INSTITUTE FOR MARINE RESEARCH
DAUIN · PHILIPPINES

BLACK DIAMOND REEF

STATUS REPORT

2019

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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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Institute for Marine Research
Tugawe, Municipality of Dauin
6217, The Philippines

Front Cover: Poblacion Marine Reserve, Dauin, The Philippines. Image: Tracey Jennings

Full report written by:

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

Oscar Crehan
Head of Science, Institute for Marine Research
science@institutemarineresearch.org

Alessandra Sellini
Research Fellow, Institute for Marine Research

EXECUTIVE SUMMARY

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. Major anthropogenic risk factors include mortality and reduced growth of reef-building corals due to their high sensitivity to 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[38,50]. These anthropogenic risks interact with other large-scale acute disturbances, including tropical storms and population outbreaks of the corallivous 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[38]. Efforts are therefore shifting toward management of local and regional anthropogenic pressures to strengthen reef resilience. However, assessment of the likely effectiveness of reductions of local anthropogenic pressures requires a sound understanding of the processes that determine ecosystem trajectories.

The Philippines, represents a particularly relevant case to investigate ecosystem trajectories. Over 7,100 islands dominate the Philippine archipelago, which is located within the heart of the incredible biological diversity that is the 'Coral Triangle'. Boasting 76% of the worlds total coral species and 37% of the reef fishes of the world[39], this incredible biological diversity of the Coral Triangle is associated with some of the highest human population densities and growth rates in the world[50]. Changes to the health of coastal ecosystems are exposing coastal populations to the erosion of food security and income, deteriorating coastal protection and other challenges. They are affecting people who are already impoverished and are among the least able to respond to the changes that are occurring in their environment[50]. Reef fisheries have estimated to directly contribute to 15 – 30% of the Philippines total known national municipal fisheries (obtained from licenses issued through local- government areas), with nearly 70% of the protein food intake being fish. The stark contrast between poverty, hunger and deprivation amidst this increasing want is rapidly declining reef resources. It is therefore no surprise that it is in the Philippines that reefs are at the highest risk from overexploitation, destructive fishing and other human related impacts such as coastal development and sedimentation. If these processes are allowed to continue, these changes will exacerbate poverty and social instability within the region, with wider consequences for the region and the world. It is imperative that we address the core issue of anthropogenic climate change whilst at the same time addressing the key threats that are rising from local stressors.

ABBREVIATIONS

ABBREVIATION	TERM IN FULL
1-D	Simpsons Index of Diversity
2D	2-Dimensional
3D	3-Dimensional
AIMS	Australian Institute of Marine Science
BBD	Black Band Disease
BrBD	Brown Band Disease
CPCe	Coral Point Count with Excel Extension
COTS	Crown of Thorns Starfish
DEM	Digital Elevation Model
HYP	Hyperplasia
IMR	Institute for Marine Research
LTRMP	Long Term Reef Monitoring Project
NEO	Neoplasia
PP	Porites Pinking
S	Species Richness
SCUBA	Self Contained Underwater Breathing Apparatus
SE	Standard Error
SEB	Skeletal Eroding Band
SfM	Structure from Motion
SVS	Stereo Video System
UVC	Underwater Visual Census

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1. INSTITUTE FOR MARINE RESEARCH

The Institute for Marine Research (IMR) is a grassroots non-profit organization 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 Municipality of Dauin.

The Institute will deliver the science to help realize three key long-term impacts for the Municipality:

1. Improve the health and resilience of marine and coastal ecosystems across the Municipality
2. Ensure economic, social and environmental net benefits for Dauin's marine industries and coastal community
3. Protect Dauin's coral reefs and other tropical marine environments from the effects of climate change and coastal development

The Dauin *Long-Term Reef Monitoring Project* (*LTRMP*) was established by IMR in February 2019 to track fine-scale changes in the overall reef community of Dauin's fringing reef system, and realize the three key long-term impacts for the Municipality. More specifically, the aims of the Dauin *LTRMP*:

1. Understand how benthic composition (measured as percentage cover, species diversity indices, species abundance, structural complexity, slope and rugosity) influences fish community structure (measured through biomass, species abundance, trophic groups, and species diversity indices)
2. Document the effect of disturbances such as *Acanthaster plancii* (Crown of Thorns Starfish, COTS) and *Drupella spp.* outbreaks, typhoons, and bleaching events. The data will also provide awareness of other threats to the reef (such as coral disease, human activity, illegal poaching, high nutrient outflow, trash) that will be of concern to reef managers
3. Document the effects of temperature, changing light regimes, dissolved oxygen, and pH on the seasonal and annual variability of Dauin's fringing reef

All results collected as part of the *LTRMP* will be used to:

a) Publish and present annual Outlook reports to policy-makers within the Local Government Unit (LGU)
b) Determine 'areas of concern' with regards to unsustainable practices occurring within the Municipality
c) Publish findings on a wider scientific platform to expand our current knowledge of coral reef ecosystems

2. A MESSAGE FROM THE DIRECTORS

What an action-packed and rewarding start to our first research season here in the Philippines! With 19 research sites within the Municipality of Dauin, we have this reef system well monitored!

With that being said, these results are just the beginning.

We have a long road to go with deepening our research to understand the resiliency state of our reef system towards the threats and challenges associated with our changing climate. On a localised platform, our results are catching a glimpse of the negative, human-induced practices that are exacerbating coral mortality within the region.

Our first step towards reef conservation is awareness and partnership. We are proudly partnering not only with Dauin's Local Government Unit (LGU), but with various local resorts, NGOs and other local stakeholders who wish to share our common goal of preserving Dauin's coastal ecosystem.

We would also like to take this opportunity to say how proud and thankful we are of our Research Assistants and Fellows who have not only assisted the Institute in meeting our seasonal research objectives, but for everything that comes both afterwards and in-between. From the months of data analysis, to the weeks of interpretation of findings into site reports. From creating school lesson plans, and environmental awareness initiatives. You have helped to take IMR to a whole new level. Our heartfelt thanks to you all.

- Chelsea Waters & Rafael Manrique

3. METHODOLOGY

3.1 SURVEY SITES

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. Nineteen core sites were selected for seasonal and annual monitoring. These sites span the variation in the coral reef composition of benthic and fish communities across the Municipality, and account for the zoning history of its associated no-take marine protected areas. The nineteen core sites consist of fifty metre transects that are laid out parallel to the reef crest, between depth ranges of 1 – 6 metres and 7 – 12 metres. Surveys are conducted bi-annually to account for seasonal variability, with "dry" season surveys running from February to July, and "wet" season surveys running from August to January. Sites will be surveyed at the same time each year.

Black Diamond reef is located in front of the new development of 'Black Diamond Resort', located within Barangay Lipayo. Four fifty metre replicates (n = 4) were conducted between the months of February and July.

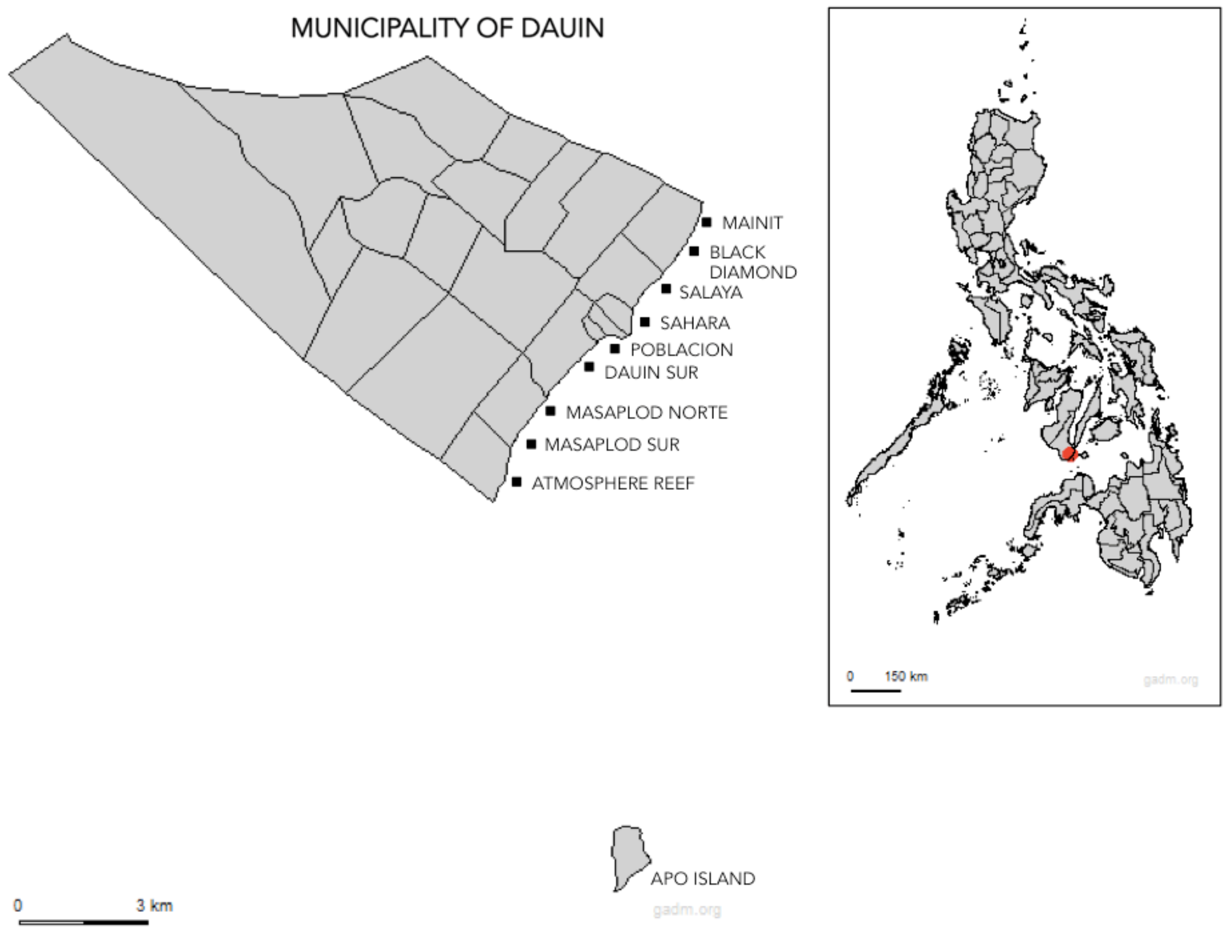


Figure 3.1. Location of the Municipality of Dauin and IMRs survey sites on Negros Oriental, the Philippines. Maps sourced from GADM database of Global Administrative Areas (2015) under a CC BY licence, used with permission.

3.2 RESEARCH TECHNIQUES

3.2.1 3-Dimensional Reef Modelling

A 3D camera rig consisting of two *GoPro Hero 5 Black* cameras attached to a one-metre long aluminium pole is assembled. The cameras are placed 90 centimetres apart, having one on each end of the pole[44]. The cameras are placed in a downward facing position at the beginning of the 50 metres. The aim of the diver is to get over 60% overlap from pictures to ensure they can be aligned, with preliminary testing indicating this method decreases alignment errors over single passes or higher image intervals[59]. The rig is kept approximately 2 meters above the substrate with the cameras always aimed straight down at the substratum, the lens moving in one plane rather than following the contours of the scene[62]. A lawnmower pattern is conducted at a steady pace, 1 metre either side of the transect.

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 availability of food. 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[41,66].

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[40,41].

These 3D models are produced at scale, allowing IMR scientists to measure different attributes associated with the structural complexity of coral reefs, such as surface complexity (3D/2D suface area), curvature, volume and slope, across large extents in a fraction of the time that takes to do it underwater. With the advances in photogrammetry software and high performance computing 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 could never measure before, including being able to see how complex the surface of the reef is.

3.2.2 Diver Operated Stereo Video System

Transects are conducted using a diver-operated Stereo-Video System (SVS; SeaGIS, Melbourne, Australia), comprised of two GoPro Hero 5 Black video cameras. Transects are 50 metres long following the reef contour. Surveys are conducted by two people; the SVS operator and a second diver responsible for distance measurements. To minimise potential disturbance to the fish community, cameras are set to record and synchronised prior to entry. Transects begin with the cameras pointing vertically down. The SVS operator is alerted via a fin tug to indicate the start of the transect. At this point cameras are now pointed along the reef, with another fin tug indicated the end of the transect after a further 50 metre. Cameras are angled approximately 20° downwards, and kept approximately 0.5 metres above the substrate, filming the reef scape along the transect. Transects take approximately 5 - 6 minutes to film using SCUBA. Footage is analysed in EventMeasure software v3.51 (SeaGIS, Melbourne, Australia) allowing the calibrated SVS footage to be synchronised and fish total lengths to be measured. EventMeasure also resolves centre points of each individual fish encountered into distances on a three-dimensional coordinate system, allowing the exclusion of fish outside 2.5 metres either side and 5 metres in front of the camera system. Side distance restrictions maintains a consistent belt along the transect, while a front distance restriction prevents variations in visibility (e.g. turbidity, light intensity) from influencing data.

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 a widely used method 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 a logistically simple, non-destructive, and cost-effective method of surveying fish. However, the effectiveness of UVC 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 the 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 not only record fish species with more precision and accuracy than the traditional Underwater Visual Census (UVC) techniques, but efficiently quantifyies the abundance and size of reef fish[67,68]. 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 spatial coverage.

3.2.3 Benthic Assays

Benthic surveys of stationary benthic organisms are conducted following the technique of the Australian Institute of Marine Science (AIMS) LTMP. Benthic surveys are conducted along the transect line. At each site, single frames are shot at 1 metre intervals using a GoPro camera. Fifty still frames are shot along each 50 metre transect, with the camera held approximately 50 centimetres above the substrate. Photographs are analysed through the use of CPCe software by Kohler and Gill (2006). Underwater photographic frames are overlaid by a matrix of randomly distributed points. In this case, thirty random points are overlaid and generated in the whole frame of each photo and used for identification. Point overlay is used to characterise the benthos, and estimate percentage type of organism and substrate in the image[46]. The species code data for each frame is stored in a .cpc file which contains the image filename, point coordinates and the identified data codes. 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 estimate seasonal and temporal trends in cover of benthic organisms at each site, zone, and throughout the municipality as a whole.

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[69,70]. Coral Point Count (CPCe) is a visual basic software designed to quickly and efficiently calculate statistical coral coverage over a specified area through the aid of photo-transects[71]. 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 analysis in Microsoft Excel. Thus, CPCe is a highly significant useful tool, particularly in coral reef monitoring, assessment and conservation.

3.2.4 SCUBA Search

SCUBA searches are designed to provide a more detailed picture of the causes and relative scale of coral mortality, and are conducted following a modified version of AIMS LTMP. SCUBA searches are made along a fixed 50 m transect, with a 2 m belt (1 metre either side of the central tape measure). Numbers are recorded for the following: 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).

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).

4. RESULTS

4.1 Benthic Cover

Results of overall benthic cover at Black Diamond reef show abiotic categories (rock, rubble and sand) to be the dominant substrate type (52.3%), followed by coral (24.4%) and seagrass (10.8%) (fig. 4.1). A total of 17 Scleractinian coral genera were recorded, with *Acropora spp.* (19.8%) proving to be the most abundant, followed by *Porites spp.* (1.5%) (fig 4.2). The remaining coral genera had a limited abundance (≤0.05%). Indices of coral diversity revealed a Simpsons Index of Diversity (1-D) of 0.33. The evenness of this coral spread across transects, calculated through Pielou's Evenness Index (*J'*), was 0.30.

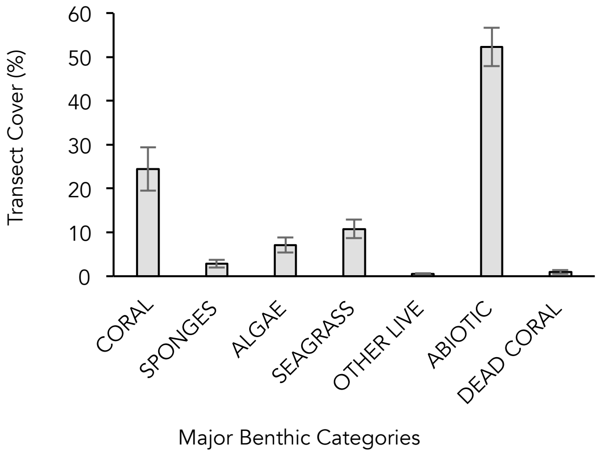
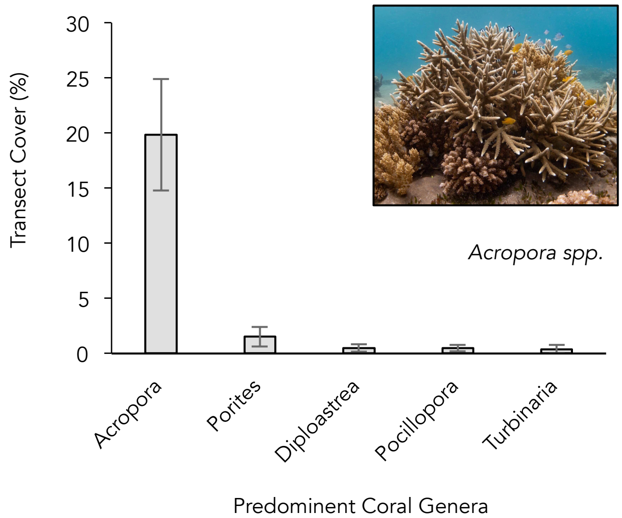


Figure 4.1 Average percentage cover of all major benthic categories with standard error (± SE) recorded at Black Diamond reef during the dry season of February to July 2019.



Acropora spp.

Figure 4.2 Average percentage cover of the five major coral genera with standard error (± SE) recorded at Black Diamond reef during the dry season of February to July 2019.

4.2 Reef Impacts & Coral Mortality

In the surveyed space, bleaching and trash were the most prevalent causes of disturbance, contributing to 33.3% of the total disturbances. All bleaching instances affected *Fungia spp.* exclusively. Affected *Fungia spp.* experienced total bleaching (100% bleached tissue). Fishing trash was the most prevalent (75%), whilst general trash was recorded to a lesser extent (25%) (Table 1).

Coral disease was also present within the Black Diamond reef survey space. Recorded disease included Porites Pinking (PP) and Skeletal Eroding Band (SEB) disease, both affecting *Porites spp.* SEB was only present on 1 colony, affecting 1.55% of the total colony.

No *Acanthaster plancii* (COTS) or suspected feeding scars were recorded. *Drupella spp.* predation was low within the surveyed reef, with only one instance recorded on *Acropora spp.*

Table 1. Reef impacts recorded at Black Diamond reef during the dry season of February to July 2019 with ranking and trends.

Measurement	*Current Value*	*Ranking*	*Last Season Value*	*Trend*
Coral Bleaching (count/100m^2)	2	9th	n/a	n/a
Disease (incidences/100m^2)	1	4th	n/a	n/a
Acanthaster plancii (count/100m^2)	0	12th	n/a	n/a
Drupella spp. (count/100m^2)	0.5	8th	n/a	n/a
Trash (count/100m^2)	2	2nd	n/a	n/a

4.3 Fish

Black Diamond reef recorded a total fish abundance of n = 295, a species richness of S = 41, and a total biomass of 2.94 kg/250m^2. *Pomacentridae* (damselfish) had both the highest recorded abundance and species richness (n = 203, S = 14), followed by *Labridae* (wrasse) (n = 26, S = 7), and *Plotosidae* (catfish) (n = 26, S = 1).

Pomacentridae (damselfish) also had the highest total biomass at 1.67 kg/250m^2, accounting for more than half of the toal biomass recorded at Black Dimaond. This was followed by *Labridae* (wrasse) and *Plotosidae* with biomass totals of 0.30 kg/250m^2 and 0.22 kg/250m^2 respectively (figure 4.3). Grouping fish into trophic groups showed that most fish were omnivores (n = 99, S = 7) followed by planktivores (n = 94, S = 9). The trophic group with the greatest total biomass were the planktivores (1.25 kg/250m^2) followed by herbivores (0.83 kg/250m^2). Fish that fit within two trophic groups were counted separately in each group. Those within three or more groups were counted as omnivores (figure 4.4).

Commercially important families recorded at Black Diamond reef include *Labridae (0.30* kg/250m^2), *Acanthuridae (0.18* kg/250m^2), *Lutjanidae (0.09* kg/250m^2), *Serranidae (0.08* kg/250m^2), *Mullidae (0.07* kg/250m^2) and *Scaridae* (0.02 kg/250m^2). No *Haemulidae* (sweetlips) or *Lethrinidae* (emperor) were found within Black Diamond reef.

4.4 Reef Complexity

Results from our 3-Dimensional reef reconstructions reveal an average rugosity index of 18.05 ± 7.25, and a slope value of 0.1802 ± 0.1253. Figure 4.5 shows the rugosity and slope across the site.

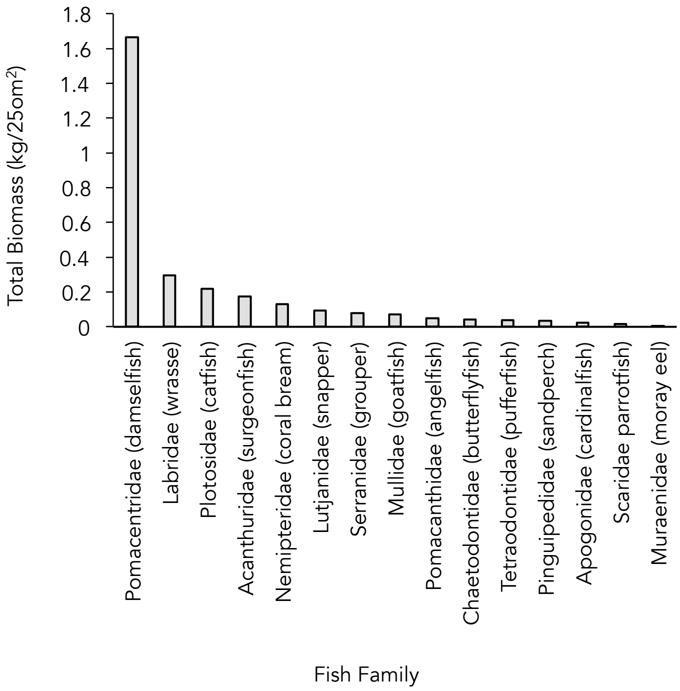


Figure 4.3 Total biomass (kg/250m^2) of fish families recorded at Black Diamond reef during the dry season of February to July 2019.

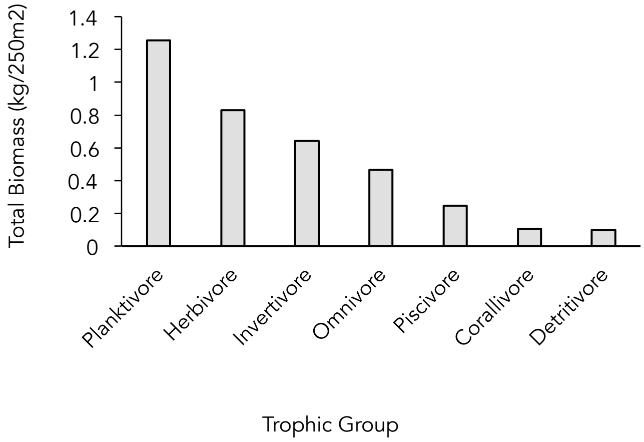


Figure 4.4 Total biomass (kg/250m^2) of fish trophic groups recorded at Black Diamond reef during the dry season of February to July 2019.

Table 2. Summary of findings at Black Diamond reef during the dry season of February to July 2019 with ranking and trends

Measurement	*Current Value*	*Ranking*	*Last Season Value*	*Trend*
Coral Cover (%)	24.43	4th	n/a	n/a
Algal Cover (%)	7.1	5th	n/a	n/a
Coral 1-D	0.33	10th	n/a	n/a
No. of Fish	295	8th	n/a	n/a
Fish Biomass (kg/250m^2)	2.94	10th	n/a	n/a
Fish 1-D	0.9	6th	n/a	n/a
Rugosity (RQ)	18.05	1st	n/a	n/a

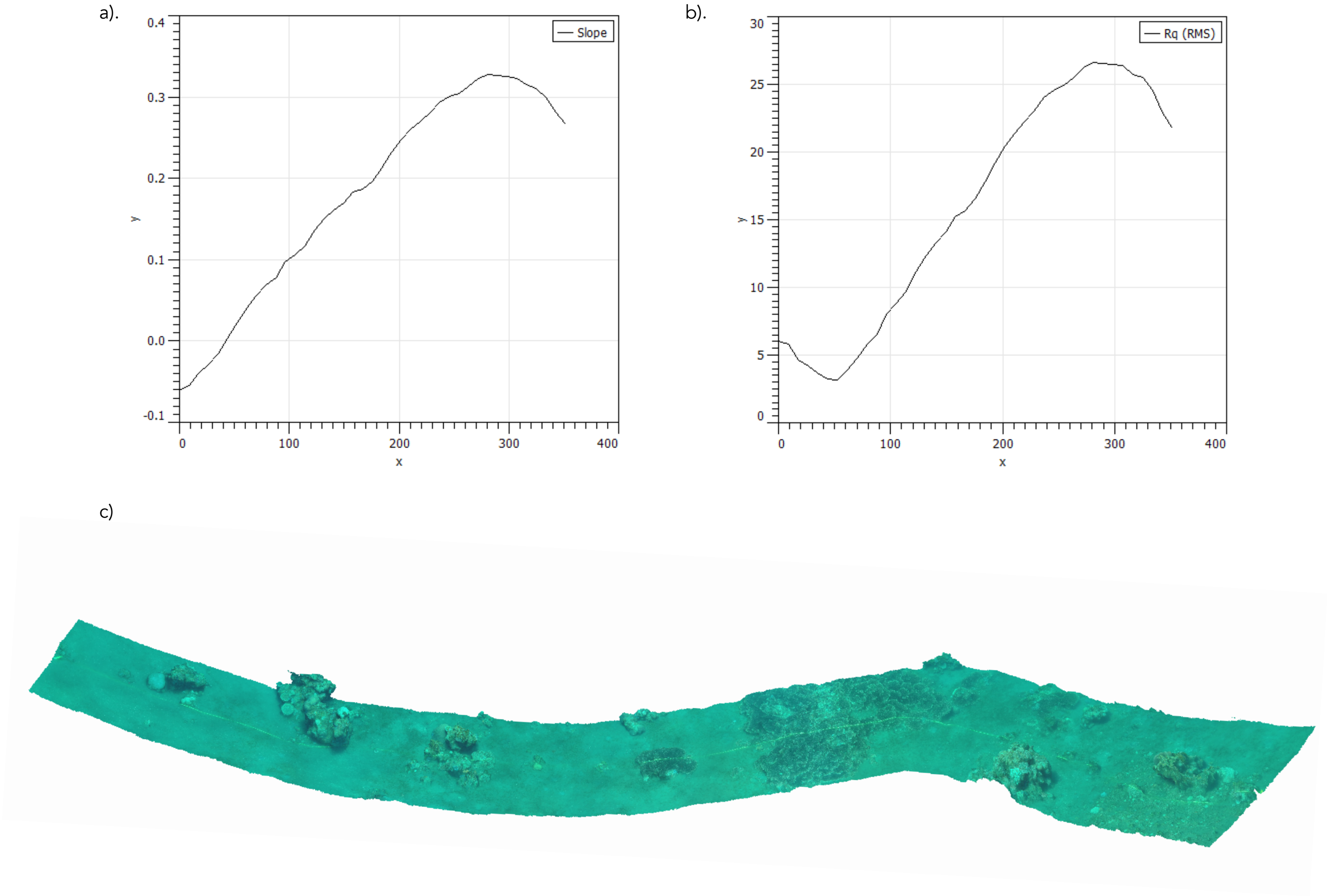


Figure 4.5 a) Average slope along the transect at 10m (replicate A). Scale is in mega pixels with 300MP being equal to 50 meters on the transect. b) Average rugosity along the transect at 10m (replicate A). Scale is in mega pixels with 300MP being equal to 50 meters on the transect. b) Digital Elevation Model (DEM) produced with SfM photogrammetry techniques at 5m (replicate B).

5. DISCUSSION

Black Diamond reef presents an interesting site to study ecosystem trajectories, as this reef is monitored as a non-MPA site parallel to a coastal development project.

Despite being characterised by a high percentage of abiotic categories, Black Diamond reef retains a relatively high percentage of coral cover. Whilst 17 different coral genera have been recorded, *Acropora spp.* was exceedingly more predominant. Concerns are raised when *Acropora spp.* dominant reef states are recorded, due to their vulnerability to heat[1,2], acidification[4], and storms. Moreover, *Acropora spp.* is more susceptible to *Drupella spp.*[5] and COTS[6] predation. Fortunately these disturbances are either absent or have a low prevalence, however continuous monitoring of this reef will be required to anticipate action against climate change.

Trash was the most prevalent impact, comprising mainly of fishing trash. Since Black Diamond is not currently an MPA, locally generated fishing activities are acceptable. Fishing activities should not, however, result in a direct increase in discarded fishing line. Attention needs to be brought to the local fisherman about the hazards of discarded fishing line to marine life, and an underwater clean-up will need to be organised for this area.

Fishing activities can also influence fish assemblage within this reef system. Commercially important fish were recorded within this area, proving this site acceptable for local fisherman. Abundance and biomass for these commercially important species is low at this site, particularly in comparison to other survey sites within Dauin. Studies have lined fishing to a shift towards smaller fish sizes, both from size-targeted removal[8] and shift in fish life-histories towards earlier maturation and declining adult body size[9,10]. Consistent monitoring of fish populations at this site will be required to ensure reef functions are being maintained, particularly before Municipal ordinance is required due to fishing efforts proving to be too pervasive on the reef.

General trash was markedly lower, however present within this reef. Construction work is currently taking place for a new resort, and if construction waste (e.g. cement bags) is not properly disposed of, can be a source of localised trash. Moreover, construction work could increase land runoff (including silt and chemicals) and alter water quality. Heavy metal (copper and cadmium) have been found to trigger coral bleaching[13], and despite genera-specific studies being limited, they have been found to trigger zooxanthellae expulsion in at least one species of *Acropora*[14]. Potential land runoff from the construction site can also increase water turbidity, decreasing available light and thus impairing the photosynthetic abilities of the zooxanthellae[15,16]. Whilst a coral can actively remove sediments deposited on the colony surface, if sediment accumulation exceeds the clearance rate, they can ultimately become smothered and tissue death by hypoxia can occur[16]. Tabulate *Acroporid* colonies have been associated with superior abilities to clear sediment due to their morphology[16,17]. This is reassuring for the large percentage of tabulate *Acroporid* colonies within Black Diamond reef, however continuous monitoring and semi-permeable membrane devices (SPMDs) will need to be deployed to monitor change in water quality.

The high abundance of seagrass recorded is already acting as an important buffer. Seagrass beds can improve water quality by either stabilising[20] or trapping[21] sediments, and absorbing nutrients (nitrogen and phosphorus)[21,22] that may have been generated by land runoff. Thus mitigating or reducing eutrophication. Considering the role of seagrass in reef health, as well as its high-value ecosystem services[22,23], monitoring of this ecosystem is strongly recommended. Just like coral, seagrass can be impacted by sediments and chemicals[24] generated by coastal development as well as diving activities.

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