Micro-Fragmenting as a Method of Reef Restoration using *Montipora capricornis*

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Abstract

Micro-fragmenting is a process currently being used as a method of reef restoration for coral reefs, but there have been few studies quantifying the effects of this process on growth rate. The purpose of this project was to find the ideal size to micro-fragment coral. If one large piece of *Montipora capricornis* is micro-fragmented into smaller pieces, ranging from 0-6 sq. cm cross-sectional area, then the larger pieces will have a faster growth rate compared to the smaller pieces. To perform this project, one piece of *Montipora capricornis* was cut, using a saw blade, into 48 fragments. Each fragment was attached to ceramic disks using cyanoacrylate adhesive. Fragments were placed in a 29-gallon tank equipped with lights, a filter, a heater, twelve *Calcinus spp.* (red-legged hermit crabs), twelve *Margarites pupillus* (Margarita Snails), and live rock. Supplements were added accordingly. The fragments were grown for nine weeks with measurements taken approximately every two weeks. Exact measurements of fragments were found using the computer imaging program, GIMP. There was a polynomial relationship between the initial coral size and growth rate, with an r-squared value or 0.9219.

Introduction

While working with pieces of coral at MOTE Marine Laboratory in the Florida Keys, David Vaughan accidently broke a piece of coral that had attached itself to the bottom of the tank, and he thought nothing of this. A week later he came back to this tank and discovered that this small piece of coral was not only still alive, but had also grown. He had discovered the process of micro-fragmenting. Today MOTE Marine Laboratory uses the process of micro-fragmenting to restore reefs, but there has not yet been any research that quantifies the difference in growth rate between micro-fragmented pieces of coral and large, mature pieces of coral. Coral is a keystone species in coral reefs and is what physically

Literature Review

The Importance of Coral Reefs

Coral reefs and their structural complexity have started experiencing a global degradation, however, because of the limited scale and replicability of reefs many studies have been restricted and are incapable of having a complete understanding of the role of coral in this complex ecosystem. A qualitative and quantitative analysis of the current literature presented, in regards to the importance of structural complexity of coral reef ecosystems, is offered by this study. The number of publications about coral reef complexity has increased over the past forty years, with an increase in the different methodologies used to evaluate the structure.

Existing data shows a negative relationship between structural complexity and algal cover, this could prove the importance of coral complexity which enhances herbivory through reef fishes. The area of total live coral and branching coral was positively related to structural complexity. Habitat characteristics, such as this, have a collinear relationship with structural complexity, but there is evidence of improved coral recovery from disturbances when there is already a high complexity of coral in the reef. Urchin densities were negatively correlated with the structural complexity of a reef. This suggests that urchins are eroding the reef structure, or the social behavior of urchins when in an open area disturbs the reef

in coral reefs has led to the understanding of the importance of structural complexity in the coral reef ecosystem (Graham & Nash 2012).

The only well documented examples of the importance of reef complexity and its correlation to the health of a reef are studies performed on fish abundance. Most studies found a positive correlation between structural complexity of coral and the diversity, quantity, and/or biomass of reef fishes. The strength of this relationship is varied across studies. The importance of reef complexity on corals, algae, and other invertebrates has been understudied and data is less conclusive. Reef structural complexity can also influence fish biomass for fisheries, as well as increasing shoreline protection by dissipating wave energy (Graham & Nash 2012).

A search of ISI Web of Science data-base was done using these keywords: coral reef AND rugosity OR complexity OR topography OR structure OR shoreline protection OR matrix AND structure. The results were 158 publications, after a thorough check for pertinence to coral reefs. The methods used for measuring the structural complexity of the reef were found from primary research. The relationships between structural complexity and coral reef communities, or human activities were drawn from each study and classified as positive, negative, or neutral. Studies that utilized a rugosity test that could be calculated using RI = linear/ surface, where linear is the distance covered by a taught chain/ rope and surface is measured when the chain/rope is laid over the structure and shape of the reef. The study also had to record the density, or biomass of different components of the reef. Information about six different components of the reef e

Reef management has an astounding impact on reef fish communities, and it therefore could affect the strength of the relationship between structural complexity and other reef communities. The management of the area was then also investigated and its influence recorded. Access to the coral reef was divided into four categories: open access with no restrictions, restrictions on types of fishing gear used, protected areas mixed with open fishing areas, and no-take protected areas. No-take areas prohibit anyone form fishing or removing anything from that area (Graham & Nash 2012).

Technological advances have allowed for the quantification of structural complexity to improve, with some studies focused on the colony level, and others using side-scan sonar to assess reef complexity. The relationship between increased structural complexity and ecosystem service have positive effects due to structural complexity. Structural complexity was also analyzed to have positive effects on tourism, as well as shoreline protection. A strong negative relationship between algal cover and coral reef complexity was found.

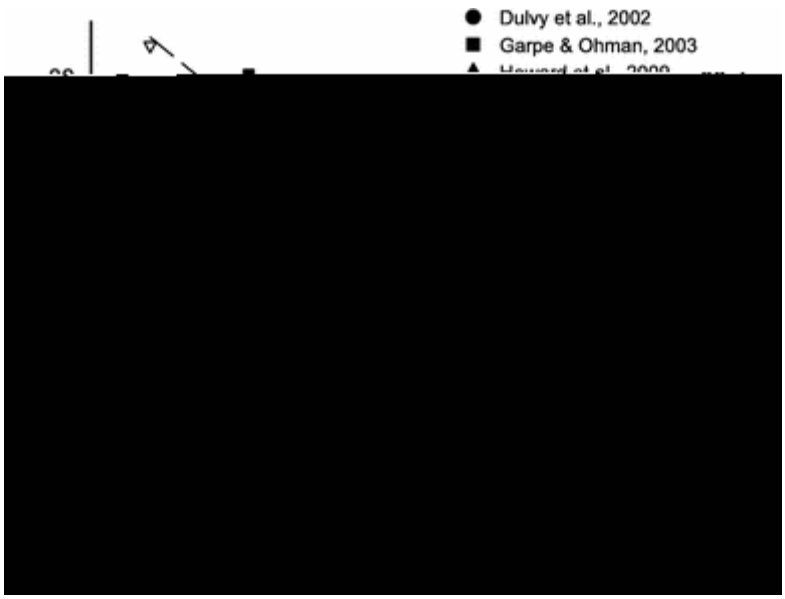

Figure 1. Relationship between percentage algal cover (turf & macroalgae) and structural complexity (RI). Open symbols are studies from the Caribbean, while closed symbols are studies from the Indo-Pacific (Graham & Nash 2012)

The coral cover of each site was also positively related to the structural complexity, but it only correlated for Indo-Pacific reefs. Caribbean reefs showed a neutral relationship, but the range of coral for the Indo-Pacific region was much higher than the Caribbean. Also, many of the studies did not have enough data points to be analyzed. There was a stronger correlation

Figure 3.

represent management regime: green sites are open to fishing, orange sites are subject to gear restrictions, yellow sites have a mix of open and protected areas, red sites are no take. Open symbols are studies from the Caribbean, while closed symbols are studies from the Indo-Pacific (Graham & Nash 2012)

Coral is Dying

J.E.N. Veron of the Australian institute of Marine Science has discovered and documented more than 20% of the coral species in the oceans. He began his investigation on coral when he noticed that there were slight differences between the same species at different locations. After travelling around the world and talking to locals he came to the conclusion that corals species intermix and produce new hybrids of species formed connected to their parent species. Through this research Veron found an overarching problem, that coral was becoming extinct. He reviewed previous analyses of coral reef extinctions and discovered the effects of changing sea levels, temperature stresses, and human-influenced changes in nutrient levels. All of these increased his concern for the health of the world reefs. Another concern that Veron had was crown-of-thorn starfish, which eat coral. Veron thought that the populations of these destructive starfish were soaring because of the decrease in predators, but it turned out that it was because the crown-of-thorn starfish larvae thrive in polluted waters (McCalmon, 2014).

Before scientists started studying coral reefs people had taken the ocean and its inhabitants for granted, and thought that they were imperishable. Unfortunately, that was not true, and many locations do not have laws to protect coral, such as in the Central Indo-Pacific. Here coral reefs degenerated to masses of coral skeletons by the time Veron arrived. This was most likely due to coral bleaching, which has come in waves over the past few decades since the 1980s. This first mass bleaching was recorded between 1981 and 1982, and the next between 1997 and 1998. These each affected reefs in over 50 countries. The worst mass bleaching event

point the oceans may be so acidic that coral skeletons become soluble in seawater. Phytoplankton, the bottom of every marine food chain, will be affected as dramatically as coral if this intense acidification occurs, leading to destruction for all marine animals (McCalmon, 2014).

Coral is also often physically harmed by human interactions, including motor boats, scuba divers, overfishing, pollution, and eutrophication, the enrichment of an ecosystem with nutrients, commonly nitrogen and phosphorous (Osinga, et al, 2011).

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How to Micro-Fragment Coral

Coral propagation has gained interest because knowledge of procedures involved in simple divisions of reef invertebrates has become a common practice. Passive induction included strategies of division that do not necessarily create a free-living clone. These techniques are used to stimulate budding through fission. Examples of this include slicing the periphery of stolen mat of hardy soft corals, including Star Polyps. This stimulates the coral to grow at a faster rate. Captive coral propagation is done through a variety of influence and imitations of natural reef dynamics (Calfo, 2002).

The most frequent coral propagation is imposed fragmentation of coral which is done by cutting, breaking or sawing the coral. These actions are on purpose and used to increase the asexual reproduction of coral. This form of propagation will most likely be the common aquaculture technique used until sexual reproduction can be utilized in aquarium growth (Calfo, 2002).

New aquarists should learn what species of coral are good for cutting into. Certain corals do not ac

of the *Alcynoniid* family which tend to produce mucous when stimulated. Optimum conditions are needed to give corals the best opportunity to grow. *Trachyphyllia* has been shown to have amazing success when fragmented. Aquarists have fragmented whole *Sarcophyton* individuals into 1/4 and 1/2" fragments that were thrown into a rubble trough to produce many hundreds of daughter colonies from the single parent colony (Calfo, 2002).

Before fragmenting coral the ideal technique for fragmentation must be decided on. Many corals when fragmented will produce clones of the original colony, as well as have an increase in growth rate. Fragmenting also makes the coral more susceptible to disease. One major consideration before fragmenting is how much mucous the species will produce. The heavy mucous species tend to be worse subjects and do better with less sudden techniques for propagation, or a more passive techniques, especially for LPS species. The *Acropora* corals are an exception and tend to react very positively to fragmentation (Calfo, 2002).

Mushroom and toadstool corals tend to be sensitive to handling and do not fare well when fragmented. A *Sarcophyton* coral is very hardy and near indestructible when cut. Plastic cable tis can be used to attach mucous producing corals to substrates. When mucous is produced it stimulates the growth of bacteria already on the exterior of the coral and this could lead to an infection before the cut coral has time to heal(Calfo, 2002)..

Sceleratin corals need a similar consideration, in regards to mucous production. Morpphology is also an important concern because some stony corals are excessively easy to fragment, such as Euphylliids which are branching corals. Separating the branches allows for an increase in light and water flow to the branches of the colony. With SPS corals the same technique could be used. Massive and encrusting corals have a lower success rate with micro-fragmenting. This included brain corals, such as *Favia* and *Favites*, which are very similar but

well when fragmented. Soft corals that tend to respond well after fragmented include: *Lobophytum*, *Sarcophyton*, and *Sinularia* species (Calfo, 2002)..

When beginning fragmentation the largest division is the best option. Fast, clean cuts should be made with a razor or scalpel instead of using scissor which crush the coral. Very sharp scissors could be used with caution (Calfo, 2002).

Micro-fragmenting as a method for reef restoration

Micro-

For many different organisms, size directly corresponds to survivorship, fecundity, and the outcome of competitive interactions. Clonal organisms -a group of genetically identical individuals, that have grown in a given location, all originating from a single ancestor- such as coral, have a higher mortality rate the smaller they are. This leave the smallest classes, such as larvae, newly settled planulae, and small fragments at a high risk. The energy of these smaller classes of coral is concentrated on the asexual reproduction, to increase their size as quick as possible and therefore lower their mortality rates. Once coral colonies reach a certain size the energy of coral switches from asexual reproduction to sexual reproduction. Similarly, if a sexually mature reef is fragmented into a smaller size then its resources are concentrated on re-growing, not reproducing. This is the basic idea behind coral fragmenting, taking a large piece of coral and requiring it to put its energy into increasing the size of the fragment (Forsman, Page, Toonen & Vaughan, 2015).

Fragmentation and fission (division of the colony) commonly occur naturally due to a variety of causes: physical disturbance, wave damage, erosion, predation, sedimentation, disease, parasitism, and partial bleaching. Fusion, portions of coral growing together, also naturally occurs and is a valuable strategy for small reefs. It gives them more access to shared resources, a competitive advantage by occupying more space, regaining sexual maturity and reproductive capacity, and escaping vulnerability associated with small colonies. Fusion can occur among genetically identical fragments, or settled larvae. Juvenile cnidiarians can fuse with kin, conspecies, or even conheners, creating chimerism, fusion between genetically different colonies, which has often been connected to struggles among partners. But, it also has been

Previous experiments have shown that fusion in juvenile coral could reduce size induced mortality. If conditions are controlled then the survivorship of small colonies could increase. Small culture fragments (~1 cm^2) as well as juvenile colonies can combine with genetically identical colonies through fusion and have the possibility to increase growth for coral aquaculture. Being able to promote growth over a pre-determined substrate could help in a variety of applications, including proliferation of rare coral species, developing standard growth assays, coral aquaculture, and reef restoration. Fusion rates of *Orbicella faveolata* and *Pseudodiploria clivosa* were used to calculate the rates of coverage increase. Another similar experiment was performed on *Porites lobata* to characterize the tissue spreading and determine if abiotic and biotic factors in two different environments influence the rates of growth. Additionally, qualitative and quantitative observations of isogenic colony fusion was compiled on a myriad of coral species in the Atlantic and Pacific Oceans (Forsman, Page, Toonen & Vaughan, 2015).

Five ramets of similar sizes from the same original colony of *Orbicella faveolata* were fragmented into 0.86 ± 22 cm^2 (average ± stdev) pieces and then epoxied to 5 ceramic 20 × 20 cm tiles. Attachment of these fragments was performed with cyanoacrylate gel and fragments were spaced out evenly, approximately 1 cm apart from each other. Twenty to twenty-three fragments were placed on each tile. For *Pseudodiploria clivosa,* five, separate colonies were fragmented into 3.05 ± 1.02 cm^2 (average ± stdev) pieces and then attached to 5 different 20 × 20

helped circulate and aerate water. The shore snail *Batillaria minima* was used to control algal growth, as well as daily siphoning of detritus, and manual removal of encroaching algae. Removal of algae was focused on the area between fragments so that it would not prevent the

Micro

Figure 5. Relationship between initial and final size (Forsman, Page, Toonen & Vaughan, 2015)

During a 4 month time period micro-fragments of *O. faveolata* increased by 293 cm^2 and *P. clivosa* fragments increased by 222 cm^2. This approximates to ~11 cm and ~9 cm of increased colony diameter, assuming circular colony growth. This study measured change in area covered by thin sheets of live encrusted tissue, which would not be comparable to many field studies because they quantify change in maximum diameter or linear extension, for example many Caribbean corals grow 0.5-

The growth rate of both species are within the expected bounds of linear rates of growth, which explains the 86% and 88% variation and the second polynomial curve explained between 94% and 97% of the variance in growth rates. This showed that the growth rates of fragments probably accelerated near the end of the experiment. Difference in growth rate could be explained by a variety of reasons, but the initial fragment size was evidently very important, because smaller fragments grew at a slower rate compared to larger fragments. The scope of the experiment did not consider multiple effects of growth rate, including seasonality, temperature, colony age, or other biotic and abiotic factors. Previous works have shown a clear correspondence between the size of fragmented pieces and growth rates, and that larger fragments grew at a faster rate (Forsman, Page, Toonen & Vaughan, 2015).

Care of a Salt Water Aquarium Tank

Understanding how to properly set up and care for a salt water aquarium was necessary for maintaining a healthy, controlled environment for the coral fragments. Coral is a very fragile species and even if everything is running properly and looks fine one day in twelve hours all of a s inhabitants could die (Jason Ryan, personal communication, October 25, 2015). First, set up the tank, install the filtration system, and fill the aquarium with freshwater, preferably treated by reverse osmosis. Untreated city water, if used, should be treated with a de-chlorinator in

After the aquarium has run independently for a few days, with the equipment functioning properly start adding aragonite-based substrate and live rock. Adding 2-3 inches of live sand that donates beneficial bacteria and micro-organisms to the aquarium is also suggested. After placing sand and substrate in the tank move onto adding some live rock (Drs. Foster & Smith Educational Staff, 2015).

Live rock is a porous, aragonite-based rock that has been gathered from rubble zones of ocean reefs and hosts large quantities of helpful bacteria and micro-organisms. Additionally, live rock grants fish and other organisms a good hiding spot and assists in preserving healthy water parameters. Live rock provides a tank with an aesthetic appeal as well as a natural, biological filtration, moreover providing a necessary environment for fish and invertebrates. Add approximatelms a

Micro

Research Plan

A. Researchable question:

How does the original size of micro-fragmented pieces of *Montipora capricornis* affect the two-dimensional cross section area growth rate of the coral?

B. Hypothesis:

If one large piece of *Montipora capricornis* is micro-fragmented into smaller pieces ranging from 0-6 sq. cm cross-sectional area, then the larger pieces will have a faster growth rate compared to smaller pieces of coral.

C. Description in detail of methods or procedures

To perform this experiment, a tank was set up to place the micro-fragmented coral in. After visiting an aquarium store and talking with employees there, who have extensive experience with setting up tanks and maintaining them, the tank that was selected to be used was a 29-gallon bio-cube that contains filters, lights, and everything else needed to maintain a tank, besides a heater incorporated into the tank. The tank was set-up according to the instructions of the aquarium store, and other reliable sources.

One piece of *Monitpora capricornis* will be micro-fragmented into various sizes between 0.5 cm^2, and 6.0 cm^2 using a saw at Ja be epoxied with a marine super-glue on an aragonite substrate plug that was much bigger than fragment, in order for coral fragments to have room to grow. Plugs will be labeled with letters according to size and placed randomly in the tank. The tank was be regulated by snails (*Margaritea pupillus*) and hermit crabs (*Calcinus spp.*) that will clean the algae and act as a bio-filter maintaining the environment within the tank. Once the tank had established a healthy environment, one kenya tree (*Capnella spp.)* was

corals, would survive in the tank. After the soft coral has survived for one week the micro-fragmented coral was brought in.

The process for micro-fragmenting coral involved using a saw to cut between polyps and

^{2}, and 5.0 cm^2, but the exact topographic surface area will be measured for each fragment and recorded. Different sizes were taken from different regions of the coral, an

not on the percent, and whether or not there is a notable difference between the starting sizes of coral fragments in the species of coral.

Micro

sections of the coral, not just the portion that it covered. If it was obvious that a piece of coral had deceased then it was not counted in the results.

Results

The growth rate, as well as the percent growth rate, area increase, and percent area increase, of 39 micro-fragmented pieces of coral was calculated 68 days after the initial micro-fragmentation.

Table 3. Results of the growth rate, percent growth rate, area increase, and percent area increase of fragmented pieces of *Montipora capricornis*.

<1 cm^2	1-1.5 cm^2	1.5-2 cm^2	

Figure 7. This graph represents the percent that each coral setting grew per day. Percent growth is the percent growth (final size/initial size) over the number of days (68).

As the initial size of the coral increased the percent growth decreased. This relationship resulted in a polynomial line of best fit, with an r-squared value of 0.93.

Figure 8. The area increase (cm^2) dependent upon the initial size (cm^2) of the coral fragments.

Figure 9. This graph represents the percent increase over the 68 days of the experiment. Percent increase was based on the final size divided by the initial size.

As the initial size of the coral fragments increased the percentage growth decreased, even though they had a higher overall increase in area. There was a strong polynomial relationship between the initial size 12 Tf(99(th de)-7(c)4(he isTf(99(th de)-re)5(la3Tf(99(( ))-9(a)(99()41t)-3(ial si)-2(TJ./F2

There was a moderate correlation between the initial size of fragments, and the growth rate, with an r-squared value of 0.42. Overall there is a visible trend of an increase in growth rate as the initial size of fragments increased, which is seen more clearly on figure 6.

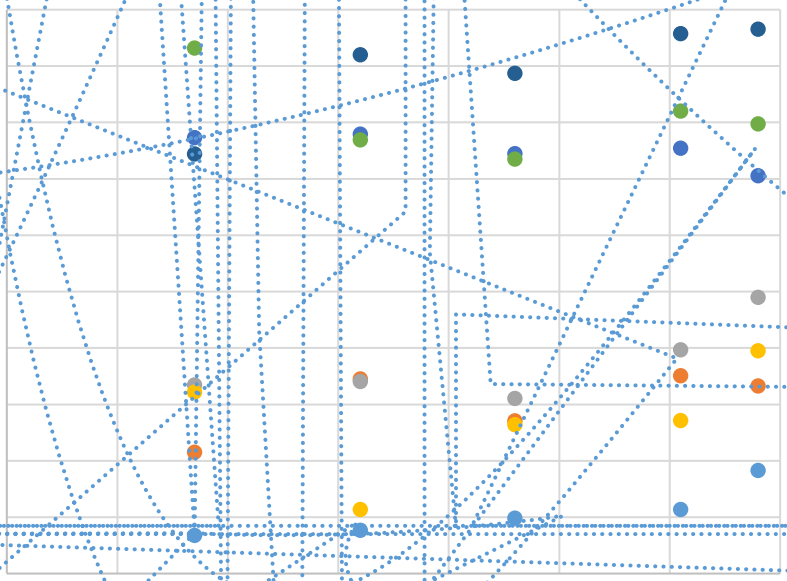

Figure 12. A scatterplot of the growth rate of each range of coral fragments with polynomial lines of best fit.

There was not a consistent change in the growth rate from day 17 to day 68. None of the growth rates remained constant, nor did any of them increase or decrease linearly. Three settings (1 1.5 cm^2, 2.5-3 cm^2, and 4-6 cm^2) had a negative polynomial line of best fit, with r-squared values of 0.56, 0.76, and 0.85, respectively.

Data Analysis and Discussions

The data showed that the largest pieces (avg. 4.933 cm^2 ± 0.897 cm^2) grew at a rate 234% faster than the smallest pieces (avg. 0.869 cm^2 ± 0.121 cm^2), and there was a polynomial trend with an r-squared value of 0.92, showing a strong correlation. The percent growth rate decreased as the initial size increased, which is because although the smaller pieces overall had a slower growth rate it was a much larger percent of their original size. Any small increase in smaller pieces of fragments would have a much higher percent increase, just because some of these fragments started at much smaller sizes. This experiment was looking for a faster growth rate, because a faster growth rate meant that the coral would be asexually reproducing faster.

The percent increase is size decreased as the initial micro-fragmented size increased. The smaller pieces had a smaller increase in size, but relative to their original sizes it was larger compared to the larger initial sizes, which is why this trend is seen. The goal of this experiment was to find the ideal size to micro-fragment coral, and the size that had the largest increase in area would be preferable. The percentage is not important, because the overall increase in area has a higher priority than a higher percentage increase.

The maximum value for this polynomial line of best fit is 6.62 cm^2, which is outside of the range of data. The line of best fit for the scatterplot of each individual fragment had a maximum initial size value of ne someze value of ne someze value of n5(a) e8g(e)4Tf1 0 0 1 72.02q0.00000912

Conclusion

The increase in area, both percentage and overall area shows that micro-fragmenting is a legitimate method of propagating coral growth. The polynomial line chosen for the growth rate vs. initial size, with the averaged data, was chosen because it is likely that the curve would decrease once the coral was micro-fragmented to a certain large size. This is because there is a point where fragmented pieces of coral would not be small enough to have the necessity of increasing their size rapidly. The overall increase in size was also calculated to have a positive trend, with the size difference increasing as the initial size increased. This is most likely because the growth rate was higher in the larger pieces of coral. The fragments of coral grew to double, or more of their original size in only 68 days. The growth rate increased overall, but there was no increase in the larger pieces of coral. Contrastingly the smaller pieces increased their growth rate in a polynomial trend upward. The growth rate was higher in the larger fragments, and increased as the size of fragments also increased, which proved the hypothesis, that larger pieces of micro-fragmented *Montipora capricornis* would have a greater growth rate (cm^2/day) compared to smaller micro-fragmented pieces.

Assumptions and Limitations

In order to conduct this experiment assumptions had to be made. First, it was assumed that *M. capricornis* would only grow two-dimensionally, covering a larger area. Also, that the initial 3-D height would not affect the growth rate. The overall shape of the original piece of coral was also assumed to not affect the growth rate. The conditions of the tank were considered to be consistent throughout the floor of the tank, because the fragments were not rearranged during the experiment. It was also assumed that because the fragments came from the same parent coral, with the same DNA, they would all start with the same growth rate, no matter their location within the coral. If the fragmented pieces fell off of the ceramic reef disk it was assumed that it would not affect their growth rate, because they were reattached five days later and the rest of the pieces were not growing, only recovering from the trauma of micro-fragmentation. This project was limited by time constraints, as well as the amount of coral available from a single,

Future Applications

The work of this experiment suggests that the ideal size to micro-fragment coral is either around or above 5 cm^2

Literature Cited

Calfo,

Appendix

Table 4. Raw Data after 68 days, organized by size.

	2 I	1 D	1 C	1 A	2.5 G	1.5 E	2 E			AVG	STDEV	
Day 1	1.0722	1.19376	1.19804	1.20212	1.24483	1.26754	1.26938			1.20684	0.06762	5.6032
Day 17	1.29538	1.59159	1.73183	1.53995	1.68711	1.99559	2.26782			1.72989	0.31775	18.3683
Day 32	1.89202	2.17524	2.33673	3.12586	2.09195	2.23634	2.93405			2.39889	0.45576	18.9988
Day 46	2.19135	2.36951	2.58581	3.63101	2.58703	2.41984	3.45966			2.74917	0.56261	20.4647
Day 61	2.74162	3.22264	3.28243	4.57148	3.37207	3.08035	4.20841			3.497	0.65086	18.612
Day 68	3.14003	3.53699	3.00208	4.79078	3.6046	3.3143	4.49587			3.69781	0.68414	18.5011
growth rate 17	0.01313	0.0234	0.0314	0.01987	0.02602	0.04283	0.05873			0.03077	0.01546	50.2547
growth rate 32	0.02562	0.03067	0.03558	0.06012	0.02647	0.03028	0.05202			0.03725	0.01346	36.1357
growth rate 46	0.02433	0.02556	0.03017	0.0528	0.02918	0.02505	0.04761			0.03353	0.01169	34.8692
growth rate 61	0.02737	0.03326	0.03417	0.05524	0.03487	0.02972	0.04818			0.03754	0.01023	27.2458
growth rate 68	0.03041	0.03446	0.02653	0.05277	0.0347	0.0301	0.04745			0.03663	0.00974	26.5949
% growth rate	4.30673	4.35721	3.68503	5.86069	4.25831	3.84521	5.20852			4.5031	0.77055	17.1116
area increase	2.06783	2.34323	1.80404	3.58866	2.35976	2.04676	3.22649			2.49097	0.66247	26.5949
% area increase	292.858	296.29	250.582	398.527	289.565	261.475	354.179			306.211	52.3975	17.1116

	2 C	+ H	+ I	+ E	+ B	AVG	STDEV	
Day 1	3.02762	3.07711	3.12564	3.13987	3.17402	3.10885	0.05722	1.8406
Day 17	4.21096	3.89166	5.34754	3.39303	4.36246	4.24113	0.72132	17.0076
Day 32	5.55357	4.68737	5.85415	4.17302	4.62936	4.97949	0.69873	14.0322
Day 46	5.4479	5.24997	6.84817	4.8748	6.17746	5.71966	0.7892	13.7981
Day 61	6.46735	6.03004	7.76963	6.31741	7.56602	6.83009	0.78403	11.4791
Day 68								

	+A	+ K	+ J	AVG	STDEV	
Day 1	4.29874	4.42727	5.56705	4.76435	0.69812	14.6531
Day 17	4.97466	6.18129	6.05441	5.73679	0.66306	11.558
Day 32	6.57656	7.05625	6.99617	6.87633	0.26134	3.80054
Day 46	7.66778	7.41881	8.08586	7.72415	0.33708	4.36397
Day 61	9.13798	8.45012	9.12647	8.90486	0.39386	4.42294
Day 68	9.10261	8.23499	10.8834	9.407	1.3502	14.3531
growth rate 17	0.03976	0.10318	0.02867	0.0572	0.0402	70.2779
growth rate 32	0.0719					

Table 5. Summarized Data with STDEV

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