PROJECT TITLE: **"SMALL SCALE CORAL RESTORATION THROUGH MINERAL ACCRETION ON MALAPASCUA ISLAND, CEBU, PHILIPPINES"**

PROJECT PROPONENTS

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PROJECT FACILITATORS

A project of this nature requires a variety of key components in order to realise any level of eventual success. Among these are relevant expertise, long term commitment and locally based logistical support. This proposal has been assembled with exactly these requirements in mind. The three main proponents of the proposal are briefly introduced below.

CORALIVE

Coralive.org was founded on the motivation of helping the oceans and everything related to them in order to make it a healthier place. This includes restoration of coral reefs and coastal habitats, managing marine protected areas, collecting environmental data, create livelihood solutions for the local population as well as passing on knowledge and experience through environmental education programs. All of our work is done by us and in cooperation with local stakeholders from the private sector, governments and other organizations.

Coralive.org is a registered Non-for-Profit Organization in Switzerland: CHE-311.736.420 (Swiss Association Registration Number)

PEOPLE AND THE SEA

People and the Sea is a SEC-registered (CN201625259) marine conservation NGO based on the island of Malapascua, Daanbantayan, Cebu since 2015. Their objective is to support local communities, businesses and other stakeholders in identifying innovative ways to manage their marine environment and have a positive economic impact. People and the Sea believes in an integrated, collaborative approach to achieve meaningful community development and sustainable marine resource management.

People and the Sea's operation is founded on four core 'pillars': Science, Education, Alternative Entreprise, and Solid Waste Management (SEAS). The organisation is fully funded by ecotourism where foreign tourists come and join expeditions and get involved with all ongoing activities. Community engagements, coupled with regular and ongoing marine habitat assessments, have led the Barangay Council of Logon as well as the Municipal Environment and Natural Resources Office (MENRO) of Daanbantayan to identify People and the Sea as a partner in effecting environmental management activities that trigger positive change among its community members.

TEPANEE

Established in 2008, Tepanee has grown to be one of the most prominent and popular resort on the island of Malapascua.

Despite their success, their respect for the environment has never diminished. Recognising the effect that tourism can have on Malapascua's environment, Tepanee was the first resort to install a water desalination unit, a rainwater collection system, LED lighting, and a centralised solar panel system.

Aside for actions to protect the environment of Malapascua, Tepanee also takes an active role in supporting the local community, regularly giving their support to local initiatives or even leading social developmental programmes such as the Malapascua Children's Swimming Club.

PROJECT BACKGROUND

With the ongoing effects of climate change, corals are facing difficulties growing, spreading and/or recovering from severe disturbances such as bleaching, strong tropical depressions or anthropogenic factors. Furthermore, areas that have previously been damaged (for example, by blast fishing) are less likely to make timely recoveries to full health. Coral restoration efforts aim to jumpstart the regeneration process. More so, the mineral accretion technology increases survival rates of small fragments, boosts coral growth speed and aids build-up of resilience against the aforementioned severe weather events.

Stretches of coastline around Malapascua have been identified and surveyed by People and the Sea over recent years. Several areas are known for having little coral coverage, low levels of fish biomass, low coral cover and invertebrate abundancies. These areas would be well suited to initiate a pilot project of mineral accretion coral restoration in cooperation with the barangay, the local government unit and other relevant stakeholders.

SITE HISTORY

Recent study by Licuanan et al., 2017, covering 166 coral reef stations all over the Philippines concluded that the average hard coral cover for the country was 22%, which is 10% lower than reported in the 1990's (Licuanan and Gomez 2000, Licuanan et al., 2017).

The surveys conducted by People and the Sea have shown that the hard coral cover of the survey areas in Dakit Dakit, Sunken Dakit and Barrio, all located next to the target area (see 'Site Selection' section below) are 30%, 18% and 19% respectively with significant reduction in hard coral cover in these habitats due to the Yolanda typhoon and previous anthropogenic effects, including fishing pressure. Conversely, there are multiple areas around Malapascua that are in excess of 30 and 40% hard coral cover (Mermaid, Lighthouse, Coral Garden North and Coral Garden East) and are composed of similar coral genus and/or species as well as depth range and biotic parameters as the proposed site.

The rise in tourism popularity on the island has resulted in dynamite fishing and reef impacting methods of fishing moving further offshore. This pseudo-management control of tourism over destructive fishing techniques has significantly reduced anthropogenic effects on Malapascua's reef habitats in recent years. However, impacts from trash and fishing gear are still regularly observed around the island. Coral diversity and impacts assessments carried out by People and the Sea staff indicated that the selected site for the artificial reef has relatively little observable evidence anthropogenic impact. Coral damages and fragments were observed in very low quantities and there were no observations of coral predators such as COTs, *Drupella* sp or *Coralliophila violacea.*

ACTIVE RESTORATION

Passive restoration relies on the ability of corals to naturally recover and grow after an impact event. Passive restoration is usually limited to managing human activities near reefs and eliminating known anthropogenic causes of reef damage e.g., dynamite fishing (Rinkevich, 2005). Passive restoration is generally more effective where reef stressors are acute or in the case of significant one-off events in protected areas (Yap, 2003).

To date the 4 year monitoring program undertaken by People and the Sea shows little to no significant increase in hard coral cover in sites subject to passive restoration and management measures alone.

In the instances where passive management measures have failed to achieve recovery, active restoration can play a crucial role in catalysing the recovery process. Active reef restoration involves direct actions aiming to improve health of damaged reefs such as modifying the reef with natural or artificial structures (Rinkevich, 2014).

Active restoration, via this mineral accretion nursery pilot project, aims primarily to stock the coral frames with live fragments that have been previously broken off by storms or divers and are already scattered on the reef – Corals of Opportunity (COPs). If necessary, there is the potential to source some fragments of target species or genus from intact colonies following the 10% criteria as stated by Frias-Torress *et al*. (2015).

Active restoration can be a cost-effective option for small scale rehabilitation efforts that do not divert funding from other coastal management priorities; in the example of this proposal, the transplantation of corals to patches of denuded reef close to tourist establishments, that is funded by paying guests and charitable donations.

PROJECT AIMS

This restoration project seeks to improve the state of the habitat and resilience of the ecosystem in the wake of Typhoon Yolanda, coupled with years of exploitative/destructive fishing activity and poor habitat management. The proposed structures will act as a mineral accretion reef structure as well as a possible coral gardening nursery that can both increase the biodiversity and composition of the reef as well as act as an area to supply future restoration and gardening.

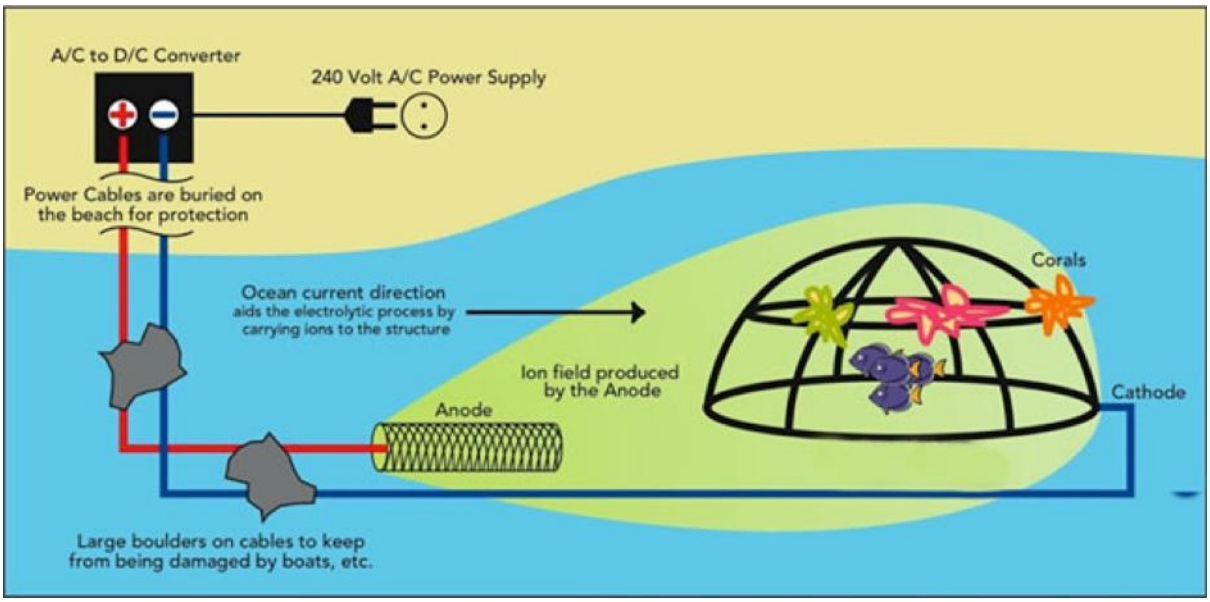
Coral transplantation and artificial reefs remains the current methods of choice in active reef restoration since they result in an immediate increase in live coral cover and substrate complexity and thus attract fish and invertebrates to the degraded area. Where significant numbers of herbivores are attracted, algal grazing increases which can further benefit corals and other sessile invertebrates of the surrounding areas by creating space for larval settlement and preventing phase shifts to a system dominated by macro-algae.

The selected COPs and potential sources of cropped corals will be chosen to reflect the species diversity of the surrounding less-impacted habitat at the location as well as being documented as successfully used in previous reef restoration projects.

The restoration project will also add socio-economic developments for the local stakeholders via additional sustainable tourism enterprises as well as training in eco-tourism practises, reef monitoring and restoration methods for aiding the project as well as boosting tourism interactions with project presentations.

MINERAL ACCRETION

The support of coral growth through electrical stimulation has existed for many decades. It has been the efforts of Coralive.org that have brought the freely available technology to a constant, stable and long lasting working level with exact calculations for efficient outcomes. Below is a diagram of the basic setup to be expected:



Mineral Accretion utilizes low voltage electricity to improve the health and growth rates of corals and other marine organisms. As electricity flows to the metal structures placed underwater, limestone will accumulate onto those structures which is the building material of most hard corals. Corals growing on these electrified artificial reefs tend to grow 3-4 times faster, and survive much better during bleaching events, disease outbreaks, and other disturbances. Although invented in the 1970's, this technology has yet to become widespread, mostly due to previous patent protections and high costs of installation and maintenance.

In the process, low voltage, direct current is applied to two pieces of metal that are submerged in the ocean. At one end of the circuit is the anode, where electrons flow from a special rare-earth metal & titanium mesh through the sea water towards the metal structure, which is called the cathode, in order to deposit calcium carbonate. The electrification of water via very low voltages results in the formation of very small amounts of gasses (chlorine on the anodic side, hydrogen of the cathode side). Around the anode the environment becomes slightly acidic, around the cathode the environment becomes slightly alkaline. Low voltage current and the gases produced have proven to be safe for the surrounding environment and organisms.

For mineral accretion, corals are planted onto the cathode structure. These are usually collected as corals of opportunity, mostly laying on the ground, broken off by wave action, fishing lines, anchors, carless divers and snorkelers, etc. These fragments can be collected while diving with baskets, carefully transported to the nursery/restoration site without taking them out of the water, and then attached with a non-galvanized metal wire, onto the structure (cathode).

PROJECT OBJECTIVES

- Creating 7 x aesthetically, dome shaped welded reef structures made from 12mm rebar steel wire and 3.5mm rebar steel matting for corals of opportunity to be planted on
- Dimension of structures are 1.5mt in diameter, and 0.75mt in height
- Rock piles underneath the domes for benthic and invertebrate life
- Placing one 10 Amp anodes in the area of the domes
- Installing a AC/DC 10V, 10 Amp solution Power supply
- Laying a 75mt robust cable and interconnect all structures
- Cover the reef structures with locally sourced “corals of opportunity” fragments
- Knowledge transfer to all stakeholders including maintenance advice

PROJECT FINANCING

It is important to recognise that this project will incur not only significant ‘start-up’ costs, but that its eventual success will also rely on a longer term financial commitment that ensures that monitoring and maintenance of the structures is regularly conducted. These costs have been carefully budgeted for, and the source of the requisite funding will be provided for by the project facilitators.

It should be made clear that NO funding, grants, loans, fee exemptions, or indeed, and financial assistance of any sort is being requested from any level of government (Baranagay, LGU, Provincial or National). While we commit to working with the local government through all stages of this proposal, we would like to make clear that all funding is being privately sourced.

MATERIALS AND METHODS

SITE SELECTION – TEPANEE RESORT

The mineral accretion method requires the use of a constant electrical supply. As one of the facilitators of this project proposal, areas adjacent to the Tepanee Resort on the south-west corner of Malapascua have been investigated. This area has been shown to contain degraded reef that could benefit from active restoration. In addition, the electrical source required for mineral accretion technologies can be supplied by Tepanee.

Minimum depth required for the structure is proposed to be 2m at low tide. A detailed survey of the benthos and depth gradients in proximity to Tepanee have been undertaken to assess potential locations for the artificial reef. The area was assessed for suitability on the following criteria:

- Depth sufficient for frame placement,
- Substrate suitable for implementation of frame placement,
- Habitat which is a suitable distance to shore for reducing costs for electrical supply,
- Habitat with a small distance to shore for monitors and visitors to observe the structures,
- Site which is easily accessible from land,
- Site sheltered to minimize risk of structures damaged by weather
- Habitat that has been affected due to Yolanda,
- Habitat that has no other observable anthropogenic affects,
- Habitat which has need for Active Rehabilitation (low hard coral cover),
- Habitat which has sufficient equivalent nearby habitat for sourcing COP and cropping.

People and the Sea marine scientists have conducted visual transects of the depth, substrate and coral categories (branching, massive etc.) in the proposed artificial reef location and have proposed alternate areas that fit the criteria 1-5 above (Appendix 1).

People and the Sea Marine Scientists have also undertaken coral diversity belts on the proposed area in order to better describe to genus level the composition of the reef habitat in the area as well as any impact assessment such as recently killed coral due to any bleaching or environmental damage, anthropogenic affects, or predation via crown of thorns (COTs), *Drupella* sp or *Coralliophila violacea* (Appendix 2).

From People and the Sea's previous coral management and monitoring surveys, we have indicated areas where equivalent COP and potential coral cropping may be viable for collecting sufficient coral fragments for the frames.

CORAL SELECTION

The corals used for the artificial reef will reflect the species composition of the surrounding reef as much as possible and sourced from COPs that are found in habitat similar to the artificial reef. A coral diversity belt was undertaken by People and the Sea (Appendix 2) in the proposed area to assess the genus diversity of hard corals. The survey revealed there were 23 genera along the first transect and 27 genera along transect 2. The predominant genus observed along both transects were*, Acropora, Pocillopora, Seriatopora, Porites, Pavona as well as Favites*.

The artificial reefs will primarily focus on the fast growing, complex habitat forming *Acropora*, *Pocillopora* and *Seriatopora* genera while adding secondary groups of genera when the first phase of corals have established, including *Pavona*, *Porites* and *Monitpora*.

The COPs for the first phase will be collected from branching, table and digitate coral forms.

People and the Sea assessed the suitability of COP donor sites on the following criteria:

- Distance from artificial reef to minimize the stress of transportation,
- Health state of the site and availability of coral,
- Identifying comparable abundance and diversity of coral species,
- Similarity of environmental conditions of site (e.g., depth, benthic composition, sedimentation, current strength).

Taking into account the above criteria, People and the Sea proposes that the COPs used for the artificial reef will be selected from the nearby locations of Ka Osting, Sunken Dakit and Dakit Dakit sites (Figure 1), all located within a short distance from the proposed artificial reef. The sites contain similar coral genus composition and depth profiles and have compatible COP's available to use on the structures.

Figure 1: Primary locations for the source of Corals of Opportunity (COPs) to be collected as fragments for the artificial reef.

Ka Osting: A shallow sea rise between the depths of 3 to 9 metres, the site contains plenty of tabulate, branching and digitate *Acropora* corals (Figure 2) that have natural breakage as well as diver damage.

Sunken Dakit: a shallow coral site (3 – 6 meters) with a mix of soft and hard corals. Observations of broken branching *Acropora, Pocillopora* and *Seriatopora* (Figure 2) and digitate and tabulate *Acropora* are frequent and are due to currents and surge.

Dakit Dakit: Shallow reef around islet (3-8 meters) with observations of broken branching *Acropora, Pocillopora* and *Seriatopora* and digitate and tabulate *Acropora (Figure 2)* from currents and diver damage.

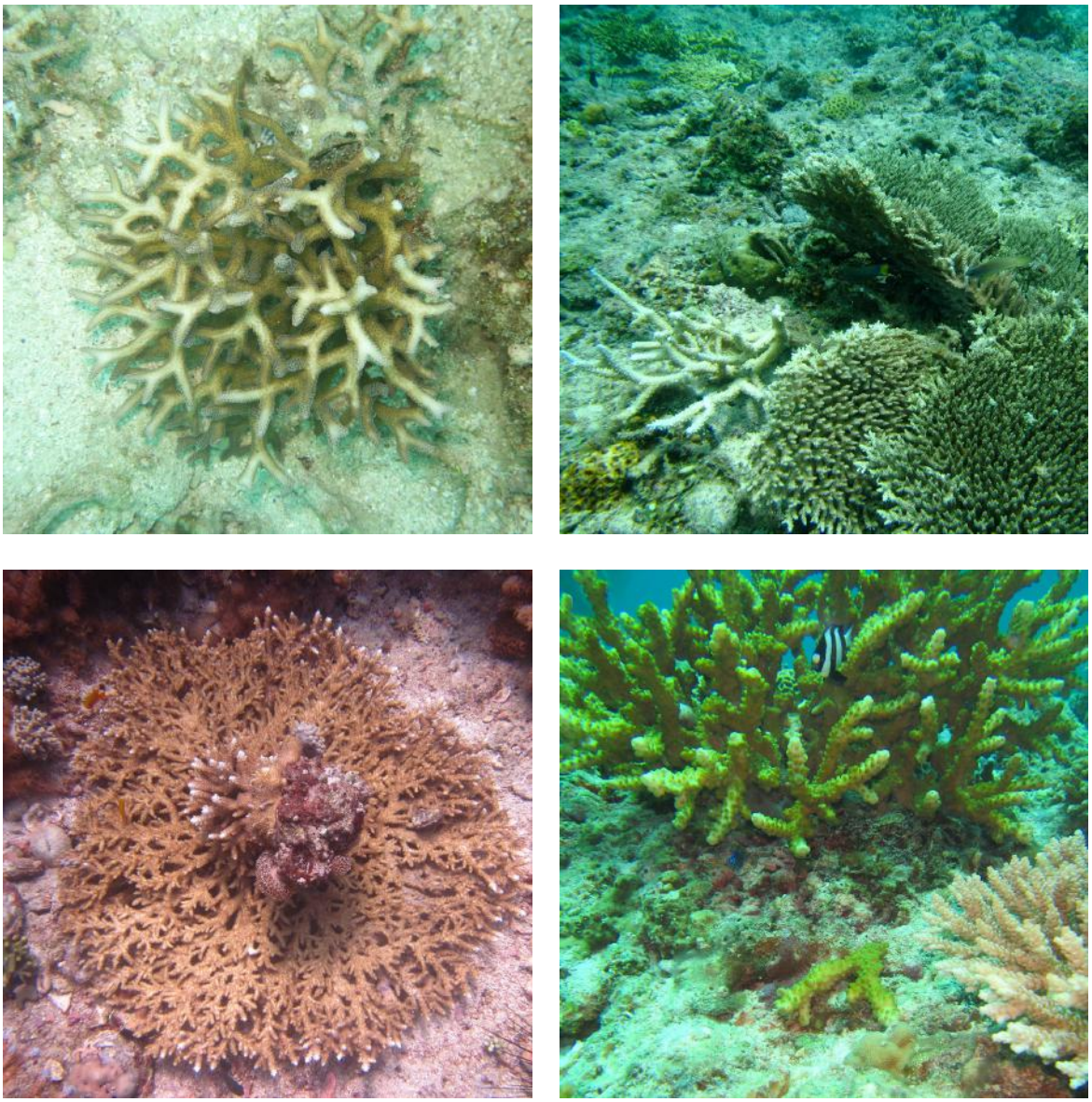


Figure 2: Examples of Corals of Opportunity (COPs) to be selected as fragments for the artificial reef. This includes branching *Pocillopora* and *Seriatopora* at Sunken Dakit (top left), tabulate, branching and digitate *Acropora* at Dakit Dakit (top right and bottom left) and digitate, branching and tabulate *Acropora* at Ka Osting. (bottom right).

COLLECTION AND HANDLING

Corals of opportunity (COPs) can be found lying on the seabed where they are in danger of being moved around by waves, further broken, abraded or smothered by sediment and eventually could die. They are easily collectable and transportable to a restoration site in baskets that are kept in the sea at all time.

COPs collected in the surrounding area are to be the primary source of corals used for the artificial reef. They will be sectioned into pieces or nubbins suitable for attachment to the artificial reef. The size range proposed for pieces is 5 – 10cm. Any dead or unhealthy coral fragments will be pruned away prior to attachment to limit the risk of spreading diseases or predators. Only well trained and thoroughly briefed staff will be involved for selection of coral genus/species and for collection and cropping.

Divers will use clean cotton or surgical gloves and will manipulate corals touching preferably the non-living part of the fragment and place them carefully inside the basket. The fragments should touch each other as little as possible. Once the baskets will be full, they will be brought to the restoration site directly by diving if feasible. If the restoration site is further away, the baskets containing sea water will be lifted onto the boat so fragments will remain fully submerged at all times.

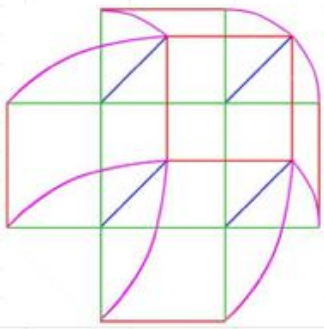
Avoiding exposure to sun is of utmost importance. A key criterion in the selection of COP collection sites is distance from the restoration site with regard to both the ease of transport as well as minimal stress for the transported corals. In the unlikely event that transit distances are increased, or unexpected delays are encountered, the water inside the baskets will be replenished with fresh sea water at least once every 30 min to avoid negative chemical reaction amongst the coral fragments.

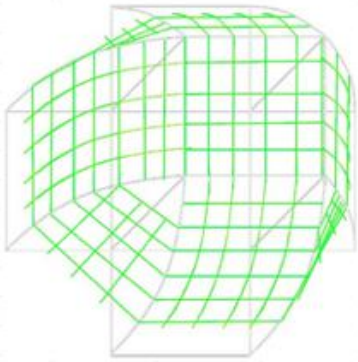
Once arrived at the restoration site, the baskets will be put back into the ocean and quickly submerged. The fragments then will be removed from the baskets and placed on a flat surface in preparation for attachment to the restoration structures.

The proposed artificial reef aims to eventually host approximately 500 fragments in total. Each one of the seven frames requires an initial 30 - 50 fragments with a 15 - 30 cm spacing between fragments, which lead to a total of 200 - 350 fragments to be collected in the initial phase.

ARTIFICIAL STRUCTURE MATERIALS AND DIMENSIONS

Structure (Rebar):						
Width:	1,50	m	Height Factor:	2	Rebar Surface:	0,81 m2
Thickness Rebar:	0,012	m	--> Height:	0,75 m		
Length of Rebar:	21,60	m				
Parts to be cut:	1,50	m	--> 4x	--> Base		
	0,6	m	--> 8x	--> Sides & Top		
	0,75	m	--> 4x	--> Vertical		
	0,98	m	--> 8x	--> Rounds		
Rebars (6m) needed:	4	pcs.	Waste/Dome:	2,40 m		
Mesh (Steel Matting):					Mesh Surface:	0,58 m2
Thickness Rebar Mesh:	0,0055	m				
Hole Size:	0,15	m	-->	6 inch		
Width:	1,22	m	-->	4 feet		
Length:	2,44	m	-->	8 feet		
Mesh Rebar surface:	33,41	m				
Mesh to be bought:	1,1					
					Total Surface:	1,39 m2
					Total Amp:	1,39 Amp
					Domes per Anode:	7,2





Materials used for building and electrifying the structure
150m of heavy duty 2 core, round $10mm^2$ wire
50m of 1mm non galvanized wire
10 Volt / 10 Amp waterproof AC/DC Power Supply Unit
1 x 10 Amp Anode
Electrical Boxes, Connectors, Tubes, Earth anchors, Shackles, Cement, etc.
5 x 2mx1m 5.5mm pre-welded metal sheet with 15cmx15cm holes
16 x 6m rebar 12mm

MAINTENANCE

The structures are intended to be largely self-sufficient once they are in place. Maintenance is only necessary if there are unusual circumstances occurring. Mineral accretion is credited as being detrimental to algae growth on and around the structure. People and the Sea staff will conduct regular checks of the following:

- Power supply – if current is flowing and if there are significant changes in voltage
- Cables – if in place and good condition (including the splitter underwater and connection between the structures)
- Structures – are bubbles forming? Is the cable still closely connected to the structure (redo every 6 months)
- Anode – are there also small amounts of bubbles forming?
- Corals – keep them debris, algae & sponge free. If there are diseases spreading maybe replace these corals, bring new corals fragments to the structures if needed/wanted
- Predators – keep the corals free from prevalent predators e.g. Drupella, Crown of Thorns starfish
- Water quality – monitor pH, temperature, and salinity

Any turf algae or sponge present on the frame will be removed via wire brushes, knives or toothbrushes. Any algae in the vicinity of coral fragments will be removed carefully as to not damage any new coral growth. Any sessile filter feeders can be scraped away with a butter knife or paint scraper. Any algae growth in competition with a coral fragment will be removed using a toothbrush.

Maintenance will be done by People and the Sea on a bi-weekly basis, depending on the phase of the project or due to circumstances at hand. After severe weather events, extra checks will also be undertaken.

MONITORING PROGRAM

The date, location, depth, temperature, number of total colonies and number of colonies per species/ genus and dive length shall be recorded for all coral collection dives.

The total number of fragments per species/genus will be monitored for each frame and each attached fragment selected for monitoring will be given a unique code and a tag placed near the fragment. Randomly selected fragments from each frame (n=15) will be used for assessment of growth rates. Growth will be assessed by recording the maximum length of each fragment at selected time intervals. A photo database will be maintained for recording growth over time.

The frames will be checked twice a month. Every fragments health will be recorded by assessing a percentage of bleaching and algae cover. Each month, pictures of each side and leg of the frame will be taken in an effort to evaluate fragment growth. Unaided recruitment of coral on the frames will also be monitored at genus/species level as well as being added to the database for growth monitoring. Survival per frame will be recorded via monitoring the mortality of the fragments in each frame.

Coral Health	Description
Healthy	100% living tissue on the fragment
<50% dead	More than 50% living tissue left on the fragment
>50% dead	Less than 50% living tissue left on the fragment
Dead	No living tissue present on the fragment
Pale	Discolouration towards pale
Bleached	Polyps present and fragment is bright white

Regular visual checks on the status of the transplants will be performed by People and the Sea to look for predation pressures (COT, *Drupella*) instances of disease, algae competition and bleaching.

The proposed coral frame location will also be assessed for water quality before and after the implementation of the structures on the following parameters:

- Temperature
- pH
- Turbidity
- Current
- Nutrient levels.
- Salinity

Three non-electrified control frames with the same size, coral fragment placement and genus diversity and habitat placement will be placed in vicinity of the mineral accretion set up, at a distance to not be affected by the electrical current. These frames will be maintained and monitored with the same methods as for the electrified frames. The growth rates and health monitoring will be collected as a control and for the purposes of comparison.

COLLABORATION AND RESEARCH POTENTIAL

The planning and implementation of this project is being conducted in close coordination with the Bureau of Fisheries and Aquatic Resources (BFAR) and Department of Environment and Natural Resources (DENR) regional office 7. This artificial reef structure can serve as monitoring or demonstration site of these government agencies with regards to AR establishment, innovative technology, sustainable marine tourism, and participatory management. Linkage and possible research potential of this project can also be worked out with the Department of Science and Technology-Philippine Council of Agriculture, Aquatic and Natural Resources Research and Development Council (DOST-PCAARRD)

This project can also offer a lot of research potential ranging from simple Senior High School Special Investigative Project to a more in-depth academic requirement such as undergraduate special problem, graduate thesis and dissertations in either the biological (specifically marine) or social sciences. This project will be open to external collaboration with interested universities, with preference given to students of state universities or colleges such as University of the Philippines, Cebu Technical University, and Siliman University.

FUTURE BIODIVERSITY MONITORING

The artificial reef site will have fish and invertebrate baseline diversity and abundances surveys implemented in accordance with People and the Sea's existing fish and invertebrate monitoring activities. These surveys will be undertaken at 6 - 12 month intervals after the coral frames have been installed and will continue to be monitored into the future to assess any change in biodiversity generated via the implementation of the structures.

REPORTING OF PROJECT PROGRESS

It is the belief of all facilitators of this project that information and findings should be regularly and freely reported on, such that other interested stakeholders may learn from and/or engage in the process now, or in the future.

Results of the data collected herein will be presented to all key stakeholder groups. Specifically this will include:

- The local community of Barangay Logon, thru the Barangay Council
- The Local Government Unit of Daanbantayan through the Office of the Municipal Mayor
- The Municipal Environment and Natural Resources Office (MENRO)
- The Bureau of Fisheries and Aquatic Resources (BFAR)
- The Department of Environment and Natural Resources (DENR)
- All other collaborating entities or organisations.

After the initial 'set-up' phase of the artificial reef, a status report will be produced and made available. Subsequent to this, People and the Sea will provide a comprehensive annual report to all stakeholder groups (as outlined above) to enable a wide range of data sharing about this innovative and compelling method of reef restoration

SOCIO-ECONOMIC OUTCOME ASSESSMENT

Working on a permanent basis on the island, People and the Sea has established strong relationship with different groups of the Malapascua community (tour guides, homestays, barangay, schools, etc.) through projects related to alternative entrepreneurship, education and solid waste management. The organisation is also about to employ a full-time Fisheries Liaison Officer, whose main objective will be to initiate and develop a long term partnership with the fisherfolk groups. These networks can be mobilised and involved in the building, monitoring and management of the structure.

Involving the community from the outset is critical to the success of the project. A range of projects can be undertaken to ensure the community is aware – and proud – of being home to a coral restoration project, while helping some of these groups achieve educational and potential economic benefits:

- Workshops with People Associations to communicate on the project, desired outcomes and identify volunteers/helpers from the community
- Identify direct benefits for the different groups, and support them in implementing necessary steps to achieve those benefits
- Involve students of the elementary and high schools
- Possible implementation of 'sister' structure managed by the community

Tepanee staff will be trained in environmentally friendly practises such as reef safe sunscreens, good snorkelling practices to avoid coral breakage as well as be given presentations on the projects aims and objectives to give to their resort guests to enhance the experience for tourists. The number of visitors that Tepanee Resort and any other stakeholder takes to the coral frames as part of a tourism experience will be recorded.

There exists the potential for additional income to be generated via this example of an environmental engagement enterprise. Should this occur, it will also be recorded in order to indicate the social and economic enhancement that the artificial reef project has generated.

The proximity of the project site to the Dakit Dakit MPA as well as the additional income and interest generated for stakeholders engaging tourists in the site should result in local engagement and ownership, resulting in protection of the study site from further anthropogenic impacts, such as fishing or diver damages.

EXPECTED OUTPUT

The establishment of this AR structure is expected to increase the live coral cover and biodiversity of the reef-associated organisms. The photos in Figure 3 shows the successful colonization of the mineral accretion project implemented by Coralive in the Maldives.

In time, the coral fragments grown on the artificial reef may be utilized for future propagation projects around the island. As the corals grow they may become too heavy and crowded for the artificial structures. Taking fragments from the artificial structure as relocating them onto equivalent habitats that are degraded is a way of utilising coral for active restoration without impacting natural donor colonies.

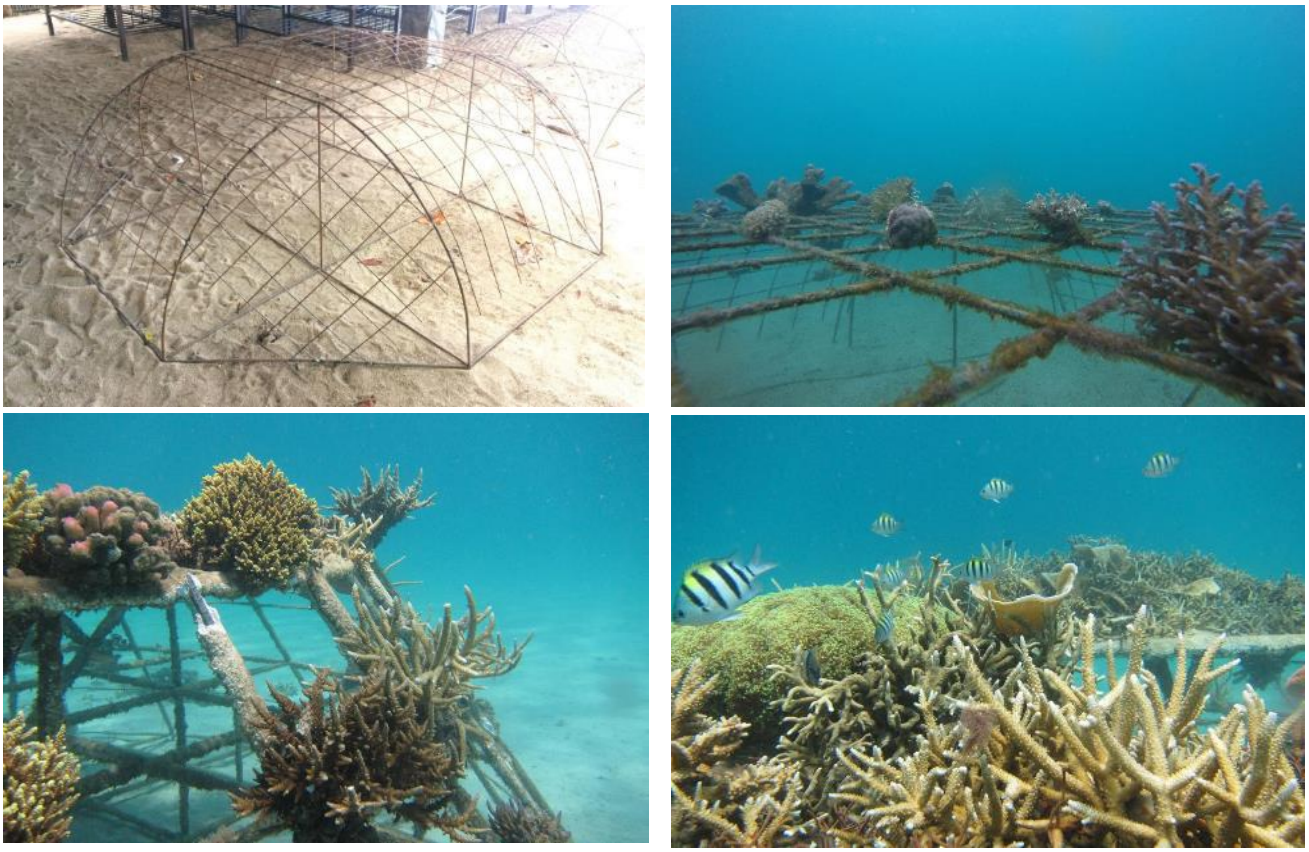


Figure 3: Mineral Accretion Artificial reef installed by Coralive team in Maldives.

IMPLEMENTATION TIMELINE

The majority of the implementation phase of the project involves exact preparation of the equipment. Afterwards a total of 2-3 weeks for the technical installation is allotted (delays not included). Further planting of coral fragments can be done in the subsequent weeks.

Deliverables	Time Estimate	Responsible Facilitator
Inspection of site, determination of exact distances, organizing logistics	**COMPLETE**	**People and the Sea**
Producing, ordering and shipping of material and equipment before project	**90 days**	**Coralive**
Setup work site with 1 technician, volunteers and other stakeholders	**1 day**	**Coralive/Tepanee/People and the Sea**
Final Hardware, Equipment and Tool acquisitions	**2 days**	**Coralive/Tepanee**
Welding Reef structures	**5 days**	**Coralive/Tepanee**
Placing Reef structures, including earth anchors	**2 days**	**People and the Sea & Coralive**
Building Base structures and installation of 1 Anodes	**2 days**	**Coralive**
Laying power line and Power Supply Units to the structures	**1 day**	**Coralive/People and the Sea**
Interconnecting all domes	**2 days**	**People and the Sea & Coralive**
Testing and finishing up work site	**2 days**	**Coralive/Tepanee**
Initial coral fragment collecting, placing and teaching methodology	**3 days**	**People and the Sea & Coralive**
Placing Coral fragments	**Ongoing**	**People and the Sea & Coralive**
Capacity-building for stakeholders	**2 days**	**People and the Sea /Tepanee**
Monitoring and preparation of Reports	**Ongoing**	**People and the Sea**

The proposed time to initiate the project is after the Habagat season, which usually ends end of October. At present, the preferred implementation date would be early 2019. This is dependent on prevailing weather conditions and the availability of stakeholders and can be adjusted accordingly.

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APPENDIX 1: ARTIFICIAL REEF SITE SURVEY

BACKGROUND

Depth gradient transects were undertaken in order to ground truth the substrate and depth profile of the proposed artificial reef structures, and to assess whether depth is sufficient to promote growth and provide adequate protection from wave damages. The transects also provide observations of the substrate along the profile to find key area for anchoring or pinning the structures in place without harming any present habitat.

People and the Sea conducted transects at the proposed site location (Figure 1). Two transects were placed across the proposed location of the structures. Two additional subsequent transects were implemented in order to find a potential alternative area.

People and the Sea first conducted a beach profile at low tide in order to have a base Chart Datum (CD) to measure depth (tide 0.1m, 8/8/18, 1600H). Subsequent to this, the transect lines were placed perpendicular to the beach (210°), starting from the low tide mark at transect points T13 and T14 (Figure 2). The transects ran for 60m (transect tape length) and depth measurements were taken every 5 meters along the transect lines.

Secondary transects were conducted with the same methodology on T6 and T9 (0.3m, 17/08/18, 0900H) to find substrate and depth profiles more suitable for the structures. The depth profiles were adjusted according to CD at the time of data collection.

Figure 1: Proposed site location for the artificial reef, in the south east corner of the beach at Tepanee Resort.

SUBSTRATE

Suitability of substrate and depth combinations for the placement for the artificial reef structures are summarized in Table 1. Existing hard coral areas are to be avoided not to impact existing reef biota. Dead coral algae substrate can consist of complex boulders of dead coral and are not optimal terrain for the structures. Rubble fields consist of unattached fragments of broken rock and dead coral, typically from previous disturbance events and may indicate areas of high wave action or other disturbances which may reduce the viability of the artificial reef. Rock will provide a hard surface for the frames to be attached to, but raises concerns regarding the unevenness of the surface. Sandy areas will provide substrate which is relatively level and can be anchored to via sand bags, rock dump or large rebar pins. Care has to be taken to make sure sedimentation and turbidity will not be an issue in high wave-action area.

	Substrate					
Depth at low tide (m)		Hard Coral	Dead Coral / Algae	Rubble	Rock	Sand
	<2.0m					
	2.0 - 2.5m					
	>2.5 – 3m					
	+3m					

Table 1: Suitability assessment for the placement for the artificial reef structures (Poor in red, moderate in orange, acceptable in light green, optimal in dark green).

RESULTS

Figure 2: Low tide demarcation on Tepanee beach at 4pm on the 8/8/18 (left) and the transect lines laid from transect points T6, T9, T13 and T14 (right).

PRIMARY TRANSECT LINES

Along the primary transect lines the maximum recorded depth at a distance of 60 meters from shore was 2.1 meters (Figure 3). The areas observed within the primary transect lines were not the most suitable substrate for the artificial reefs (Table 2). Reported turbidity and wave action in the area during the times of the survey were high, making in water photographs of the points of interest along the transect lines unusable.

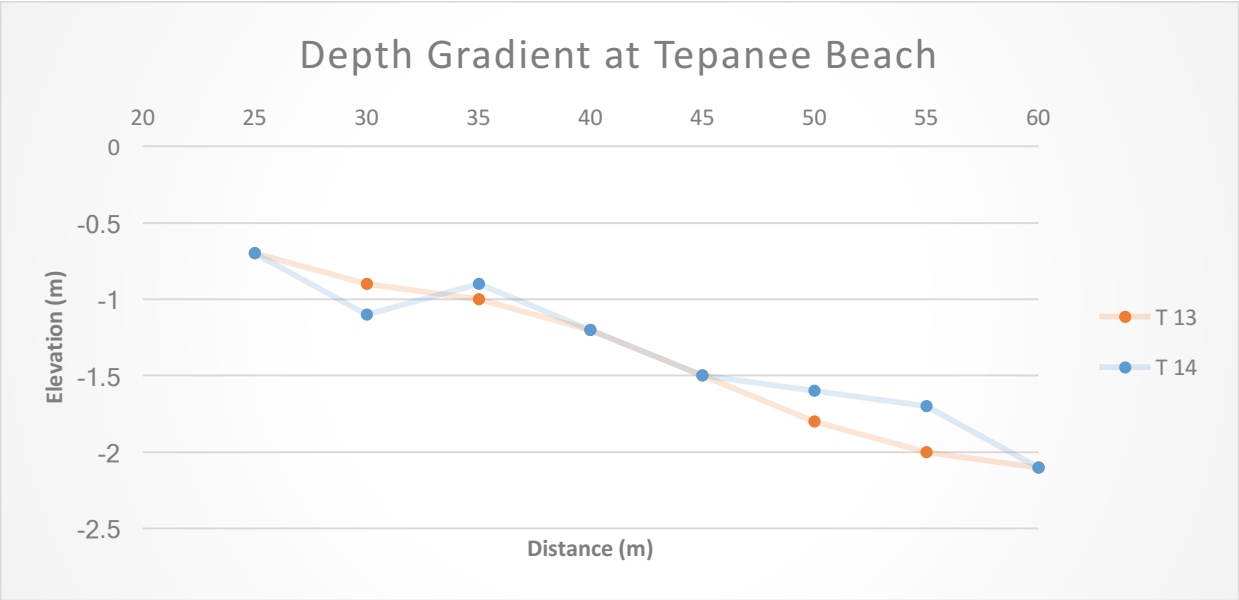

Figure 3: Depth profile for the two primary transects surveyed at Tepanee beach with an orientation of 210° and a length of 60m.

Transect 13												
Meters	5	10	15	20	25	30	35	40	45	50	55	60
Substrate	RC	HC	SD	SD	RC	RC	SD	SD	RC	RC	RC	SD
Depth	-	-	-	-	0,7	0,9	1	1,2	1,5	1,8	2	2,1
Suitability												
Transect 14												
Substrate	RC	SD	SD	SD	SD	HC	SD	SD	RC	RC	RC	SD
Depth	-	-	-	-	0,7	1,1	0,9	1,2	1,5	1,6	1,7	2,1
Suitability												

Table 2: Substrate observed along the two primary transects at Tepanee beach (depth in first 20m was negligible due to low tide and high turbidity).

SECONDARY TRANSECT LINES

People and the Sea undertook subsequent surveys consisting of 100m long transects perpendicular to shore. The transects were selected to ground truth areas that may be deeper with more suitable substrate based on aerial photographs. The secondary transects had similar substrate and depth

profiles as the original transects out to a distance of 60m from shore. Between 60m and 100m from shore, the transects identified benthic compositions and depths more suitable for artificial reefs (Figure 4 and Table 3).

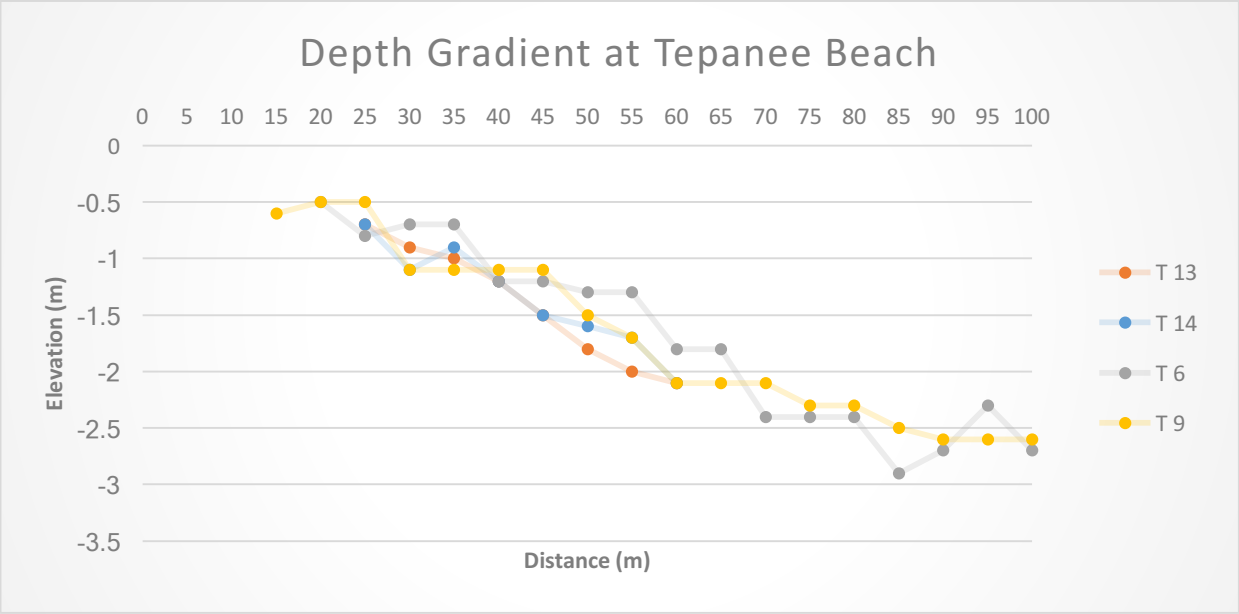

Figure 4: Depth profile of all primary and secondary transects surveyed at Tepanee beach with an orientation of 210° and lengths of 60m (T13 and T14) and 100m (T6 and T9).

Transect 6																				
Meters	05	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Substrate	SG	SG	SG	SG	RC	SG	RC	SG	SG	SD	RC	SC	SD	SD	RC	SD	RK	SC	HC	RC
Depth	-	-	-	0,5	0,8	0,7	0,7	1,2	1,2	1,3	1,3	1,8	1,8	2,4	2,4	2,4	2,9	2,7	2,3	2,7
Suitability																				
Transect 9																				
Substrate	RC	RC	RC	SD	SD	SD	SD	SD	SD	SD	RC	SD	SD	RC	SD	SD	SD	RC	RC	RC
Depth			0,6	0,5	0,5	1,1	1,1	1,1	1,1	1,5	1,7	2,1	2,1	2,1	2,3	2,3	2,5	2,6	2,6	2,6
Suitability																				

Table 3: Substrate observed along the two secondary transects at Tepanee beach (depth in first 20m was negligible due to low tide and high turbidity).

CONCLUSIONS

The site surveys identified low suitability for the artificial reef within the area located less than 60m away from shore at low tide (80m from electrical supply). The secondary transects identified potential positions for the artificial reef to be placed between 60m and 100m away from shore according to depth and substrate suitability. However, additional factors have to be considered for site positioning including the following practical difficulties:

- Additional cost for installation.

A location which is further than 60m away from shore at low tide (>80 m from the electricity supply point) would require more wire to link the frames.

- Distance for guests to swim

With the structures place further away from the house beach, the likelihood of the guests wanting to partake in visiting the reef structure could be reduced.

- Proximity to boat channel.

A concern with the structures being set up further from the beach is that it may overlap a busy boat channel used extensively on the island, which may arise safety concerns.

APPENDIX 2: CORAL DIVERSITY ASSESSMENT

BACKGROUND

People and the Sea conducted two coral diversity and impact assessment belts in the area which has been proposed for the artificial reef. The transects consisted of two 20m x 5m transects, placed 100m and 90m from the beach at an angle of 120° (Figure 1). The surveys were undertaken on 24/09/2018 with a tide of 0.1m.

The Coral Diversity Belts record the number of different Genera of hard corals found inside the transect to reflect the habitat diversity where the frames will be placed. The Coral Diversity Belts provide information on site diversity compared to other sites around the island and allow researchers to estimate health and potential resilience of the habitat. The Impact Assessment survey records the number of impacts observed, including anthropogenic (trash, fishing gear) and coral predation (Drupella sp., Crown-of-thorns and Coralliophila violacea).

Figure 1: Location of the two Coral Diversity and Impact Assessment Belts transects.

SITE DESCRIPTION

The two transects (Figure 2) were placed in a low gully (3.2m) comprised of hard and sandy substrate. The area contained little to no impacts in regards to anthropogenic effects and coral predation. The

sites contained multiple long-spined urchins (Diadema sp) and collector urchins (Tripneustes gratilla). Coral recruits were present for Favidae, Acroporidae and Pocilloporidae genera, but in low abundances.

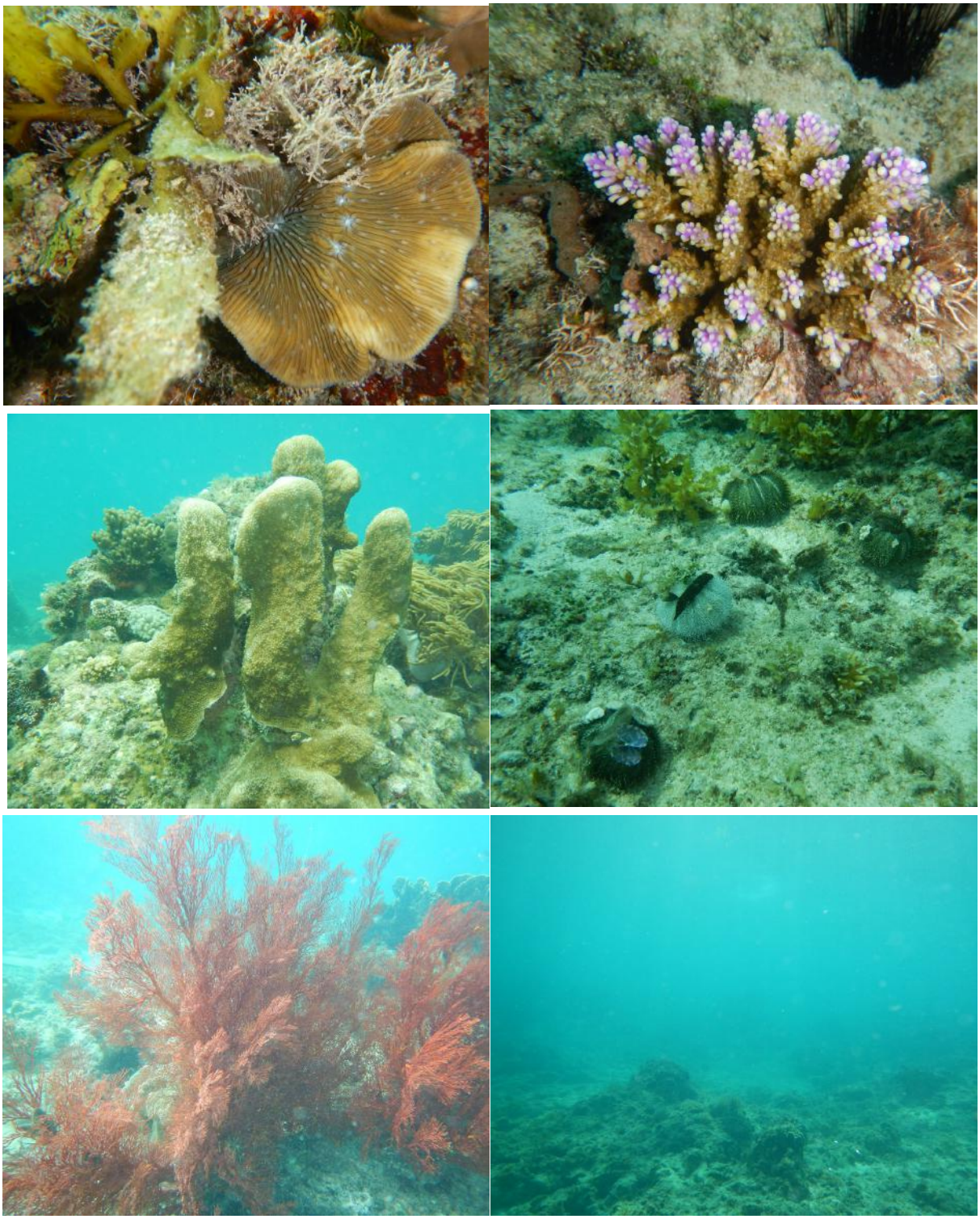

Figure 2: *Lithophyllon* sp., *Acropora* sp., *Isopora* sp., *Tripneustes gratilla*, *Gorgonian* sp., and survey site substrate overview.

GENERA PRESENT

The predominant genera observed along both transects were *Acropora, Pocillopora, Seriatopora, Pavona, Porites* and *Favia* (Table 1). Most of the area was predominately constituted of rock or sandy

substrate with patches of macroalgae and sparsely comprising hard corals. In the vicinity of the transects was a large 2m x 1m gorgonian coral.

Coral Genus **Total**	**Coral Diversity Belt 1** **23**	**Coral Diversity Belt 2** **27**
Acropora	X	X
Astreopora		X
Monitpora		X
Pocillopora	X	X
Stylophora	X	X
Seratiopora	X	X
Porites	X	X
Gonipopora	X	X
Galaxia	X	X
Turbinaria	X	X
Psammocora	X	X
Lobophyllia	X	X
Fungia	X	X
Stylocoecenelia		X
Pavona	X	X
Leptoseris	X	
Hydnophora		X
Montastrea	X	X
Favia	X	X
Favites	X	X
Leptastrea	X	
Cyphastrea		X
Platygyra	X	X
Goniastrea	X	X
Echinophyllia		X
Lithophyllon		X
Euphyllia	X	
Heliofungia		X
Millepora	X	X
Isopora	X	X
Heliopora	X	

Table 1: total diversity and coral genus present in each transect.

CONCLUSIONS

The two transect sites comprised habitats that were moderate in hard coral diversity, but low in hard coral coverage and abundances. Recruit levels were relatively low compared to other surveyed sites around Malapascua indicating a low rate of natural recovery. There were little to no coral impacts present on the site. No trash was recorded and no fishing gear was observed. No occurrence of coral predation was recorded in either belt.