INSTITUTE FOR MARINE RESEARCH
DAUIN · PHILIPPINES

LIPAYO II

(Artificial Reef)

ANNUAL REPORT

February 2019 – January 2020

DISCLAIMER

The research reported herein is based on initial analyses of complex datasets as part of the Dauin Reef Long Term Monitoring Project, and should not be considered definitive in all cases. Institutions or individuals interested in the results or applications of the Institute for Marine Research are invited to contact the Director at the Dauin address below.

For additional copies of this report, please phone IMR on (+63) 917 110 0421 or write to us at info@institutemarinereserch.org

This report, along with a range of information about IMR, is available online at www.institutemarineresearch.org

Institute for Marine Research
Lipayo-Magsaysay Road, Tugawe
Municipality of Dauin
6217, Philippines

Front Cover: Maayong Tubig Marine Reserve
Image: Becky Tooby

Full report written by:

Chelsea Waters
Director, Institute for Marine Research
chelsea@institutemarineresearch.org

Jennifer Brand
Head of Science, Institute for Marine Research
science@institutemarineresearch.org

Ella Sibbering
Research Fellow, Institute for Marine Research

OUR MISSION

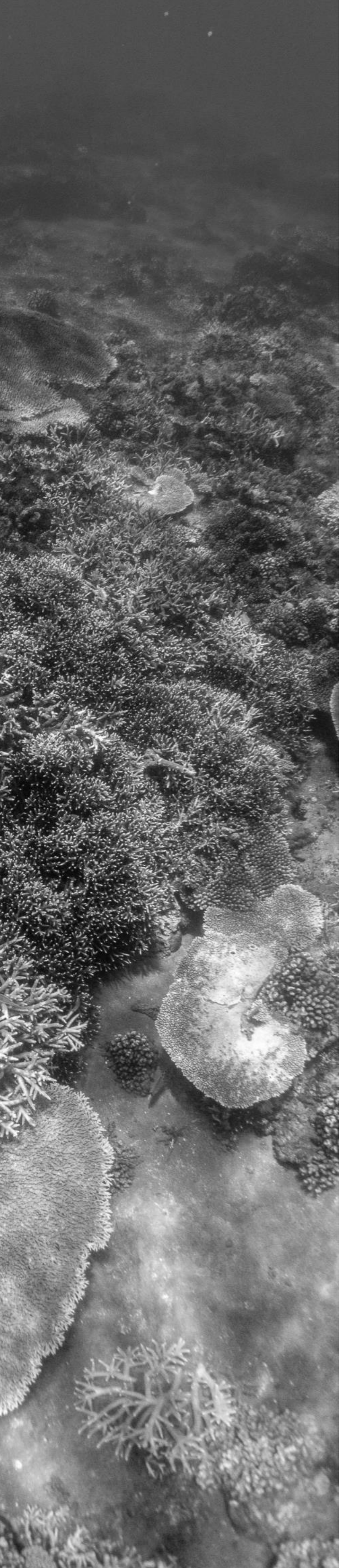
The Institute for Marine Research is a grassroots non-profit organisation that conducts long-term and fine-scale research on coastal marine ecosystems, using this scientific evidence to educate, transform and encourage locally led marine conservation strategies within the Philippines.

OUR VISION

“We at the Institute for Marine Research strive to be instrumental in the making of an environmentally literate and sustainable community through and evidence-based conservation approach, creating a world that is better and wiser than the one we have now.”

- A message from the Founders

In partnership with



Dauin Long-Term Reef Monitoring Project Aims

1. To understand how benthic composition influences fish community structure and invertebrate community composition.

    a. Will reef fish community structure be influenced by changes to percentage coral cover, habitat structural complexity and rugosity?
    b. What habitat does the benthic cover of the Dauin Municipal reef employ?
    c. What is the relative importance of coral cover, structural complexity, and diversity in determining the structure of reef fish communities in Dauin?
    d. Do structurally complex benthic communities support a greater diversity of fish species, regardless of a low percentage coral cover?
    e. How do rugose benthic communities support fish and invertebrate communities?

2. To document the effect of disturbances such as crown of thorns outbreaks, typhoons and bleaching events, and to provide awareness of other threats to the reef and other issues of concern to reef managers.

    a. What is the resiliency factor of ecosystems composed of high structural complexity, rugosity, percentage coral cover and coral diversity in response to storms and bleaching events?
    b. Is there a relationship between benthic measurement (structural complexity, percentage cover, rugosity, diversity) and the abundance of trash, crown of thorns and disease?
    c. What are the major localised impacts that affect the Dauin reef system, and where do the major localised impacts originate from?

3. To document the effects of temperature, light and current on the annual and seasonal variability of coral and fish populations.

    a. How is coral calcification affected between seasons?
    b. Will coral calcification be higher under high temperature and light regimes, with results dependent on bleaching status and storm intensity?
    c. Are threats to the Dauin reef system directly influenced by humans, and how will these threats be manipulated by current shifts and storm intensity?
    d. How do seasonal variations affect benthic cover and fish assemblage?

ABBREVIATIONS

Abbreviation	Term in full
1-D	Simpsons Index of Diversity
2D	2-Dimensional
3D	3-Dimensional
AIMS	Australian Institute of Marine Science
ANOSIM	Analysis of Similarities
BBD	Black Band Disease
BrBD	Brown Band Disease
CPCe	Coral Point Count with Excel Extension
COTS	Crown of Thorns Starfish
DEM	Digital Elevation Model
DO-SVS	Diver-Operated Stereo Video System
HYP	Hyperplasia
IMR	Institute for Marine Research
LTRMP	Long Term Reef Monitoring Project
MIF	Mobile Invertebrate Feeder
MPA	Marine Protected Area
NEO	Neoplasia
NMDS	Non-metric Multidimensional Scaling
PP	Porites Pinking
SR	Species Richness
SCUBA	Self-Contained Underwater Breathing Apparatus
SE	Standard Error
SEB	Skeletal Eroding Band
SfM	Structure from Motion
SRH	Scheirer–Ray–Hare

TABLE OF CONTENTS

1. METHODOLOGY

1.1 SURVEY SITES

Dauin is a fourth class Municipality in the province of Negros Oriental, Philippines. Nineteen core sites at eleven locations were selected for seasonal and annual monitoring. These sites span the variation in the coral reef composition of benthic and fish communities across the Municipality, and account for the zoning history of its associated no-take marine protected areas. The nineteen core sites consist of one to two 50m transects, between depth ranges of 1 – 6 metres and 7 – 12 metres. Surveys are conducted bi-annually to account for seasonal variability, with dry season surveys from February to July, and wet season from August to January. The Lipayo artificial reef is located in southern end of the Lipayo barangay, in the northern region of the Dauin LTRMP. Three 50m transects were conducted between the months of February 2019 and January 2020.

1.2 RESEARCH TECHNIQUES

Benthic Assays

Images taken along the 50m transect line were analysed using Coral Point Count with excel extensions (CPCe) software[1]; a visual software designed to quickly and efficiently calculate statistical coral coverage over a specified area through the aid of photo-transects[1]. Point overlay was used to characterise the benthos and determine the percentage cover of each type of organism and substrate in the image[2]. Categories recorded are: Scleractinian coral genera, octocorals, hydroids, bivalves, other hexacorals, sponge growth forms, "other live", algae, seagrass, dead coral and abiotic (e.g. sand, rock). For each category of benthic organism, the mean values for percent cover at each site are used to analyse seasonal and temporal trends in cover of benthic organisms at each site, zone, and throughout the municipality as a whole.

SCUBA Search: Reef Impacts & Coral Mortality

The SCUBA search provides a more detailed picture of the causes and relative scale of coral mortality, which assist in examining the reef in greater detail and interpreting trends in benthic cover at permanent sites. SCUBA searches were conducted along the 50m transect, with a 2m belt. The following impacts were recorded: *Acanthaster plancii* (crown-of-thorns starfish; COTS), COTS feeding scars, *Drupella spp.*, *Drupella spp.* feeding scars, unknown scars, coral bleaching and coral disease (black band disease, white syndrome, brown band disease, Porites pinking, skeletal eroding band disease, hyperplasia and neoplasia). Images were captured to record the impact found, the affected coral genera, and the size of the affected area relative to the entire colony.

Diver-Operated Stereo Video System (D-O SVS)

Understanding of fish ecology and our ability to effectively manage fish populations requires accurate data on diversity, abundance and size. IMR utilises a Diver-Operated Stereo Video System, an innovative technology which allows our researchers to record fish species with more precision and accuracy than the traditional techniques, and efficiently quantify the abundance and size of reef fish[3,4]. Rather than relying on *in situ* identification and length estimates, collected video data can be annotated in the lab, reducing time in the field and/or enabling greater coverage.

Transects were conducted using a DO-SVS comprised of two *GoPro Hero 5 Black* cameras. The SVS operator moved at a steady pace (adjusting for currents), filming the reef scape along the 50m transect, taking 5 - 6 minutes. EventMeasure V5.25 was used to measure fish encountered along the transect. It excludes fish outside 2.5m either side of and 5m in front of the camera system, maintaining a consistent survey belt. Each fish encountered within the transect belt was identified to species level, and measured when possible. Fish biomass was estimated using the equation $W=aL^b$, where W is weight (g), L is fish length (cm), and a and b are species-specific allometric constants obtained from FishBase[5]. Fish species were classified into functional groups; grazers / detritivores, scrapers / small excavators, browsers, detritivores, obligate corallivores, planktivores, invertivores and piscivores/scavengers[6]. The invertivores / sessile group was included with the invertivores. Fish species were also categorised into IUCN Red List Categories[7] (Not Evaluated, Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild and Extinct), as well as their commercial value (Commercial, Minor, Subsistence fisheries, None) according to FishBase[5].

3-Dimensional Reef Modelling

Structural complexity is a key habitat feature that influences ecological processes by providing primary and secondary resources to organisms, such as shelter from predators and food availability. As such, structural complexity of coral reefs drives numerous functions directly linked to the resilience of these ecosystems[8,9].

IMR researchers are making use of rapid advances in technology to monitor reef structural complexity by recreating and measuring reefs in 3D. The 3D structure of the reef is accurately reconstructed by using underwater images taken at pace across a reef transect, using a technique called photogrammetry[10,11]. These 3D models allow IMR scientists to measure different attributes associated with the structural complexity of coral reefs, such as surface complexity (3D/2D surface area), curvature, volume and slope, across large extents in a fraction of the time that takes to achieve the same results underwater.

A 3D camera rig was used to obtain video footage of the survey transect. The cameras were faced directly down at the substratum[12] at the beginning of the 50m transect, with the rig approximately 2m above the substrate. A lawnmower pattern was followed at a steady pace, covering 1m either side of the transect line, along the 50m transect. Stills were extracted from videos, which were used to generate a 3D model, using Structure from Motion software and photogrammetry principles. Images were aligned and alignment was optimised to fit k4 and a dense cloud was created. Surface line length (length), range, Rq (RMS), slope and variation were analysed.

Metadata

Before every survey, air temperature, wind speed, tidal state, sea state and boat activity (fishing and diving boats present) were recorded. This can be used in conjunction with any other data collected as required.

.

2. RESULTS

2.1 *Benthic Cover*

Results of overall benthic cover at the Lipayo artificial reef show abiotic categories (rock, rubble and sand) to be the dominant substrate type (wet: 81.5% ± 4.13%), a 2.87% increase since dry season 2019 (dry: 78.7% ± 4.89%). Abiotic substrate is followed by coral, which increased 1.60% (dry: 9.13% ± 3.30%; wet: 10.7% ± 3.05%) and sponges, which decreased 0.93% (dry: 4.27% ± 1.38%; wet: 3.33% ± 0.89%) from dry to wet season (Fig 2.1.1). A 2.87% reduction in turf algae was observed (dry season: 3.4% ± 1.20%; wet season: 0.53% ± 0.22%) accounting for the 2.93% reduction in overall algae cover (dry season: 5.8% ± 1.92%; wet season: 2.87% ± 0.89%) (Fig 2.1.2).

A total of 7 Scleractinian coral genera were recorded during the 2019 survey year at this site. *Acropora* spp. and *Porites* spp., consisting of 35.3% and 25.9% of total coral cover in the wet season respectively, remained the most abundant coral genera. *Acropora* spp. showed a 1.33% decrease (dry: 4.60% ± 2.05%; wet: 3.27% ± 1.09%) in transect cover from the dry season 2019 whereas *Porites* showed a 0.27% increase (dry: 2.13% ± 0.25%; wet: 2.40% ± 1.68%) (Fig 2.1.3). This accounts for an increase in coral diversity (Simpson's Index 1-D) of 0.13 (dry season: 0.67; wet season: 0.80) and an increase in species evenness (Pielou's Evenness) of 0.27 (dry season: 0.63; wet season: 0.90).

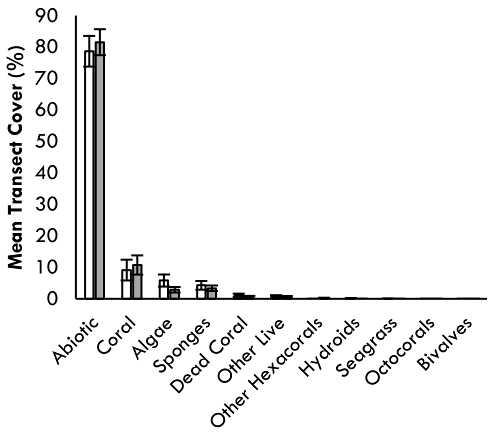


Fig 2.1.1: Mean cover (% ± SE) of all major benthic categories recorded at the Lipayo artificial reef, with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

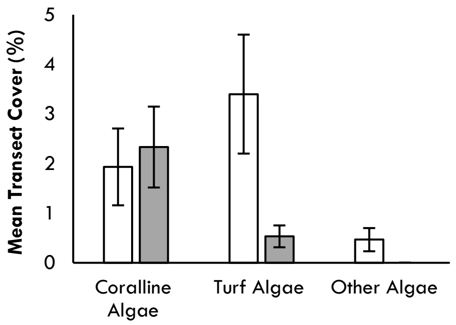


Fig 2.1.2: Mean cover (% ± SE) of algal types recorded at the Lipayo artificial reef, with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

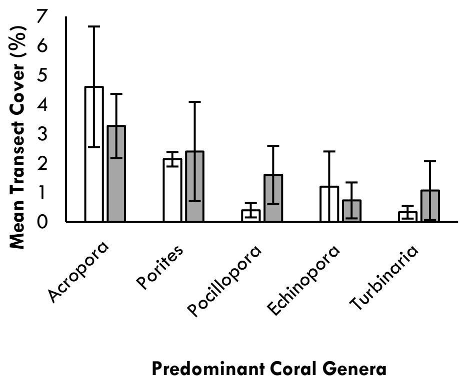


Fig 2.1.3: Mean cover (% ± SE) of predominant coral genera recorded at the Lipayo artificial reef, with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

2.2 *Reef Impacts & Coral Mortality*

Across the year, 9 occurrences of impacts were recorded at the Lipayo artificial reef (dry: 7; wet: 2). There was a 100% decrease in counts of bleaching recorded in the wet season from a total of 4 counts recorded in the dry season. Each bleaching occurrence affected different coral genera (Favia, Goniastrea, Montastrea and Porites), and affected an average of 67% of the coral tissue. Seasonal variation also saw a reduction in unknown scars recorded from dry to wet season (dry: 2; wet: 1). All unknown scars were recorded on the coral genus Pocillopora, affecting on average 68% of the colony. A single count of trash was recorded during the wet season and none recorded during the dry season. One count of fishing gear was recorded during the dry season with no fishing gear present during the wet season. There were no counts of Crown of Thorns starfish (COTs), disease, direct destruction, Drupella spp. or stone fishing recorded across the whole year (Table 1).

Table 1: Reef impacts recorded at the Lipayo artificial reef during dry and wet seasons of 2019 with trends.

Impact (count/100m^2)	Last Season (Dry 2019)	Current Season (Wet 2019)	Trend
Coral Bleaching	4.0	0	↘
Fishing Gear	1.0	0	↘
General Trash	0	1.0	↗
Direct Destruction	0	0	⇔
Disease	0	0	⇔

2.3 Fish

The Lipayo artificial reef recorded a total fish abundance of n = 523 for the wet season and n = 559 for the dry season. A decrease in total species richness (S) of S = 11 (dry: S = 60; wet: S = 49) was observed from dry to wet season. *Pomacentridae* was the most species rich family recorded in both seasons and the most abundant family recorded in the dry season (Fig 2.3.1), *Labridae* and *Serranidae* followed as most species rich in both seasons. During wet season *Plotosidae* was the most abundant family recorded, although all fish recorded were from one species (S = 1), followed by *Pomacentridae* and *Serranidae*.

A decrease in total biomass of 5.8 kg/250m^2 (dry: 24.4 kg/250m2; wet: 18.6 kg/250m^2) from dry to wet season was observed. Biomass recorded in the wet season does not include any of the 17 individuals recorded from the family *Congridae* as biometrics were unobtainable, no individuals of *Congridae* were recorded in the dry season. In the dry season *Caesionidae* (7.13kg/250m^2) had the highest recorded biomass followed by *Serranidae* (4.65kg/250m^2) and *Pomacentridae* (3.92kg/250m^2). However, in the wet season *Siganidae* (4.50kg/250m^2) recorded the highest biomass followed by *Pomacentridae* (3.12kg/250m^2) and *Plotosidae* respectively (2.22kg/250m^2) (Fig 2.3.2).

Grouping fish into trophic groups shows that planktivores accounted for the largest biomass recorded at the Lipayo artificial reef in the dry season however, a 7.44kg/250m^2 reduction was seen in the wet season (dry: 8.28kg/250m^2; wet: 0.84kg/250m^2) which is accredited to a 6.73kg/250m^2 reduction in the family *Caesionidae*. During wet season, fish classified as herbivores and planktivores accounted for the highest biomass recorded, showing a 4.16kg/250m^2 increase from dry to wet season (dry: 2.33kg/250m^2; wet: 6.49kg/250m^2), 4.49kg/250m^2 of this biomass was from the family *Siganidae* which were not observed during the dry season at the Lipayo artificial reef. Those within three or more groups were classified as omnivores (Fig 2.3.3).

There was a reduction of 4.04kg/250m^2 in fish biomass recorded for species categorised as commercially important from dry to wet season (dry: 15.18kg/250m^2; wet: 11.14kg/250m^2) at the Lipayo artificial reef. Families *Caesionidae* and *Serranidae* show the largest reduction in biomass from dry to wet season with a 6.66kg/250m^2 and 3.26kg/250m^2 reduction recorded respectively (Fig 2.3.4). *Siganidae* accounted for the highest biomass recorded in the wet season (4.49kg/250m^2), compared with the dry season where no *Siganidae* were recorded (Fig 2.3.4).

2.4 Reef Complexity

Results of the 3-Dimensional reef reconstructions reveal a decrease in the average rugosity index of 0.71 (dry: 3.34 ± 1.63; wet: 2.63 ± 1.28), and an increase in slope value of 0.25 (dry: -0.37 ± 0.17; wet: -0.12 ± 0.19) from dry to wet season (Table 2).

Table 2. Summary of findings at the Lipayo artificial reef during dry season of Feb - Jul 19 and wet season of Aug 19 - Jan 20 with trends.

Measurement	*Last Season (Dry 2019)*	*Current Season (Wet 2019)*	*Trend*
Coral Cover (%)	9.13	10.7	↗
Algal Cover (%)	5.2	2.87	↘
Coral 1-D	0.67	0.80	↗
Fish abundance (count/250kg^2)	559	523	↘
Fish biomass (kg/250m^2)	24.4	18.6	↘
Fish 1-D	0.06	0.25	↗
Rugosity (Rq)	3.34	2.63	↘

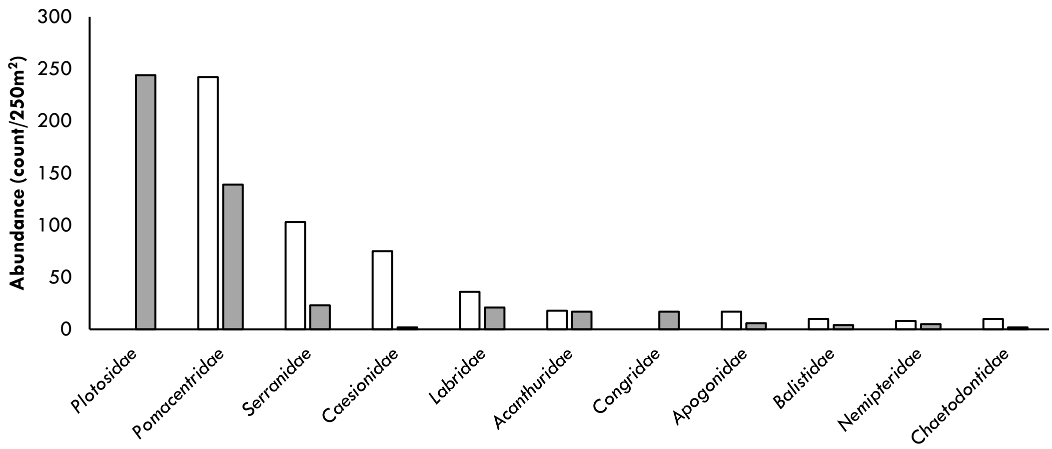


Fig 2.3.1: Abundance (count/250m^2) of fish families recorded at the Lipayo artificial reef, with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

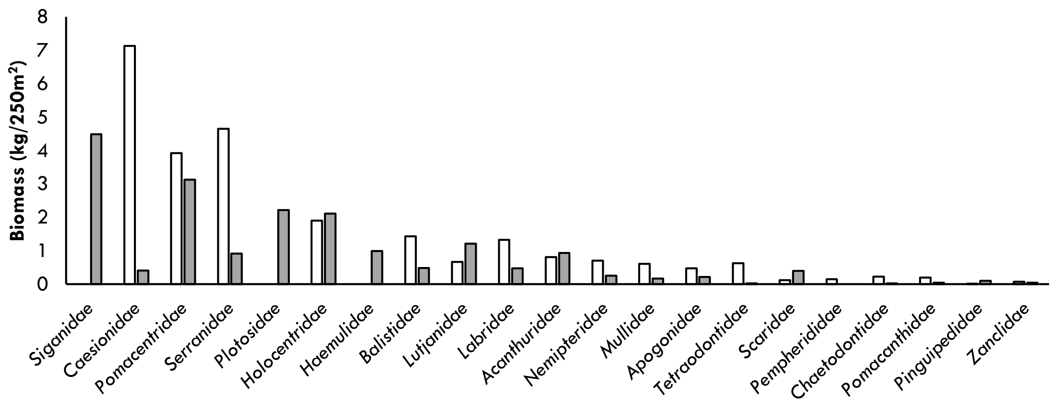


Fig 2.3.2: Biomass (kg/250m^2) of fish families recorded at the Lipayo artificial reef, with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

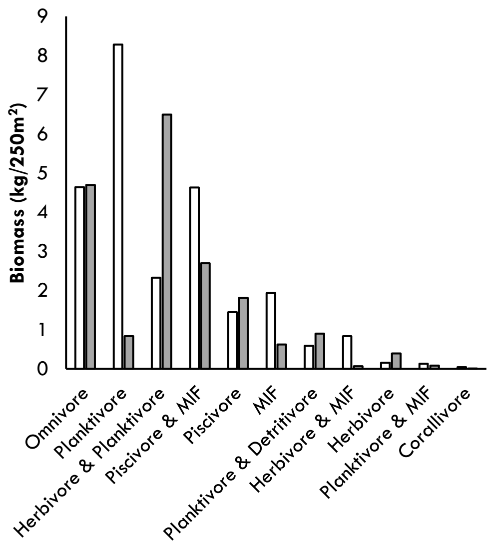


Fig 2.3.3: Biomass (kg/250m^2) of fish trophic groups recorded at the Lipayo artificial reef, with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan). MIF = mobile invertebrate feeder

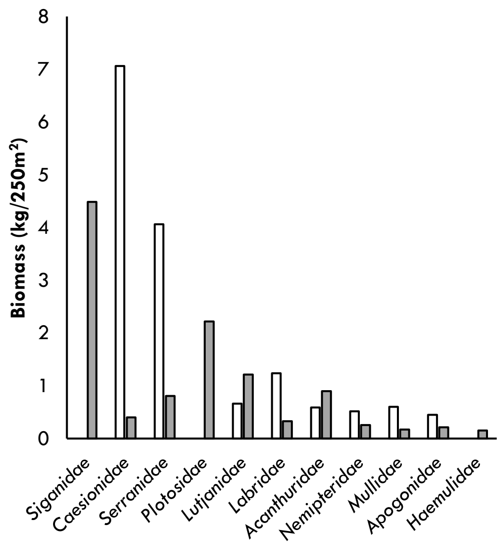


Fig 2.3.4: Biomass (kg/250m^2) of commercially important species (CIS) of each fish family recorded at the Lipayo artificial reef, with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

3.DISCUSSION

This report documents the annual development of the reef assemblage and community make-up of the Lipayo artificial reef, with findings contributing to the baseline dataset of the IMR Dauin LTRMP. Evaluating the efficacy of artificial structures in enhancing or sustaining biodiversity on tropical coral reefs is key to assessing their role in reef conservation or management. It must be noted that any differences observed between seasons from this first survey year may be as a result of seasonal fluctuations in the ecology of the reef, or long-term trends that will continue over several years; data from several years of the IMR Dauin LTRMP is required in order to determine this.

Results of benthic colonisation of the artificial reef structures reveal coral to be the most dominant benthic recruitment type, followed by sponge and algae. Whilst results do not differ significantly between seasons, minor advances in coral growth have been identified. With the Lipayo artificial reef being a site of erratic high water circulation, artificial structures raised from the sandy bottom increase flow and reduced sedimentation, which are conducive to coral growth and reproduction[13]. Structural design, alongside the absence of erect macroalgae supports the linear extension of coral recruits[13]. Acropora *spp.* and *Porites spp.* contributed predominantly to this percentage of new recruits. Whilst *Acropora spp.* is a rapid colonizer of new habitats due to its fast-growing nature, the presence of a variety of genera indicate there is a positive influence towards coral larval settlement and subsequent linear extension. For coral larval settlement to occur there must be a combination of: microbe-microbe interactions within surface biofilms, physical factors of the benthic environment on a microscopic scale, and the production of chemical cues[14]. With Coralline Algae (CA) presence on the rise, this should subsequently favour a rise in recorded coral cover. This is supported by Tebben *et al*. 2011 who found that a specific microbe strain from the genus *Pseudoalteromonas*, cultured from the surface of CA, produces the small molecule tetrabromopyrrole (TBP) that induces both coral attachment and metamorphosis[15]. However, due to this microscopic nature of chemical cues influencing coral larval settlement, continued monitoring of coral growth should be incorporated with CA recordings.

Sponge and algal matrix has declined slightly, however percent cover is already minimal. As the artificial reef substratum is biologically altered, becoming more complex over time, it is natural for community differentiation and successional patterns to occur[16]. These results indicate that these pioneering organisms are becoming replaced by more persistent and biologically complex organisms as the "soak" time of the structure increases.

Coral mortality assessments reveal the absence of corallivorous invertebrate predators (*Drupella spp., Acanthaster plancii*) as well as disease and bleaching sightings. Whilst this is largely associated to the low coral coverage, the capacity for *Drupella spp.* and *Acanthaster plancii* to dominate this site could be scarce due to The Lipayo artificial reef being an isolated and predominantly sandy bottom site. Studies of *Acanthaster plancii* settlement reveal post-settlement survival to be greatest in relatively shallow waters of obliquely exposed fore reef habitats where there is a high cover of coral rubble[17], as such The Lipayo artificial reef is unlikely to be affected. Regardless, the nearshore nature of this artificial reef to the coastline could expose this site to direct terrestrial influences in the future.

The make-up of the fish assemblage at the Lipayo artificial reef site reveals minimal dissimilarities between its neighbouring natural reef sites. These are interesting results considering there are important habitat differences between artificial and natural reefs. The small size of the artificial reef generates a higher ratio of reef perimeter to reef surface area compared with a natural reef. This difference has been suggested to contribute to a higher recorded density of fish found on artificial reefs[18]. When analysing the progression of the reef fish assemblage at The Lipayo artificial reef, fish biomass, abundance, and diversity has seen an overall seasonal decline, with additional modifications in the species make-up. *Siganidae* (rabbitfish), and subsequently the planktivores & herbivore trophic guild (*Siganidae, Pomacentridae* and *Acanthuridae*) now contribute to the majority of the biomass at this site, which is a consistent trend across neighbouring natural reef sites. Whether this artificial reef site is simply supporting a high proportion of transient reef fish from neighbouring reef sites, or if a seasonal variation in food availability is accounting for this site wide shift will continue to be studied. Regardless, the decline in turf and macroalgae from the artificial substrates can be explained by this shift in herbivory biomass.

Piscivorous fish biomass has made marginal improvements, suggesting a combination of MPA enforcement and/or prey availability. Due to artificial reefs differing to natural reefs in terms of both vertical relief and structural complexity[18], it is important to understand the extent to which this predator presence will affect prey abundances and subsequently refuge capacity. 3-Dimensional reef reconstructions of the Lipayo artificial reef reveal structural metrics to be significantly lower than its neighbouring natural reefs. These results reveal that even in the absence of fishing pressure, insufficient prey refuge could inhibit the carrying capacity and species composition of this site. Instead, this artificial reef will support a higher proportion of transient fish species moving between neighbouring natural reefs. What conservation goal this artificial reef will support for reef fish communities will continue to be understood.

Overall, these results reveal a benthic shift towards a more structurally complex surface configuration that favours coral settlement. Even when coral growth is favoured, records of coral mortality are absent for this season. Whether this benthic succession will further promote a reef fish assemblage similar to natural reefs and support the conservation goal of this artificial reef will be a case for continuous studies as per the Dauin LTRMP.

4. REFERENCES

1. Kohler, K.E., Gill, S.M. (2006). Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Computers & Geosciences, 32: 1259-1269
2. Stopnitzky, S. (2014). Studying Reefs, Staying Dry. Khaleb bin Sultan Living Oceans Foundation. [Accessed May 2020]. Available at: https://www.livingoceansfoundation.org/studying-reefs-staying-dry/
3. Holmes, T. H., Wilson, S. K., Travers, M. J., Langlois, T. J., Evans, R. D., Moore, G. I., ... & Hickey, K. (2013). A comparison of visual-and stereo-video based fish community assessment methods in tropical and temperate marine waters of Western Australia. Limnology and Oceanography: Methods, 11(7), 337-350.
4. Andradi-Brown, D. A., Gress, E., Wright, G., Exton, D. A., & Rogers, A. D. (2016). Reef fish community biomass and trophic structure changes across shallow to upper-mesophotic reefs in the Mesoamerican Barrier Reef, Caribbean. PLoS One, 11(6), e0156641.
5. Froese, R., & Pauly, D. (2019). FishBase, The Global Database of Fishes. [Accessed May 2020]. Available at: https://www.fishbase.se/search.php
6. Obura, D., & Grimsditch, G. (2009). Resilience assessment of coral reefs: assessment protocol for coral reefs, focusing on coral bleaching and thermal stress. IUCN Climate Change and Coral Reefs Marine Working Paper Series – No 4. Gland, Switzerland: IUCN.
7. IUCN 2020. The IUCN Red List of Threatened Species. Version 2020-1. [Accessed March 2020]. Available at: https://www.iucnredlist.org
8. Fisher, W. S., Davis, W. P., Quarles, R. L., Patrick, J., Campbell, J. G., Harris, P. S., ... & Parsons, M. (2007). Characterizing coral condition using estimates of three-dimensional colony surface area. Environmental Monitoring and Assessment, 125(1-3), 347-360.
9. Done, T. T. (1997, January). Decadal changes in reef-building communities: implications for reef growth and monitoring programs. In Proceedings of the 8th International Coral Reef Symposium, Panama, 24-29 June 1996-pages: 1: 411-416. Smithsonian Tropical Research Institute.
10. Snavely, N., Seitz, S. M., & Szeliski, R. (2008). Modeling the world from internet photo collections. International journal of computer vision, 80(2), 189-210.
11. Westoby, M. J., Brasington, J., Glasser, N. F., Hambrey, M. J., & Reynolds, J. M. (2012). 'Structure-from-Motion'photogrammetry: A low-cost, effective tool for geoscience applications. Geomorphology, 179, 300-314.
12. Young, G. C., Dey, S., Rogers, A. D., & Exton, D. (2018). Correction: Cost and time-effective method for multi-scale measures of rugosity, fractal dimension, and vector dispersion from coral reef 3D models. PloS one, 13(7), e0201847.
13. Higgins, E., Scheibling, R.E., Desilets, K.M., Metaxas, A. (2019) Benthic community succession on artificial and natural coral reefs in the northern Gulf of Aqaba, Red Sea. PLoS ONE 14(2): e0212842.
14. Sharp, K. H., D. Distel, and V. J. Paul. 2011. Diversity and dynamics of bacterial communities in early life stages of the Caribbean coral Porites astreoides. ISME J. 6: 790 – 801.
15. Tebben, J., D. M. Tapiolas, C. A. Motti, D. Abrego, A. P. Negri, L. L. Blackall, P. D. Steinberg, T. Harder (2011). Induction of larval metamorphosis of the coral Acropora millepora by tetrabromopyrrole isolated from a Pseudoalteromonas bacterium. PLoS One 6: e19082.
16. Carter, A., Prekel, S. (2008). Benthic colonization and ecological successional patterns on a planned Nearshore artificial reef system in Broward County, SE Florida. Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008, Session number 24.
17. Wilmes, J.C., Schultz, D.J., Hoey, A.S., Messmer, V., Pratchett, M.S. (2020). Habitat associations of settlement-stage crown-of-thorns starfish on Australia's Great Barrier Reef. Coral Reefs.
18. Sharp, K. H., D. Distel, and V. J. Paul. 2011. Diversity and dynamics of bacterial communities in early life stages of the Caribbean coral Porites astreoides. ISME J. 6: 790 – 801.