

8-7-2024

## The Effects of Simulated Predation and Nursery Structure on Post-Outplant Survival and Growth of Sexual Juveniles of Six Caribbean Coral Species

Jarrold Little

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# Thesis of Jarrod Little

Submitted in Partial Fulfillment of the Requirements for the Degree of

## Master of Science Marine Science

Nova Southeastern University  
Halmos College of Arts and Sciences

August 2024

Approved:  
Thesis Committee

Committee Chair: Joana Figueiredo, Ph.D.

Committee Member: David Gilliam, Ph.D.

Committee Member: David Smith, Ph.D.

NOVA SOUTHEASTERN UNIVERSITY  
HALMOS COLLEGE OF ARTS AND SCIENCES

*The Effects of Simulated Predation and Nursery Structure on Post-Outplant Survival and Growth of Sexual Juveniles of Six Caribbean Coral Species*

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Submitted to the Faculty of  
Halmos College of Arts and Sciences

In partial fulfillment of the requirements for the degree of Master of Science with a specialty in:

Marine Science

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**Abstract:**

Over the past few decades, increasing frequency and severity of direct and indirect anthropogenic stressors have resulted in reef degradation and decreased coral cover and diversity. In South Florida, coral propagation *ex situ* has gained popularity as a means to restore coral cover. Outplanting sexually propagated corals on the reef is particularly important as it contributes to greater genetic diversity and potentially overall reef resilience. However, these corals typically experience high levels of predation following outplanting, significantly reducing coral survival, and thus constitute a major bottleneck to the success of restoration efforts. This study assessed if simulated predation events on sexually propagated coral juveniles prior to deployment offshore (hereafter termed outplanting) can prime them to generate a physical and/or chemical anti-predatory response mechanism. Sixteen-eighteen month old (4.8-47.6mm diameter) juveniles from six species (*Colpophyllia natans*, *Diploria labyrinthiformis*, *Montastraea cavernosa*, *Orbicella faveolata*, *Pseudodiploria strigosa*, and *Pseudodiploria clivosa*) grown at NSU's *ex situ* nursery were used in this study. The juveniles of each species were divided into two groups: a group where individuals were poked with a needle 2 and 4 days prior to outplanting, and a control group where individuals were not exposed to simulated predation. Following that, both groups were outplanted to NSU's *in situ* nursery, with half of each group being either cemented to modules or fastened to a tree. Outplants were monitored on days 7, 18, 34, and 81. The effectiveness of simulated predation and *in situ* grow-out structure on the post-outplant survival and growth of the coral juveniles was assessed. Corals cemented on modules had significantly higher survival rates than those attached to trees, with modules showing 59% survival compared to 53% for trees after 81 days. Coral growth varied significantly over time, but no differences in growth were found between poked vs. unpoked corals or between different nursery structures. Initial coral size influenced predation outcomes, with smaller corals being less likely to be predated but having lower survival if predated.

**Keywords:** sexual recruits, predation, survival, growth

## **Acknowledgments**

I first want to thank the members of my thesis committee: Dr. David Gilliam, Dr. David Smith, and especially my committee chair, Dr. Joana Figueiredo. The advice and suggestions from my committee throughout my project allowed me to complete this research.

My project would not have been possible if I did not receive constant support and assistance from all the members of the Marine Larval Ecology and Recruitment lab: Dr. Joana Figueiredo, Chelsea Petrik, Ryan Chabotte, Ian Johnson, Nepsis Garcia, Michael Hood, Krista, LaForest, Daisy Ponce, Liam Abrams, Danielle Macias, Ashley Shen, and Chloe Daniel. Additionally, I would like to thank Dr. Gilliam for allowing me to use the offshore nursery, and the members of the Coral Reef Restoration and Monitoring lab: Shane Weaver, and Michelle Mair for assisting me in taking pictures. This research was supported by funds from MSC Foundation and the Florida Department of Environmental Protection.

Most of all, I would like to thank my family and friends for supporting me throughout this endeavor. I truly could not have done this without the endless support from my parents, Jelena, and little Aleksandar.

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## Introduction

Coral reefs are among the world's most productive and diverse habitats. Habitat, breeding grounds, nutrient cycling, primary production, fisheries, and coastal protection are examples of essential ecosystem services coral reefs provide, many of which greatly benefit humans (Woodhead et al., 2019). Despite their value, over the past few decades, coral reef ecosystems have been threatened by direct and indirect anthropogenic stressors, such as ocean acidification, overfishing, increased average ocean temperatures, and pollution (Carpenter et al., 2008; Hoey et al., 2016; Lapointe et al., 2019). In Florida's Coral Reef, the accumulation of these stressors has resulted in over 90% loss in coral cover since the 1970s, according to the National Oceanic and Atmospheric Administration (NOAA) Mission: Iconic Reefs project (2022). Bleaching events resulting from more intense and frequent thermal anomalies in Florida have caused mortality (Eakin et al., 2019; Heron et al., 2016) and higher susceptibility to diseases like the 2014 (ongoing) outbreak of stony coral tissue loss disease (Gintert et al., 2019; Hayes et al., 2022; Walton et al., 2018). Additionally, nutrient pollution (Lapointe et al., 2019; Vega Thurber et al., 2014) and increased sedimentation have been linked to bleaching and mortality of corals (Rogers, 1990; Weber et al., 2012).

In Florida and the Caribbean, restoration programs actively place corals on the reefs to mitigate degradation and restore structural complexity and genetic diversity. Most restoration efforts focus on the asexual fragmentation of *Acropora cervicornis* and *Acropora palmata* (Boström-Einarsson et al., 2020) because of their fast growth, endangered status, and ability to create complex habitat on the reef (Lirman & Schopmeyer, 2016; Ware et al., 2020). With advancements in microfragmentation techniques, restoration efforts for slow-growing massive, bouldering, and brain morphologies are becoming more viable (Page et al., 2018). Restoring species with diverse morphologies improves species richness, resilience, resistance to stressors and maximizes reef ecosystem services. An alternative to fragmentation is sexual coral propagation, which has the advantage of creating novel genetic combinations, potentially increasing the coral population's resilience to climate change (Baums, 2008; Guest et al., 2014). Advances in sexual propagation techniques over the past decade have made it an increasingly viable reef restoration method; however, this method is still more costly, labor intensive, and requires specialized *ex situ* rearing facilities (Guest et al., 2014; Ligson et al., 2020).

In Florida, one of the primary bottlenecks to sexual propagation as an effective reef restoration method is post-outplant mortality from intense fish predation of coral juveniles by parrotfish (Scaridae) and butterflyfish (Chaetodontidae) (Horoszowski-Fridman et al., 2015; Koval et al., 2020). Predation from fish is the most intense the first week after outplanting, with Smith et al. (2021) finding that over 50% of outplants experienced predation in the first week. Similar studies by Koval et al. (2020) found initial predation levels of 73%, and Page et al. (2018) recorded 40% predation of outplants. Larger juvenile size does correlate with increased post-outplanting survival and growth rates (Ligson et al., 2020; Lusic et al., 2020; Rivas et al., 2021). To reach larger sizes, corals must be held at *in situ* coral nurseries for a longer period, increasing costs and required holding tank space (Guest et al., 2014). The use of cages and spikes to provide physical protection to coral outplants has been shown to reduce predation, but once the physical barrier is removed, the outplants still experience intense predation (Koval et al., 2020; Rivas et al., 2021). A recent study by Harrell & Lirman (2023) explores the idea of reducing predation by chemically defending coral through feeding the macroalgae *Dictyota* prior to outplanting, finding that *Orbicella faveolata* had lower predation mortality after being fed *Dictyota*.

Corals have a few defense mechanisms, such as stinging cells (nematocysts), mucous excretion, sweeper tentacles, and polyp retraction: however, the effectiveness of these mechanisms against fish predation seems to be insufficient to prevent predation on corals, especially small corals (Paruntu et al., 2022; Shnit-Orland & Kushmaro, 2009). Given that a coral colony is composed of polyp clones, the colony can survive partial mortality (tissue loss) due to predation and regrow; additionally, since polyps communicate with other polyps in the colony, there is a possibility that increased defense mechanisms could be activated in new and existing tissues (Gochfeld, 2004). Gochfeld (2004) found that partial predation by butterflyfish increased nematocyst density in addition to a behavior change in previously predated corals. The polyps of corals exposed to predation would retract entirely into the corallum, leading to reduced predation by butterflyfish. Additionally, placing corals at an *in situ* nursery with low level predation exposure prior to outplanting to a reef improved survival, growth rates and reduced predation impacts (Horoszowski-Fridman et al., 2015). Chemical predatory defense mechanisms remain to be identified in scleractinian corals; however, they are found in several other colonial



marine organisms, such as sponges and gorgonians (Pawlik & Fenical, 1992; Harvell et al., 1993).

*In situ* coral nurseries are vital to coral reef restoration, allowing coral fragments to grow until they reach a size they can be re-fragmented and/or outplanted on the reef (Rinkevich, 1995, 2005). *In situ* nurseries typically grow corals using methods that either attach the corals to structures on the seabed or suspend them in the water column (O'Donnell et al., 2017). Suspension in the water column can be done in long-lines or trees. Coral trees are vertical, tree-like structures with PVC branches from which coral fragments are attached, allowing for reduced sedimentation, enhanced water flow, and improved nutrient uptake (Nedimyer et al., 2011). Coral modules are flat platforms attached near the seabed, simulating natural coral growing conditions and providing stability, especially in strong currents (Shaish et al., 2008). The choice between coral trees and coral modules depends on the specific needs of the coral species being cultured and the environmental conditions of the nursery site.

This project aims to evaluate the effectiveness of inducing an anti-predatory response in corals at an *ex situ* nursery before outplanting while simultaneously comparing coral survival on two different structures (module and tree). We hypothesize that poking the coral with a needle, i.e. causing a small, non-lethal injury, would reduce predation, and therefore boost outplant survival and growth rates, allowing for corals to be outplanted while still small in size without experiencing intense predation-based mortality. Additionally, we hypothesize that there will be lower levels of predation in corals placed on trees compared to modules. Because sexual propagation is relatively expensive, outplanting (smaller) corals earlier would greatly contribute to reduce production costs and labor, and free up space at the nurseries for new recruits.

## **Methods**

### *Study species*

Corals of the species *Colpophyllia natans*, *Diploria labyrinthiformis*, *Montastraea cavernosa*, *Orbicella faveolata*, *Pseudodiploria strigosa*, and *Pseudodiploria clivosa* produced sexually at Nova Southeastern University's Marine Larval and Recruitment lab during the Summer 2022 spawning were used to test the effect of simulated predation on survival and growth post-outplanting. The corals of each species were held *ex situ* in recirculating tanks, covered in shade

cloth, allowing for the PAR range to be around  $150 \mu\text{mol s}^{-1} \text{m}^{-2}$  at noon. Corals were fed four times per week. Water changes and water quality measurements (ammonia, nitrate, nitrite, phosphate, calcium, alkalinity, and magnesium) were performed weekly. The tiles holding corals were cleaned of algae weekly under a microscope, including right before outplanting.

### *Experimental Treatments*

Corals from each species were randomly assigned to one of four treatments: (1) Poked before outplant and Grow-out in Module, (2) Not Poked: Grow-out in Module, (3) Poked before outplant and Grow-out in Tree, (4) Not Poked: Grow-out in Tree. Each treatment group had 5 replicates/coral juveniles of each species (except for *P. strigosa* which only has 4 replicates/corals per treatment group), resulting in a total of 116 juvenile corals. A needle was used to poke coral individuals under a microscope to simulate a small predation event. The needle was inserted into the coral at a  $90^\circ$  angle with enough force to pierce the tissue until the skeleton was reached. The coral was poked near a polyp but not directly on a polyp mouth to limit excessive damage or polyp death. Tiles holding corals were labeled on one side as a reference point to help visually create eight radial sections in the coral. The area on the coral that is poked is moved one section clockwise each time to prevent the same area from receiving multiple pokes in a row. Poking treatments occurred 4 and 2 days prior to outplanting to give them 2 days to recover before being outplanted. Each individual was given an identification number and photographed to determine initial size (surface area) one day prior to outplanting.

### *Outplant structures*

The corals were moved to Nova Southeastern University's *in situ* nursery, located ( $26^\circ 7' 28.32''$  N  $80^\circ 5' 49.32''$  W) north of Port Everglades. Within the "Tree" group, coral tiles were affixed to an underwater tree branch using screws. The tree was anchored to the seafloor and held afloat by buoys and allowed to sway with the current. Each branch of the tree accommodated 10 individuals of the same species, with the *P. strigosa* branch only having 8. Meanwhile, members of the "Module" group were secured with cement to a broad horizontal seabed table approximately 1m off the seafloor. Corals from each species were arranged in clusters of 5 (or 4 for *P. strigosa*), categorized based on whether they belonged to the Poked or Non-poked group.

### *Monitoring and data collection*

Each coral was visually assessed for survival (live, dead), predation (presence of bite marks; missing corals were assumed to be predated) and health (healthy, paling, bleaching, and tissue loss not due to predation), and photographed at the *in situ* nursery 7 days, 18 days, 34 days, and 81 days after being outplanted. These photographs were placed into ImageJ, and the tissue surface area of each coral was calculated.

### *Data Analysis*

All data analysis was conducted in RStudio version 4.2.1. A survival analysis Cox model was conducted to test the effect of time and treatment on post-outplant survival. A generalized linear mixed-effect model (GLMM) with a Gaussian distribution was used to compare the post-outplant growth, using treatment, time, and location as fixed factors and species and coral as random factors, with tissue surface area as the continuous response. To test if initial size had an effect on predation, individuals of each species were broken up into three size categories: largest 1/3, middle 1/3, and smallest 1/3, and contingency tables were used to determine if there was an association between initial size and survival. A GLMM with a Gaussian distribution was used to compare the recovery (re-growth) after predation by removing time point 0 from the dataset and using time, treatment, and location as fixed factors and coral as a random factor, with tissue surface area as the continuous response.

## **Results**

### *Survival*

Corals cemented on modules (Module) had a significantly higher survival than those attached to trees ( $p = 0.001$ ) (Figure 1). The concordance index for this model was 0.61, indicating moderate predictive accuracy. Likelihood ratio, Wald, and Score tests confirmed the significance of the model ( $p = 0.004$ ). After 81 days of outplant, corals in trees had 53% survival, whereas survival at the modules was significantly higher, 59% (Table 1). Simulated predation (poking) prior to outplanting did not significantly affect post-outplant survival ( $p = 0.47$ ).

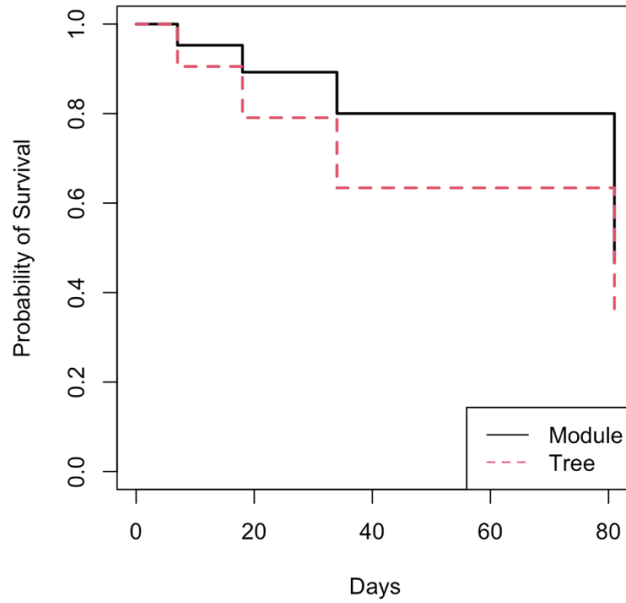


Figure 1. Probability of coral survival post-outplanting over time (days) between Modules and Trees.

Table 1. Coral survival rates post-outplanting over time (days) between Modules and Trees

Species	Survival							
	Tree				Module			
	7 days	18 days	34 days	81 days	7 days	18 days	34 days	81 days
<i>O. faveolata</i>	90%	90%	90%	90%	100%	100%	100%	70%
<i>C. natans</i>	40%	40%	40%	40%	90%	90%	90%	70%
<i>M. cavernosa</i>	50%	50%	50%	40%	70%	70%	70%	40%
<i>P. strigosa</i>	50%	50%	50%	50%	100%	100%	87.5%	87.5%
<i>D. labyrinthiformis</i>	40%	40%	40%	20%	30%	30%	30%	0%
<i>P. clivosa</i>	100%	100%	90%	90%	100%	100%	100%	90%
Combined	62%	62%	60%	53%	81%	81%	79%	59%

### Growth

The tissue surface area of the corals significantly changed over time ( $p < 2.2 \times 10^{-16}$ ) (Figure 2). Post-hoc pairwise comparisons indicated significant differences in coral size between all time points (GLMM,  $p < 0.001$ ). Residual analysis confirmed no significant autocorrelation in model residuals (DW = 0.84185,  $p = 0.1327$ ). There was no statistical difference in growth for poked vs unpoked corals (GLMM,  $p > 0.05$ ); additionally, there was no statistical difference for corals grown in trees vs. corals grown in the modules (GLMM,  $p > 0.05$ ).

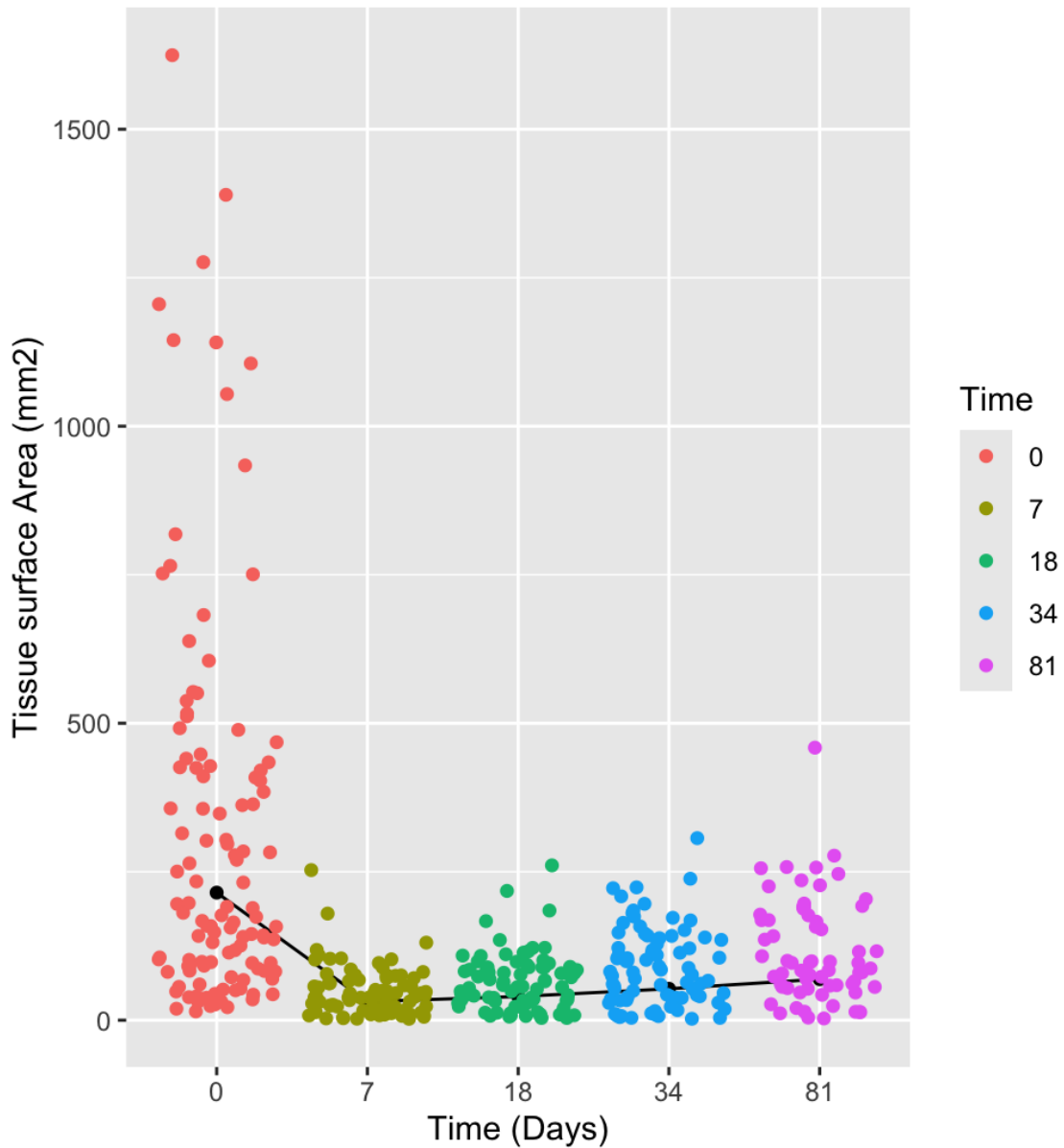


Figure 2. Tissue surface area (mm<sup>2</sup>) of corals over post-outplanting time. Each color is representative of a different time point

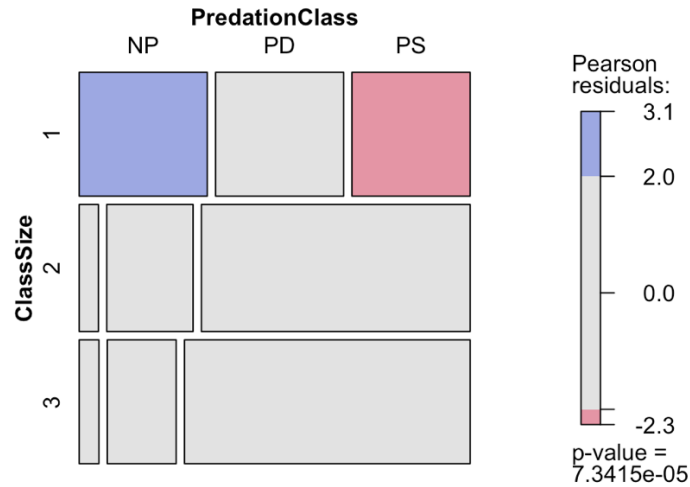


Figure 3. Predation rates and predation outcomes based on a coral’s size class, with Class 1 representing the smallest 1/3 individuals, Class 2 the middle 1/3 and Class 3 largest 1/3 of each species (NP=not predated, PD= predated and died, PS=predated and survived). There is a significant association between coral size and the likelihood the coral is predated and survives ( $p=7.34\times 10^{-5}$ ). Specifically, smaller corals (class size 1) are less likely to be predated (high positive residuals, highlighted in blue), but, if predated, are more likely to die (high negative residuals, highlighted in red).

### *Predation and Initial Size*

Analysis of species’ survival, predation, and recovery growth over an 81-day period reveals variation among species in survival rates, with *Pseudodiploria clivosa* having the highest survival rate at 90%, while *Diploria labyrinthiformis* had the lowest at 10%. Predation rates were uniformly high across species, ranging from 40% for *Montastrea cavernosa* to 100% for *P. clivosa* and *Orbicella faveolata*. Despite experiencing predation, all species exhibited notable tissue recovery growth. Notably, *Colpophyllia natans* showed the highest tissue recovery at 235.1 %, increasing from an average tissue surface area of 42.2 mm<sup>2</sup> to 141.4 mm<sup>2</sup>. *Montastraea cavernosa*, although heavily predated had a 176.6% recovery rate. The overall predation rate across all species was 85% with an average tissue recovery growth of 136.7%, indicating substantial resilience and regrowth potential among coral species studied. There was a significant association between the size of the coral and predation ( $\chi^2 = 54.825$ ,  $df = 4$ ,  $p = 7.34\times 10^{-5}$ )

(Figure 3). Corals belonging to the smallest class size showed a significantly greater chance of not being predated than larger corals. However, when the smaller corals were predated, they had a significantly lower chance of survival than corals of size classes 2 and 3. Coral of size classes 2 and 3 were similarly predated.

### *Recovery*

After the first week of outplanting, when most predation occurred, the coral regrew; their tissue surface area significantly increasing from day 7 to 81 after outplanting ( $p = 2 \times 10^{-16}$ , Fig. 4) with the post hoc analysis pairwise comparisons indicating significant differences in size among all time points (all  $p < 0.0001$ ). The re-growth rate differed significantly among species ( $p < 0.05$ , Table 2). The interactions between time and species ( $p = 0.015$ ) and location and time ( $p = 0.035$ ) were found to be slightly significant. Conversely, outplanting location and poking vs. non-poking treatments did not significantly affect growth. It appears there is initially a quicker recovery for corals on modules; however, growth on trees catches up and is almost identical to modules in the following time points.

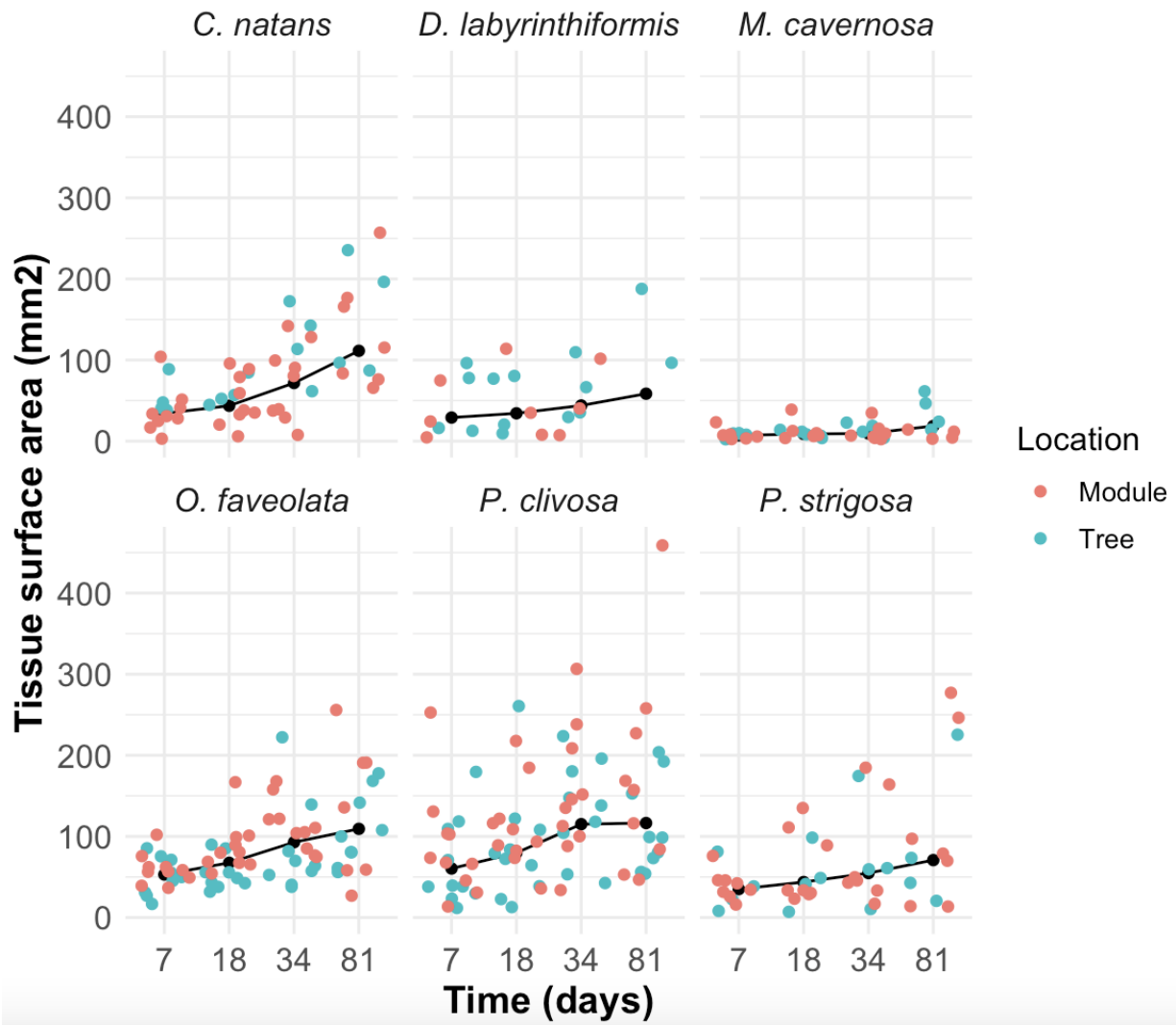


Figure 4. Comparing Recovery/Re-growth of individuals for each species and for different locations after the initial predation event.

## Discussion

In this study, I found that predation was most intense the first week after outplanting, and corals attached to modules had higher chances of survival than the ones grown on trees, but grew at similar rates. Importantly, the smallest corals of each species had a significantly higher chance of not being predated than larger corals, suggesting a potential predation size exclusion. However, if a small coral was predated, it had a significantly lower chance of survival as a larger percentage of its total tissue was removed. Coral recovery, i.e. re-growth rate after the initial



predation, differed among species, likely due to their different morphology. The exposure to simulated predation prior to outplanting did not improve survival, i.e. minimize predation, nor affect growth. It is possible that the exposure to non-lethal simulated predation was not performed for a long enough duration to prime an anti-predatory response and thus result on improvements to post-outplant success.

Predation by fish was most intense for all six coral species within the first week following outplanting, with 85% of individuals experiencing predation, likely because fish curiously bite all new elements in their environment, but within a week get used to it and predation plummets. This observation is consistent with the findings in previous coral predation studies (Harrell & Lirman, 2023; Koval et al., 2020; Page et al., 2018; Rivas et al., 2021; Smith et al., 2021). Scaridae (parrotfishes) and Balistidae (triggerfishes) are frequently found at the *in situ* nursery, and predated corals had bite marks from individuals belonging to these two families. It is unclear if these predation events resulted from fish biting corals within their territory because they are novel, if they are being indirectly grazed by individuals trying to consume nearby algae, or if the fish are directly feeding on the outplants. Previous studies on parrotfish predation (Bruckner et al., 2000; Bruggemann et al., 1994) and triggerfish predation (Gibbs & Hay, 2015) have shown that both families exhibit territorial behavior and are known to bite corals that are in their territories. However, recent research has experimented with outplanting coral skeletons alongside live corals to observe whether territorial fish attack both dead skeletons and living corals. The outcomes indicate that these corallivorous fishes primarily target live corals rather than skeletons, suggesting that fish bite live corals due to their nutrient content (proteins and lipids) rather than as a territorial response (Harrell & Lirman, 2023; Rivas et al., 2021). It is possible that fish are more attracted to the corals within the first week due to higher production of mucous induced by the “outplant shock”. Corals release more mucus when trying to adapt to new/stressful changing environmental conditions such as temperature, sedimentation, and light availability (Dehnert et al., 2023; Forrester et al., 2012). Some fish species have been found to show a preference toward macrophytic tissue properties (Prado & Heck Jr, 2011), and coral mucus serves as a source of carbohydrates that predators can use for energy (Wild et al., 2010). It may lead corallivores to use chemoreception to target stressed corals during foraging (Cole et al., 2008; Hay, 2009). Fish are not likely to be trying to consume the algae as tiles since these cleaned before outplanting and this would not explain the strike

reduction in predation after one week. It is possible that the presence of divers and/or the handling of corals and resuspension of sediment (and food therein) inadvertently attract predatory fish species to the area, increasing the likelihood of predation events occurring shortly after outplanting. In my study, only one individual showed evidence of predation after the first week, indicating that fish likely adjust to the presence of the coral juveniles. The potential importance of fish territoriality and the relationship between nutritional content and predation need further investigation to determine why outplants are so heavily predated (only) shortly after outplanting.

Conversely to the expected, in this study, corals grown on trees experienced higher predation and mortality than corals grown in the module, closer to the benthos. Generally, trees are considered a more effective grow-out structure because they place corals further from the benthic habitat where they are more exposed to predators, sedimentation and algal overgrowth (Nedimyer et al., 2011; Young et al., 2012). This discrepancy could be due to the age/size of the corals used in this study relative to the others which usually use trees to grow fragments (>10cm) of less fleshy adult corals, like *Acropora*. Additionally, this study did take place over a short period, so differences in coral mortality between structures may differ in longer time periods. Depth, turbidity, currents, and duration of time corals are kept in the nursery are likely to influence the effectiveness of grow-out structures at *in situ* nurseries, and thus should be considered when choosing between structures (Maneval et al., 2021; Poquita-Du et al., 2017; Shaish et al., 2008). In this study, all mortality resulted from predation, and the discrepancy in survival between the structures is likely due to the 89% of the corals grown in the trees having experienced predation. The coral nursery has a large population of triggerfish and parrotfish likely attracted to the “habitat” structure and refuge from predators provided by the trees (Oakley-Cogan et al., 2020). At the last observation (81 days), new mortality was observed on the modules that was not caused by predators but likely algal overgrowth, which was not seen on the tree. Since only one module and one tree were utilized in the study, higher replication is essential to draw robust conclusions.

Smaller corals seem to experience at least some level of predation exclusion, which if confirmed could be used to maximize long-term outplanting success. Smaller outplants were found to be significantly less predated than the larger individuals, but the larger individuals showed significantly higher survival rates when predated. This finding agrees with results from

several previous studies stating that large outplants had increased survival when compared to small outplants (Jayewardene et al., 2009; Ligson et al., 2020; Okubo et al., 2007). Smaller corals may be less visible to predators and allow them to remain undetected. Alternatively, the lower predation rates observed in smaller corals could be attributed to the principles of optimal foraging theory in which predators prioritize feeding on larger, nutrient-rich food as it is a more efficient use of energy than targeting smaller food (Cachera et al., 2017; Townsend & Winfield, 1985). Predation of smaller outplants was more likely to leave no tissue behind for regeneration and thus cause (full) mortality, instead of just partial mortality of the coral. The initial coral size on post-outplant survival is key in shaping the success of restoration efforts and the resilience of coral reef ecosystems. Given the cost associated with growing corals in *ex situ* nurseries, early outplanting significantly reduces costs (Ligson et al., 2020). A trade-off emerges between coral size (directly related to time spent in *ex situ* nursery) and likelihood of survival post-outplanting, highlighting the need to determine the “ideal size” for each species to optimize coral restoration efforts. Determining the size at which corals achieve the highest survival rates at smaller sizes ensures efficient utilization of *ex situ* nursery facilities, enabling outplanting with minimal mortality.

After predation ceased, surviving corals of all species regrew and increased their live tissue considerably, which is critical for the effectiveness of reef restoration efforts. Surviving outplants experienced an 84% loss of tissue area in only seven days. Such an intense predation could severely impact long-term survivorship, for example, Page et al. (2018) reported *Orbicella faveolata* outplants which experienced a greater than 40% tissue loss from predation did not survive. However, over the span of 74 days from the initial to the final observations, the surviving outplants exhibited a tissue size increase of 136.7% (Table 2), indicating rapid tissue regeneration. This rapid tissue regeneration can reduce mortality from algal colonization, borers, and pathogens (Highsmith, 1982; Kaufman et al., 2021). The differential growth rate among species aligns with previous knowledge. Scleractinian corals growth rates vary across species and life histories (Crabbe, 2009; Dullo, 2005; Peter, 2007) likely because of their morphology, and susceptibility to environmental stressors (Hughes & Jackson, 1985; Loya et al., 2001). Additionally, species-specific symbiosis with algae and their nutritional requirements also impact growth patterns (Dullo, 2005; Hall, 1997; Stat et al., 2008).

Predation of coral outplants poses a significant constraint on reef restoration efforts, highlighting the need for a more comprehensive understanding of predator behavior and the anti-predatory mechanisms of corals to optimize outplanting methodologies. Fish predation can cause mass coral mortality and tissue loss primarily in the first week post-outplant. Further investigation into the optimal size of coral outplants, the use of scalable predator exclusion from biodegradable coral-access minimizers, and the effects of long term simulated (nonlethal) predation will be beneficial for developing effective strategies to reduce predation and improve recovery. By addressing these challenges through targeted research, we can improve the resilience and diversity of coral reef systems.

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