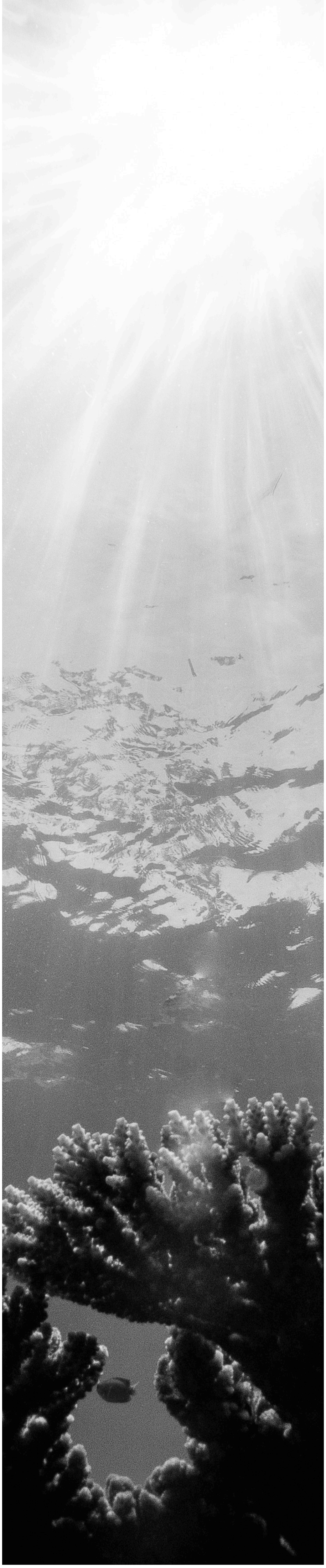
INSTITUTE FOR MARINE RESEARCH

DAUIN · PHILIPPINES

2019

OUTLOOK REPORT

Dauin Long-Term Reef Monitoring Project



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.

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

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Front Cover: Maayong Tubig Marine Reserve
Image: Becky Tooby

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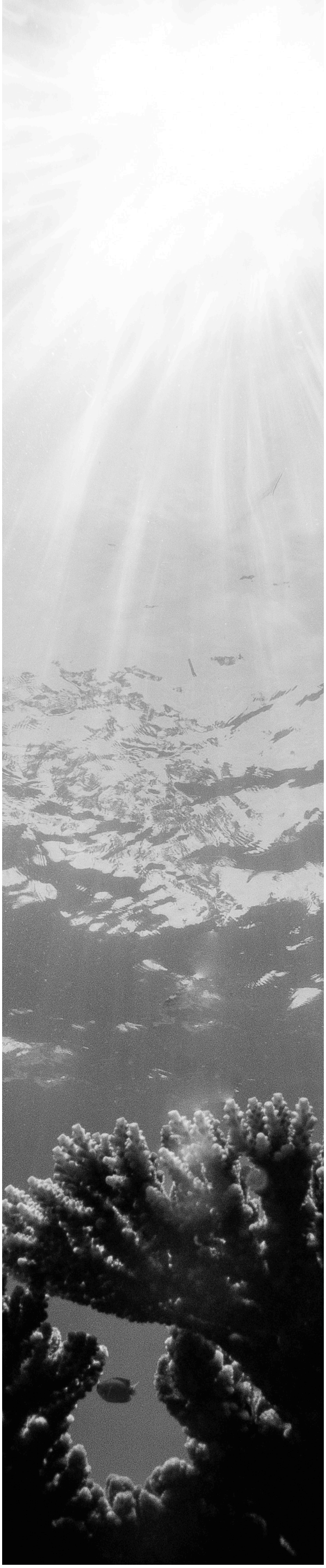


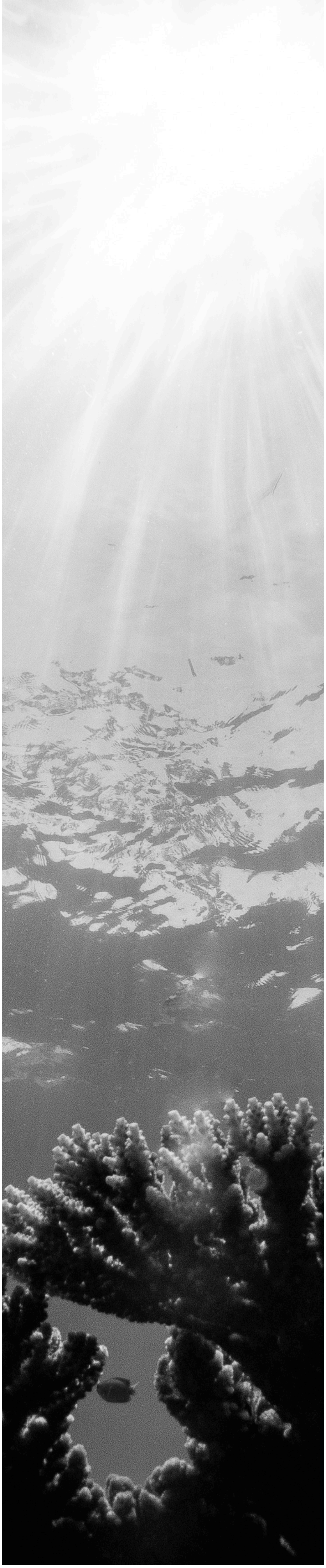
OUR MISSION

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



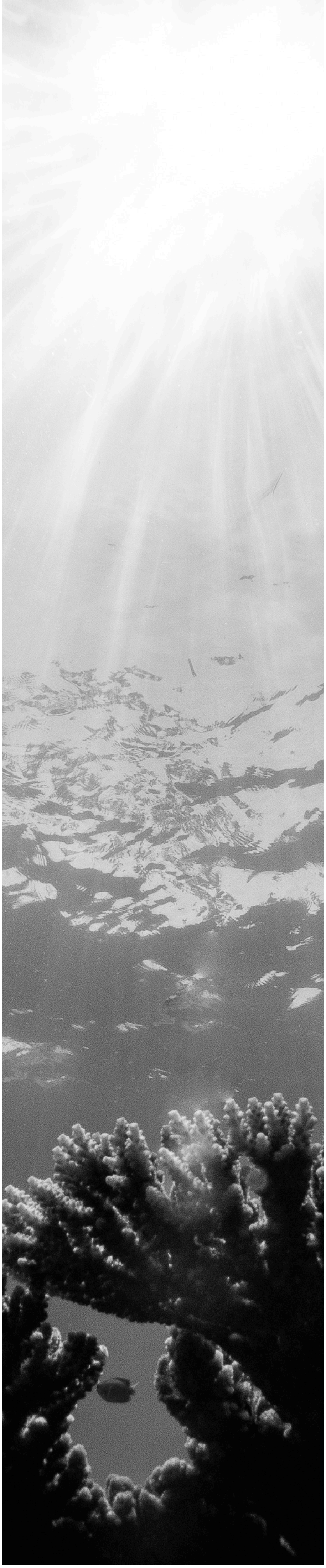
A MESSAGE FROM THE DIRECTORS

What a fantastic first year for the Institute for Marine Research!

The Institute hit the ground running this year with our efforts to fulfil the mission we have for this NGO; to be a key resource for the community of Dauin, educating, transforming and encouraging locally led marine conservation strategies here in the Philippines. We officially completed our first two seasons of the *Dauin Long Term Reef Monitoring Project*, collecting data for both dry and wet seasons from all the reef sites found along the 13km of Dauin's beautiful coastline. Completing all of our surveys resulted in thousands of pictures and hundreds of hours of video, giving us a fine scale snapshot of these coastal reefs. We have definitely come away from this year with a deeper understanding of the Dauin inshore reef, as well as a great respect and appreciation for everyone who helped us along the way.

As firm believers in evidence based conservation we have used our analysed data to shape our community outreach efforts, allowing us to communicate the most pressing problems to our community stakeholders. This resulted in various successful meetings with government officials, as well as private business owners along the coast. These meetings conveyed our data as well as highlighted the areas of concern that we could work on together. The Dauin local government unit have truly partnered with us in these endeavours, and our success would not be possible without their continuing support. We also had the privilege of becoming partners with ONE International School here in Dauin, who have allowed us test our environmental education programs starting from a very early age. The successful building of relationships within the community and the establishment of IMR as a true ally of the local population will be instrumental in future endeavours towards the goal of an ecologically literate and sustainable Dauin.

To advance this research we will continue to step up our efforts to continue to develop a deeper understanding of the coastal marine ecosystems here in Dauin. The more in depth our knowledge, the better we will be able to fulfil our mission. We will solidify and expand the relationships with our community partners, and in the realm of research it is our wish to continue to push to have the most high tech and fine scale methodologies available to us. To advance this research we will continue to collaborate with researchers and organizations from all over the world.



Our students came from all over the world and were instrumental in the research conducted for this report. Research Assistants, Research Divemasters, Instructor Development Candidates, and Research Fellows all learned the ins and outs of our methodologies and data analysis, taking big steps to become leaders in marine science and conservation. Some even went as far as to write site reports and help build the framework of our community outreach campaigns and activities. It must be said that we certainly learned as much from them as they did from us. We would like to sincerely thank them all: Brent Baran, Anthony DelVeccio, Alessandra Sellini, Patricia Zwolinski, Gabrielle Blackwood, Alex Ormandy, Anastasia Forbes, Alexandra Curry, David Salgado, Lily Brinn, Ted Fornoles, Paul Allen, Ella Ferrandis, Johan Allerie, Jorden Ivey, Stacey Arbour, Jess Miller and Ella Sibbering. We would also like to thank our incredibly talented and dedicated staff; Oscar Crehan, Jennifer Brand, and Becky Tooby, as they are integral to the success of this project.

We look forward to the years ahead with enthusiasm knowing there is still so much research to be done, so much work to be accomplished, and so many unknowns to be discovered. As long as we continue to have the capable and experienced staff and support from our friends and partners, the Institute for Marine Research is well on its way to accomplish its vision. The Institute will continue to grow and face the challenges that are placed in front of us as we always have, with determination and a strong shared sense of purpose.

Yours Sincerely,

Rafael Manrique & Chelsea Waters

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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

1. INTRODUCTION

The world's coral reefs are being severely degraded by the activities of humans, and the need to reduce local threats to offset the effects of increasing global pressures is now widely recognized. The Institute for Marine Research aims to use its scientific evidence to educate, transform and encourage locally led marine conservation strategies within the Philippines, ultimately reducing these local threats.

Major anthropogenic threats include rising seawater temperatures, ocean acidification, deteriorating water quality, destructive fishing, over-exploitation of key marine species, and the direct devastation of coastal ecosystems through unsustainable coastal development, which all risk mortality or reduced growth of reef-building corals due to their high sensitivity[1,2]. These anthropogenic threats interact with large-scale acute disturbances, including tropical storms and population outbreaks of the corallivorous Crown of Thorns starfish (COTS) *Acanthaster plancii*, which may also increase in frequency and intensity in response to human activities.

Regional policies can no longer protect reefs from global-scale devastation due to climate change-associated heat stress and intensifying tropical storms[2]. Efforts are therefore shifting towards management of local and regional anthropogenic pressures to strengthen reef resilience. A sound understanding of the processes that determine ecosystem trajectories is needed to assess the likely effectiveness of management strategies to reduce local anthropogenic pressures. Long-term and fine-scale monitoring of exemplar ecosystems is therefore essential.

1.1 The Philippines

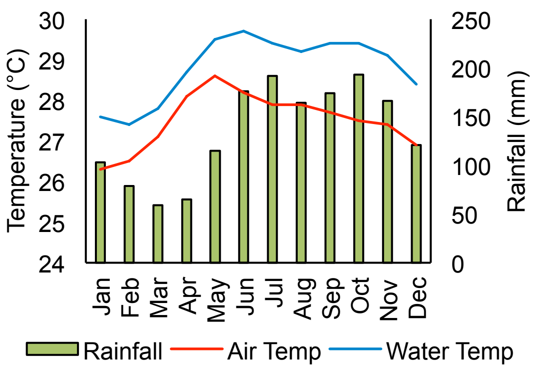
The Philippines represents a particularly relevant case study to investigate ecosystem trajectories. The Philippine archipelago is comprised of over 7100 islands, located within the heart of the Coral Triangle. With 76% of the world's Scleractinian coral species (over 400 species) and 37% of the reef fishes of the world[2,3], this incredible biodiversity is coupled with some of the highest human population densities and growth rates in the world[1].

Changes to the health of coastal ecosystems are exposing coastal populations to food and income insecurity, deteriorating coastal protection among other challenges; they are affecting people who are already impoverished and are amongst the least able to respond to changes that are occurring in their environment[1]. Reef fisheries have been estimated to directly contribute 15-30% of the Philippines total known national municipal fisheries (obtained from licences issued through local government areas), where nearly 70% of the dietary protein intake is from fish. However, the Philippines' main fish species and marine organisms show signs of overfishing, and coastal habitats are degrading due to multiple anthropogenic activities in coastal areas[4]. The stark contrast between poverty, hunger and deprivation amidst this increasing demand is leading to a rapid decline in reef resources. It is therefore no surprise that coral reefs in the Philippines are at very high risk from overexploitation, destructive fishing and other human related impacts such as coastal development, sedimentation, and as a result of anthropogenic climate change coral bleaching and ocean acidification.

Human activities now threaten an estimated 88 percent of Southeast Asia's coral reefs, with 50 percent of these having a threat level of "high" or "very high"[2]. In the Indo-Pacific, coral cover has dropped from approximately 50 – 22% in just 40 years[5]. If this continues, the changes to the ecosystem will exacerbate poverty and social instability within the region, with wider consequences for the Philippines and globally. It is imperative that we address the core issue of anthropogenic climate change whilst at the same time addressing key threats arising from local stressors.

1.2 Seasonal Weather Patterns

Negros Oriental falls under the Philippines Type III climate, where seasons are not very pronounced, although it is relatively dry from December to May, and relatively wet for the rest of the year. In the Bohol Sea, the lowest monthly average water temperatures are in February, at around 27.20°C, and the highest are in June, at around 30.00°C. The dry season (Filipino: Amihan) is dominated by north-easterly trade winds, bringing moderate temperatures and little rainfall, whereas the wet season (Filipino: Habagat) is dominated by south-westerly winds with hot, humid weather and heavy rainfall.



Average air and water temperature and rainfall of Philippines Type III climate (measurements from Cebu city)[6]. Data from 1982 – 2012.

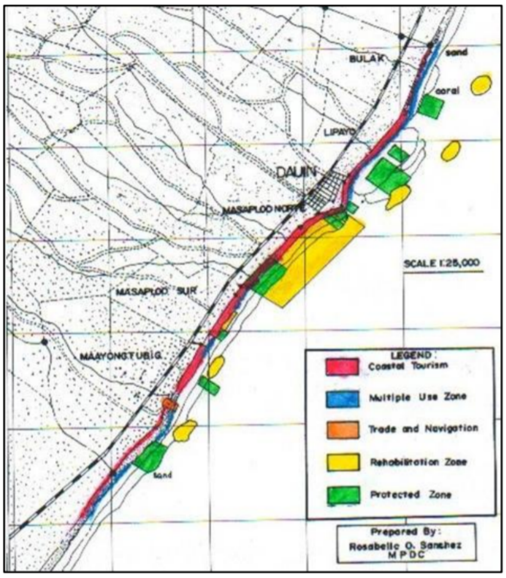
Whilst this report examines the differences between the data collected from the first two survey seasons (dry and wet 2019) of the IMR DLTRMP, it is important to consider that some seasonal fluctuations may not yet be apparent, as several years of data may be required to highlight these variations. Furthermore, any significant changes observed from this first survey year may be as a result of seasonal fluctuations or long-term trends; again, data from several years of the IMR DLTRMP is required in order to determine this.

1.3 Municipality of Dauin

Dauin, a fourth-class municipality in the province of Negros Oriental, is no exception to the critical reliance of reef resources for the wellbeing and subsistence of this coastal community. Together with a steadily growing population, Dauin has experienced first-hand the strain of pushing local fisheries beyond their biological limit – to the reef ecosystem and to the future of social and food security to this small coastal community.

Dauin has since shifted to community led establishment of several coastal management zones in the form of marine protected areas (MPAs). MPAs have the potential to protect at-risk ecosystems, habitats or species, as well as maintain and enhance coral reef resilience and biodiversity[7-9]. As such, MPAs have been distributed across the municipality to regulate fishing pressures, abolish destructive practices, and address important issues such as food security, economic growth, and ecosystem resilience. Additionally, one artificial reef site has been constructed (Lipayo II), with the aim of sheltering fauna, increasing structural complexity and promoting juvenile recruitment[10].

This report provides baseline information for Dauin's reefs after one year of surveying, examining key trends in benthic composition, coral mortality and fish community structure. Seasonal changes are also investigated.



Dauin Coastal Zoning Map; Marine Protected Areas in green.[11]

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.

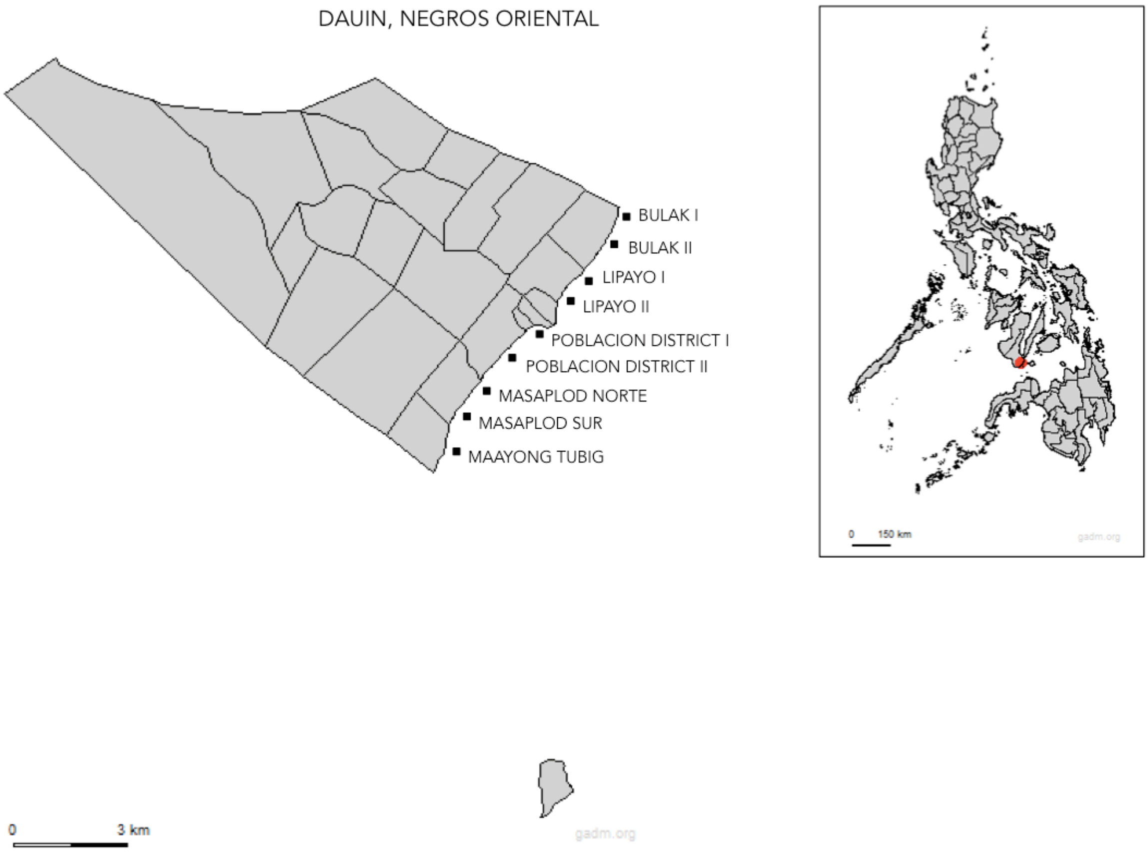
    a. What is the resiliency factor of ecosystems composed of high structural complexity, rugosity, percentage coral cover and coral diversity in response to storms and bleaching events?
    b. Is there a relationship between benthic measurement (structural complexity, percentage cover, rugosity, diversity) 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?

2. MATERIALS AND METHODS

Dauin is a fourth class Municipality in the province of Negros Oriental, Philippines. The Municipality stretches across nine kilometres of coastline, bordered in the north by Bacong, and Zamboanguita in the south. The Dauin coastline was split into three research zones (North, Central and South), each zone 3km long. Nineteen core sites at eleven locations were selected for monitoring. These sites span the variation in coral reef composition, benthic and fish communities across the Municipality, and account for the zoning history of its associated no-take marine protected areas. The 19 core sites each have one 50m transect that runs parallel to the reef crest, between depth ranges of 1 – 6m and 7 – 12m. Surveys are conducted bi-annually to account for seasonal variability, with dry season surveys running from February to July, and wet season surveys running from August to January.



Location of the Municipality of Dauin and IMRs survey sites on Negros Oriental, the Philippines. Maps sourced from GADM database of Global Administrative Areas (2015) under a CC BY licence, used with permission.

2.1 Research Techniques

2.1.1 Benthic Assays

Surveys of sessile benthic organisms were conducted following the Australian Institute of Marine Science (AIMS) LTMP methodology[12,13]. Images were taken along the transect line using a *GoPro* camera held approximately 0.5m above the substrate. One image was taken per 1m interval, totalling fifty images per 50m transect. Analysis of benthic assays used CPCe software[14], where underwater images are overlaid by a matrix of 30 randomly distributed points generated in the full frame of each photo and used for identification. Point overlay was used to characterise the benthos and determine the percentage cover of each type of organism and substrate in the image[15]. The species code data for each image is stored in a .cpc file which contains the image filename, point coordinates and the identified data codes.

Points were identified based on a predetermined codec, which contains all Indo-pacific Scleractinian coral genera, octocorals, hydroids, bivalves, other hexacorals (anemones, corallimorphs and zoanthids), sponge growth forms, "other live" (ascidian, crown of thorns starfish, cyanobacteria, other e.g. fish), algae, seagrass, dead coral and abiotic (see Appendix 7.1 for full codec). The data from individual frames can be combined to produce inter and intra transect and site comparisons via automatically generated Excel spreadsheets. 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. The non-parametric Scheirer–Ray–Hare (SRH) test was used to compare benthic cover between sites and seasons.

Introduction to Benthic Assays:

With the world's coral reefs being severely degraded by the activities of humans, there is a need to efficiently assess and monitor reefs even at the regional and local level[16,17]. Coral Point Count with excel extensions (CPCe) is a visual software designed to quickly and efficiently calculate statistical coral coverage over a specified area through the aid of photo-transects[14]. These transect images are assigned with spatial random points for user's further identification. It can also perform both image calibration and area analysis of the benthic features, and has the ability to automatically generate results in Microsoft Excel. Thus, CPCe is a highly useful tool, particularly in coral reef monitoring, assessment and conservation.

2.1.2 SCUBA Search: Reef Impacts & Coral Mortality

The SCUBA search is designed to provide a more detailed picture of the causes and relative scale of coral mortality, and was conducted following a modified version of AIMS LTMP methodology[12]. SCUBA searches were conducted along the 50 m transect, with a 2 m belt (1m either side of the transect line). 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).

For all of the above, images were captured using a *GoPro* camera, to record a) the impact found, b) the affected coral genera, and c) the size of the affected area and the entire colony (measuring length, width and where possible height). To examine potential differences in impact incidences between seasons, the Kruskal-Wallis rank sum test was used.

Introduction to Reef Impacts and Coral Mortality

SCUBA searches have been used by the LTMP to provide information on sources of coral mortality, which assist in examining the reef in greater detail and interpreting trends in benthic cover at permanent sites. SCUBA searches enable:

I. The detection of low-level populations of COTS. At low densities they are cryptic and more difficult to detect by methodologies such as the manta tow.
II. SCUBA searches provide a method for the detection of juvenile COTS, which because of their small size and cryptic behaviour, are not easily seen in benthic or 3-Dimensional modelling assays.
III. SCUBA searches enable the diver to detect other factors that may be causing coral mortality such as *Drupella spp.*, bleaching or disease (e.g. white syndromes and black band disease).

2.1.3 Diver Operated Stereo Video System (DO-SVS)

Transects were conducted using a Diver-Operated Stereo Video System (DO-SVS; SeaGIS, Melbourne, Australia), comprised of two *GoPro Hero 5 Black* cameras. To minimise potential disturbance to the fish community, cameras were set to record and synchronised prior to entry, and the SVS operator was at the front of the survey team. At the start of the 50m transect, the cameras were orientated parallel to the substrate, angled approximately 20° downwards and kept approximately 0.5m above the substrate. The SVS operator moved at a steady pace (adjusting for currents), filming the reef scape along the 50m transect; transects take approximately 5 - 6 minutes.

EventMeasure V5.25 (SeaGIS, Melbourne, Australia) was used to synchronise SVS footage, calibrate camera measurements, and measure fish encountered along the transect. EventMeasure resolves centre points of each individual fish encountered into distances on a three-dimensional

Introduction to the Diver Operated Stereo Video System

Understanding of fish ecology and our ability to effectively manage fish populations requires accurate data on diversity, abundance and size. Underwater visual census (UVC) surveys have been widely used to collect data on coastal fish assemblages. UVC requires divers to identify and count fishes within a predetermined area, or by distance-based sampling. This is logistically simple, non-destructive, and cost-effective, however the effectiveness for reliable long-term monitoring is influenced by inter-observer variability and inaccuracies in estimating the length of fish and sampling areas. In addition, a combination of identification, counting and size estimations of fish requires extensive training and experience.

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 UVC techniques, and efficiently quantify the abundance and size of reef fish[18,19]. 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.

coordinate system. This allowed the exclusion of fish outside 2.5m either side of and 5m in front of the camera system; side distance restrictions maintain a consistent survey belt along the transect and front distance restrictions prevent variations in visibility (e.g. turbidity, light intensity) from influencing data. Each fish encountered within the transect belt was identified to species level. For fish visible in both cameras, measurements are possible; for those only seen in the left-hand side video, a point identifying the fish to species level was recorded. 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[22]. The genus mean was used when allometric constants for a specific species were not available. For points (where length measurements were not possible), the mean length for the species recorded across all depths and survey sites was used. Where fish were unidentifiable to species level (small size, blurry etc.), entries of family/genus were included in abundance data, but not in diversity or biomass data, as no suitable allometric constants were available. Length at first maturity of all fish species (where available) were obtained from FishBase[22].

Fish species were classified into functional groups; grazers / detritivores, scrapers / small excavators, browsers, detritivores, obligate corallivores, planktivores, invertivores and piscivores/scavengers[20]. The invertivores / sessile group was included with the invertivores. Trophic groups were allocated following the FishBase 'Food Items' table, using the Food I-III hierarchical classification of food items consumed by a species, based on diet composition of >20% of recorded items accessed through FishBase[21,22]. The proportional biomass of each functional group was also calculated at each site. Fish species were also categorised into IUCN Red List Categories[23] (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[22].

Due to the limited number of replicates at this point in the IMR Dauin LTRMP, statistical analysis was limited to mostly descriptive statistics and preliminary trends. Initial statistical testing on fish species abundance and biomass used analysis of similarities (ANOSIM) and non-metric multidimensional scaling (NMDS) to explore differences in community composition. NMDS plots were constructed to explore the relationship between fish communities and seasons using the "vegan" package[24] in R[25]. Continuous variables (coral cover) were converted into categorical variables (high/low, depending on if the value fell above or below the mean for that variable). Multivariate dispersion was used as a measure of beta-diversity. For fish biomass, a Bray-Curtis dissimilarity matrix was constructed based on fourth-root transformed fish species biomass for NMDS. The "indicspecies" package was used to explore potential indicator species between seasons and depths.

2.1.4 3-Dimensional Reef Modelling

A 3D camera rig consisting of two *GoPro Hero 5 Black* cameras placed 0.9m apart on a one-metre long aluminium pole[26] was used to obtain video footage of the survey transect. The cameras were set to wide-angle, resolution of 1080 pixels and 60 frames per second. The principles for this method of stereo-video measurement are described in Harvey and Shortis (1995)[27]. The cameras were faced directly down at the substratum[28] 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. The operator aimed for at least 60% overlap of the path to ensure images can be aligned; preliminary testing indicates this method decreases alignment errors over single passes or higher image intervals[29].

Stills were extracted at a rate of one per 30 frames from both camera videos, which were used to generate a 3D model (Agisoft Metashape Standard 9), using Structure from Motion (SfM) software and photogrammetry principles. Images were aligned with a high accuracy, generic preselection, key point limit of 40,000, tide point limit of 1000, and with an adaptive camera model fitting. The alignment was optimised to fit k4 and a dense cloud was created with medium quality, mild depth filtering, with point colours calculated, and trimmed to 1m either side of the transect. The exported XYZ cloud was rasterised and empty space was removed by filling continuous empty areas with a mask before removing the mask that lay over the transect. Row statistical functions were calculated excluding the masked region;

Introduction to 3-Dimensional Reef Modelling

Structural complexity is a key habitat feature that influences ecological processes by providing a set of primary and secondary resources to organisms, such as shelter from predators and food availability. The spatial configuration and morphology of corals create complex structures that serve as habitats for a large number of species inhabiting coral reefs. As such, structural complexity of coral reefs drives numerous functions directly linked to the resilience of these ecosystems[30,31].

Despite the importance of reef structure in the long-term functioning of these systems, quantifying its complexity is a time-consuming exercise. Therefore, advancing our understanding of how structural complexity influences reef dynamics requires improving our efficiency and ability to quantify multiple metrics of 3D structural complexity in a repeatable way, across spatial extents, whilst maintaining a high resolution.

IMR researchers are making use of rapid advances in technology to monitor reef structural complexity by recreating and measuring reefs in 3D. Using off-the-shelf cameras, the 3D structure of the reef is accurately reconstructed by underwater images taken at pace across a reef transect. These images are aligned and referenced using a technique called photogrammetry, which allows the recovery of the exact position of each pixel in the images, recreating the 3D structure of the reef[32,33].

These 3D models are produced, allowing 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. With advances in photogrammetry software and high performance hardware, automated analyses of structural complexity across all IMR-monitored reefs in Dauin is now possible and at a minimal cost. Characteristics of the reef surface are believed to play an important part in the early life of corals and subsequent reef recovery. We can now measure things we never could before, including the complexity of the reef scale.

surface line length (length), range, Rq (RMS), slope and variation (Gwyddion)[34]. More information on the metrics used is available from Gwyddion[34]. Mantel tests in the "vegan" package[24] in R[25] were used to examine potential correlation between 3D metrics on fish community composition. NMDS plots were constructed to explore the relationship between fish communities and rugosity using the "vegan" package[24] in R[25]. Continuous variables (rugosity) were converted into a categorical variable (high/low depending on if the value fell above or below the mean for that variable). Multivariate dispersion was used as a measure of beta-diversity.

2.1.5 Metadata

Before every survey dive, air temperature (ºC), wind speed (kts), tidal state (low/high, rising/falling), sea state (calm/ slight/ moderate/ rough) and boat activity (number of fishing and diving boats present) were recorded. This can be used in conjunction with any other data collected when needed.

3. RESULTS

3.1 Benthic Composition

Benthic cover across Dauin's reefs show abiotic substrate types dominate (52%), formed primarily of sand (38%) and rubble (10%). This is followed by hard coral cover (21%), dead coral (9%), algae (8%) and sponges (4%) (Fig 3.1.1).

Benthic categories that showed significant differences between dry and wet season were abiotic, dead coral, algae and sponges (Fig. 3.1.2). No categories showed significant differences between seasons without a significant effect of site (sponges), an interaction effect of season and site (abiotic), or both (algae and dead coral) (Table 3.1).

Benthic composition varies greatly between sites (Fig 7.5.0). Four benthic categories showed no significant differences between seasons but between survey sites; coral, bivalves, hydroids and seagrass. The only major benthic category that showed no significant differences between sites or seasons is the category 'Other hexacoral'. The category 'Other live' has not been analysed as this occurs when a CPCe point on the image falls on mobile benthos, therefore on an organism not contributing to the benthic composition.

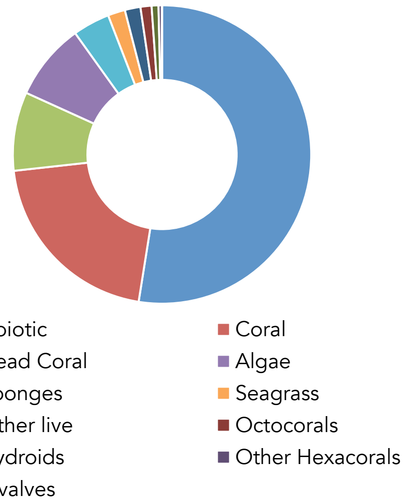


Fig 3.1.1: Relative mean transect cover of major benthic categories along Dauin Reef for the 2019 survey year.

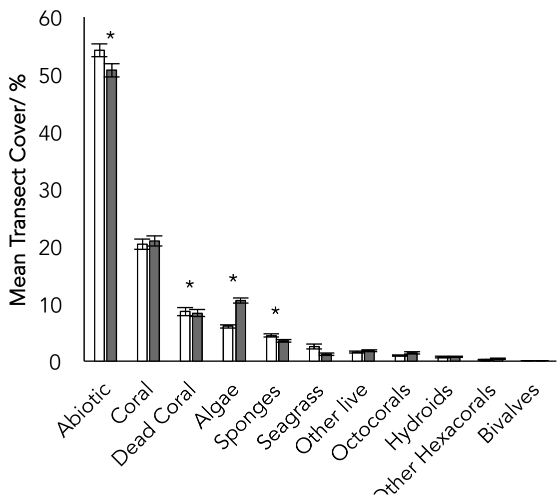
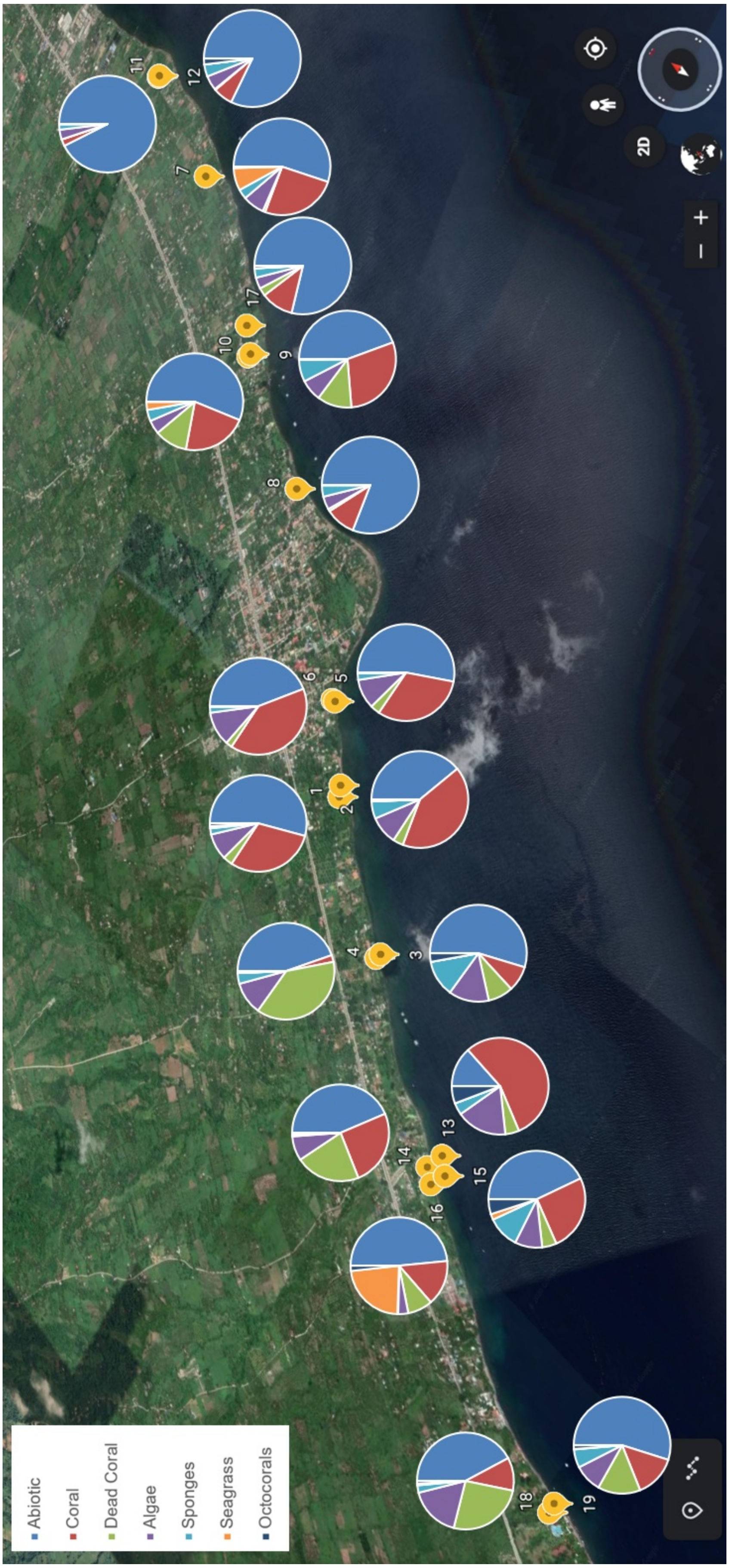


Fig 3.1.2: Mean transect cover (% ± SE) of major benthic categories along Dauin Reef separated by season (dry season (White): Feb 19-July 19 and wet season (Grey): Aug 19-Feb 20). * represents significant differences between seasons (p<0.05).

Table 3.1: Significant effects of season, site and the season*site interaction term on different benthic components. * represents significant differences (p<0.05).

	Season	*Site*	*Interaction*		*Season*	*Site*	*Interaction*		*Season*	*Site*	*Interaction*
Coral		*		Turf algae	*		*	**Sponges**	*	*	
Abiotic	*		*	**Dead coral**	*	*	*	Ball	*		
Rock	*	*		Recently dead coral				Barrel	*		*
Rubble	*	*	*	Dead coral with algae	*	*	*	Branching	*		*
Sand		*		Coral rubble	*	*	*	Encrusting		*	
Algae	*	*	*	**Octocoral**		*	*	Fan		*	*
Coralline algae	*	*	*	**Bivalves**		*		Rope	*	*	*
Halimeda	*	*	*	**Hydroids**		*		Tube	*	*	*
Other algae	*	*	*	**Seagrass**		*		**Other hexacoral**			



Satellite map of survey sites with major benthic category proportions for the 2019 survey year. Graphs on shore side refer to 5m survey sites and those positioned in the water refer to 10m sites.

3.1.1 Coral

A total of 44 Scleractinian coral genera were recorded during the first year of surveys, 41 in dry season and 41 in wet. The coral genera *Acropora, Anacropora, Porites, Echinopora* and *Pocillopora* dominate the Dauin reef system, contributing to 79% of all coral cover between them (29%, 19%, 18%, 7% and 7% respectively) (Fig 3.1.3), with the remaining coral genera contributing less than 3% each (Fig 3.1.4). Three genera were observed only in the dry season; *Alveopora*, *Oxypora* and *Scolymia*. Three genera were observed only in wet season; *Caulastrea*, *Polyphyllia* and *Sandalolitha*. None of the coral genera with percent cover equal to or greater than 0.1% showed any significant differences between seasons (Fig 3.1.4), although 10 out of 15 genera with percent cover greater than 0.1% showed significant differences between sites; *Favia*, *Goniopora*, *Montipora*, *Pectinia* and *Turbinaria* showed no significant differences. Diversity indices show minimal, yet positive changes to genera diversity, richness and evenness from dry to wet season (Table 3.2).

Looking at the five most dominant coral genera across sites, it is clear that most sites with higher coral cover tend to be dominated by one, or a few, coral genera (Fig 3.1.5). For example, Poblacion District II at 10 (Site 1) and 5m (Site 2), are sites with proportionally very high *Porites* cover. *Echinopora* dominates Poblacion District I at 10m (Site 5). *Anacropora* dominates Masaplod Sur and Masaplod Sur MPA, both at 5 and 10m (Sites 13-16). Many sites are dominated by *Acropora*, such as Bulak II at 10m (Site 7), Lipayo I Sur at 10 (Site 9) and 5m (Site 10), and Maayong Tubig at 5m (Site 18).

Coral cover varies according to site, with no significant changes from dry to wet season (Table 3.2). Masaplod Sur MPA at 10m (Site 13) showed significantly greater coral cover (51.3%) than all other survey sites (Fig 3.1.6, 7.2.1). The sites with the next highest coral cover are Poblacion District II at 10m (Site 1) and Poblacion District I at 5m (Site 6), both with 39.7%. Sites with the lowest coral cover (<5%) are Masaplod Norte at 5m (Site 4) and Bulak I at 5m (Site 12) (Fig 3.1.6, 7.2.1).

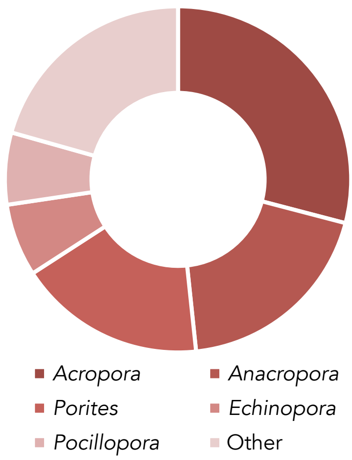


Fig 3.1.3: Relative mean transect cover of most common coral genera along Dauin Reef for 2019 survey year, where the colour gradient from dark to light represents descending percentiles.

Table 3.2: Diversity indices for the 2019 survey year as a whole, and separated by season. Mean genera richness refers to per transect, whereas total richness refers to the whole Dauin study area.

Diversity Index	*Year*	*Dry*	*Wet*	*Trend*
Shannon (SW)	1.38	1.29	1.48	↗
Simpson (1-D)	0.57	0.53	0.62	↗
Mean Genera richness (S)	13.21	12.79	13.63	↗
Total Genera richness (S)	44	41	41	→
Pielou's Evenness (J')	0.55	0.51	0.58	↗

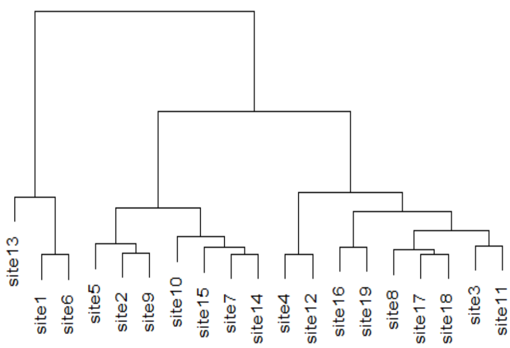


Fig 3.1.6: Cluster dendrogram showing similarities between coral cover of different sites

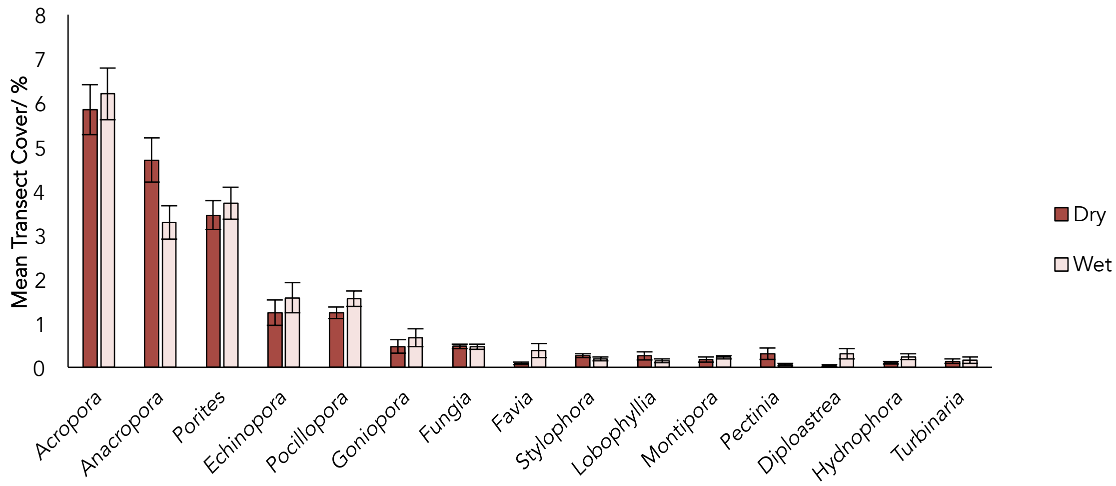


Fig 3.1.4: Mean transect cover (% ± SE) of 15 most common coral genera along Dauin Reef separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

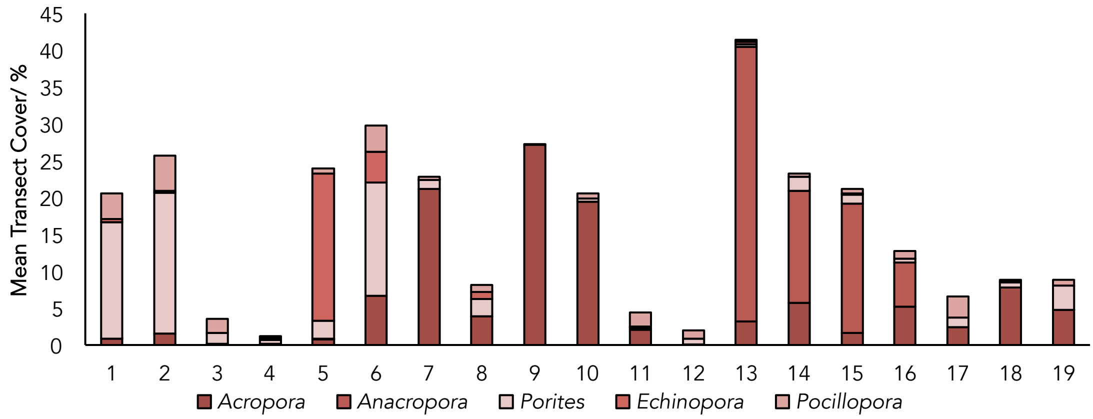


Fig 3.1.5: Mean transect cover (%) of 5 most common coral genera along Dauin Reef survey sites for the 2019 survey year.

3.1.2 Abiotic Cover

Sand, rubble and rock comprise 99.98% of abiotic coverage, with shell, trash and fishing gear as the remaining 0.02% (Fig 7.2.1). Sites with highest abiotic percent cover include Bulak I 10m (Site 11) and 5m (Site 12), with 76.1% and 90.1% respectively, Lipayo II at 10m (Site 8), with 80.1% and Lipayo I Norte at 10m (Site 17), with 78.1%. Sites with lowest abiotic cover include Masaplod Sur MPA at 10m (Site 13), Poblacion District II at 10m (Site 1), Masaplod Sur at 10m (Site 15) and Maayong Tubig at 5m (Site 18), with 12.5%, 37.1%, 40.1% and 41.7% respectively.

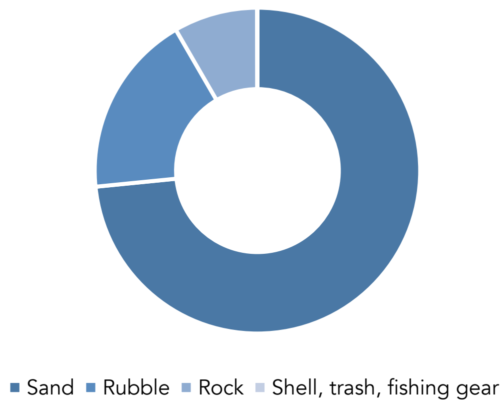


Fig 3.1.7: Relative mean transect cover (%) of abiotic categories along Dauin Reef survey sites for the 2019 survey year, where the colour gradient from dark to light represents descending percentiles.

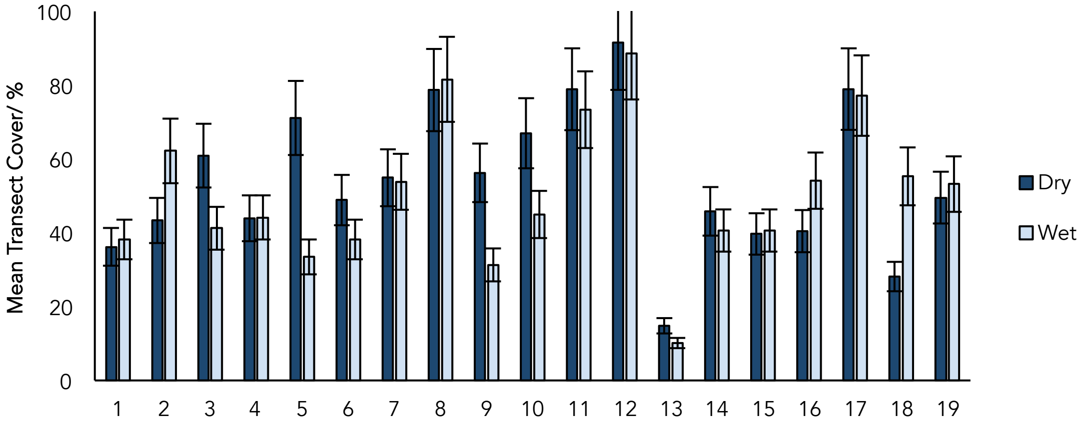


Fig 3.1.8: Mean abiotic transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

Abiotic cover as a major category shows an overall decline from dry to wet season, but differences vary between sites, as shown by the significant interaction term (Table 3.1, Fig 3.1.8). Poblacion District I at 10m (Site 5) shows the greatest decrease in abiotic percent cover, of 37.7%, from 71.1% in the dry season to 33.5% in the wet. Lipayo I Sur at 10m (Site 9) and 5m (Site 10) also show significant declines in abiotic cover of 25.0% and 22.0% respectively. Conversely, Maayong Tubig at 5m (Site 18), Poblacion District II at 5m (Site 16) all show increases of abiotic increases of abiotic cover from dry to wet season, with 27.1%, 18.8% and 13.7% increases respectively. The three dominant abiotic substrates (rock, rubble and sand) show different relationships between season and site.

Rock coverage changes significantly with season and site (Table 3.1). Poblacion District II at 10m (Site 1) has significantly higher percent rock cover than all other sites, with an average of 16.0% (Fig 7.2.2, 7.2.3). This is followed by Poblacion District II at 5m (Site 2), Poblacion District I at 5m (Site 6), and Maayong Tubig at 10m (Site 19) and 5m (18), with 8.5%, 7.6%, 7.3% and 6.7. Sites with lowest percent rock cover are Bulak I at 5m (Site 12), Bulak II at 10m (Site 7), and Lipayo I Sur at 10m (Site 9) and 5m (Site 10), with 0.5%, 0.7%, 1.1% and 1.2% respectively.

Seasonally, percent rock cover increased significantly from 3.9% in the dry season to 4.8% in the wet, across Dauin as a whole.

Sand cover changes significantly only with site (Table 3.1, Fig 3.1.9, 7.2.4); Bulak I at 5m (Site 12) has the highest average percent sand cover at 87.0%, followed by Lipayo II at 10m (Site 8), Bulak I at 10m (Site 11) and Lipayo I Norte at 10m (Site 17), with 76.9%, 73.4% and 72.1% respectively. Sites with the lowest average percent sand cover are Poblacion District II at 10m (Site 1), Poblacion District I at 10m (Site 5), Masaplod Sur within the MPA boundaries at 10m (Site 13) and Poblacion District I at 5m (Site 6), with 7.8%, 8.4%, 8.6% and 11.8% respectively.

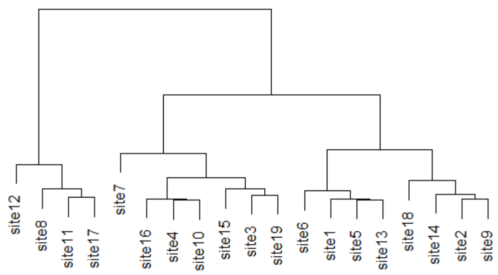


Fig 3.1.9: Cluster dendrogram showing similarities between sand cover of different sites

Rubble coverage varies with site, season and the interaction term (Table 3.1). Looking at site, Poblacion District I at 10 (Site 5) and 5m (Site 6) show significantly higher rubble percent cover than all other sites, with 38.7% and 24.2% respectively (Fig 3.1.10, 7.2.5). All other sites have rubble cover below 16%. Sites with the lowest rubble cover are Lipayo II at 10m (Site 8), Masaplod Norte at 5m (Site 4), Bulak I at 10m (Site 11) and Masaplod Sur at 5m (Site 16), with 0.4%, 1.0%, 1.0% and 1.3% respectively.

Seasonally, percent rubble cover shows a significant decline, from 12.6% in the dry season to 6.5% in the wet. Although this is an average decrease in rubble cover of ~6%, the changes in percent rubble cover between seasons are site specific, with 12 out of 19 sites showing a decrease in rubble cover, and the other 7 showing increases (Fig 3.1.11). Sites that show the greatest decreases in rubble cover include Poblacion District I at 10m (Site 5), Lipayo I Sur at 5 (Site 10) and 10m (Site 9), Masaplod Norte at 10m (Site 3) and Poblacion District I at 5m (Site 6), with decreases of 45.2%, 25.8%, 19.5%, 18.2% and 16.7%. Sites with the greatest increases in rubble cover include Maayong Tubig at 5 (Site 18) and 10m (Site 19), Poblacion District II at 5m (Site 2), Masaplod Sur outside of MPA boundaries at 5m (Site 16) and Bulak I at 10m (Site 11), with increases of 20.4%, 7.9%, 6.4%, 1.5% and 1.3% respectively.

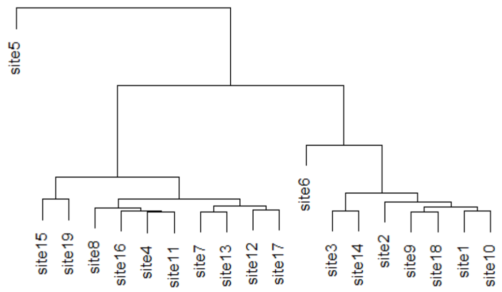


Fig 3.1.10: Cluster dendrogram showing similarities between rubble cover of different sites

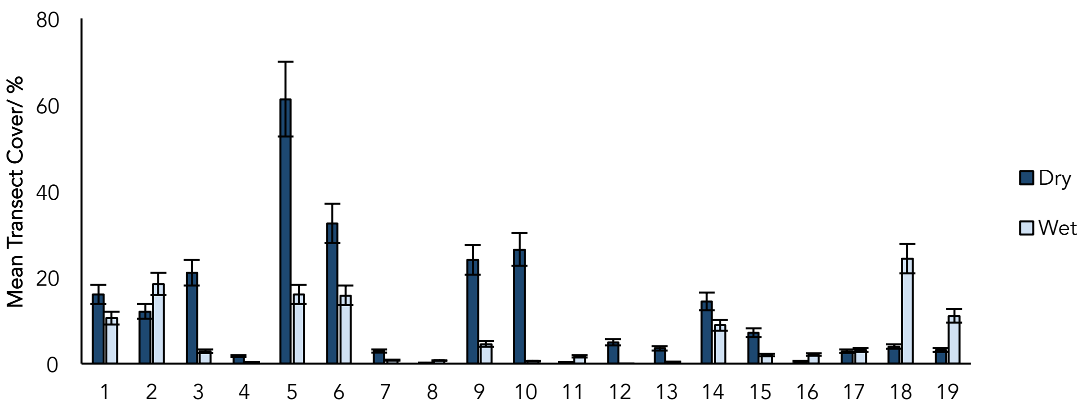


Fig 3.1.11: Mean rubble transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

3.1.3 Dead Coral

Coral rubble (CR) contributes to on average 79.4% of dead coral, whereas dead coral with algae (DCA) and recently dead coral (RDC) contribute 18.2% and 2.3% respectively (Fig 3.1.12). Sites with highest annual dead coral percent cover are Masaplod Norte at 5m (Site 4), Maayong Tubig at 5m (Site 18) and Masaplod Sur MPA at 5m (Site 14), with 37.4%, 25.4% and 21.4% respectively. All other sites have annual average dead coral percent cover below 15%. Sites with the lowest annual percent dead coral cover include Bulak I at 5 (Site 12) and 10m (Site 11), Lipayo II at 10m (Site 8) and Bulak II at 10m (Site 7), with 0.0%, 0.3%, 0.8% and 0.8% respectively.

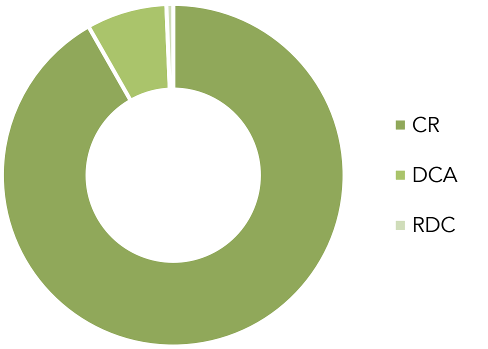


Fig 3.1.12: Relative mean transect cover of dead coral categories (CR: coral rubble, DCA: dead coral with algae, RDC: recently dead coral) along Dauin Reef for 2019 survey year.

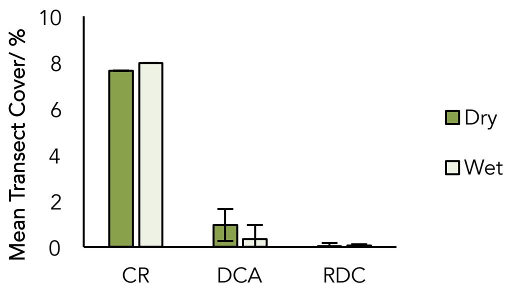


Fig 3.1.13: Mean dead coral transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20) and type; CR: coral rubble, DCA: dead coral with algae, RDC: recently dead coral.

Dead coral cover as a category significantly decreases from dry to wet season, but seasonal changes vary between sites, as shown by the significant interaction term (Table 3.1, Fig 3.1.13). Lipayo I Sur at 5m (Site 10) shows the greatest increase in dead coral percent cover, of 20.9%, from 0.5% in the dry season to 21.4% in the wet. Lipayo I Sur at 10m (Site 9) and Masaplod Norte at 10m (Site 3) also show significant increases in dead coral cover, 14.7% and 12.3% respectively. Conversely, Maayong Tubig at 10 (Site 18) and 5m (Site 19), and Masaplod Norte at 5m (Site 4) all show decreases of dead coral cover from dry to wet season, with 49.1%, 15.4% and 6.9% decreases respectively. Within the dead coral category, relationships of percent cover, season and site are consistent; CR and DCA percent cover both show significant changes with season, site and the season*site interaction term (Table 3.1). RDC, contributing to a very minor portion of benthic cover, shows no relationships with site, season or the interaction term.

Coral Rubble cover varies with site; Masaplod Norte at 5m (Site 4) shows significantly higher CR percent cover than all other sites, with 37.3% (Fig 3.1.14, 7.2.6). Other sites with high percent CR cover include Maayong Tubig at 5m (Site 18) and Masaplod Sur MPA at 5m (Site 14), with 25.1% and 21.2% respectively. All other sites have CR percent cover below 15%. Sites with lowest CR cover are Bulak I at 5m (Site 12), Bulak II at 10m (Site 7), Bulak I at 10m (Site 11), (Site 8) and Lipayo I Sur at 10m (Site 9), all of which have less than 1% CR cover.

Seasonally, average CR cover increases from 7.6% in dry season to 8.0% in wet (Fig 3.1.14). Although this equates to change of 0.4%, percent changes between seasons are site specific. 13 of 19 sites show an increase in CR cover; greatest increases are seen at Lipayo I Sur at 5 (Site 10) and 10m (Site 9), with increases of 21.0% and 18.2% respectively, and greatest decreases to CR cover are seen at Maayong Tubig at 5 (Site 18) and 10m (Site 19), with decreases of 49.2% and 16.2% respectively (Fig 3.1.15).

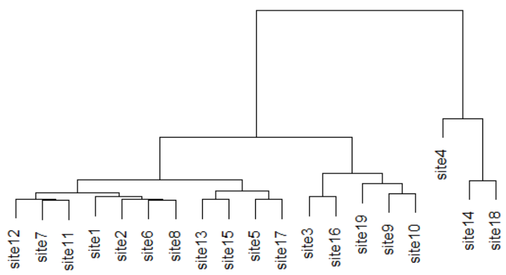


Fig 3.1.15: Cluster dendrogram showing similarities between coral rubble cover of different sites.

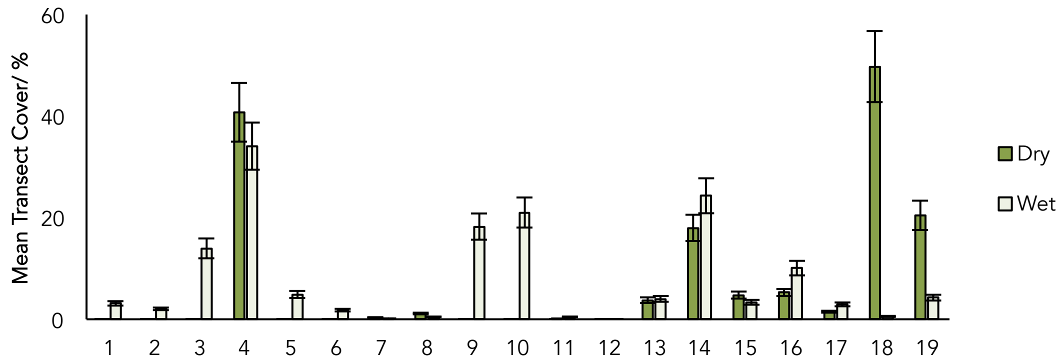


Fig 3.1.14: Mean coral rubble transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

Dead Coral with Algae average percent cover for sites is much lower, ranging from 0-2.1%, with Lipayo I Sur 10m (Site 9), Poblacion District II 5 (Site 2) and 10m (Site 1), and Poblacion District I at 5m (Site 6) having average DCA coverage above 1% (Fig 7.2.7, 7.2.8). All other sites have negligible coverage of DCA.

Seasonally, average DCA cover shows a decrease from 0.9% to 0.3%. Although this equates to change of 0.6%, percent changes between seasons are site specific (Fig 7.2.7, 7.2.8). 13 of 19 sites show a decrease in DCA cover; greatest decreases are seen at Lipayo I Sur at 10m (Site 9), Poblacion District II at 10 (Site 1) and 5m (Site 2), with decreases of 3.5%, 2.7% and 2.2% respectively, and greatest increases are seen at Maayong Tubig at 10m (Site 19), Masaplod Sur at 5m (Site 16) and Masaplod Sur MPA at 5m (Site 14), with increases of 0.7%, 0.7% and 0.5% respectively.

3.1.4 Algae

Turf algae, coralline algae and other algae combined contribute to 92.4% of algae recorded, with *Halimeda* contributing 7.6% and sargassum contributing <0.01% (Fig 3.1.16). Sites with the highest annual algae percent cover are Maayong Tubig at 5m (Site 18), Masaplod Sur MPA at 10m (Site 13) and Masaplod Norte at 10m (Site 3), with 17.0%, 15.7% and 12.6% respectively. Sites with the lowest annual algae percent cover are Bulak I at 5m (Site 12), Masaplod Sur at 5m (Site 16) and Lipayo I Norte at 10m (Site 17), with 3.2%, 3.3% and 3.7% respectively.

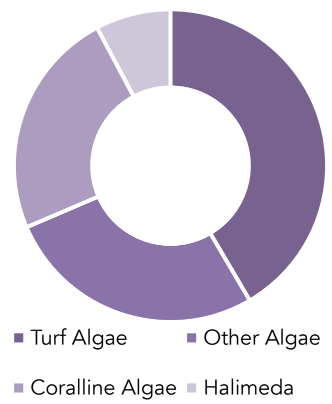


Fig 3.1.16: Relative mean transect cover of algae categories along Dauin Reef for 2019 survey year.

Algae cover significantly increases from dry to wet season, but differences vary between sites, as shown by the significant interaction term (Table 3.1, Fig 3.1.17). Maayong Tubig at 5m (Site 18) shows the greatest increase in algae percent cover, of 20.2%, from 6.9% in dry season to 27.1% in wet. Poblacion District I at 10m (Site 5), Masaplod Norte at 10 (Site 3) and 5m (Site 4) also show significant increases in algal cover, 16.8%, 9.4 and 9.2% respectively. Conversely, Poblacion District II at 5m (Site 2), Lipayo II at 10m (Site 8), and Bulak I at 10m (Site 11) all show decreases of algae cover from dry to wet season, with 11.8%, 2.9% and 1.9% decreases respectively.

Within the algae category, relationships of percent cover, season and site are largely consistent; coralline algae, *Halimeda* and other algae cover all show significant changes with season, site and the interaction term (Table 3.1, Fig 3.1.18). Turf algae shows a significant change with season and the season*site interaction term, but not site as a standalone. Sargassum shows no significant relationships with these factors.

Turf algae shows a significant increase from 1.7% in dry season to 5.2% in wet. Although this equates to a 3.5% increase, the changes in turf algae cover between seasons are site specific, with 13 out of 19 sites showing an increase in turf algae cover, and six showing decreases (Fig 3.1.19). Sites that show greatest increases in turf algae cover include Maayong Tubig at 5m (Site 18), Masaplod Norte at 5m (Site 4), Poblacion District I at 10m (Site 5), and Masaplod Norte at 10m (Site 3), with increases of 23.4%, 12.2%, 8.3% and 7.2%. Sites with greatest decreases in turf algae cover include Poblacion District II 5m (Site 2), Lipayo II at 10m (Site 8) and Masaplod Sur at 10m (Site 15), with decreases of 3.6%, 2.9% and 1.7% respectively.

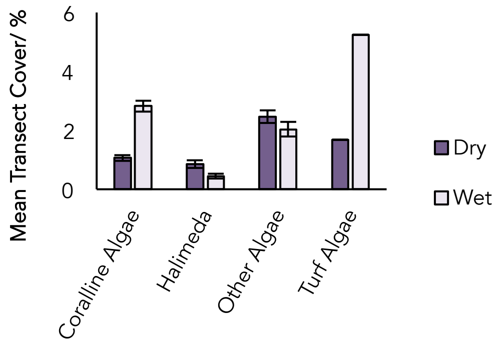


Fig 3.1.17: Mean algae transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20) and type.

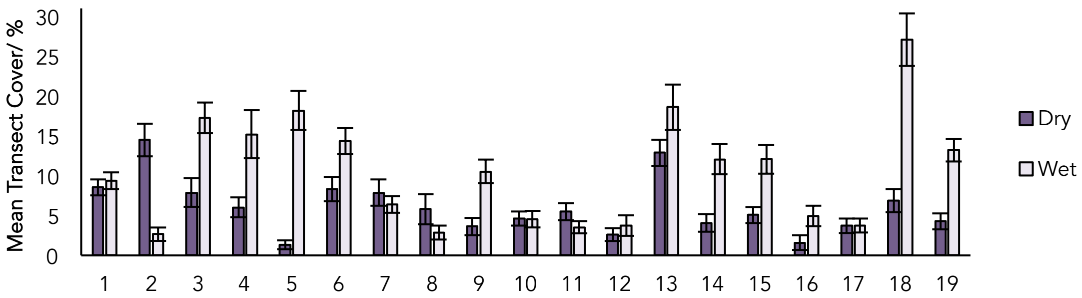


Fig 3.1.18: Mean algal transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

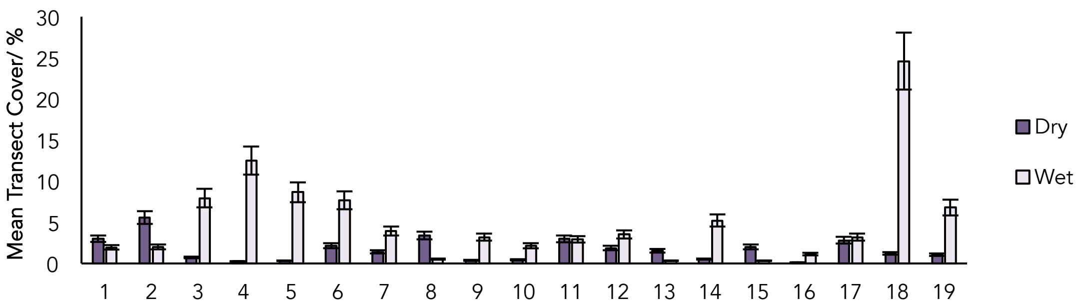


Fig 3.1.19: Mean turf algae transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

Coralline algae cover varies with site, season and the interaction term. Looking at site, Poblacion District I at 10m (Site 5), Poblacion District II at 10m (Site 1), Masaplod Norte at 10m (Site 3), Lipayo I Sur at 10m (Site 9) and Maayong Tubig at 10m (Site 19) show significantly higher coralline algae percent cover than all other sites, with 5.2%, 4.7%, 4.5%, 4.1% and 3.8% respectively (Fig 3.1.20, 7.2.9). All other sites have coralline algae cover below 2.5%. Sites with the lowest coralline algae cover are Masaplod Sur at 5m (Site 16), Bulak I at 5m (Site 12), Lipayo I Sur at 5m (Site 10) and Lipayo I Norte at 10m (Site 17), with 0.1%, 0.2%, 0.3% and 0.5% respectively.

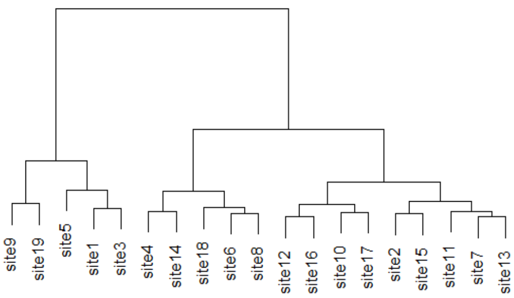


Fig 3.1.20: Cluster dendrogram showing similarities between coralline algal cover of different sites

Seasonally, coralline algae cover shows a significant increase from 1.1% in the dry season to 2.8% in the wet (Fig 3.1.21). Although this equates to an average increase in coralline algae cover of 1.6%, the changes in percent coralline algae cover between seasons are site specific, with 13 out of 19 sites showing an increase. Sites that show greatest increases in coralline algae cover include Poblacion District I at 10m (Site 5), Masaplod Norte at 10m (Site 3), Lipayo I Sur at 10m (Site 9) and Poblacion District II at 10m (Site 1), with increases of 8.5%, 6.5%, 6.2% and 4.7%. Sites with greatest decreases in coralline algae cover include Bulak I at 10m (Site 11) and Masaplod Sur outside at 5m (Site 15), with decreases of 1.4% and 0.2% respectively.

Halimeda cover varies with site, season and the interaction term, although the response differs from that of coralline algae. Looking at site, Masaplod Norte at 10m (Site 3), Poblacion District I at 5m (Site 6), Poblacion District II at 5m (Site 2), Masaplod Norte at 5m (Site 4) and Lipayo I Sur at 5m (Site 10) have significantly higher *Halimeda* percent cover than all other sites, with 2.6%, 2.2%, 2.2%, 2.1% and 1.7% respectively. All other sites have less than 1% *Halimeda* cover. Poblacion District I at 10m (Site 5), Bulak II at 10m (Site 7), Lipayo II at 10m (Site 8), Bulak I at 10m (Site 11) and Maayong Tubig at 10m (Site 19) all had no records of *Halimeda* along the transects (Fig 7.2.10, 7.2.11).

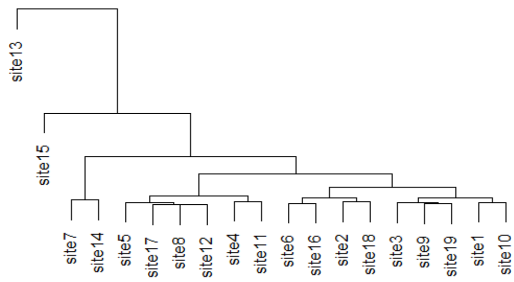


Fig 3.1.22: Cluster dendrogram showing similarities between other algae cover of different sites

Seasonally, percent *Halimeda* cover shows a significant decrease, from 0.8% in dry season to 0.4% in wet. Although this equates to an average decrease in *Halimeda* cover of 0.4%, changes in percent *Halimeda* cover between seasons are site specific, with 7 out of the 13 sites with *Halimeda* showing an increase. Sites that show greatest increases in *Halimeda* cover include Masaplod Sur MPA at 5m (Site 14), Lipayo I Sur at 5m (Site 10) and Masaplod Sur at 5m (Site 16), with increases of 0.6%, 0.5% and 0.5% respectively. Sites with the greatest decreases in *Halimeda* cover include Poblacion District II at 5m (Site 2), and Masaplod Norte at 5 (Site 4) and 10m (Site 3), with decreases of 4.1%, 3.4% and 2.3% respectively.

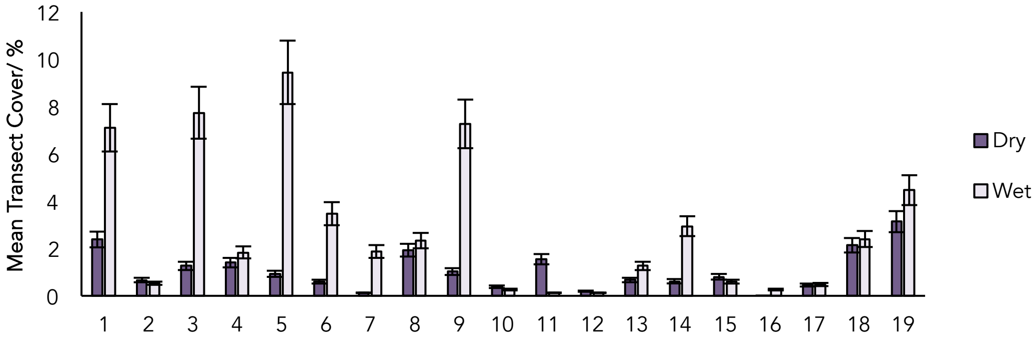


Fig 3.1.21: Mean coralline algae transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

Other algae, which includes macroalgae such as *Turbiniaria spp.*, *Dictyota spp.* and *Udotea spp.*, also varies with site, season and the interaction term. Looking at site, Masaplod Sur and Masaplod Sur MPA at 10m (Site 15 and 13), Bulak II at 10m (Site 7) and Masaplod Sur MPA at 5m (Site 14) have higher 'other algae' percent cover than other sites, with 13.7%, 6.5%, 3.4% and 3.1% respectively (Fig 3.1.22, 7.3.2). All other sites have less than 3% 'other algae' cover. Poblacion District I at 10m (Site 5), Lipayo I Norte at 10m (Site 17), Bulak I at 5m (Site 12), Lipayo II at 10m (Site 8), Masaplod Norte at 5m (Site 4) and Bulak I at 10m (Site 11) all had 'other algae' percent cover less than 1%.

Seasonally, percent 'other algae' cover shows a significant decrease, from 2.5% in dry season to 2.0% in wet (Fig 3.1.23). Although this equates to an average decrease in 'other algae' cover of 0.5%, changes in percent cover between seasons are site specific, with 5 out of 19 sites showing an increase in 'other algae'. Sites with greatest decreases in 'other algae' cover include Bulak II at 10m (Site 7), Poblacion District II at 5m (Site 2) and Maayong Tubig at 5m (Site 18), with decreases of 5.7%, 3.9% and 3.4% respectively. Sites that show the greatest increases in 'other algae' cover include Masaplod Sur and Masaplod Sur MPA at 10m outside (Site 15 and Site 13), and Maayong Tubig at 10m (Site 19), with increases of 8.7%, 6.3% and 1.9% respectively.

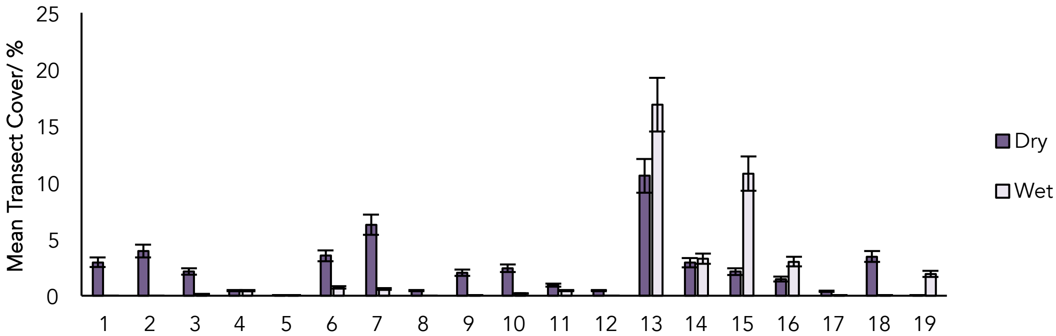


Fig 3.1.32: Mean other algal transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

3.1.5 Sponge

Encrusting, branching and tube sponge combined contribute to 89.7% of sponge recorded, with rope sponge contributing 6.7% and ball, barrel and fan sponges contributing 3.6% combined (Fig 3.1.33, 3.1.34). The percent cover of sponge across Dauin's reefs decreased significantly from dry to wet season. There are also significant differences in percent sponge cover between sites (Fig 3.1.35, 7.2.12), although there is no interaction effect of site and season (Table 3.1).

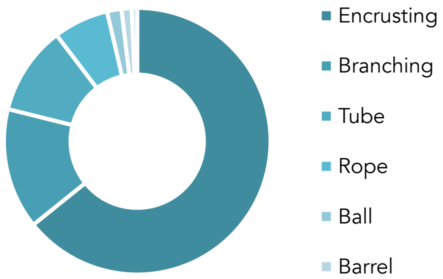


Fig 3.1.33: Relative mean transect cover of sponge categories along Dauin Reef for 2019 survey year, where the colour gradient from dark to light represents descending percentiles.

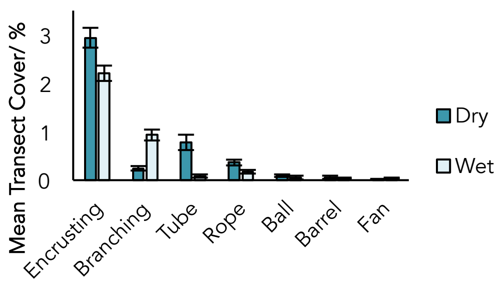


Fig 3.1.34: Mean sponge transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20) and growth form.

Masaplod Norte at 10m (Site 3) and Masaplod Sur at 10m (Site 15) show the greatest mean percent sponge cover, significantly higher than all other sites, with 11.3% and 10.0% respectively. Sites with the lowest sponge percent cover are Masaplod Sur at 5m, both within and outside of the MPA boundaries (Site 14 and 16 respectively), which have less than 1% sponge cover. Within the sponge category, all of the 7 growth forms studied show significant differences between seasons, sites and/or the interaction term (Table 3.1, Fig 3.1.35). Ball, barrel and fan sponges all have average percent covers of less than 0.1% each, hence significant differences are minor.

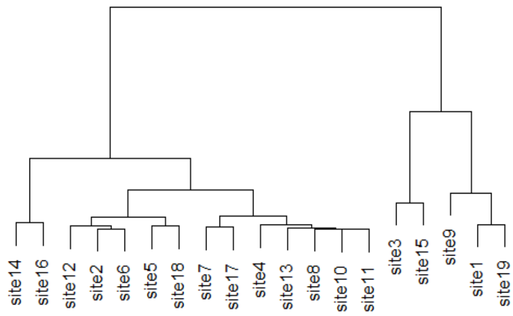


Fig 3.1.35: Cluster dendrogram showing similarities between sponge cover of different sites

Encrusting sponge cover varies significantly only between sites (Table 3.1); Masaplod Norte at 10m (Site 3) has significantly greater encrusting sponge cover than all other sites, with an average of 9.5%, followed by Lipayo I Sur at 10m (Site 9) and Poblacion District II at 10m (Site 1), with 6.1% and 4.4% respectively (Fig 3.1.36, 7.2.13). Sites with the lowest encrusting sponge cover are Masaplod Sur and Masaplod Sur MPA at 5m (Site 16 and Site 14), Masaplod Sur at 10m (Site 15), Maayong Tubig at 5m (Site 18), Bulak I at 5m (Site 12) and Masaplod Sur MPA at 10m (Site 13), which have percent covers of less than 1%.

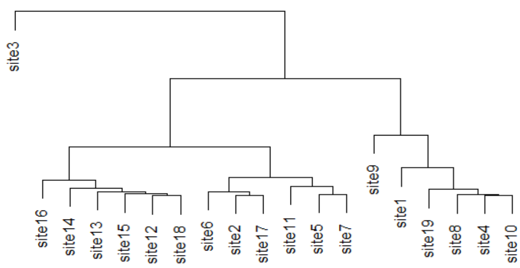


Fig 3.1.36: Cluster dendrogram showing similarities between encrusting sponge cover of different sites

Branching sponge varies significantly between season (Fig 3.1.37), with an average of 0.2% in dry season and 0.9% in wet. The effect of season is site specific, as shown by the significant interaction term (Table 3.1). Sites with greatest increases in branching sponge cover include Masaplod Sur at 10m (Site 15), Masaplod Sur MPA at 10m (Site 13) and Maayong Tubig at 10m (Site 19), with increases of 5.3%, 3.1% and 2.9% respectively. Sites that show greatest decreases in branching sponge cover include Lipayo Sur I at 10m (Site 9), Poblacion District II at 10m (Site 1) and Masaplod Norte at 5m (Site 4), with declines of 1.2%, 1.0% and 0.4% respectively.

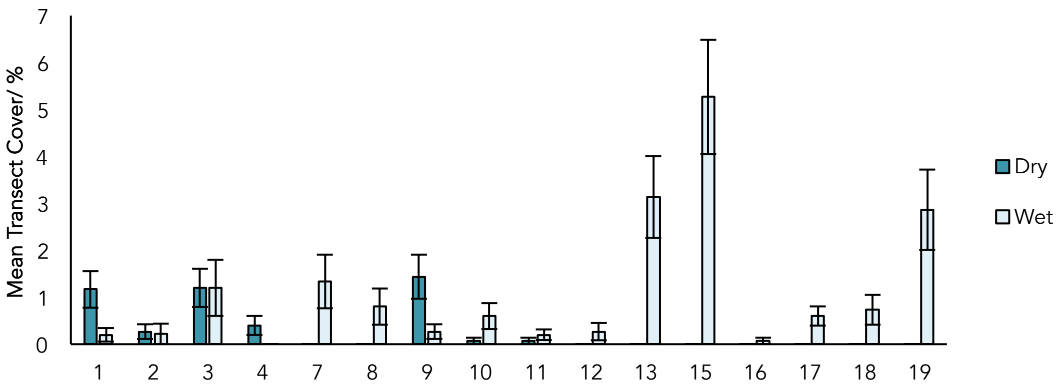


Fig 3.1.37: Mean branching sponge transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

Tube sponge cover varies with site, season and the interaction term. Masaplod Sur at 10m (Site 15) has significantly higher tube sponge cover than all other sites, at 6.6%. All other sites have less than 1% cover, and only 10 out of 19 sites had records of tube sponge along the transect. (Fig 7.2.14, 7.2.15)

Seasonally, percent tube sponge cover significantly decreases, from 0.8% in dry season to 0.1% in wet. Although this equates to an average decrease of 0.7%, changes in percent tube sponge cover between seasons are site specific, with 6 out of 10 sites showing a decrease. Masaplod Sur at 10m (Site 15) shows the greatest decrease in tube sponge cover, of 13.3% down to 0% in the wet season. All other sites show fluctuations in tube sponge cover of less than 0.5%. The only sites that show increases in tube sponge cover are Bulak I at 5 (Site 12) and 10m (Site 11), and Maayong Tubig at 10m (Site 19), with increases of 0.5%, 0.1% and 0.3% respectively.

Rope sponge cover varies with site, season and the interaction term. Looking at site, Maayong Tubig at 5 (Site 18) and 10m (Site 19), and Masaplod Sur MPA at 10m (Site 13) have significantly higher rope sponge percent cover than all other sites, with 1.3%, 1.0% and 1.0% respectively. All other sites have less than 1% rope sponge cover. Poblacion District II at 5 (Site 1) and 10m (Site 2), Lipayo I Sur at 10m (Site 10), Bulak I at 5m (Site 12) and Masaplod Sur at 10m (Site 15) all had no records of rope sponge along the transect (Fig 7.2.16, 7.2.17).

Seasonally, percent rope sponge cover shows a significant decrease, from 0.4% in dry season to 0.2% in wet (Fig 7.2.18). Although this equates to an average decrease in rope sponge cover of 0.2%, changes in percent rope sponge cover between seasons are site specific, with 8 out of 14 sites with rope sponge showing a decrease. Sites that show the greatest decreases in rope sponge cover include Poblacion District II at 5m (Site 2) and

Masaplod Sur MPA at 10m (Site 13), with decreases of 2.0% and 1.1% respectively. All other sites show fluctuations in rope sponge cover of less than 1%. Sites with the greatest increases in rope sponge cover include Masaplod Norte at 10m (Site 3) and Bulak I at 10m (Site 11), with increases of 0.6% and 0.4% respectively.

Ball sponge cover significantly changes only with season; site has no impact on ball sponge cover, or on the effect of season on ball sponge cover. Ball sponge cover decreased from wet to dry season, with 0.09% cover in the dry season and 0.05% in the wet (Fig 3.1.34).

Barrel sponge cover also varies between season, but again the change in cover is site specific (Table 3.1); for all sites except Lipayo I Norte at 10m (Site 17), this sponge type is recorded only in the dry or wet season, not both, accounting for the significant changes in barrel sponge percent cover (Fig 7.2.19).

Fan sponge cover varies significantly with site, but the season*site interaction also has a significant effect on fan sponge cover. Looking at site, only 7 out of the 19 survey sites had recorded presence of fan sponge. Of those that did, mean percent cover was no more than 0.25%. Poblacion District II at 10m (Site 1) has significantly higher fan sponge percent cover than all other sites, with 0.2%. All other sites have less than 0.1% fan sponge cover (Fig 7.2.20, 7.2.21).

Seasonally, percent fan sponge cover shows no significant change from dry to wet season (Table 3.1, Fig 7.2.22). Having said this, there is a significant season*site interaction effect on fan sponge cover (Table 3.1). This is largely due to the fact that when fan sponge is present at a site, it is in such low quantities that it almost exclusively appears only in one season or the other; the only case with fan sponge recorded during both seasons is at Poblacion District II at 10m (Site 1).

3.1.6 Seagrass

Seagrass was recorded along the transects of 7 survey sites, although it accounts for on average only 1.9% of the benthic composition of Dauin's reefs, as 15 of 19 sites show negligible percent seagrass cover (<1%). The highest seagrass percentage cover was recorded at Masaplod Sur at 5m (Site 16), at 22.2%, significantly higher than all other sites (Fig 7.2.23, 7.2.24). Other sites with significantly greater average percent cover of seagrass include Bulak II at 10m (Site 7) with 7.4%, Lipayo I Sur at 5m (Site 10) with 2.7% and Masaplod Sur at 10m (Site 15), with 1.8%. There was no significant difference between seagrass percent cover between dry and wet season (Table 3.1).

3.1.7 Hydroids

Hydroids represent a minor component of the benthic composition of Dauin's reefs, averaging a coverage of 0.7%. Most sites showed negligible hydroid coverage (<1%), although the sites with highest percentage cover, Bulak I at 10m (Site 11) and Poblacion District II at 10m (Site 1), showed an average hydroid coverage of 4.0% and 3.6% respectively, significantly higher than most other sites (Fig 7.2.25, 7.2.26). There was no significant difference between hydroid percent cover between the dry and the wet season (Table 3.1).

3.1.8 Bivalves

Bivalves contribute on average 0.02% to the benthic composition of Dauin's reefs, as the least prevalent major category (Fig 3.1.1). All sites show negligible bivalve coverage (<1%); Masaplod Norte at 10m (Site 3) has the highest bivalve coverage. Other site with bivalves recorded were Poblacion District II at 10m (Site 1), Lipayo I Sur at 10m (Site 9), Poblacion District I at 5m (Site 6) and Masaplod Norte at 5m (Site 4) (Fig 7.2.27, 7.2.28). There was no significant difference between bivalve percent cover between the dry and the wet season (Table 3.1)

3.2 Reef Impacts & Coral Mortality

A total of 657 impacts were recorded throughout the 2019 survey year across Dauin's reefs, with similar total counts per season (dry: 333, wet: 324). However, when examining counts per replicate, an average of 10.6 impacts per 100m^2 was seen across the entire survey year, with 8.5 in dry season and 14.1 in wet. Coral bleaching has been the most prevalent impact during the 2019 research year, followed by *Drupella spp.* feeding activity, unknown scarring and trash (Fig 3.2.1). No significant differences were observed in bleaching incidences between seasons (Fig 3.2.2) or sites. Incidences of *Drupella spp.* feeding activity, unknown scarring, trash and direct destruction were significantly higher during wet season (Fig 3.2.2). An increase in coral bleaching and disease incidence was found, although not significant. Fishing gear, stone fishing and COTS were all found only during dry season (Fig 3.2.2).

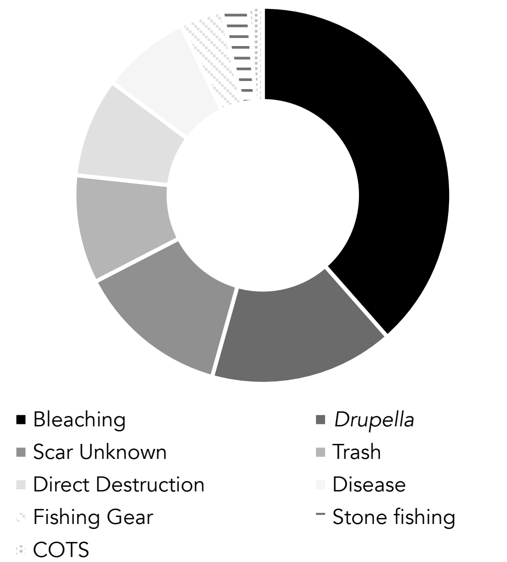


Fig 3.2.1: Relative occurrence of recorded impacts along Dauin Reef for 2019 survey year, where the colour gradient from dark to light represents descending percentiles.

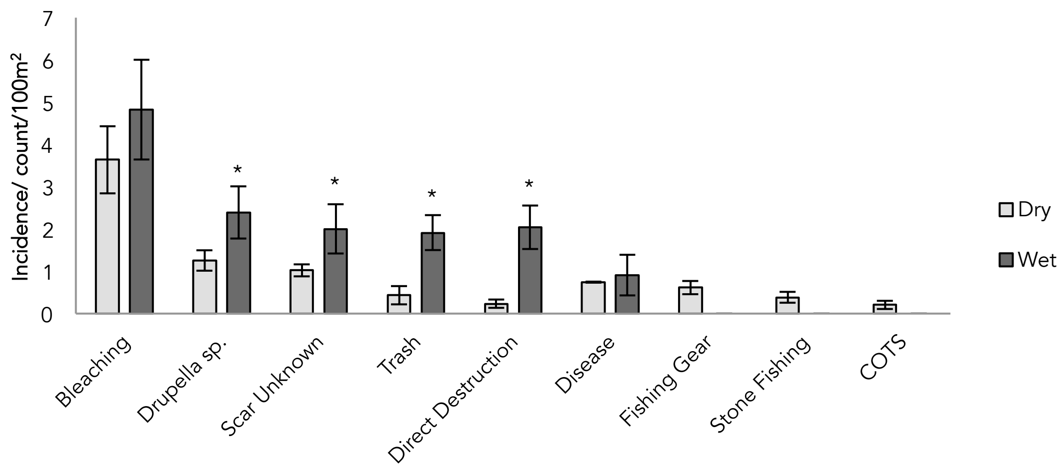


Fig 3.2.2: Mean incidence (count/100m^2 ± SE) of recorded impacts along Dauin Reef separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20). * represents significant differences between seasons ($p<0.05$).

3.2.1 Coral Bleaching

A total of 253 incidences of bleaching were recorded throughout the 2019 survey year (dry: 142, wet: 111) (Fig 3.2.2), averaging at 4.2 counts per 100m^2. Bleaching remained fairly consistent throughout the year across Dauin's reefs (Fig 3.2.3); season, site and depth had no significant effect on the incidence of bleaching during this survey year. More coral genera were recorded affected by bleaching during dry season (24) than wet season (20), although a greater average area of each colony was bleached in the wet season (83%) than the dry season (49%). The incidence of bleaching and area of colony affected is genera specific (Fig 3.2.4); *Fungia* had much higher incidences of bleaching than all other genera, whereas *Favia*, *Pocillopora* and *Montastrea* had the highest percentage areas of colony affected.

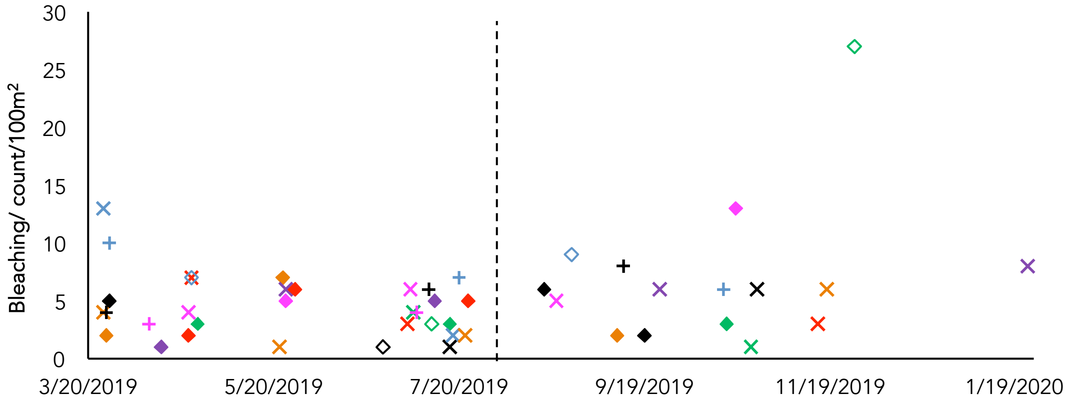


Fig 3.2.3: Total incidence (count/100m²) of recorded bleaching impacts along Dauin Reef separated by season, represented by the dotted vertical line (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20). Different symbols represent different survey sites.

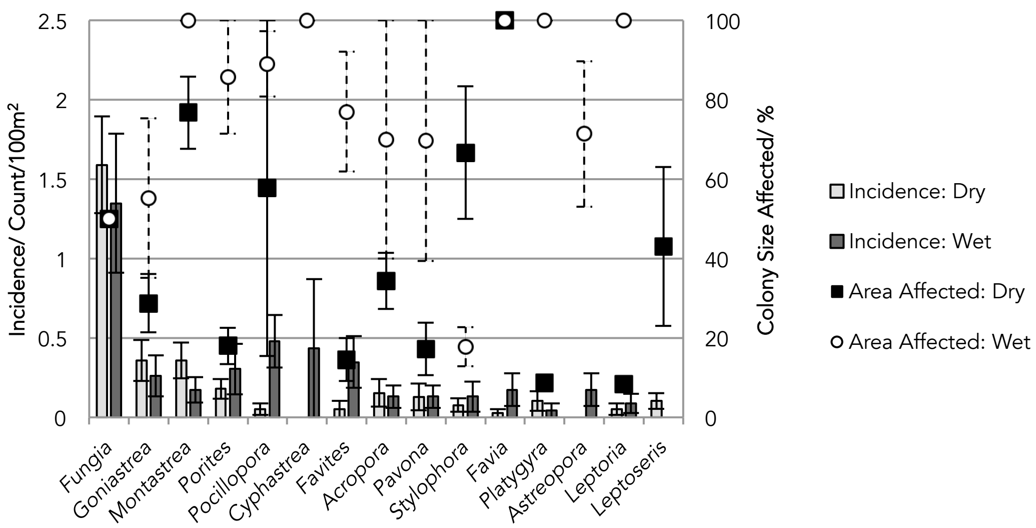


Fig 3.2.4: Mean incidence (count/100m² ± SE) and the size of the affected area (Colony Size Affected/ % ± SE) of bleaching events on 15 most commonly bleached coral genera along Dauin Reef separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

3.2.2 Other Impacts

Drupella spp. feeding activity had significantly higher incidences in wet season than in dry (Fig 3.2.3), as well as affecting a greater average area of the colony (dry: 30%, wet: 33%). COTS were found exclusively during dry season, with a total of 8 COTS found, and an average incidence of 0.4 per 100m² transect (Fig 3.2.2). During the dry season, COTS were found on Acropora (2), Lobophyllia (1), Pachyseris (1), Platygyra (1), Pocillopora (1), Seriatopora (1) and Stylophora (1). Most affected genera by unknown scarring were Acropora (dry: 8, wet: 23), Pocillopora (dry: 14, wet: 8) and Anacropora (dry: 8, wet: 3). Direct destruction affected Acropora the most (70% of recorded direct destruction incidences impacted *Acropora*). The most common diseases recorded throughout the survey year were White Syndrome

Disease, Skeletal Eroding Band Disease and Porites Pinking. Recorded genera affected by any disease were *Porites* (21 records), *Pocillopora* (14), *Acropora* (9), *Fungia* (2), *Goniastrea* (1), *Pachyseris* (1), *Pavona* (1) and *Psammacora* (1).

Whilst most impacts such as bleaching, direct destruction, disease and *Drupella spp.* feeding activity affect all or most survey sites, other impacts are more site specific in their effect (Table 7.3.1). For example, fishing gear is seen at more than 1.0 count/100m^2 at a few locations; Lipayo I, Bulak I, Masaplod Norte, Masaplod Sur MPA and Lipayo I Norte. Stone fishing is seen at only Lipayo I Sur, Masaplod Sur MPA and Masaplod Sur. COTS have only been recorded at Maayong Tubig, Poblacion District II and Masaplod Sur, although they have been seen near survey sites of some other locations such as Masaplod Sur MPA, but outside of the transect area. Most sites show fairly consistent counts of impacts, averaging 21 per 100m^2 transect, although a few sites have notably higher or lower impact counts; Lipayo I Sur has 40 per 100m^2, whereas Lipayo I Norte and Lipayo II have 14 and 7 per 100m^2 respectively (Fig 3.2.5).

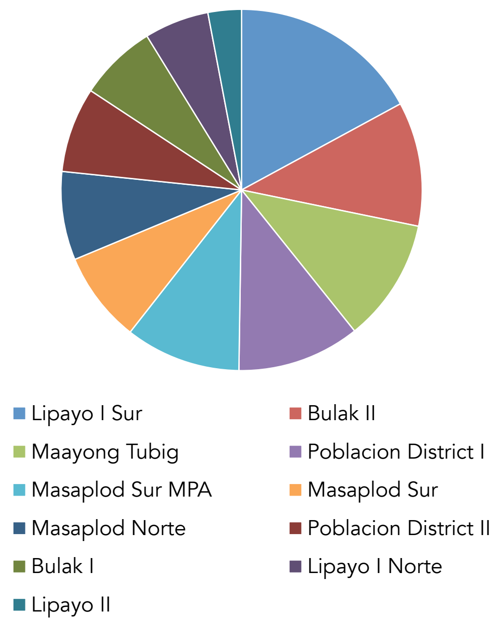


Fig 3.2.5: Relative mean total impact count per 100m^2 transect for the 2019 survey year, separated by survey location along Dauin Reef.

3.2.3 Genera Affected

Acropora is the most commonly impacted genera recorded, followed by *Fungia*, *Pocillopora* and *Porites* (Fig 3.2.6). *Acropora* is affected mostly by *Drupella spp.* feeding activity, followed by unknown scarring, direct destruction, bleaching and disease, mostly White Syndrome Disease. *Anacropora* is mostly recorded impacted by unknown scarring. *Galaxea* is impacted by bleaching, *Drupella spp.* feeding activity and unknown scarring. *Pocillopora* is mostly impacted by unknown scarring, *Drupella spp.* feeding activity, disease (predominantly Skeletal Eroding Band Disease) and bleaching. *Porites* is mostly impacted by disease (Porites Pinking and White Syndrome Disease) and bleaching. *Seriatopora* is mostly impacted by bleaching, unknown scarring and COTS. *Stylophora* is mostly impacted by bleaching, *Drupella spp.* feeding activity and unknown scarring. *Goniastrea, Goniopora, Fungia* and *Pavona* are impacted almost exclusively by bleaching, with a few counts of disease, *Drupella spp.* feeding activity, unknown scarring and direct destruction. *Platygyra* is exclusively impacted by bleaching, except for one count of COT. *Cyphastrea*, *Favites* and *Montastrea* are exclusively impacted by bleaching (Fig 3.2.7).

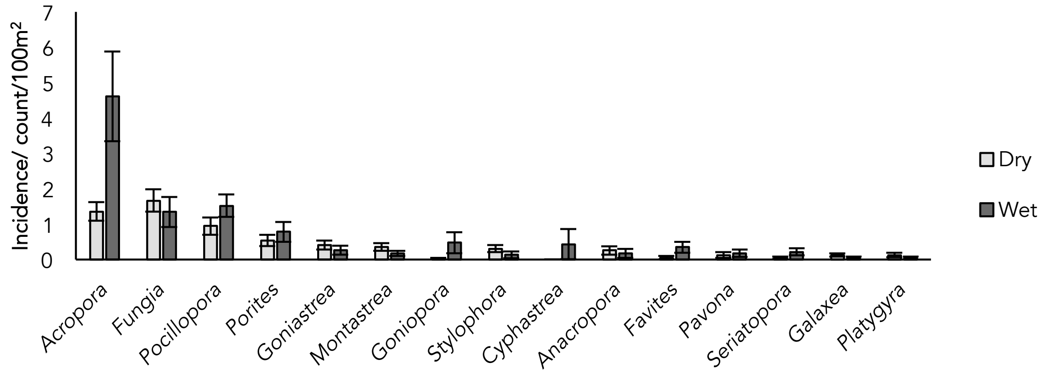


Fig 3.2.6: Mean incidence (count/100m^2 ± SE) of all recorded impacts on 15 most frequently impacted coral genera along Dauin Reef, separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

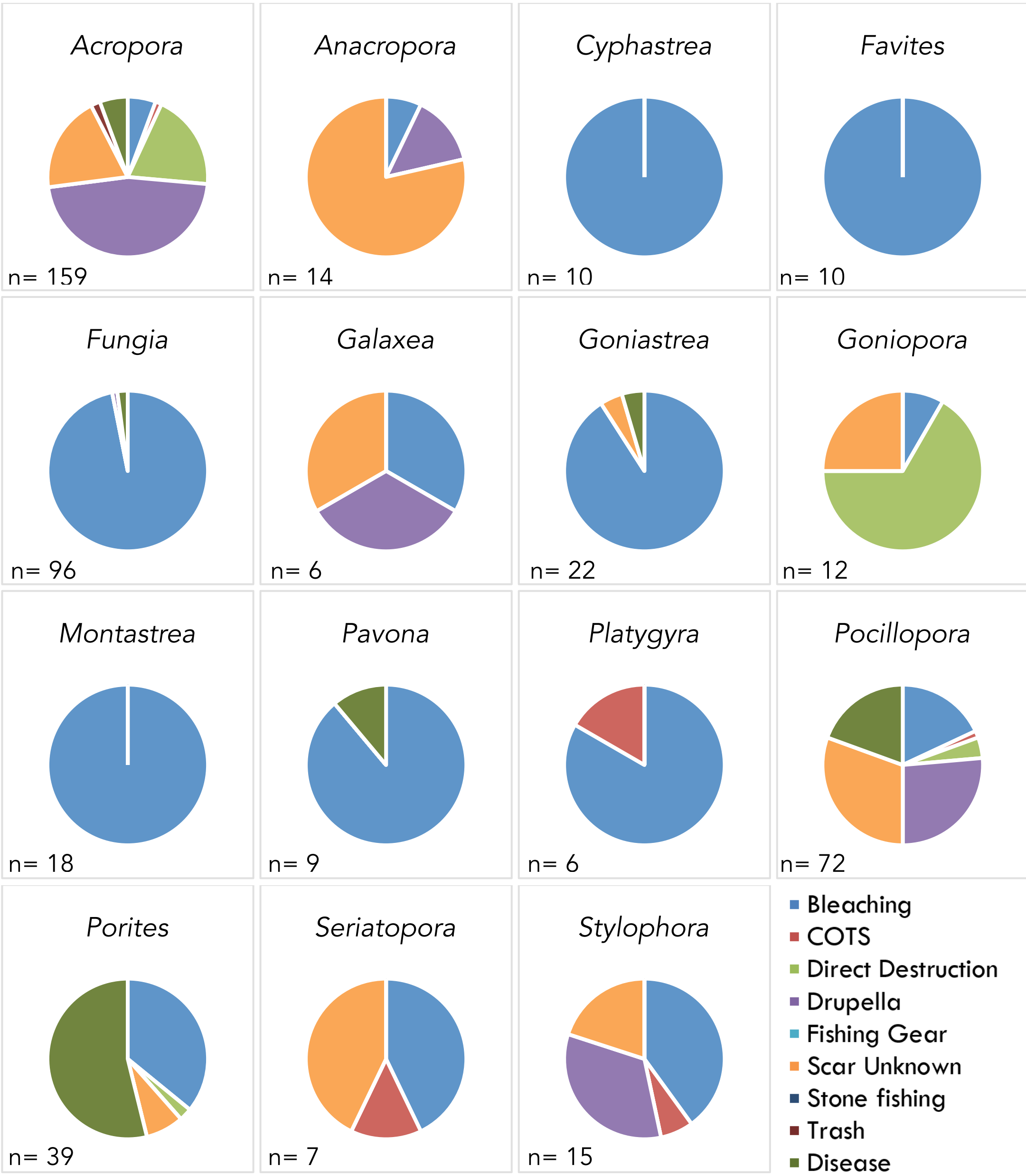


Fig 3.2.7: Relative incidence of different impacts recorded on 15 most frequently impacted coral genera along Dauin Reef. n refers to the total number of impacts recorded for the genus for the full 2019 survey year.

3.3 Reef Fish Community Structure

3.3.1 Fish Families

A total of 21593 fish were recorded during the 2019 survey year, with a total biomass of 458.46kg of fish and a species richness of 248 within 37 fish families. This equates to an average of 569 fish per 250m^2 transect, weighing 12.06kg, and with an average species richness of 45.

Pomacentridae accounts for 68% of fish by abundance, and 21% of fish biomass. The next most abundant families are *Labridae*, *Serranidae*, *Acanthuridae* and *Caesonidae*, accounting for 9%, 4%, 3% and 2% respectively (Fig 3.3.1). The relatively high abundance of the *Serranidae* family is due to two species; *Pseudanthias huchtii* (Threadfin anthias) and *Pseudanthias tuka* (Yellow striped fairly basslet), which comprise 93% of the Serranidae family by abundance.

In terms of biomass, *Pomacentridae* is followed by *Serranidae*, *Lutjanidae*, *Caesionidae*, *Labridae*, *Acanthuridae* and *Siganidae*, accounting for 9%, 9%, 8%, 7%, 7% and 5% respectively (Fig 3.3.2). Regarding species richness, families with the highest species richness include *Labridae* (47), *Pomacentridae* (44), *Chaetodontidae* (15), *Apogonidae* (14), *Serranidae* (13), *Acanthuridae* (12), *Scaridae* (12), *Lutjanidae* (11) and *Mullidae* (10) (Fig 3.3.3). The species accumulation curve has not yet begun to plateau (Fig 3.3.4), suggesting that the fish communities among Dauin's reefs have not yet been surveyed representatively after the 38 replicates of the 2019 survey year.

Seasonal total fish abundance more than doubled, from 7148 (33% of annual fish abundance) in dry season, to 14445 (67%) during wet. The change in biomass between seasons was not statistically significant, from 180.77kg in dry and 227.69kg in wet, although this is still a large increase. Examining these trends as averages per transect, analysis of similarities (ANOSIM) revealed a weak difference ($p=0.034$, $R=0.08$) between the abundance of fish species between dry and wet seasons. However, when analysing biomass, no significant difference was seen between seasons ($p=0.868$, $R=-0.045$). No significant differences were observed in community composition between the two survey depths (5 and 10m), when examining abundance ($p=0.281$, $R=0.021$) or biomass ($p= 0.8681$, $R =-0.04584$). These results are shown clearly in the NMDS plot showing Season and Depth for fish biomass (Fig 3.3.5).

Species richness for the dry season came in at 178, whereas for the wet season, 218 species were recorded. Equating this to an average across one 250m^2 transect, the dry season had an average fish abundance of 376, with an average biomass of 9.51kg, and a species richness of 41. Conversely, in the wet season, an average of 760 fish were recorded per 250m^2 transect, weighing 11.98kg, with a species richness of 49. Species richness is fairly consistent across seasons and sites, with 15 out of 19 sites showing fluctuations of no more than ± 15 species. Maayong Tubig at 10m (Site 19) shows the greatest change in species richness between seasons, an increase of 42 species, double that of the next greatest change (Poblacion District I at 10m (Site 5), with 21 more species).

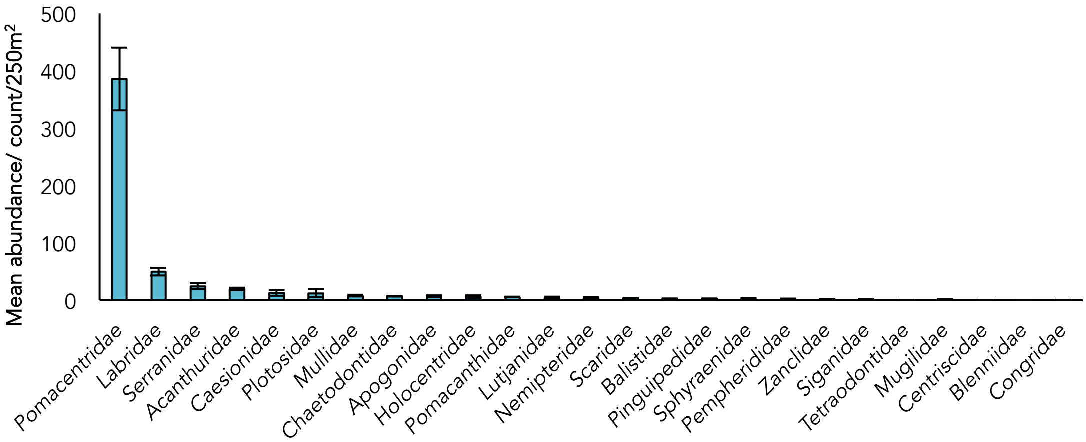


Fig 3.3.1: Mean abundance per transect (count/250m^2 ± SE) of 25 most abundant fish families recorded along Dauin Reef for the 2019 survey year.

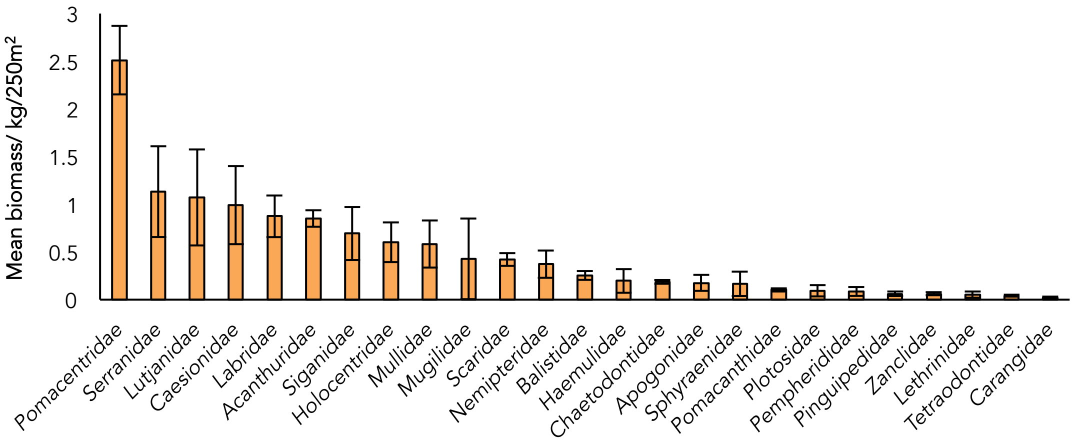


Fig 3.3.2: Mean biomass per transect (kg/250m^2 ± SE) of the 25 fish families that contribute the most to biomass, recorded along Dauin Reef for the 2019 survey year.

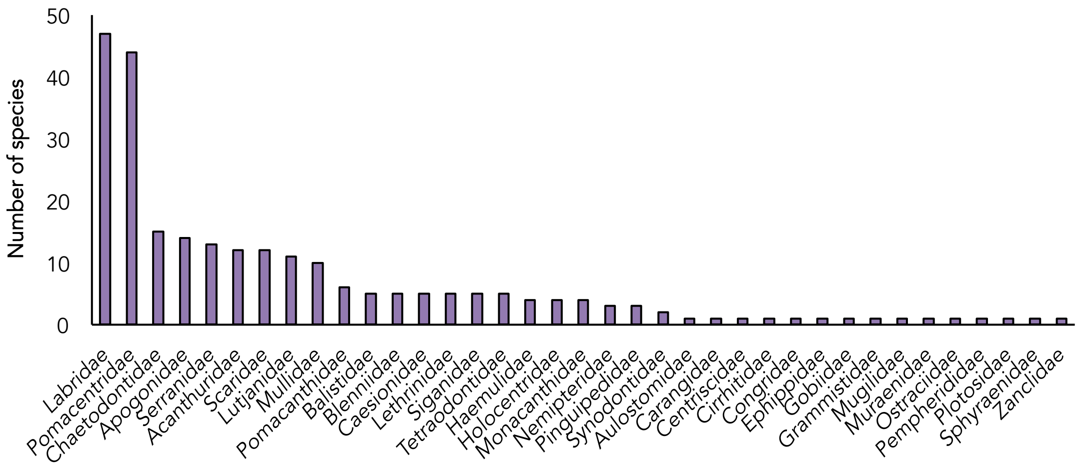


Fig 3.3.3: Total species richness of all fish families recorded along Dauin Reef for the 2019 survey year.

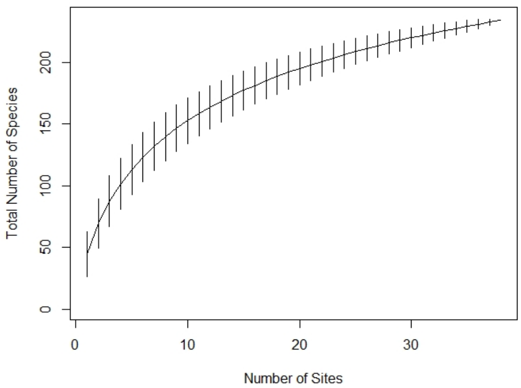


Fig 3.3.4: Species Accumulation Curve for the cumulative total number of species recorded across Dauin reef survey sites.

Looking at fish families, the trends between dry and wet season are largely consistent, with *Pomacentridae* accounting for the majority of fish by abundance and biomass, followed by *Labridae, Serranidae* and *Acanthuridae* for abundance. Trends in biomass vary slightly between seasons, with the dry season showing greatest biomass contributors (in order) as *Pomacentridae, Lutjanidae, Serranidae, Caesionidae, Acanthuridae* and *Labridae*, whereas the wet season puts these in order of *Pomacentridae, Labridae, Caesionidae, Serranidae, Siganidae, Acanthuridae, Mugilidae, Mullidae and Lutjanidae*.

No potential indicator species were flagged during statistical testing for the dry season, although five were selected for the wet season; *Parupeneus pleurostigma* (0.0471*), *Parupeneus cyclostomus* (0.0086**), *Meiacanthus grammistes* (0.0463*), *Chromis ternatensis* (0.0338*) and *Chromis viridis* (0.0195*). Of these five, four were recorded exclusively in the wet season (*Parupeneus pleurostigma* n=6, *Parupeneus cyclostomus* n=12, *Meiacanthus grammistes* n=8, and *Chromis viridis* n=443). *Chromis ternatensis* was recorded during both seasons, but at much greater abundances during the wet season (dry n= 491 wet n= 3044, dry n sites = 9).

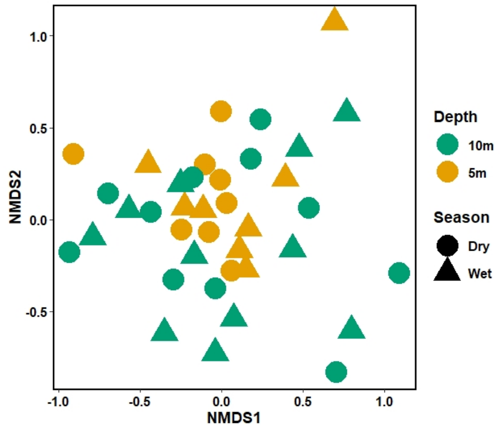


Fig 3.3.5: Non-metric multidimensional scaling (NMDS) plot of fish biomass weighted communities for each depth and season.

Looking at the IUCN Red List Categories[23] of the recorded species from the 2019 survey year, the vast majority of species recorded are considered species of Least Concern (177 species), followed by species that are Not Evaluated (66 species) (Fig 3.3.6, 3.3.7). Four of the species recorded during 2019 are currently considered Data Deficient (*Aeoliscus strigatus*[35] (Razorfish), *Chaetodon ocellicaudus*[36] (Spot-tailed Butterflyfish), *Lutjanus xanthopinnis*[37] (Yellowfin Snapper), *Siganus unimaculatus*[38] (Blotched foxface). Only one species recorded during the 2019 survey year is listed as a Near Threatened species; *Scarus hypselopterus*[39] (Yellow-tail Parrotfish), which was recorded four times during the wet season (no records during the dry season), twice at Poblacion District I at 5m, once at Poblacion District II at 5m and once at Masaplod Sur MPA at 10m. Two of the species recorded during 2019 are categorised as Vulnerable (*Oxymonacanthus longirostris*[40] (Orange spotted filefish), and *Epinephelus fuscoguttatus*[41] (Brown-marbled grouper). *O. longirostris* was recorded twice during the 2019 survey year, both at Poblacion District I at 5m during the dry season. *E. fuscoguttatus* was also recorded twice during the 2019 survey year; once during dry season at Lipayo II at 10m, and once during wet season at Masaplod Norte at 10m.

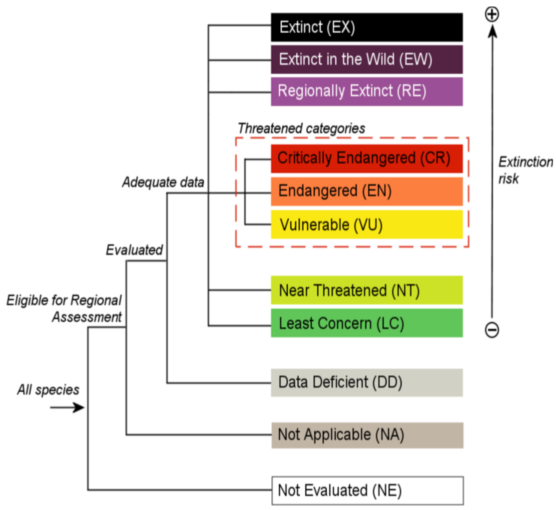


Fig 3.3.6: Structure of IUCN Red List categories[42]

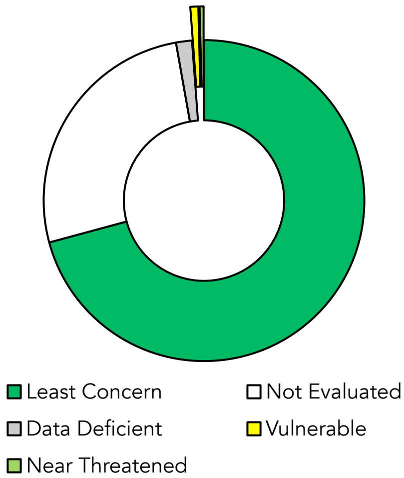


Fig 3.3.7: Relative number of species within each IUCN Red List Category for the 2019 survey year. Highlighted outside of pie are Vulnerable and Near Threatened species

Non-metric multidimensional scaling (NMDS) and beta-dispersion plots indicate that there may be slight differences in the fish communities between seasons (Fig 3.3.8a), location along the coastline (Fig 3.3.8b) and amount of coral cover (Fig 3.3.8c). There appears to be little differentiation in the fish communities based on depth (Fig 3.3.8d).

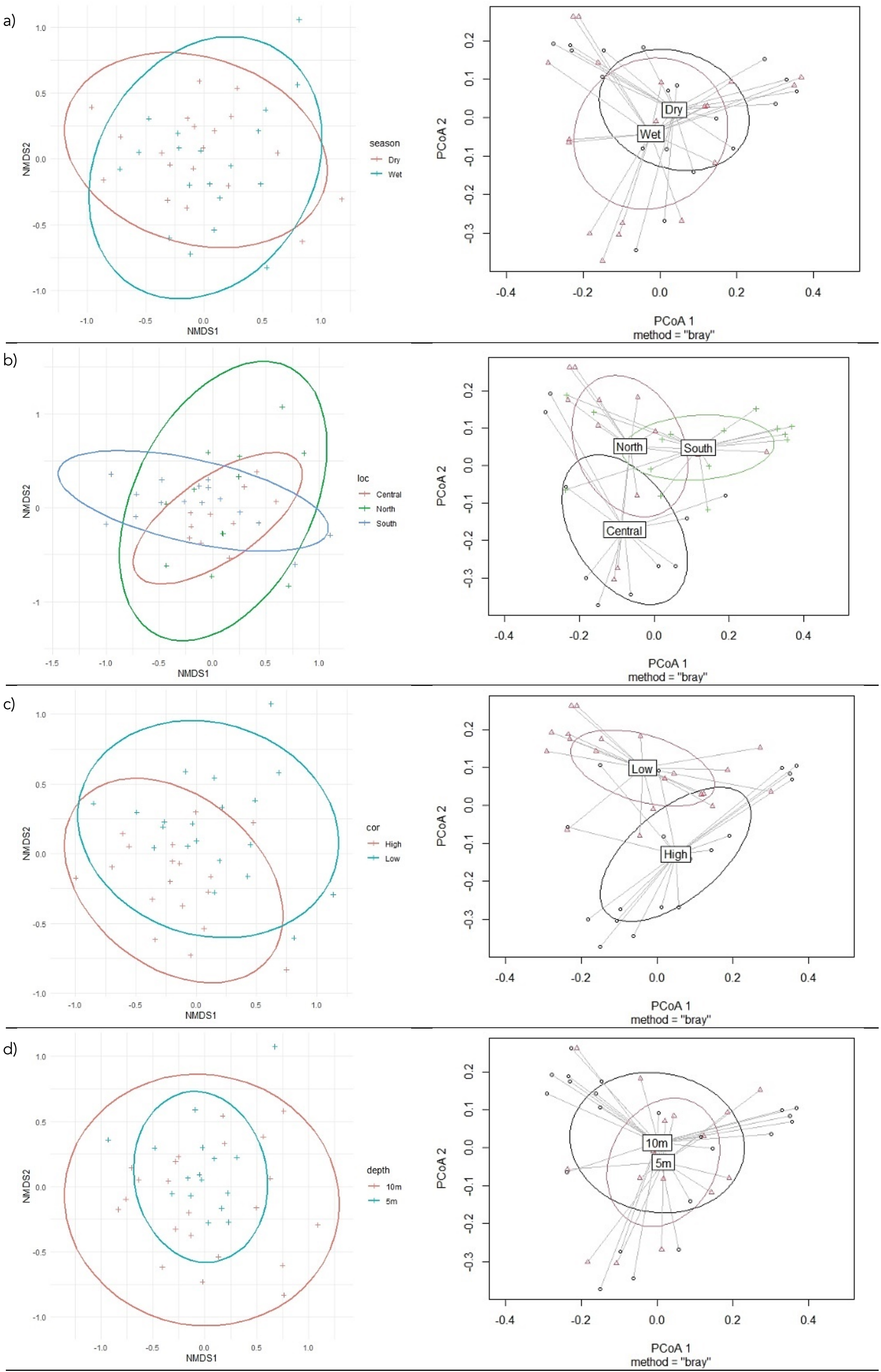


Fig 3.3.8: Non-metric multidimensional scaling (NMDS) (Left) and beta-dispersion plots (Right) of fish biomass weighted communities according to a) season, b) location along the Dauin coastline, c) coral cover, and d) depth.

3.3.2 Trophic Structure

Examining relative fish abundance and biomass by trophic groups, the Herbivore & Planktivore group is the most abundant across Dauin's reefs, followed by exclusive Planktivores and Omnivores, with average abundances of 174, 164 and 140 per 250m^2 transect (Fig 3.3.9). All other trophic groups showed average abundances of less than 30 per transect. Biomass trends are similar (Fig 3.3.10), with the same top three trophic groups, although in a different order; exclusive Planktivores followed by Omnivores and then Herbivore & Planktivores, with 2.64kg, 2.50kg and 2.17kg respectively. Piscivore & Mobile Invertebrate Feeders (MIF) contribute much more to community structure in terms of biomass than abundance, with biomass close to that of the Herbivore & Planktivore group, at 2.07kg. Consistently the lowest contributors to community structure in terms of both abundance and biomass are the Corallivore & Herbivores, the Corallivore & MIFs, and exclusive Detritivores (Fig 3.3.11).

The trends in most abundant fish and highest contributors to biomass are largely consistent between seasons. The three most abundant trophic groups are the same between seasons, although in a different order; dry 1st Herbivore & Planktivore, 2nd Omnivore and 3rd

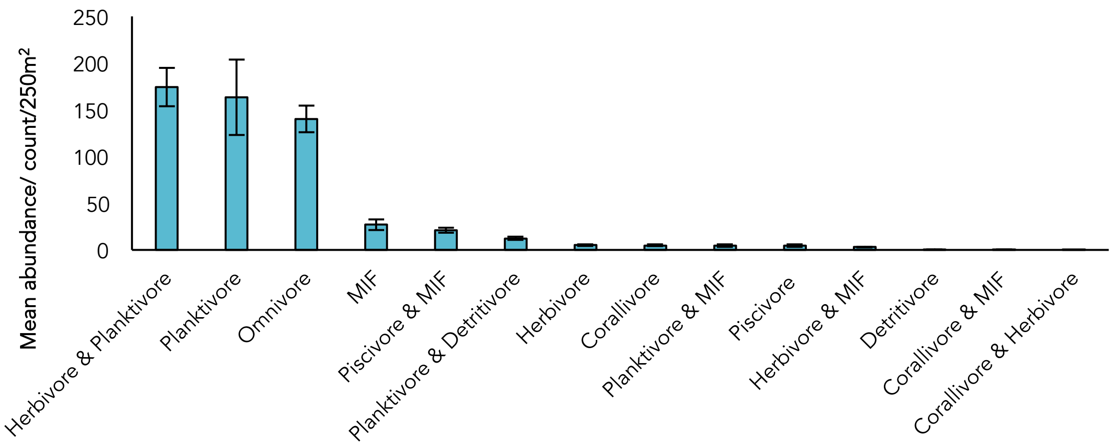


Fig 3.3.9: Mean abundance per transect (count/250m^2 ± SE) of fish functional groups recorded along Dauin Reef for the 2019 survey year. MIF: Mobile Invertebrate Feeder

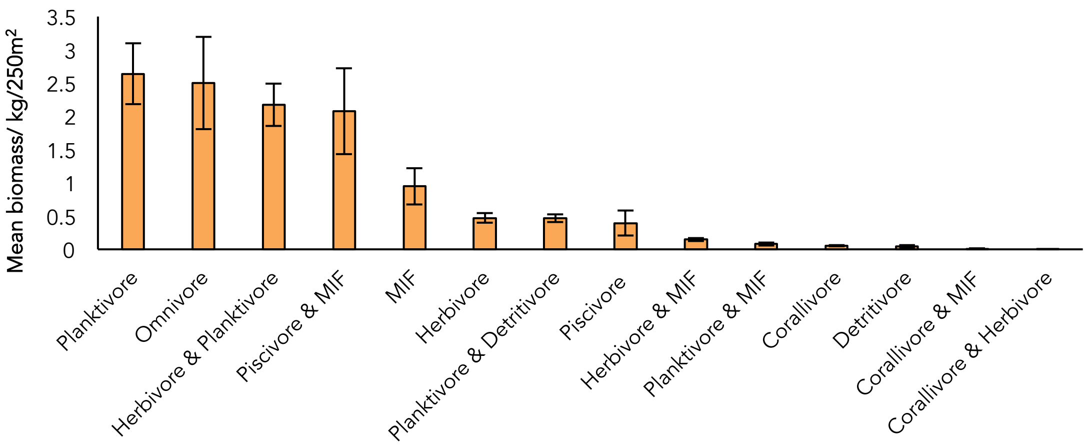


Fig 3.3.10: Mean biomass per transect (kg/250m^2 ± SE) of fish functional groups, recorded along Dauin Reef for the 2019 survey year. MIF: Mobile Invertebrate Feeder

Planktivore, wet 1st Planktivore, 2nd Herbivore & Planktivore and 3rd Omnivore (Fig 3.3.12). The trends of all other trophic groups are consistent between seasons, except for Corallivores and Piscivores; Corallivores are much more abundant than Piscivores in dry season, whereas in wet season this is reversed (Fig 3.3.12). It is important to note however that this difference equates to very few fish on average; a difference of two fish between Corallivores and Piscivores in dry season, and less than one fish in wet. In terms of contribution of different trophic groups to overall biomass, the difference between seasons is slightly more pronounced; dry 1st Piscivore & MIF, 2nd Planktivore, 3rd Omnivore, 4th Herbivore & Planktivore, wet 1st Planktivore, 2nd Omnivore, 3rd Herbivore & Planktivore and 4th Piscivore & MIF (Fig 3.3.12). The trends of all other trophic groups are largely consistent between seasons, although Piscivores overtake Herbivores, and Planktivore & Detritivores show a relative decrease in contribution to biomass from dry to wet season. NMDS and beta-dispersion plots suggest there may be some divergence in community composition regarding functional groups (Fig 3.3.13), although weak.

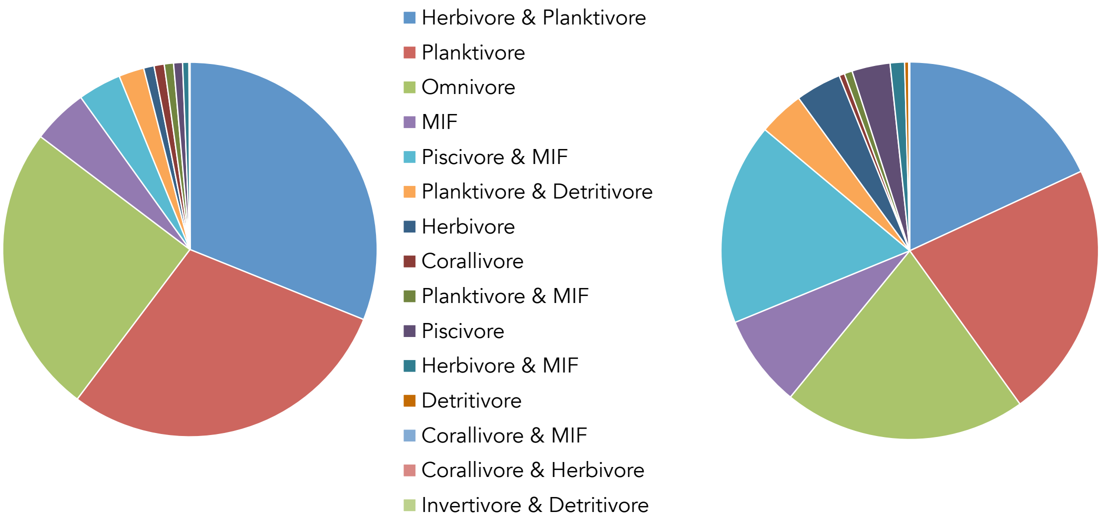


Fig 3.3.11: Relative mean abundance (left) (count/250m^2) and biomass (right) (kg/250m^2) per transect of fish functional groups recorded along Dauin Reef for the 2019 survey year. MIF: Mobile Invertebrate Feeder

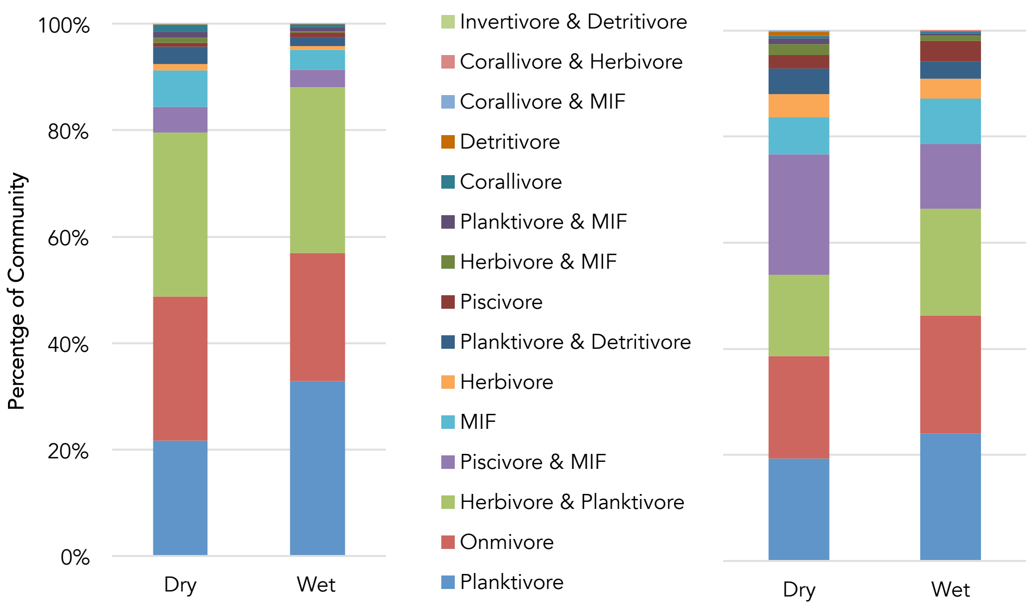


Fig 3.3.12: Relative mean abundance (left) and biomass (right) (%) of fish functional groups per 250m^2 transect recorded along Dauin Reef separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20). MIF: Mobile Invertebrate Feeder

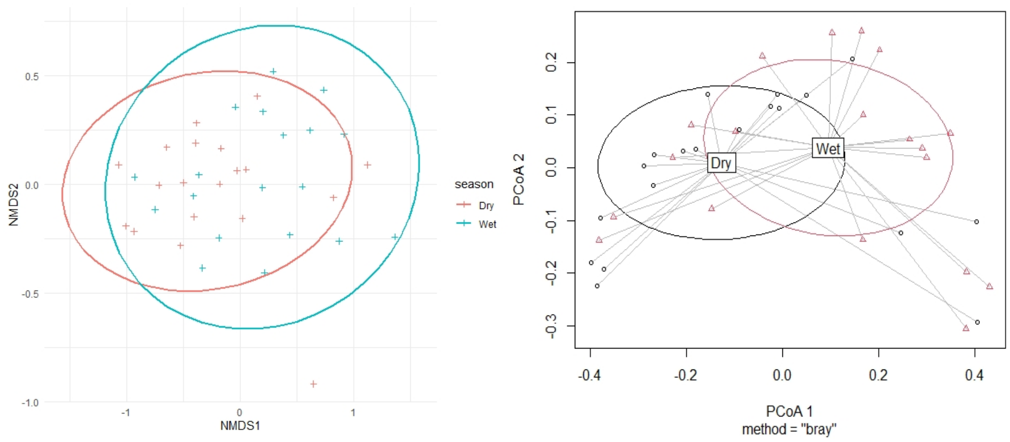


Fig 3.3.13: Non-metric multidimensional scaling (NMDS) (Left) and beta-dispersion plots (Right) of fish functional group biomass weighted communities according to season

3.3.3 Commercially Important Fish

Over the course of the 2019 survey year, a total of 2842 commercially important fish individuals were recorded, equating to 13% of all recorded fish. 75 commercially important fish species were recorded (30% of total species richness), across 18 different fish families. *Labridae* has the most commercially important fish species recorded during our survey year (16), followed by *Lutjanidae* (9), *Mullidae* (9), *Serranidae* (9) and *Acanthuridae* (6) (Fig 3.3.14). An average of 12 commercially important fish species were recorded per 250m^2 transect (27%). The most abundant commercially important fish families are *Labridae*, *Acanthuridae*, *Caesionidae* and *Plotosidae* (Fig 3.3.15) whereas the biggest contributors to biomass of commercially important fish are *Caesionidae*, *Lutjanidae*, *Serranidae* and *Siganidae* (Fig 3.3.16). The relative abundance and biomass contributions to the fish community of commercially important fish species varies greatly between sites (Fig 3.3.17). For example, Lipayo II at 10m (Site 8) and Masaplod Norte at 5m (Site 4) have the greatest abundance of commercially important fish, and when also considering biomass, Bulak I at 10m (Site 11), Masaplod Norte at 10m (Site 3) and Lipayo I Sur at 10m (Site 9) are also included in the sites with the highest amount (by weight) of commercially important fish species (Fig 3.3.17).

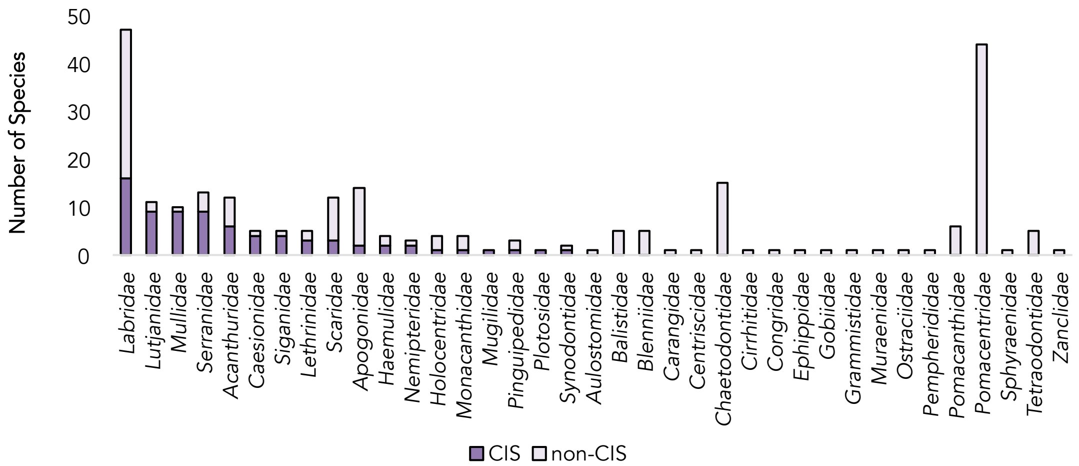


Fig 3.3.14: Total number of species of all fish families recorded along Dauin reef for the 2019 survey year, separated into commercially-important species (CIS) and non commercially-important species (non-CIS).

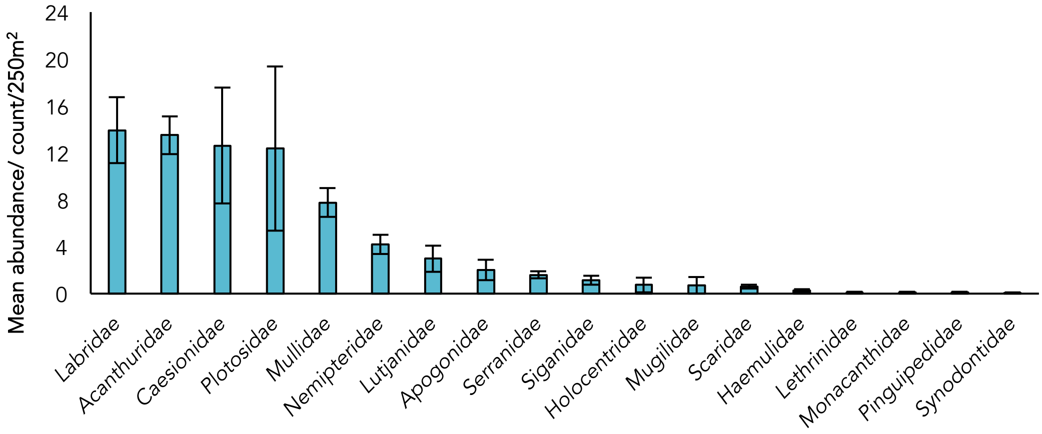


Fig 3.3.15: Mean abundance per transect (count/250m² ± SE) of commercially important fish species, grouped into families, recorded along Dauin reef for the 2019 survey year.

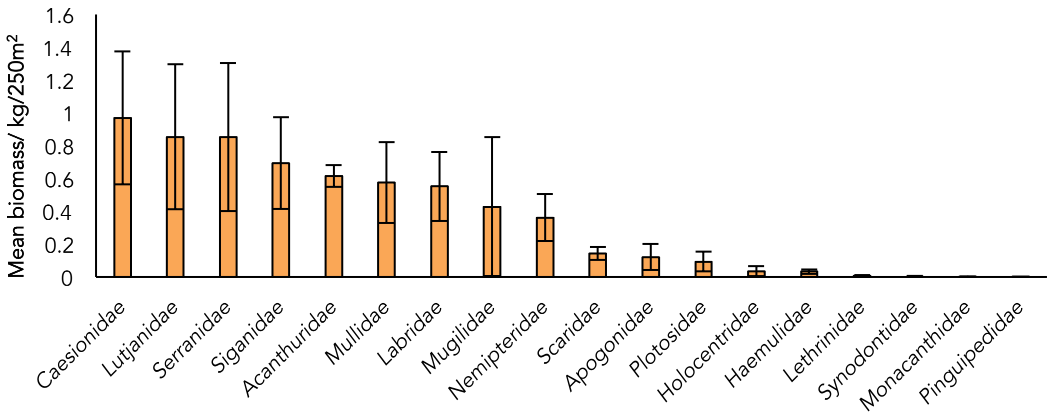


Fig 3.3.16: Mean biomass per transect (kg/250m² ± SE) of commercially important fish species, grouped into families, recorded along Dauin Reef for the 2019 survey year.

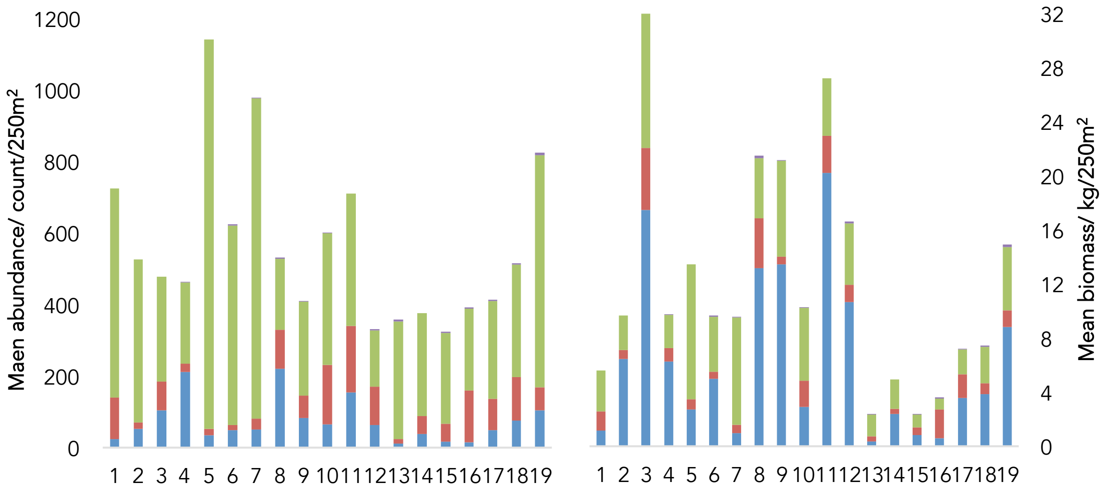


Fig 3.3.17: Mean site abundance (left) and biomass (right) (%) of fish separated by commercial importance (blue: commercial; red: minor; green: no; purple: subsistence fisheries) categories and site, recorded along Dauin Reef for the 2019 survey year.

In dry season, commercially important fish accounted for 16.6% of all fish recorded, and in wet they accounted for 11.4%, with an average number of commercially important fish per transect annually of 75 (13%), dry season 63 (11%) and wet season 87 (15%). An average of 10 commercially important fish species were recorded per transect in dry season, and 13 in wet. NMDS plots suggest there is little difference in community composition of commercially important species between seasons (Fig 3.3.18).

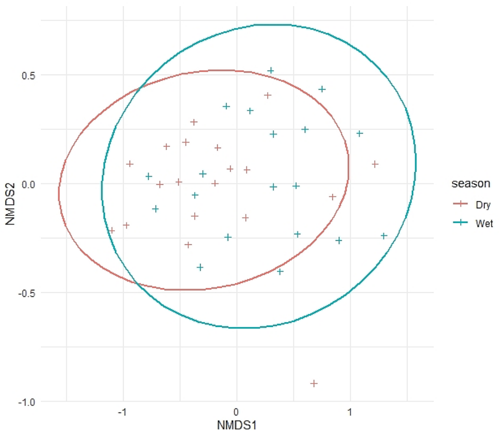


Fig 3.3.18: Non-metric multidimensional scaling (NMDS) of biomass weighted commercially important fish species communities by season

Examining commercially important fish species abundance by family, trends are largely consistent between dry and wet seasons (Fig 7.2.32), with the exception of the *Plotosidae*, which sees a very large spike in wet season, due to one highly dense school of *Plotosus lineatus* recorded at Lipayo II at 10m (Site 8), where 244 individuals were recorded (explaining the very large standard error bar). The other large difference between seasonal abundances is that of the *Mullidae*, which is as a result of a large increase in *Parupeneus multifasciatus*, although this is not attributable to one individual site, with increases in abundances seen across 15 out of 19 survey sites.

Looking at biomass, the greatest differences between seasons are found in *Lutjanidae*, *Mugilidae*, *Serranidae*, *Mullidae* and *Siganidae* (Fig 7.2.33). Regarding *Lutjanidae*, the biggest inter-seasonal changes are due to declines in the recorded species *Lutjanus argentimaculatus* (Mangrove red snapper) (dry: 0.656kg/250m^2, wet: 0.113kg/250m^2) and *Lutjanus biguttatus* (Two-spot Banded Snapper) (dry: 0.287kg/250m^2, wet: 0.004kg/250m^2). Within *Mugilidae*, the seasonal fluctuation can be attributed to the only commercially important species in this family; *Crenimugil seheli* (Bluespot mullet), which was absent entirely from dry season records. The large decline in biomass of commercially important species within the *Serranidae* is attributed to the sharp decline in *Plectropomus laevis* (Black-saddled coral grouper), which contributed on average 0.852kg/250m^2 to biomass in dry season, and was absent entirely from surveys in wet season. Within the *Mullidae*, the increase in biomass of commercially important fish species is attributable to *Parupeneus barberinus* (Dash-and-dot goatfish), which increased from 0.188kg/250m^2 in dry season to 0.567kg/250m^2, in wet. The large increase in biomass of commercially important fish species within *Siganidae* is attributable to *Siganus guttatus* (Orange-spotted spinefoot a.k.a. Golden rabbitfish), whose average biomass more than doubles from dry to wet season (dry: 0.380kg/250m^2, wet: 0.813kg/250m^2). It is important to note that for *P. laevis* the average length from FishBase is used to calculate biomass, as no measurements of this species were recorded in the 2019 survey year, which could potentially overestimate the contribution of this species to overall biomass. Of the commercially important fish species that were recorded and measured during the 2019 survey year (n=64), lengths at first maturity (obtained from FishBase) are unavailable for most. For species where this information is available, the size distribution of the population can be examined, to determine the proportion of juveniles to adults. Species with exclusively juvenile populations are *Myripristis murdjan* and *Lutjanus argentimaculatus* (Fig 3.6.4). *Plotosus lineatus* and *Lutjanus fulvus* have largely juvenile populations, *Parupeneus multifasciatus* has a more balanced juvenile to adult proportion, whereas populations of *Epinephelus merra*, *Lutjanus vitta* and *Thalassoma hardwicke* are skewed towards mature adults (Fig 3.3.19). For Siganus guttatus, the recorded population was exclusively adults (Fig 3.3.19). However, it is important to note sample sizes of these populations – with five out of nine of these species having 10 or less measured observations, overall size distributions of these species cannot be easily described at this point in the IMR Dauin LTRMP.

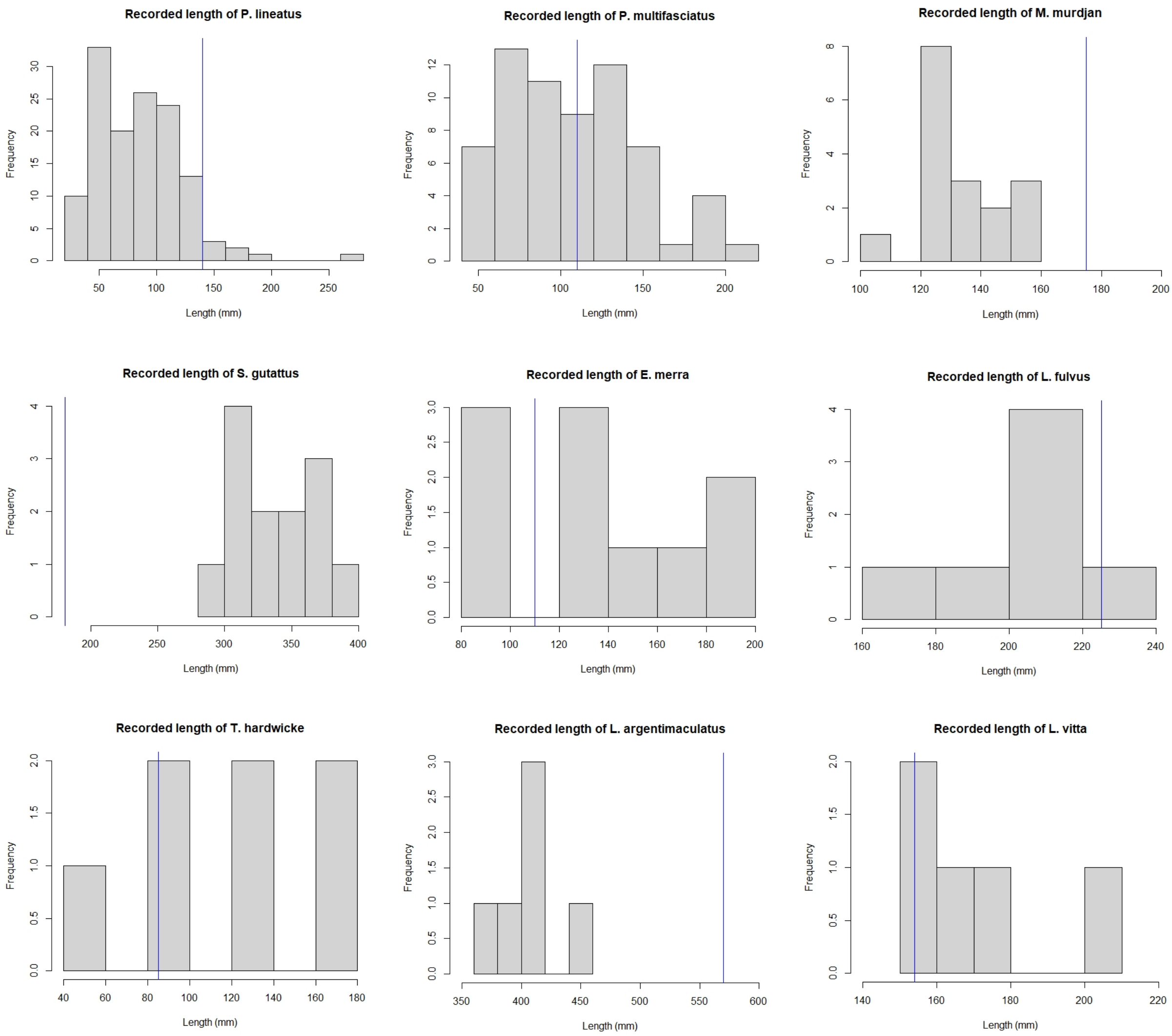


Fig 3.3.19: Frequency distribution of recorded lengths for 9 commercially important fish species; Plotosus lineatus (n=133), Parupeneus multifasciatus (n=65), Myripristis murdjan (n=17), Siganus guttatus (n=13), Epinephelus merra (n=10), Lutjanus fulvus (n=7), Thalassoma hardwicke (n=7), Lutjanus argentimaculatus (n=6) and Lutjanus vitta (n=5). Blue vertical line represents length at first maturity, according to FishBase 2020[22].

3.3.4 Reef Fish and Structural Complexity

Dauin's patchy reefs show variation in structural complexity, from sand-dominated structures (e.g. Bulak I), artificial reef sites (Lipayo II) and coral fields (e.g. Masaplod Sur MPA). Most sites (12 out of 19) show minimal changes to 3-Dimensional complexity (below ±5 RMS) between seasons. Sites that show higher changes to 3-D structure (Sites 6, 19, 4, 18, 11, 2, 14) are likely due to divergence in the survey path (Fig 3.3.22).

Averaging 3D metrics (length, rugosity, slope, variation and range) across sites, all metrics show increases from dry to wet season, with the exception of slope which decreases from 0.101 in dry season to -0.068 in wet (although variations of 0.204 in dry and 0.186 in wet suggest the decrease is not significant) (Fig 3.3.23).

Mantel tests on the effect of 3D metrics on fish community structure showed that all the environmental matrix of all 3D metrics combined had no significant effect on fish community structure (p= 0.9745, R= -0.1737). Individual metrics also showed no significance; Rugosity p= 0.9626, R= -0.1479, Slope p= 0.9807, R= -0.1657, Length p= 0.7402, R= -0.05518, Variation p= 0.903, R= -0.1086 and Range p= 0.9565, R= -0.1416. Correlations of rugosity and fish abundance and biomass are very weak, when looking at the entire fish population (R^2= 0.0021 and 0.0008 respectively), as well as specifically at the *Pomacentridae* family (R^2= 0.0057 and 0.0011 respectively) (Fig 3.3.24). Non-metric multidimensional scaling (NMDS) and beta-dispersion plots indicate that differences in the fish communities between high and low rugosity are negligible (Fig 3.3.25).

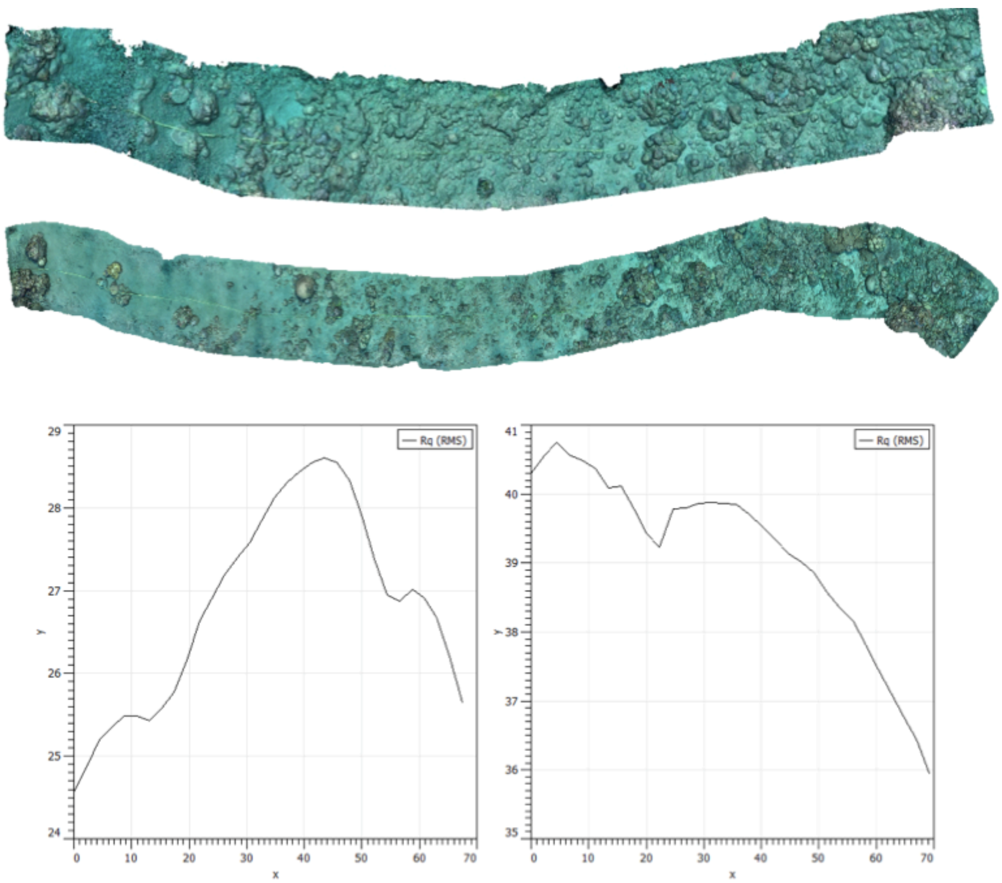


Fig 3.3.22: Above: Digital elevation models of Poblacion District II (Site 2) between wet and dry seasons of 2019, produced with SfM photogrammetry techniques at 5m. Below: Average rugosity (Rq) of Poblacion District II (Site 2) at 5m between wet and dry seasons of 2019 (scale is in megapixels).

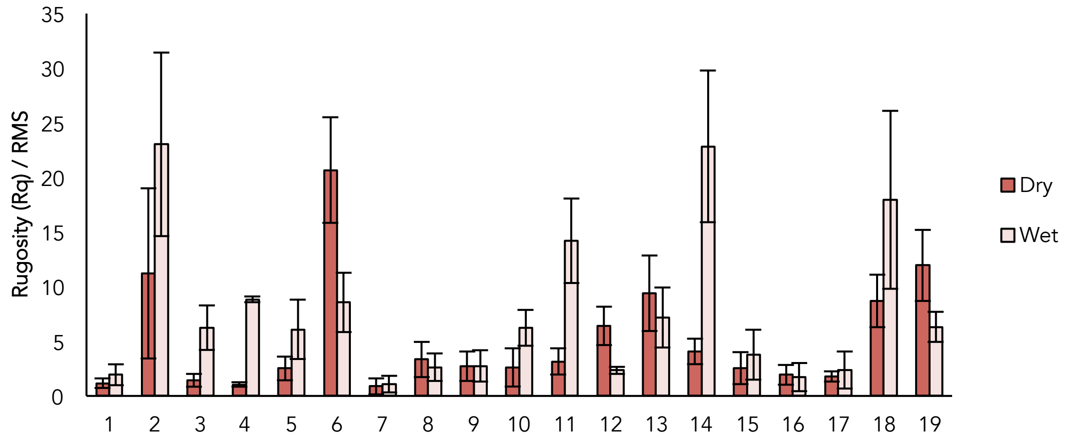


Fig 3.3.23: Mean Rugosity (Rq, RMS ±) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

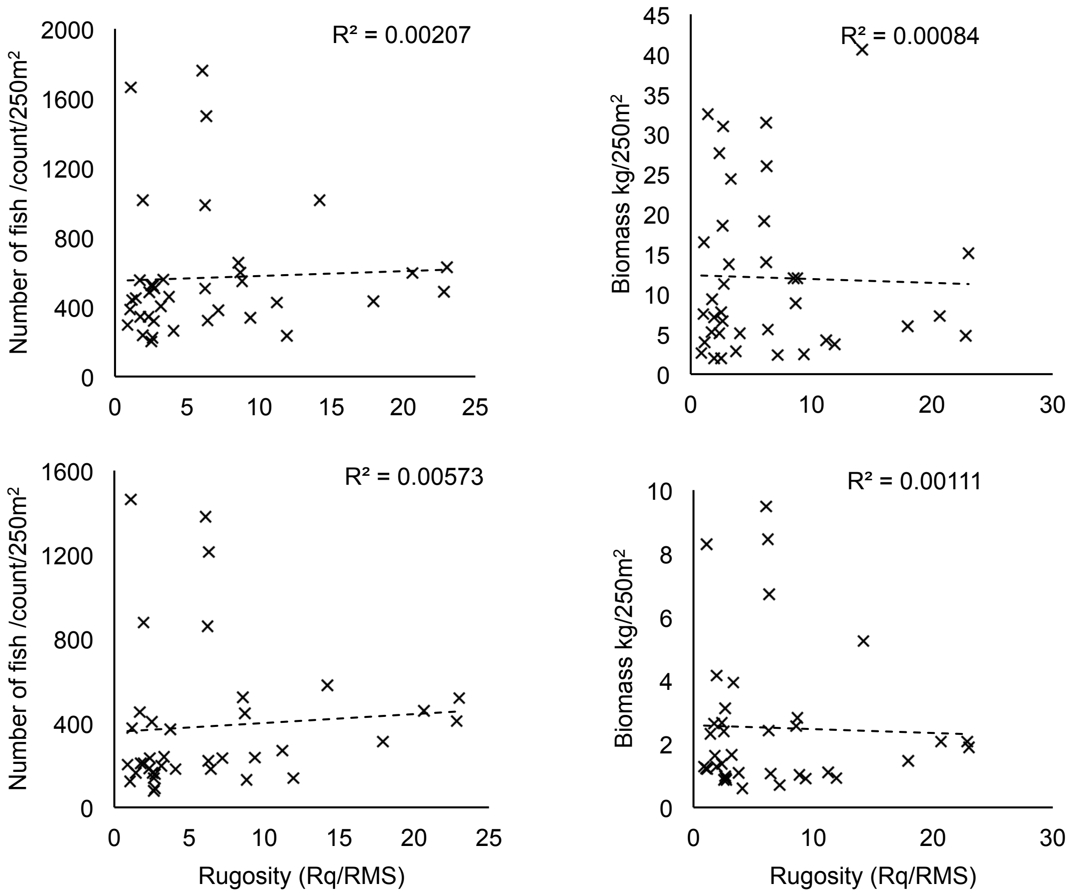


Fig 3.3.24: Rugosity (Rq, RMS ±) vs total fish abundance (count/250m^2) (left) and biomass (kg/250m^2) (right) along Dauin Reef survey sites, with trendline and r^2 values for all fish (top) and exclusively Pomacentridae (bottom).

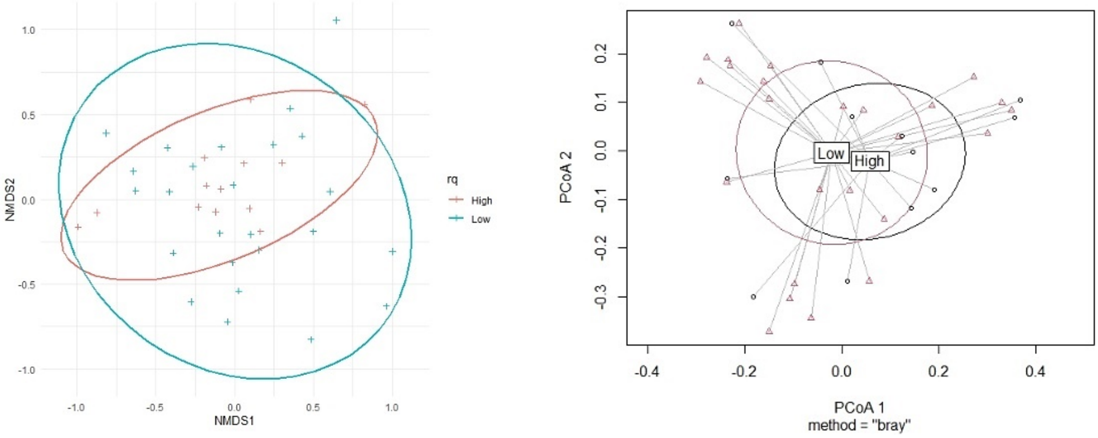


Fig 3.3.25: Non-metric multidimensional scaling (NMDS) (Left) and beta-dispersion plot (Right) of fish biomass weighted communities according to rugosity.

4. DISCUSSION

Characterizations of small-scale spatial patterns over a one-year time period have been used to explore factors that drive population structure within the Dauin Municipal reef ecosystem (Negros Oriental, Philippines).

4.1 Benthic Composition

Abiotic components (predominantly sand and rubble) contribute to the primary percentage of the benthic cover occurring within this fringing reef ecosystem, followed by coral, algae and sponge. Reefscapes are often a consortium of stable consolidated habitat and unconsolidated reef, the latter of which is physically unstable and has the potential to cause abrasion and burial of juvenile coral[43]. With Dauin's benthic reef state comprised primarily of this unconsolidated habitat, subsequent reef accretion rates and dispersal capabilities of other sessile marine organisms become restricted. It must be noted that high diversity of coral reefs is generally attributed to the systems relative instability and several disturbance hypotheses. At the core of these hypotheses is the postulate that reef coral communities undergo cycles of destruction and renewal. Diversity is maintained by changing species composition in response to disturbances, whereby reef regeneration after disturbances depends on various physical and biological factors. On the Dauin inshore reef, typhoon disturbance history is linked closely with coral dominant reef sites, causing partial destruction of coral skeletons and/or reef rock. The fate of these destroyed framework components is not only influenced by subsequent erosion and redeposition, but also subject to taphonomic processes, which include constructional processes, such as framework growth, sedimentation and burial, as well as marine diagenetic cementation[44,45]. Research obtained from the 2019 survey year reveals a combination of erosion and biogenic constructional processes are occurring, potentially providing preliminary stabilization. This is supported by the seasonal rise in Coralline Algae (CA) and sponge at Dauin's rubble dominant reef sites (Masaplod Norte, Maayong Tubig and Lipayo I Sur). Studies have shown sponge to settle and stabilize rubble piles within a month of rubble production[46,47,48]. Wulff (1984) referred to binding by sponges as temporary binding, with rigid binding being performed by subsequent encrustations by CA. Encrusting sponges were found to "glue together" the interior of rubble piles down to 2m below the rubble surface, while erect sponges bound adjacent pieces through superficial overgrowth[47]. Within the Dauin reef, encrusting sponge has seen site-specific improvements at only select rubble dominant sites (Masaplod Norte, Maayong Tubig and Lipayo I Sur). It is possible that the cause of damaged framework along the Dauin coast may have disparities in its severity of mechanical damage, with permanent wave agitation and bioturbation further hindering the stabilization ability of biogenic cementation. Therefore it should not be assumed that recovery is synchronous across affected reef sites. CA has however seen percentage improvements at all previously disturbed sites across seasons. Due to their calcified cell walls, heavy fixation to the substrate, as well as intra and extra-skeletal cementation, CA becomes a preliminary agent for rigid binding[49]. CA calcification is directly based on CA physiology, and depends on factors that support photosynthesis such as light availability and inorganic nutrients[50]. Typically, growth rates range from 0.03 to 22mm/year, depending on these environmental conditions[50]. Therefore it must be highlighted that whilst the calcification of CA results in rigid binding and recovery of Dauin's inshore reefs, this will be a gradual and long-standing process.

Alongside the seasonal rise in CA, the high prevalence of coral within the ecosystem suggests that the dynamics of pH and seawater chemistry are favouring net calcification rates. Rates of biogenic carbonate sediment production are affected by natural and anthropogenic alterations in water quality parameters including temperature, salinity, nutrients, light availability, pCO_2, and aragonite saturation state[51,52]. Rates of calcification are influenced by these parameters, with studies demonstrating coral calcification responds negatively to rapid changes in temperature on time scales of weeks or less due to thermal stress[53,54], or more gradually to seasonal changes in water temperature[55]. No significant difference in overall coral cover was identified between dry and wet seasons, suggesting seasonal forcing and linear extension of the skeleton is undetectable amidst an annual timespan. Factors such as biogeochemical dissolution and remineralization processes, tidal flushing, regional upwelling and oceanographic circulation patterns can dampen, enhance or swamp biologically driven fluctuations in pH, temperature and subsequent seasonal calcification fluctuations[51,52]. However, causality cannot be assigned to the spatial patterns in pH and seawater chemistry suggested here due to lack of a quantitative hydrodynamic and water chemistry data for this coastline. Discrimination of calcification cycles (or lack thereof) will be essential for identification of long-term trends in Dauin's reef calcification rates. Further data on light, temperature, carbonate chemistry, water motion, and/or nutrient uptake rates are required for predicting the effects of resource management actions on the health of this coastal ecosystem.

Acropora spp., Echinopora spp., Porites spp., Anacropora spp. and *Pocillopora spp.* are the dominant coral genera found across the Dauin reefscape, contributing to 79% of annual recorded coral cover. The distribution of these genera is not even across surveyed regions; rather genera growth shows site specificity. The concern regarding lack of diversity within reef sites and dominance of a single genera can be highlighted by results of impact and coral mortality assays, revealing *Acropora spp., Porites spp.* and *Pocillopora spp.* to be most susceptible to impacts such as disease, bleaching, predation from corallivous invertebrates, and direct destruction. The capacity for this reef ecosystem to absorb recurrent disturbances or shocks and adapt to change whilst retaining essentially the same function and structure is the core research focus of the Dauin LTRMP. With deficient data showcasing previous disturbance history and the local environmental conditions that shape Dauin's fringing reef, this information becomes the first of its kind to understand both the ecological ability for Dauin's reef to resist or survive a disturbance, as well as the rate of recovery required for this reef assemblage to return to its original condition. Fortunately, the current disturbances facing these predominant coral genera are mostly small and localised lesions, with bleaching to be observed across *Acropora spp., Pocillopora spp.* and *Porites spp.* colonies, albeit causing only partial bleaching to colony surface areas, with bleaching prevalence inconsistent across reef sites. Instead, *Fungia spp., Goniastrea spp.* and *Montastrea spp.* experienced the highest susceptibility to bleaching across reef sites. Hoeksema's (1989) recordings of *Fungia spp.* off the coast of Jakarta found bleaching of the mushroom coral to be size-dependent, and largely connected to their life histories[56]. Understanding the environmental factors that explain bleaching severity within Dauin (such as depth, spatial location of colonies relative to the reef edge, microhabitat, colony size, and colony morphology) is important in predicting future events[58]. Currently depth does not play a role in bleaching prevalence, however with carbonate sand being an abiotic component of Dauin's reefscape, it has the potential to be highly reflective, amplifying light intensity to neighbouring corals[57].

Algal cover shows a significant increase from dry to wet season, with turf algae predominantly contributing to this rise. Turf algae show site-specific upsurges, targeting areas with the aforementioned disturbance history. Filamentous turf algae is often first to colonise bare substrate, which is commonly observed after large-scale coral mortality[59,60,61]. Turf algae establishes faster in previously algal-dominated areas, indicating a higher supply of propagules from the direct surrounding environment[62]. Prevalence of scrapers within these reef sites (i.e. *Scaridae*, *Scarus*) should provide the capacity to remove algae and sediment by close cropping, facilitating settlement, growth and survival of coralline algae and corals[63]. Herbivorous fish contribute relatively little to total biomass of reef fish across the Dauin reefscape, posing preliminary concerns over the capacity for algal removal from previously disturbed sites. The decline in other macroalgae (e.g. *Turbiniaria spp., Dictyota spp.* and *Udotea spp.)* suggests the small herbivorous fish population may not yet be of concern, rather the distribution of herbivores within their functional grouping (i.e. large excavators, small excavators, scrapers, grazers, browsers and grazers/detritivores) requires deeper understanding.

4.2 Reef Impacts & Coral Mortality

Supplementary assessments of coral health indicate a variety of localised stressors are causing direct mortality to the holobiont of corals within the Dauin reefscape. *Drupella spp.*, trash and direct destruction have all seen a significant seasonal rise, whilst bleaching, disease and *Acanthaster plancii* prevalence have plateaued across the wet season months.

The widespread recreational use of coral reefs for snorkelling and SCUBA diving can contribute to reef degradation through both direct and indirect stressors. These impacts recorded as part of the Dauin LTRMP include destruction of the coral skeleton from both direct (fin) damage, and indirect (boat anchor) damage. These recordings have seen a seasonal rise in prevalence, with potential linkages to the shift in the number of tourist visitors from low to high season. In addition to destruction from tourism, the presence of the *muro-ami* fishing strategy has also seen site-specific skeletal coral damage. *Muro-ami* is a Japanese fishing method used in reef fishing, effecting fish capture by spreading a net in an arc around reefs or shoals, and with the use of scarelines, fisherman drive fish towards the waiting net by pounding stone or rocks into the surrounding waters, making it highly destructive to underlying corals. In 1986, the Department of Agriculture banned *muro-ami* in Philippine waters due to the tremendous damage it causes to coral reefs. Not only has *muro-ami* been recorded within select marine reserves within Dauin, so too has fishing trash which follows the same pattern of site distribution. This suggests the marine reserves of Lipayo and Masaplod Sur have forgone enforcement measures and are weakly-functioning "paper parks"[106]. Following physical damage to the coral skeleton from this technique, the major concern regards the susceptibility of coral to secondary stressors. After injury, coral diverts its energy to the repair and regeneration of tissue[64]. Tissue can be regenerated by an initial limited amount of energetic resources[65,66], likely drawn from nearby unaffected tissue[67]. The energetic cost of repair has been suggested to increase disease susceptibility by lowering the immune responses of the coral[68]. Furthermore, lesions caused by fragmentation could be sites for the introduction of pathogens, increasing susceptibility to disease[69]. Lesions may also attract corallivores[70,71,72], which can act as vectors for disease[73,74,75]. Both Lipayo and Masaplod Sur have seen a rise in *Drupella spp*. predation, both on whole and fragmented *Acropora spp.* colonies, with Masaplod Sur also experiencing a rise in white syndrome disease. Synergistically to physical damage, the wet season swells may have increased nutrient loads in the water column via water mixing. Nutrient enrichment experiments suggest a change in ambient nutrient levels can negatively affect the physiology of the coral, potentially resulting in a further increased susceptibility to disease alongside fragmentation[76,77]. The conservation goals of the Lipayo and Masaplod Sur marine reserves will need to be readdressed in order to curb the spread of secondary holobiont infections as a result of these previously stated anthropogenic activities.

4.3 Fish Composition & 3-Dimensional Reef Modelling

A total of 37 fish families were recorded along the Dauin inshore reef, with a total species richness of 248. *Pomacentridae* and *Serranidae* (genus *Pseudanthias*) comprised both the major abundance and biomass of reef fish along the coastline, and across seasons. No statistical significance was highlighted for seasonal differences in fish biomass, however a weak significance between fish species abundance has been identified from dry to wet season, with beta dispersion plots and NMDS also revealing species abundance to differ based on location and coral cover. Coral reefs closer to the equator are subject to monsoonal conditions that are characterised by annual wind and precipitation cycles, rather than changes in ambient sea temperature found in temperate waters[80]. Reef fishes in equatorial regions may time their spawning to coincide with periods when winds and currents are at their weakest, presumably to limit the dispersal of larvae away from natal reefs and increase the chances of settlement to suitable habitats[96]. The Philippines is influenced by the reversing wind pattern of the East Asian monsoon[81]. From November to early March, strong winds from the northeast predominate, whilst July to September experience strong winds from the southwest. Much of the study area for the Dauin LTRMP is sheltered from the southwest monsoon due to the tall mountains on south-eastern Negros (e.g. Mt Talinis; Cuernos de Negros, elevation: 1,903m). Winds during inter-monsoonal months (April to June, and October) are lighter and more variable in direction. If trends continue, the rise in fish abundance from dry to wet survey season could be linked to enhanced retention of larvae during the southwest monsoon and inter-monsoonal periods when wind strength and currents weaken. This would occur if recruits that settle on reefs are produced within the same general locality, therefore monsoon-induced seasonal variation in the strength of local currents would have a significant influence on the annual pattern of recruitment[80].

Five indicator species have been identified to account for seasonal differences in species abundance; *Parupeneus pleurostigma, Parupeneus cyclostomus, Meiacanthus grammistes, Chromis viridis,* and *Chromis ternatensis.* This is supportive of previous findings at locations close to the equator where wind has the most consistent effect on settlement patterns of reef fishes, particularly in damselfishes[78,79,80]. Alongside seasonal differentiation, results are also indicative of habitat, specifically coral, preference. A large number of studies support a positive relationship between abundance and live coral cover, which is expected to be particularly important in explaining the abundance of obligate coral-dwelling species, corallivorous fishes, or species reliant on coral habitat for recruitment[85,86,87,88]. Coral cover would have a greater influence on fish abundance than on fish species richness, as a higher coral cover increases habitat area without necessarily increasing the range of habitat types available[89]. Studies of *Chromis viridis* revealed habitat specificity beyond the level of broadly defined coral cover and morphology, showing a preference for specific coral species (*Acropora spp.* and *Pocillopora spp.*)[94], with a study of settling *Chromis viridis* preferring settlement with conspecific adults within *Acropora spp.* colonies[95]. In addition, the species richness and abundance of reef fish communities have often been related to structural topographic complexity; a measure of variation in the vertical relief of the habitat[82,83,84]. High topographic complexity may promote high abundance and diversity due to increased refuge availability, decreased encounter rates between competitors and their prey, consequently reducing the effects of predators and competition[90,91,92,93]. The Dauin LTRMP data on topographic complexity, including rugosity, remain weakly correlated with total fish abundance and the *Pomacentridae* family. The species accumulation curve has not yet begun to plateau, with results not yet supportive of habitat complexity dictating species richness. Regardless, these results reveal topographic complexity and species preference is not universally important in predicting reef fish diversity and abundance, as it co-varies with other important spatial and environment characteristics as previously discussed with larval distribution and seasonality. Settlement patterns and habitat preferences of coral reef fish within the Dauin inshore reef will become apparent with continued monitoring, and will be important for targeted management and habitat enhancement.

Coastal marine ecosystems are increasingly subjected to a wide range of anthropogenic and natural disturbances, leading to a decline in habitat quality, quantity and connectivity[97,98]. Coral loss and degradation of coral reef habitats will have a significant influence on the abundance and diversity of coral reef fishes[99]. Functional group analyses are being increasingly used to examine how reef fish assemblages respond to disturbances and habitat degradation, due to their classification based on trophic level, ecological role, body size, home range, habitat associations, or a combination of these factors[99]. The trophic structure of the Dauin inshore reefscape supports a high prevalence of habitat generalists, consisting largely of herbivore & planktivores, followed by planktivores & omnivores. Studies have explored changes in the biodiversity and functioning of coral reef fish assemblages following distinct episodes of coral loss caused by acute disturbances such as bleaching, severe tropical storms, outbreaks of *Acanthaster plancii* or experimentally imposed disturbances. Results of post-bleaching communities on the Great Barrier Reef reveal the reef fish assemblage to be dominated by generalist planktivores, benthic omnivores and detritivores[63], with disturbance having a greater impact on resource specialists. This suggests frequent and intense coral loss will cause reef fish communities to become dominated by habitat generalists at the expense of coral-dwelling specialists. Whether the trophic structure of the Dauin inshore reef is also indicative of post-disturbance recovery, correlating with previously discussed benthic data, will require continued monitoring of trophic structuring.

The direct removal of reef fish from the ecosystem has also been explored; 75 commercially important fish species (30% of total species richness) across 18 different fish families have been identified from the Dauin LTRMP. *Labridae, Acanthuridae, Caesonidae* and *Plotosidae* were the most abundant commercially important fish families, with *Caesonidae, Lutjanidae, Serranidae* and *Siganidae* being the biggest contributors to biomass. The relative abundance and biomass of these commercially important fish species varied greatly between sites, with some inter-seasonal changes. Specifically, *Siganus guttatus* abundance more than doubles from dry to wet season. Studies of *S. guttatus* in central Java, Indonesia, indicate that an increased gonadal activity occurs twice each year, lasting from September to October (2 months) and from March to May (3 months)[101]. The period from September to October appears to be the major reproductive season, with both seasons coinciding with the transition between dry and rainy season, suggesting that periodic changes in the aquatic environment related to tropical typhoons trigger gonadal development of this fish in the area[101]. During the reproductive season, synchronized spawning occurs in association with a particular lunar phase[100]. These findings suggest the high prevalence of *S. guttatus* recorded during the Dauin wet season is associated with synchronous spawning behaviour. Contrary to results from *S. guttatus*, *Plectropomus laevis* was absent during the wet survey period. Large predatory and commercially important coral reef fish, such as *P. laevis,* have compromised fitness and performance with high temperatures[103]. Given that most teleosts are ectotherms, increases in ocean temperatures will lead to inevitable increases in baseline metabolic rates, which may be partially compensated for through increased food intake[103]. Predatory fish from low-latitude regions spend a significant proportion of their time completely inactive when exposed to high summer temperatures, with inactivity increasing with temperature from 21°C to 30°C[105]. This reduction in swimming and activity patterns are likely to influence foraging efficiency and the ability to capture prey, but also potentially influence species demography with long-term activity patterns and space use[102,103]. Ocean temperatures along the Dauin coastline see a seasonal rise from dry to wet season, therefore it could be suggested that absence of *P. laevis* from wet season surveys is associated with an inactivity period due to external environmental influences. As *P. laevis* is a commercially important fish species, it must also be highlighted that the absence as a result of targeted fishing pressure is also a possibility. With the marine reserves of Dauin protecting potential spawning aggregations, commercially important species, as well as the IUCN Red Listed species of *Scarus hypselopterus, Oxymonacanthus longirostris,* and *Epinephelus fuscoguttatus,* the long-term monitoring of fish assemblages across the Dauin reefscape will assist in highlighting site-specific aggregation areas whilst improving and tightening protection measures across the Municipal waters.

5. CONCLUSION & FUTURE WORK

When assessing the spatial patterns of Dauin's reefscape over a one year time period, results reveal site-specific fluctuations in disturbance history, anthropogenic use, benthic composition, and subsequent fish assemblage and recruitment patterns. Whilst seasonality comes into play when addressing species specific fish distribution patterns, continued long-term monitoring will be required to gauge patterns with regards to settlement, rigid binding, nutrient loading and anthropogenic use. Key areas of management concern have been highlighted, as well future research required by the Institute to better understand the current findings of the Dauin LTRMP.

5.1. Management Action

1. Readdress the conservation goals of the Lipayo and Masaplod Sur marine reserves as a result of the continued recordings of fishing line and the destructive *muro-ami* fishing technique.
2. Continue to enforce protection measures on Masaplod Norte, Maayong Tubig and Lipayo I Sur marine reserves, which are currently undergoing processes of recovery post-typhoon.
3. Enforce protections at Lipayo I Sur, Masaplod Norte and Bulak marine reserves to ensure continual rise in their reef biomass of commercially important species and allow for spill-over effect.
4. Tighten enforcement on Poblacion District I, Poblacion District II, Masaplod Sur, Lipayo II and Masaplod Norte marine reserves due to the presence of "*Vulnerable*" and "*Near Threatened*" IUCN Red Listed species.

5.2. Future Research

1. Continue to understand both the ecological ability for Dauin's reef to resist or survive a disturbance, as well as the rate of recovery required for this community to return to its original condition.
2. Determine rates of biogenic carbonate sediment production, and the presence (or absence) of calcification cycles as influenced by anthropogenic and/or environmental processes (e.g. seasonality, water temperature, nutrients, pCO_2, light availability).
3. Understand what environmental factors explain bleaching severity within Dauin, such as depth, spatial location of colonies relative to the reef edge, microhabitat, colony size, and colony morphology.
4. Determine the abundance and distribution of herbivores within their functional grouping (i.e. large excavators, small excavators, scrapers, grazers, browsers and grazers/detritivores), and the effects this distribution has on algal cover.
5. Identify factors driving *Drupella spp.* and *Acanthaster plancii* abundance and spread.
6. Determine susceptibility of corals to disease and predation from corallivores as a result of post-fragmentation from direct destruction.
7. Understand settlement patterns and habitat preferences of coral reef fish within the Dauin inshore reef.
8. Continue to examine the size structure of commercially important reef fish within the Dauin inshore reef to determine their species-specific reproductive potential.

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7. APPENDICES

7.1 CPCe Codec

ACAN	ACR	ALV	ANAC	ASTR	AUS	CATA	CAUL	COEL	COSC	CTEN	CYC	CYN	CYPH	DIPL	DUNC	ECHI	ECHP	EUPH	FAV	FAVI	FUN	GALA	GARD	GONI
GONO	HALO	HELI	HERP	HET	HETP	HYDN	ISOP	LOBO	LEP	LEPT	LEPTA	LITH	MON	MONT	MERU	MOSE	MYC	OULO	OXY	PACH	PARA	PAVO	PECT	PHYS
PLAT	PLER	POC	PODA	POLY	POR	PSAM	SAN	SCAP	SCOL	SER	STY	SYMP	TRAC	TUBA	TURB	ZOO	UC	GG	SC	SP	TP	HEL	LC	MP
STH	DRU	GC	SL	AM	CM	Z	SPB	SPBL	SPBR	SPE	SPF	SPR	SPT	ASC	COT	CY	O	HM	SA	TA	CA	OA	SG	RDC
DCA	CR	R	RB	S	SH	T	FG	UNK	TAPE	WAND	SHAD	BL	BBD	BLBD	WSD	NEO	HYP	SEBD	PP	FS	IVB	OD		

	Acanthastrea (ACAN)	Leptoria (LEPTA)	Anemone (AM)	Sand (S)
	Acropora (ACR)	Leptoseris (LEPT)	Corallimorph (CM)	Shell (SH)
	Alveopora (ALV)	Lithophyllon (LITH)	Zoanthid (Z)	Trash (T)
	Anacropora (ANAC)	Lobophyllia (LOBO)	Gorgonian (GG)	Coral Rubble (CR)
	Astreopora (ASTR)	Merulina (MERU)	Heliopora (HEL)	Dead Coral with Algae (DCA)
	Australogyra (AUS)	Montastrea (MONT)	Sea Pen (SP)	Recently Dead Coral (RDC)
	Catalaphyllia (CATA)	Montipora (MON)	Soft Coral (SC)	Unknown (UNK)
	Caulastrea (CAUL)	Moseleya (MOSE)	Tubipora (TP)	Shadow (SHAD)
	Coeloseris (COEL)	Mycedium (MYC)	Drupella (DRU)	Tape (TAPE)
	Coscinaraea (COSC)	Oulophyllia (OULO)	Giant Clam (GC)	Wand (WAND)
	Ctenactis (CTEN)	Oxypora (OXY)	Scallop (SL)	Bleached coral point (BL)
	Cycloseris (CYC)	Pachyseris (PACH)	Lace Coral (LC)	Brown Band Disease (BBD)
	Cynarina (CYN)	Paraclavarina (PARA)	Millepora (MP)	Black Band Disease (BLBD)
	Cyphastrea (CYPH)	Pavona (PAVO)	Stinging Hydroid (STH)	White Syndrome Disease (WSD)
	Diploastrea (DIPL)	Pectinia (PECT)	Sponge Ball (SPBL)	Neoplasia (NEO)
	Duncanopsammia (DUNC)	Physogyra (PHYS)	Sponge Barrel (SPBR)	Hyperplasia (HYP)
	Echinophyllia (ECHI)	Platygyra (PLAT)	Sponge Branching (SPB)	Skeletal Eroding Band Disease (SEBD)
	Echinopora (ECHP)	Plerogyra (PLER)	Sponge Encrusting (SPE)	Porites Pinking (PP)
	Euphyllia (EUPH)	Pocillopora (POC)	Sponge Fan (SPF)	Feeding Scar (FS)
	Favia (FAV)	Podabacia (PODA)	Sponge Rope (SPR)	Invertebrate Burrow (IVB)
	Favites (FAVI)	Polyphyllia (POLY)	Sponge Tube (SPT)	Other disease (OD)
	Fungia (FUN)	Porites (POR)	Coralline Algae (CA)	
	Galaxea (GALA)	Psammocora (PSAM)	Halimeda (HM)	
	Gardineroseris (GARD)	Sandalolitha (SAN)	Other Algae (OA)	
	Goniastrea (GONI)	Scapophyllia (SCAP)	Sargassum (SA)	
	Goniopora (GONO)	Scolymia (SCOL)	Turf Algae (TA)	
	Halomitra (HALO)	Seriatopora (SER)	Seagrass (SG)	
	Heliofungia (HELI)	Stylophora (STY)	Ascidian (ASC)	
	Herpolitha (HERP)	Symphyllia (SYMP)	Crown of Thorns (COT)	
	Heterocyathus (HET)	Trachyphillia (TRAC)	Cyanobacteria (CY)	
	Heteropsammia (HETP)	Tubastrea (TUBA)	Other (O)	
	Hydnophora (HYDN)	Turbinaria (TURB)	Fishing Gear (FG)	
	Isopora (ISOP)	Unknown Coral (UC)	Rock (R)	
	Leptastrea (LEP)	Zoopilus (ZOO)	Rubble (RB)	

7.2. Additional Figures

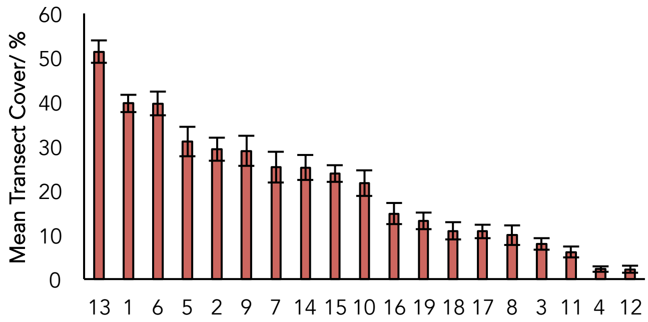

Fig 7.2.1: Mean transect cover (% ± SE) of Scleractinian coral along Dauin Reef survey sites for the 2019 survey year.

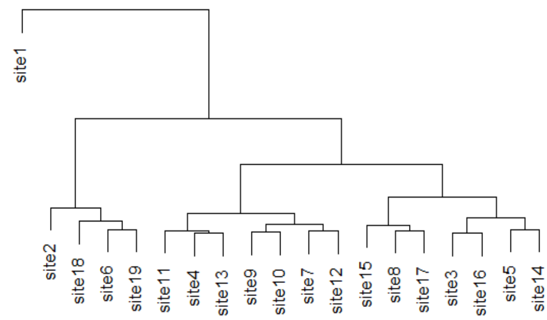

Fig 7.2.2: Cluster dendrogram showing similarities between rock cover of different sites.

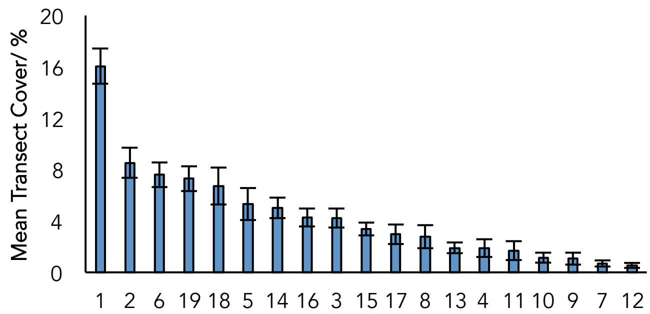

Fig 7.2.3: Mean transect cover (% ± SE) of rock along Dauin Reef survey sites for the 2019 survey year.

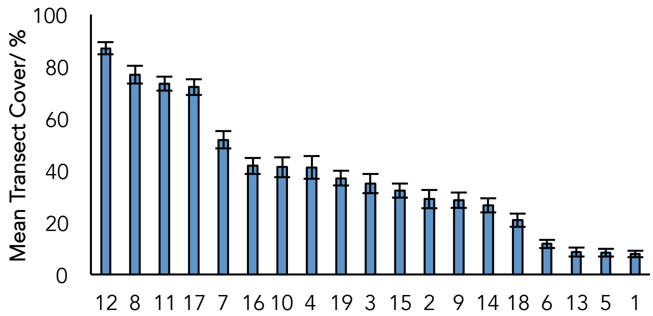

Fig 7.2.4: Mean transect cover (% ± SE) of sand along Dauin Reef survey sites for the 2019 survey year.

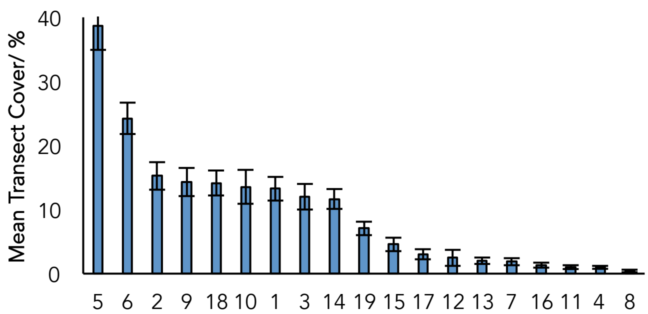

Fig 7.2.5: Mean transect cover (% ± SE) of rubble along Dauin Reef survey sites for the 2019 survey year.

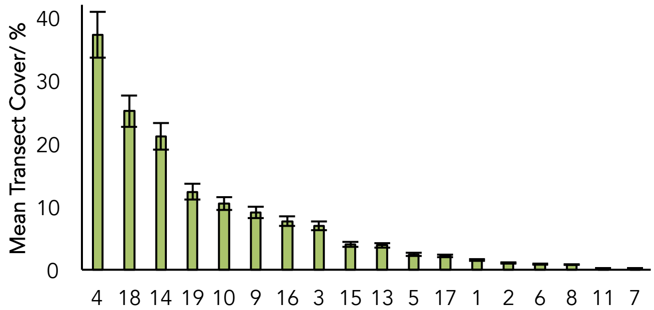

Fig 7.2.6: Mean transect cover (% ± SE) of coral rubble along Dauin Reef survey sites for the 2019 survey year.

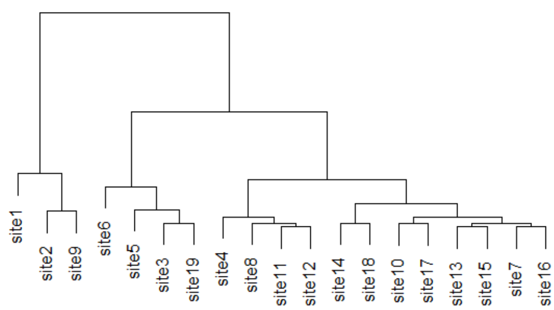

Fig 7.2.6: Cluster dendrogram showing similarities between dead coral with algae cover of different sites.

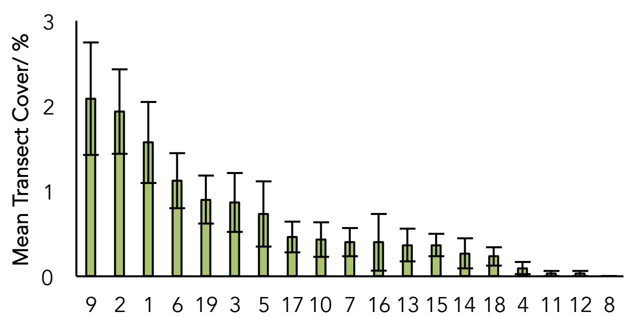

Fig 7.2.8: Mean transect cover (% ± SE) of dead coral with algae along Dauin Reef survey sites for the 2019 survey year.

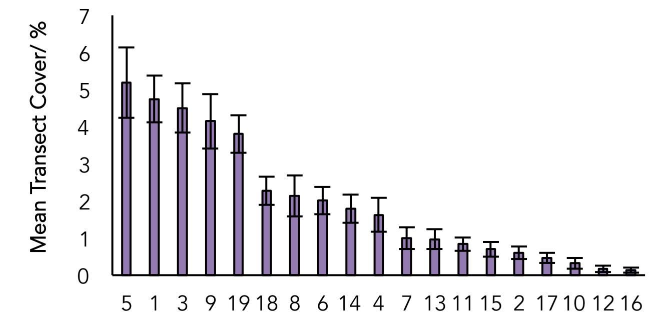

Fig 7.2.9: Mean transect cover (% ± SE) of coralline algae along Dauin Reef survey sites for the 2019 survey year.

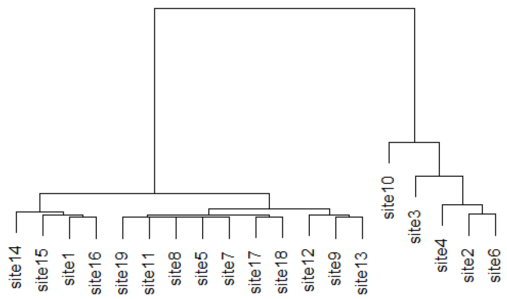

Fig 7.2.10: Cluster dendrogram showing similarities between Halimeda cover of different sites.

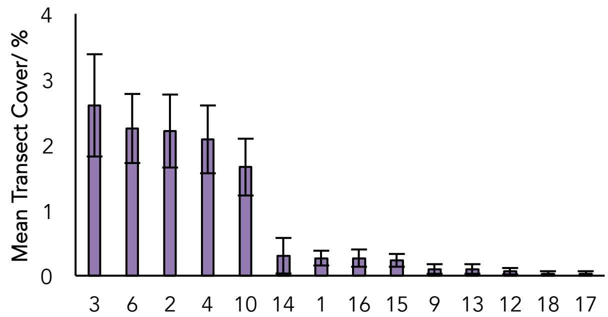

Fig 7.2.11: Mean transect cover (% ± SE) of Halimeda along Dauin Reef survey sites for the 2019 survey year.

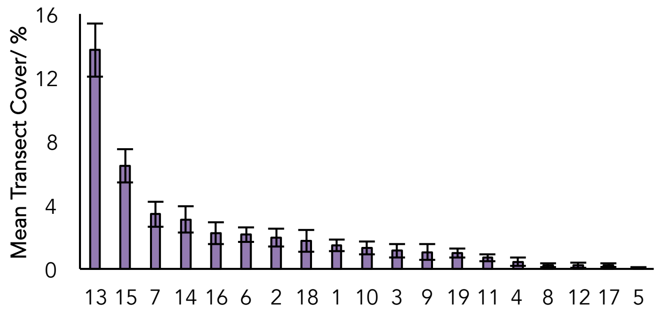

Fig 7.2.12: Mean transect cover (% ± SE) of other algae along Dauin Reef survey sites for the 2019 survey year.

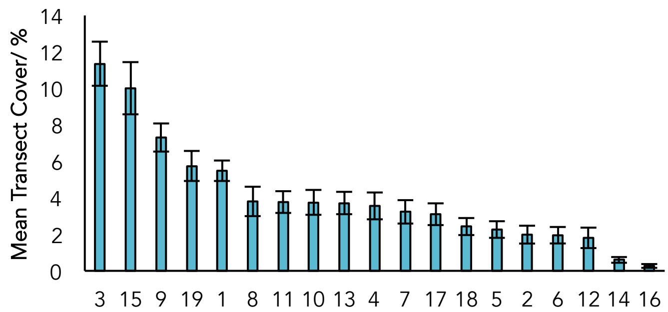

Fig 7.2.13: Mean transect cover (% ± SE) of sponge along Dauin Reef survey sites for the 2019 survey year.

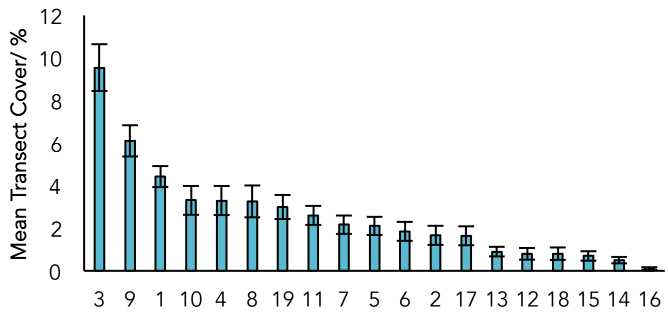

Fig 7.2.14: Mean transect cover (% ± SE) of encrusting sponge along Dauin Reef survey sites for the 2019 survey year.

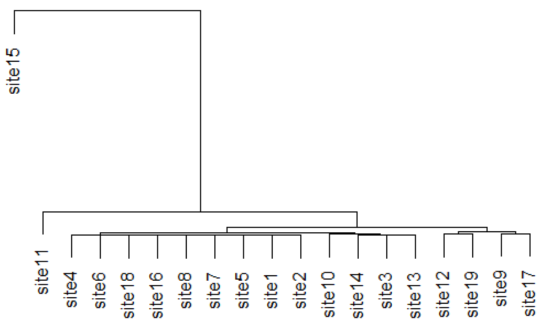

Fig 7.2.15: Cluster dendrogram showing similarities between tube sponge cover of different sites.

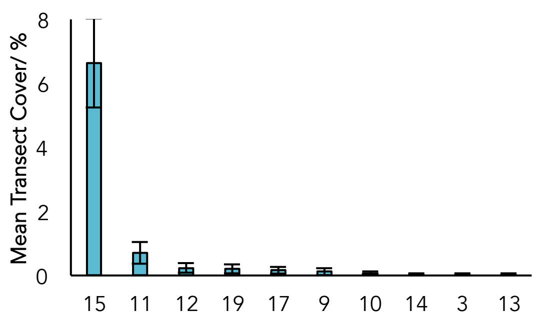

Fig 7.2.16: Mean transect cover (% ± SE) of tube sponge along Dauin Reef survey sites for the 2019 survey year.

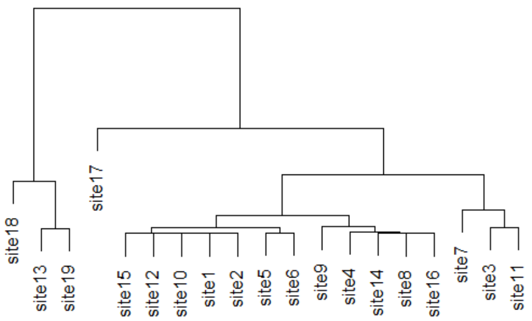

Fig 7.2.17: Cluster dendrogram showing similarities between rope sponge cover of different sites.

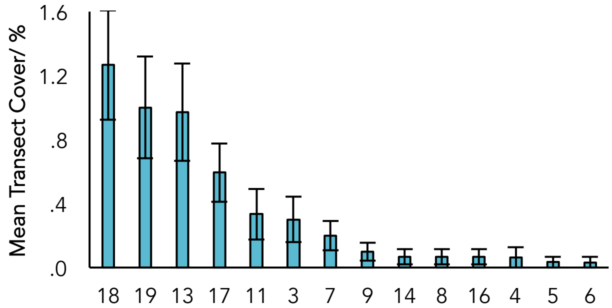

Fig 7.2.18: Mean transect cover (% ± SE) of rope sponge along Dauin Reef survey sites for the 2019 survey year.

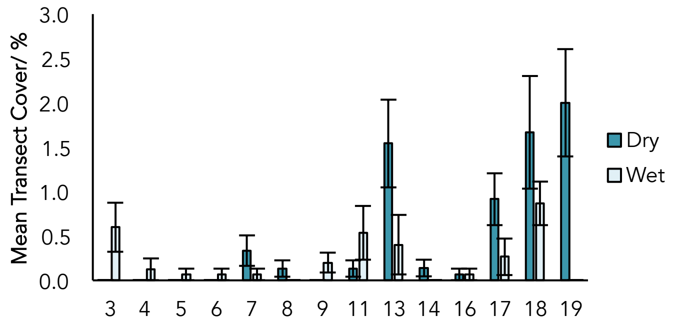

Fig 7.2.19: Mean rope sponge transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

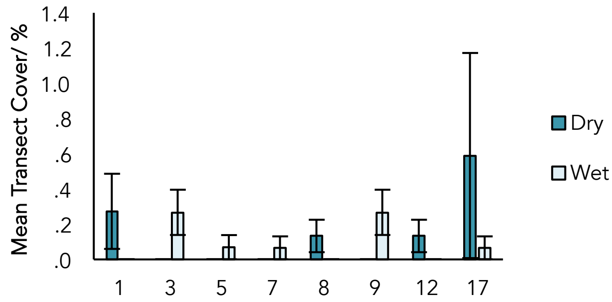

Fig 7.2.20: Mean transect cover (% ± SE) of barrel sponge along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

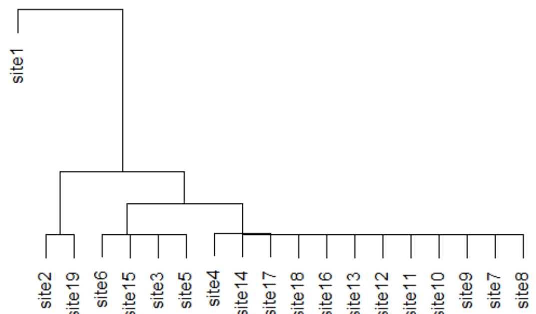

Fig 7.2.21: Cluster dendrogram showing similarities between fan sponge cover of different sites.

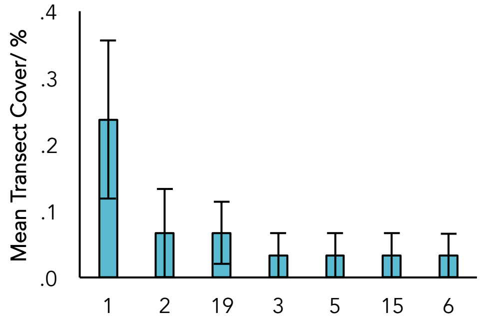

Fig 7.2.22: Mean transect cover (% ± SE) of fan sponge along Dauin Reef survey sites for the 2019 survey year.

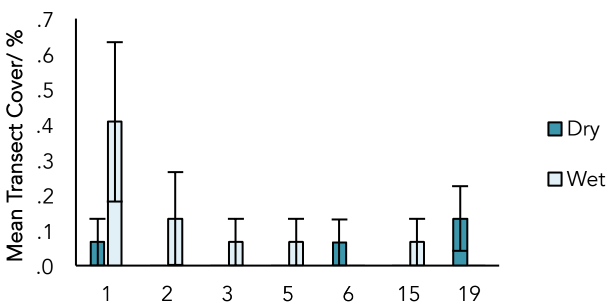

Fig 7.2.23: Mean fan sponge transect cover (% ± SE) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

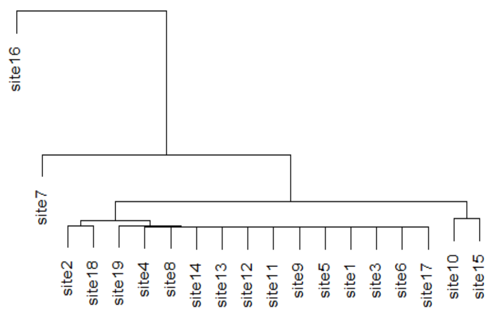

Fig 7.2.24: Cluster dendrogram showing similarities between seagrass cover of different sites.

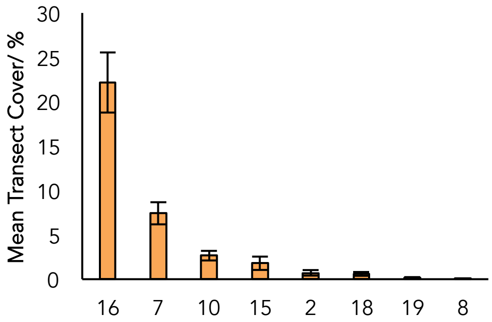

Fig 7.2.25: Mean transect cover (% ± SE) of seagrass along Dauin Reef survey sites for the 2019 survey year.

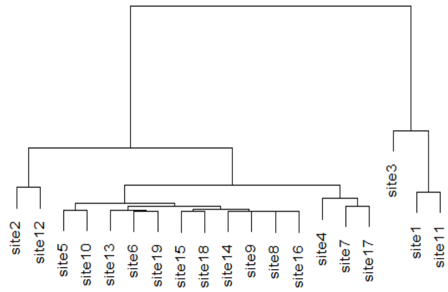

Fig 7.2.26: Cluster dendrogram showing similarities between hydroid cover of different sites.

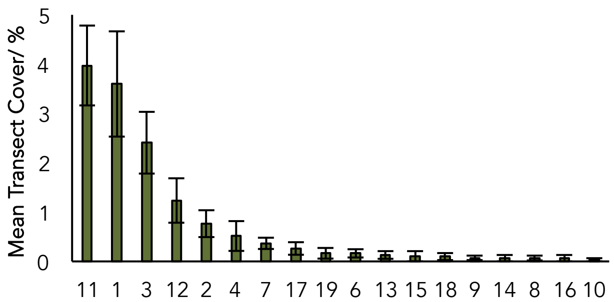

Fig 7.2.27: Mean transect cover (% ± SE) of hydroids along Dauin Reef survey sites for the 2019 survey year.

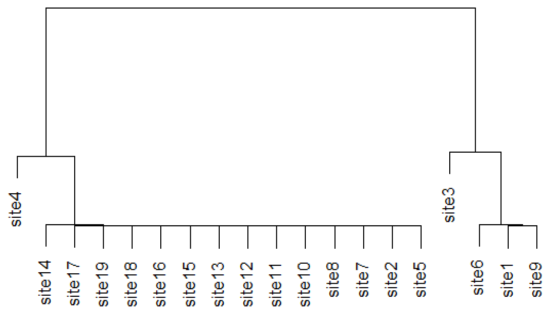

Fig 7.2.28: Cluster dendrogram showing similarities between bivalve cover of different sites.

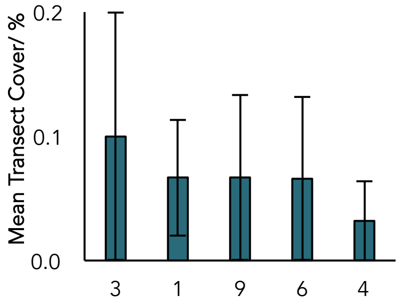

Fig 7.2.29: Mean transect cover (% ± SE) of bivalves along Dauin Reef survey sites for the 2019 survey year.

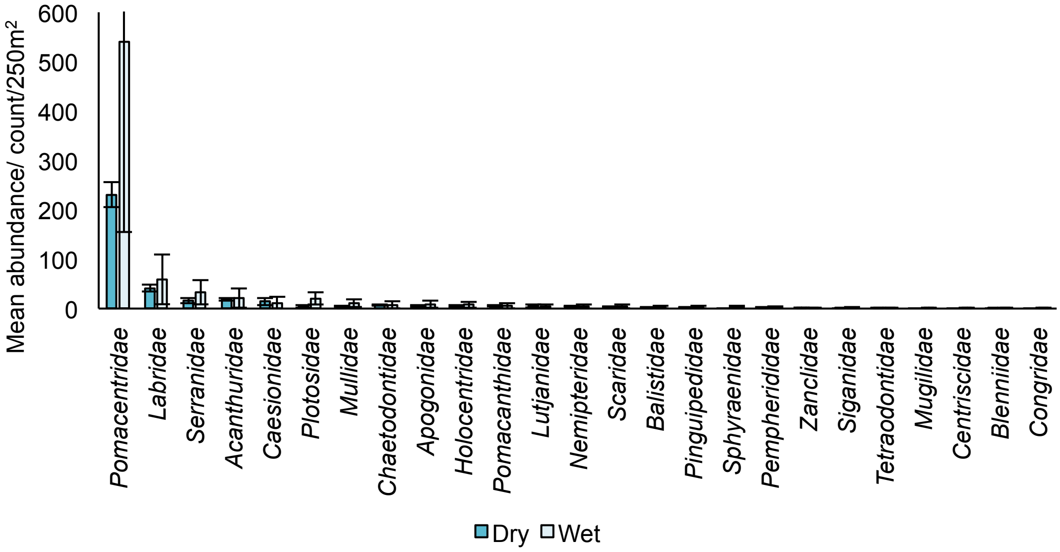

Fig 7.2.30: Mean abundance per transect (count/250m^2 ± SE) of 25 most abundant fish families recorded along Dauin reef separated by season (dry Season: Feb 19-July 19 and wet Season: Aug 19-Feb 20).

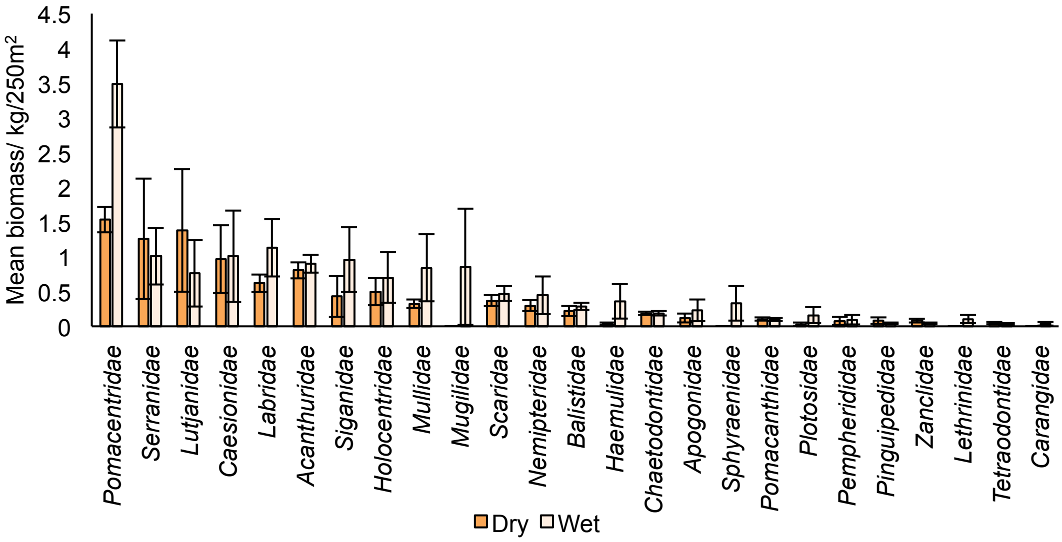

Fig 7.2.31: Mean biomass per transect (kg/250m^2 ± SE) of the 25 fish families that contribute the most to biomass, recorded along Dauin Reef separated by season (dry Season: Feb 19-July 19 and wet Season: Aug 19-Feb 20).

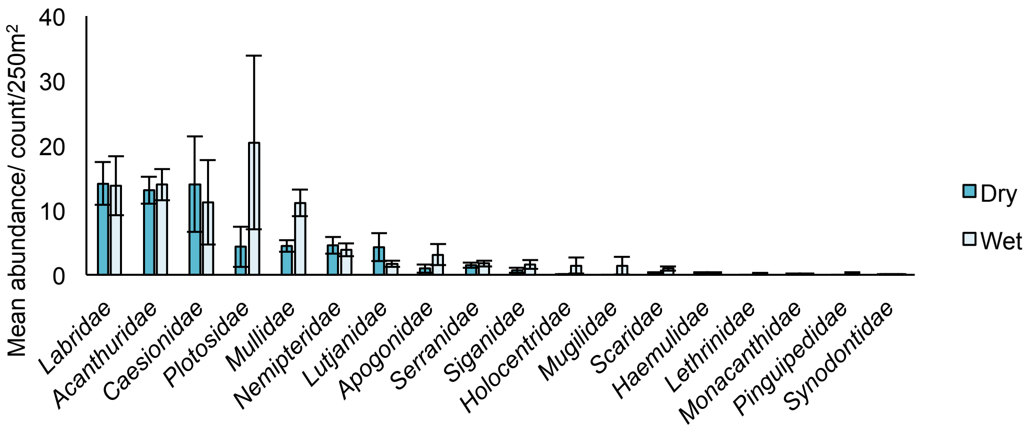

Fig 7.2.32: Mean abundance per transect (count/250m^2 ± SE) of commercially important fish species, grouped into families, recorded along Dauin Reef separated by season (dry Season: Feb 19-July 19 and wet Season: Aug 19-Feb 20).

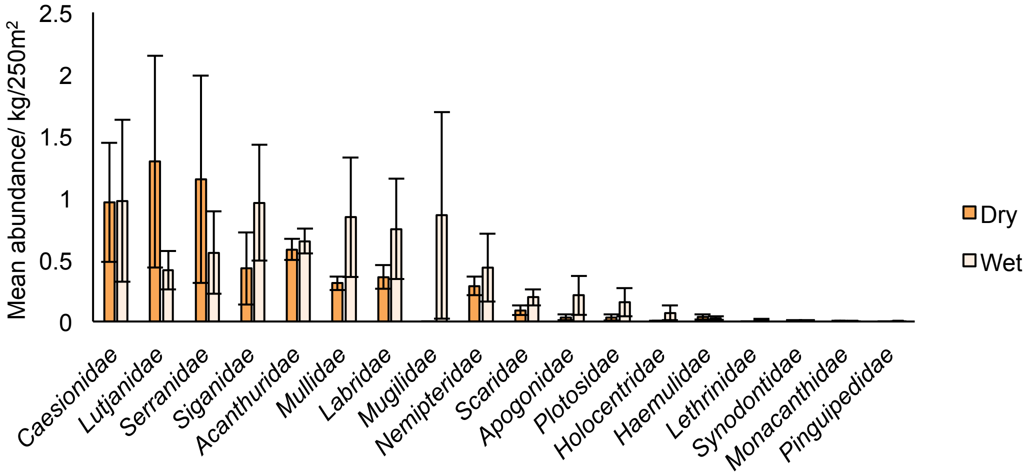

Fig 7.2.33: Mean biomass per transect (kg/250m^2 ± SE) of commercially important fish species, grouped into families, recorded along Dauin Reef separated by season (dry Season: Feb 19-July 19 and wet Season: Aug 19-Feb 20).

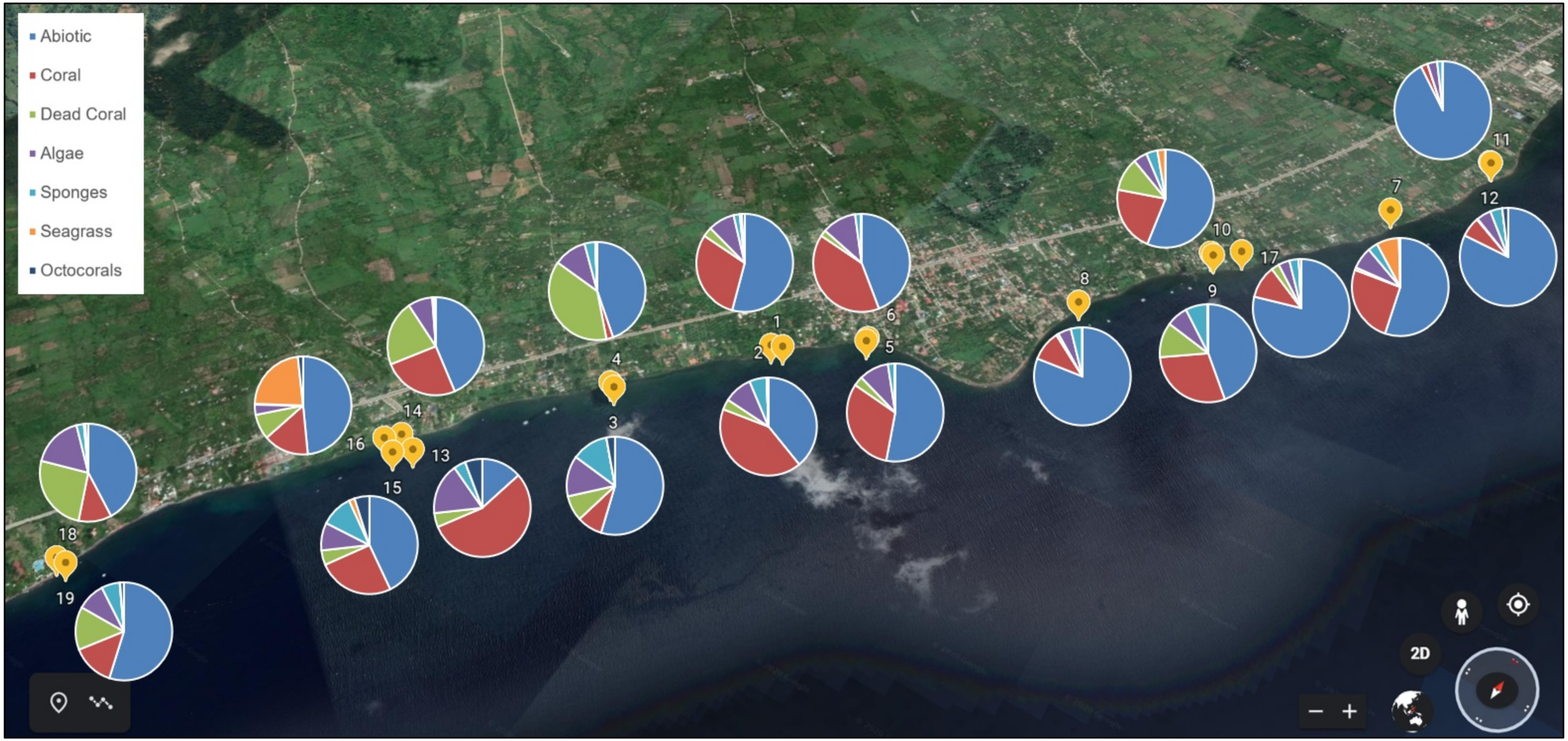

Fig 7.2.30: Satellite map of survey sites with major benthic category proportions for the 2019 year. Graphs on shore side refer to 5m depth survey sites and those in the water show 10m sites.

7.3 Additional Tables

Table 7.3.1: Mean incidence per location (count/100m2) of each recorded impact along Dauin Reef separated by season (Dry Season: Feb 19-July 19 and Wet Season: Aug 19-Feb 20).

	Acanthaster plancii (COTS)			Bleaching			Direct Destruction			Disease			*Drupella* sp.		
Site Name	Dry	Wet	Trend	Dry	Wet	Trend	Dry	Wet	Trend	Dry	Wet	Trend	Dry	Wet	Trend
Bulak I	0.0	0.0	→	1.8	0.0	↘	0.0	2.0	↗	0.5	1.0	↗	1.3	0.0	↘
Bulak II	0.0	0.0	→	2.0	1.0	↘	0.5	8.0	↗	1.0	0.0	↘	0.5	8.0	↗
Lipayo I Norte	0.0	0.0	→	3.0	3.0	→	0.5	1.0	↗	1.0	0.0	↘	1.0	0.0	↘
Lipayo I Sur	0.0	0.0	→	2.8	9.0	↗	0.0	3.3	↗	0.5	0.3	↘	3.5	6.0	↗
Lipayo II	0.0	0.0	→	3.5	0.0	↘	0.0	0.0	→	0.0	0.0	→	0.0	0.0	→
Poblacion District I	0.0	0.0	→	7.3	4.7	↘	0.3	0.7	↗	1.7	4.0	↗	1.0	2.0	↗
Poblacion District II	0.8	0.0	↘	4.4	3.0	↘	0.4	1.0	↗	1.6	1.0	↘	1.4	2.0	↗
Masaplod Norte	0.0	0.0	→	4.8	5.0	↗	0.0	0.5	↗	0.5	0.0	↘	0.3	0.0	↘
Masaplod Sur MPA	0.0	0.0	→	3.8	1.7	↘	0.2	4.7	↗	0.3	1.0	↗	2.2	3.3	↗
Masaplod Sur	0.3	0.0	↘	5.7	4.0	↘	0.0	1.0	↗	0.3	0.3	→	0.3	2.0	↗
Maayong Tubig	0.8	0.0	↘	1.0	16.5	↗	0.8	1.0	↗	0.8	0.0	↘	0.5	1.5	↗

	Fishing Gear			Scar Unknown			Stone fishing			Trash		
Site Name	Dry	Wet	Trend	Dry	Wet	Trend	Dry	Wet	Trend	Dry	Wet	Trend
Bulak I	1.5	0.0	↘	0.0	2.0	↗	0.0	0.0	→	0.3	6.0	↗
Bulak II	1.5	0.0	↘	0.0	0.0	→	0.0	0.0	→	0.5	3.0	↗
Lipayo I Norte	1.0	0.0	↘	1.0	1.0	→	0.0	0.0	→	1.0	0.0	↘
Lipayo I Sur	0.3	0.0	↘	0.8	4.0	↗	3.0	0.0	↘	1.5	5.0	↗
Lipayo II	0.5	0.0	↘	1.0	1.0	→	0.0	0.0	→	0.0	1.0	↗
Poblacion District I	0.0	0.0	→	1.0	1.7	↗	0.0	0.0	→	0.7	0.7	→
Poblacion District II	0.0	0.0	→	1.2	1.0	↘	0.0	0.0	→	0.0	0.0	→
Masaplod Norte	0.3	4.0	↗	0.8	1.5	↗	0.0	0.0	→	0.5	0.5	→
Masaplod Sur MPA	1.3	0.0	↘	2.0	3.3	↗	0.2	0.0	↘	0.2	0.0	↘
Masaplod Sur	0.0	0.0	→	1.7	2.7	↗	0.7	0.0	↘	0.0	0.0	→
Maayong Tubig	0.5	0.0	↘	1.0	0.0	↘	0.0	0.0	→	0.5	1.0	↗

Table 7.3.2 3D metrics (length, rugosity, slope, variation, range with ± (arb. units)) along Dauin Reef survey sites separated by season (dry season: Feb 19-July 19 and wet season: Aug 19-Feb 20).

	1			2			3			4			5			6		
	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ
Length	25.2	43.7	-18.6	61.2	229.0	-167.8	34.8	126.3	-91.5	22.7	257.8	-235.2	70.2	148.4	-78.2	174.5	111.9	62.6
±	25.8	27.1		25.9	66.8		17.5	53.3		13.0	5.0		32.4	75.3		61.7	62.2	
Rq(RMS)	1.2	1.9	-0.8	11.2	23.0	-11.8	1.4	6.3	-4.8	1.0	8.8	-7.8	2.5	6.1	-3.6	20.7	8.6	12.1
±	0.4	1.0		7.8	8.4		0.6	2.0		0.2	0.3		1.1	2.7		4.8	2.7	
Slope	0.2	0.0	0.2	0.5	-0.4	0.9	-0.1	0.1	-0.2	-0.1	0.0	-0.2	0.0	0.0	0.0	0.5	-0.4	0.8
±	0.1	0.1		0.4	0.2		0.1	0.1		0.2	0.0		0.1	0.1		0.3	0.6	
Variation	9.7	17.7	-8.1	33.6	86.7	-53.1	7.4	38.5	-31.1	5.9	77.3	-71.5	19.4	40.3	-20.9	90.2	45.5	44.7
±	10.3	11.8		23.3	27.7		5.6	18.4		2.8	11.0		11.4	26.2		29.1	24.4	
Range	3.6	6.0	-2.4	28.1	70.7	-42.5	4.0	17.6	-13.6	3.3	29.8	-26.5	7.9	19.4	-11.5	63.7	25.2	38.5
±	1.6	3.0		23.7	31.6		2.0	8.4		0.8	0.9		2.9	9.1		18.3	11.5	

	7			8			9			10			11			12		
	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ
Length	26.2	45.5	-19.3	33.0	53.0	-20.0	39.1	39.9	-0.8	95.6	102.5	-7.0	59.2	165.4	-106.2	103.8	55.5	48.4
±	21.8	13.0		10.3	30.7		7.7	25.5		22.6	55.7		15.2	67.7		41.8	25.5	
Rq(RMS)	0.9	1.1	-0.2	3.3	2.6	0.7	2.7	2.7	0.0	2.6	6.2	-3.6	3.2	14.2	-11.0	6.4	2.3	4.1
±	0.8	0.8		1.6	1.3		1.3	1.4		1.8	1.7		1.2	3.9		1.8	0.3	
Slope	0.0	0.1	-0.1	-0.4	-0.1	-0.2	0.2	0.0	0.2	0.0	-0.1	0.1	0.2	-0.4	0.5	-0.1	0.1	-0.1
±	0.1	0.1		0.2	0.2		0.2	0.2		0.1	0.3		0.1	0.2		0.3	0.2	
Variation	6.1	9.8	-3.7	13.1	14.9	-1.9	12.6	11.8	0.7	21.0	23.9	-2.9	14.5	60.3	-45.8	24.7	14.2	10.6
±	6.3	4.5		7.1	9.4		3.9	8.9		10.8	6.5		3.7	13.3		6.3	6.0	
Range	2.3	5.4	-3.1	10.0	7.6	2.4	7.3	7.7	-0.3	8.2	19.3	-11.0	9.1	46.5	-37.4	19.6	8.1	11.5
±	2.1	2.2		4.9	4.2		3.0	5.6		4.4	5.7		3.8	15.4		5.9	1.7	

	13			14			15			16			17			18			19		
	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ
Length	164.9	156.0	8.9	34.4	247.2	-212.8	32.6	65.0	-32.4	75.4	33.1	42.3	55.0	63.0	-8.1	93.6	123.4	-29.8	95.2	150.8	-55.6
±	88.9	55.3		12.4	72.9		25.6	38.1		29.1	16.7		29.1	43.5		32.9	74.1		29.8	86.9	
Rq(RMS)	9.4	7.2	2.2	4.1	22.8	-18.7	2.5	3.8	-1.2	1.9	1.7	0.2	1.8	2.4	-0.6	8.7	18.0	-9.3	12.0	6.3	5.6
±	3.5	2.8		1.2	6.9		1.5	2.3		0.9	1.3		0.5	1.7		2.4	8.2		3.3	1.4	
Slope	-0.2	-0.2	-0.1	0.4	0.4	0.0	-0.2	-0.1	-0.1	0.0	0.0	0.0	-0.1	0.1	-0.1	0.4	-0.6	1.0	0.7	0.1	0.6
±	0.1	0.2		0.1	0.3		0.3	0.1		0.1	0.1		0.1	0.1		0.3	0.2		0.7	0.2	
Variation	41.4	40.2	1.3	13.6	85.9	-72.4	11.0	15.0	-4.0	14.1	6.7	7.4	13.8	14.7	-0.9	31.1	54.0	-22.9	51.4	41.7	9.8
±	21.0	14.3		6.3	25.2		7.3	9.7		5.3	4.4		6.1	14.0		9.1	28.4		8.8	22.5	
Range	29.1	23.4	5.7	12.3	65.5	-53.2	7.1	10.0	-2.9	6.5	4.1	2.4	6.2	6.6	-0.4	26.2	52.0	-25.8	40.1	21.5	18.7
±	13.8	10.9		5.9	18.1		4.7	7.3		3.5	3.7		2.2	5.1		7.6	27.8		9.2	6.4	

7.4 Commercially Important Fish Species in the Philippines

Family	*Genus*	*Species*	*2019 n=*	*Family*	*Genus*	*Species*	*2019 n=*
Acanthuridae	*Acanthurus*	*auranticavus*	*10*	*Lutjanidae*	*Lutjanus*	*monostigma*	*2*
Acanthuridae	*Acanthurus*	*pyroferus*	*21*	*Lutjanidae*	*Lutjanus*	*rivulatus*	*1*
Acanthuridae	*Ctenochaetus*	*striatus*	*462*	*Lutjanidae*	*Lutjanus*	*russellii*	*4*
Acanthuridae	*Naso*	*hexacanthus*	*1*	*Lutjanidae*	*Lutjanus*	*vitta*	*8*
Acanthuridae	*Naso*	*lituratus*	*7*	*Lutjanidae*	*Macolor*	*macularis*	*11*
Acanthuridae	*Naso*	*unicornis*	*12*	*Monacanthidae*	*Amanses*	*scopas*	*4*
Apogonidae	*Ostorhinchus*	*aureus*	*76*	*Mugilidae*	*Crenimugil*	*seheli*	*27*
Apogonidae	*Ostorhinchus*	*hartzfeldii*	*1*	*Mullidae*	*Mulloidichthys*	*flavolineatus*	*16*
Caesionidae	*Caesio*	*caerulaurea*	*2*	*Mullidae*	*Parupeneus*	*barberinoides*	*1*

Caesionidae	*Pterocaesio*	*pisang*	104
Caesionidae	*Pterocaesio*	*tessellata*	191
Caesionidae	*Pterocaesio*	*tile*	182
Haemulidae	*Plectorhinchus*	*chaetodonoides*	5
Haemulidae	*Plectorhinchus*	*polytaenia*	5
Holocentridae	*Myripristis*	*murdjan*	28
Labridae	*Anampses*	*meleagrides*	1
Labridae	*Cheilinus*	*chlorourus*	3
Labridae	*Cheilinus*	*fasciatus*	3
Labridae	*Cheilinus*	*oxycephalus*	1
Labridae	*Cheilinus*	*trilobatus*	5
Labridae	*Cheilio*	*inermis*	17
Labridae	*Choerodon*	*anchorago*	1
Labridae	*Coris*	*batuensis*	12
Labridae	*Coris*	*gaimard*	23
Labridae	*Gomphosus*	*varius*	5
Labridae	*Halichoeres*	*scapularis*	34
Labridae	*Hemigymnus*	*melapterus*	5
Labridae	*Novaculichthys*	*taeniourus*	8
Labridae	*Oxycheilinus*	*digramma*	4
Labridae	*Thalassoma*	*hardwicke*	10
Labridae	*Thalassoma*	*lunare*	397
Lethrinidae	*Lethrinus*	*atkinsoni*	2
Lethrinidae	*Lethrinus*	*erythracanthus*	1
Lethrinidae	*Monotaxis*	*grandoculis*	1
Lutjanidae	*Lutjanus*	*argentimaculatus*	16
Lutjanidae	*Lutjanus*	*biguttatus*	40
Lutjanidae	*Lutjanus*	*decussatus*	18
Lutjanidae	*Lutjanus*	*fulvus*	13
Mullidae	*Parupeneus*	*barberinus*	47
Mullidae	*Parupeneus*	*ciliatus*	1
Mullidae	*Parupeneus*	*crassilabris*	13
Mullidae	*Parupeneus*	*cyclostomus*	12
Mullidae	*Parupeneus*	*multifasciatus*	193
Mullidae	*Parupeneus*	*pleurostigma*	6
Mullidae	*Upeneus*	*tragula*	7
Nemipteridae	*Scolopsis*	*bilineata*	70
Nemipteridae	*Scolopsis*	*ciliata*	89
Pinguipedidae	*Parapercis*	*cylindrica*	3
Plotosidae	*Plotosus*	*lineatus*	470
Scaridae	*Chlorurus*	*bleekeri*	19
Scaridae	*Scarus*	*ghobban*	1
Scaridae	*Scarus*	*tricolor*	3
Serranidae	*Cephalopholis*	*argus*	15
Serranidae	*Cephalopholis*	*boenak*	1
Serranidae	*Cephalopholis*	*miniata*	3
Serranidae	*Cephalopholis*	*sonnerati*	1
Serranidae	*Cephalopholis*	*urodeta*	15
Serranidae	*Epinephelus*	*fuscoguttatus*	2
Serranidae	*Epinephelus*	*merra*	20
Serranidae	*Plectropomus*	*laevis*	3
Serranidae	*Pseudanthias*	*squamipinnis*	2
Siganidae	*Siganus*	*corallinus*	2
Siganidae	*Siganus*	*guttatus*	28
Siganidae	*Siganus*	*puellus*	1
Siganidae	*Siganus*	*virgatus*	12
Synodontidae	*Saurida*	*gracilis*	2