INSTITUTE FOR
MARINE RESEARCH
DAUIN · PHILIPPINES

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FRAGS

User Manual

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Front Cover: Lipayo Artificial Reef, Dauin, Negros Oriental, Philippines
Image: Dana Mcconnell

ACKNOWLEDGEMENT

This project would not be feasible without the funding support from the PADI Aware Foundation. This funding has allowed IMR to drastically alter the coral cover at the Lipayo Artificial Reef site (Dauin, Negros Oriental, Philippines) with 600m2 of thriving coral colonies (~1 coral per m2). Secondly, to the IMR staff and students who contributed to these planting efforts. In particular Dana Mcconnell, Katrina McPherson, Cristina Lucas, Jennifer Brand and Dan Hughes, each of whom played integral roles in project operations, and keeping up with the complex monitoring schedule to ensure the survival of our corals of opportunity. Their knowledge and enthusiasm towards the success of the FRAGS project is inspiring. We can't wait to watch these corals thrive and spawn!

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1.0 CORAL RESTORATION

Coral reefs have been declining at an unprecedented rate for the past few decades (Gouezo *et al*. 2019, Bruno *et al.* 2007), with global climate change being the driving factor behind most large-scale coral loss events (Hughes *et al.* 2019). A lack of natural recruitment and insufficient time for recovery between disturbance events conspire to make natural recovery unlikely, or even impossible in many locations (Montefalcone *et al.* 2018, Jones *et al.* 2009). With the continued decline of hard coral cover around the world, the degradation of coral ecosystems is evident (Carpenter *et al*. 2008).

Passive restoration methods such as Marine Protected Areas (MPAs) and no take zones, have been a staple of coral reef conservation for most of the last century. However, research has shown that ideal conservation consists of both habitat protection as well as habitat restoration (Boström-Einarsson *et al*. 2020). For the restoration of coral reefs, enhancing coral cover and abundance via restoration initiates can ensure that sufficient breeding corals will remain on the reef to aid in coral resilience and post-disturbance recovery, whilst also ‘buying time’ for corals as other organizations continue to take action on the global climate change issue (Boström-Einarsson *et al.* 2020).

Coral restoration approaches have advanced greatly over the last 20 years, with restoration projects now reported in over 56 countries (McLeod *et al*. 2022). Restoration techniques can be grouped into three major categories: a) asexual restoration methods, b) sexual restoration methods, and c) substrate enhancement methods. The use of these techniques varies greatly in order to address the specific challenges faced by the target reef, often defined by the level of degradation sustained by the environment.

2.0 INTRODUCTION TO FRAGS

The Institute for Marine Research's (IMRs) Functional Restoration and Growth Studies (FRAGS) project was designed in 2022 with the purpose of determining the reseeding potential of artificial reefs (ARs) in recruitment poor locations post coral transplantation. Super Typhoon Odette (Rai) in December 2021 uprooted entire coral colonies from their base, which continued to undergo breakage, scouring and burial due to their inability to reattach to the unstable reef substrate. IMRs FRAGS project utilized these susceptible corals (Corals of Opportunity; COPs) by manually attaching the fragments to various artificial structures. These artificial structures were comprised of various materials: concrete, metal, or a combination of the two. Using artificial structures to transplant COPs (rather than suitable natural substrate) ensures space availability for incoming larvae, which is essential for maintaining site resilience.

Through a series of detailed monitoring and research efforts, IMR hope to determine the ability for previously coral-devoid ARs to become preliminary refuges to COPs, and later result in the sexual maturity of these COPs with the potential to reseed nearby and previously disturbed natural reefs. This will be the first project to define the reseeding potential of COPs grown onto artificial structures. By utilizing artificial structures devoid of coral due to limitations in background natural recruitment, yet are proven to be withstanding against incoming typhoons, could drastically improve post-disturbance survival of fragmented colonies.

3.0 PRELIMINARY SETUP (A GUIDE)

3.1 SITE SELECTION

The Lipayo AR located in Dauin (Negros Oriental, Philippines) was selected for active restoration due to the presence of preestablished artificial structures **(Figure 1)**. These structures were deployed between 2007 and 2016, however due to their deployment occurring in a recruitment limited location these structures contain low to no coral cover (<15%).

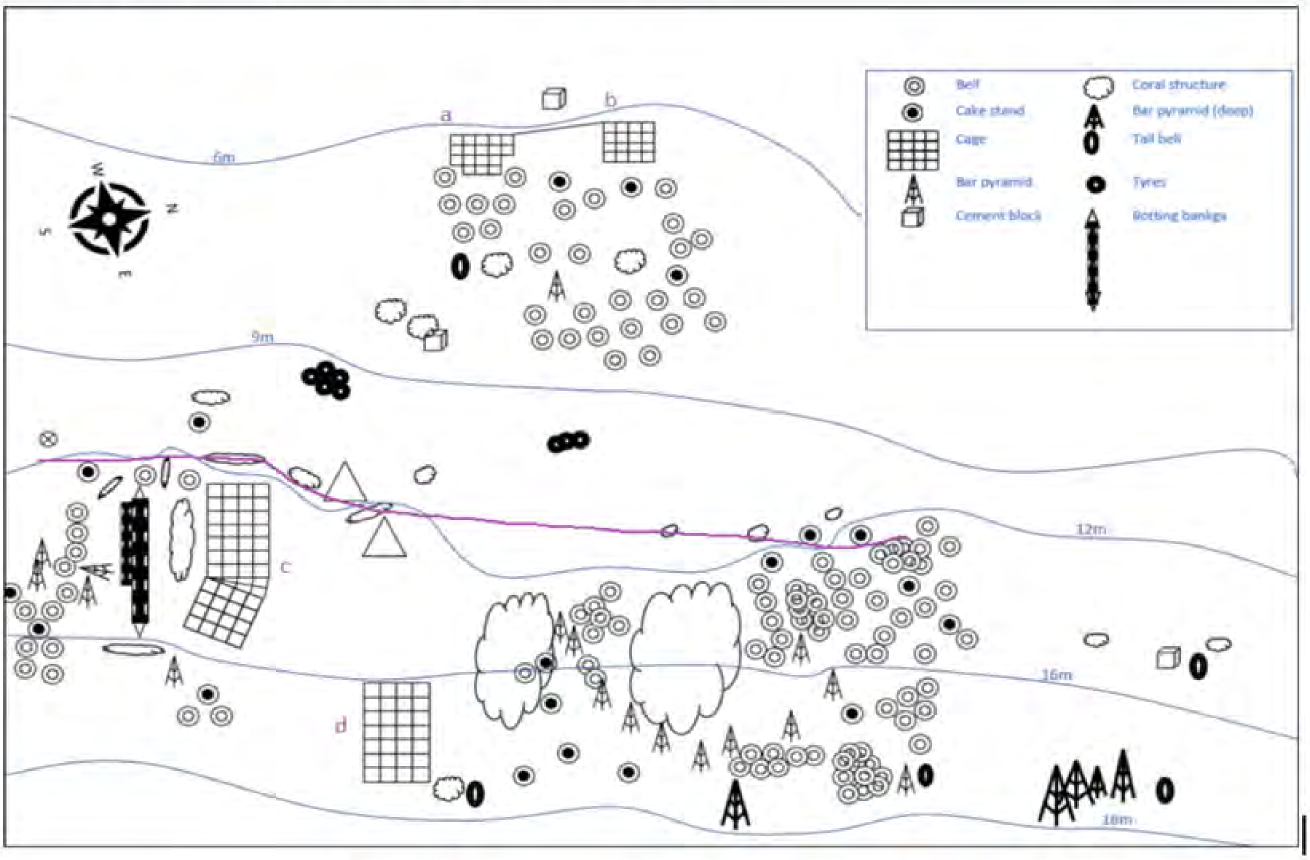


Figure 1. Site map of the Lipayo AR in Dauin (Negros Oriental, Philippines) including location of AR structures across depth countours.

3.1 (A) MATERIALS

In the early onset phase of AR restoration, substrata utilized for coral attachment was often composed of repurposed industrial materials (i.e. tyres, cinder block, PVC pipe, mesh nets). Whilst repurposing materials can seem advantageous due to: the material avoiding ending up in landfills, and some materials promoting larval settlement, complex ramifications post AR deployment have been identified (Chava *et al.* 2021).

For example, materials that have been saturated in toxins or are toxic themselves can often leach into the surrounding ecosystem as the materials begin to degrade underwater (Chava *et al.* 2021). As time progresses, a decrease in overall reef health and coral cover could occur as a result. Similarly, small and unstable materials of opportunity that are currently being used around the world for ARs, create problems when looking at storm surge and overall ocean movement (Chava *et al.* 2021). Due to the fact that the structures are not heavy enough to provide stable substrata, or are not attached thoroughly to the ocean floor, the structures can easily shift with any ocean movement (Chava *et al.* 2021). This leads to the possibility of them crushing the surrounding reef, as well as, the structures moving from the intended location entirely. Since there were a plethora of problems that arose when trying to use these materials of opportunity such as tires and small pieces of "trash" or construction waste, organizations have since moved past building ARs with materials of opportunity. Instead, many coral restoration projects are choosing to build their own structures that more similarly resemble a "natural" reefscape and therefore provide better structure and attachment for the corals in the restoration area.

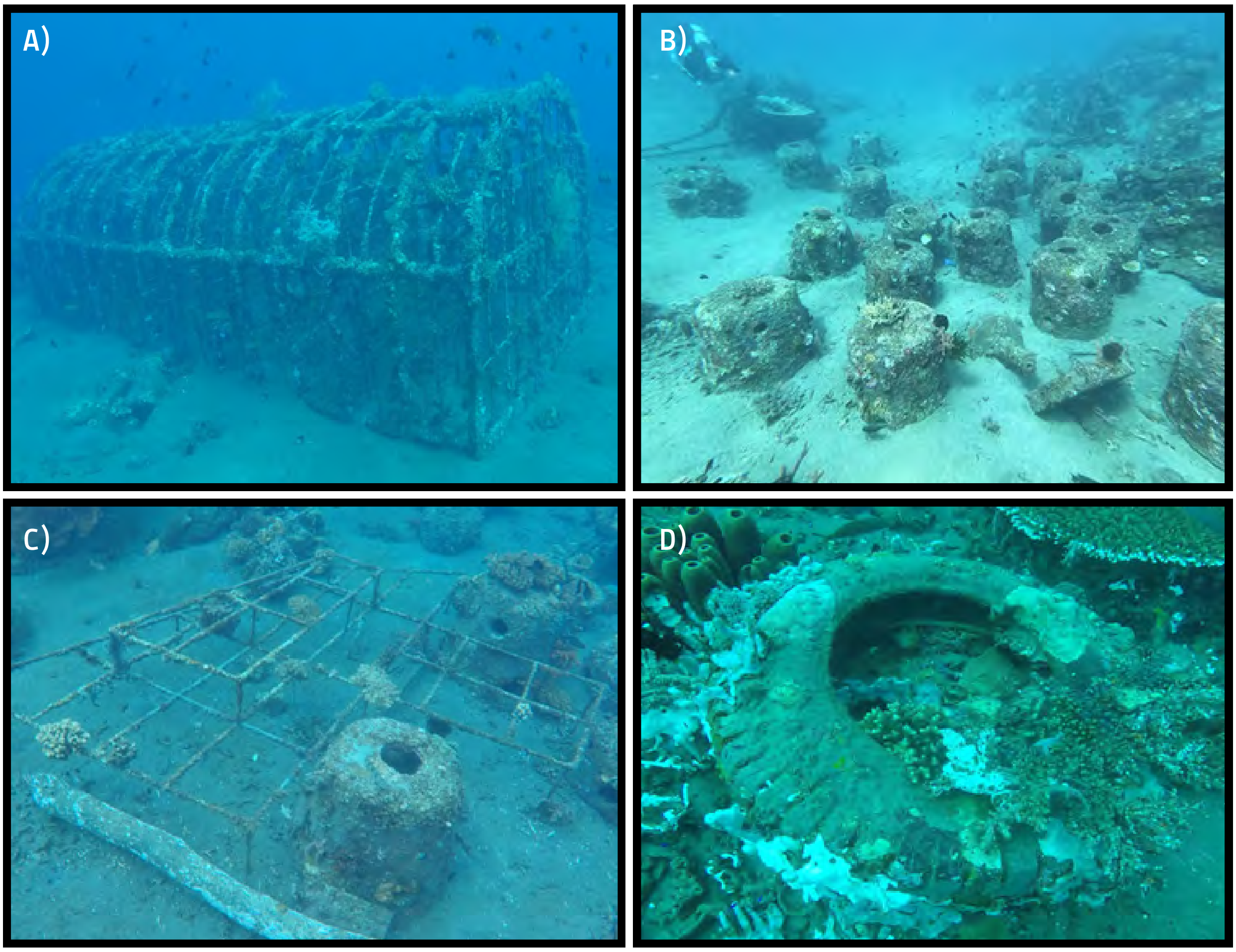


Figure 2. Artificial reef structures selected for COP attachment. A) Two 'deep' metal cages, B) 46 concrete bells C) Two 'shallow' metal cages, and D) Rubber tires (not used for active restoration).

Here in Dauin, the AR structures that were chosen for coral attachment are a mixture of **metal** and **concrete.** These materials have been constructed in the form of two large rebar cages, an abundance of small concrete 'bells', 'cake stands', and a smaller table-like cage. Miscellaneous AR structures (i.e. car tires) were not chosen for coral attachment, as these structures are not conducive towards long-term coral survival (i.e. material deterioration or instability)**(Figure 2).** Structures at Dauin's AR site were initially deployed as a community initiative with the effort to induce natural larval settlement due to substrate availability at a predominantly sandy ecosystem. For this reason structures have not been attended or maintained for almost a decade, allowing natural ecosystem succession to develop over previously bare material. This has added a complex challenge towards preliminary coral attachment onto AR materials, and continues to grow without mortality pressures associated with benthic competitors existing on the structures. Before manually attaching COPs to an AR structure, extensive cleaning of the structure was performed to facilitate attachment and alleviate the potential of preliminary mortality pressures associated with the surrounding competing benthos.

With this knowledge, pilot trials were conducted by attaching 73 fragments across concrete and cage structures to determine survivorship preferences towards material. Whilst no significant overall difference in substrate preference was detected (cage 44%, bells 32%) within the first 12-weeks of attachment (**Figure 3**), long-term monitoring has identified that the settlemet of benthic competitors and their retention (despite rigoruours cleaning) will ultimately affect survivorship outcomes.

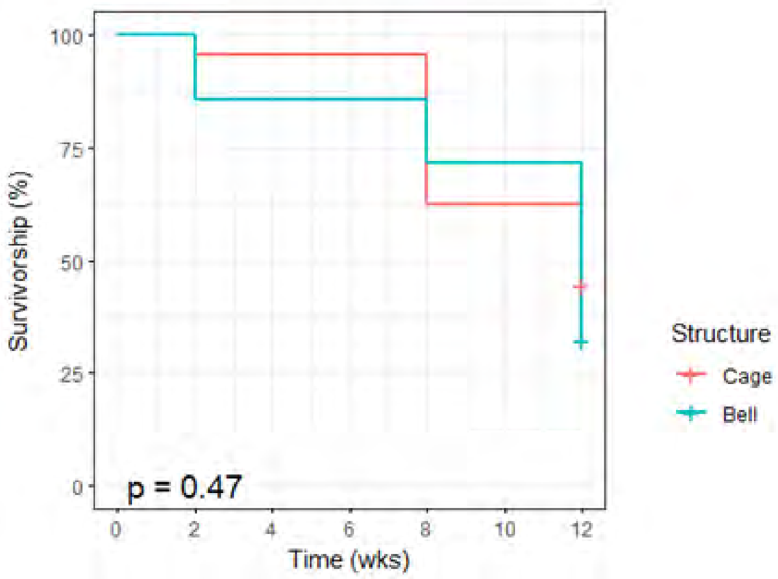


Figure 3. Kaplan-Meier survival curves of fragments from 0 weeks (initial planting) to 12 weeks post planting, separated by artificial material. Groups have the same survival probabilities (p>0.05).

3.1 (B) PRE-EXISTING BENTHOS

If AR structures are deployed alongside planting efforts, the need to clean or remove existing benthos will not exist. The bare AR substrate will also reduce maintenance efforts required to promote coral growth. As previously mentioned, Dauin's AR site consists of pre-existing structures that have facilitated the settlement of early benthic organisms for up to a decade (**Figure 4**). Direct coral attachment to these structures without intervention was not feasible without compromising on coral health. Therefore, the following considerations were made to promote COP growth and attachment:

1. Preliminary removal of all biofoul at the site of attachment
2. Monitoring and maintenance post-attachment
3. Structural maintenance at 1-2 week intervals post-attachment
4. Keeping in mind, nature will always win. Unless you have the time, money and energy to spend maintaining the coral outplants frequently, trying to find areas that will require little maintenance is important. These low maintenance areas should have:
    - Low sponge and algal cover
    - Plant corals away from pre-existing benthos
    - In close proximity to a healthy reef (increased chance of grazing organisms to assist with algal control)

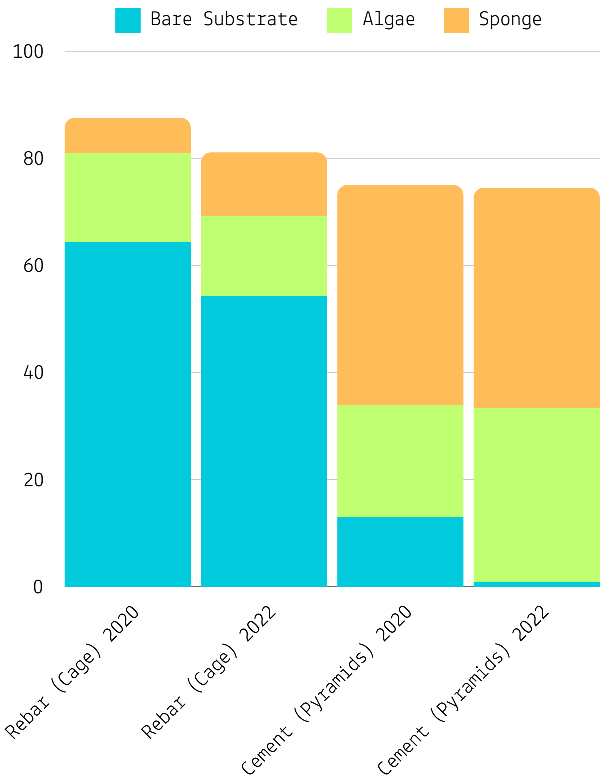


Figure 4. Change in benthic cover (%) from 2020 to 2022 between rebar and cement structures.

Terpios hoshinota ("coral killing sponge") is a fast growing encrusting sponge found throughout the Indo-Pacific. It usually is seen in the color variations of gray, purple, and red, and is capable of outcompeting and physically smothering well established adult coral colonies (**Figure 5**). Not only does it kill existing coral colonies, it also reduces benthic diversity by outcompeting other benthic organisms from establishing in the area. Once the Terpios hoshinota has taken over a section of a reef, no other organisms can exist there. This fast growing sponge has taken over a majority of the structure at the AR site and is one of the most common causes of coral death seen. At our AR site, IMR have battled the fast growth rate of this sponge whilst operating on a restricted maintenance schedule. To reduce mortality pressures associated with the presence of Terpios hoshinota, IMR have attempted to:

1. **Ensure that the COPs are devoid of Terpios hoshinota prior to attachment**
- This can be achieved by either choosing COPs that do not have any sponge present, or fragging/cutting a COP (with a healthy margin) that does have some of the sponge present to save the rest of the coral.

2. **Remove Terpios hoshinota from the entirety of the AR structure prior to attachment**
- Removal of the sponge: both from where the COP is slated [1] [2] [3] to be manually attached to the structure, and any nearby portions that may hinder COP growth and attachment. This will assist in creating a buffer zone between the COP and any potential areas where the sponge may be present.
- Keep in mind that the sponge encrusts and grows over every surface type. This means that if the structures have bivalves or barnacles growing on them, making sure that the sponge is removed from that uneven surface is important. If the sponge is not removed entirely, it will regrow underneath the newly planted coral in a matter of days.

3. **Conduct routine maintenance every 1-2 weeks in order to maintain a buffer zone between the COPs and any sponge that may be present.**

Figure 5. Example of *Terpios hoshinota* outcompeting live coral tissue on AR structures.

3.2 DEPTH SELECTION

When choosing a restoration site, depth is an important factor to consider. Shallower reef areas (<15m) provide ease of access for maintenance, with high light penetration promoting faster coral growth. However, shallow reefs also have some adverse effects such as an increase in biofoul growth, higher possible destruction from wave and storm action, and an increased potential for human impacts due to recreational use. ARs in particular, are generally placed along a depth gradient that is across sandy reefscapes. The amount of sediment moved and deposited in this area is often exacerbated by wave exposure and strong currents, which can smother/hinder coral growth in shallow reef areas.

Reef Depth 1 - 15m		**Reef Depth 15m+**	
PROS	**CONS**	**PROS**	**CONS**
• Increased coral growth due to light availability • Longer dive time (greater planting potential) • Greater community awareness due to ease of access	• Greater exposure to UV stress (coral bleaching risk) • Increase in biofouling on structures • Exposure to destruction due to: Storm and wave action	• Reduced light exposure leading to a lessened possibility of UV stress • Less biofouling on AR structures • Less probability of destruction due to storm and wave action due to depth	• Reduced light leads to reduced coral growth • Shorter dive time (decreased planting potential) • More difficult to have community engagement and awareness

3.3 FRAGMENT SELECTION (FINDING A COP)

When seeking out a COP, there are a few factors to keep in mind. It is important to look at the morphology/growth form, overall health, size and ease of attachment of each COP that is being chosen. If a COP passes all of these requirements, there is a better chance of it surviving past the first few weeks post planting and eventually naturally attaching itself onto the AR structure. When trying to restore a reef, it is pertinent to look at increasing or at least maintaining as much diversity in corals as possible. Since most COPs consist mainly of branching corals due to how easily they break, most COPs found around the reef will tend to be of a similar genus and morphology. This can cause unintentional bias in regards to what COPs are chosen. Because of this, it is useful to search for variety in COP sizes, growth forms and genus/species. This will end up creating a healthier and more diverse reef that is being restored. In order to accurately choose COPs with these factors in mind, a more in depth explanation for each category is listed in the following sections.

3.3 (A) COP MORPHOLOGY

Corals can be differentiated into a few categories in relation to coral morphology. The morphologies utilised in this study includes: branching, encrusting, foliose, massive and submassive. Most of the corals that are utilised in coral restoration projects are those of a branching morphology (59%) (**Figure 6**). In AR restoration, manual attachment of branching morphologies can be achieved with ease, with our findings showing that corals of the branching morphology tend to grow well on all AR structures. The two types of structure that were used for the attachment of branching corals to were: metal cage structures via the use of cable ties, and the concrete bell structures using marine safe epoxy. On both structures the branching corals grew quickly and encrusted over their attachment mediums (cable ties/epoxy) as well as encrusting over the AR structure. Encrusting or foliose morphologies grew best when either attached to the concrete bells via epoxy, or on the thicker supporting bars of the metal cages. Lastly, submassive or massive morphologies grew best when attached solely to the concrete bell structures via the use of epoxy. Since these morphologies tend to have a slower growth rate, they require a more stable attachment area.

3.3 (B) COP GENUS/SPECIES

Due to the abundance and fast growth rates of Acropora corals, they are often the most sought out in regards to coral restoration (30% of restoration projects worldwide). As a branching genus, they are easy to fragment and attach to most AR structures. However, following IMRs 12-week pilot study, significant difference in survivorship between genus type was identified. The brooding genus *Pocillopora spp.* achieved higher survivorship than both *Acropora spp.* and *Stylophora spp.*. COP health and size played a key role in these survivorship outcomes, highlighting genus-specific planting regimes are required to faciliate higher attachment and survivorship.

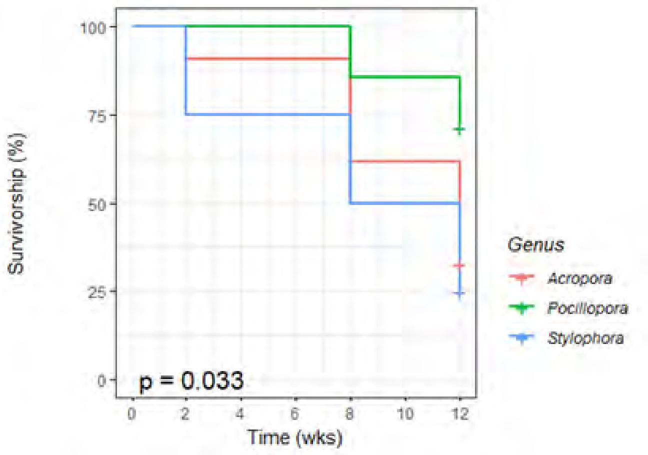


Figure 6. Kaplan-Meier survivorship preferences between 3 coral genera during a 12-week pilot study. Genera do not have the same survival probability ($p<0.05$).

3.3 (C) COP SIZE/HEALTH

When choosing a COP to attach, there are a few key factors to keep in mind. COP size and overall health is extremely important for the longevity of the outplanted coral. If a coral is too small, it is at risk of becoming outcompeted by the surrounding benthos (algae and sponge). However if a coral is too large, it can also increase the chance that it will be harder to attach securely and the risk of losing the coral before it has an opportunity to attach itself to the structure will increase. Due to these factors, it is important to search for corals that are at least 8 cm in length (branching morphologies), and 6-8 cm in size for encrusting, massive or submassive morphologies (Figure 8). However, in order to preserve diversity, smaller than ideal COPs were planted with the hope that they would survive and grow to naturally attach to the structure. Whilst this can be seen as a gamble, enough success has been seen that it can be worth the effort. By “pruning” dead, damaged or diseased portions of the coral off, the chances of the COP surviving greatly increased. However, a threshold has been identified in which COPs are no longer suitable for restoration (**Figure 7**).

Figure 7. Examples of suitable and not suitable COPS for AR restoration. A), B) and C) are examples of healthy COPs of an appropriate size that will be ideal to plant onto AR structures. No disease, scouring, bleaching or any other impact is present on the corals. D) *Goniastrea spp.* presents signs of bleaching on the corallite walls, which is common in this species of coral. It is still deemed as healthy and can be used as a COP to outplant. E) Coral presents with what looks like Rapid Tissue Necrosis (RTN) which is affecting the branch in the middle. This impact will eventually spread to the other branches, and the COP is not large enough to fragment with a healthy margin to save the rest of the coral. F) This coral presents with bleaching. Because it is so small (single corallite), it is not usable due to size and impact. Coral is unlikely to survive initial planting.

3.3 (D) COP ATTACHMENT & ORIENTATION

The specific orientation of COPs various attachments was dependent on both the morphology of the coral, as well as the type of structure that it will be manually attached to. Our recommendations from the field are the following:

1. **Branching Morphology:**
- Favor "upper" orientations of AR surfaces to promote faster growth and natural attachment
- Suitable for all attachment methods (Epoxy and Cable tie) (**Figure 8**)
- Suitable for all AR structures (Concrete, Metal, Mixed)

2. **Encrusting, Submassive, and Massive Morphologies:**
- Natural attachment facilitated across "upper" and "side" orientations
- Size matters for orientation during attachment: <5 cm preferable on "side" orientation, >5 cm preferable on "upper" orientation
- Faster growth facilitated on "upper" orientations
- Preference towards 'bell' structures over 'cage' due to larger attachment surface
- Preference towards epoxy attachment method

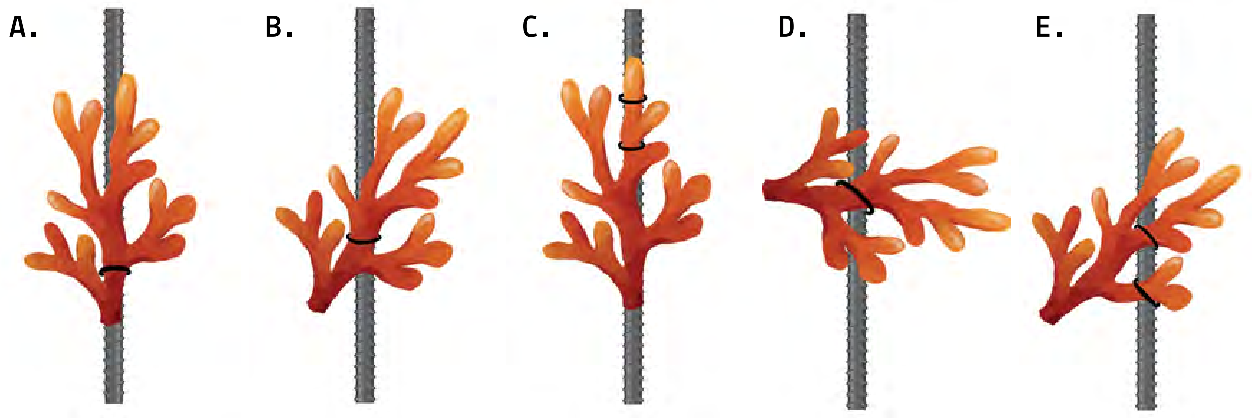


Figure 8. COP attachment and orientation options on metal cages. A) This is the most ideal orientation, promoting stabilisation and natural attachment of the COP with multiple points of contact with the structure. The single cable tie around the "trunk" or thickest part of the coral is fastened horizontally and not diagonally which also lessens the possibility that the cable tie will come loose or begin to cut into the coral over time. B) Can be used depending on coral size and shape. However, it is not an ideal placement for the coral in regards to providing attachment points for the coral to the metal bar of the AR structure. C) Acceptable orientation. Not the most stable for the coral due to the weak state of the branches closer to any new growth. Additionally, there is unnecessary cable tie use. This coral could be attached securely with one cable tie lower down on the middle 'trunk' of the coral. D) Not ideal attachment or orientation for this COP. The coral is sideways and will not be as supported on the structure as it could be if the orientation was changed. Additionally, the cable tie is fastened diagonally which could cause the tie to come loose or cut into the coral. E) This is also not an ideal attachment method. The coral branches are usually thinner and more fragile, which means that there is a possibility that they will break easier. Because of this, they do not provide the best points of attachment. Also, the use of double cable ties is not necessary to secure this coral due to its small size. **Image credit: Max Kessler**

When conducting monitoring dives, it was noted that some corals were either completely dead, or there was an empty epoxy slot/cable tie in the area depending on what AR structure was restored and/or which COP attachment method was used (**Figure 9**). For the areas that had a broken cable tie or empty epoxy slot, direct destruction caused by human impact could have been the cause due to the popularity of this dive site. However as we continue to experiment with new attachment techniques and materials, we can also assume that some of the initial mortality or loss that occurred in the first few weeks post planting could have been caused by ineffective attachments at the time of planting. During the beginning of this project, various methods to attach COPs utilising epoxy were tested. The first epoxy that was used in the project was called 'Pioneer Marine Epoxy'. This epoxy is easily accessible in the Philippines and relatively inexpensive. However, this epoxy has proved ineffective for a variety of reasons. First, this epoxy consists of a part A (epoxy resin putty) and B (hardening agent) which can only be mixed out of the water. Once these two parts are combined the epoxy will begin to harden in about 30-45 minutes depending on outside conditions. Secondly, due to epoxy preparation occurring ex situ, an appropriate ratio had to be estimated for the amount of COPs to be planted. This estimation can cause an over or under supply of epoxy. Finally, the hardening time of the epoxy varied dramatically once in contact with water, often not capable of facilitating attachment due to the epoxy completely hardening over throughout the dive. We have now changed to a more expensive, but more effective epoxy called 'Apoxie Sculpt' which can be mixed in situ and provides more secure attachment points.

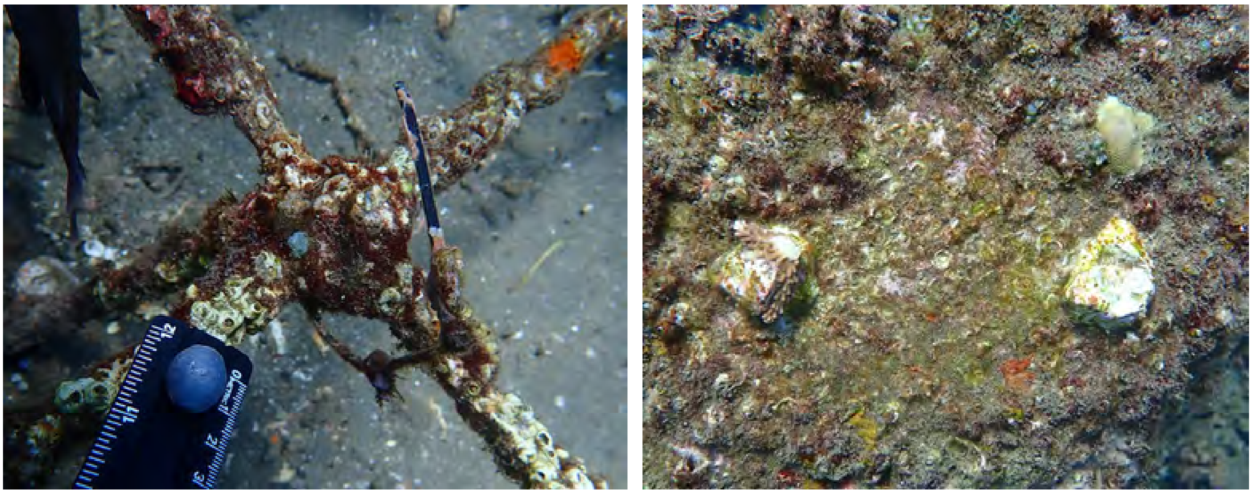


Figure 9. Empty attachment spots on various AR structures. A) Broken Cable tie on a metal cage, and B) Empty epoxy on a concrete bell. The epoxy slot still has a piece of Acropora fragment in it. This indicates that the coral was most likely removed from the structure via direct destruction.

EXAMPLE 1: ATTACHING FRAGMENTS OF THE SAME COP

If any of the COPs were to be accidently fragmented into multiple smaller pieces, it is important to attach them to the structure in close proximity in hopes that they end up growing and fusing together faster. The larger the outplant can be, the better chance of survival it generally has. During our planting, we experimented with this with multiple genera and morphologies. A great example of how planting these fragments near each other can be beneficial is with a *Seriatopora spp.* COP that was planted. While fragging off a section that was dead, it split into two smaller sections. Instead of either planting them far apart from each other or not planting them at all, we used cable ties to securely attach them to one of our cages and now at 16 weeks the fragments have both grown over the cable tie and grown in size, so that they are fused together to create one healthy coral (**Figure 10**).

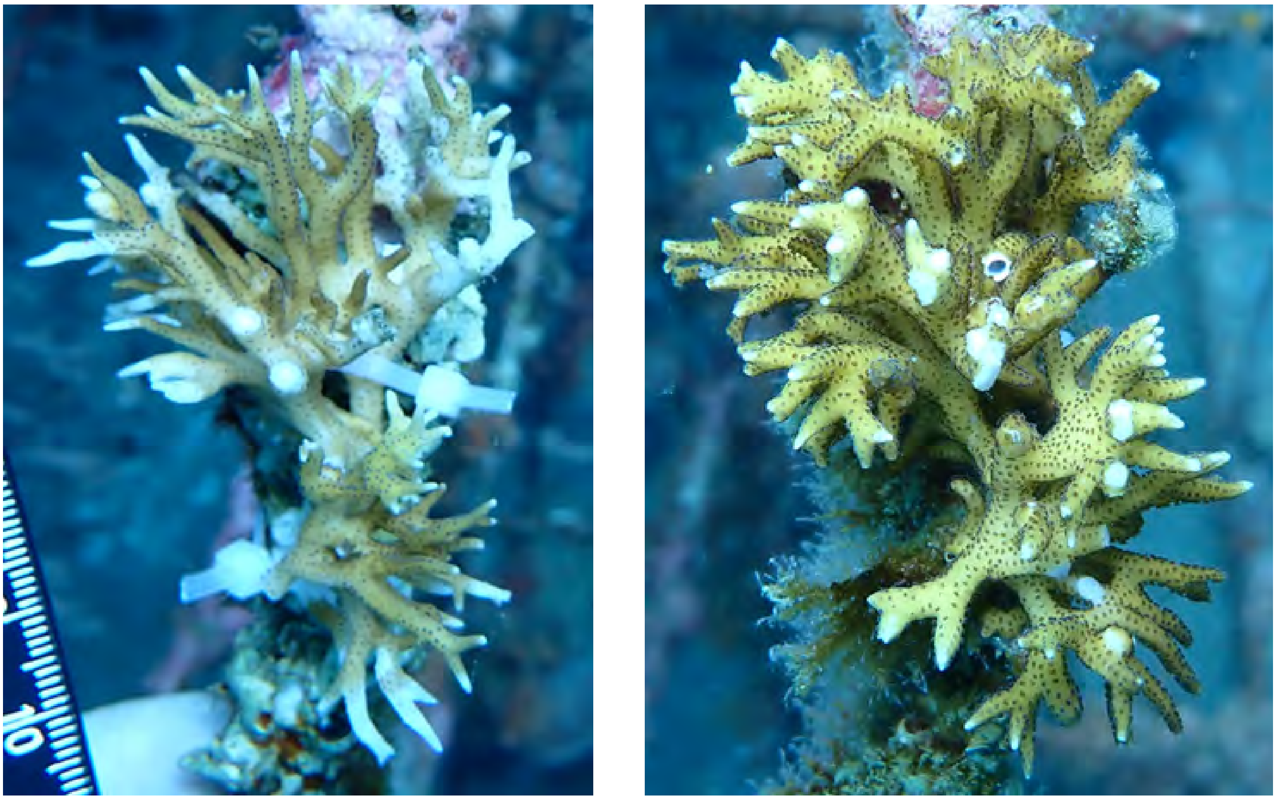


Figure 10. A *Seriatopora* COP that was previously fragged into two smaller pieces and attached to a metal AR structure using cable ties. The coral fragments have now fused together and the coral is thriving.

EXAMPLE 2: COP ATTACHMENT (CAGES / BELLS)

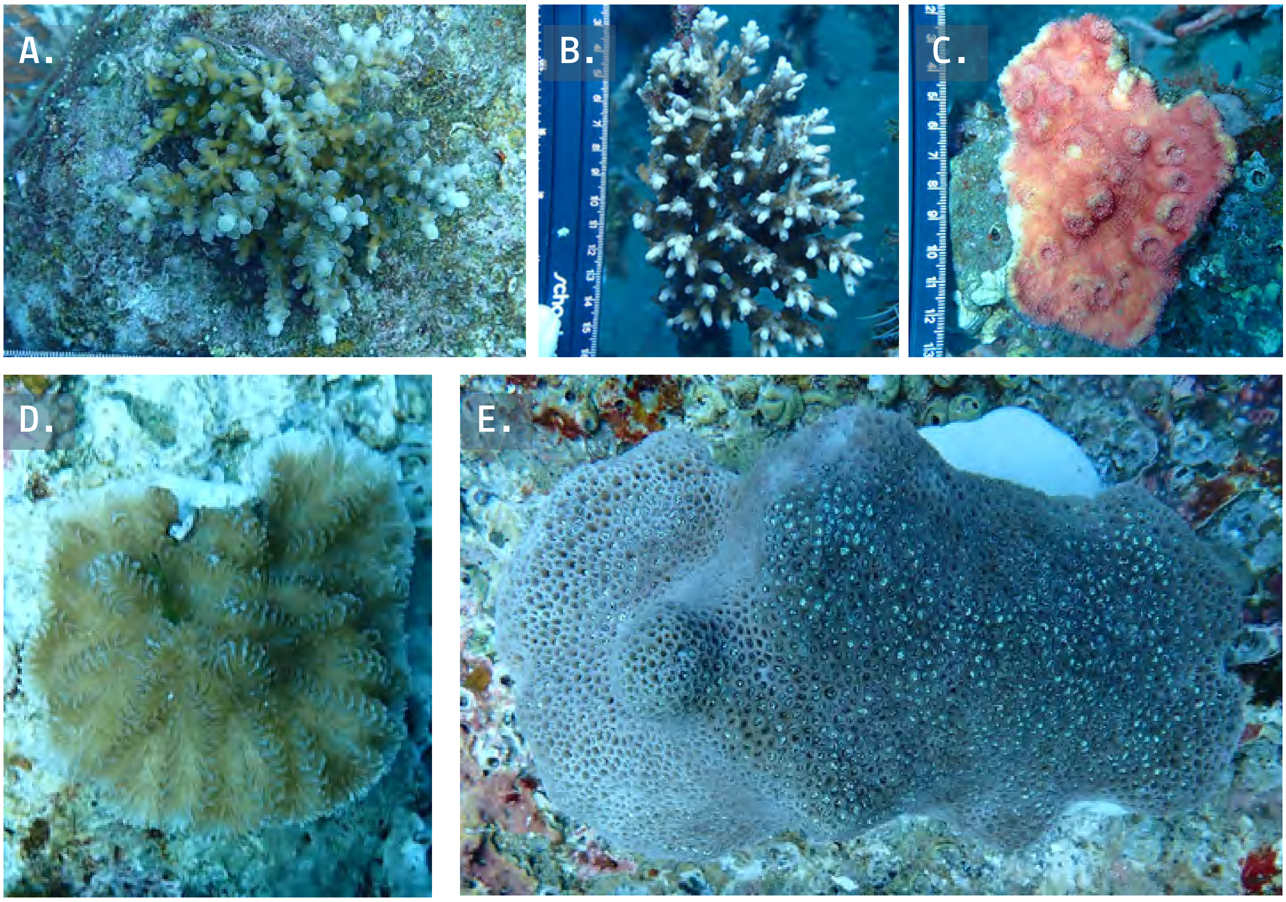


Figure 11. Examples of COP attachment onto metal cages and concreate bells. A) Branching COP attached using epoxy to a concrete bell. This coral is attached at the top of the structure with the branches facing up, so as to promote better and faster growth and natural attachment to the AR structure. Epoxy is used sparingly at the base at multiple attachment points to give it stability, but not too much as to smother the coral. B) Branching COP attached using cable ties to a metal cage structure. This coral is attached near the top of the metal cage and has two cable ties (one at the top and one near the bottom) to promote natural attachment and provide stability. The branches are facing up towards the sun to promote growth. C) Encrusting COP attached toone of the thicker bars on a metal cage. This was a trial coral to see how encrusting corals survived and grew on the cage structure. Two pieces of epoxy were placed underneath to secure it. This coral morphology would not be conducive to plant on the skinnier bars, however it is growing well on the larger surface that the big bar provides. D) Encrusting COP attached to the side of a concrete bell. This coral is attached at the base by one epoxy piece, due to its smaller size. The initial epoxy for encrusting corals has to be good in order to provide stable attachment long enough that the coral will start to naturally encrust and attach to the structure on its own. E) Submassive COP attached to the top of a concrete bell. This coral was placed on the top of the bell for more stability due to its size. Three pieces of epoxy were used to anchor it down with sloping pieces showing down the sides in hopes that the coral will start to naturally encrust down the epoxy and anchor the coral to the AR structure.


CRESSI

4.0 MONITORING

Monitoring of COP attachment, survival and growth occurred across the following intervals: Time Zero (T0-Initial outplant), 1 week (1W), 2 weeks (2W), 4 weeks (4W), 8 weeks (8W), 3 months (3M), 6 months (6M), 9 months (9M), 12 months (12M). After 12 months, monitoring sessions will occur once a year to determine the reproductive potential of the colony. More frequent monitoring efforts is required in the first 8 weeks to ensure natural attachment of the COP to the structure has occurred. However, most COPs became dislodged between T0 and 1W post-outplant.

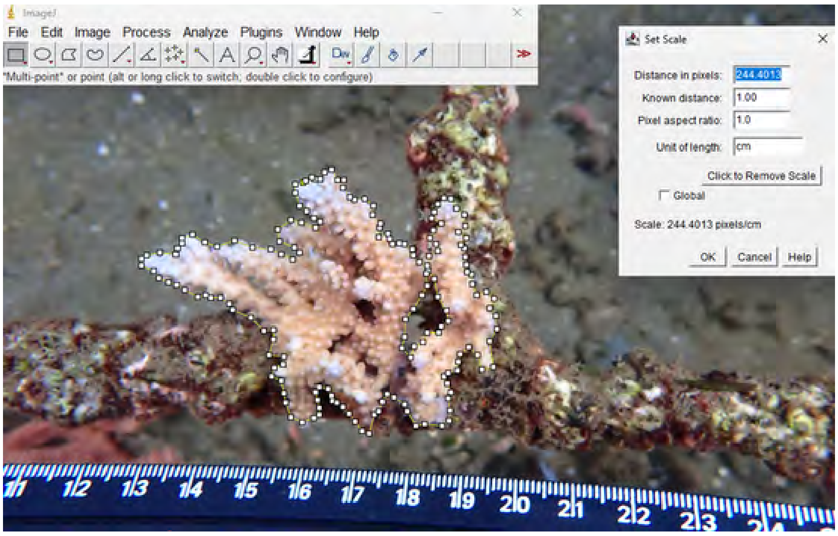
Growth measurements were obtained by taking a photo of each colony at every monitoring interval using an Olympus TG6 Tough camera with housing, and a ruler fitted with weights to maintain a negative buoyancy. Photos for growth estimates were obtained by placing the ruler flush with the top of the coral, with the metric side closest to where the coral is attached to the AR structures. The camera should be positioned at an angle that shows the size and overall health of the coral in the most representative way (typically top down). Additionally, the camera should be focused on the coral and not on the ruler, and the photo should not be blurry. Lastly, the entire coral should also be visible in the photo without any portions cropped out or missing. These images were uploaded onto imageJ, where the area of the colony could be calculated. This method of data collection and analysis provides a more precise measurement due to the analysis being performed out of the water which catered towards a greater number of colonies to be captured on each monitoring dive. However an inaccurate ruler placement, or a blurry/cut off image can influence area calculations.

A Guide to ImageJ

The ImageJ software is used after the in-water monitoring session is completed in order to calculate the growth/reduction of each COP over time. While in water, divers are taught to take a photo of each coral with the weighted ruler properly in frame. Once the divers are back at base, they are able to upload all of the photos taken during their monitoring dives and prepare them for analysis. Once all of the photos from the day have been uploaded, they can then be analyzed and measured using the ImageJ software. The basic steps to complete this analysis are as follows:

Step 1: Take a photo of the coral. While capturing the image, keep in mind that the ruler should be even with the top of the coral and held in such a way that the metric side ends up facing the coral. Once the photo is taken, it can then be uploaded to a computer and prepared for analysis.

Step 2: Take the uploaded photo and open the ImageJ software. (The software is pictured in the top left of the photo above). The next step you need to complete is to set the scale of the photo. This is where the ruler comes into play. You will need to set the scale of the photo by giving the software a known distance. For example, in most of our imaging we use a set scale of 3 cm by selecting that distance on the ruler in the photo. Once the scale has been set, it will now adopt that measurement for the remainder of this process.

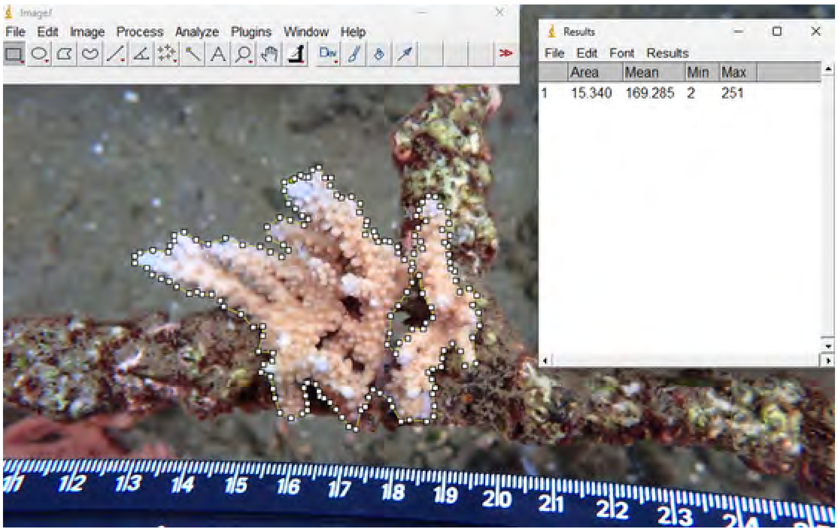


"Multi-point" or point (alt or long click to switch; double click to configure)

Distance in pixels: 244.4013
Known distance: 1.00
Pixel aspect ratio: 1.0
Unit of length: cm
☐ Global
Scale: 244.4013 pixels/cm

.

Step 3: The last step in this process is to take the measurement of the total area of the coral. In this example, the Acropora COP has been selected by a series of points and when measured comes to a total of 15.340 cm sq. This process can be repeated over several monitoring times to see any increase or decrease in overall coral size.



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   Area    Mean     Min  Max
1  15.340  169.285  2    251
```

While this process is very handy and fairly easy to complete, there are a couple of factors that can hinder accurate measurements. For example, if the ruler is held at an angle or too close/far away from either the camera or coral, it can give an inaccurate scale when you set it for the photo and therefore show an increase or decrease in coral size where it does not seem accurate.

EXAMPLE: MONITORING / ANALYSIS

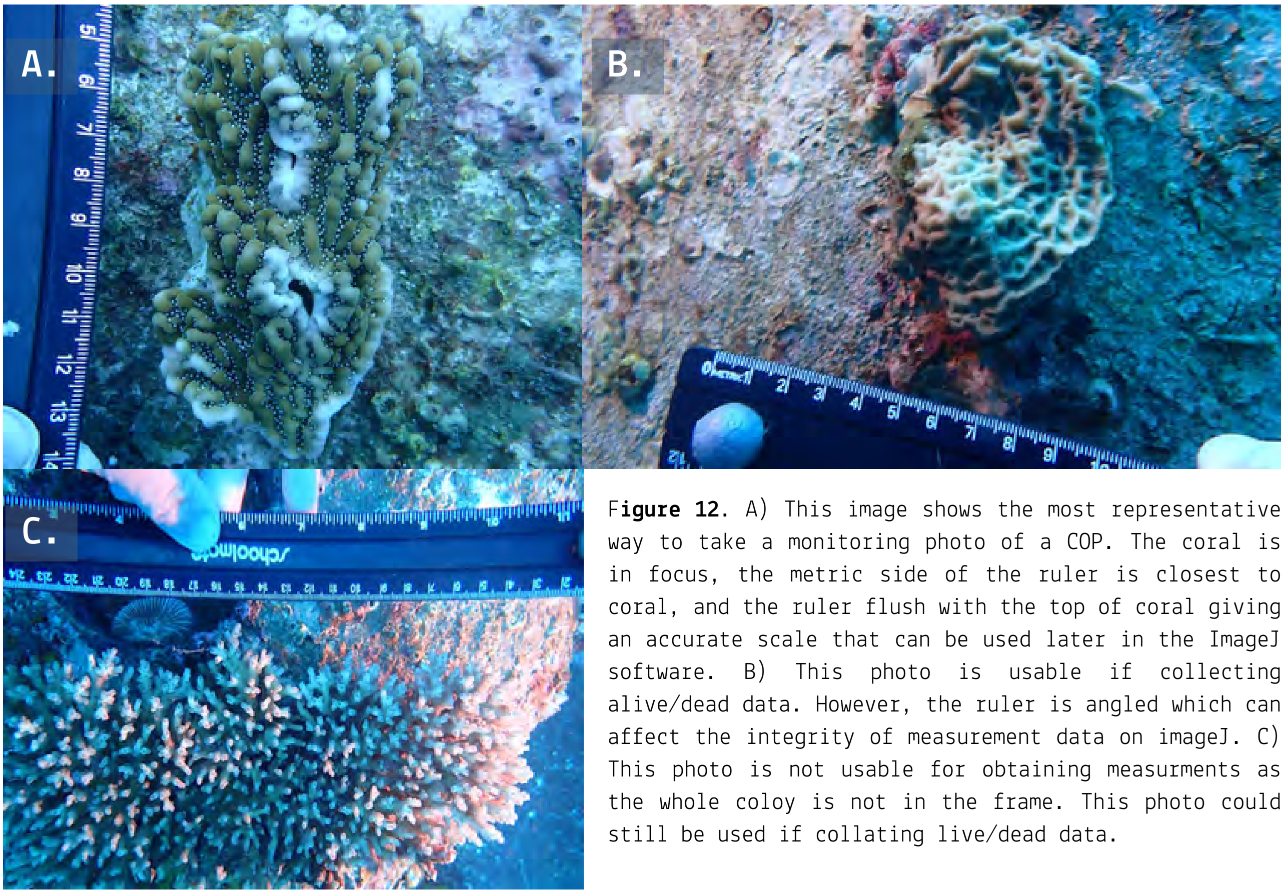
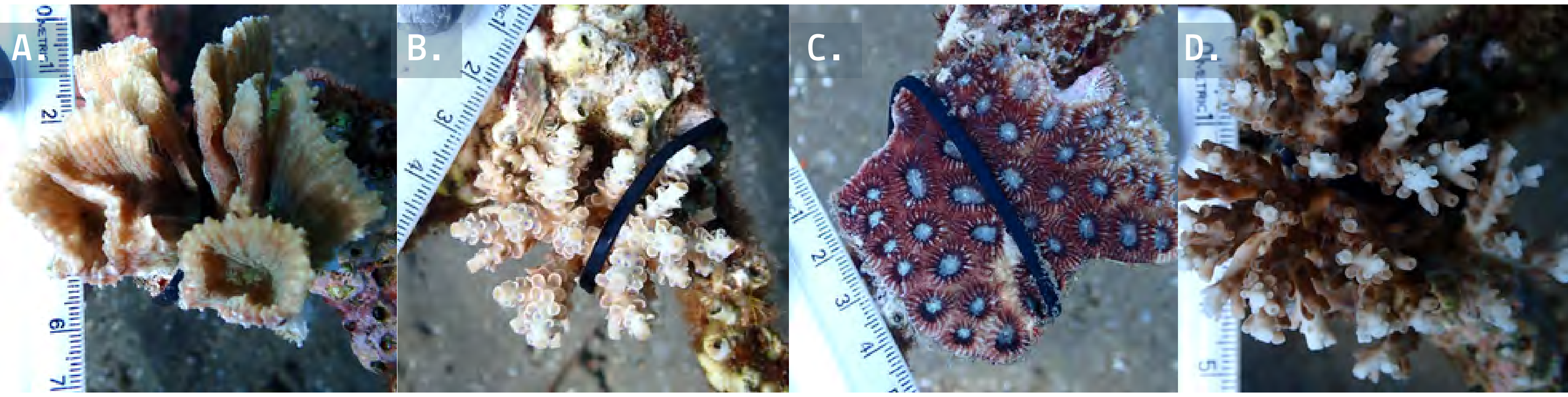


Figure 12. A) This image shows the most representative way to take a monitoring photo of a COP. The coral is in focus, the metric side of the ruler is closest to coral, and the ruler flush with the top of coral giving an accurate scale that can be used later in the ImageJ software. B) This photo is usable if collecting alive/dead data. However, the ruler is angled which can affect the integrity of measurement data on imageJ. C) This photo is not usable for obtaining measurments as the whole coloy is not in the frame. This photo could still be used if collating live/dead data.

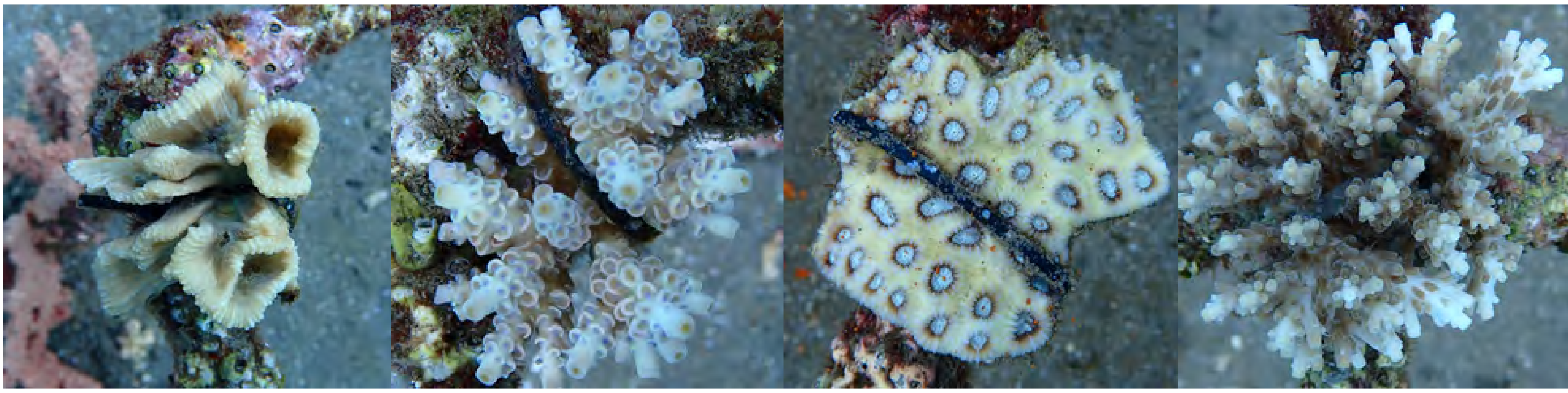
Coral A- Pectinia
Coral B- Acropora
Coral C- Dipsastraea
Coral D- Acropora

‘SHALLOW CAGE’ MONITORING:

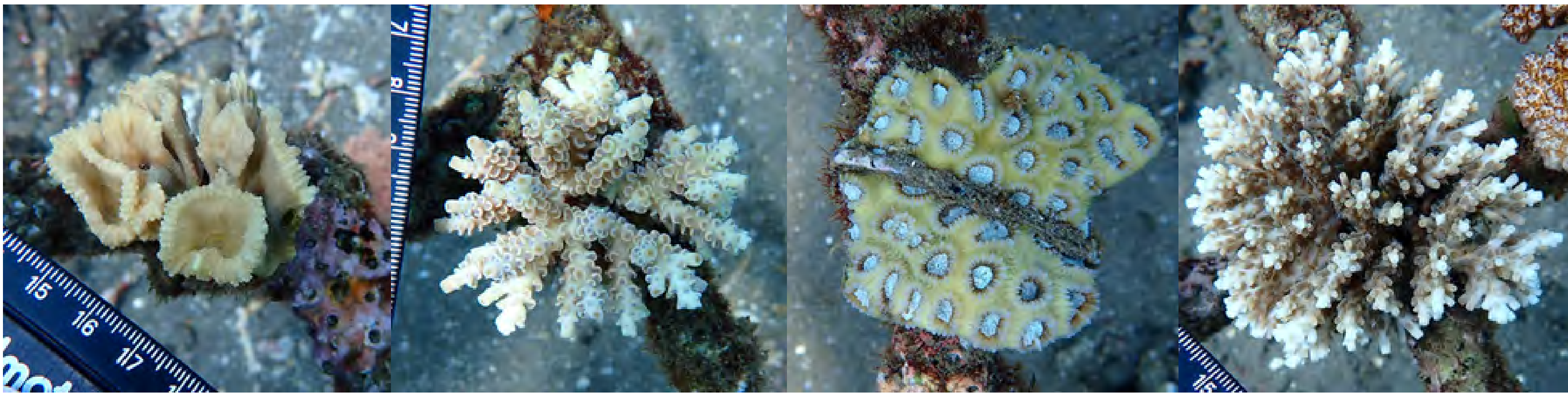
Time Zero (T0)- Initial Planting



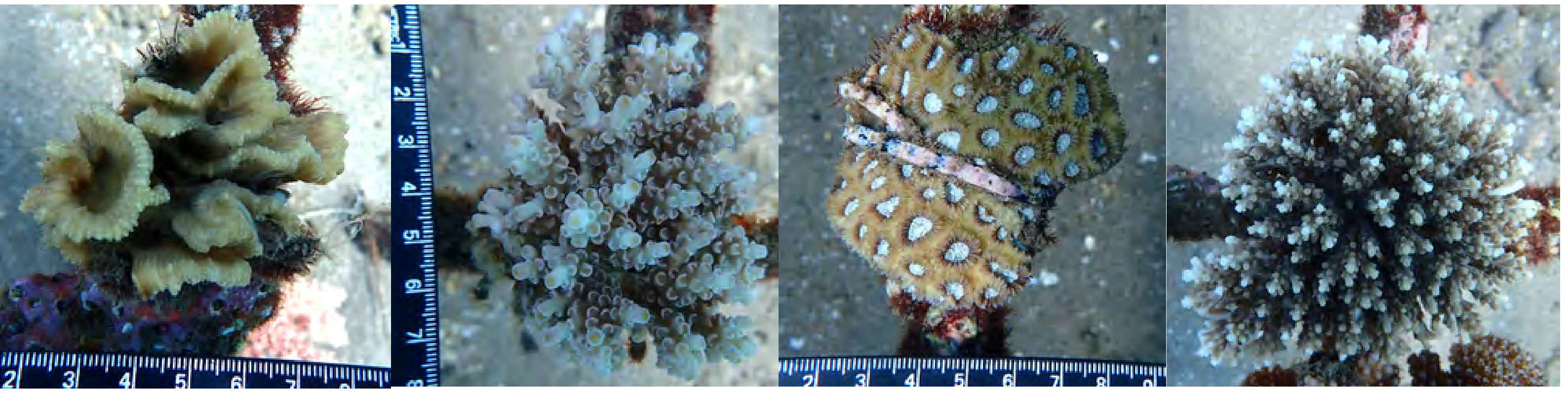
Four Weeks (4W)- Monitoring



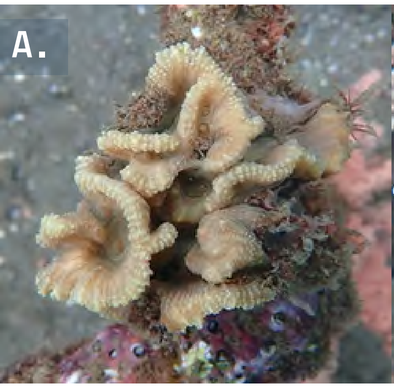
Sixteen Weeks (16W)- Monitoring

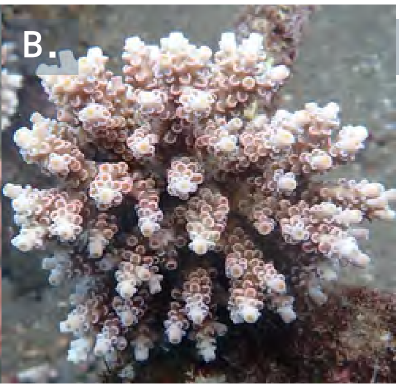


Thirty-two Weeks (32W)- Monitoring



Forty Weeks (40W)- Monitoring





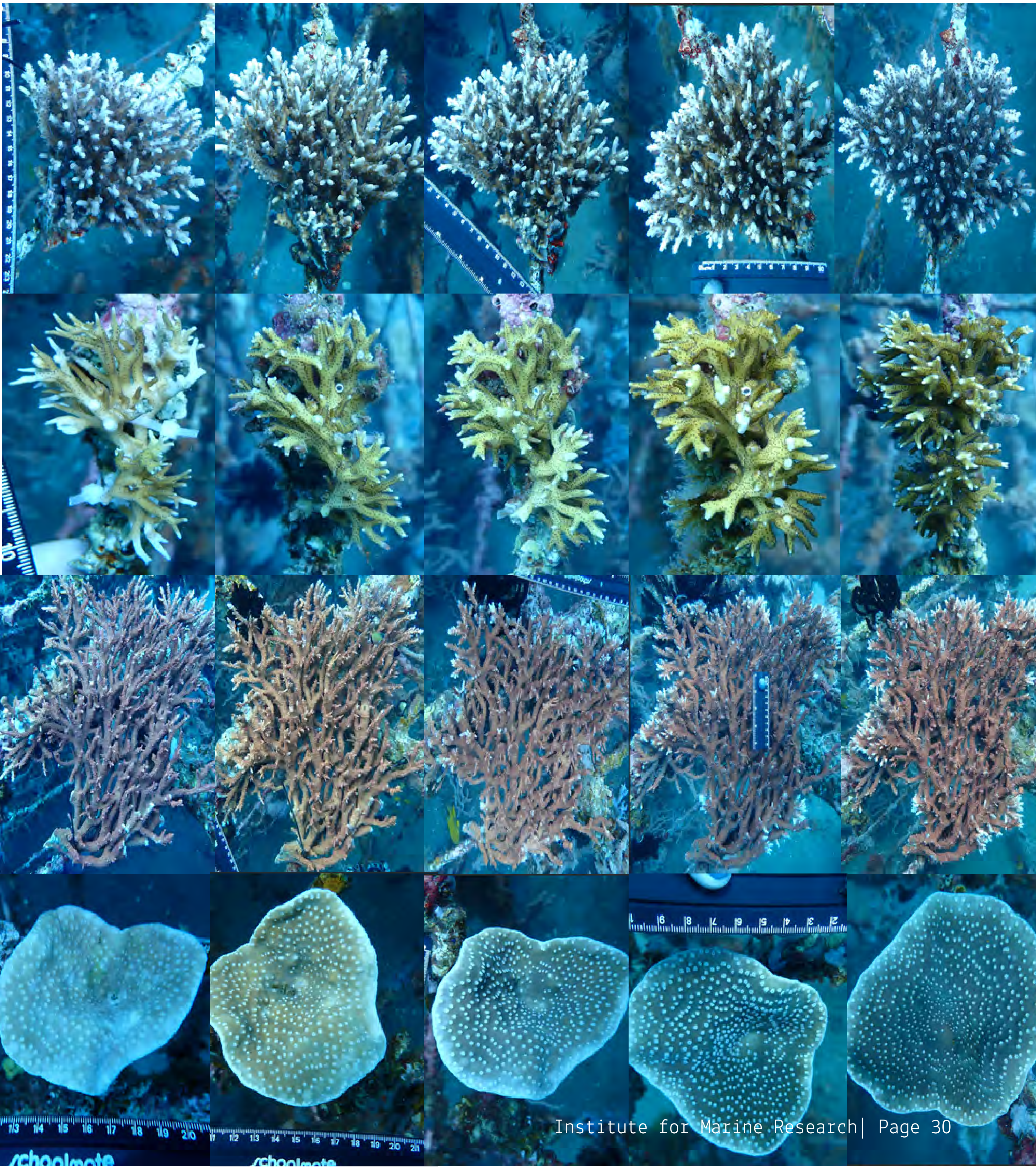
C.

Coral has detached from the structure prior to this monitoring period (Reason for detachment unknown)

‘MIDDLE CAGE’ MONITORING:

Coral A- Acropora
Coral B- Seriatopora
Coral C- Acropora
Coral D- Turbinaria

(T0)- Time Zero **(4W)- 4 weeks** **(8W)- 8 weeks** **(16W)- 16 weeks** **(24w)- 24 weeks**



‘DEEP CAGE’ MONITORING:

Coral A- Montipora
Coral B- Pectinia
Coral C- Acropora
Coral D- Pleorgyra

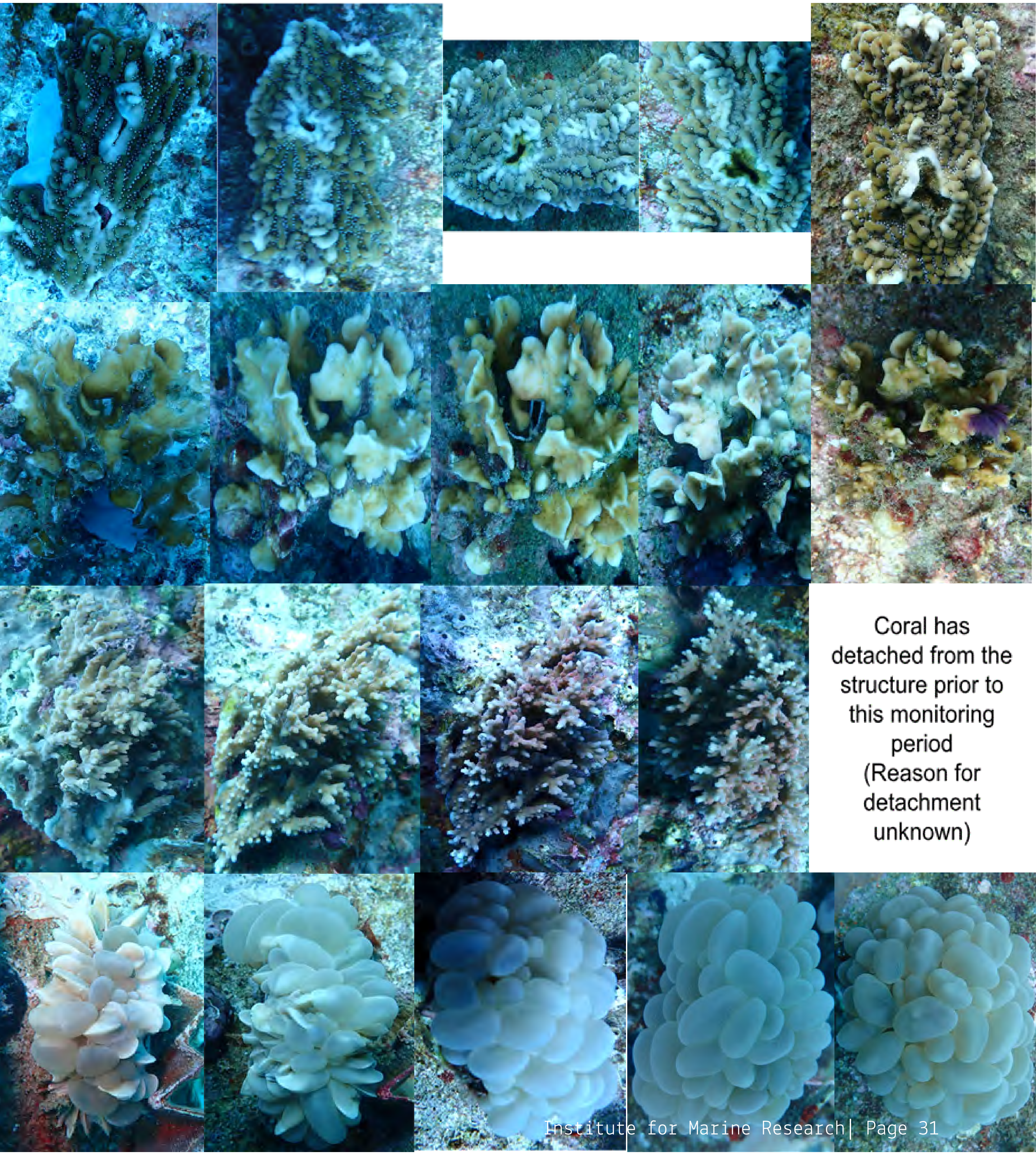
(T0)- Time Zero

(4W)- 4 weeks

(8W)- 8 weeks

(16W)- 16 weeks

(24w)- 24 weeks



Coral has detached from the structure prior to this monitoring period (Reason for detachment unknown)

PROTECT WHAT YOU LOVE

5.0 MAINTENANCE

To maintain the health of the newly outplanted COPs, the area surrounding the corals will need to be maintained and cleaned to remove biofouling. The interval at which the necessary maintenance dives will take place, will depend on how fast biofoul accumulates at your site (frequency of maintenance dives to be determined upon outplanting and subsequent algal growth rates). Since the COPs are most at risk of becoming overgrown or smothered by algae and sponge when the corals are smaller and attempting to attach to your structures, it is likely that a weekly routine maintenance (removing of hydroids, sponge, turf algae and other biofoul immediate vicinity of COP) will only be required during the early phase of this project. As the corals grow and attach, the larger fragments will be able to outcompete surrounding benthos and become more resilient to algal and sponge competition. At our local restoration site, we have noted that most of our coral mortality is due to the COPs being outcompeted by turf algae (a heterogeneous assemblage of various algaes) and a fast growing encrusting sponge. However, most of the corals have been able to outcompete the various algaes and sponges. Once the branching COPs have passed the two month mark and encrusted themselves onto the AR structures, they seem to be at a level at which they can survive with little to no human interference. Yet, the massive and encrusting COPs require more maintenance for a longer period of time, due to their slow growth rates and inability to outcompete the surrounding benthos.

Not only did the divers scrub and clean the structure surrounding the COPs, but corals that were loose or needed to be reattached were then fixed at this time. The time spent conducting the maintenance depended on how many corals needed to be reattached or fixed. The areas in which the most fixing was needed was on the metal cage structures. The COPs that had been planted via cable ties had often become loosened over time and therefore needed to have the ties tightened or be redone completely. However, even with limited time to conduct maintenance, we were able to keep the study sites fairly maintained with the brief exception of a few week period where our divers could not go out due to extenuating circumstances.

6.0 BUDGET & SPENDING

The aim of this project was to restore 600m2 of artificial reef (~1 coral/m2) within one year. This was achieved across 424 planting / monitoring / maintenance dives, ensuring the attachment, survival and growth of each restored coral of opportunity. A total pf 500,000 PhP was donated by the PADI Aware Foundation to achieve this project goal. Diving expenses (tanks, sanctuary fees, transportation etc.) comprised 74.1% of the project expenditure (**Figure 13**). The remaining 25.9% was allocated towards field equipment, with monitoring equipment (cameras, softwares etc.) taking 22.3% of allocation. This was followed by planting equipment (epoxy, cable ties etc.) at 2.6% and maintenance equipment (wire brushes) at just 1%.

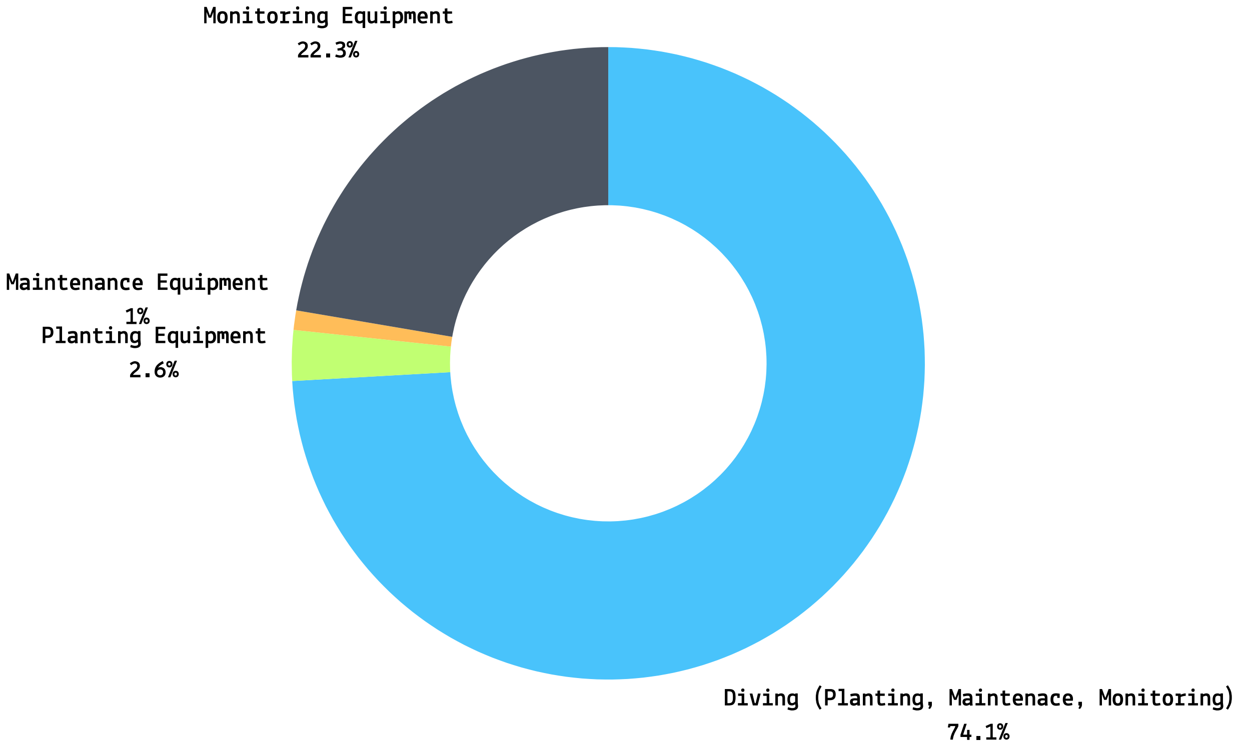


Figure 13. Distribution of grant funding betweeen March 2023 - March 2024 period required to meet the restoration goal of 600m2 of restored artificial reef at the Lipayo Artificial Reef site (Dauin, Negros Oriental, Philippines).

7.0 RECOMMENDATIONS

Overall results of the study highlight no significant difference in survival between material, or genus used. Instead, failed attachment (49%) and benthic competition (27%) remained the driving factors behind coral mortality throughout the project. The following recommedations have been created to promote coral survivorship, and reduce spending on repeat planting efforts:

1. **Prepare the site.** Always deep clean AR structures prior to attaching any COPs. This includes the coomplete removal of sponge, turf algae, and even sediment.
2. Use **high quality, high longevity materials** for COP attachment.
3. **‘Apoxie Sculpt’** is a good medium for attaching COPs to concrete AR structures.
4. **Thick cable ties** are more durable for COP attachment on cages (cheap, thin cable ties tend to break during the tightening process).
5. Invest in multiple **fragging tools** to increase productivity underwater. On FRAGS dives that included more divers, productivity was reduced when we hit a “bottleneck” situation regarding tool use.
6. When searching for a COP, **be selective** and choose larger, healthier COPs. When running short on time during a dive, some COPs pulled for attachment can be less than ideal. Factors affecting the survival of the COP on structures include size and health at initial attachment.
7. Conduct routine **maintenance dives** (ideally once per week per structure).

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