INSTITUTE FOR MARINE RESEARCH
DAUIN · PHILIPPINES

LIPAYO I

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Front Cover: Maayong Tubig Marine Reserve
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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

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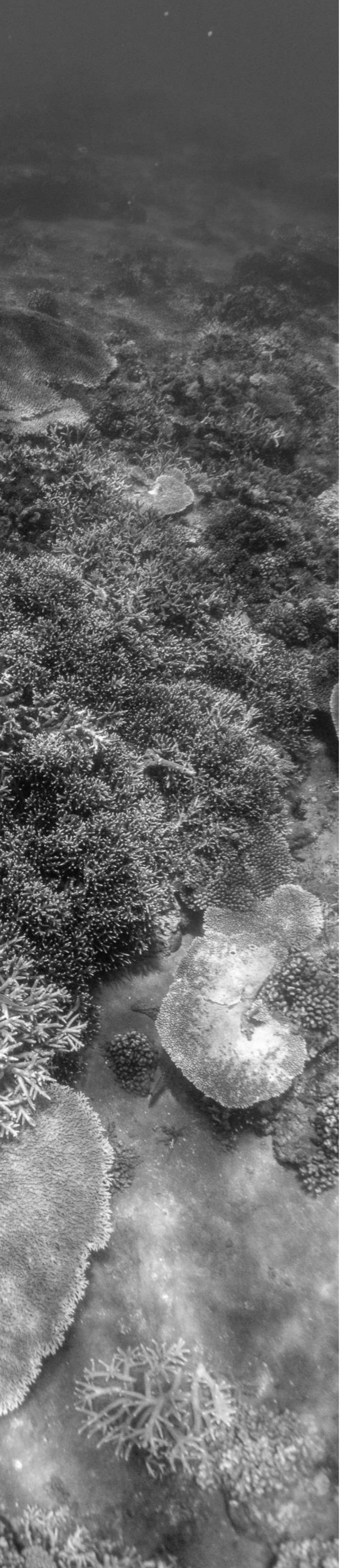

Dauin Long-Term Reef Monitoring Project Aims

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

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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 Marine Protected Area (MPA) is one of the largest along the Dauin coastline, hence the LTRMP surveys two locations within – north and south. Ten 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.

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2. RESULTS

2.1 Benthic Cover

Lipayo I Norte

The benthic composition at Lipayo I Norte is dominated by abiotic substrate (rock, rubble and sand), with a mean transect cover of 78.1%. Abiotic cover decreased by 1.8% over the year (dry:79%, wet: 77.2%) (Fig 2.1.1), with sand decreasing the most (2.6% decline, dry: 73.4%, wet: 70.8%) (Fig 2.1.2). Rubble increased by 0.2% (dry: 2.9, wet: 3.1%), and rock increased by 0.6% (dry:2.7%, wet: 3.3%) (Fig 2.1.2).

Scleractinian corals cover a mean of 10.8% of substrate at this site, increasing 1% from dry to wet season (dry: 10.3%, wet: 11.3%) (Fig 2.1.1). A total of 23 Scleractinian corals were recorded at Lipayo I Norte with *Pocillopora* being the most abundant with an annual average of 2.9% (dry: 2.6%, wet: 3.1%) (Fig 2.1.3). *Acropora* was the 2nd most abundant (annual average: 2.4%, dry: 3.1% , wet: 1.7%) followed by *Porites* (annual mean cover: 1.3%, dry: 0.9%, wet: 1.7%) (Fig 2.1.3).

Simpson's diversity index (1-D) for hard corals remained fairly consistent between seasons (dry 1-D= 0.82, wet 1-D= 0.84). Genera richness was similar between seasons with 15 genera recorded during dry season and 16 recorded during wet, although across the entire survey year 24 different genera were recorded. Pielou's evenness index (J') during dry and wet season was 0.78, however, when calculated for the entire survey, it decreased to 0.67.

Algae was the third largest contributor to overall benthic composition (annual average 3.7%) only increasing 0.008% from dry to wet season (dry: 3.7%, wet: 3.7%) (Fig 2.1.1). Turf algae cover increased 0.4% from dry to wet (dry: 2.8%, wet: 3.2%), whereas 'other algae' decreased by 0.3% (dry: 0.4%, wet: 0.1%), as does Halimeda by 0.1% (dry: 0.1%, wet: 0%) (Fig 2.1.4). There is no change in coralline algae cover (0.5%) between seasons (Fig 2.1.4).

Lipayo I Sur

The benthic composition at Lipayo I Sur is dominated by abiotic substrate (rock, rubble and sand) with a mean transect cover of 49.9%. There is a decrease of 23.5% in abiotic components from dry season to wet season (dry: 61.6%, wet: 38.1%) (Fig 2.1.1), with rubble decreasing the most (22.6% decline, dry: 25.2%, wet: 2.6%) (Fig 2.2.2). Sand and rock also decreased but only by 0.2% (dry: 34.9%, wet: 34.7%) and 0.7% (dry: 1.5%, wet: 0.8%) respectively (Fig 2.1.2). Trash increased at this site from completely absent in the dry season, to 0.03% in the wet (Fig 2.1.2).

Scleractinian corals cover a mean of 25.3% of the benthos at this site, increasing by 4.8% from dry to wet season (dry: 22.9%, wet: 27.7%) (Fig 2.1.1). A total of 14 Scleractinian coral genera were recorded at this site, with *Acropora* (dry: 21.8%, wet: 24.8%) as the most abundant, followed by *Diploastrea* (dry: 0%, wet: 1.3%) and *Pocillopora* (dry: 0.1%, wet: 0.6%) (Fig 2.1.3). Simpson's diversity index (1-D) for hard corals remained fairly consistent between seasons (dry 1-D= 0.14, wet 1-D= 0.19). The 5m site showed a greater genera richness (10) and diversity (1-D= 0.23) than the 10m site (7 genera, 1-D=0.1). Pielou's evenness was lower at depth (5m J'=0.24, 10m J'=0.12).

Dead coral made up the third largest contributor to overall benthic composition (annual mean cover 11.1%), increasing by 17.9% from dry to wet (dry: 2.2%, wet: 20.1%) (Fig 2.1.1). Coral rubble increased by 19.6% from dry to wet season (dry: 0%, wet: 19.6%) while dead coral with algae decreased by 1.8% (dry: 2.2%, wet: 0.4%) (Fig 2.1.5). There was also a marginal increase of 0.2% in recently dead coral (dry: 0.08, wet: 0.1%) (Fig 2.1.5).

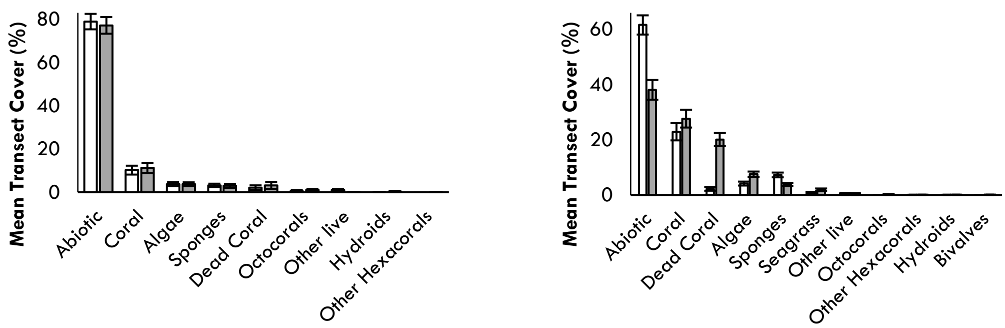

Fig 2.1.1: Mean cover (% ± SE) of all major benthic categories recorded at Lipayo reef Norte (left) and Sur (right), with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

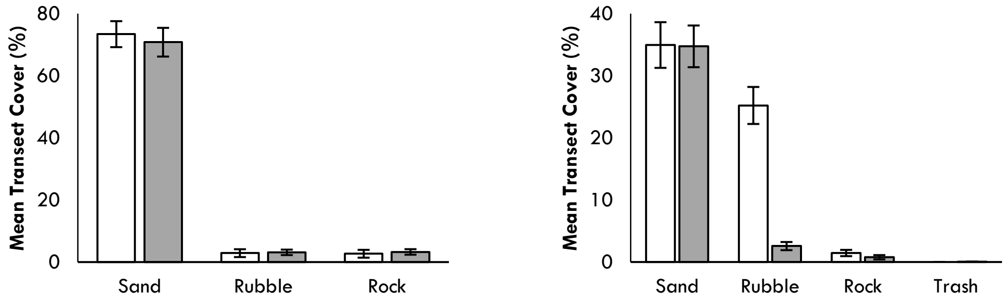

Fig 2.1.2: Mean cover (% ± SE) of abiotic types recorded at Lipayo reef Norte (left) and Sur (right), with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

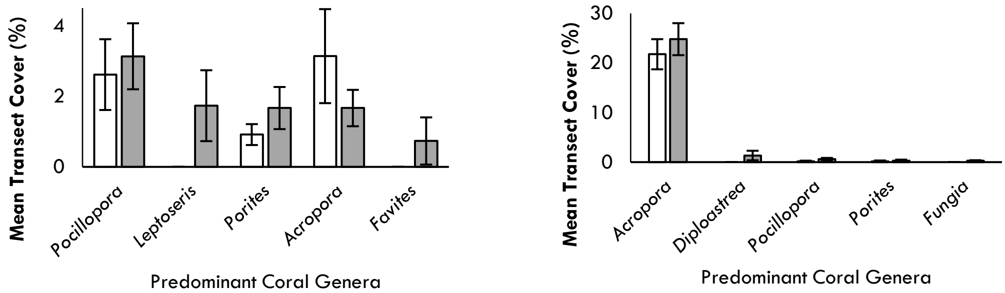

Fig 2.1.3: Mean cover (% ± SE) of predominant coral genera recorded at Lipayo reef Norte (left) and Sur (right), with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

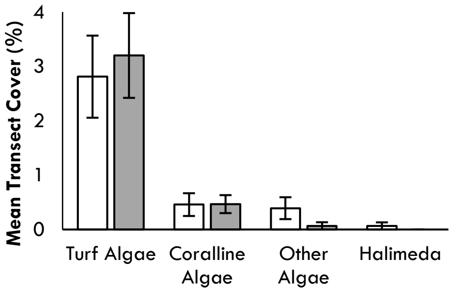

Fig 2.1.4: Mean cover (% ± SE) of algal types recorded at Lipayo reef Norte, with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

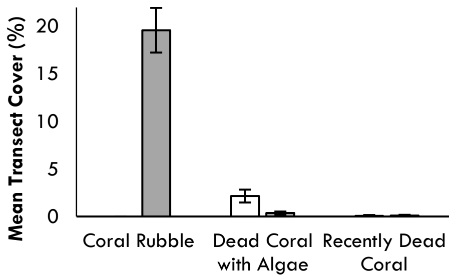

Fig 2.1.5: Mean cover (% ± SE) of dead coral types recorded at Lipayo reef Sur, with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

2.2 Reef Impacts & Coral Mortality

Lipayo I Norte

Coral bleaching was the most prevalent impact recorded at Lipayo I Norte with 9 instances recorded over the year (Fig 2.2.1), affecting on average 76.4% of the colony. There were no seasonal variations with coral bleaching instances, with 3.0 counts/100m^2 during both dry and wet seasons (Fig 2.2.2). The average affected area of the colonies was higher during the dry season (dry: 85.3%, wet: 37%) and the most frequently affected coral genera was Goniastrea.

Unknown scarring was recorded at Lipayo I Norte reef, with 3 instances recorded over the year (dry n= 2, wet n= 1) (Fig 2.2.1). The 1 count during wet season was suspected *Acanthaster plancii* (Crown of Thorns Starfish, COTS).

Drupella spp. were also recorded at Lipayo I Norte reef, with 2 instances recorded, both during dry season (Fig 2.2.1). *Drupella* spp. affected on average 5.23% of the colony, and affected *Acropora* (dry n= 1, wet n= 0) and *Stylophora* (dry n= 1, wet n= 0).

Overall trends at Lipayo I Norte indicate an increase in direct destruction. There was no change in bleaching and unknown scarring. There was a decreasing trend in recorded *Drupella* spp., trash, fishing gear and disease. There were no recorded incidences of stone fishing or COTS (Fig 2.2.1).

Lipayo I Sur

Coral bleaching was the most prevalent impact recorded at Lipayo I Sur Reef, with 38 instances over the year, impacting on average 60.8% of the colony. The dry season saw fewer instances of coral bleaching than the wet season (dry: 2.8

count/100m^2, wet: 9.0 count/100m^2) (Fig 2.2.1, 2.2.2), although more of the colony was affected during wet season (dry: 31.5%, wet: 61.9%). 12 coral genera were bleached: *Acropora* (dry n= 0, wet n= 1), *Astreopora* (dry n= 0, wet n= 1), *Favites* (dry n= 0, wet n= 4), *Fungia* (dry n= 4, wet n= 12), *Goniastrea* (dry n= 3, wet n= 2), *Leptoria* (dry n= 0, wet n= 1), *Merulina* (dry n= 1, wet n= 0), *Montastrea* (dry n= 1, wet n= 0), *Montipora* (dry n= 0, wet n= 2), *Pavona* (dry n= 1, wet n= 1), *Pocillopora* (dry n= 1, wet n= 2) and *Stylophora* (dry n=0, wet n= 1).

Drupella spp. were recorded at Lipayo I Sur reef, with 32 instances recorded over the year (dry n=14, wet n= 18) (Fig 2.2.1). *Drupella* spp. affected on average 28.8% of the colony, with *Acropora* being the most frequently affected coral genera (dry n= 13, wet n= 18), although *Pocillopora* was also affected by *Drupella* (dry n= 1, wet n= 0).

Unknown scarring was also recorded 15 times during the survey year (dry n= 3, wet n= 12) (Fig 2.2.1). All recorded unknown scarring during wet season was suspected *Drupella* spp. The majority of unknown scarring was at depth (10m n= 10, 5m n= 5).

Overall trends at Lipayo I Sur, indicate an increase in bleaching, *Drupella* spp., unknown scarring, trash, fishing gear and direct destruction. There was a decreasing trend in stone fishing and disease. There were no recorded instances of *Acanthaster plancii* (Crown of Thorns Starfish) (Fig 2.2.1).

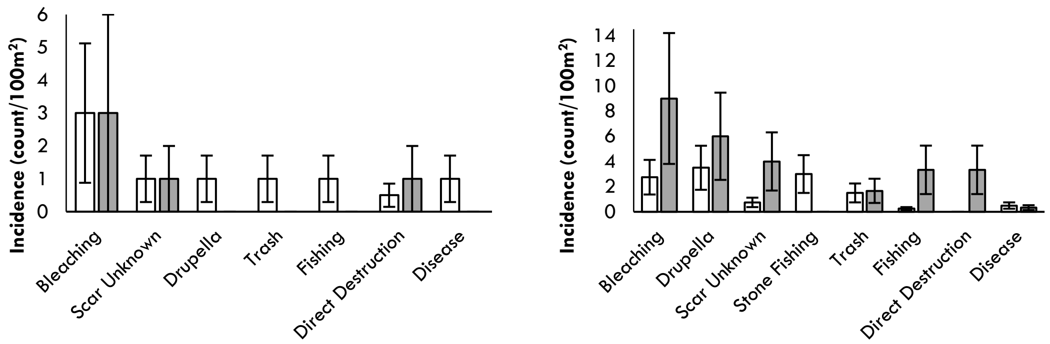

Fig 2.2.1: Mean incidence (count/100m^2 ±SE) of reef impacts recorded at Lipayo reef Norte (left) and Sur (right), with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

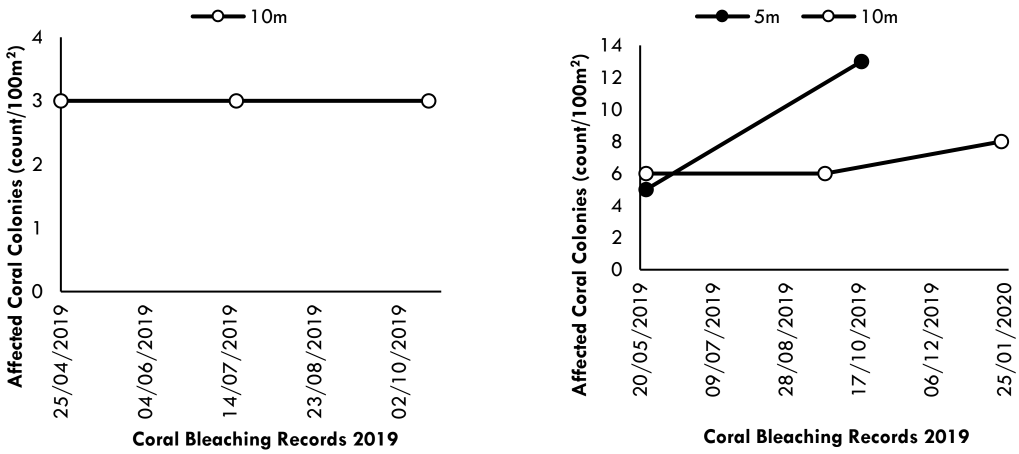

Fig 2.2.2: Number of bleaching coral colonies recorded along the transect at Lipayo reef Norte (left) and Sur (right), within the 2019 survey period.

Table 1: Reef impacts recorded at Lipayo reef Norte (left) and Sur (right) during dry and wet seasons of 2019 with trends.

Impact (count/100m^2)	Last Season (Dry 2019)	Current Season (Wet 2019)	Trend
Coral Bleaching	3.0	3.0	⇔
Scar Unknown	1.0	1.0	⇔
Drupella spp.	1.0	0.0	↘
Trash	1.0	0.0	↘
Fishing Gear	1.0	0.0	↘

Impact (count/100m^2)	Last Season (Dry 2019)	Current Season (Wet 2019)	Trend
Coral Bleaching	2.8	9.0	↗
Drupella spp.	3.5	6.0	↗
Scar Unknown	0.8	4.0	↗
Stone Fishing	3.0	0.0	↘
Trash	1.5	1.7	↗

2.3 Fish

Lipayo I Norte

Lipayo I Norte recorded a total fish abundance for 2019 of n=829 (dry n= 345, wet n=484). *Pomacentridae* was the most abundant family during both seasons (dry n=209, wet n=235,) (Fig 2.3.1). In dry season the next most abundant fish family was *Caesionidae* (dry n=25, wet n=0), followed by *Serranidae* (dry n=22, wet n=115). In contrast the 2nd most abundant family during wet season was *Serranidae*, followed by *Apogonidae* (dry n=0, wet n=64) (Fig 2.3.1). Species richness was higher in wet season (dry S=344, wet S=479) although biomass decreased (dry: 9.3kg/250m^2, wet: 5.1 kg/250m^2). Total biomass recorded for the year at Lipayo I Norte was 14.4kg.

Commercially important families recorded at Lipayo I Norte include: *Acanthuridae* (dry: 0.63kg/250m^2, S=3, wet: 0.5kg/250m, S=2), *Caesionidae* (dry: 2.92kg/250m^2, S=1, wet: 0kg/250m^2, S=0), *Labridae* (dry: 0.19kg/250m^2, S=1, wet: 0.51kg/250m^2, S=3), *Mullidae* (dry: 0.72kg/250m^2, S=2, wet: 0.12kg/250m^2, S=3), *Nemipteridae* (dry: 0.84kg/250m^2, S=2, wet: 0.39kg/250m^2, S=2), *Serranidae* (dry: 0kg/250m^2, S=0, wet: 0.07kg/250m^2, S=1), *Siganidae* (dry: 0kg/250m^2, S=0, wet: 0.23kg/250m^2, S=1).

Grouping fish into trophic groups, the group with greatest biomass was the Planktivores (dry: 3.03kg/250m^2, wet: 0.98kg/250m), although the most abundant was the Omnivores (dry n=110, wet n=167). During dry season the most abundant trophic groups were Herbivore & Planktivores, Omnivores and Planktivores, whereas in wet season the most abundant were Planktivores, Omnivores and Herbivore & Planktivores. The largest biomass in dry season was from Planktivores, Herbivore & Planktivores and Omnivores, whereas in wet season the largest biomass was from Herbivore & Planktivores, Planktivores and Omnivore (Fig 2.3.3). The top three feeding guilds both in terms of abundance and biomass remain consistent.

Lipayo I Sur

Lipayo I Sur recorded a total fish abundance for 2019 of n=2029 (dry n=539, wet n=1490). *Pomacentridae* was the most abundant family in both seasons (dry n=171, wet n=1017), followed by *Labridae* (dry n=83, wet n=176) (Fig 2.3.1). There were seasonal differences between the 3rd most abundant fish families; *Acanthuridae* in dry season (dry n=56, wet n=90), *Serranidae* in wet Season (dry n=24, wet n=122) (Fig 2.3.1). Species richness was higher in wet season (dry S=67, wet S=75) although biomass decreased (dry: 37.6kg, wet: 25.3kg). Total biomass recorded for the year was 62.9kg.

Commercially important families recorded at Lipayo I Sur reef include: *Acanthuridae* (dry: 0.93kg/250m^2, S=1, wet: 0.99kg/250m^2, S=1), *Apogonidae* (dry: 0.06kg/250m^2, S=1, wet: 0.08kg/250m^2, S=1), *Haemulidae* (dry: 0.05kg/250m^2, S=1, wet: 0.11kg/250m^2, S=1), *Holocentridae* (dry: 0.02kg/250m^2, S=1, wet: 0.59kg/250m^2, S=1), *Labridae* (dry: 0.18kg/250m^2, S=6, wet: 0.18kg/250m^2, S=6), *Lutjanidae* (dry: 2.84kg/250m^2, S=2, wet: 0.4kg/250m^2, S=2), *Monacanthidae* (dry: 0.01kg/250m^2, S=1, wet: 0kg/250m^2, S=0), *Mullidae* (dry: 0kg/250m^2, S=0, wet: 0.83kg/250m^2, S=4), *Nemipteridae* (dry: 0.4kg/250m^2, S=2, wet: 0.36kg/250m^2, S=2), *Serranidae* (dry: 8.1kg/250m^2, S=2, wet: 0.06kg/250m^2, S=2), and *Siganidae* (dry: 0kg/250m^2, S=0, wet: 0.13kg/250m^2, S=1).

Grouping fish into trophic groups showed that across the entire survey year the greatest contributors to biomass was Piscivore & Mobile Invertebrate Feeders (MIF) (dry: 11.69kg/250m^2, wet: 1.44kg/250m^2), whereas the most abundant was Planktivores (dry n=41, wet n=281). During dry season the most abundant trophic groups were Herbivore & Planktivores, Omnivores and Planktivores, whereas the most abundant during wet season were Planktivores, Herbivore & Planktivores and Omnivores; the top three feeding guilds in terms of abundance remain consistent seasonally. During dry season the largest biomass was attributed to Piscivore & MIFs, Planktivores and Piscivores, in contrast to wet season where greatest biomass is attributed to Omnivores, Planktivores and Herbivore & Planktivores (Fig 2.3.3).

2.4 Reef Complexity

Lipayo I Norte

Results from the 3-Dimensional reconstructions reveal, during dry season, a rugosity index of 1.775 ± 0.4716, and a slope value of -0.05051 ± 0.1161 During wet season at 10m, a rugosity index of 2.369 ± 1.694 and a slope value of 0.08834 ± 0.06978 (Table 2).

Lipayo I Sur

Results from our 3-Dimensional reef reconstructions at 5 m during dry season reveal a rugosity index of 2.612 ±,1.755, slope value of 0.02326 ± 0.07614. The wet season 5m survey shows a rugosity index of 6.231 ± 1.663, slope value of -0.1254 ± 0.2614 (Table 2).

At 10m our results from the 3-Dimensional reconstructions reveal, during dry season, a rugosity index of 2.704 ± 1.338, and a slope value of 0.2214 ± 0.1563. During wet season at 10m, a rugosity index of 2.732 ± 1.44 and a slope value of 0.009585 ± 0.2395 (Table 2).

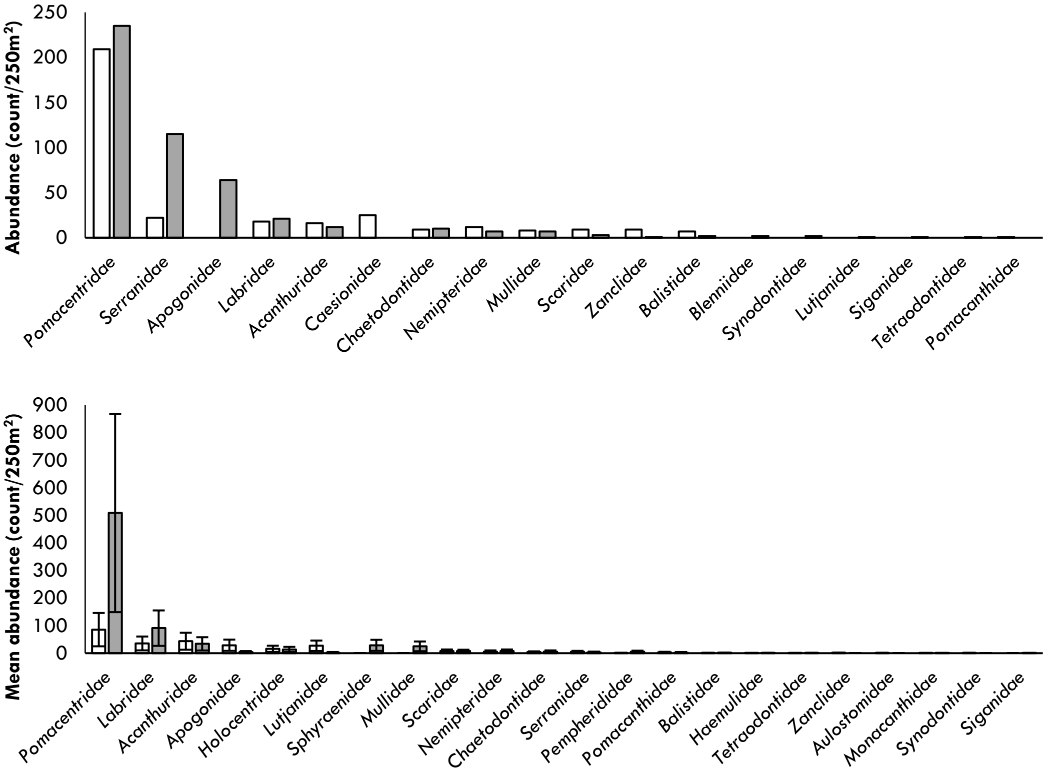

Fig 2.3.1: Mean abundance (count/250m^2 $\pm$ SE) of fish families recorded at Lipayo reef Norte (top) and Sur (bottom), with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

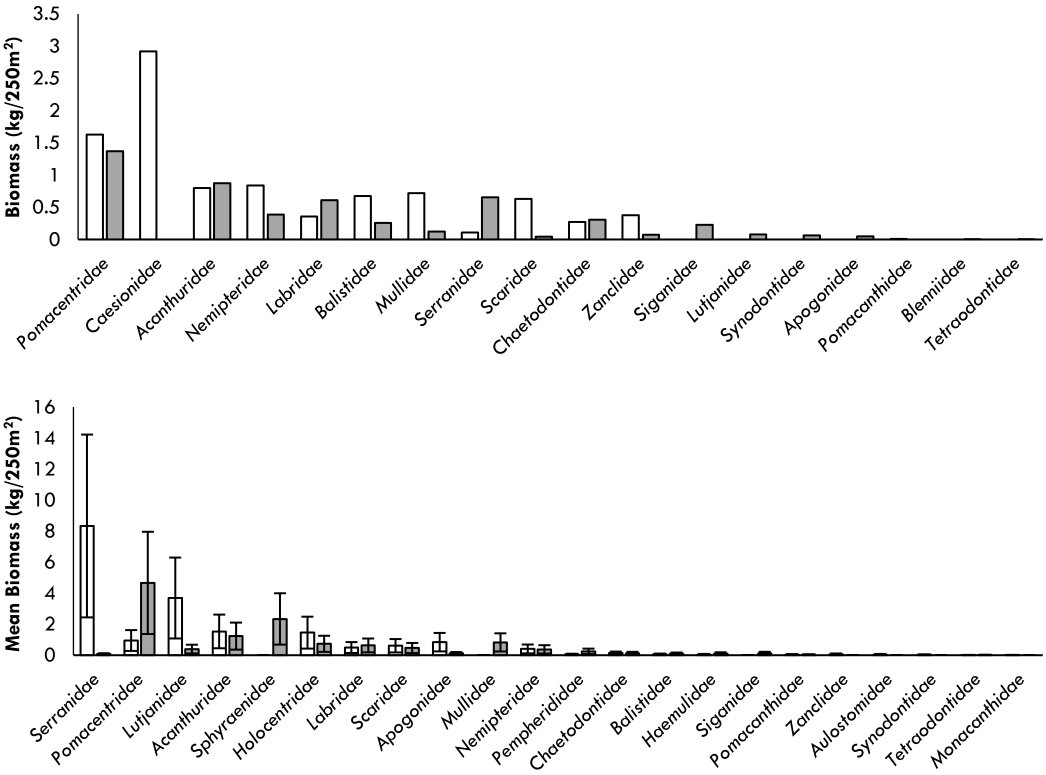

Fig 2.3.2: Mean biomass (kg/250m^2 $\pm$ SE) of fish families recorded at Lipayo reef Norte (top) and Sur (bottom), with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan).

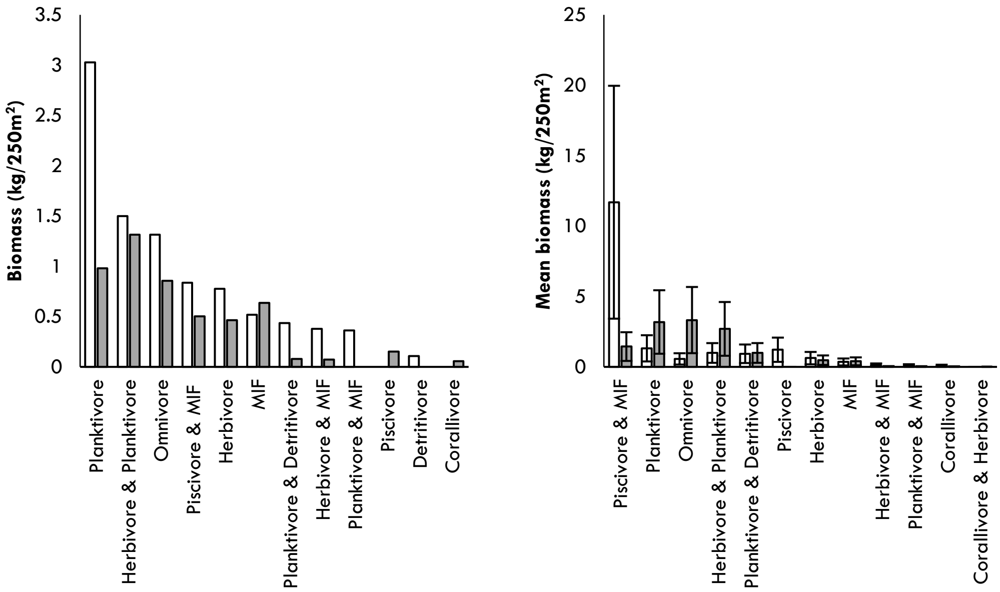

Fig 2.3.3: Mean biomass (kg/250m² ± SE) of fish trophic groups recorded at Lipayo reef Norte (left) and Sur (right), with white representing dry season (Feb - Jul), and grey representing wet season (Aug - Jan). MIF = mobile invertebrate feeder

Table 2: Summary of findings at Lipayo reef Norte (left) and Sur (right) 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 (%)	10.3	11.3	↗
Algal Cover (%)	3.7	3.7	⇔
Coral 1-D	0.82	0.84	↗
Fish abundance (count/250m²)	345	484	↗
Fish biomass (kg/250m²)	9.33	5.11	↘
Fish 1-D	0.07	0.11	↗
Rugosity (RQ)	**10m** 1.775 ± 0.4716	**10m** 2.369 ± 1.694	↗

Measurement	Last Season (Dry 2019)	Current Season (Wet 2019)	Trend
Coral Cover (%)	22.9	27.7	↗
Algal Cover (%)	4.1	7.5	↗
Coral 1-D	0.14	0.19	↗
Fish abundance (count/250m²)	539	1490	↗
Fish biomass (kg/250m²)	37.64	25.27	↗
Fish 1-D	0.044	0.115	↘
Rugosity (RQ)	**5m** 2.612 ± 1.755 **10m** 2.704 ± 1.338	**5m** 6.231 ± 1.663 **10m** 2.732 ± 1.44	↗

3.DISCUSSION

This report documents the annual development of the reef assemblage and community make-up of the Lipayo reef, with findings contributing to the baseline dataset of the IMR Dauin LTRMP. 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.

Lipayo reef is a recovering reef, following typhoon Pablo in 2012. The Lipayo Marine Reserve is dominated by abiotic components (rock, sand and rubble), with sand making up the majority of this abiotic category. These results are consistent between seasons, with the northern section having a higher percentage of abiotic components in comparison to the southern reef. Looking at the entire Marine Reserve, abiotic is followed by coral with a recorded growth of 2.9% from dry to wet season, largely attributed to the southern reef. *Acropora spp.* made up the majority of coral present, despite them being the most susceptible to damage during typhoons. This is due to fast growing corals having the ability to take advantage of the newly found substrate post-disturbance and monopolising[13,14]. This is concerning in the long term as a less diverse site is less resilient, especially when exposed to a variety of disturbances such as disease, typhoons, outbreaks of corallivorous invertebrates, overfishing and climate change[15]. Lipayo was recorded as being the most impacted site in the LTRMP by *Drupella spp.* with 4.8 counts per $100m^2$. There are a number of factors that contribute to Lipayo's susceptibility to this. Firstly, *Drupella spp.* favour fast growing corals, of which Lipayo reef has plenty (mostly *Acropora spp.*)[16]. Secondly, *Drupella spp.* have been observed to congregate post natural disturbances. In Lipayo's case, typhoon Pablo[17]. Thirdly, higher water temperatures and increased water eutrophication encourage recruitment of *Drupella spp*[18]. At Lipayo, *Drupella spp.* counts increased during wet season, when there is increased run off from the neighbouring coast and water temperatures are at their highest for the year[19].

The southern reef saw a rise in the dead coral category from dry to wet season, with a proportionally high abundance of coral rubble recorded during wet season. This may also be linked to the Lipayo reef being an *Acropora spp.* dominant ecosystem. As it is fast growing, favouring linear extension over the bulk density of the skeleton, it is more susceptible to damage[20]. With the wet season, comes strong winds and wave action that can easily damage fragile structures, especially at shallower depths. It must be noted that coral rubble is also a natural part of reef regeneration and so it's presence on a healthy reef is not disturbing[21]. The high diversity of coral reefs is attributed to the hypothesis that reef communities undergo cycles of destruction and renewal[22,23,24,25]. Coral is eroded by many processes, both natural and anthropogenic, leaving coral rubble. This coral rubble is then stabilized by interlocking components, sponges, algae and seagrass which helps support successful colonization of new coral polyps[26]. Lipayo, however, has some of the highest mean percentages of coral rubble along the Dauin coast (see results in 2019 Outlook Report). Anthropogenic factors should not be ignored in their capacity to increase coral rubble through direct destruction. *Muro-ami* (Stone-fishing) as well as direct contact from divers, can break off delicate coral branches, becoming coral rubble. Evidence of *muro-ami* was recorded at 1.7 counts/$100m^2$ at Lipayo for the 2019 year. This highly destructive practice of throwing rocks into the water to scare fish into pre-placed nets, has been outlawed since 1986 by the Department of Agriculture. The fringing nature of Lipayo's reef also leads to other anthropogenic impacts, with continued recordings of trash and fishing gear. The Philippines is highly reliant on fish for their main source of protein and so fishing pressures on this reef in particular are an important issue.

An additional driver of coral mortality within the Lipayo Marine Reserve was coral bleaching. Lipayo was the most impacted site along the Dauin coast in regards to bleaching (see results in 2019 Outlook Report). Despite the prevalence of *Acropora spp.*, only 2 instances of bleaching were recorded on *Acropora spp.* Other coral genera were more affected, especially *Fungia spp.* with 1.6 counts per $100m^2$. Previous research has found conflicting results as to whether fast growing (branching, tabular etc.) coral genera are more or less susceptible to bleaching [27,28,29]. There are many factors that can lead to bleaching of corals of different genera. These include environmental variables (competition intensity, depth etc.), microhabitat, as well as species traits (colony size etc.)[30]. Further investigation will be required to determine the bleaching sensitivity of coral genera in Dauin.

The fish population at Lipayo reef replicate the trend on the Dauin coastline, with greater abundance during wet season compared to dry season (see results in 2019 Outlook Report). The most abundant family was *Pomacentridae*, with higher numbers recorded during wet season. Due to the nature of the benthic composition, smaller fish are able to easily take shelter in the branches of *Acropora spp*[31]. *Acropora spp.* have been shown to sustain an abundant population of small bodied fish such as *Pomacentridae*[32]. With regards to biomass (kg/250m^2), both north and southern sections recorded higher biomass during dry season. In the southern part of the site, the large biomass of *Serranidae* during dry season can be attributed to *Plectropomus laevis* sighted which contributed to 43% of the biomass recorded during dry Season. *Serranidae* tend to be ambush predators, preferring to hide in craves and crevices to wait for their prey[33]. Their absence from the wet season survey may be attributed to the time of the survey not coinciding with their feeding movements.

There are a number of commercially important fish found on this reef, most notably *Serranidae* and *Lutjanidae*. Schooling *Lutjanidae* are often seen across Lipayo reef which could explain why this site is highly impacted by fishing debris. There was also a school seen by surveyors during wet season but they were at a greater depth and so not included in the LTRMP data. Fish abundance fluctuations are influenced by many behavioural (migration, spawning etc.), biological (mortality, growth etc.) and physical processes (temperature, currents etc.)[34]. Further study would be needed to determine which of these processes correlates with the observed seasonal depth migration of *Lutjanidae* seen at Lipayo. *Muro-ami* evidence was documented more during dry season, whereas records of other fishing gear were higher in wet season. This could be due to a change in target fish as seasons change and their abundance also changes.

The Piscivore & Mobile Invertebrate Feeder trophic group decreased dramatically from dry to wet season, mostly attributed to *Plectropomus laevis* and a school of *Lutjanus biguttatus*. Both are commercially important species and their biomass at this site signifies how important it is to enforce stricter fishing measures which may enable surrounding areas to benefit from 'spill over' fish assemblages in future[35]. Exclusively piscivorous fish were not recorded in high numbers during either season. Piscivores showed a decline from dry to wet season, despite overall fish abundance increasing. This is concerning for the future health of Lipayo reef as piscivores are important as they help to structure the reef fish communities as well as driving population dynamics[36]. Their reduced numbers may also be linked to species-specific behavioural, physical or biological processes leading to migration during wet season[34]. The fish that are recorded in greater abundance along the Dauin coast are almost all generalist feeders. Generalists feed over more than one trophic guild and so are capable to adapting should one food source be in short supply[37]. In contrast, specialist feeders are more susceptible to changes in the surrounding ecosystem[37]. This is promising for the immediate future of Lipayo's reef, as the species recorded will be more resilient and are able to adapt to changes in the composition of the reef community[28].

High rugosity has been shown to help maintain a more biodiverse community on coral reefs[38]. The southern section has a 14.5% higher mean coral cover than the north as well as a higher rugosity (especially at 5m). This supports a higher species diversity, total biomass and abundance of fish compared to the northern section of the reef. As a whole, Lipayo's rugosity has increased over the last year, potentially linked with some stabilisation of the substrate, allowing Scleractinian corals and other complex benthic organisms to attach. Continued monitoring will be needed to determine if this trend continues. If it does, a larger, more diverse fish population may be supported. However, if fishing pressure continues at the same level, there may not be a correlated increase in fish numbers or biomass.

Continued monitoring will be important to track the ongoing changes at Lipayo's fragile post-disturbance reef. It will also determine if the coral rubble prevalent at this site will be stabilized or if the erosion at Lipayo outweighs the regeneration of the reef. Despite its MPA status, the presence of fishing line and evidence of *muro-ami* show that greater enforcement is necessary to protect Lipayo's reef[39]. Community willingness to cooperate is needed to reduce exploitation of the resources inside the MPA[40]. Only then can Lipayo reef have the best chance to recover.

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