Researching Coral Growth in Land-Based vs Water-Based Nurseries

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Abstract

Corals are a vital part in the balance of the underwater ecosystem. With their slow growth rate and sensitivity to sudden and drastic changes, the reefs are slowly dying. By identifying if corals grow at a quicker rate in land-based nurseries (*ex situ*) or in water-based nurseries (*in situ*), colonies can slowly be restored. If restoration practitioners know where corals grow quicker, they can better manage their grow-out strategies. A faster grow-out allows for the corals to be outplanted earlier, all working together to restore the reef. This study was completed with four individual genotypes from four targeted parental crosses of *Acropora cervicornis* (Staghorn Coral, "ACER"). The data was collected by taking standardized photos on July 2, 2024 and October 14, 2024, (3 months and 12 days apart). The photos were analyzed using ImageJ to measure the change in surface area between time points and polyp height. Results show that polyp height is greater in *in situ* nurseries whereas the corals surface area increases at a quicker rate in *ex situ* nurseries. The treatment location with higher growth rate is dependent on the parental cross. These results suggest that restoration practitioners should consider using a combination of *ex situ* and *in situ* nurseries depending on the parental cross to boost restoration efforts of *A. cervicornis*.

Introduction

The National Oceanic and Atmospheric Administration (NOAA) reported that coral reefs provide an economic value of 3.4 billion dollars a year through tourism, fisheries, and coastal protection. As the ocean is experiencing rapid changes in heat, sea level, and salinity, corals are dying at an increased rate. During the 2023 coral bleaching event in the Florida Keys there was 100% coral mortality at Sombrero Reef and 99% at Cheeca Rocks (Coral Restoration Foundation, 2023). Coral restoration efforts involve growing corals in controlled environments and outplanting them back onto damaged reefs. This strategy is a vital conservation strategy to counteract the loss of corals and rejuvenate the fragile underwater ecosystem in the Florida Keys.

A coral's growth rate can range anywhere between 0.3 centimeters to 10 centimeters per year depending on the species (NOAA, 2024). One of the most common practices to promote coral growth is fragmentation. Fragmentation is when corals are cut into smaller pieces using a special saw or pliers depending on their size. This practice is effective because "when the corals are broken up it stimulates rapid healing and growth to replace the polyps it has lost. This growth rate is at least 25 times faster than the growth rate from larvae and means corals can be grown in weeks and months rather than years" (Baker, 2019). This is especially true for

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Staghorn Coral, *Acropora cervicornis* (ACER), a species of coral that is well known in the Florida Keys for how vastly they covered the reefs, and would rebound well after hurricanes and large storms with the help of fragmentation. Coral sexual reproduction, although a slower process to develop compared to asexual methods like fragmentation, plays an essential role in restoration efforts by introducing new genetic diversity. Genetic variation is important for building resilient coral reefs as it helps increase the chances of survival in the changing underwater world.

Restoration practitioners grow corals in nurseries on land, in raceways, or underwater, on PVC trees. The objective of this study is to determine whether corals grow faster in land-based (*ex-situ*) or water-based(*in-situ*) nurseries. In addition to the nursery location, the study also considered the differences in parental crosses. It was predicted that corals located in the land-based nursery would exhibit a higher growth rate compared to those located in the water-based nursery. Corals from different genetic crosses were used to examine how genetic diversity influences coral growth and their resilience to various nursery conditions. This approach aims to understand how combining different genetic lines of ACER can improve restoration efforts. Finding a higher growth rate can decrease the time it takes for corals to grow, allowing for them to not only grow quicker but be fragmented and outplanted earlier. This would assist in the restoration of natural coral reefs to preserve species that are sensitive to swift physical changes.

Methodology

The corals studied belonged to four different parental crosses (3e x 7s, 3e x 31s, 3e x 50s, and 31e x 50s) with the e representing eggs from the mother and s representing sperm from the father (Table 1). There were 16 different corals with 2 initial replicates of each. These coral genotypes were chosen to study how each of these parental crosses responds to each nursery location and because we know about the resilience of the parents. AC3 and AC7 are both disease resistant, AC50 is bleaching resistant, and AC31 is susceptible to bleaching.

3e x 7s	3e x 31s	3e x 50s	31e x 50s
21-AC-22	21-AC-42	21-AC-71	21-AC-143
21-AC-23	21-AC-46	21-AC-72	21-AC-145
21-AC-27	21-AC-47	21-AC-73	21-AC-146
21-AC-29	21-AC-48	21-AC-77	21-AC-147

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Table 1. List of the parental crosses and their sexual recruits (genotypes) used in this study. 21 is the year the corals spawned, AC is the coral type (Acropora cervicornis, Staghorn Coral,ACER), and the last number represents their genotype id.

On July 1, 2024 the 32 corals were transported from Mote Marine Laboratory and Aquarium's Summerland Key location (24244 Overseas Highway, Summerland Key, Florida 33042) to Mote Marine Laboratory and Aquarium's Key Largo location (103800 Overseas Highway, Key Largo, Florida 33037). The corals were acclimated to their tanks overnight. The plugs were prepped by putting the genotype and replicate number in sharpie on the bottom and top rim of the coral plug. The writing was secured with a thin layer of coral safe glue to ensure it does not peel or fade over time. On July 2, 2024 each individual coral was fragmented into five replicate fragments. A Gryphon AquaSaw with a Diamond Band was used to cut the coral. A unique feature on this saw is that it allows for corals to be cut quickly and precisely without cutting your fingers and drips saltwater as it is running to ensure corals do not get overheated. Once the corals were cut and mounted to their labeled plugs, standardized photos were taken. To achieve the same photo distance and angle each time, a PVC frame with a scale on an extended arm for the Olympus Tough TG-6 camera was created (Figure 1).

Figure 1. Custom PVC frame for capturing standardized photos. The arm outstretched away from the camera frame has sharpie marks indicating every half inch to calibrate the images so accurate distances were measured.

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On July 29, 2024, 80 of the corals (5 replicates per genotype) were moved to the *in situ,* or water-based*,* nursery in Key Largo. The remaining 5 replicates per genotype were kept in the raceways at the land-based nursery on Key Largo. Standardized photos were taken on October 14, 2024 for the second time point, approximately 3 months later. Photos were analyzed using the image processing software ImageJ (Version 1.54g). Surface area was measured as the total area of living coral tissue (Figure 2A). Polyp height was measured as the height of individual polyps (Figure 2b). Each measurement was collected three times and then averaged to account for human error. From there, the mean for the crosses and the standard error, the variation between individuals measured, was calculated. A smaller error bar indicates less variation and a uniform growth, a larger error bar shows a larger variety of growth rates among genotypes within a specific parental cross.

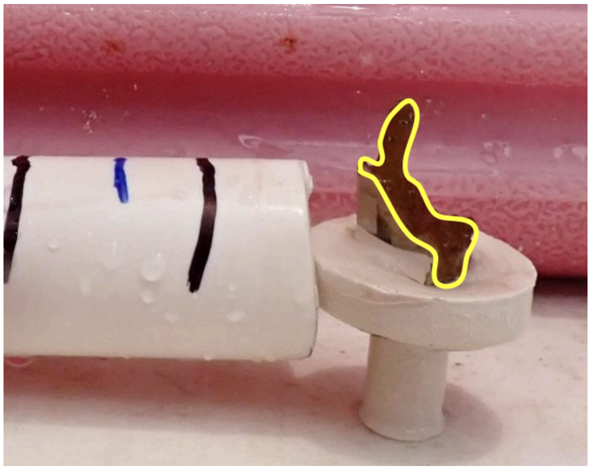

Figure 2a : Shows imitation of how coral surface area was measured. Inside the line includes all coral with no background or plug inside.

Figure 2b: Shows imitation of how the polyp height was measured. The three yellow lines show locations in which polyp height was measured for this coral.

Results

The data given in Figure 3 illustrates the difference in surface area growth over three months between all corals in the land-based and water-based nursery conditions. Although the bar graphs indicate a slightly higher growth rate in land-based conditions the overlapping error bars indicate that this difference is not statistically significant.

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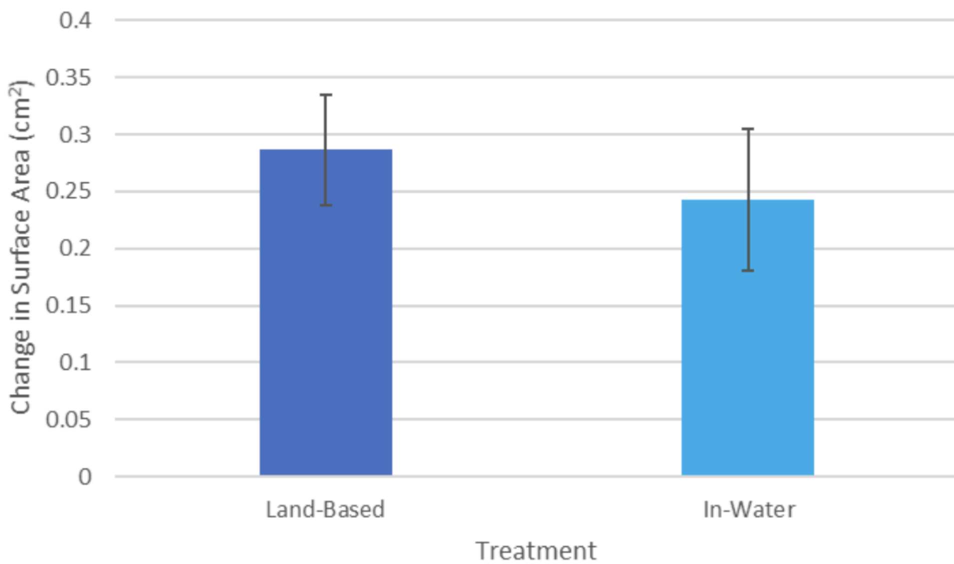

Figure 3. Bar graph showing all of the land-based corals and water-based corals surface area change between July 2, 2024 and October 14, 2024.

Figure 4 allows for an in-depth comprehension on each parental cross. One result that was particularly notable was the growth of the 31ex50s and 3ex50s crosses. Both of these groups' surface area increased at a faster rate on land than in water. This is particularly intriguing given that they both have the same father, 50s. The parental cross 31ex50s exhibited a surface area increase at a higher rate on land than in water with non-overlapping error bars between the conditions, making these likely statistically significant growth differences. In contrast 3ex31s exhibited a near equal surface area growth in both land based and water based nurseries, suggesting that environmental conditions may not significantly affect this parental crosses growth rate. It is important to note that the error bars for the water-based nursery were larger, which indicates a greater variability in the growth response for the replicates in these environments. An unexpected finding, though not statistically significant, was the faster growth of 3ex7s corals in the water based nursery. Although this result did not achieve statistical significance in these trials, it highlights a potential trend that could be investigated in the future, as it contrasts the general expected land-based growth advantage found in the other crosses.

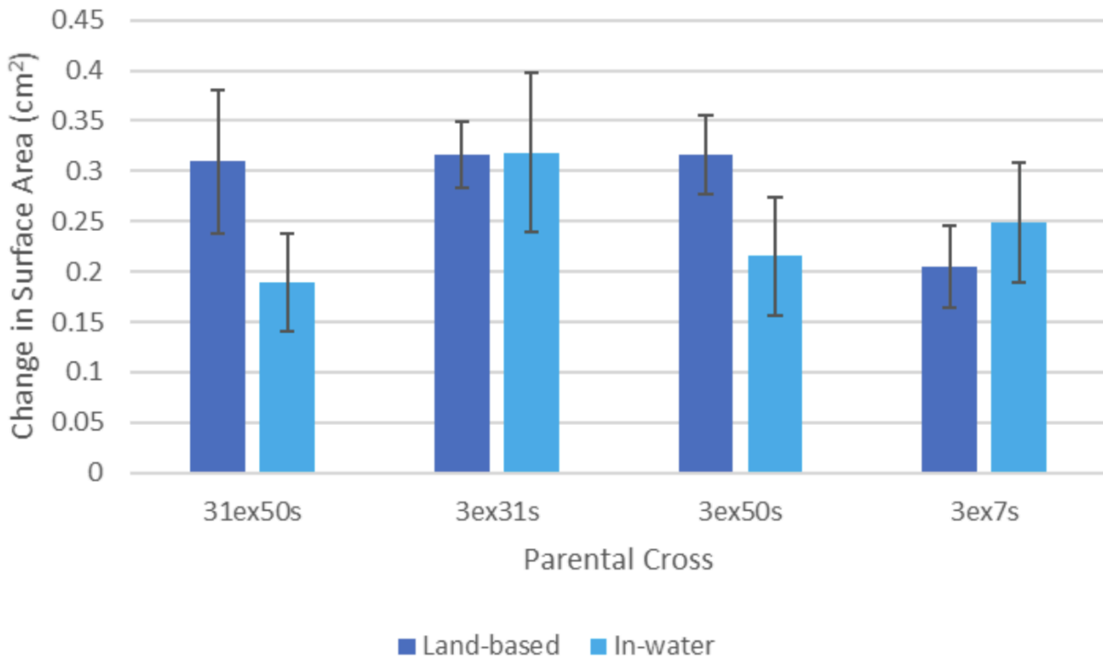

Figure 4. Shows each parental cross's land-based and water-based surface area showing surface area changes between July 2, 2024 and October 14, 2024.

The data presented in Figure 5 highlights the difference in polyp height between all corals in land-based and water-based conditions. Polyp height was consistently greater in water-based nursery-grown corals compared to those grown on land. The non-overlapping error bars further support the statistical significance of the observed difference.

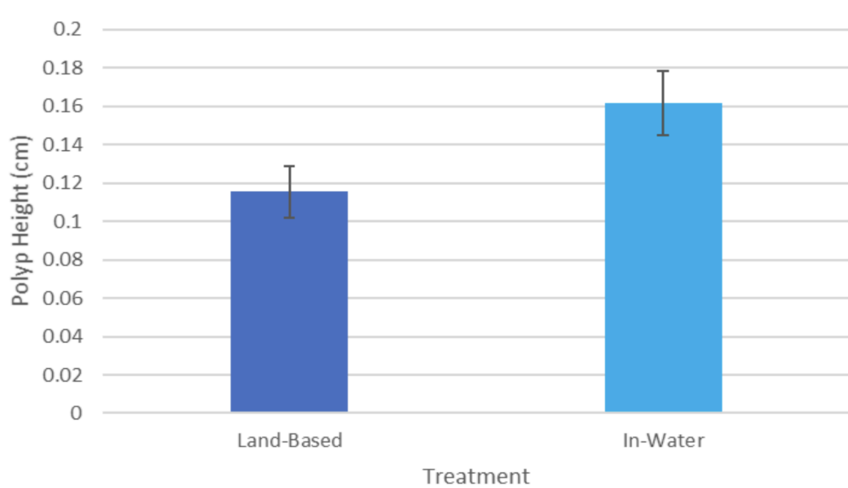

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Figure 5. Shows all corals' polyp height from October 24, 2024 comparing the land-based and water-based nurseries.

Comparing land-based and water-based growth the general trend observed indicates the water based conditions promote a greater growth of polyp height in most parental crosses. However, one exception was 3ex7s in which the polyp height was almost identical in both conditions, indicating that environmental factors did not significantly influence the growth of this cross (Figure 6). The 31ex50s and 3ex31s both share AC31 as a common parent, have a similar growth pattern, and have a polyp height increase more significant in the water-based conditions. This supports the general trend of increased growth in water-based environments and the difference between crosses. This consistency between these two crosses suggest that AC31 is more responsive to water-based growing conditions. For 3ex50s, polyp height tended to be greater in the water-based nursery compared to the land-based nursery. However, error bar comparison showed that there is likely no significant difference between these two treatments for this cross. This result follows the trend seen in the other crosses, suggesting that the water-based nursery promotes a slightly increased polyp growth rate. Other factors, like genetics or environmental interactions, could be playing a role as well.

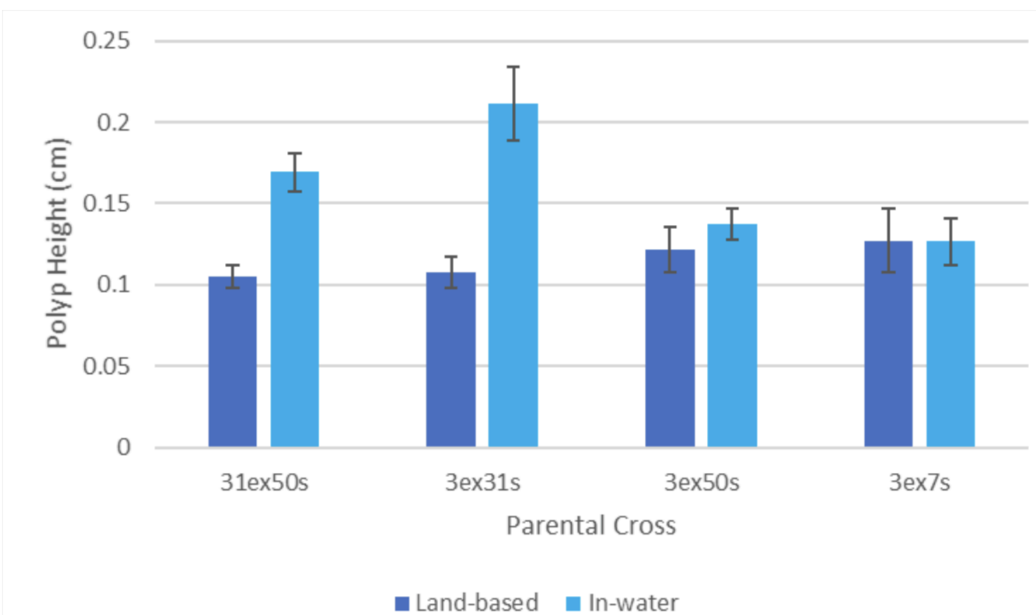

Figure 6. All coral parents polyp height growth measured on October 14, 2025 comparing land-based and water-based growth.

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Discussion

The objective of this study was to determine if coral growth was affected by the nursery location and the parental crosses. This was completed by measuring the change in growth over three months and twelve days of individual ACER corals from different parental crosses held in either Mote's land-based nursery on Key Largo, FL, or Mote's in-water nursery at about 25 ft deep near Key Largo, FL. Results show that each coral cross reacted differently to their location. The 'top grower' of the parental crosses was 3ex31s. The surface area grew about the same both in the land-based nursery and the water-based nursery. When located in the land-based nursery, the corals' surface area grew more, however the polyp heights grew more in the water-based nursery. Mote grows most of their *Acropora cervicornis* corals in water-based nurseries because they have found that this species does better *in situ*, which supports my research findings that the corals' polyp height grows at a quicker rate in water-based nurseries.

This study can be repeated with a few slight changes. The corals used in this experiment were three years old. Starting this project from their spawning moment for a year or two would be interesting to see. It would allow for insight on if the corals' ages or if fragmentation before the project played a role in their growth. Changing a few of the design elements could also improve outcomes. The PVC standardized photo rigging kept the camera in the same location but the rig didn't prevent the camera from flopping forwards or backwards. Although managing the camera's angle on land was easy, it proved difficult scuba diving. Any movement, either caused by the diver or the current, resulted in the camera angle shifting. This resulted in the measurements for coral height to have high amounts of error and ultimately were discarded. Furthermore, the coral standardization photos were taken from the side, and since a majority of the corals grew over the top of the plug instead of branching upwards, taking the standardized photos from above, looking down on the coral, would have provided a more precise measurement for surface area. Additionally, on the fragmentation date (July 2, 2024) some of the corals experienced various stages of bleaching. On July 8, 2024 corals 21-AC-27 replicate one and two died due to coral bleaching. All corals in 21-AC-71 and 21-AC-145 showed mild bleaching, 21-AC-145 and 21-AC-147 experienced severe bleaching, while the rest of the corals experienced very little to no bleaching on July 2, 2024. Stress from transportation the day before, fragging, and the air temperature being 32.78 ℃ (91 ℉) being the suspected cause. Ultimately, refining the experimental design and accounting for factors such as coral age, bleaching, and photo angle could provide more accurate results and allow for further insight to coral growth and health.

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