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A biotic survey of outcroppings and Pinctada longisquamosa in Oyster Pond, San Salvador Island, Bahamas, one year after Hurricane Joaquin

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University Honors Thesis

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Abstract

Oyster Pond is one of the marine inland ponds located on San Salvador Island, Bahamas. Oyster Pond has connections to the ocean through a series of conduits in the pond, which cause the salinity of the pond to be a marine pond, except after a hurricane and during a drought. Oyster Pond has a variety of marine life such as algae, small fish, and invertebrates occurring in mangroves, flocculent, conduits, and biotic outcroppings. The focus of this research was to evaluate the impact of the 2015 Hurricane Joaquin (17 months later) on water chemistry and the marine life of the biotic outcroppings. Findings show that water chemistry had returned to normal levels (pH, salinity) and outcropping biota, as measured by species richness, were the same compared to a March 2016 study. Notably, macro algae that were absent after the hurricane as reported in 2016 were still not reestablished in 2017. Age estimations of a small sample of *Pinctada longisquamosa* showed that a majority of the oysters were produced post-Hurricane Joaquin. Based on these results, it seems that while water chemistry is back to normal, not enough time has passed for some biota, specifically species of macro algae, to recover from the storm's impact.

Acknowledgement

This project was conducted under the Biology, Geology, and Environmental Sciences Department at the University of Tennessee, Chattanooga. I would like to give my greatest appreciation to Dr. Ford for her time, commitment, and advice. Since the first class I had Dr. Dawn Ford in Conservation of Biodiversity during my sophomore year, she has continued to change my perspective on this world. I would also like to thank Dr. Ann Holmes for being there to help guide me along the way. I would like to thank Luke Black and Alex Schwartz for helping me gather and identify data, without them I would have not been able to accomplish this. Lastly, I would like to thank the UTC Honors College for opening the doors to be able to experience life-changing adventures such as the Tropical Island Ecology and Geology course that allowed me to travel to San Salvador in March 2016 when I first discovered my passion for biological research.

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Introduction

San Salvador Island is one of the outer islands of the Bahamas (Figure 1). This small island is the result of the build-up of marine sediment and organisms. The San Salvador platform is the result of shallow-water sedimentation occurring since the Cretaceous period, which was over sixty-five million years ago (Carew and Mylroie, 1994; Figure 2). The carbonate deposition has kept pace with subsidence at a rate of 1m/40,000 years (Mullins and Lynts, 1977). The Sangamon, the last interglacial period, elevated the sea level 6 meters higher than it is now, while the Wisconsin glacial period, dropped sea level over 140 meters compared to the shoreline today and sea level is currently rising at the rate of 3 millimeters per year, producing noticeable changes (Cole et al., 2007).

The island, approximately 12 miles long and 6 miles wide, has many interior lakes and ponds. There is little development on the island with small settlements, an airport, and the Gerace Research Centre, a field station for scientific research. On the northeast part of the island behind the Gerace Research Centre, there are many small ponds, including Crescent, Moon Rock, Oyster, Reckley Hill, and Osprey (Gamble and Kindler, 2012; Figure 3). Marine ponds have an average salinity level of 33-37 parts per thousand (ppt), while a hyper saline pond has a salinity value above 38 ppt. Crescent, Moon Rock, and Oyster Ponds, for example, are considered to be marine ponds, which means that their salinity normally stays the same range as the ocean. Reckley Hill and Osprey are considered hyper saline ponds, meaning that the salinity of these ponds stays above the average salinity of the ocean. Marine ponds have many connections to the ocean, while hyper saline ponds have fewer connections and tend to have higher evaporation levels due to not being able to replenish the water thus increasing the salinity.

One aspect that makes the marine ponds unique is that because they stay at a consistent salinity as the ocean; whenever a hurricane or tropical storm hits the island, the pond salinity will decrease temporarily. This change is due to the increased rainfall that comes with hurricanes; rainfall will dilute the pond, causing the salinity to lower (Gamble and Kindler, 2012). This is important for the species living in the ponds, because with changes in salinity, harm can be done to the species, including causing death (Gamble and Kindler, 2012). In addition to salinity, pH levels in a pond are an important limiting factor.

There are more than 7,000 species of green algae known; green algae, like plants, contain two forms of chlorophyll which is used to capture light energy to fuel to production of the algae (University of California Museum of Paleontology [UCMP], 2017). The inland ponds of San Salvador Island host an array of species: such as algae, fish, and invertebrates. Previous studies have recorded species of green and red algae in Oyster and Crescent Ponds (Ford and Abernathy, 2014). A few of the green algae include *Batophora oerstedii, Acetabularia crenulata, Acetabularia calyculus, Anadyomene spp., Cladophoropsis macromeres, Dictyosphaeria sp., Microdictyon marinum,* and *Pedobesia sp.* (Ford and Abernathy, 2014; Richardson and Mitchell, 1994). The red algae identified in Oyster Pond include *Daysa croyaniana, Polysiphonia spp., and Spyridia spp.* Red algae are unique because of its ability to absorb blue light and reflect red light. This is caused by the presence of a pigment called phycoerythrin (Richardson and Mitchell, 1994). Blue light is able to reach greater depths than red light; therefore, red algae are able to live in at greater depths in the water versus other algae species (UCMP, 2017).

Oyster Pond, like many interior ponds, contains several habitats. A gelatinous flocculent layer of variable thickness rests along the bottom of the pond, and is made up of decomposing dead and or fragmented mangrove leaves. Another habitat found in the pond is the mangroves and their prop roots that ring the pond margins and help protect the pond from strong winds and erosion. The pond has biotic outcroppings. Outcroppings often are emergent above the surface of the flocculent. Outcroppings are an accumulation of biotic growths that can consist of different algae, invertebrates, and other species (Figure 4). The fourth habitat is the conduit mouths, which connect Oyster Pond to the ocean. The conduits allow Oyster Pond to maintain the same salinity as the ocean (Figure 5).

In March 2016, my research was focused on the impact that Hurricane Joaquin had on the outcroppings in the pond. Using a field guide by Diehl et al., 1988 to identify the species of some of the invertebrates found in the pond outcroppings. These include species of: cnidarians, echinoderms, mollusks, and sponges. Cnidaria are invertebrates with stinging cells and tentacles surrounding the mouth; jellyfish, sea anemones, and corals are cnidarians (Figure 6; Diehl, 1988). A few cnidarians that live in the ponds include: *Aiptasia pallida, Bartholomea annulata, and Bougainvillia spp.* An echinoderm is a marine animal that has a radically symmetrical coelomate examples are starfishes and urchins (Figure 7; Hickman 1998). The echinoderms found in ponds on the island include *Synaptula hydriformis* (sea cucumber) and the brittle star. Mollusks are invertebrates that have a soft unsegment body lacking segmented appendages and is commonly protected by a calcareous shell. Mollusks found in Oyster Pond include *Isognomon alatus* and *Pinctada longisquamosa* (Diehl et al., 1988; Figure 8). Sponges are invertebrates having a cellular grade of construction without true tissue or organ formation. *Chondrilla nucula*, the chicken liver sponge, is an example of a sponge found in Oyster Pond (Figure 9; Zea, S., Henkel, T.P., and Pawlik, J.R. 2014).

Species respond in a variety of ways to stressors such as tropical storms and hurricanes. With the heavy rainfall amounts often associated with hurricanes, the resulting reduction in salinity in the pond causes some species to die off and others to go into a stress mode that causes them to reproduce before dying off. In some ponds where they are not protected externally by mangroves, this type of reproduction caused by severe storms is common, but with other ponds it takes a very severe storm for the pond to go into a stress mode (Baxter and Cole, 2011). Oyster Pond is one of the ponds that are protected by mangroves that form a protective fringe around the pond margins. It takes a severe storm and significant rainfall to cause visible effects on the species living in the pond because of the pond's protection by the mangroves.

One natural biological event that occurs in Oyster Pond due to strong storms is an event called suicide spawning. Cole (2011) identified this natural event in Oyster Pond in his study. According to Cole, Oyster Pond contains some of the oldest species of *Pinctada longisquamosa,* but they do not exhibit a rapid growth rate. However, what Cole noticed in Oyster Pond is that when there is a strong storm, such as a hurricane, a suicide spawning event will occur. Suicide spawning in Oyster Pond is when the older *Pinctada longisquamosa* go through a period of spawning and then die off (Baxter and Cole, 2011).

In October 2015, San Salvador region was hit by category 4 Hurricane Joaquin, which stalled for a few days in the area, causing a huge impact on the island of San Salvador. Hurricanes are cyclonic storms that normally occur between the months of May-November. Due to the location of the Bahamas, on average they experience more hurricanes than most areas (Sipahioglu, 2008). “The storm rapidly intensified as it moved toward the Bahamas. At one point Joaquin saw a pressure drop of 57 mill bars in about 39 hours, going from a strong tropical storm to a Category 4 in the process” (The Weather Channel, 2015). Figure 10 shows an image from the beach on San Salvador Island Post Hurricane Joaquin. It was noted that debris was reduced on the beach because the strong storm pushed the debris over the dunes.

In March 2016, research was conducted in Oyster Pond to research the effects that Hurricane Joaquin had on the pond just 5 months after the event. Data from this study found that Hurricane Joaquin had a direct impact on the pond; algae that was previously found was no longer there; the pond no longer flourished like it did from previous studies done before the hurricanes in 2014 and 2015.

What was noticed from the comparison was that there was a significant amount of juvenile fish, an increase in oyster population, and many algae in their sexual state, but a decrease in algae species that were previously there. The algae that was not found were the red algae: *Dasya crovaniana, Polysiphonia subtilissima*, and green algae: *Anadyomene stellata* and *Pedobesia lamourouxii*. Based on the research it seemed the pond was recovering, with the increase in juvenile fish and algae in their sexual state, with hopes that one year later the pond will have returned back to the previous state it was in prior to the hurricane.

As a result, for my 2017 study, there were two hypotheses:

Hypothesis 1: One year later, Oyster Pond has returned to its normal state prior to Hurricane Joaquin with the exception of an increase in *Pinctada longisquamosa.* I expect that the outcroppings will be larger and more diverse, the red algae *Dasya crovaniana, Polysiphonia subtilissima*, and green algae *Anadyomene stellate*, and *Pedobesia lamourouxii* will be found again. I expect that the salinity of the pond will be back to normal salinity.

Hypothesis 2: One year later, Oyster Pond has not returned to its original state; smaller outcroppings are present and no sightings of the red algae *Dasya crovaniana, Polysiphonia subtilissima* and green algae *Anadyomene stellate* and *Pedobesia lamourouxii,* but there is an increase in the *Pinctada longisquamosa.* The salinity levels have not changed or altered since my previous research.

These two hypotheses were based on previous studies done on Oyster Pond. According, to Cole (2007), Oyster Pond recovers faster than most ponds due to its connection to the ocean. These connections balance the salinity, and the mangroves protect the pond from strong winds and agitated water.

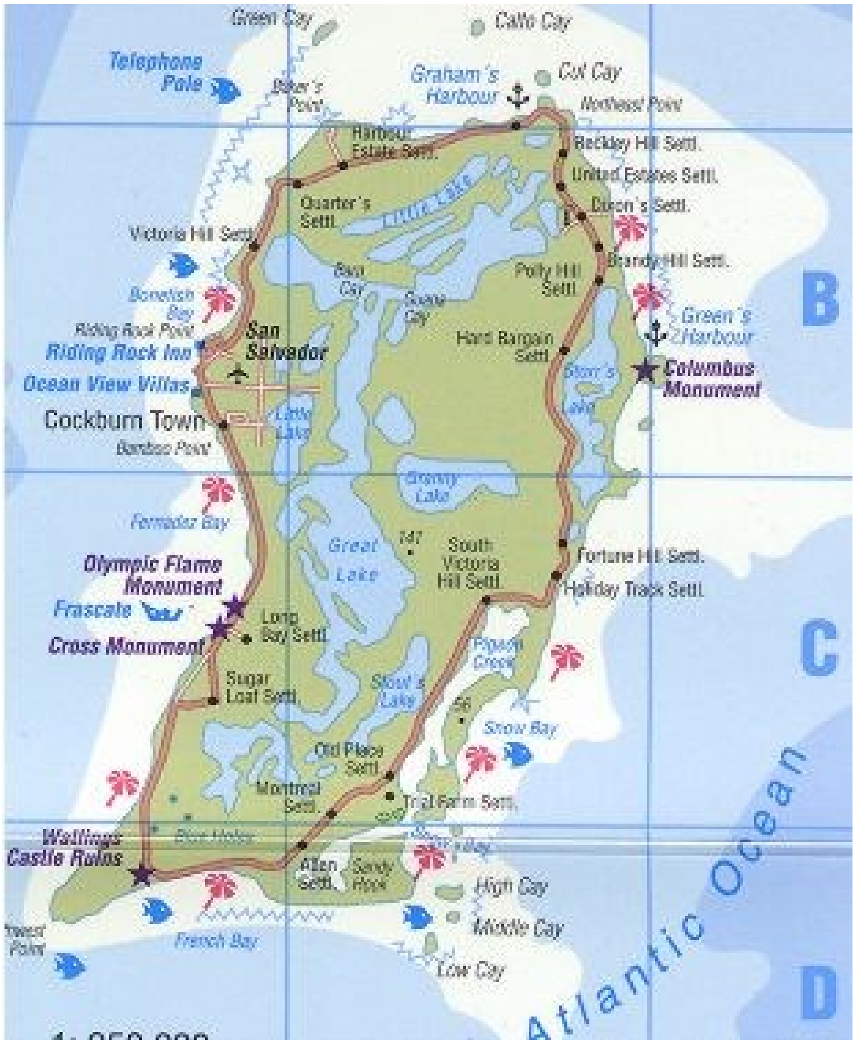

Figure 1: A map of San Salvador Island Bahamas

Figure 2: Fossilized coral located on San Salvador Island

Figure 3: Map of northern end of San Salvador Island ponds (Kokesh, n.d.).

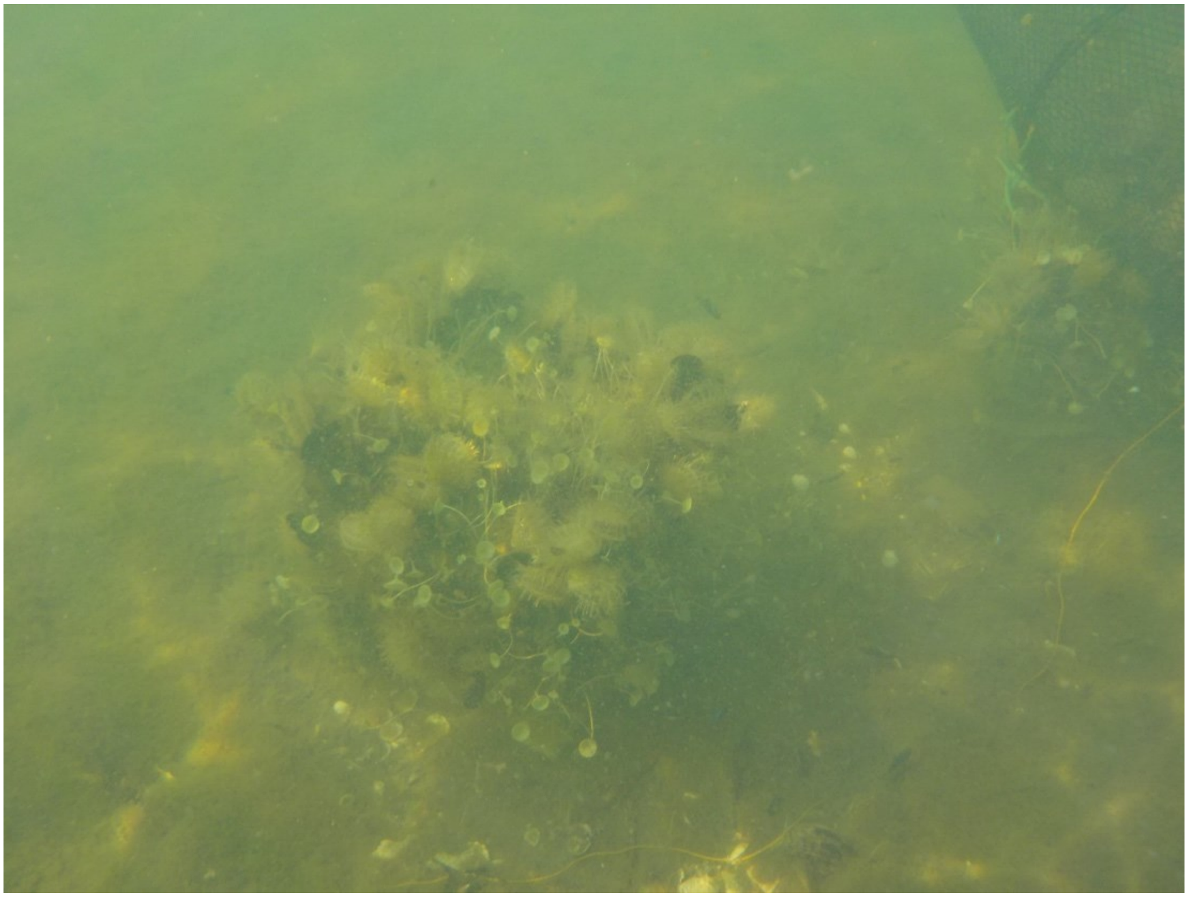

Figure 4: An example of an outcropping along the Oyster Pond bottom.

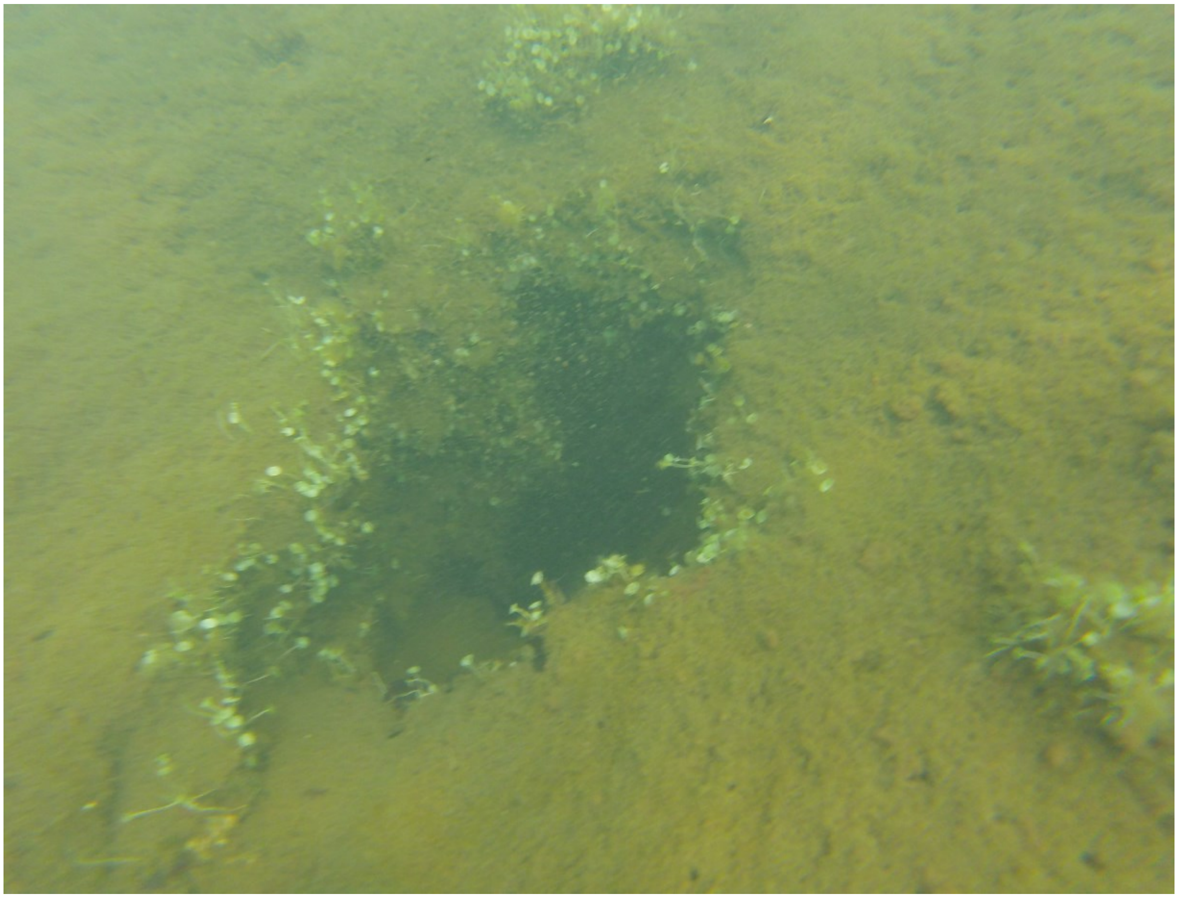

Figure 5: Conduit mouth located in Oyster Pond and populated by *Acetabularia* and other algae.


Figure 6: A sea anemone found in Oyster Pond.

Figure 7: A brittle star found in Oyster Pond.

Figure 8: An oyster found in Oyster Pond, encrusted by *Acetabularia crenula*ta and other organisms.

Figure 9: Chicken liver sponge found in Oyster Pond, in front of a 1 meter by 1 meter white PVC quadrat.

Figure 10: Plastic and debris collected on the beach, deposited by Hurricane Joaquin, waves and ocean currents.

Methodology

Study Area

This study was conducted at Oyster Pond, approximately one-mile south of the Gerace Research Centre (GRC) located on San Salvador Island, Bahamas (Figure 11). Oyster Pond was surveyed on March 12^{th}, 13^{th}, 14^{th}, and 16^{th}, 2017, from approximately 9:00 A.M. until 3:00 P.M.

Sampling Strategy

For this study, outcroppings were surveyed using four 50-meter transect lines located 20 and 40 meters east and west sides of the north entrance to the pond.

Outcroppings that occurred along the transect lines were sampled (line-intercept method). A 1-meter quadrat was used to identify species on the outcropping within that quadrat on the transect line. A quadrat helps to objectively focus investigations along the transect lines.

Samples and photographs from the outcroppings were taken to the lab at GRC for further identification and analysis. This was done so that anything that could not be identified visually in the field could be identified at the lab with identification books and a digital microscope.

To calculate growth rate of the Scaly Pearl Oyster, *Pinctada longisquamosa*, hinge lengths were measured in millimeters on 20 specimens. The hinge lengths were measured to calculate the age of each *Pinctada longisquamosa*. Cole (2016) developed this method to translate the lengths of the straight hinge in mm to ages in months.

Outcroppings

To conduct the pond research, we used snorkel gear to facilitate finding and investigating the outcroppings along the bottom of Oyster Pond. Four starting points along the margins adjacent to the north entrance of the pond were measured and marked with pink flagging tape, which was removed after our last study. Two 50m transects were run from starting points at 20 m and 40 meters west of the north entrance to the pond, and a duplicate set was run on the east side of the entrance (Figure 12). These distances were chosen because it gave enough separation for there to be significant differences. Using snorkel gear and a compass for guidance, we swam along the length of each transect line and marked the end of the transect lines with a visible buoy.

We completed sampling and measuring the western side transects, then the eastern side ones. We surveyed any outcroppings and species living on the outcroppings, recording notes on a dive board. We used a 1-m^2 quadrat every five meters to span the transect line. Any outcropping within that quadrat was studied and specimens were collected. Specimens were carefully collected by hand from the outcroppings and put into Ziploc bags, which were labeled according to the transect line-intercept to keep organized. Photos of each of the quadrats were taken with a Go Pro camera, allowing for more visual observation back at the lab.

Once we returned to the lab, specimens that had been collected were taken to the wet lab. Further study of the samples collected from that day was conducted, using a digital microscope that captured figures. Careful identification of the species was done by using the microscope and identification books. Oyster hinges were measured by using a measuring tape to determine the age.

Water Samples

Water samples of Oyster Pond were taken by gathering water in Ziploc bags. Samples were taken back to the lab and using 2 methods, a water chemistry kit and a refractometer for salinity, and a pH meter were used. Multiple water samples were analyzed to ensure that there were no discrepancies in the samples.

South
Entrance

North
Entrance

Figure 11: Oyster Pond taken from Google Earth

Figure 12: Aerial drone view of the transect lines being marked at the 20 and 40 meter lines east from the entrance.

Results

Transect Line Data

Table 1 show species identified in 2017, as compared to previous years. Samples from line 1 and 2 (20 and 40 meters west) collected from the west side of the pond included the following: burnt mussels, sea cucumbers, mangrove oysters, shrimp, gastropods, bivalves, worms, anemones, mermaids' wineglass, and scaly pearl oysters. The further west from the entrance the more abundant the outcroppings came, but the further towards the middle of the pond, fewer outcroppings were noticed (Figure 13, 14, and 15).

Transect lines 2 and 4 on the east side of the pond had the same species as on the west side, with a richness of the *Pinctada longisquamosa (*scaly pearl oyster). However, the further east from the entrance, the less abundant the outcroppings became. Similarly, the further south from the entrance, the less abundant the outcroppings became (Figure 16, 17, and 18).

Scientific Name	Common Name	2014	2015	2016	2017
GREEN ALGAE					
Acetabularia crenulata	**Mermaid's Wine Glass**	**x**	**x**	**x**	**x**
Acetabularia calyculus	**Umbrella Alga**			**x**	**x**
Anadyomene		**x**	**x**		
Batophora oerstedii			**x**	**x**	**x**
Cladophoropsis macromeres		**x**	**x**	**x**	
Dictyosphaeria	**Green bubble weed**		**x**	**x**	**x**
Microdictyon marinum		**x**			
Pedobesia spp.			**x**		
RED ALGAE					
Dasya crovaniana			**x**		
Polysiphonia			**x**		
Spyridia spp.		**x**			
CNIDARIA					
Aiptasia pallida	**Brown glass anemone**	**x**	**x**	**x**	**x**
Bartholomea annulata	**Ringed anemone**	**x**	**x**	**x**	**x**
Bougainvillia spp.		**x**	**x**	**x**	**x**
ECHINODERM					
Synaptula hydriformis	**Medusa worm**	**x**	**x**	**x**	**x**
Ophiuroidea	**Brittle star**		**x**	**x**	
MOLLUSCA					
Isognomon alatus	**Flat tree oyster**	**x**	**x**	**x**	**x**
Pinctada longisquamosa	**Scaly pearl oyster**	**x**	**x**	**x**	**x**
Gastropods	**Multiple species**			**x**	**x**
PORIFERA					
Chondrilla nucula	**Chicken liver sponge**	**x**	**x**	**x**	**x**
ANNELIDA					
Trypanosyllis spp.			**x**	**x**	**x**
Arenicola cristata	**Lugworm**				**x**
Polynoidae spp.	**Scale worm**				**x**
ARTHROPODA					
Artemia spp.	**Brine shrimp**	x	**x**	x	**X**
SPECIES RICHNESS		13	18	16	16

Table 1: Species identified and richness from 2014-2017. *2014-2015. Ford and Abernathy

One limitation of this study is that because this survey of species used visual and sampling methods, there are likely species not included in this data because they do not have a large presence or are under the surface of the outcropping. Most identification of species was made through a cross-comparison of previously collected data (Ford and Abernathy, 2014) as well as a field guide of the San Salvador inland ponds (Diehl 1988).

The Ford and Abernathy, 2014 research references an unknown algae species in their findings. However, it was later to be discovered that this is not algae but a branching hydroid belonging to the phylum Cnidaria. In March 2016, identification of this unknown hydroid was made as the family Bougainvilliidae and genus *Bougainvillea* through the World Registry of Marine Species database (Schuchert 2015). This species was also found again in the 2017 study. We were able to visually identify this through microscopy, by the species' distinctive length of the shaft and branches, and the sparse hydranth tips (Figure 19).

One new species found in the pond was the *Polynoidae spp.,* known as the scale worm (Figure 20). The scale worm is protected by large overlapping plates, which are fringed with tubercles and hairs (Read, 2004).

Unidentified egg sacs and *Pinctada longisquamosa*

In 2016, unidentified egg sacs were found in large quantities in the pond nesting near the bottom of the pond (Figure 21). The egg sacs have a gelatin-like texture and normally do not break open when you swim through them. These egg sacs had not yet been identified in Oyster Pond, so it was hypothesized that because of the increase in the *Pinctada longisquamosa* these must be oyster egg sacs. After, surveying the pond in

March 2017, and discovering that there were not as many *Pinctada longisquamosa (*scaly pearly oyster) as we hypothesized, more research was done to conclude what kind of egg sac these were. Based on field guides of San Salvador Island, it was concluded that these egg sacs belonged to the *Arenicola cristata* species. The *Arenicola cristata* (south Atlantic lugworm) can reach 30 cm in length, is reddish or greenish red in color, and during the spring produces an elongated egg mass that can reach 90 cm (Sept J. 2016). The lugworms start producing their eggs in the spring, which is why there was an abundance of them during March 2016.

Samples were gathered of the scaly pearly oyster to take back to the lab to measure the hinges of the oysters to get an estimate of the oysters' ages (Table 2). Based on the lengths of the hinges, it was determined that a majority of the oysters were produced post-Hurricane Joaquin and only a few were from prior to Hurricane Joaquin

Sample	Size	Age in Months	Birthdate
1	24 mm	25	Feb-15
2	25 mm	26	Dec-14
3	19 mm	14	Jan-16
4	22 mm	17	Oct-15
5	26 mm	31	Aug-14
6	24 mm	25	Feb-15
7	22 mm	17	Oct-15
8	20 mm	15	Dec-15
9	17 mm	12	Mar-16
10	21 mm	16	Nov-15
11	21 mm	16	Nov-15
12	22 mm	17	Oct-15
13	19 mm	14	Jan-16
14	27 mm	33	Jun-14
15	20 mm	15	Dec-15
16	25 mm	26	Dec-14
17	23 mm	23	Apr-15
18	16 mm	11	Apr-16
19	19 mm	14	Jan-16
20	15 mm	10	May-16

Table 2: *Pinctada longisquamosa* age based on length using Cole's (2016) method.

Water Chemistry

Water chemistry in Oyster Pond has varied throughout the years, but the average salinity of Oyster Pond is 37 ppt. It was concluded the water chemistry was back to normal salinity ranges in 2017, with a salinity of 37 ppt and a pH of 7.49 (Table 3). This indicates that the pond is recovering from the effects of Hurricane Joaquin, and this will allow for establishment and growth of the species found in the pond pre-Joaquin.

	2017	2016	2015	2012
pH	7.49	7.54	7.74	
Salinity	37 ppt	35.5 ppt	34.45 ppt	37.1 ppt

Table 3: pH and Salinity results from Oyster Pond.

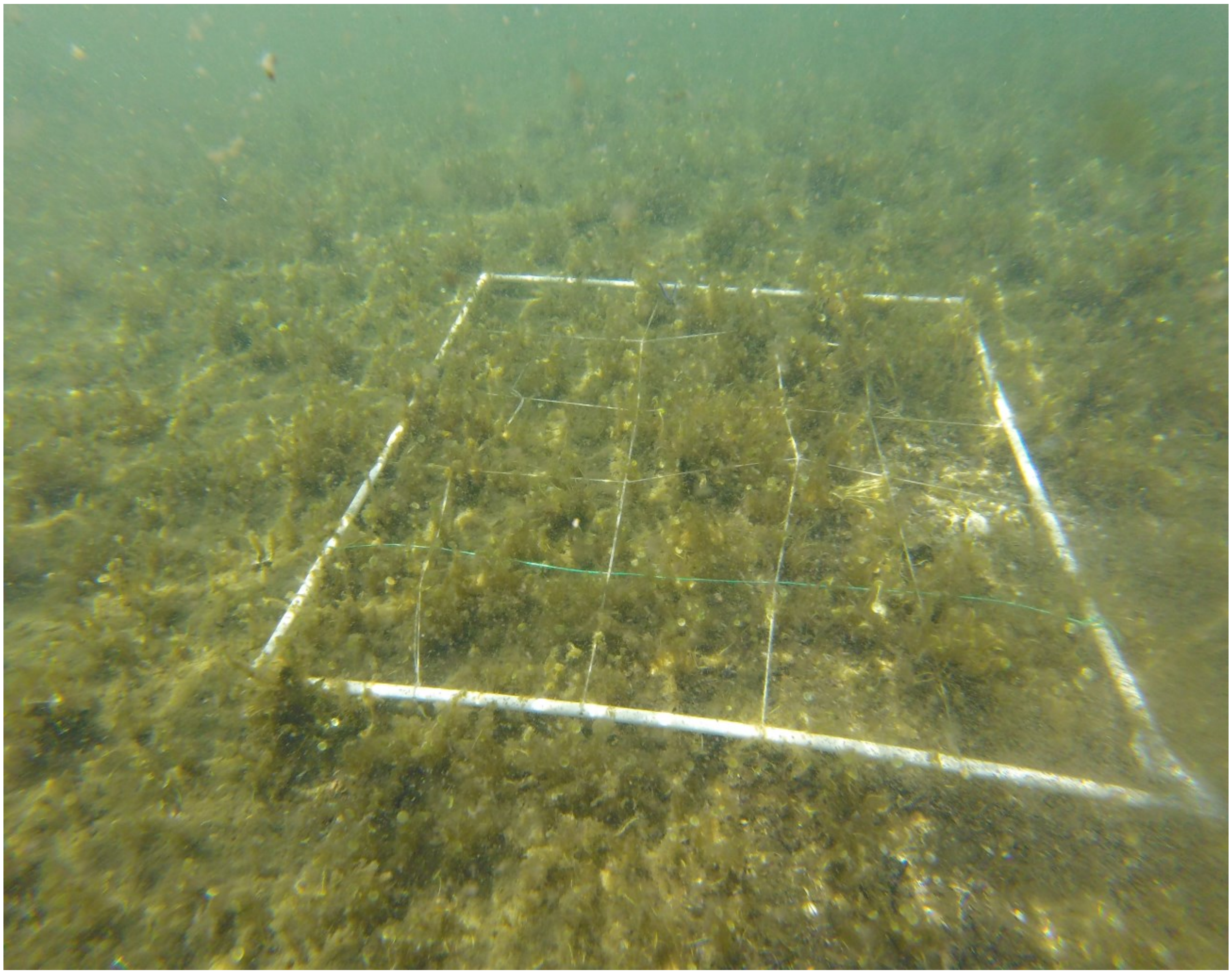

Figure 13: Quadrat technique deployed 40 meters to the west of the entrance

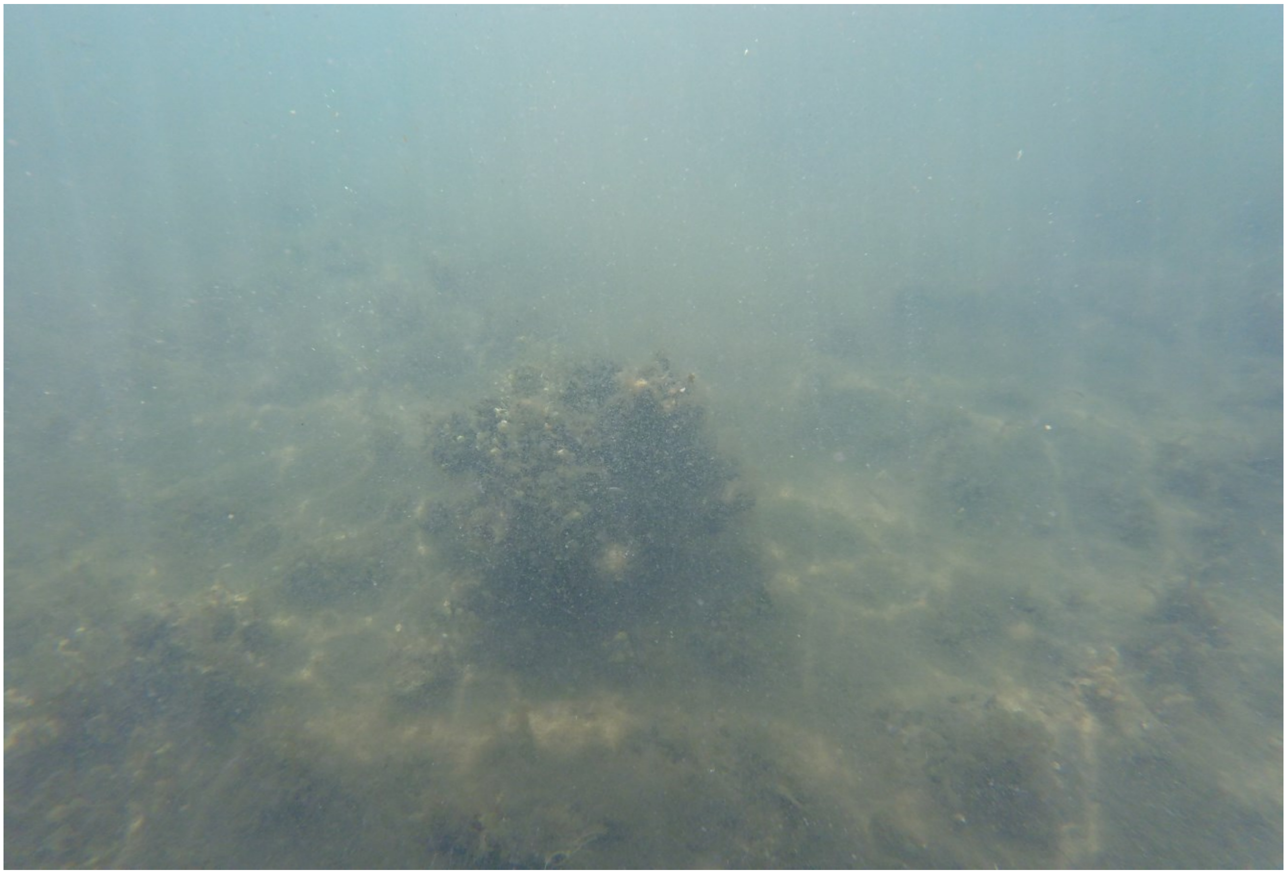

Figure 14: outcropping located 20 meters to the west from the entrance

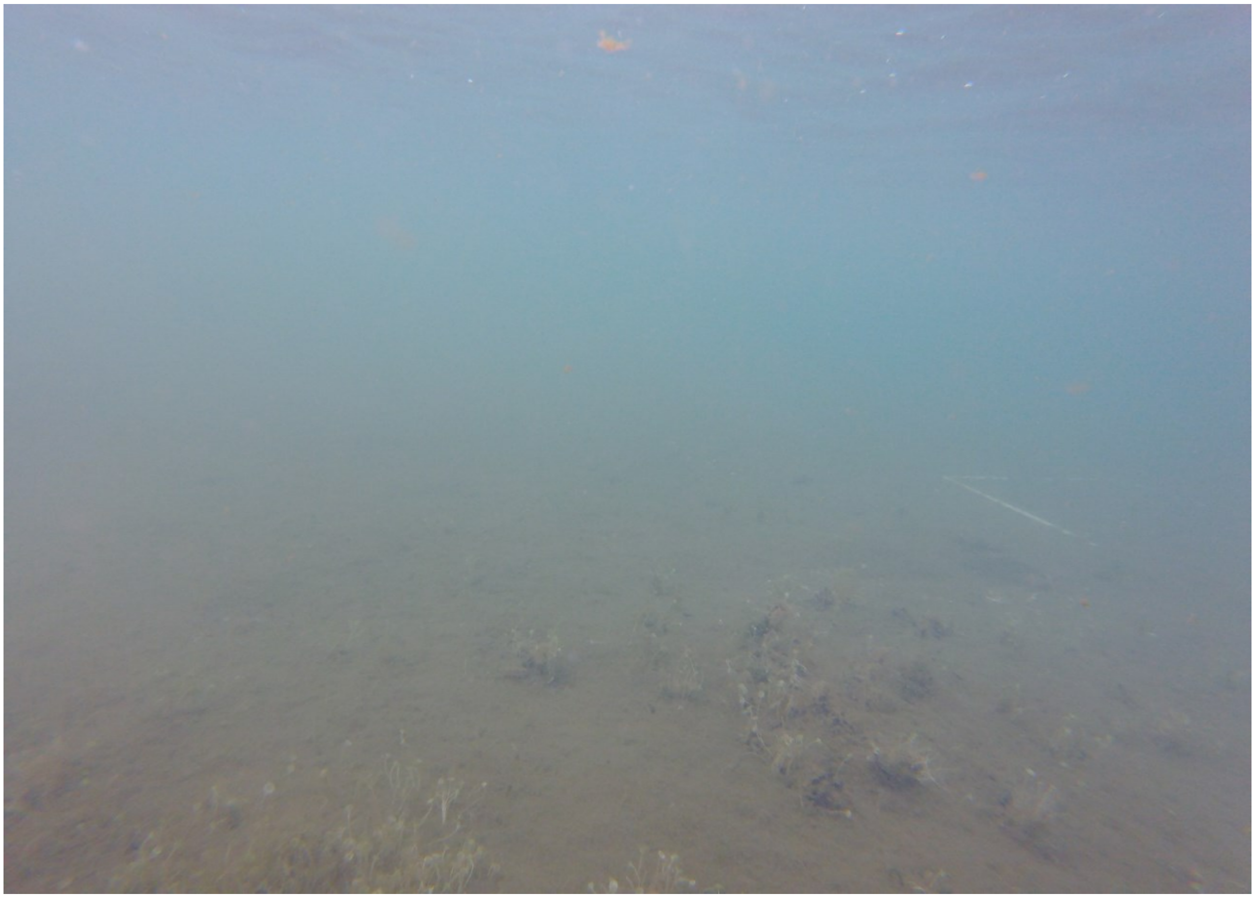

Figure 15: 40 meters to west of the entrance and 30 meters south

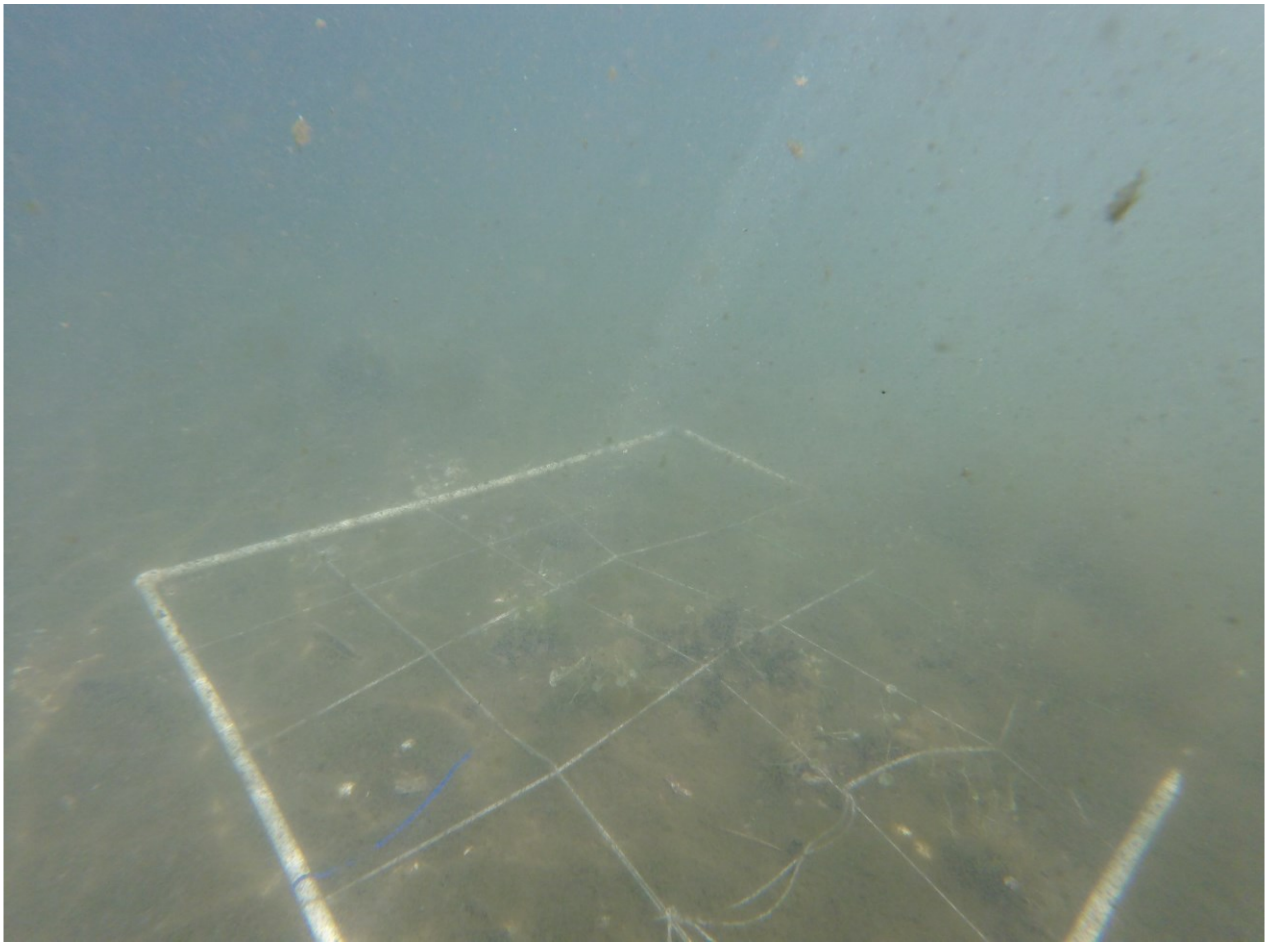

Figure 16: 40 meters to the east of the entrance

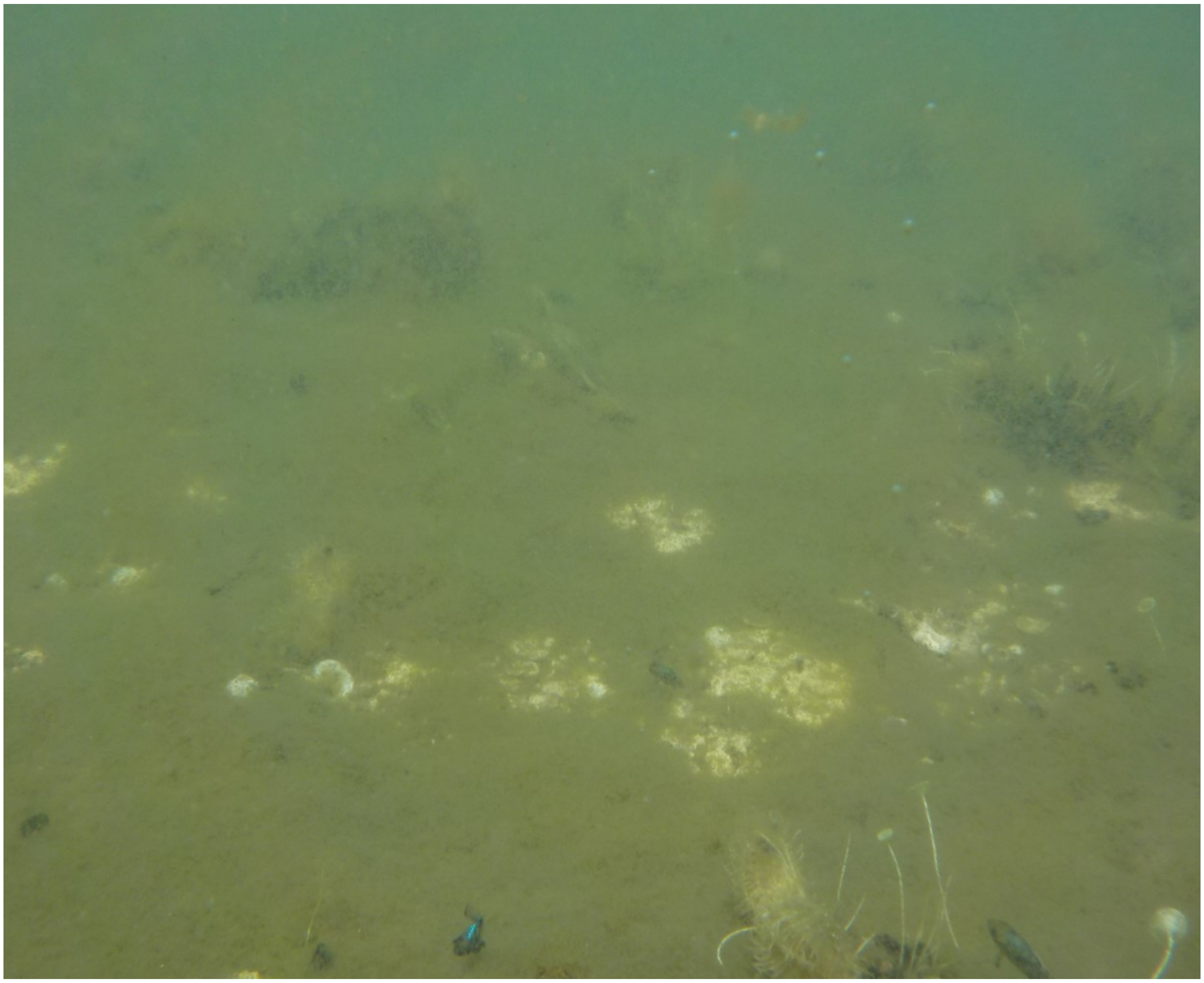

Figure 17: 20 meters to the east of the entrance

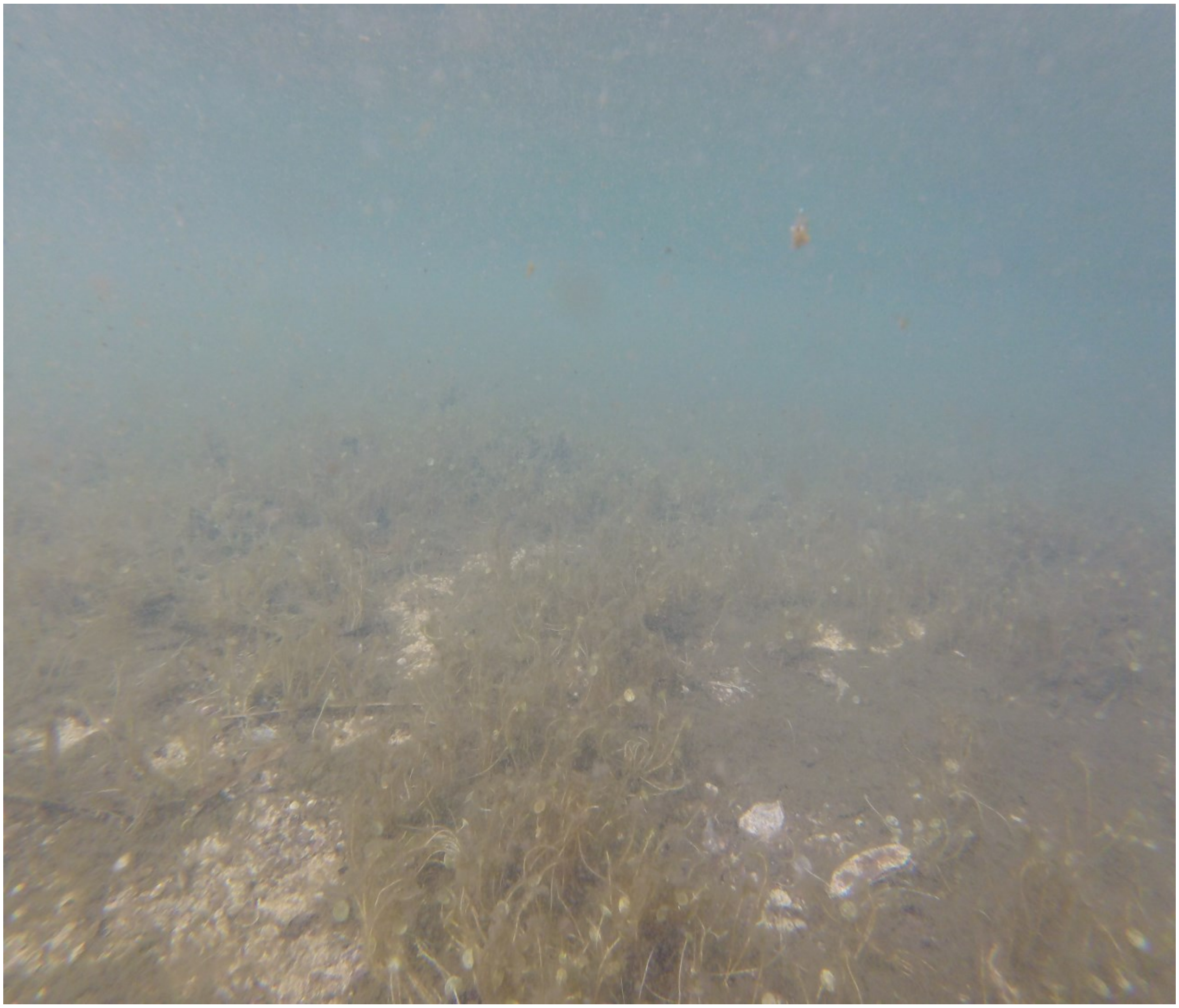

Figure 18: 20 meters to the east of the entrance and 30 meters south

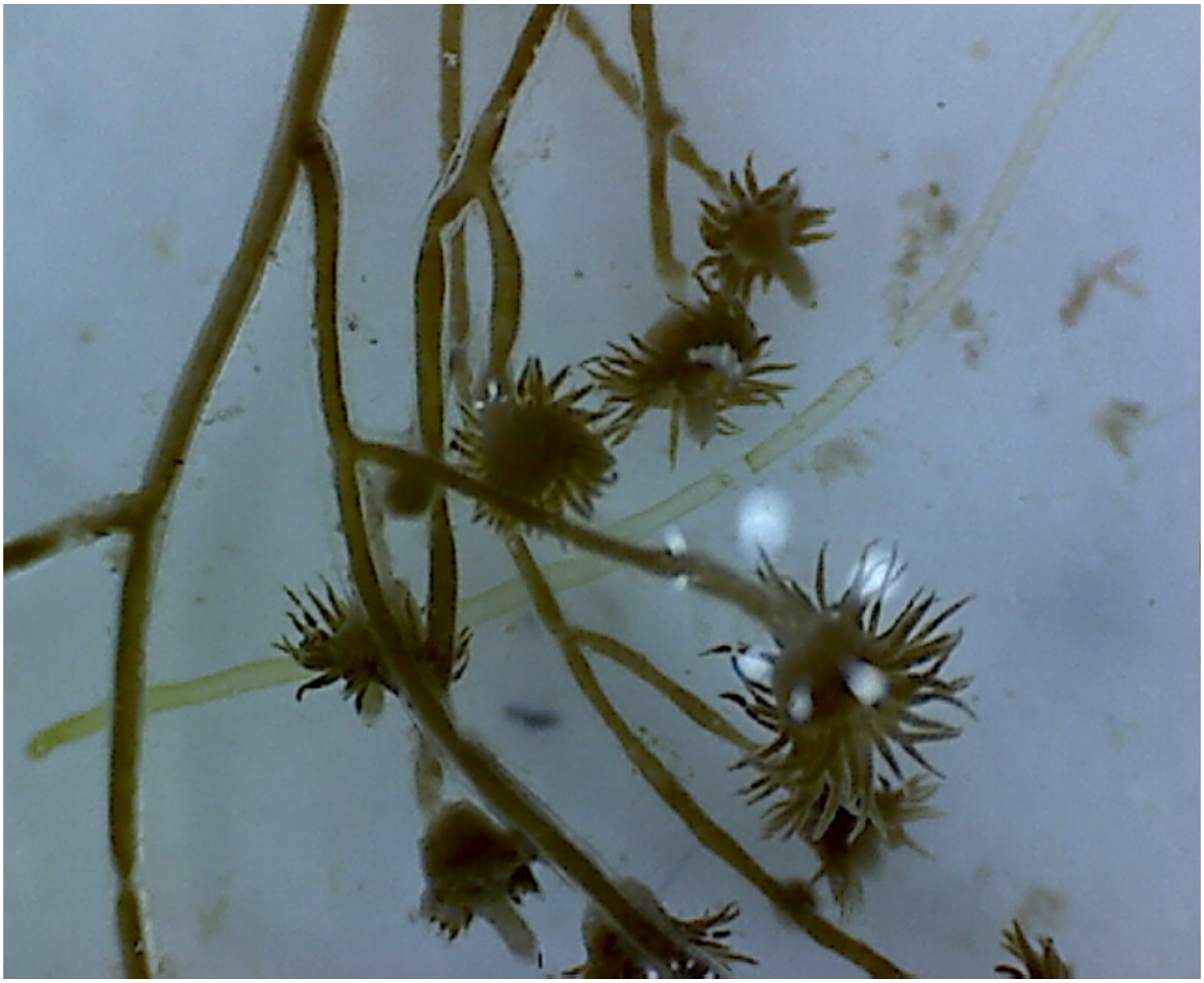

Figure 19: Figure of unknown hydroid: *Bougainvillia*

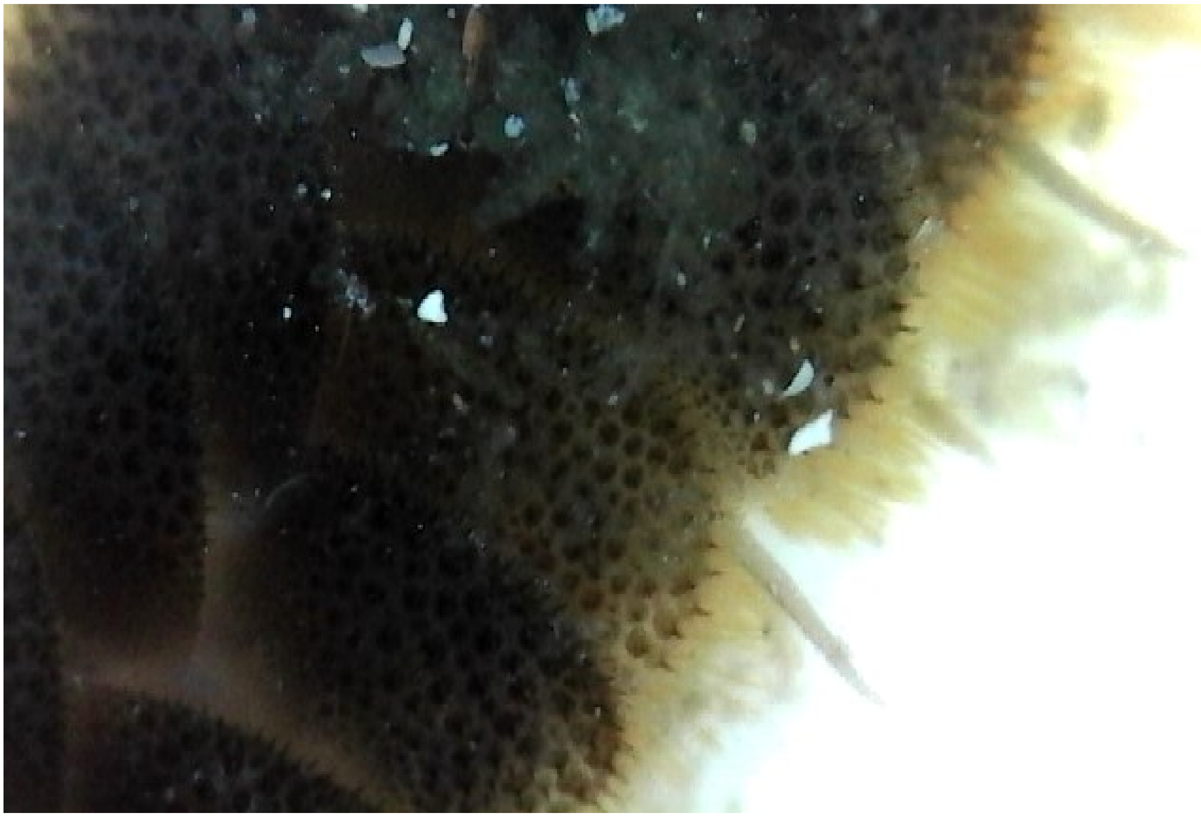

Figure 20: Scale Worm

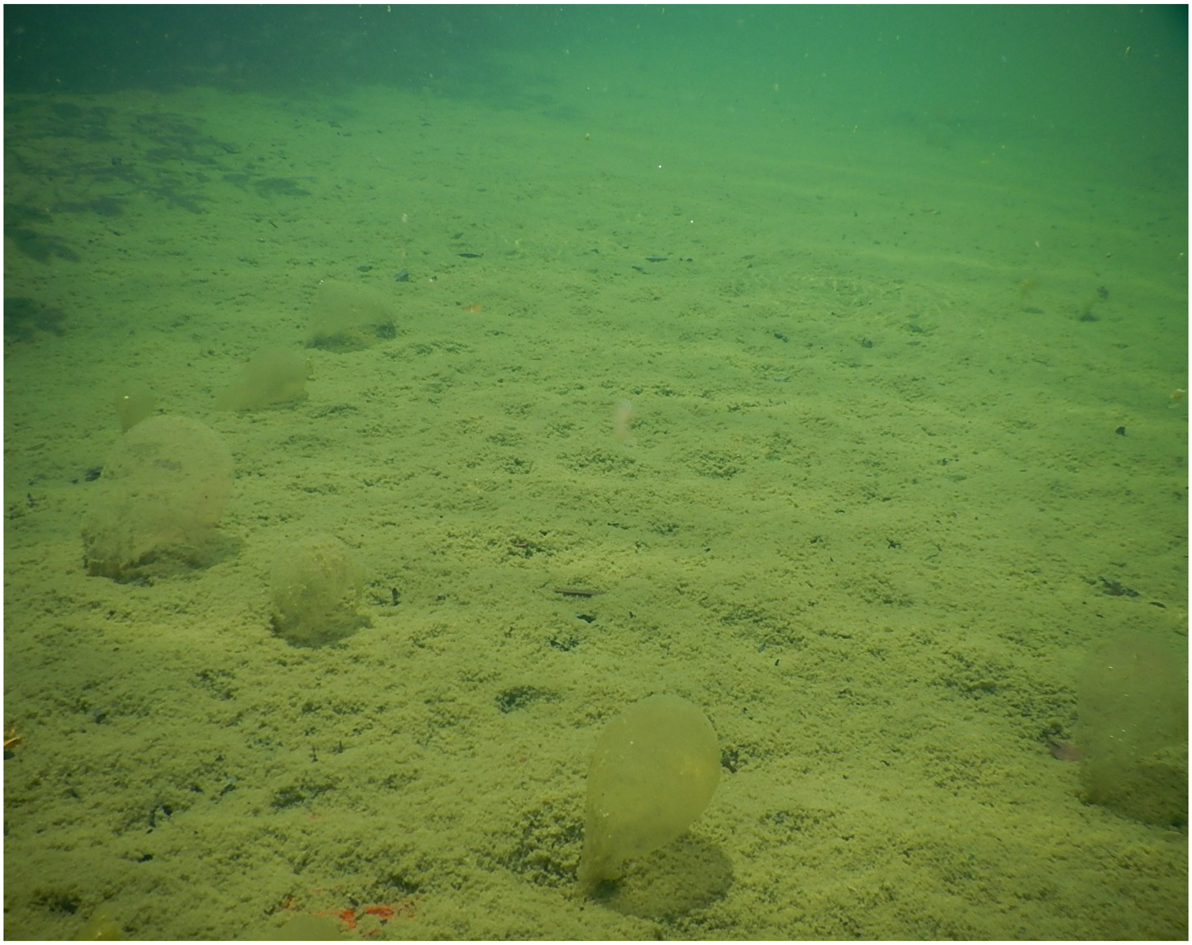

Figure 21: lug worm *Arenicola* egg sacs on the bottom of Oyster Pond.

Discussion and Conclusion

To restate the hypothesis:

Hypothesis 1: One year later, Oyster Pond has returned back to its normal state prior to Hurricane Joaquin with the exception to an increase in *Pinctada longisquamosa.* I expect that the outcroppings will be larger and more diverse, the red algae: *Dasya crovaniana, Polysiphonia subtilissima*; and green algae: *Anadyomene stellate*, and *Pedobesia lamourouxii* will be found again. I expect that the water levels will be back to normal salinity.

And

Hypothesis 2: One year later, Oyster Pond has not returned to its original state; smaller outcroppings are present and no sightings of the red algae: *Dasya crovaniana, Polysiphonia subtilissima* and green algae: *Anadyomene stellate*, and *Pedobesia lamourouxii,* but there is an increase in the *Pinctada longisquamosa.* The salinity levels have not changed or altered since my previous research.

Researched gathered this year about the outcroppings and compared to previous years (Ford and Abernathy, 2014) it cannot be determined that the outcroppings are recovering. It was visually noticeable that there were more outcroppings than in March 2016, but without the increase in species richness or identification of missing species it is hard to say that the pond is recovering back to its original state and it does not support this hypothesis. While, most of the species were present, there was still an absence in the red algae *Dasya crovaniana, Polysiphonia subtilissima*; and the green algae:

Anadyomene stellate, and *Pedobesia lamourouxii*. With the absence of those, the species richness remained the same from the study done in March, 2016. Based on measurements of the *Pinctada longisquamosa, an* assumption can be made that the oysters went through an event called suicide spawning. Cole (2011) found that similar events were occurring in Oyster Pond. According to Cole, Oyster Pond contains some of the oldest species of *Pinctada longisquamosa,* and that there is not a rapid growth rate. However, what Cole noticed in Oyster Pond is that when there is a strong storm such as a hurricane, a suicide spawning event will occur. Suicide spawning occurs when older *Pinctada longisquamosa* go through a period of spawning and then die off. According to Cole and based on research done in March 2016 and 2017, symptoms of this natural event were inferred using the *Pinctada longisquamosa* populations in Oyster Pond (Baxter and Cole, 2011). Based on the measurement of the hinges of the oysters, a large percentage of the oysters were produced after the hurricane of October 2015.

Last year the assumption was made that the egg sacs were *Pinctada longisquamosa,* and it was pivotal to the research, when we discovered that the egg sacs belonged to the lugworms *(Arenicola cristata).* The egg sacs had not been identified by us in Oyster Pond, but going forward this will help others to not misidentify them. There were visually numerous egg sacs found in the pond during the March 2016 study. This could be because the lugworm starts spawning when water temperatures get to 61-64 degrees Fahrenheit, which is the typical average temperature of Oyster Pond during March (D'Asaro and Chen, 1976). There could have also been an increase in lugworm egg sacs due to a decrease in the salinity levels during March 2016 (salinity 34.5 ppt) compared to the March 2017 salinity level of 37 ppt. Lugworms typically live in a salinity range below 35 ppt and above 10 ppt, and the average salinity of Oyster Pond is 37 ppt. (D'Asaro and Chen 1976). The average salinity of Oyster Pond is not the typical salinity range for lugworms, this may be why there were fewer egg sacs in March 2017 compared to March 2016 numbers.

Observing many of the same invertebrate species from the last research conducted in March 2016, the same species were found but some in varying quantities. This study showed that the water chemistry had returned back to its normal range, a decrease in algal species, and a recovering *Pinctada longisquamosa* community. Compared to March 2016 data, the same number of species was found in pond (16 species). These species are not same for both years though. In March 2016, there were green algae (*Cladophoropsis macromeres),* and an echinoderm (a brittle star), but neither of these species were identified in March 2017. In March 2017, two new species were identified both Annelida (*Arenicola cristata* and *Polynoidae spp.)*, though neither had been identified before in Oyster Pond. Based on past data and the results, the hypothesis cannot be supported that Oyster Pond is recovering from Hurricane Joaquin's effects. Hurricane Joaquin, unfortunately, was a strong storm with lasting effects that will take longer for Oyster Pond populations to recover.

Additional Information

One thing that was noted was that where the mangroves flourished the outcroppings were nearly non-existent and where the mangroves were mostly dead, the outcroppings flourished the most (Appendix A). Using work done by Luke Black was pivotal to understanding why the outcroppings might not flourish on the sides that the mangroves flourished. From Luke Black's research gathered that on the south side of Oyster Pond exhibited the most species coverage (80% species coverage), while the south side exhibited the fewest outcroppings in my study. The east-side mangroves had species coverage of 70%; the east side contained the next smallest amount of outcroppings. The north side contained the next to most outcropping, while the mangroves only had about 50% species coverage. The west-side mangroves contained the lowest amount of species coverage, and are where the most outcroppings were found, more than any other side (Appendix A, Figures 1-4).

Next, a study was done observing the work done by Alex Schwartz and the richness of outcroppings near the conduits. This did not seem to have a significant influence on the placement of the outcroppings and their richness. The conduits that found were located near the middle of the pond, where we did not study the richness of the outcroppings. Based on the observations though, while searching for the conduits there are very few outcroppings toward the middle of the pond. This could by mostly due to the depth in the middle and most algae species are not able to absorb enough sunlight, and algae are the main food source for oysters and other species.

Conclusions

The findings did not validate either of the hypotheses, but seemed to validate parts of both hypotheses. Species richness of the outcroppings was the same from 2016 to 2017; there was no increase, as was expected. One can expect some variability in species richness of algae and invertebrates from one year to another. However, it is clear that the red algae that disappeared after Hurricane Joaquin have not returned to the Oyster Pond. Water chemistry returned back to its normal state of 37 ppt, which can be significant to the survival and reproduction of species living in the pond. The *Pinctada longisquamosa* had a large community of young oysters that were produced after the hurricane

Appendix A

Observed Species	**West** Average Percent Coverage	**East** Average Percent Coverage	**North** Average Percent Coverage	**South** Average Percent Coverage
Atlantic Lugworm Egg sacks (Near prop roots)	30%	10%	30%	5%
Isognomon alatus (Black Mangrove Oyster)	20%	15%	15%	42%
Pinctada longisquamosa (Scaly Pearl Oyster)	9%	30%	13%	8%
Unknown Hydroid	50%	0%	0%	35%
Acetabularia calyculus (Mermaid's Wineglass)	30%	60%	48%	20%
Acetabularia crenulata (Mermaid's Wineglass)	30%	60%	48%	20%
Batophora oerstedii (Green Algae)	0%	15%	5%	0%
Dictyosphaeria ocellata (Green Algae)	0%	5%	2.50%	0%
Chrondilla nucula (Chicken Liver Sponge)	0%	0%	2%	10%
Batillaria minima (snail)	2.50%	0%	0%	0%
Certium lutosum (snail)	0%	2.50%	2.50%	0%
Total Biota Coverage	**40%**	**70%**	**50%**	**80%**

Table 1: Mangrove species abundance. Credit: Luke Black

Figure 1: East mangroves prop root, 70% species richness

Figure 2: West mangroves prop root, 40% species richness

Figure 3: North mangroves 50% species richness


Figure 4: South mangroves 80% species richness

Works Cited

Baxter, J. and Cole, E. (2011). Proceedings of the Thirteenth Symposium on the Natural History of the Bahamas. *Patterns of Sex Determination in the Scaly Pearl Oyster in Four Achialine Ponds on San Salvador Island, Bahamas*.

Carew, J. L., and J. E. Mylroie. 1995. Depositional model and stratigraphy for the Quaternary geology of the Bahamas islands. Pp. 5-32 in Curran, H. S., and White, B., eds. Terrestrial and shallow marine geology of the Bahamas and Berumda. Geological Society of America Special Paper 300.

Cole, Eric, Nicole Hoft, and John Campion. *The Effect of Hurricane Activity on Scaly Pearl Oysters, Pinctada Longisquamosa, In Two Dissimilar Inland Marine Ponds on San Salvador Island, Bahamas*. Thesis. St. Olaf College, 1996. N.p.: n.p., n.d. Print.

D'Asaro, Charles N, and Henry C Chen. "Florida Sea Grant Program." *Lugworm Aquaculture*, Sept. 1976, pp. 5–5., nsgl.gso.uri.edu/flsgp/flsgpt76005.pdf.

Diehl, F., Mellon, D., Garrett, R., and Elliot, N. (1998). A Field Guide to the Invertebrates of San Salvador Island. *(Diehl, Mellon, Garrett, and Elliot, 1998)*. Retrieved August 20, 2017, from http://plantphys.info/bahamas/copyright/diehl.pdf

Ford, Dawn and Jalana Abernathy. 2014-2015. "Biotic Survey of Reckley Hill, Crescent, and Oyster Ponds: Preliminary Findings."

Gamble, D. and Kindler, P. (2012). Proceedings of the 15th Symposium on the Geology of the Bahamas and Other Carbonate Regions. *Water Quality Monitoring on San Salvador Inland Lake*.

Hickman, Cleveland. *A Field Guide to Sea Stars and Other Echinoderms of Galapagos.* 1998.

"Hurricane Joaquin Recap." (n.d.): n. pag. *The Weather Channel*. Web. 03 Apr. 2016.

Mullins, H.T., and G. W. Lynts. 1977. Origin of the Northwestern Bahama platform: review and reinterpretation. Geological Society of America Bulletin 88:1447-1461

Kokesh, B. (n.d.). "Research at Mines." *Museum of Geology - SDSMT*, sdsmtcoastalbiomes.weebly.com/research-at-mines.html .

Read, G. *Polynoidae*, 2004, www.annelida.net/nz/Polychaeta/Family/F-Polynoidae.htm.

Richardson, J., and Mitchell, G. (1994). Field Guide to Common Algae. *Field Guide to Common Marine Algae of San Salvador Island Bahamas*. Retrieved August 20, 2017, from http://plantphys.info/bahamas/copyright/richardson.pdf

Schuchert, Peter. "The polyps of *Oceania armata* identified by DNA barcoding (Cnidaria, Hydrozoa)." *ZooBank.org*, 2015, zoobank.org/urn:lsid:zoobank.org:pub:4E6ECC01-4A45-4B81-BA63-2F44D7EB4BB8

Sept, J. Duane. *Atlantic seashore field guide: Florida to Canada*. Stackpole Books, 2016.

Sipahioglu, S. (2008). *Tracking Storms Through Time: Event Deposition and Biological Responds in Storr's Lake, San Salvador Island, Bahamas*. Master of Science Thesis. The University of Akron.

Zea, S., Henkel, T.P., and Pawlik, J.R. 2014 "The Sponge Guide." *The Sponge Guide a Picture Guide to Caribbean Sponges,* www.spongeguide.org/.

University of California Museum of Paleontology. (2017). *Introduction to the Green Algae*. [online] Available at: http://www.ucmp.berkeley.edu/greenalgae/greenalgae.html [Accessed 24 Aug. 2017].

University of California Museum of Paleontology. (2017). *Introduction to the Rhodophyta*. [online] Available at: http://www.ucmp.berkeley.edu/protista/rhodophyta.html [Accessed 24 Aug. 2017].