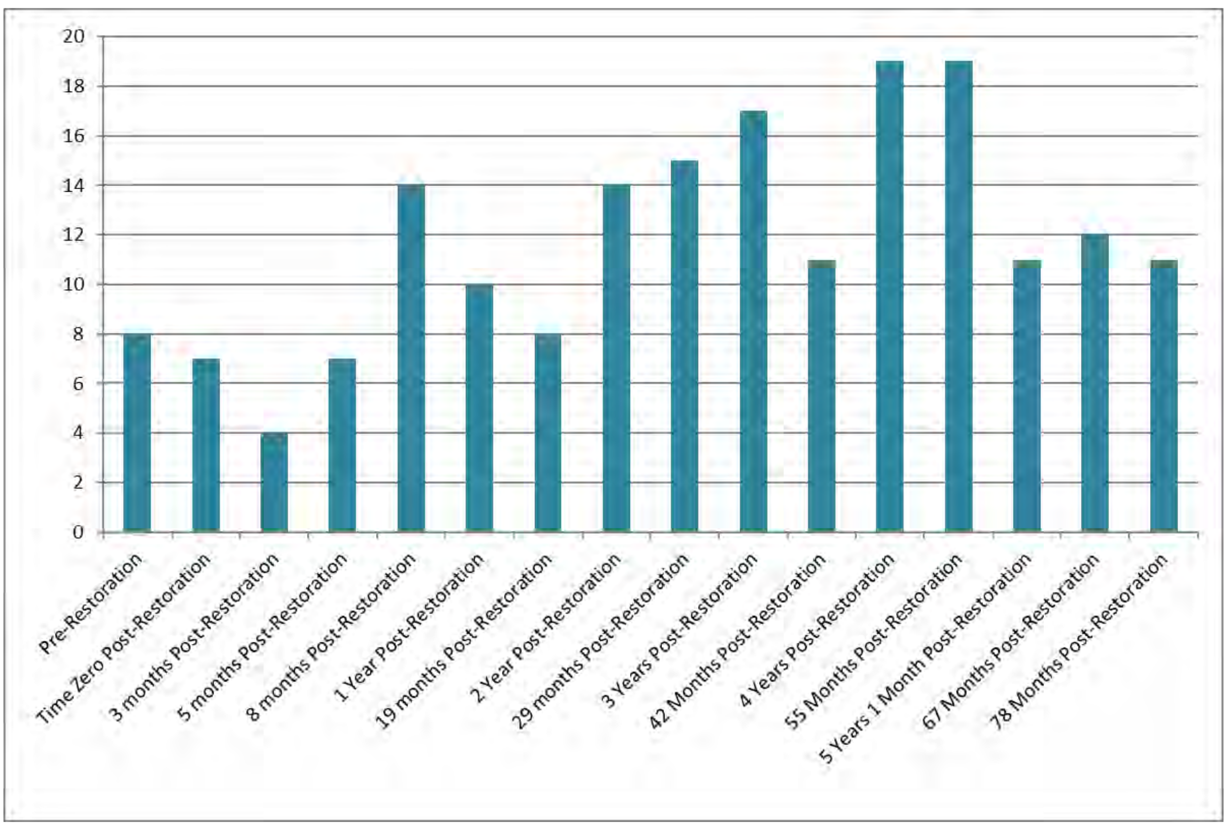


Figure 40: Phase 1a Die-off Restoration Area Aquatic Invertebrate Abundance Overtime

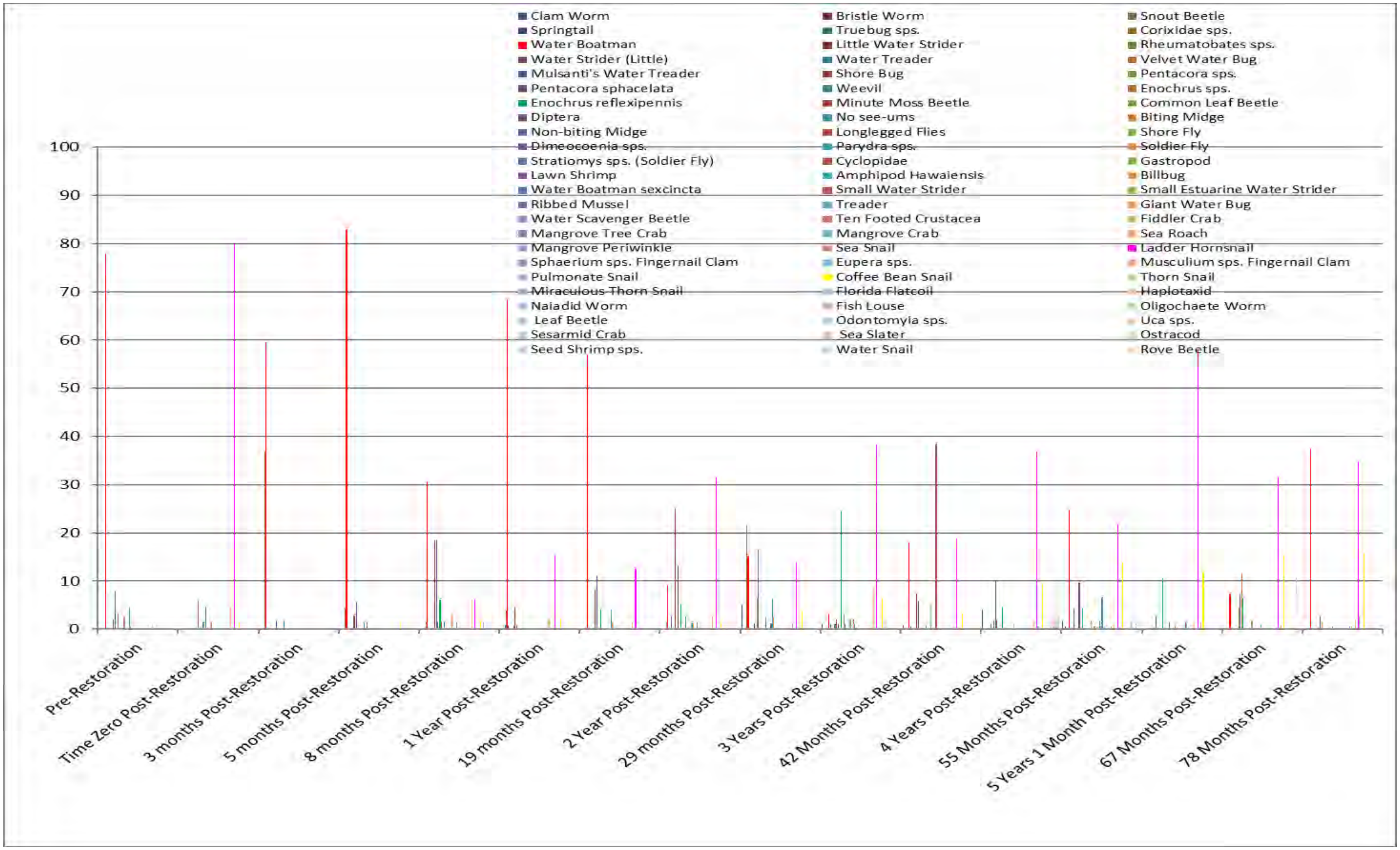
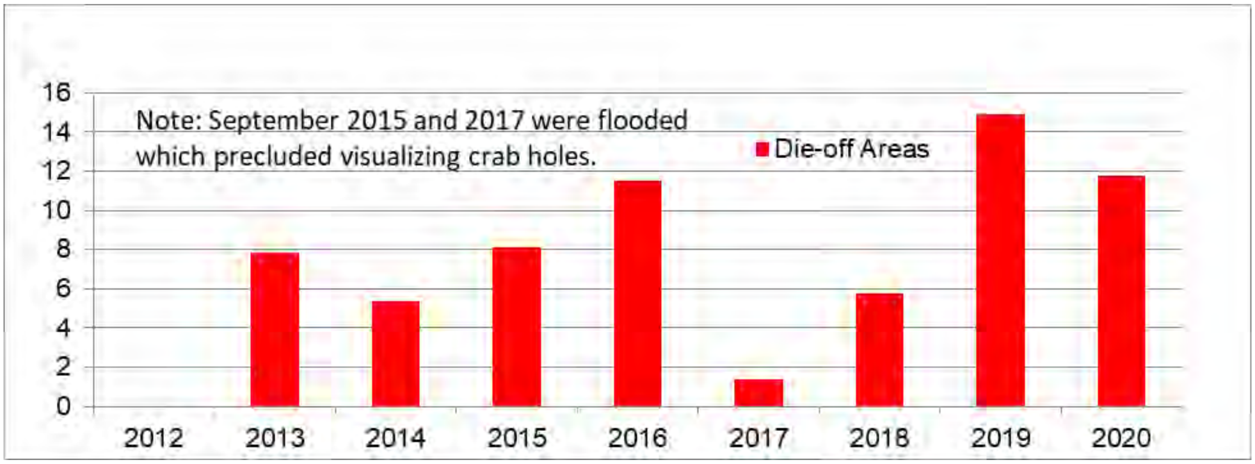


Figure 41: Phase 1a Average Crab Holes Overtime within the Four 1 m^2 Quadrats in the Die-off Restoration Area



CONCLUDING REMARKS

The restoration plan instituted within the Phase 1a die-off area definitively illustrated that a mangrove die-off that occurs because of anthropogenic hydrologic alteration can be re-vegetated with mangroves, if the mangrove system is "replumbed" to mimic the natural hydrology that existed prior to anthropogenic alteration and tidal flushing is re-established. The southern portion of the Phase 1a mangrove die-off north of C.R. 92 within the near vicinity of the hand-dug tidal channels continues to show promise. Mangrove saplings and young trees are established and a canopy is forming. Species of aquatic and terrestrial organisms commonly found in mangrove forests continue to utilize the die-off area and some crab species are now present. Hurricane Irma has impacted this area and the long-term effects are uncertain particularly in the reference forest. This area has shown an increase in stress and continued mortality. Only time will tell if the mature mangrove forest will rebound and at what pace and extent the forest will recuperate from this storm. The good news is the storm appears to have caused only a temporary setback to the Phase 1a restoration area as the area is exhibiting signs of ecosystem recovery.

Focus in 2021 will shift to the major die-offs to the south of C.R. 92 (Phase 1b and Phase 2a) in anticipation of promised restoration construction commencement in the late spring of 2021. The trees in the old die-off area to the north of C.R. 92 should continue to flourish as long as the tidal flow and flushing action does not become impeded causing water impoundment. Periodic checks on the area is advised to prevent this from happening. The adjacent reference area to the north of C.R. 92 will continue to be monitored for hurricane recovery as per permit conditions this area was to serve as the reference area for all phases of the restoration. Due to the conditions of the reference area it is likely not feasible for comparative analysis. However it is beneficial to discern the state of this area over time to determine if intervention is warranted (Appendix 8).

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TABLE 1: Tree Condition Overtime by Plot Phase 1a

Plot 1D February 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 1D September 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 1D September 2013

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 1D September 2014

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 1D September 2015

Number	BLACK	RED	WHITE	TOTAL
Alive	5	0	0	5
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	5	0	0	5

Plot 1D September 2016

Number	BLACK	RED	WHITE	TOTAL
Alive	32	2	9	43
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	32	2	9	43

Plot 1D October 2017

Number	BLACK	RED	WHITE	TOTAL
Alive	45	5	43	93
Stressed	7	4	16	27
Very Stressed	1	0	2	3
Dead	0	0	0	0
Total	53	9	61	123

Plot 1D January 2018

Number	BLACK	RED	WHITE	TOTAL
Alive	40	9	39	88
Stressed	9	1	18	28
Very Stressed	4	0	11	15
Dead	1	0	0	1
Total	54	10	68	132

Plot 1D January 2019

Number	BLACK	RED	WHITE	TOTAL
Alive	57	8	39	104
Stressed	13	2	32	47
Very Stressed	2	0	12	14
Dead	3	0	3	6
Total	75	10	86	171

TABLE 1: Tree Condition Overtime by Plot Phase 1a

Plot 1D	February 2020			
Number	BLACK	RED	WHITE	TOTAL
Alive	76	15	93	184
Stressed	7	0	9	16
Very Stressed	0	0	1	1
Dead	1	0	6	7
Total	84	15	109	208

TABLE 1: Tree Condition Overtime by Plot Phase 1a

Plot 2D February 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 2D September 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 2D September 2013

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 2D September 2014

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 2D September 2015

Number	BLACK	RED	WHITE	TOTAL
Alive	8	1	19	28
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	8	1	19	28

Plot 2D September 2016

Number	BLACK	RED	WHITE	TOTAL
Alive	35	16	47	98
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	35	16	47	98

Plot 2D October 2017

Number	BLACK	RED	WHITE	TOTAL
Alive	18	15	11	44
Stressed	17	5	23	45
Very Stressed	9	2	24	35
Dead	0	0	0	0
Total	44	22	58	124

Plot 2D January 2018

Number	BLACK	RED	WHITE	TOTAL
Alive	17	14	14	45
Stressed	21	8	29	58
Very Stressed	7	1	17	25
Dead	0	0	0	0
Total	45	23	60	128

Plot 2D January 2019

Number	BLACK	RED	WHITE	TOTAL
Alive	30	21	33	84
Stressed	20	8	25	53
Very Stressed	2	0	1	3
Dead	1	0	5	6
Total	53	29	64	146

TABLE 1: Tree Condition Overtime by Plot Phase 1a

Plot 2D February 2020

Number	BLACK	RED	WHITE	TOTAL
Alive	24	30	41	95
Stressed	22	3	15	40
Very Stressed	5	0	3	8
Dead	2	0	1	3
Total	53	33	60	146

TABLE 1: Tree Condition Overtime by Plot Phase 1a

Plot 3A February 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	13	0	0	13
Stressed	14	0	0	14
Very Stressed	4	0	0	4
Dead	0	0	0	0
Total	31	0	0	31

Plot 3A September 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	10	0	0	10
Stressed	17	0	0	17
Very Stressed	3	0	0	3
Dead	1	0	0	1
Total	31	0	0	31

Plot 3A September 2013

Number	BLACK	RED	WHITE	TOTAL
Alive	6	0	0	6
Stressed	22	0	0	22
Very Stressed	2	0	0	2
Dead	0	0	0	0
Total	30	0	0	30

Plot 3A September 2014

Number	BLACK	RED	WHITE	TOTAL
Alive	6	0	0	6
Stressed	21	0	0	21
Very Stressed	3	0	0	3
Dead	0	0	0	0
Total	30	0	0	30

Plot 3A September 2015

Number	BLACK	RED	WHITE	TOTAL
Alive	5	0	0	5
Stressed	13	0	0	13
Very Stressed	12	0	0	12
Dead	0	0	0	0
Total	30	0	0	30

Plot 3A September 2016

Number	BLACK	RED	WHITE	TOTAL
Alive	5	0	0	5
Stressed	17	0	0	17
Very Stressed	6	0	0	6
Dead	2	0	0	2
Total	30	0	0	30

Plot 3A October 2017

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	3	0	0	3
Very Stressed	4	0	0	4
Very Very Stressed	19	0	0	19
Dead	2	0	0	2
TOTAL	28	0	0	28

Plot 3A January 2018

Number	BLACK	RED	WHITE	TOTAL
Alive	2	0	0	2
Stressed	17	0	0	17
Very Stressed	6	0	0	6
Dead	1	0	0	1
Total	26	0	0	26

Plot 3A January 2019

Number	BLACK	RED	WHITE	TOTAL
Alive	2	0	0	2
Stressed	17	0	0	17
Very Stressed	6	0	0	6
Dead	0	0	0	0
Total	25	0	0	25

TABLE 1: Tree Condition Overtime by Plot Phase 1a

Plot 3A February 2020				
Number	**BLACK**	**RED**	**WHITE**	**TOTAL**
Alive	0	0	0	0
Stressed	19	0	0	19
Very Stressed	6	0	0	6
Dead	0	0	0	0
Total	25	0	0	25

TABLE 1: Tree Condition Overtime by Plot Phase 1a

Plot 4A February 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	12	0	0	12
Stressed	4	1	0	5
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	16	1	0	17

Plot 4A September 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	12	0	0	12
Stressed	4	1	0	5
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	16	1	0	17

Plot 4A September 2013

Number	BLACK	RED	WHITE	TOTAL
Alive	11	0	0	11
Stressed	5	1	0	6
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	16	1	0	17

Plot 4A September 2014

Number	BLACK	RED	WHITE	TOTAL
Alive	10	0	0	10
Stressed	6	1	0	7
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	16	1	0	17

Plot 4A September 2015

Number	BLACK	RED	WHITE	TOTAL
Alive	7	0	0	7
Stressed	8	0	0	8
Very Stressed	2	1	0	3
Dead	0	0	0	0
Total	17	1	0	18

Plot 4A September 2016

Number	BLACK	RED	WHITE	TOTAL
Alive	8	1	0	9
Stressed	7	0	0	7
Very Stressed	1	0	0	1
Dead	0	0	0	0
Total	16	1	0	17

Plot 4A October 2017

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	4	1	0	5
Very Stressed	3	2	0	5
Very Very Stressed	9	0	0	9
Dead	0	0	0	0
TOTAL	16	3	0	19

Plot 4A January 2018

Number	BLACK	RED	WHITE	TOTAL
Alive	1	1	0	2
Stressed	4	2	0	6
Very Stressed	9	0	0	9
Dead	2	0	0	2
Total	16	3	0	19

Plot 4A January 2019

Number	BLACK	RED	WHITE	TOTAL
Alive	0	1	0	1
Stressed	5	1	0	6
Very Stressed	5	1	0	6
Dead	4	0	0	4
Total	14	3	0	17

TABLE 1: Tree Condition Overtime by Plot Phase 1a

Plot 4A February 2020				
Number	BLACK	RED	WHITE	TOTAL
Alive	0	2	0	2
Stressed	5	0	0	5
Very Stressed	5	0	0	5
Dead	0	1	0	1
Total	10	3	0	13

TABLE 1: Tree Condition Overtime by Plot Phase 1a

Plot 3D December 2015

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 3D September 2016

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 3D October 2017

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
TOTAL	0	0	0	0

Plot 3D January 2018

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 3D January 2019

Number	BLACK	RED	WHITE	TOTAL
Alive	1	0	0	1
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	1	0	0	1

Plot 3D Febraury 2020

Number	BLACK	RED	WHITE	TOTAL
Alive	13	0	0	13
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	13	0	0	13

TABLE 2: Sapling Condition Overtime by Plot Phase 1a

Plot 1D February 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 1D September 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	1	0	0	1
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	1	0	0	1

Plot 1D September 2013

Number	BLACK	RED	WHITE	TOTAL
Alive	14	0	0	14
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	14	0	0	14

Plot 1D September 2014

Number	BLACK	RED	WHITE	TOTAL
Alive	28	0	4	32
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	28	0	4	32

Plot 1D September 2015

Number	BLACK	RED	WHITE	TOTAL
Alive	81	5	39	125
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	1	0	0	1
Total	82	5	39	126

Plot 1D September 2016

Number	BLACK	RED	WHITE	TOTAL
Alive	113	11	88	212
Stressed	2	0	1	3
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	115	11	89	215

Plot 1D October 2017

Number	BLACK	RED	WHITE	TOTAL
Alive	107	9	45	161
Stressed	7	0	9	16
Very Stressed	1	0	1	2
Dead	1	1	1	3
Total	116	10	56	182

Plot 1D January 2018

Number	BLACK	RED	WHITE	TOTAL
Alive	114	11	47	172
Stressed	25	2	14	41
Very Stressed	2	0	6	8
Dead	4	0	2	6
Total	145	13	69	227

Plot 1D January 2019

Number	BLACK	RED	WHITE	TOTAL
Alive	101	14	44	159
Stressed	23	1	4	28
Very Stressed	0	0	5	5
Dead	12	0	6	18
Total	136	15	59	210

TABLE 2: Sapling Condition Overtime by Plot Phase 1a

Plot 1D February 2020

Number	BLACK	RED	WHITE	TOTAL
Alive	101	10	21	132
Stressed	22	1	10	33
Very Stressed	2	0	0	2
Dead	7	1	6	14
Total	132	12	37	181

TABLE 2: Sapling Condition Overtime by Plot Phase 1a

Plot 2D February 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 2D September 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 2D September 2013

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 2D September 2014

Number	BLACK	RED	WHITE	TOTAL
Alive	22	3	30	55
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	22	3	30	55

Plot 2D September 2015

Number	BLACK	RED	WHITE	TOTAL
Alive	45	22	30	97
Stressed	1	0	0	1
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	46	22	30	98

Plot 2D September 2016

Number	BLACK	RED	WHITE	TOTAL
Alive	36	47	21	104
Stressed	0	0	1	1
Very Stressed	0	0	0	0
Dead	1	1	1	3
Total	37	48	23	108

Plot 2D October 2017

Number	BLACK	RED	WHITE	TOTAL
Alive	56	89	23	168
Stressed	7	4	5	16
Very Stressed	0	0	1	1
Dead	4	5	2	11
Total	67	98	31	196

Plot 2D January 2018

Number	BLACK	RED	WHITE	TOTAL
Alive	55	118	25	198
Stressed	9	7	5	21
Very Stressed	2	0	2	4
Dead	10	4	4	18
Total	76	129	36	241

Plot 2D January 2019

Number	BLACK	RED	WHITE	TOTAL
Alive	37	120	20	177
Stressed	11	5	5	21
Very Stressed	0	2	2	4
Dead	12	3	3	18
Total	60	130	30	220

TABLE 2: Sapling Condition Overtime by Plot Phase 1a

Plot 2D February 2020

Number	BLACK	RED	WHITE	TOTAL
Alive	7	72	3	82
Stressed	5	10	1	16
Very Stressed	1	2	1	4
Dead	37	47	21	105
Total	50	131	26	207

TABLE 2: Sapling Condition Overtime by Plot Phase 1a

Plot 3A February 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	2	0	0	2
Very Stressed	1	0	0	1
Dead	0	0	0	0
Total	3	0	0	3

Plot 3A September 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	2	0	0	2
Very Stressed	0	0	0	0
Dead	1	0	0	1
Total	3	0	0	3

Plot 3A September 2013

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	1	0	0	1
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	1	0	0	1

Plot 3A September 2014

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 3A September 2015

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 3A September 2016

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 3A October 2017

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 3A January 2018

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

Plot 3A January 2019

Number	BLACK	RED	WHITE	TOTAL
Alive	0	0	0	0
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	0	0	0	0

TABLE 2: Sapling Condition Overtime by Plot Phase 1a

Plot 3A February 2020

Number	BLACK	RED	WHITE	TOTAL
Alive	1	3	0	4
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	1	3	0	4

TABLE 2: Sapling Condition Overtime by Plot Phase 1a

Plot 4A February 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	4	1	0	5
Stressed	3	1	0	4
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	7	2	0	9

Plot 4A September 2012

Number	BLACK	RED	WHITE	TOTAL
Alive	4	1	0	5
Stressed	3	1	0	4
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	7	2	0	9

Plot 4A September 2013

Number	BLACK	RED	WHITE	TOTAL
Alive	7	3	2	12
Stressed	2	1	0	3
Very Stressed	0	0	0	0
Dead	1	0	0	1
Total	10	4	2	16

Plot 4A September 2014

Number	BLACK	RED	WHITE	TOTAL
Alive	7	4	0	11
Stressed	2	0	1	3
Very Stressed	0	0	1	1
Dead	0	0	0	0
Total	9	4	2	15

Plot 4A September 2015

Number	BLACK	RED	WHITE	TOTAL
Alive	9	4	0	13
Stressed	2	0	1	3
Very Stressed	0	0	1	1
Dead	0	0	0	0
Total	11	4	2	17

Plot 4A September 2016

Number	BLACK	RED	WHITE	TOTAL
Alive	17	3	0	20
Stressed	0	0	1	1
Very Stressed	0	0	1	1
Dead	0	0	0	0
Total	17	3	2	22

Plot 4A October 2017

Number	BLACK	RED	WHITE	TOTAL
Alive	10	2	1	13
Stressed	15	2	0	17
Very Stressed	2	1	2	5
Dead	0	0	0	0
Total	27	5	3	35

Plot 4A January 2018

Number	BLACK	RED	WHITE	TOTAL
Alive	1	3	0	4
Stressed	9	2	1	12
Very Stressed	12	0	0	12
Dead	5	0	2	7
Total	27	5	3	35

Plot 4A January 2019

Number	BLACK	RED	WHITE	TOTAL
Alive	14	16	0	30
Stressed	7	0	1	8
Very Stressed	0	0	0	0
Dead	9	0	0	9
Total	30	16	1	47

TABLE 2: Sapling Condition Overtime by Plot Phase 1a

Plot 4A February 2020				
Number	**BLACK**	**RED**	**WHITE**	**TOTAL**
Alive	23	22	1	46
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	1	0	1
Total	23	23	1	47

TABLE 2: Propagule Condition Overtime by Plot Phase 1a

Plot 3D December 2015

Number	BLACK	RED	WHITE	TOTAL
Alive	2	0	0	2
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	2	0	0	2

Plot 3D September 2016

Number	BLACK	RED	WHITE	TOTAL
Alive	15	0	3	18
Stressed	0	0	0	0
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	15	0	3	18

Plot 3D October 2017

Number	BLACK	RED	WHITE	TOTAL
Alive	13	0	0	13
Stressed	2	0	3	5
Very Stressed	0	0	0	0
Dead	0	0	0	0
Total	15	0	3	18

Plot 3D January 2018

Number	BLACK	RED	WHITE	TOTAL
Alive	15	0	0	15
Stressed	2	0	0	2
Very Stressed	0	0	3	3
Dead	0	0	0	0
Total	17	0	3	20

Plot 3D January 2019

Number	BLACK	RED	WHITE	TOTAL
Alive	15	0	0	15
Stressed	2	0	1	3
Very Stressed	0	0	2	2
Dead	0	0	0	0
Total	17	0	3	20

Plot 3D February 2020

Number	BLACK	RED	WHITE	TOTAL
Alive	7	0	1	8
Stressed	1	0	1	2
Very Stressed	0	0	1	1
Dead	0	0	0	0
Total	8	0	3	11

TABLE 3: Phase 1a Mangrove tree and sapling floristic characteristics 2020

		Tree Numbers					Sapling Numbers			
Type	Plot	% Canopy	B	R	W	Total	B	R	W	Total
D	1	41.2	83	15	103	201	125	11	31	167
D	2	70.6	51	33	59	143	13	84	5	102
A	3	47.1	25	0	0	25	1	3	0	4
A	4	0	10	2	0	12.0	23	22	1	46
	Total		169	50	162	381	162	120	37	319

		Tree Numbers					Sapling Numbers			
Type	Plot	% Canopy	B	R	W	Total	B	R	W	Total
D	3D	0	13	0	0	13	8	0	3	11

B=Black Mangrove (*Avicennia germinans L.*) R=Red Mangrove (*Rhizophora mangle L.*) W=White Mangrove (*Laguncularia racemosa L.*) D = Restoration Area (Die-off Area Phase 1) A = Reference Area (Primarily Black Mangrove (*Avicennia germinans L.*) Forest)

Table 4: Ground Cover Species Composition Phase 1a February 2020

Plot	Type	Quadrat	% Ground Cover/ Quadrat	Count	Common Name	Life Stage	Order	Family	Genus	Species
1		1	40	1	White Mangrove	tree	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
				5	Black Mangrove	sapling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				1	White Mangrove	sapling	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
				1	White Mangrove	seedling	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
		2	80	3	White Mangrove	tree	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
				6	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				1	White Mangrove	sapling	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
				4	Black Mangrove	sapling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				1	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				3	White Mangrove	seedling	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
		3	40	3	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				3	White Mangrove	tree	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
				1	White Mangrove	seedling	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
				4	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
		4	45	4	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				3	White Mangrove	tree	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
				2	White Mangrove	sapling	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
				5	Black Mangrove	sapling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				2	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				3	White Mangrove	seedling	Myrtales	Combretaceae	*Laguncularia*	*racemosa*

D = Restoration Area (Die-off Area Phase 1) A = Reference Area (Primarily Black Mangrove (*Avicennia germinans* L.) Forest)

Table 4 continued. Ground cover species composition Phase 1a February 2020.

Plot	Type	Quadrat	% Ground Cover/ Quadrat	Count	Common Name	Life Stage	Order	Family	Genus	Species
2	D	1	30	1	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				1	White Mangrove	tree	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
				2	Red Mangrove	tree	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				2	Red Mangrove	sapling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
		2	35	5	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				5	Red Mangrove	sapling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				1	Black Mangrove	seedling	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
		3	20	4	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				1	Black Mangrove	sapling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
		4	60	3	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				6	Red Mangrove	sapling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				1	Red Mangrove	seedling	Malpighiales	Rhizophoraceae	Rhizophora	mangle

Plot	Type	Quadrat	% Ground Cover/ Quadrat	Count	Common Name	Life Stage	Order	Family	Genus	Species
3	A	1	10	2	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				1	Red Mangrove	seedling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				25	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
3	A	2	25	1	Black Mangrove	trees	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				3	Red Mangrove	seedling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				24	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
		3	10	1	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				1	Red Mangrove	seedling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				10	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
		4	50	3	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				20	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*

D = Restoration Area (Die-off Area Phase 1)   A = Reference Area (Primarily Black Mangrove (Avicennia germinans L.) Forest)

Table 4 continued. Ground cover species composition Phase 1a February 2020.

Plot	Type	Quadrat	% Ground Cover/ Quadrat	Count	Common Name	Life Stage	Order	Family	Genus	Species
4	A	1	20	2	Black Mangrove	sapling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				3	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
		2	50	1	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				2	Black Mangrove	sapling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				1	Red Mangrove	sapling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
		3	40	3	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				1	Red Mangrove	sapling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				1	Red Mangrove	seedling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
		4	40	1	Red Mangrove	sapling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				2	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*

Plot	Type	Quadrat	% Ground Cover/ Quadrat	Count	Common Name	Life Stage	Order	Family	Genus	Species
3D*	D	1	10	2	Black Mangrove	seedlings	Lamiales	Acanthaceae	*Avicennia*	*germinans*
		2	75	3	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				2	Black Mangrove	sapling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
		3	0	1	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
		4	60	1	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				3	Black Mangrove	sapling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				1	White Mangrove	sapling	Myrtales	Combretaceae	*Laguncularia*	*racemosa*
				6	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*

* *Batis sps*. was found in approximately 1/3 of Plot 3D

D = Restoration Area (Die-off Area Phase 1)   A = Reference Area (Primarily Black Mangrove (*Avicennia germinans* L.) Forest)

Table 5: Crab Hole Densities by Site and Quadrat Phase 1a February 2020

	Site and Quadrat																			
Type	Restoration Area Plots								Reference Area Plots*								Restoration Area Plot *(added in 2015)			
Plot	1				2				3				4				3D			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
#	11	7	23	27	2	9	8	7	2	4	6	4	1	1	4	0	0	3	0	5

*Reference Plots were flooded and visibility was poor to discern crab holes. Restoration Plot 3D was also inundated

Table 6: Invertebrates by Plot and Quadrat Phase 1a February 2020.

					Restoration Area									
					Plot 1					Plot 2				
Order	Family	Genus	Species	Common name	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Total	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Total
Archaeopulmonata	Ellobiidae	*Coffeus*	*melampus*	coffee bean snail	93	36	25	32	186	5	0	0	5	10
Neotaenioglossa	Littorinidae	*Littoraria*	*angulifera*	mangrove periwinkle	1	1	0	0	2	0	0	0	0	0
Mytiloida	Mytiloida	*Geukensia*	*demissa*	ribbed mussel	2	3	0	0	5	5	6	0	3	14
Neotaenioglossa	Cerithiidae	*Bittiolum*	*varium*	grass cerith	6	0	1	1	8	0	0	0	0	0
				Total	102	40	26	33	201	10	6	0	8	24

					Reference Area*									
					Plot 3					Plot 4				
Order	Family	Genus	Species	Common name	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Total	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Total
Archaeopulmonata	Ellobiidae	*Coffeus*	*melampus*	coffee bean snail	1	0	1	4	6	0	0	0	0	0
Mytiloida	Mytiloida	*Geukensia*	*demissa*	ribbed mussel	4	3	12	7	26	0	0	0	0	0
Decapoda	Crustacea			mangrove mud crab	0	0	0	0	0	0	0	1	0	1
				Total	5	3	13	11	32	0	0	1	0	1

*High water levels present in the Reference plots

					Restoration Area Plot (added in 2015)*				
					Plot 3D**				
Order	Family	Genus	Species	Common name	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Total
Archaeopulmonata	Ellobiidae	*Coffeus*	*melampus*	coffee bean snail	0	1	0	7	8
Neotaenioglossa	Cerithiidae	*Bittiolum*	*varium*	grass cerith	0	6	0	9	15
				Total	0	7	0	16	23

*High water levels present in Plot 3D
** Water Boatman (*Trichocorixa reticulate)* found throughout the plot

Table 7: Phase 1b Mangrove tree and sapling floristic characteristics 2020.

		Tree Numbers					Sapling Numbers			
Type	Plot	% Canopy	B	R	W	Total	B	R	W	Total
D	G2D	0	0	0	0	0	0	0	0	0
D	G10D	0	0	0	0	0	0	0	0	0
D	G14D	0	0	0	0	0	0	0	0	0
A	G4A	0	1	0	0	1	0	0	0	0
A	G7A	94.1	1	0	0	1	0	0	0	0
A	G12A	58.8	6	8	0	14	1	42	0	43
	Total		8	8	0	16	1	42	0	43

B=Black Mangrove (*Avicennia germinans L.*) R=Red Mangrove (*Rhizophora mangle L.*) W=White Mangrove (*Laguncularia racemosa L.*) D = Restoration Area (Die-off Area Phase 1) A = Reference Area (Primarily Black Mangrove (*Avicennia germinans L.*) Forest)

Table 8: Crab Hole Densities by Site and Quadrat Phase 1b February 2020

	Site and Quadrant											
Type	Restoration Area Plots											
Plot	G2D				G10D				G14D			
	1	2	3	4	1	2	3	4	1	2	3	4
#	0	0	0	0	0	0	0	0	0	0	0	0

	Site and Quadrant											
Type	Reference Area Plots											
Plot	G4A				G7A				G12A			
	1	2	3	4	1	2	3	4	1	2	3	4
#	0	0	0	0	0	0	0	4	13	11	9	6

Table 9: Invertebrates by Plot and Quadrat Phase 1b February 2020.

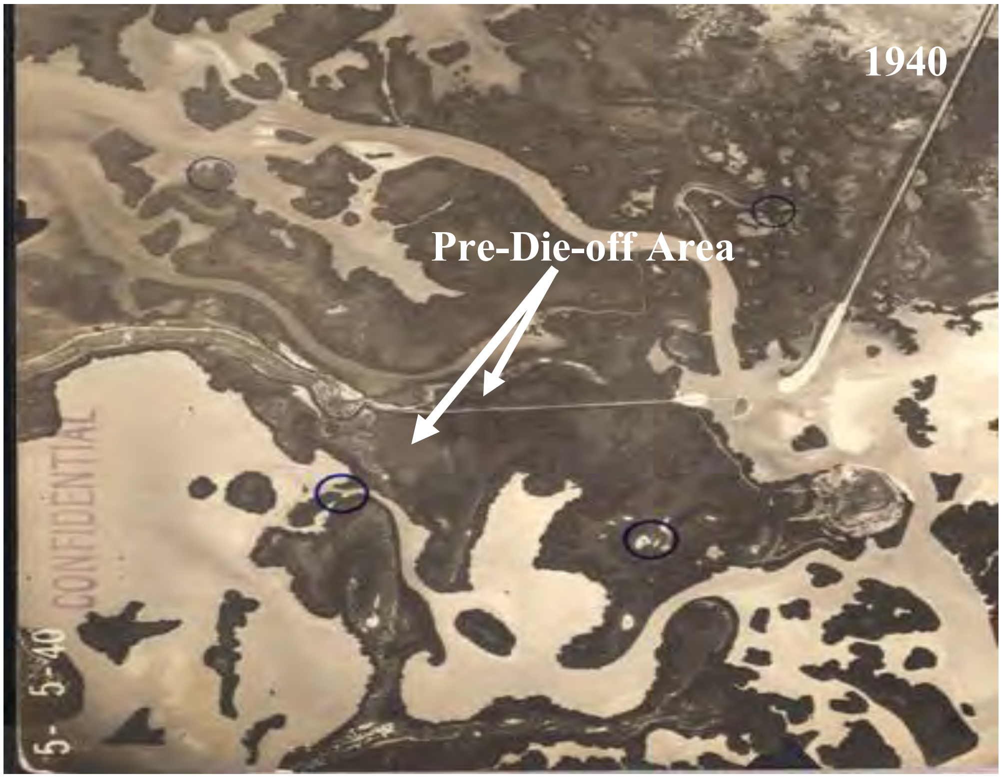
					Restoration Area														
					Plot G2D					Plot G10D					Plot G14D				
Order	Family	Genus	Species	Common Name	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Total	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Total	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Total
Water Boatman (*Trichocorixa reticulate)* found throughout all of the Restoration Plots and No other spes were observed. All Restoration Plots were flooded																			

					Reference Area														
					Plot G4A					Plot G7A					Plot G12A				
Order	Family	Genus	Species	Common Name	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Total	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Total	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Total
Archaeopulmonata	Ellobiidae	*Coffeus*	*melampus*	coffee bean snail	0	0	0	0	0	0	0	0	0	0	22	0	3	4	29
Neotaenioglossa	Littorinidae	*Littoraria*	*angulifera*	mangrove periwinkle	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
Mytiloida	Mytiloida	*Geukensia*	*demissa*	ribbed mussel	0	0	0	0	0	0	0	0	0	0	1	2	0	0	3
Neotaenioglossa	Cerithiidae	*Bittiolum*	*varium*	grass cerith	1	0	0	0	1	4	3	0	3	10	0	0	0	0	0
				Total	1	0	0	0	1	4	3	0	3	10	23	3	3	5	34

Table 10: Ground cover species composition Phase 1b February 2020.

Plot	Type	Quadrat	% Ground Cover/ Quadrat	Count	Common Name	Life Stage	Order	Family	Genus	Species
G2D	Restoration	ALL	0	No mangrove ground cover was observed in any of the quadrats						
G10D	Restoration	ALL	0	No mangrove ground cover was observed in any of the quadrats						
G14D	Restoration	ALL	0	No mangrove ground cover was observed in any of the quadrats						
G4A	Reference	1	0	No mangrove ground cover was observed in this quadrat						
		2	0	No mangrove ground cover was observed in this quadrat						
		3	0	No mangrove ground cover was observed in this quadrat						
		4	0	1	Black Mangrove	Seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
*algae was present in all 4 quadrats (≤5% per quadrat)										
G7A	Reference	1	25	1	Black Mangrove	tree	Lamiales	Acanthaceae	*Avicennia*	*germinans*
		2	0	No mangrove ground cover was observed in this quadrat						
		3	0	No mangrove ground cover was observed in this quadrat						
		4*	0	No mangrove ground cover was observed in this quadrat						
* A buttonwood tree *(Conocarpus erectus)* whose base is outside of the plot was hanging into approximately 0.5% of quadrant 4										
G12A	Reference	1	15	3	Red Mangrove	sapling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				1	Red Mangrove	seedling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				7	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
		2	20	1	Red Mangrove	tree	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				2	Red Mangrove	seedling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
		3	25	1	Red Mangrove	sapling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				7	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
		4	18	2	Red Mangrove	sapling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				1	Black Mangrove	sapling	Lamiales	Acanthaceae	*Avicennia*	*germinans*
				2	Red Mangrove	seedling	Malpighiales	Rhizophoraceae	*Rhizophora*	*mangle*
				1	Black Mangrove	seedling	Lamiales	Acanthaceae	*Avicennia*	*germinans*

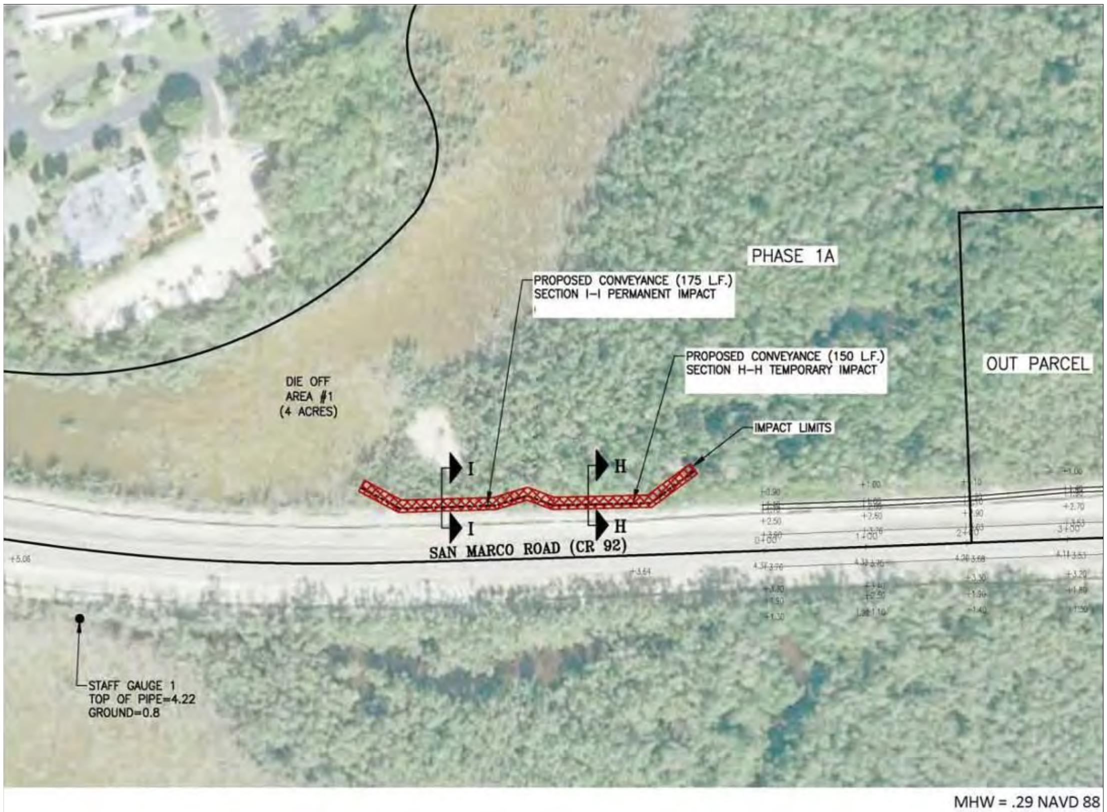
Figure 1: Pre-Development (1940) and Post-Development (2002)



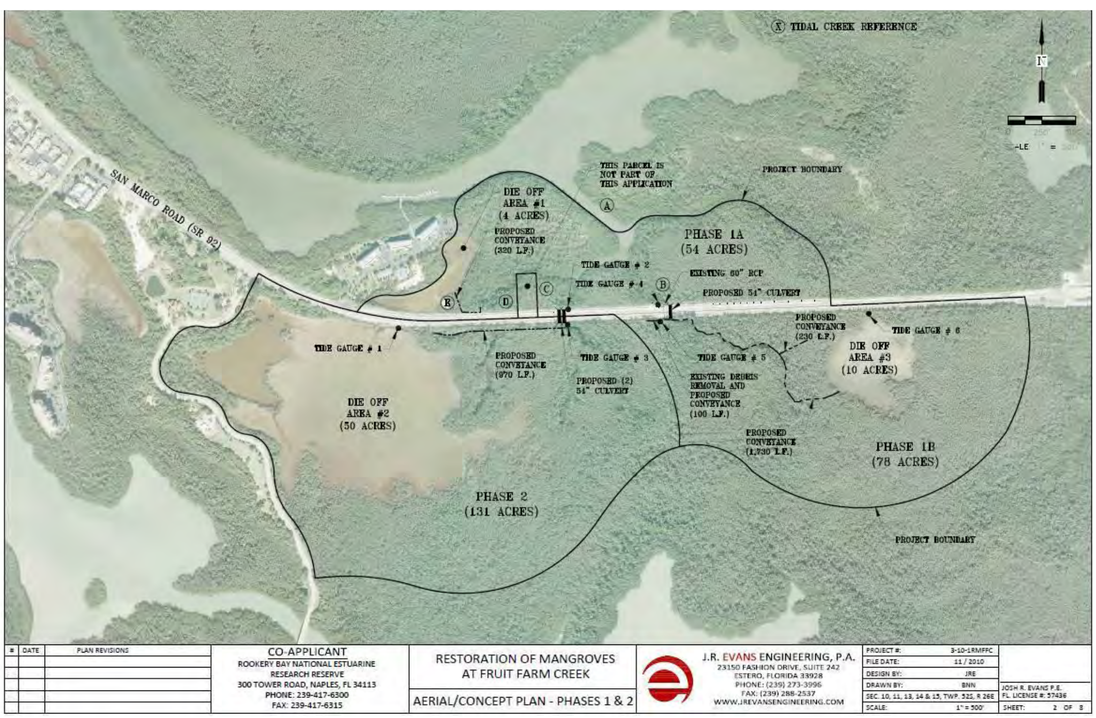
Aerial courtesy of USGS

Aerial courtesy of Collier County Property Appraiser

Figure 3: Restoration Design



a) Phase 1a



b) Phases 1a, 1b and 2

Figure 4: Phase 1a Plot Locations

Aerial courtesy of Google Earth

Figure 5: Phase 1b Mangrove Plot Locations

Aerial courtesy of Google Earth

Figure 6: Plot Established in Phase 1a in 2015 to Monitor Hand-Dug Channel Extensions

Aerial courtesy of Google Earth

Figure 7: Phase 1a & 1b Aquatic Faunal Plot Locations

Aerial courtesy of Google Earth

Appendix 1: Restoration in Progress 2012

Pre-Clearing of Ditch

Ditch Clearing

Post-Clearing of the Ditch – Tidal Connection to Die-off Completed 2012

Appendix 1: Restoration in Progress 2015

One of the Completed Hand-dug Channels placed within the Die-off Area to Establish a Tidal Connection to Fruit Farm Creek River that leads into the Gulf of Mexico. These hand-dug channels allow impounded freshwater to drain and allows for tidal flushing to occur within the die-off.

Appendix 2: Phase 1a Plot Photograph Gallery

Baseline Pre-Restoration Phase 1a Die-off Area Plot 1D Northwest View 2/21/2012

Phase 1a Area 1 Baseline Pre-Restoration
Plot Type: Restoration (Die-off) (D)
Plot 1D Location:

East (X)	North (Y)
17432730	2868329

Monitoring Dates:

Mangrove: 2/21 – 2/22/2012
Epifaunal: 2/21 - 2/22/2012
Aquatic Fauna: 4/17 – 4/18/2012

Appendix 2: Phase 1a Plot Photograph Gallery

Baseline Pre-Restoration Phase 1a Die-off Area Plot 2D Northwest View 2/21/2012

Phase 1a Area 1 Pre-Restoration Baseline
Plot Type: Restoration (Die-off) (D)
Plot 2D Location:

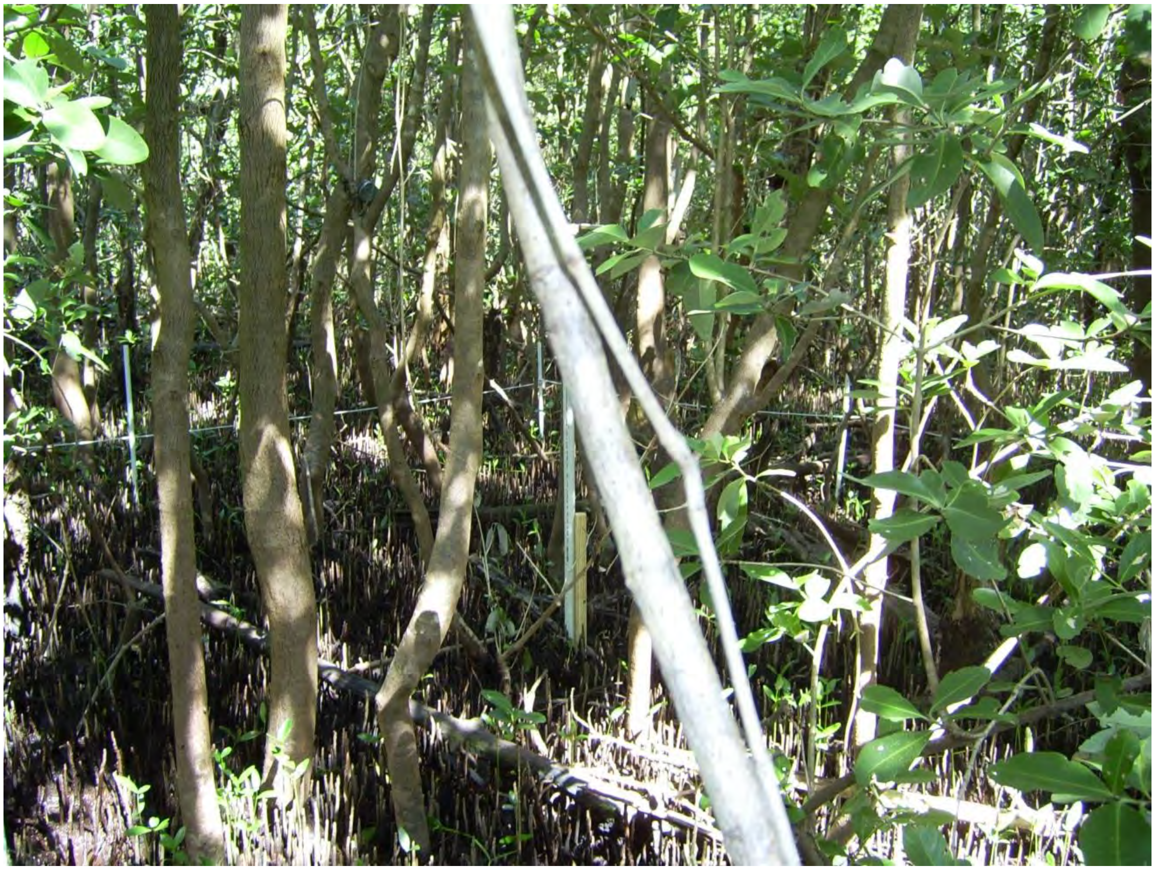
East (X)	North (Y)
17432764	2868333

Monitoring Dates:

Mangrove: 2/21 – 2/22/2012
Epifaunal: 2/21 - 2/22/2012
Aquatic Fauna: 4/17 – 4/18/2012

Appendix 2: Phase 1a Plot Photograph Gallery

Phase 1a Reference Plot 3A Northwest View 2/21/2012



Phase 1a Area 1
Plot Type: Reference (A)
Plot 3A Location:

East (X)	North (Y)
17432856	2868345

Monitoring Dates:

Mangrove: 2/21 – 2/22/2012
Epifaunal: 2/21 - 2/22/2012
Aquatic Fauna: 4/17 – 4/18/2012

Appendix 2: Phase 1a Plot Photograph Gallery

Phase 1a Reference Plot 4A Northwest View 2/21/2012

Phase 1a Area 1
Plot Type: Reference (A)
Plot 4A Location:

East (X)	North (Y)
17432965	2868326

Monitoring Dates:

Mangrove: 2/21 – 2/22/2012
Epifaunal: 2/21 - 2/22/2012
Aquatic Fauna: 4/17 – 4/18/2012

Appendix 2: Phase 1a Plot Photograph Gallery

One Year Post-Construction Phase 1a Plot 1D Northwest View 9/18/2013

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 1 Location:

East (X)	North (Y)
17432730	2868329

Monitoring Dates:

Mangrove: 9/18/2013
Epifaunal: 9/18/2013
Aquatic Fauna: 9/16 -9/17/2013

Appendix 2: Phase 1a Plot Photograph Gallery

One Year Post-Construction Phase 1a Plot 2D Northwest View 9/18/2013

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 2 Location:

East (X)	North (Y)
17432764	2868333

Monitoring Dates:

Mangrove: 9/18/2013
Epifaunal: 9/18/2013
Aquatic Fauna: 9/16 -9/17/2013

Appendix 2: Phase 1a Plot Photograph Gallery

One Year Post-Construction Phase 1a Plot 3A Northwest View 9/18/2013

Phase 1 Area 1
Plot Type: Reference (A)
Plot 3 Location:

East (X)	North (Y)
17432856	2868345

Monitoring Dates:

Mangrove: 9/18/2013
Epifaunal: 9/18/2013
Aquatic Fauna: 9/16 -9/17/2013

Appendix 2: Phase 1a Plot Photograph Gallery

One Year Post-Construction Phase 1a Plot 4A Northwest View 9/18/2013

Phase 1 Area 1
Plot Type: Reference (A)
Plot 4 Location:

East (X)	North (Y)
17432965	2868326

Monitoring Dates:

Mangrove: 9/18/2013
Epifaunal: 9/18/2013
Aquatic Fauna: 9/16 -9/17/2013

Appendix 2: Phase 1a Plot Photograph Gallery

Two Years Post-Construction Phase 1a Plot 1D Northwest View 09/15/2014

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 1D Location:

East (X)	North (Y)
17432730	2868329

Note: High Tide

Monitoring Dates:

Mangrove: 9/15/2014
Epifaunal: 9/15/2014
Aquatic Fauna: 9/18 -9/19/2014

Appendix 2: Phase 1a Plot Photograph Gallery

Two Years Post-Construction Phase 1a Plot 2D Northwest View 09/15/2014

Phase 1a Area 1
Plot Type: Restoration (Die-off) (D)
Plot 2D Location:

East (X)	North (Y)
17432764	2868333

Note: High Tide

Monitoring Dates:

Mangrove: 9/15/2014
Epifaunal: 9/15/2014
Aquatic Fauna: 9/18 -9/19/2014

Appendix 2: Phase 1a Plot Photograph Gallery

Two Years Post-Construction Phase 1a Plot 3A Northwest View 09/15/2014

Phase 1a Area 1
Plot Type: Reference (A)
Plot 3A Location:

East (X)	North (Y)
17432856	2868345

Note: High Tide

Monitoring Dates:

Mangrove: 9/15/2014
Epifaunal: 9/15/2014
Aquatic Fauna: 9/18 -9/19/2014

Appendix 2: Phase 1a Plot Photograph Gallery

Two Years Post-Construction Phase 1a Plot 4A Northwest View 09/15/2014

Phase 1 Area 1
Plot Type: Reference (A)
Plot 4A Location:

East (X)	North (Y)
17432965	2868326

Note: High Tide

Monitoring Dates:

Mangrove: 9/8/2014
Epifaunal: 9/8/2014
Aquatic Fauna: 9/18 -9/19/2014

Appendix 2: Phase 1a Plot Photograph Gallery

Three Years Post-Restoration Phase 1a Die-off Area Plot 1D Northwest View 09/24/2015

Phase 1a Area 1 Post-Restoration
Plot Type: Restoration (Die-off) (D)
Plot 1 Location:

East (X)	North (Y)
17432730	2868329

Note: High Tide

Monitoring Dates:

Mangrove: 9/24/2015
Epifaunal: 9/24/2015
Aquatic Fauna: 9/24 -9/25/2015

Appendix 2: Phase 1a Plot Photograph Gallery

Three Years Post-Restoration Phase 1a Die-off Area Plot 2D Northwest View 09/27/2015

Phase 1a Area 1 Post-Restoration
Plot Type: Restoration (Die-off) (D)
Plot 2 Location:

East (X)	North (Y)
17432764	2868333

Note: High Tide

Monitoring Dates:

Mangrove: 9/27/2015
Epifaunal: 9/27/2015
Aquatic Fauna: 9/24 -9/25/2015

Appendix 2: Phase 1a Plot Photograph Gallery

Three Years Post-Restoration Phase 1a Reference Plot 3A Northwest View 09/24/2015

Phase 1a Area 1
Plot Type: Reference (A)
Plot 3 Location:

East (X)	North (Y)
17432856	2868345

Note: High Tide

Monitoring Dates:

Mangrove: 9/24/2015
Epifaunal: 9/24/2015
Aquatic Fauna: 9/24 -9/25/2015

Appendix 2: Phase 1a Plot Photograph Gallery

Three Years Post-Restoration Phase 1a Reference Plot 4A Northwest View 09/24/2015

Phase 1a Area 1
Plot Type: Reference (A)
Plot 4 Location:

East (X)	North (Y)
17432965	2868326

Note: High Tide

Monitoring Dates:

Mangrove: 9/24/2015
Epifaunal: 9/24/2015
Aquatic Fauna: 9/24 -9/25/2015

Appendix 2: Phase 1a Plot Photograph Gallery

Four Years Post-Restoration Phase 1a Restoration Plot 1D Northwest View 09/15/2016

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 1 Location:

East (X)	North (Y)
17432730	2868329

Note: Site started out dry but within 5 hours had a very High Tide 3ft differential

Monitoring Dates:

Mangrove: 9/15/2016
Epifaunal: 9/15/2016
Aquatic Fauna: 9/15 -9/26/2016

Appendix 2: Phase 1a Plot Photograph Gallery

Four Years Post-Restoration Phase 1a Restoration Plot 2D Northwest View 09/16/2016

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 2 Location:

East (X)	North (Y)
17432764	2868333

Note: Site started out dry but within 5 hours had a very High Tide 3ft differential

Monitoring Dates:

Mangrove: 9/16/2016
Epifaunal: 9/16/2016
Aquatic Fauna: 9/15 -9/26/2016

Appendix 2: Phase 1a Plot Photograph Gallery

Four Years Post-Restoration Phase 1a Reference Plot 3A Northwest View
09/14/2016

Phase 1 Area 1
Plot Type: Reference (A)
Plot 3 Location:

East (X)	North (Y)
17432856	2868345

Note: High Tide

Monitoring Dates:

Mangrove: 9/14/2016
Epifaunal: 9/14/2016
Aquatic Fauna: 9/15 -9/26/2016

Appendix 2: Phase 1a Plot Photograph Gallery

Four Years Post-Restoration Phase 1a Reference Plot 4A Northwest View 09/14/2016

Phase 1 Area 1
Plot Type: Reference (A)
Plot 4 Location:

East (X)	North (Y)
17432965	2868326

Note: High Tide

Monitoring Dates:

Mangrove: 9/14/2016
Epifaunal: 9/14/2016
Aquatic Fauna: 9/15 -9/26/2016

Appendix 2: Phase 1a Plot Photograph Gallery

Five Years Post-Restoration Phase 1a Restoration Plot 1D Northwest View 10/4/17

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 1 Location:

East (X)	North (Y)
17432730	2868329

Note: High Tide Plot Flooded. Weathered Hurricane Irma better than the older reference forest as young saplings were able to bend and not break. Tops were stripped of vegetation along with a decline in health, which was not unexpected.

Monitoring Dates:
- Mangrove: 10/4/2017
- Epifaunal: 10/4/2017
- Aquatic Fauna: 10/3/2017

Appendix 2: Phase 1a Plot Photograph Gallery

Five Years Post-Restoration Phase 1a Restoration Plot 2D Northwest View 10/5/2017

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 2 Location:

East (X)	North (Y)
17432764	2868333

Note: High Tide Plot Flooded. Weathered Hurricane Irma better than the older reference forest as young saplings were able to bend and not break. Tops were stripped of vegetation along with a decline in health, which was not unexpected.

Monitoring Dates:

Mangrove: 10/5-10/6/2017
Epifaunal: 10/5/2017
Aquatic Fauna: 10/3/2017

Appendix 2: Phase 1a Plot Photograph Gallery

Five Years Post-Restoration Phase 1a Reference Plot 3A Northwest View 10/3/2017

Phase 1 Area 1
Plot Type: Reference (A)
Plot 3 Location:

East (X)	North (Y)
17432856	2868345

Note: High Tide entire Plot was flooded. Hurricane Irma effects evident in downed trees, top breakage, stripped vegetation and bark and overall decline in health, which is not unexpected given the strength of this storm.

Monitoring Dates:

Mangrove: 10/3/2017
Epifaunal: 10/3/2017
Aquatic Fauna: 10/4/2017

Appendix 2: Phase 1a Plot Photograph Gallery

Five Years Post-Restoration Phase 1a Reference Plot 4A
Northwest View 10/3/2017

Phase 1 Area 1
Plot Type: Reference (A)
Plot 4 Location:

East (X)	North (Y)
17432965	2868326

Note: High Tide entire Plot was flooded. Hurricane Irma effects evident in downed trees, top breakage, stripped vegetation and bark and overall decline in health, which is not unexpected given the strength of this storm

Monitoring Dates:

Mangrove: 10/3/2017
Epifaunal: 10/3/2017
Aquatic Fauna: 10/4/2017

Appendix 2: Phase 1a Plot Photograph Gallery

Six Years Post-Restoration Phase 1a Restoration Plot 1D Northwest View 1/12/18

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 1 Location:

East (X)	North (Y)
17432730	2868329

Monitoring Dates:
- Mangrove: 1/12/2018
- Epifaunal: 1/12/2018
- Aquatic Fauna: 2/15/2018

Appendix 2: Phase 1a Plot Photograph Gallery

Six Years Post-Restoration Phase 1a Restoration Plot 2D Northwest View 1/17/2018

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 2 Location:

East (X)	North (Y)
17432764	2868333

Monitoring Dates:

Mangrove: 1/17/2018
Epifaunal: 1/17/2018
Aquatic Fauna: 2/15/2018

Appendix 2: Phase 1a Plot Photograph Gallery

Six Years Post-Restoration Phase 1a Reference Plot 3A Northwest View 1/10/2018

Phase 1 Area 1
Plot Type: Reference (A)
Plot 3 Location:

East (X)	North (Y)
17432856	2868345

Monitoring Dates:

Mangrove: 1/10/2018
Epifaunal: 1/10/2018
Aquatic Fauna: 2/16/2018

Appendix 2: Phase 1a Plot Photograph Gallery

Six Years Post-Restoration Phase 1a Reference Plot 4A Northwest View 1/10/2018

Phase 1 Area 1
Plot Type: Reference (A)
Plot 4 Location:

East (X)	North (Y)
17432965	2868326

Monitoring Dates:

Mangrove: 1/10/2018
Epifaunal: 1/10/2018
Aquatic Fauna: 2/16/2018

Appendix 2: Phase 1a Plot Photograph Gallery

Seven Years Post-Restoration Phase 1a Restoration Plot 1D Northwest View
1/22/2019

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 1 Location:

East (X)	North (Y)
17432730	2868329

Monitoring Dates:

Mangrove: 1/22/2019
Epifaunal: 1/22/2019
Aquatic Fauna: 3/20/2019

Appendix 2: Phase 1a Plot Photograph Gallery

Seven Years Post-Restoration Phase 1a Restoration Plot 2D Northwest View 1/23/2019

Phase 1 Area 1

Plot Type: Restoration (Die-off) (D)

Plot 2 Location:

East (X)	North (Y)
17432764	2868333

Monitoring Dates:

Mangrove: 1/23/2019

Epifaunal: 1/23/2019

Aquatic Fauna: 3/20/2019

Appendix 2: Phase 1a Plot Photograph Gallery

Seven Years Post-Restoration Phase 1a Reference Plot 3A Northwest View 1/22/2019

Phase 1 Area 1
Plot Type: Reference (A)
Plot 3 Location:

East (X)	North (Y)
17432856	2868345

Monitoring Dates:

Mangrove: 1/22/2019
Epifaunal: 1/22/2019
Aquatic Fauna: 3/18/2019

Appendix 2: Phase 1a Plot Photograph Gallery

Seven Years Post-Restoration Phase 1a Reference Plot 4A Northwest View 1/25/2019

Phase 1 Area 1
Plot Type: Reference (A)
Plot 4 Location:

East (X)	North (Y)
17432965	2868326

Monitoring Dates:

Mangrove: 1/25/2019
Epifaunal: 1/25/2019
Aquatic Fauna: 3/18/2019

Appendix 2: Phase 1a Plot Photograph Gallery

Eight Years Post-Restoration Phase 1a Restoration Plot 1D Northwest View 2/24/2020

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 1 Location:

East (X)	North (Y)
17432730	2868329

Monitoring Dates:

Mangrove: 2/24/2020
Epifaunal: 2/17/2020
Aquatic Fauna: COVID19 pandemic prevented spring sampling

Appendix 2: Phase 1a Plot Photograph Gallery

Eight Years Post-Restoration Phase 1a Restoration Plot 2D Northwest View 2/27/2020

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 2 Location:

East (X)	North (Y)
17432764	2868333

Monitoring Dates:

Mangrove: 2/27/2020
Epifaunal: 2/17/2020
Aquatic Fauna: COVID19 pandemic prevented spring sampling

Appendix 2: Phase 1a Plot Photograph Gallery

Eight Years Post-Restoration Phase 1a Reference Plot 3A Northwest View 2/11/2020

Phase 1 Area 1
Plot Type: Reference (A)
Plot 3 Location:

East (X)	North (Y)
17432856	2868345

Monitoring Dates:

Mangrove: 2/11/2020
Epifaunal: 2/11/2020
Aquatic Fauna: COVID19 pandemic prevented spring sampling

Appendix 2: Phase 1a Plot Photograph Gallery

Eight Years Post-Restoration Phase 1a Reference Plot 4A Northwest View 2/11/2020

Phase 1 Area 1
Plot Type: Reference (A)
Plot 4 Location:

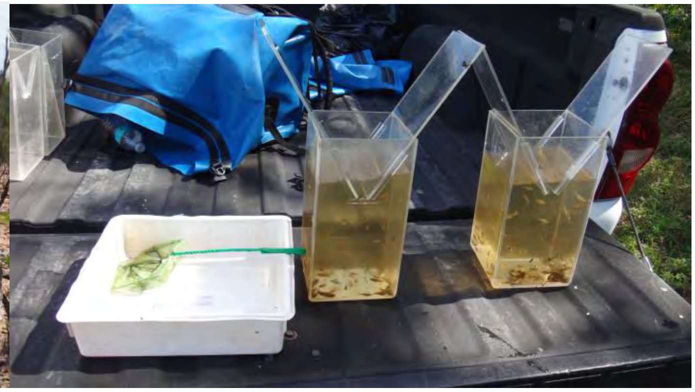
East (X)	North (Y)
17432965	2868326

Monitoring Dates:

Mangrove: 2/11/2020
Epifaunal: 2/11/2020
Aquatic Fauna: COVID19 pandemic prevented spring sampling

Appendix 3: Monitoring Fieldwork
(Phase 1a Restoration Area)

Dipnetting and Sorting Aquatic Fauna in Northern reaches of the Phase 1a Die-off



Appendix 3: Monitoring Fieldwork
(Phase 1a Restoration Area)

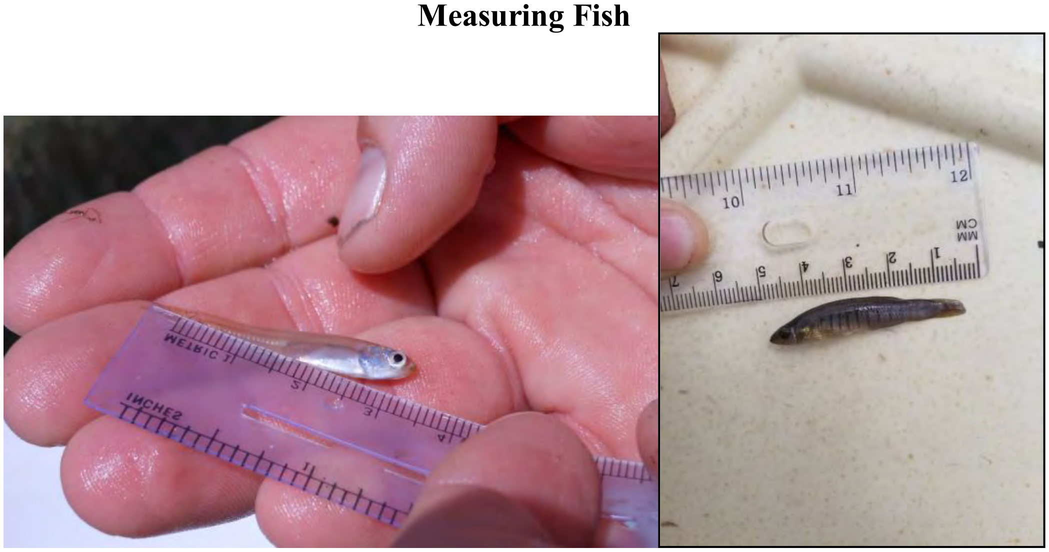
Mangrove Monitoring

Appendix 3: Monitoring Fieldwork
(Phase 1a Restoration Area)

Breder Trap soaking in the Restoration Area

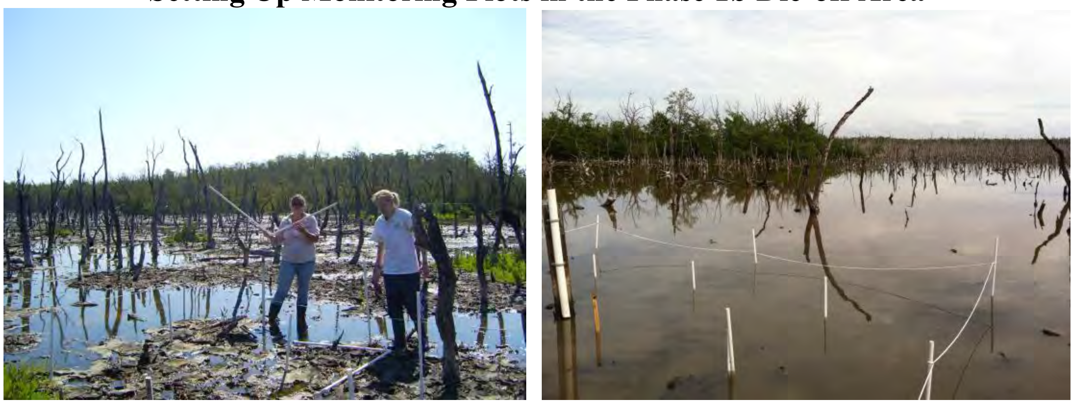
Breder Trap soaking in the Reference Area

Measuring Fish



Appendix 3: Monitoring Fieldwork
(Phase 1b Pre-Restoration)

Setting Up Monitoring Plots in the Phase 1b Die-off Area



Setting Up Monitoring Plots in the Phase 1b Reference Area

Pre-Restoration Baseline Monitoring in Phase 1b

Appendix 3: Monitoring Fieldwork
(Phase 1b Pre-Restoration)

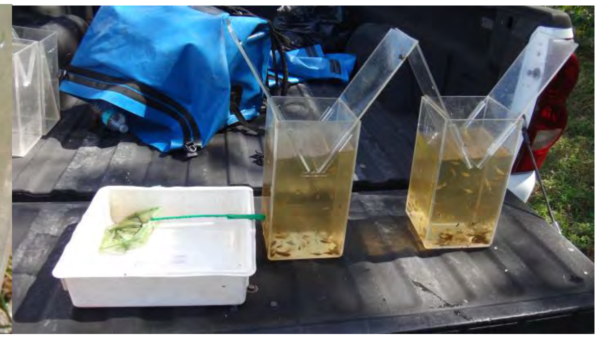
Plot G2 2017 with Periphyton Mats covering the Ground Surface

Appendix 4: Fish and Invertebrates

Pike Killifish

Common Snook

Various Fish in Breder Traps



Needlefish

Mangrove Snapper

Diamond Killifish

Sheepshead Minnow

Appendix 4: Fish and Invertebrates

Coffee Bean Snails

Appendix 4: Fish and Invertebrates

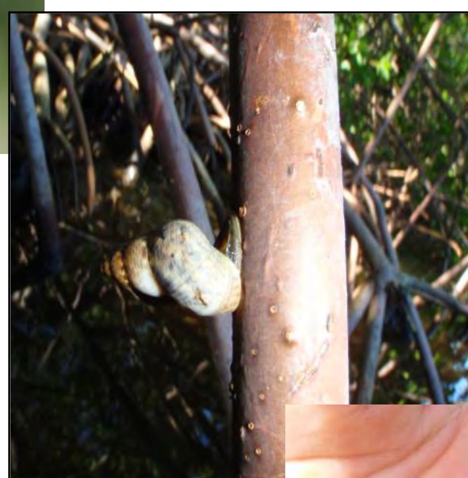
Grass Cerith

Copepod

Ladder Horn Snail

Mangrove Mud Crab

Mangrove Periwinkle



Fiddler Crab

Appendix 5: Hand-Dug Channel Extensions and Plot 3D in the Phase 1a Restoration Area

One of the New Hand-Dug Channels dug in the spring of 2015

Die-off Monitoring Plot 3D Installed September of 2015 in Restoration Phase 1a Site

Appendix 5: Hand-Dug Channel Extensions and Plot 3D in the Phase 1a Restoration Area

Phase 1a Restoration Plot 3D Northwest View 09/14/2016

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 3 Location:

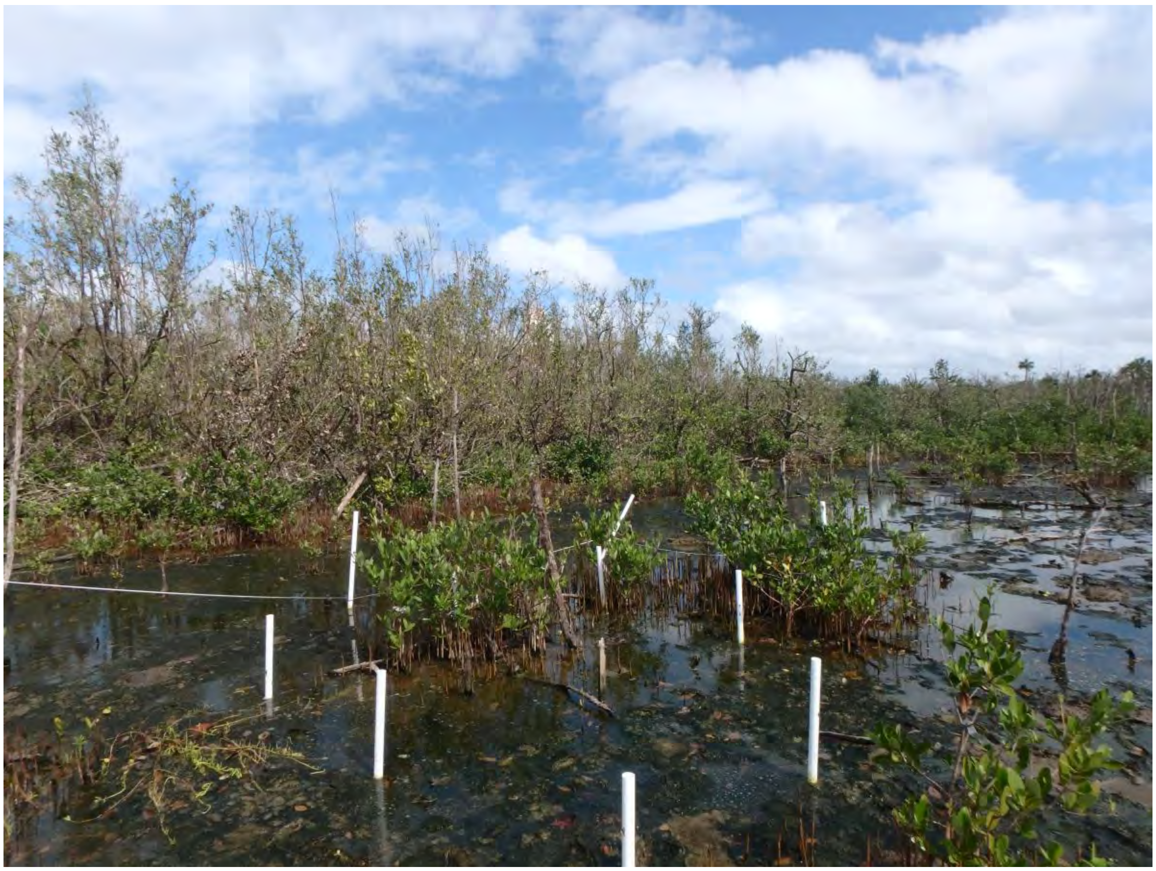
East (X)	North (Y)
17432803	2868396

Note: High Tide entire Plot was flooded
Monitoring Dates:

Mangrove: 9/14/2016
Epifaunal: 9/14/2016
Aquatic Fauna: 9/15 -9/26/2016

Appendix 5: Hand-Dug Channel Extensions and Plot 3D in the Phase 1a Restoration Area

Phase 1a Restoration Plot 3D   Northwest View 10/03/2017



Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 3 Location:

East (X)	North (Y)
17432803	2868396

Note: High Tide entire Plot was flooded
Monitoring Dates:

Mangrove: 10/3/2017
Epifaunal: 10/3/2017
Aquatic Fauna: 10/3/2017

Appendix 5: Hand-Dug Channel Extensions and Plot 3D in the Phase 1a Restoration Area

Phase 1a Restoration Plot 3D Northwest View 1/10/2018

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 3 Location:

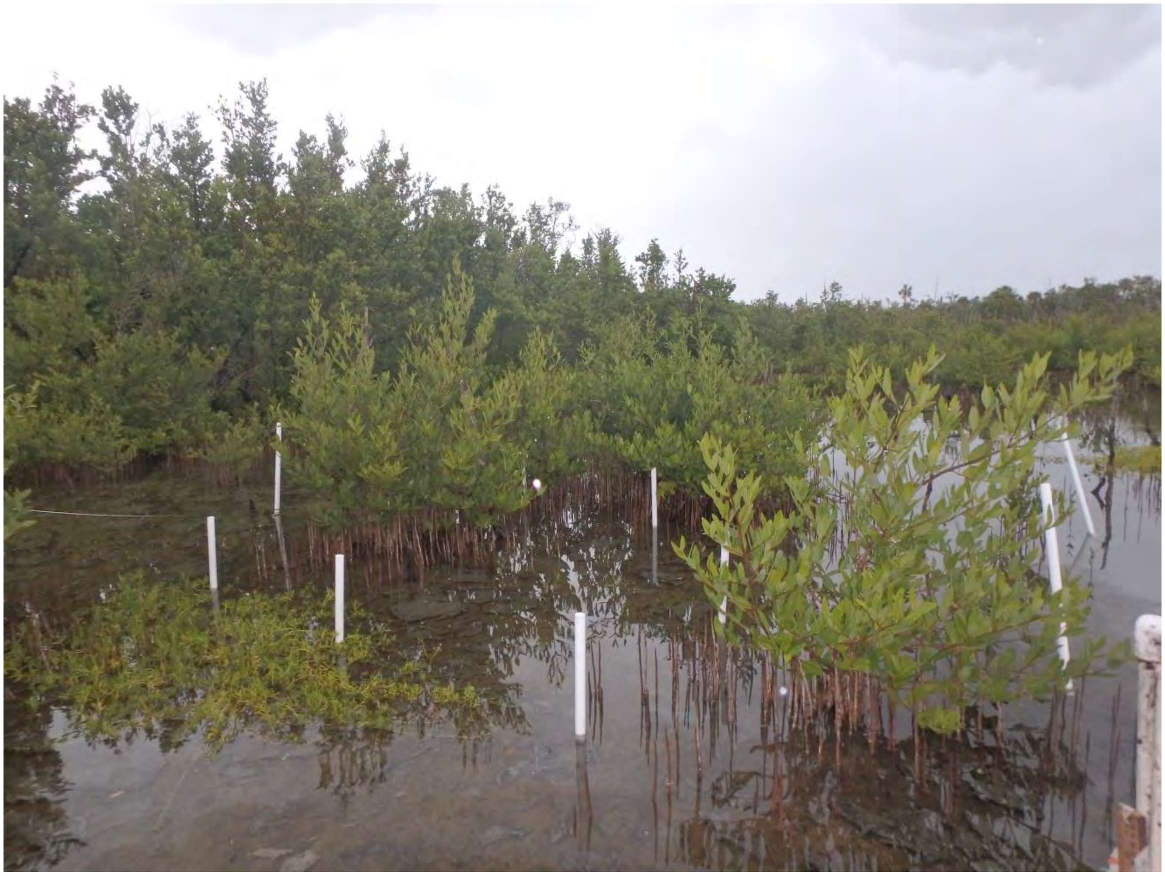
East (X)	North (Y)
17432803	2868396

Monitoring Dates:

Mangrove: 1/10/2018
Epifaunal: 1/10/2018
Aquatic Fauna: 2/15/2018

Appendix 5: Hand-Dug Channel Extensions and Plot 3D in the Phase 1a Restoration Area

Phase 1a Restoration Plot 3D Northwest View 1/24/2019



Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 3 Location:

East (X)	North (Y)
17432803	2868396

Monitoring Dates:

Mangrove: 1/24/2019
Epifaunal: 1/24/2019
Aquatic Fauna: 3/20/2019

Appendix 5: Hand-Dug Channel Extensions and Plot 3D in the Phase 1a Restoration Area

Phase 1a Restoration Plot 3D Northwest View 2//11/2020

Phase 1 Area 1
Plot Type: Restoration (Die-off) (D)
Plot 3 Location:

East (X)	North (Y)
17432803	2868396

Monitoring Dates:

Mangrove: 2/11/2020
Epifaunal: 2/11/2020
Aquatic Fauna: COVID19 pandemic prevented spring sampling

Appendix 6: Phase 1b Plot Photograph Gallery

Pre-Restoration Phase 1b Restoration Plot G2 2/12/2020

Phase 1B Area 2
Plot Type: Restoration (D)
Plot G2 Location:

East (X)	North (Y)
17432352	2868076

Monitoring Dates:

Mangrove: 2/12/2020
Epifaunal: 2/12/2020
Aquatic Fauna: 8/18/2020 – 8/20/2020

Appendix 6: Phase 1b Plot Photograph Gallery

Pre-Restoration Phase 1b Reference Plot G4 2/12/2020

Phase 1B Area 2
Plot Type: Reference (A)
Plot G4 Location:

East (X)	North (Y)
17432352	2868076

Monitoring Dates:

Mangrove: 2/12/2020
Epifaunal: 2/12/2020
Aquatic Fauna: 8/18/2020 – 8/20/2020

Appendix 6: Phase 1b Plot Photograph Gallery

Pre-Restoration Phase 1b Reference Plot G7 2/12/2020

Phase 1B Area 2
Plot Type: Reference (A)
Plot G7 Location:

East (X)	North (Y)
17432352	2868076

Monitoring Dates:

Mangrove: 2/12/2020
Epifaunal: 2/12/2020
Aquatic Fauna: 8/18/2020 – 8/20/2020

Appendix 6: Phase 1b Plot Photograph Gallery

Pre-Restoration Phase 1b Restoration Plot G10 2/12/2020

Phase 1B Area 2
Plot Type: Restoration (D)
Plot G10 Location:

East (X)	North (Y)
17432352	2868076

Monitoring Dates:

Mangrove: 2/12/2020
Epifaunal: 2/12/2020
Aquatic Fauna: 8/18/2020 – 8/20/2020

Appendix 6: Phase 1b Plot Photograph Gallery

Pre-Restoration Phase 1b Reference Plot G12 2/12/2020

Phase 1B Area 2
Plot Type: Reference (A)
Plot G12 Location:

East (X)	North (Y)
17432352	2868076

Monitoring Dates:

Mangrove: 2/12/2020
Epifaunal: 2/12/2020
Aquatic Fauna: 8/18/2020 – 8/20/2020

Appendix 6: Phase 1b Plot Photograph Gallery

Pre-Restoration Phase 1b Restoration Plot G14 2/12/2020

Phase 1B Area 2
Plot Type: Restoration (D)
Plot G14 Location:

East (X)	North (Y)
17432352	2868076

Monitoring Dates:

Mangrove: 2/12/2020
Epifaunal: 2/12/2020
Aquatic Fauna: 8/18/2020 – 8/20/2020

Appendix 7: Phase 1a Die-off Adjacent to a Tidal Channel over 8 Years 2012 – 2020

Appendix 8: Reference Plot Deterioration

Phase 1a Reference Forest

Phase 1b Reference Forest