Coral restoration of *Oculina arbuscula*: A comparison of two sites and methods at Radio Island

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Abstract

Over the past few decades, an increase in anthropogenic activities have put an enormous amount of pressure on coral communities by changing their water quality and tearing up their habitats. As a result, new methods are being developed in an effort to restore coral populations and combat the effects of negative anthropogenic impacts. The purpose of this experiment is three-fold: to restore the *Oculina arbuscula* population at Radio Island, compare two physically different sites, the East side of Radio Island with stronger currents and more boat traffic and the West side of Radio Island with weaker currents and less boat traffic, and to compare two different types of coral nurseries, a table nursery and a tree nursery. On May 31st of 2018, four coral nurseries of *O. arbuscula* were deployed at Radio Island rock Jetty, each with sixteen coral fragments. Preliminary measurements of the coral fragment's diameter and max height were recorded. The nurseries will be maintained and measurements will will be taken regularly over the course of two years.

Introduction

Corals are vital to the health of underwater ecosystems. They protect coastlines from the damaging effects of tropical storms, are home to a diverse range of marine organisms and are key players in the carbon and nitrogen cycles. Anthropogenic activities have increased global atmospheric carbon dioxide resulting in global sea surface temperature increases of 0.11°C per decade between 1971 and 2010 (Aichelman, 2016). Other common causes of the degradation of corals include coastal development, sedimentation, disease, pollution, overfishing and eutrophication. One third of corals are at risk of extinction and three fourths are highly threatened (Johnson, 2011). The decline of coral populations has prompted the development of new restoration methods in the conservation and scientific communities.

This project explores the effectiveness of different coral nurseries in the restoration of corals at Radio Island in Beaufort, North Carolina. There is no singular approach to the restoration of all coral. It is very much dependent of factors such as the physical properties (depth, temperature variability, turbidity) of the deployment site, proximity to anthropogenic activities, bottom topography and marine ecology. Therefore, restoration methods should be adapted to fit the needs of each local environment (Johnson, 2011).Several restoration methods already placed forth are coral trees and coral tables. A coral tree consists of PVC pipe, resembling the shape of a tree. The tree is tethered to the ocean floor and buoyed. Coral fragments are hung from the branches of the tree using monofilament line. A coral table also consists of PVC pipe, resembling the shape of a table. The table is tethered to the ocean floor and coral fragments are hung from a grid-like “table top” using monofilament line.

Radio Island is a small parcel of land between Morehead City and Beaufort North Carolina. On the East side, is a popular shore dive near Beaufort NC. There are very strong currents outside of slack tide. Along the actual jetty are lots of fish life, soft and hard corals, mollusks and echinoderms. The largest threat to the corals in this area comes from boaters who release their anchors over the corals, overfishing, littering, and divers running into the Jetty while diver. Maximum depth within the channel is approximately 40 fsw. Just above the jetty next to marker 3A, where we deployed the first two nurseries, the max depth at high tide is approximately 20 feet. On the West side, at the second location where we deployed the other two nurseries, the currents are weaker and are a result of eddies that form in the slight inlet on the west side of the Radio Island. The corals do not face the same magnitude of anthropogenic risks since the West side of the Island does not encounter nearly as much boater and beach traffic.

Another important consideration in the deployment of a coral nurseries is deciding what type of coral to use. In this study we use *O. arbuscula*. It is abundantly found along both sites, making it the best model of the local ecosystem (Johnson, 2011). *O. arbuscula* is not a reef building coral and is rather slow growing. One of the most interesting aspects of *O. arbuscula* is that it is a factuitively symbiotic coral, meaning that it can function normally both with and without its zooxanthellae. Coral with zooxanthellae rely on these symbiotes for their metabolic needs, while those without their zooxanthellae tend to rely on zooplankton (Aichelman, 2016). Along the Jetty, *O. arbuscula* with and without zooxanthellae can be found; however, those without zooxanthellae are far more abundant. Research has been conducted on *O. arbuscula* in the past, in fact one study found that *O. arbuscula* grew best in summer temperatures at shallower depths with greater light availability and zooplankton (Miller, 1995).

Data and Methods

<u>Scouting Locations for Nurseries</u>

A total of two sites were chosen for the placement of each pair of nurseries. In order to determine the optimal location for each of these two site the dive teams conducted extensive surveys along the jetty. These surveys included algal surveys, roaming fish surveys, and general exploratory dives in the area.

After becoming familiar with the area it became clear that there were seven factors to consider in deciding on each location. These were intensity of current, consistency of boat traffic, depth of the nursery, temperature of the water, and sediment composition underneath the coral tree. Thus, we decided to choose two sites for each pair of nurseries that experienced differences in all of these elements.

It was decided that two nurseries would be placed at the base of green day marker 3A along Radio Island Jetty (location one). Location one was chosen as it represents an area that experiences strong currents and large volume of flow, a depth of about 6.1m, heavy boat traffic, and a sandy bottom composition. Further, in placing the nursery at the base of the jetty it is also possible to avoid any damage to the nurseries due to the deployment of boating anchors. The second location was placed on the west side of Radio Island in an enclave formed by the gently curving bay and a rock wall that runs perpendicular to it. Location two contrasts location one in that it experiences a milder impact from tidal currents, little to no boat traffic, a depth of about 3m, and a bottom sediment composition that is muddier in nature.

Temperature at each site could not be evaluated prior to deploying the nurseries as no instrumentation was placed in the water. However, thermistors were deployed along each nursery in order to obtain this data (see "Instrumentation on Site" below).

In choosing to place one tree nursery and one table nursery we will be able to draw conclusions between three relationships in the future. First, it will be possible to see how suited each site is to housing a coral nursery based on the growth patterns of each set of 32 coral fragments. Second, it will be possible to evaluate how each type of nursery does in comparison to the other in different conditions. Finally, we will be able to gauge the performance of each type of nursery to the other, which will allow for more effective nursery deployments in the future.

Table Nursery Design and Construction

To begin, 8 0.61m' lengths of 3/4" PVC had two holes on opposite sides of the pipe drilled through on one end 2.5cm from the edge. A small 1cm" x 1cm" rectangular piece of wood measuring 10cm in length was inserted into these holes so it was positioned running through, and perpendicular to, the pipe. Four holes were drilled into the opposite end of each length 1.3cm from the edge with one set of two holes running perpendicular to the other. Next, two handles were shaped by bending the outer two 10cm sections of two 30cm rebar. We then mixed approximately 54kg of concrete and divided it into eight buckets, each weighing five pounds, and two larger buckets which were filled with roughly forty pounds of concrete. Once the concrete was poured into each of the smaller buckets one length of PVC with a wooden insert was placed into each bucket of wet concrete until 8cm of PVC was submerged. After the remaining concrete was divided between the two larger buckets, one shaped handle was placed into each so half of the height of the bent 4" edges were sunk into the concrete.

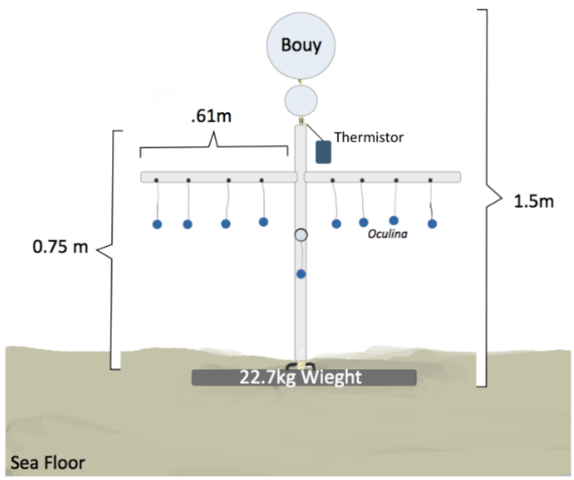
While the concrete set, the table tops that suspend the *O. arbuscula* fragments were prepared. Sixteen 15cm lengths of monofilament line were cut and fastened to one 0.3m x 0.6 metal grating by looping the line through one fishing crimper so that the length of the line fell below the table. The crimper was then closed using pliers. Each seat for an *O. arbuscula* fragment was positioned for a total of sixteen seats for the table. This was repeated for the second table, again fastening sixteen seats to the table top. The end of each of the thirty two seats was prepared for installment by looping the tail of the monofilament through a crimper and folding electrical tape over the crimper to prevent it from becoming dislodged.

After the eight 2.3kg concrete weights had set they were removed from their bucket molds and each leg was placed under one corner of a prepared table top. Two zip ties were used to fasten each leg to the table top by using the drilled holes and crossing the two ties. The larger weights were also removed from their bucket molds.

Tree Nursery Design and Construction

To construct each of the *O. arbuscula* coral tree nurseries we began drilling one set of holes at the end of two 25cm lengths of 3/4" PVC. Next, each of the 8 0.61m lengths of 3/4" PVC had holes drilled through them 15cm apart beginning 7.6cm from the edge of the pipe. Next, approximately 54kg of concrete was mixed and divided between two 30cm x 61cm x 10cm molds. While the concrete set the rest of the trees were assembled. One 4-way 3/4" PVC junction was placed at either end of both 36cm lengths of PVC pipe. Two 0.6m lengths were placed in the perpendicular junction openings, assuring that the previously drilled holes lined up parallel to the main stem of the coral tree nursery. Two 3.7m lengths of rope were then fed through the main stem of each tree nursery. The rope stemming from the top of the tree nursery was then fed through one of each size Styrofoam buoy, positioned so there was 30cm of rope between the top of the tree and the buoy, with the smaller buoy placed below the larger. The rope was tied around the larger buoy using a bowline knot and the remaining 2.5m of rope was allowed to fall below the base of the tree.

The assembled tree was then prepared to house *O. arbuscula* fragments. Thirty-two 15cm segments of microfilament were cut, and each line was threaded through one set of holes in the PVC arms of the tree. The line on top of the arm was looped around a crimper so that a 0.6cm loop was formed, and the crimper was then clamped closed using pliers. The other end of the line that serves as the housing for the *O. arbuscula* fragments was prepared in an identical manner to that of the tree nurseries (see above "Tree Nurseries".



Side View of Tree

Figure 1. Side profile of tree nursery design

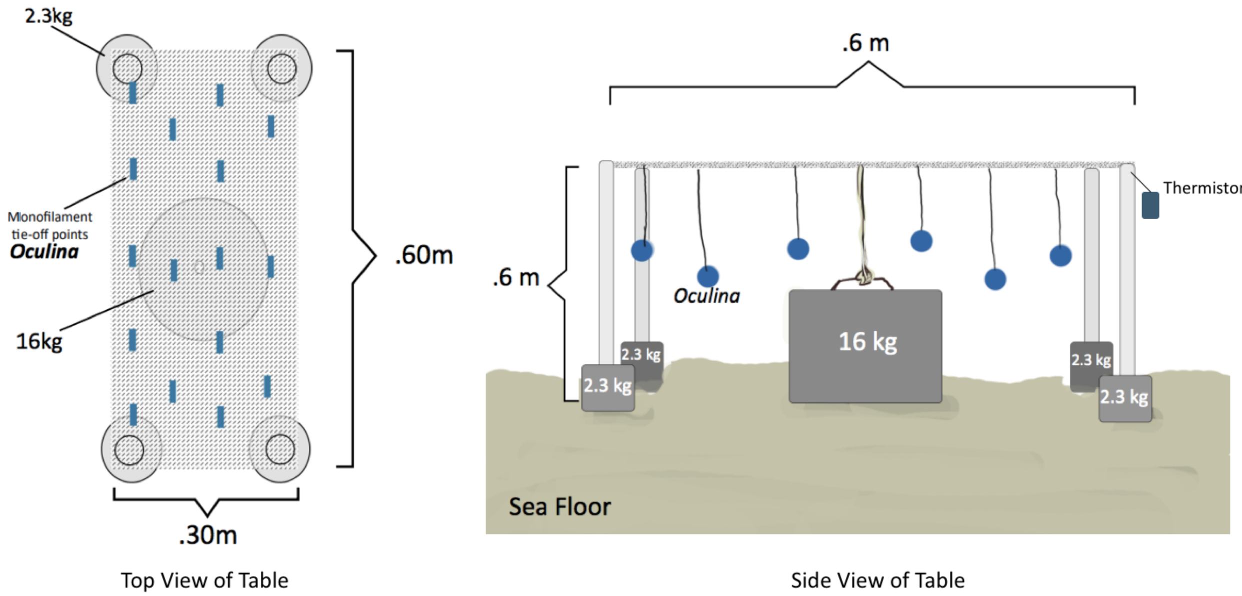


Figure 2. View of table nursery setup from above (left) and along the length of the table (right)

O. arbuscula Harvesting

Collection of *O. arbuscula* for the nursery began with a survey for corals of opportunity that could be relocated from the jetty base to the nurseries. As there were not enough fragments of broken coral found, dive teams clipped fragments from colonies of *O. arbuscula*, sampling two or three fragments per colony across a 30m horizontal distance.

Coral Nursery Deployment

To place the finished table nurseries at each location, the table and extra weight was placed on shore at Radio Island as close to the nursery location as possible. One lift bag was attached to the larger weight and another attached to the coral table. Each feature was brought into the water where the lift bags were inflated. Dive teams guided the tables and weights to the location along with one 12' length of rope and were subsequently guided to the sea floor. A bowline knot was tied around the center weight, passed around anchoring substrate, and fastened again to the center weight. Remaining rope was then fed vertically to the center of the table top and back down the weight where the rope was again tied to the center weight.

To place the finished tree nurseries both of the weights were removed from their molds and the weights and nurseries were placed on shore as close to the locations as possible. A lift bag was used to buoy and place the weight at the location first. At location one the weight was then tied to the piling using a bowline knot. The trees were then carried down to their respective locations and tied to each weight using a bowline knot. The arms were then moved so they oriented perpendicular to one another and the *O. arbuscula* fragments were seated.

O. arbuscula Placement in Nursery

To attach the *O. arbuscula* fragments, one fragment was looped through the prepared seat and said loop was tightened until it lay flush against the coral. The crimper was then depressed using pliers until it was unable to move along the monofilament. This process was repeated for all seats in each nursery, for a total of 64 seated fragments. Initial measurements of base diameter and the length of the coral, determined to be the distance from the base of the fragment to its farthest point were recorded for each fragment. For the purposes of tracking fragment growth, each coral was numbered, following the schematic displayed in rendered images one, two and three, "Tree Nursery", "Table Nursery West Side" and "Table Nursery East Side", below.

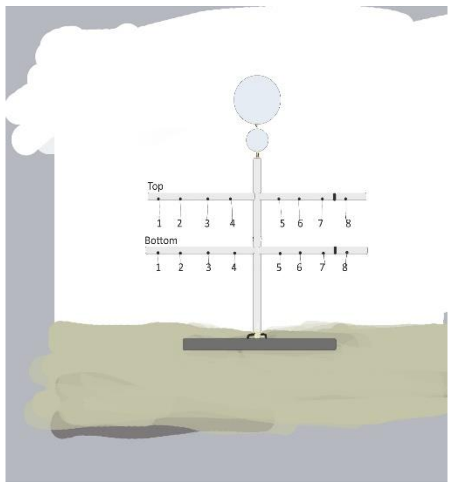


Figure 3. Schematic of numbering system for tree nurseries

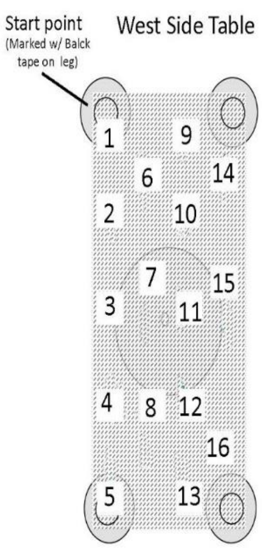


Figure 4. Schematic of numbering system for the table nursery deployed on the West side

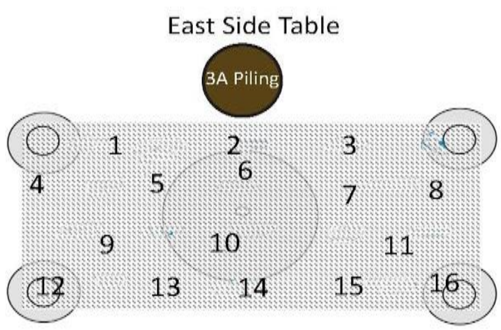


Figure 5. Schematic of numbering system for the table nursery deployed on the East side

Instrumentation On-Site

Thermistors were attached to each coral nursery and programmed to collect data every minute. Conductivity, temperature and pressure data was collected continuously from two Sea-Bird Scientific CTDs at location 1.

Preliminary Results

Due to the nature of this experimental window, it is not possible to discuss concrete conclusions about the success of the four *O. arbuscula* nurseries, both independently and in comparison to each location.

The baseline measurements for each coral nursery are summarized in the four tables below. The *O. arbuscula* fragments of each tree nursery, denoted in the table below as “U#” for the upper branch and “L#” for the lower, were numbered such that fragment 8 lies closest to the arm edge ringed with black electrical tape. For each table nursery the coral fragments were assigned numbers based on their orientation on the table and then schematics were developed for all nurseries for reference.

Table One: O. arbuscula Tree Nursery -- Location One

ID Number	Base Diameter (cm)	Length (cm)
U1	1.5 ± 0.2	3.2 ± 0.2
U2	2.0 ± 0.2	5.5 ± 0.2
U3	2.0 ± 0.2	4.2 ± 0.2
U4	3.5 ± 0.2	6.4 ± 0.2
U5	1.2 ± 0.2	5.0 ± 0.2
U6	1.75 ± 0.2	7.4 ± 0.2
U7	1.4 ± 0.2	7 ± 0.2
U8	1.8 ± 0.2	7 ± 0.2
L1	2.0 ± 0.2	5.5 ± 0.2
L2	1.0 ± 0.2	5.8 ± 0.2
L3	1.9 ± 0.2	4.7 ± 0.2

L4	1.0 ± 0.2	6.0 ± 0.2
L5	1.1 ± 0.2	4.9 ± 0.2
L6	1.8 ± 0.2	4.6 ± 0.2
L7	1.5 ± 0.2	5.6 ± 0.2
L8	1.6 ± 0.2	5.6 ± 0.2

Table Two: O. arbuscula Table Nursery -- Location One

ID Number	Base Diameter (cm)	Length (cm)
1	2.0 ± 0.2	4.5 ± 0.2
2	3.0 ± 0.2	5.5 ± 0.2
3	2.4 ± 0.2	5.0 ± 0.2
4	1.9 ± 0.2	1.9 ± 0.2
5	1.0 ± 0.2	5.0 ± 0.2
6	1.0 ± 0.2	9.4 ± 0.2
7	1.1 ± 0.2	11.0 ± 0.2
8	1.6 ± 0.2	5.9 ± 0.2
9	2.6 ± 0.2	2.5 ± 0.2
10	1.5 ± 0.2	5.0 ± 0.2
11	2.5 ± 0.2	6.0 ± 0.2
12	3.0 ± 0.2	5.5 ± 0.2
13	1.4 ± 0.2	5.3 ± 0.2
14	2.3 ± 0.2	3.8 ± 0.2
15	2.0 ± 0.2	10.6 ± 0.2
16	2.9 ± 0.2	7.1 ± 0.2

Table Three: O. arbuscula Tree Nursery -- Location Two

ID Number	Base Diameter (cm)	Length (cm)
U1	1.0 ± 0.2	4.0 ± 0.2
U2	1.4 ± 0.2	3.0 ± 0.2
U3	1.0 ± 0.2	4.0 ± 0.2
U4	1.5 ± 0.2	3.5 ± 0.2
U5	1.0 ± 0.2	3.0 ± 0.2
U6	2.5 ± 0.2	5.5 ± 0.2
U7	2.5 ± 0.2	5.5 ± 0.2
U8	1.5 ± 0.2	4.3 ± 0.2
L1	2.0 ± 0.2	6.0 ± 0.2
L2	1.5 ± 0.2	5.5 ± 0.2
L3	2.0 ± 0.2	5.0 ± 0.2
L4	1.5 ± 0.2	6.0 ± 0.2
L5	3.5 ± 0.2	8.5 ± 0.2
L6	1.5 ± 0.2	3.0 ± 0.2
L7	1.0 ± 0.2	4.0 ± 0.2
L8	1.0 ± 0.2	4.0 ± 0.2

Table Four: O. arbuscula Table Nursery -- Location Two

ID Number	Base Diameter (cm)	Length (cm)
1	1.2 ± 0.2	3.6 ± 0.2
2	1.5 ± 0.2	1.5 ± 0.2
3	1.3 ± 0.2	4.5 ± 0.2
4	1.5 ± 0.2	5.0 ± 0.2
5	1.0 ± 0.2	1.5 ± 0.2
6	1.0 ± 0.2	3.5 ± 0.2

7	1.25 ± 0.2	4.5 ± 0.2
8	1.5 ± 0.2	4.5 ± 0.2
9	1.5 ± 0.2	4.0 ± 0.2
10	1.2 ± 0.2	4.1 ± 0.2
11	2.5 ± 0.2	5.5 ± 0.2
12	5.0 ± 0.2	6.5 ± 0.2
13	1.0 ± 0.2	4.0 ± 0.2
14	1.4 ± 0.2	3.3 ± 0.2
15	1.2 ± 0.2	3.5 ± 0.2
16	2.0 ± 0.2	6.1 ± 0.2

Discussion

The purpose of these coral nurseries are to restore the *Oculina arbuscula* population at Radio Island, compare two physically different sites, the East side of Radio Island with stronger currents and more boat traffic and the West side of Radio Island with weaker currents and less boat traffic, and to compare two different types of coral nurseries, a table nursery and a tree nursery. The deployment of the *O. arbuscula* nurseries is only the first step in this project. Future plans include the inclusion of CTDs at the west nurseries and monthly monitoring of the nurseries for routine maintenance. *O. arbuscula* is a slow growing coral, so measurements of the fragments will only be taken every six months. Initially, we are to make a comparison between the two different types of nurseries used. An unforeseen issue for the tree nursery was that the branches are susceptible to falling off in the presence of strong currents, which makes the trees on the East side of Radio Island more susceptible to falling apart. If we were to repeat the experiment we would have found a way to glue or screw in joints at the points where the arms of the trees meets the base. Conversely, the structure of the table is stable but an there was an issue with the coral getting more tangled on the table due to the proximity of the corals to each other. The tree spreads the corals out better such that they tangle less with each other.

There were problems that occurred with the nurseries independent of the type of nursery deployed. The monofilament line that was used to attach the coral was found be too long in places resulting in coral fragments becoming entangled with other fragments. The method of using fishing crimpers was moderately effective. They do require a long pre-dive setup and there were issues once in the water of incorrectly place crimpers falling off, making coral attachment nearly impossible. Additionally, some of the microfilament lines we prepped fell off during the actual deployment of both trees. As a result, it us took longer to deploy all the trees than we initially anticipated. This was a problem because the current became stronger during the deployment, making securing the nurseries more difficult, burning through our air faster. The strong currents, low visibility and the precision of the ruler we used gave us the error, in centimeters, of the coral heights and diameters. Essentially, a one-day deployment turned into a three day deployment. If we were to repeat the setup we would have found a way to deploy the nurseries more effectively, minimizing time spent during and after slack tide, cut shorter microfilament lines to hang the coral on and have extra prepped and ready on hand. In the end, the method we used to attach the coral got the job done, but it could be worthwhile to look into other methods.

The ultimate goal of these nurseries is to be able to out plant new colonies into the jetty community and to determine the best nursery schematics for future coral nurseries in the surrounding area. However, even though we have some initial comparisons between the two different coral nursery types, we cannot conclusively state which nursery at either site works best. Eventually, we hope to be able to optimize the construction of the nurseries at each site and outcrop *O. arbuscula* into the local marine ecosystem.

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