Ecological Assessment of the Flora and Fauna of Mooloolaba Reefs, Queensland, Australia

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UNIDIVE
MEAM
MOOLOOLABA ECOLOGICAL ASSESSMENT & MAPPING

Ecological Assessment of the Flora and Fauna of Mooloolaba Reefs, Queensland

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Final Report

UNIDIVE

MEAM

MOOLOOLABA ECOLOGICAL ASSESSMENT & MAPPING

We, the participants of this project, would like to acknowledge the Gubbi Gubbi people and the Jinibara people, the Traditional Custodians of land and sea country of the Sunshine Coast.

We recognise that these have always been, and always will be, places of cultural, spiritual, social and economic significance. The Traditional Custodians' inherent connection to country, and ancient and enduring cultures deepen and enrich the life of our community. We wish to pay respect to their Elders – past, present and emerging. Together, we are all stronger.

This report should be cited as:
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Front cover: Photo by Chris Roelfsema 2021,
Back cover: Photos by Chris Roelfsema, Trevor Barrenger and Shannon Davis 2021

The views and interpretations expressed in this report are those of the authors and not necessarily those of contributing agencies and organisations.

Citizen Scientists Taking Care of Local Reefs

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Acknowledgements

I am pleased to share this final report created by the citizen scientists of the UniDive project: Mooloolaba Ecological Assessment and Mapping (MEAM). This report represents the persistence and efforts of the volunteers, to highlight the beautiful and important reefs of Mooloolaba, including Mudjimba Island, and the Inner and Outer Gneerings. This project was supported by over 8,000 of hours of volunteer contributions to plan the project, organise trips, teach survey techniques and identification of flora and fauna, conduct surveys, collect thousands of photos, analyse the results, and create this report.

This project represents an extraordinary adventure and significant effort for the participants and their supporters. The report showcases an impressive reef system with high coral cover and amazing marine life on the doorstep of the Sunshine Coast. The report is also evidence of a persistent team of volunteers eager to learn and care for local reefs and help bring greater attention to its unique values and importance.

In early 2020, COVID was impacting the world. Many of us went into lockdowns and faced new physical and mental challenges. We were limited in what we could do and where we could travel. Many were concerned about the future and our loved ones, friends and family – which impacted our wellbeing. This was our motivation to start something positive and in July 2020 a group of eager UniDive members came together to make a difference to the health of local reefs and fellow divers.

MEAM started in September 2020. Online academic sessions (30+) enabled members across Brisbane and the Sunshine Coast to come together virtually to connect and learn. The easing of restrictions in April 2021 allowed us to start practical training in the pool and at Point Lookout reefs followed. Three survey weekends were originally planned but they faced considerable logistical challenges due to COVID restrictions, floods, extreme weather events, and reduced access to the UniDive boat "Down Under". The project endured by adapting planned weekends to only day trips. Instead over 3 weekends in winter 2021, we surveyed over 10 months, where 11 day trips were completed and 23 were cancelled. The team persisted through the many challenges to proudly complete the project and deliver this report.

The report would not be possible without the effort of a core group of divers that organised trips, skippered the boat, prearranged tanks, prepared survey gear, ensured COVID safe protocols, collected survey data, entered survey data, processed survey data, captured photos, analysed photos, analysed data and wrote this report. Special mention goes to: Alice Twomey, Andrew O'Hagan, Andy Holland, Breanne Vincent, Bruce McLean, Catherine Kim, Cedric van den Berg, Cheryl Tan, Christina Lapid, Damien Shrier, Delphine Gonchond, Devin Rowell, Diana Kleine, Douglas Stetner, Hannah Barrenger, Henri Decoeur, Ilha Byrne, Isabelle Derouet, Jennifer Loder, Jodi Salmond, Jody Kreuger, Josh Passenger, Karen Johnson, Katharine Prata, Mark Stenhouse, Monique Grol, Nataly Gutierrez Isaza, Nicholas Hammerman, Philip Dunbavan, Rachel McVeigh, Ryan Booker, Sophie Kalkowski-Pope, Tania Alajo, Trevor Barrenger. There were many other volunteers involved in shaping and supporting this project.

The scientific project support and training team were crucial for enabling the academic expertise, practical training, quality control and analysis necessary for such an endeavour. The support team used their own time, experience, and skills to teach others as well as to help analyse the results and write this report. Thanks to: Alice Twomey (species list, review ecological data), Andrew O'Hagan (organiser supreme and setting the standard), Breanne Vincent (organiser supreme and setting the standard) Bruce McLean (finance and skipper), Catherine Kim (introduction and review), Cedric van den Berg (photogrammetry, training, presentations), Delphine Gonchond (project admin supreme, project support), Devin Rowell (mapping), Diana Kleine (CoralWatch, t-shirts, presentation, project support), Douglas Stetner (photoquadrat analysis, trainer, project support), Ilha Byrne (fish and other data), Jennifer Loder (overall input, trainer, discussion and recommendations), Jodi Salmond (Reef Check Supreme, trainer, project

support, connecting with Traditional Owners, discussion and recommendations), Jody Kreuger (trainer, boating), Josh Passenger (training, data wrangler, boating), Karen Johnson (boating, grammar and spelling check) Katharine Prata (photogrammetry), Mark Stenhouse (boating, modelling), Monique Grol (science support), Nataly Gutierrez Isaza (invertebrates, science), Nicholas Hammerman (organiser, substrate, statistics, project support), Philip Dunbavan (local knowledge, instrument maker and photogrammetry), Rachel McVeigh (local knowledge and data entry), Ryan Booker (boating, tanks and photogrammetry), Sophie Kalkowski-Pope (CoralWatch presentations), Tania Kenyon (presentations), Trevor Barrenger (boating, advisor weather and conditions, environmental section).

Regarding safety, I would like to thank all participants for conscientiously adhering to safety guidelines and procedures; and the skippers for their appropriate boat handling and for not being afraid to cancel trips when they had safety concerns. Thanks also goes to Volunteer Marine Rescue/Coastguard for keeping watch while we were out on the water.

The MEAM project was financially supported by the volunteers themselves who paid for their own trips and accommodation, which were significantly discounted by the support of several organisations. A project such as this is not possible without assistance from many passionate businesses, not for profit organisations, communities and individuals. Our gratitude goes to the many project supporters, including:

- UniDive for use of the gear, subsidised use of the "Down Under" and use of club facilities
- The University of Queensland research groups, including: Remote Sensing Research Centre for mapping gear and expertise, the Visual Ecology Lab for cameras and processing power, the UQ Boating and Diving Facility for advice and tanks, CoralWatch for survey methods, data processing and gear, the Centre of Marine Science for support, and the UQ Aquatic Centre.
- Reef Check Australia for survey methods, data and gear
- The Australian Institute of Marine Science Reef Cloud project for photo analysis
- Sealink for discounted ferry prices on training weekend
- Ken Holzheimer for subsidised boat dives and accommodation
- SunReef for donating tanks and for making it easy for survey teams to access them
- ScubaWorld for tanks and gear washing
- Maroochy Squashcourt for accommodation
- Passionate local advisors including Gary Cobb for site coordinates, and Julie Schubert and Terry Farr for their knowledge and long term documentation of local habitats and inhabitants
- Aunty Bridgett Chilli for her generous time and local knowledge of her Gubbi Gubbi country

On behalf of the team, I would like to thank the Traditional Owners of the sea country we visited. We love and hope to help protect this Sea Country with this data and report.

Another UniDive citizen science project has come to an end. This was a challenging project in a challenging time –so my sincere thanks goes to those volunteers for their persistence, it was their persistence that kept me motivated to finalise the project. More projects will follow in the future, as we need to take care of our local reefs in order to take care of ourselves.

I'd especially like to thank Djoy, Anouk and Diana for their emotional support without which the MEAM project would not have happened.

Chris Roelfsema
Volunteer UniDive MEAM Project Organiser
"Caring for Local Reefs"

Photo of the core MEAM divers during training weekend 1, March 2021

Left to right top row: Henry Decoeur, Nick Hammerman, Monique Grol, second row: Isabelle Derouet, Damien Shrier, Rachelle McVeigh, Nataly Gutierrez, Delphine Gonchond, Sophie Kalkowski-Pope Third row: Chris Roelfsema, Josh Passenger, Ken Holzheimer, Ilha Byrne, Andy Holland, Breann Vincent, Hannah Barrenger, Cheryl Tan, Catherine Kim, Fourth row: Cedric van den Berg, Bruce McLean

Photo of the core MEAM divers during training weekend 2, March 2021

Left to right top row: Jodi Salmond, Kat Prata, Boeke Elbers, Andrew O'Hagan, Mark Stenhouse, Jody Krueger, Lucas de Castro, Ranishka Hewavisenthi, Chris Roelfsema second row: Ken Holzheimer, Amber Moran, Jen Loder, Donna Easton, Karen Jonson, Diana Kleine, Rob MacTaggart, Trevor Barrenger, Ryan Booker, Christina Lapid, Tanya Alajo, Devin Rowell, Jorn Geuss

Executive Summary

Introduction

Awareness of environmental crises and change are growing among the citizens of both Australia and the world. Against the backdrop of continual environmental devastation, the value of healthy ecosystems, and their biodiversity become increasingly apparent. We urge people to contribute their time to the current climatic and environmental challenges that societies face all over the world. The importance of documenting the state and current health of these ecosystems, and an ability to engage and educate the public are our proposed way forward.

The Sunshine Coast is forcast to have the second highest growth rate of any region in Queensland, through to at least 2036. Factors such as increased development and population along the Maroochy River and surrounds, and global climate change pose real threats to this marine ecosystem. As such, it is vital that long term monitoring continues, to provide an understanding of these reef areas and initiate appropriate actions when anomalies are observed.

During the midst of the COVID pandemic in September 2020, a group of UniDive members met, and discussed the idea that conducting a new citizen science project would provide a positive goal during this negative period. This initiative follows the successful Coastcare Point Lookout project (2001-2002), Endangered Greynurse Shark Habitat mapping project (2003-2004), the award-winning Point Lookout Ecological Assessment (PLEA)(2013-2014) and the Flinders Reef Ecological Assessment (FREA) (2016-2017) conducted by UniDive. As such, in our fifth citizen science instalment, we set our eyes on Mooloolaba, creating the Mooloolaba Ecological Assessment and Mapping (MEAM) project. The aims of the project were to:

Conduct an ecological assessment of the flora and fauna at the main reefs around Mooloolaba, and report on the status and any changes of this marine environment when compared with existing ecological survey data.

In October 2020, members were recruited for the project, and the online academic training started, with practical training running from March to April 2021. Once the COVID restrictions and weather conditions eased, the first surveys were conducted in August 2021. Ongoing challenges with covid lockdowns and unfavourable weather conditions, resulted in 23 trips postponed and only 11 successful trips. The ecological data was analysed and the results in this report provide an overview of our methods, results, discussion, and findings.

Outcomes

- We observed a high proportion of hard and soft corals at Mudjimba Island, Inner and Outer Gneerings
- The relative abundance of both hard and soft corals was higher than those reported from previous surveys at Point Lookout and Flinders Reef
- Encrusting corals were the most abundant at all three Mooloolaba sites, followed by plating and foliose. Similar trends were also observed at both Flinders Reef and Point Lookout
- A high number of nudibranch species and individuals were observed, confirming Mooloolaba is an area with an exceptional nudibranch assemblage
- Coral damage, disease and marine debris were observed at all three Mooloolaba sites. Marine debris was the most common impact, with a higher prevalence at the Outer Gneerings and Mudjimba Island
- The largest variation in rugosity was shown at Mudjimba Island based on photogrammetric data
- The MEAM surveys were carried out successfully by volunteer divers, all 44 were certified in Reef Check Australia, CoralWatch and mapping survey methods

Recommendations for Management and Community

The Sunshine Coast is forecast to have the second highest growth rate of any region in Queensland through to at least 2036. Factors such as increased development and population along the Maroochy River and surrounds, and global climate change pose real threats to this marine ecosystem. As such, now more than ever, it is critical to supported targeted and collaborative efforts to care for our marine environment.

A summary of recommendations arising from the project data and active discussions are outlined below to help encourage further steps to support the unique subtropical reefs of Mooloolaba.

Continued and improved monitoring of the Mooloolaba Reefs

- Continuing annual reef health monitoring on a select number of sites and habitat mapping every five years for all reef areas, maybe beneficial for an increased understanding of the ecology of the area and for management and conservation. This information can be designed with, and shared with, local science and management agencies to help build collaborative partnerships.
- Integrating benthic imagery into monitoring offers efficiencies, long-term benthic records, and new opportunities for broader data applications. This should be considered as part of an ongoing monitoring approach to help maintain and build on existing citizen science monitoring efforts.

Strengthening ways to care for Mooloolaba Reefs

- Educating divers, spear fishers, snorkelers, fishers, and vessel skippers in practical ways to reduce physical damage through careful anchoring practices and to limit marine debris could help to reduce pressure on reef habitats and wildlife.
- Scoping the installation of boat moorings is recommended to allow safe site access, but reduce direct physical pressures, especially around heavily utilised Mudjimba Island.
- Exploring further options for site protection may be beneficial for protecting key values for the future. No marine protected areas are present within the Sunshine Coast region (except for the HMAS Brisbane shipwreck), despite Mudjimba Island being acknowledged as having cultural significance and the Outer Gneerings (Wobbe Rock) being an identified habitat for the critically endangered Grey Nurse Shark.

Building awareness of the value of local reefs

- Educating residents and visitors about Sunshine Coast reefs can help grow awareness about these unique reefs, strengthen social and environmental connections, and encourage more people to care for, and protect, these places for the future.
- Supporting opportunities for community members to contribute to citizen science can improve understanding about Sunshine Coast marine environments and wildlife.

Supporting conservation of Sunshine Coast Reefs through sharing knowledge

- Fostering opportunities to learn about Traditional knowledge, cultural connections and values of the Sunshine Coast land and sea country can assist in efforts to support more holistic understanding and conservation of the reefs and grow meaningful partnerships with Traditional Owners.
- Producing and sharing scientific publications, reports, and datasets (such as those from the MEAM project) with local authorities and managing bodies is recommended to help support management decisions and active dialogue across groups and individuals who care for the local marine environment. The results and data from this project will be made publicly available.

A more complete description of these recommendations is available in Recommendations for Management and Community.

1. Introduction

1.1. General Introduction

In 2020-2022, The University of Queensland Dive Club (UniDive) conducted an ecological assessment of flora and fauna across *eleven sites* at the Reefs around Mooloolaba, including Mudjimba Island, and the Inner and Outer Gneerings in Southeast Queensland, Australia. These sites comprise several rocky outcrops, with reef ecosystems that support and attract a diverse range of marine life. This report presents the data collected by the volunteer members of UniDive at these Mooloolaba Reefs, and where possible, compared the ecological observations with previous surveys conducted by Reef Check Australia and CoralWatch. The methods used have been used by UniDive for past projects that include: Coastcare Point Lookout project (2001-2002), Endangered Greynurse Shark Habitat mapping project (2003-2004), the award-winning Point Lookout Ecological Assessment (PLEA)(2013-2014) and the Flinders Reef Ecological Assessment (FREA) (2016-2017).

1.2. Past and Ongoing Monitoring of Mooloolaba Reefs

The Mooloolaba Reefs are part of a high-latitude chain of rocky islands and reefs that have only recently been studied in the past few decades (Saenger 1991, Banks and Harriott 1995). Previous unpublished coral studies identified 37 coral species (Harriott, Banks, Harrison, Saenger unpublished data) present in the Mooloolaba Reefs, with published studies later identifying 77 coral species within the Gneering Shoals region (Harriott and Banks 1995). Coral species richness is low relative to the southern Great Barrier Reef (244) and Flinders reef (118), which could be due to physical attributes (waves, turbidity, temperature and depth) of the site (Banks and Harriott 1995). Mooloolaba reefs contain a veneer of coral on rocky substrata, and do not form true limestone carbonate reef platforms.

While organism inventories specific to the Mooloolaba Reefs do not appear in scientific literature, some of the sites surveyed in this project have been included in wider studies (Schlacher-Hoenlinger et al. 2009, DeVantier et al. 2010). The Queensland Museum and University of the Sunshine Coast conducted an inventory assessment of larger sessile invertebrates and fish that inhabited the Ex-HMAS Brisbane after scuttling and in the adjacent reefs. Within the adjacent reefs, 192 invertebrates and fish species across 47 families were observed between 2006-2009. However in 2009, 193 invertebrates and fish species across 40 families were identified (Schlacher-Hoenlinger et al. 2009).

Additional and more recent marine species observations are publicly available via citizen science databases such as iNaturalist, which reported 159 individual species for the Mooloolaba Reef region (downloaded 29th May 2022). Private databases, such as observations recorded by (Farr and Schubert 2022) contained 210 species observed at the Inner Gneerings, 463 species at Mudjimba Island and 417 species at the Outer Gneerings (observed between 2015-2022).

Within the Mooloolaba Reefs, Mudjimba Island reefs have been classified into four distinct sites, Northwest, Ledge 1, Ledge 2 and Ledge 3 and nearly all are monitored by Reef Check Australia since 2013 (Salmond and Schubert 2021). The report identified hard coral as the dominant substrate at

Northwest, Ledge 1 and 3 with rock dominating at Ledge 2 (Salmond and Schubert 2021). Inner Gneerings contains two sites, The Caves Site 1 and Site 2. Site 1 has been monitored by RCA since 2009 and Site 2 since 2013. The RCA report identified Rock as the dominant substrates for both Site 1 and Site 2. The Outer Gneerings sites included as part of the MEAM project have not been monitored by RCA.

1.3. Indigenous History of the Sunshine Coast

For the following section we like to acknowledge Aunty Bridgett Chilli for sharing her Indigenous Knowledge of the lands and sea in which this project was completed on. Additional information has been sourced from Gubbi Gubbi leaders and local councils.

Mooloolaba and the surrounding Sea Country has been important to the Gubbi Gubbi Traditional Owners for thousands of years. The Gubbi Gubbi represents a language group made up of eight families, extending from the Burnett River and Fraser Island in the north, to the Pine River in the south. Their land takes in the eastern part of the coastal ranges including the volcanic Glasshouse Mountains and the great Mary River valley which flows from the Conondale Ranges to the sea near Maryborough.

Kabi is used for the word ‘no’ which distinguishes some of the Traditional Owner language groups in the area. Many of the places within the Sunshine Coast region retain their Gubbi Gubbi names such as Coolum, Ninderry, Caloundra, Maroochydore, Woombye and Mooloolaba - these areas were typically named after flora and fauna that were abundant in the area. For example, Woombye means black snake or scented myrtle, demonstrating the importance of plant-animal connections.

Mooloolaba, derives its name from the Aboriginal word mulu, meaning snapper fish, or mulla meaning Red-bellied Black Snake. It is recognised by Gubbi Gubbi elders as being associated with both. ‘Bah’ or ‘ba’ meaning ‘place of’ suggests that Mooloolaba was indeed recognised as ‘place of snapper’.

Gubbi Gubbi Traditional Owners offer stories about much of the Sunshine Coast geography including (but not limited to) Mount Coolum, Mount Ninderry, Tibrogargan, Ngungun, Beerwah and Mudjimba Island. Mudjimba Island finds its place in two Indigenous stories, although it is said that every family will tell the story a little differently, depending on the perspective, and the message they want to share.

The first story is about the creation of Mudjimba Island. There were two men: Coolum and Ninderry, who fought over a woman called Maroochy. Ninderry knocked Coolum’s head off and it landed in the sea to become Mudjimba Island. Maroochydore cried so much she created a river (Maroochy River) and turned herself into a black swan to swim along it searching for Coolum’s spirit.

The second story refers to an Aboriginal legend in which a woman became stranded on the island, where she lived into old age. The story goes, those two women walked down the coast from Bribie Island. When they got to Coolum they walked across a felled bunya tree to the island. When they arrived at the island a big wave pushed the tree away and the women were stuck there. They were too old to swim back so they built a house and lived there. People would see smoke coming from the island and an old woman; so, it became known as Old Woman Island.

It must be noted that Sea Country is recognised as men's business, and as such, some information is not able to be shared here. Mooloolaba has long been associated with fishing and fishing nets. Historically, the area was known for good fishing, in particular snapper (mulla; snapper, bah; place of). Men spent time on the water, and women collected abundant shellfish, of which local middens are made of.

The Sunshine Coast has been known by Indigenous peoples as a country with plentiful food. This notion was carried through in early recreational fishing for snapper in particular: “I understand that the crowd went as far as Mount Coolum, near Noosa Heads, and tried drift as far south as Deep Caloundra and Old Woman's Island, places which for years have been considered the most prolific snappering grounds outside the northern part of Moreton Bay” (Fishing, 1916). While Gneering Shoals is still known for fishing, the sheer numbers being caught over 100 years ago likely indicate stocks have been overfished.

1.4. Historical Usage and Fishing Last 100 Years

Since as early as the late 1890s, recreational fishing off the Sunshine Coast has been a popular pastime. Articles detailing the fishing triumphs of weekend fishing parties were regularly printed in local newspapers such as *(Telegraph 1901)*(Figure 1). These fishing trips were a popular form of entertainment and often resulted in catching hundreds of fish. A survey of historical newspapers was conducted on Trove (a historical repository of newspaper and media articles) using the search terms “Gneering* AND fishing” and returned 462 hits when filtered for Queensland.

Twenty-four articles describing fishing trips were found and the ones including references to a total catch were plotted (Figure 1). The total catch ranged from 90 to 1,540, but these totals were not standardised by fishing effort (i.e., length of fishing trip and number of fishers). The biggest catch of the trip and catch size were sometimes reported, “a very busy hour gave us about 100 fish, nearly all schnappe over 10lb, with an occasional big epaulette” (Mail 1927). Fishing trips by clubs were often taken over several days at multiple sites such as Caloundra, Mount Coolum, Roper Shoals, in addition to Gneerings Shoals.

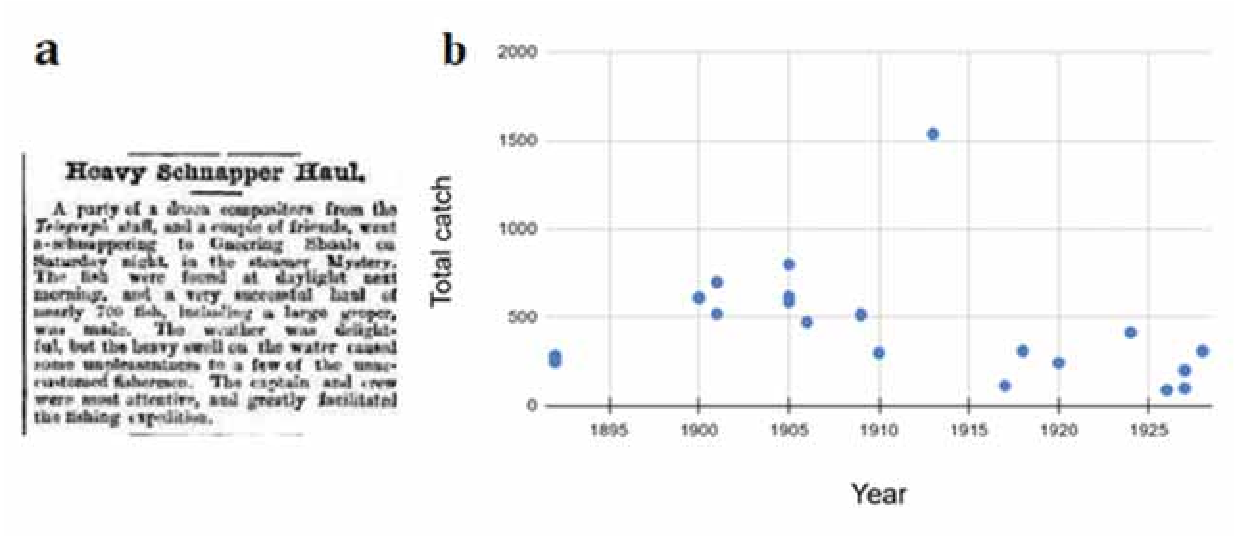

Figure 1: a) Example article of reporting of a "Heavy Schnapper Haul" of 700 fish at Gneering Shoals on August 5th, 1901, in The Telegraph. b) Plot of reported fish catch (total number of fish) in newspapers from Trove search of "Gneering AND fishing".*

1.5. Aims and Objective

The aim of the 2020-2022 UniDive Mooloolaba Reef Ecological Assessment (MEAM) project was to:

Conduct an ecological assessment of flora and fauna at the main reefs around Mooloolaba, and report on the current status and any changes when compared with existing ecological survey data.

- Conduct ecological surveys and mapping
- Test the inclusion of new RCA indicator categories
- Photogrammetry surveys to capture the 3D complexity at the surveyed sites

The survey methods were based on Reef Check Australia and CoralWatch Survey techniques, to enable a direct comparison and best mapping approaches developed by UniDive in collaboration with the Remote Sensing Research Centre at The University of Queensland. The results of these surveys will be communicated through this report, and presentations to the wider community, and to governmental agencies.

Ongoing ecological assessments of flora and fauna, substrate cover, coral types, and health impacts at the main reefs around Mooloolaba will be continually monitored by Reef Check Australia. Annual reports on the status and any changes when compared with existing ecological survey data is published and available at any time.

2. Methods

2.1. Overview

Ecological survey methods used were based on Reef Check Australia and CoralWatch methodology and mapping was consistent with the methodology used in the 2001, 2003, 2014, 2017 UniDive community projects (Roelfsema et al. 2016, Grol et al. 2019) to ensure data could be compared. However, Reef Check Australia protocols were adjusted with the aim to include more variety of locally interesting and relevant organisms. Further, the use of photogrammetry was introduced with the goal to test the feasibility of using a cutting-edge approach to capture 3D information of the surveyed area, such as rugosity. The systematic investigation of historical records on fishing activity added a further methodological novelty to this project in comparison to previous UniDive surveys.

Using local knowledge of the area of interest (Mudjimba & Gneerings), UniDive established eleven survey sites during the project. These were chosen to evenly survey the area of interest. Ten divers assessed a total of eleven sites evenly distributed around Mooloolaba Reef. Each survey involved broad scale mapping using a towed GPS (compass, depth readings and georeferenced underwater photos), 3D complexity surveys through photogrammetry, CoralWatch and Reef Check Australia transect surveys (4 x 20 m segments were assessed for substrate type, reef impacts, and fish and invertebrate species distribution and abundance). Finally, a survey of historical reports of fishing activity in the area was conducted.

UniDive volunteers were trained in the various survey techniques using online academics, pool training and during two dedicated survey training weekends. Over 60 volunteers participated in the academic training, and 44 of them participated in the practical survey weekend where they were trained in Reef Check Australia and CoralWatch survey methods from January-March 2021. All those conducting surveys completed an academic exam that included a review of the methods and identification of indicator categories for substrate, fish, inverts, and impacts surveys.

2.1.1. Survey Sites and Timing

Survey sites at Mudjimba Island and Gneerings Reefs were selected for this project due to their comparability locally, regionally, and internationally, as well as accessibility, and at a safe depth range. Eleven survey sites were established and surveyed (Figure 2). Surveys included fish abundance, benthic/substrate composition, key invertebrate species, and reef impact identification along transect lines deployed at a depth of 5 m - 15 m. Seven new transect sites were established and four sites were re-surveyed for comparison with annual reef health surveys conducted by Reef Check Australia since establishment in the area: 2007-2013. Surveys were conducted once at each location during the study period by the MEAM team to cover the spatial spread in the marine flora and fauna. Mapping of the area was conducted to characterise the bottom geography and composition.

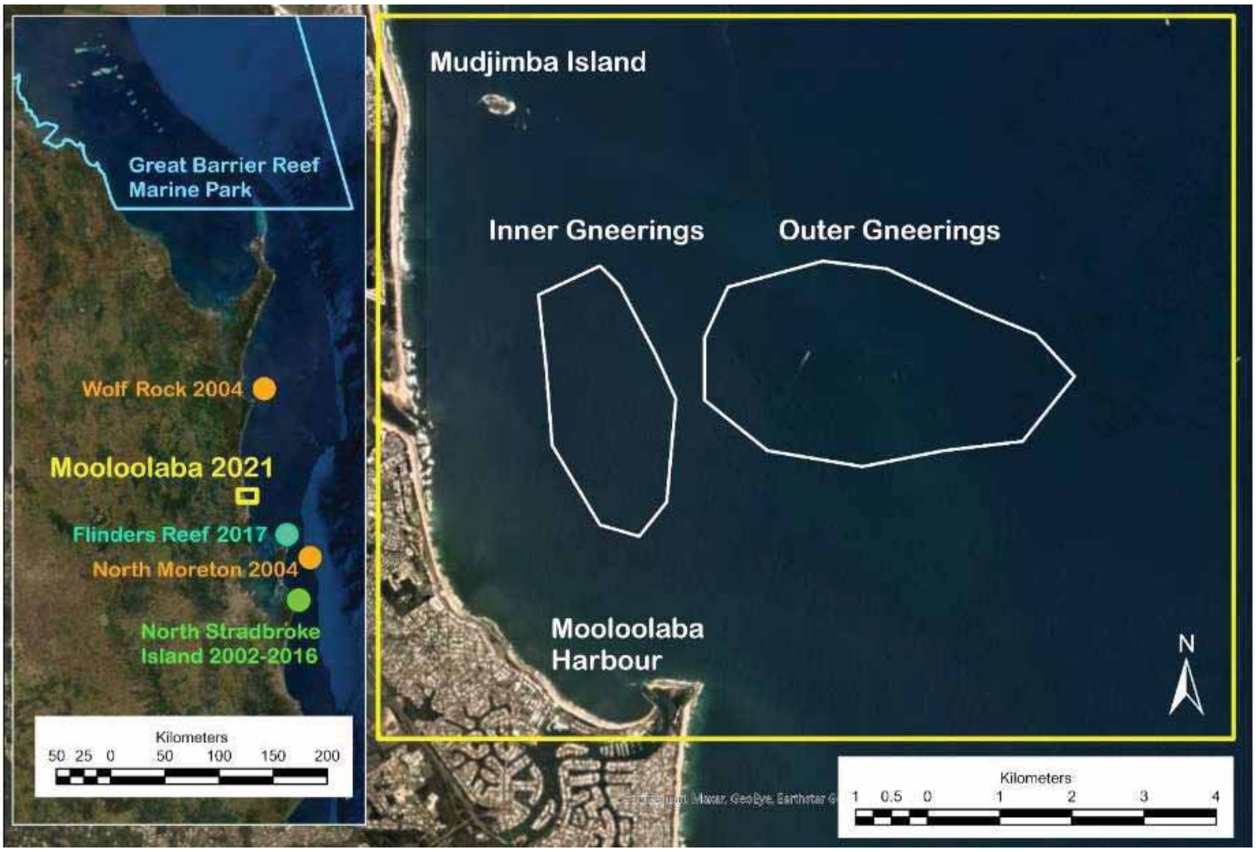

Figure 2: Mudjimba Island, Inner and Outer Gneerings Reefs at Mooloolaba, with reference to the location of previous UniDive project locations.

2.1.2. Survey Participants, Training and Quality Control

UniDive is The University of Queensland (UQ) Underwater Club (UniDive), it has over 300 members, of which 65% are mostly UQ staff and students. In 2020, UniDive initiated a baseline biological survey and mapping key of SCUBA dive sites of Mooloolaba Reef. All participants in the program were volunteers, certified divers, and members of UniDive. All survey divers had over 50 recent dives and were rescue diver trained or equivalent. These volunteers encompassed marine experts, SCUBA instructors, mapping experts and people interested in learning about the marine environment. See Appendix A for a detailed list of the volunteers and their main tasks during the project.

Over the course of 32 educational lectures, more than 60 UniDive members learned about local reef ecology in addition to Reef Check Australia, CoralWatch, 3D structural surveys and Mapping survey protocols. Lecture topics included: coral and rocky reef ecology; survey methods; identification and biology of coral, algae, substrate, fish, and invertebrates; causes and assessment of impacts; underwater photography and videography; 3D photogrammetry, mapping, and buoyancy control. Of the 44 participants, 24 were refreshed in their Reef Check Australia skills and 20 were separately trained and newly certified. Practical training was assessed in the pool and over two training weekends at North Stradbroke Island.

All divers were required to attend a series of lectures that provided training in survey methods. Competence in theory was assessed using online exams with over 120 identification questions (pass mark 85% or higher). In-water survey training consisted of two pool training sessions focussed on buoyancy and survey technique. Open water training was also conducted to ensure divers were able to correctly identify marine life, substrate categories and impacts, and that they were competent to conduct surveys. The 24 previously certified Reef Checkers were required to participate in a training weekend in which they refreshed their survey skills through practice surveys. Twelve of this group were additionally trained in Reef Check Fish ID. Reef Check training was supervised by qualified Reef Check instructors and Reef Check Australia Team leaders.

Regular review sessions were organised, and, on the eve of the first surveys of each survey weekend, the volunteers refreshed their memory by discussing survey categories with others who would have the same survey task. Data sheets were used for surveys (see Appendix B: Data Sheets), which aided in quality control. The data sheets were checked for errors or inconsistencies both directly after dives and during the data processing stage. Results derived from the quality-controlled data were presented after each survey by UniDive members with experience in Reef Check Australia and CoralWatch survey methods and or a marine science background in their field, thus providing additional quality control.

2.2. Habitat Mapping

Mapping of the Mooloolaba Reef was conducted to generate maps including polygon features (e.g., substrate types) to support our ecological understanding, planning and zoning of the sites and water depth. Feature mapping was undertaken by two divers that conducted roving surveys around the transect sites, to a maximum depth of 20 m, and recorded characteristic features. High spatial resolution satellite imagery in combination with water depth (Beaman 2010) was used as a backdrop to identify areas of interest to plan additional surveys.

2.3. Ecological Surveys

2.3.1. General Survey Approach

At each survey location a 100 m transect was located based on previous Reef Check Australia Surveys for Mudjimba Island, The Ledge and North West, plus the Inner Gneerings, Caves. The other sites were newly established to characterise the main areas around the reef. Within this 100 m length, four 20 m segments were deployed and surveyed (Figure 3). Each 20 m segment followed the designated depth contour, separated from the next transect by a 5 m gap.

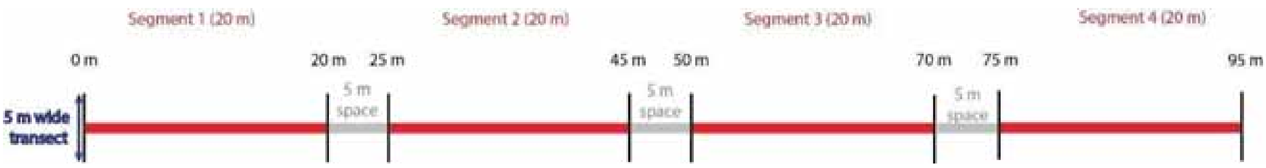

Figure 3: Placement of the transect lines Source: (Roelfsema et al. 2014, Roelfsema et al. 2016, Grol et al. 2019).

For each survey, five pairs of divers undertook mapping and/or transect surveys to identify indicator species present and major features at each site (Figure 4). Fish, invertebrates, impacts, substrate and benthos were all surveyed following Reef Check Australia protocols (Hill and Loder 2013). The Reef Check categories surveyed for counting were based on their ecological and/or economic value to both recreational and commercial fishing and the aquarium trade. Photos and video of the transects and the site fauna were taken to support identification of categories.

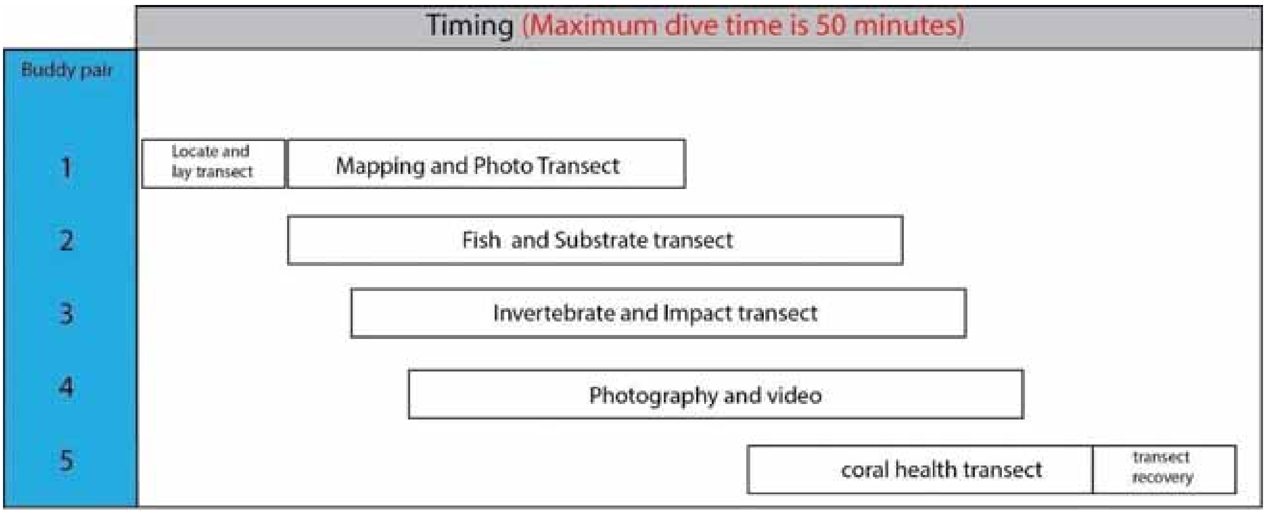

Figure 4: Timing of ecological survey dives, with a small break between buddy pair 1 and 5 so there is always a boat handler and assistant on the boat Source: (Roelfsema et al. 2014, Roelfsema et al. 2016, Grol et al. 2019).

2.3.2. *Substrate and Benthos*

Substrate surveys were conducted using the point sampling method, enabling percentage cover of substrate types and benthic organisms to be calculated. The survey method was based on the Reef Check Australia methods (Hill and Loder 2013) and was consistent with the methods used since 2001. The substrate or benthos under the transect line was identified at 0.5 m intervals, with a 5 m gap between each of the three 20 m segments (Figure 5). To the list of substrate categories recorded by the Reef Check Australia, macro algae was added to MEAM substrate surveys and included the *Asparagopsis* species, *Padina* spp, *Sargassum* spp. and *Turbinaria* spp. This was done to capture the abundance of major macro algae species on Mooloolaba Reefs, see Appendix B for data sheets and the categories surveyed.

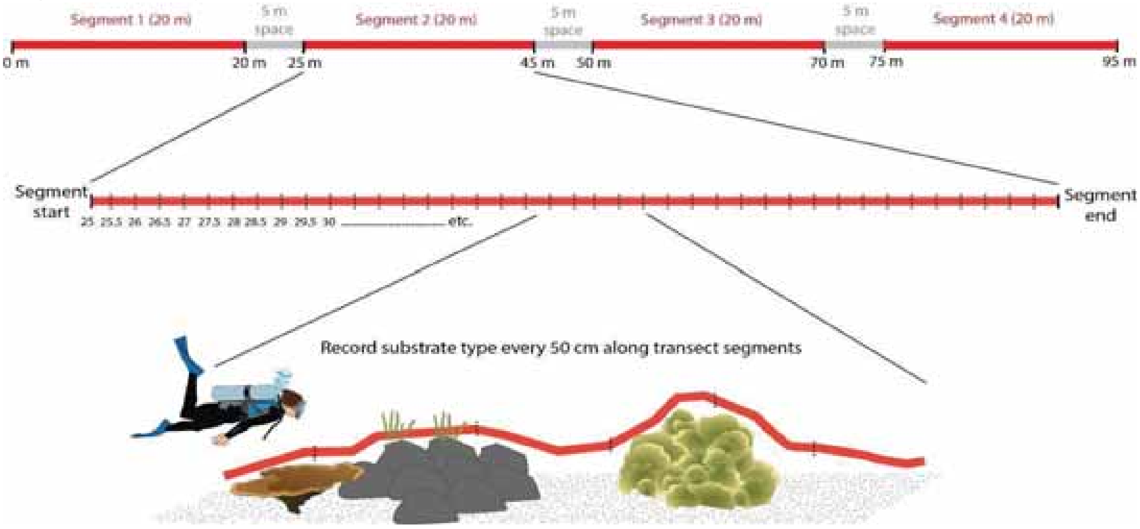

Figure 5: Detail of substrate survey transects. At every 0.5 m, using a plumb line to avoid bias, the benthic category located directly beneath the transect tape was recorded. Categories recorded included various growth forms of hard and soft coral, key species/growth forms of algae, other living organisms (i.e. sponges), recently killed coral, and, non-living substrate types (i.e. bare rock, sand, rubble, silt/clay). See Appendix B: Data for data sheet. The georeferenced photos taken along the transect (Section 2.2) provided an additional source for benthic assessment. Source: (Roelfsema et al. 2014, Roelfsema et al. 2016, Grol et al. 2019)

Visualisation and analysis of the benthic communities comprised barplots and stacked barplots. Key benthic groups, such as hard and soft corals were visualised separately with standard error to assess differences in benthic composition within and between Mudjimba, Inner Gneerings and Outer Gneerings survey sites. Further trends in benthic composition were also compared between the survey sites of MEAM and those from previous citizen science efforts, such as Flinders (FREA)(Grol et al. 2019) and Point Lookout (PLEA)(Hill and Loder 2013).

Temporal hard coral cover trends were assessed from the MEAM data and previously collected Reef Check Australia data from 2007 until present. These data were displayed as scatterplots, depicting hard coral cover through time from Mudjimba Island, Inner Gneerings, Outer Gneerings as well as previous citizen science efforts, FREA and PLEA.

For the eleven transect sites, photo quadrat surveys were conducted to gather additional information from photos and to test the ability to introduce this additional methodology to citizen science. Here photo quadrats were taken at 1 m intervals along the transect tapes, 0.5 m above the substrate providing a 1 m^2 footprint. This diver towed a dry bag in which a standard GPS logged the track of the transect (Figure 6).

Figure 6: Conceptual diagram of the georeferenced photo transects. Source: (Roelfsema et al. 2014, Roelfsema et al. 2016, Grol et al. 2019)

The collected images were analysed for benthic composition using machine learning through the Australian Institute of Marine Science's Reef Cloud photo database. More detail is available in the georeferenced photo transect manual (Roelfsema and Phinn 2009). All georeferenced photos that documented each of the reefs were plotted on top of the basic site map for each location to provide additional information for the mapping. Geolocated photos were analysed using machine learning to extract benthic and substrate categories, this was to support mapping and review the ability to include photographic surveys in future citizen science surveys.

2.3.3. Fish Species and Families

Fish populations were assessed using a visual census along the 4 x 20 m transects, following Reef Check Australia's protocols (Hill and Loder 2013). Each transect was 5 m wide (2.5 m either side of the transect tape), 5 m high and 20 m in length (Figure 7).

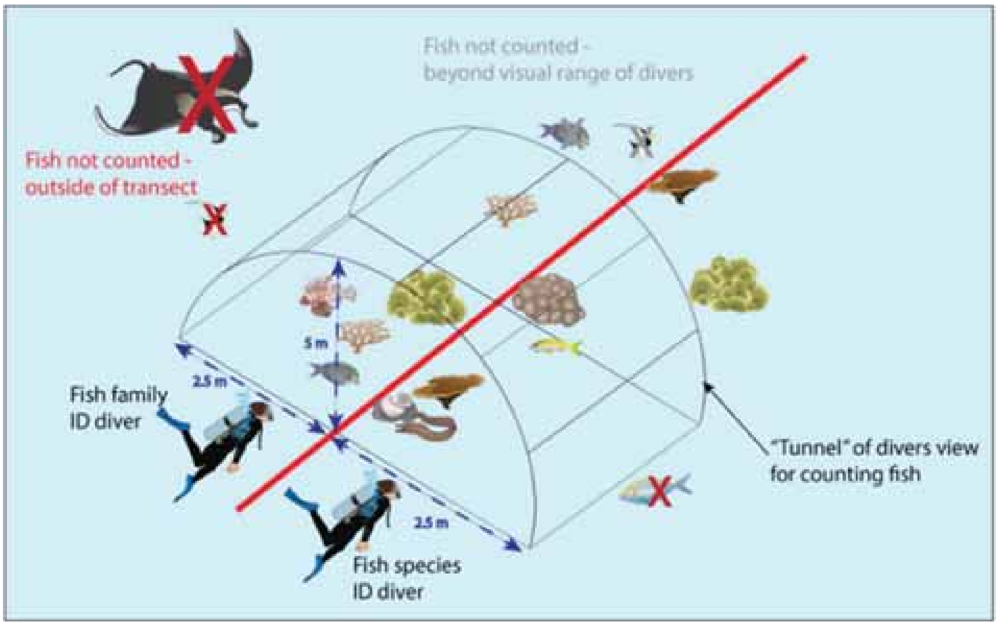

Figure 7: Diagrammatic representation of the fish survey transects showing the imaginary frame of the diver's view. Fish outside of the diver's view were only counted as well when they were seen withing the transect site (e.g. manta rays). Source: (Roelfsema et al. 2014, Roelfsema et al. 2016, Grol et al. 2019)

A fish survey diver would record fish sightings on the data sheets (Appendix B: Data Sheets). Each 20 m transect was completed in 7-10 minutes to ensure quality control. The list of 23 fish groups (families and species) recorded by Reef Check Australia was expanded by including Blue grouper, Barrumundi Cod, Bumphead parrot fish, pink snapper, Spangled Emperors other snappers, other emperors, Morwong, and Wobbegong. All recorded fish groups were chosen for their importance and value to recreational or commercial fishers, or targeted by aquarium collectors, and that were easily identified by their body shape or other characteristics. Rare or otherwise unusual species such as turtles, rays and sharks were also recorded. Abundance within key fish groups were expressed as fish abundance per 100 m2, i.e. average fish number per segment per site per season. See Appendix B Data for datasheets and the categories surveyed.

2.3.4. Invertebrates

Invertebrate populations were assessed using visual census along the 4 x 20 m transects following Reef Check Australia protocols (Hill and Loder 2013). The diver surveying invertebrates conducted a 'U-shaped' search pattern, covering 2.5 m on either side of the transect tape (Figure 8). Each 20 m transect was completed in 7-10 minutes. See Appendix B: Data for datasheet.

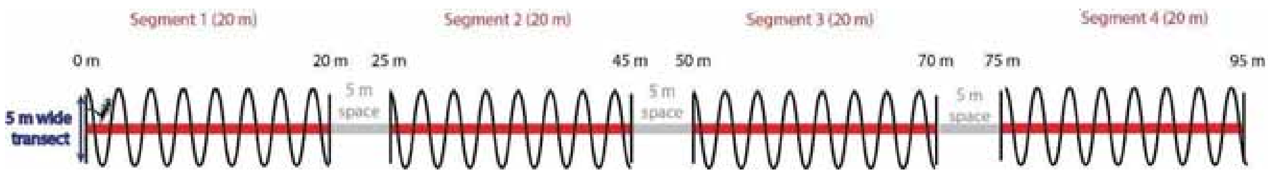

Figure 8: Diagrammatic representation of the invertebrate and reef impact survey transects. Divers swam a 5m wide transect in a U-shaped pattern along the transect tape Source: (Roelfsema et al. 2014, Roelfsema et al. 2016, Grol et al. 2019).

Invertebrate species were selected based upon their essential role in ecosystem health and functioning and/or their economic value to both commercial and recreational fishing or the aquarium trade. These species were aligned with the species selected by Reef Check Australia (Hill and Loder 2013). Additionally, other sea cucumbers and sea slugs (e.g. flatworms, and nudibranch species) were included in MEAM invertebrate surveys to contribute information about these cryptic organisms for Mooloolaba Reefs.

2.3.5. Reef Impacts

Target impacts were assessed using a visual census using the same approach as for the invertebrate survey (Figure 7) and included natural and anthropogenic impacts. Damage was assessed for scarring by the gastropod *Drupella*, only when individuals were present. Boat anchor damage also required the presence of anchor or chain to confirm. Unknown scars consisted of scraping of corallites without damaging the overall structure, while structural breakage of the coral without an obvious source was ranked as unknown damage. Fishing gear consisted of line, hooks, weights, or other fishing devices. Any other anthropogenic rubbish found on the reef was classified as general marine debris. Coral disease was identified through Reef Check standards. Photographs of the impacts were also taken for future reference.

CoralWatch, based at The University of Queensland, developed a non-destructive, inexpensive, easy-to-use tool to monitor coral health, the Coral Health Chart used in this study (Siebeck et al. 2006) (Figure 9). For each survey, coral health was measured for 20 corals along the 4 x 20 m segments. All observations within 2.5 m of a segment on either side were considered part of the transect. The surveyor swam along the segments accounting for its width and selecting at random five coral colonies per segment, i.e. 20 corals per transect. The chart was placed next to randomly chosen coral colonies and the colours on the chart were compared with the colours of the coral. The matching codes were identified for the lightest and darkest area of each coral colony and recorded on an underwater data slate. Where necessary, a torch was used to see true colours. Additionally, growth type was identified and recorded, i.e. branching, boulder, plate or soft coral.

The average colour score was calculated for each site and against previous data for both the Gneerings and Mudjimba. The average colour score and standard deviation was calculated for site groupings at the Inner Gneerings, Outer Gneerings and Mudjimba Island. Frequency distribution graphs showing the distribution of coral health scores for each of these areas were also created. Finally, the average colour health score data from MEAM surveys was compared with previous CoralWatch surveys at these sites to illustrate temporal trends.

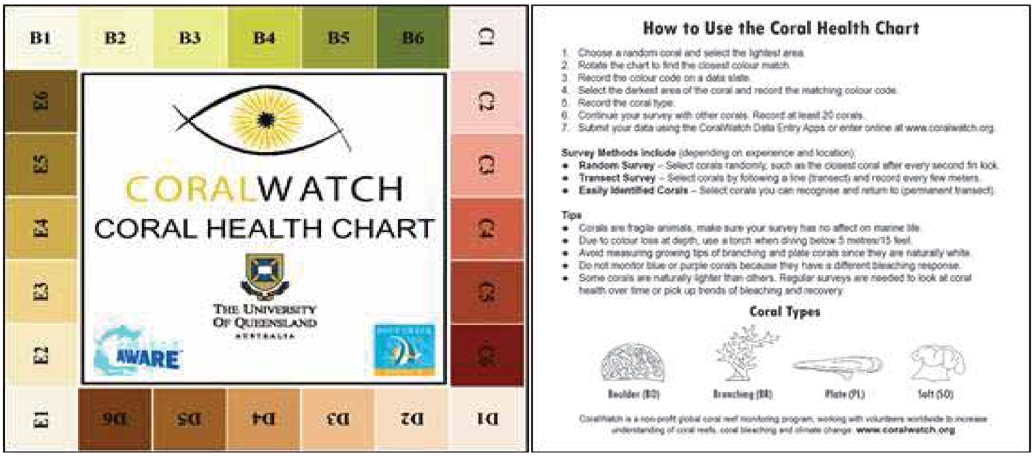

Figure 9: Coral Health Chart developed by The University of Queensland in association with the Vision, Touch and Hearing Research Centre and Centre for Marine Science in 2002. The image on the right is the front of the chart. It assigns codes to colours that suggest different levels of coral bleaching. The image on the left is the back of the chart. It provides instructions for the use of the chart.

2.3.6. Ecological Data Analysis

Analyses of the ecological data (Coral, Fish, Inverts, Impacts) focused on three levels, to assess:

1. Spatial variations around the eleven sites of the Mooloolaba area, these comparisons were conducted at both the site and area level (Mudjimba, Inner and Outer Gneerings)
2. Temporal variation of coral cover at the sites surveyed were compared to Reef Check Australia data
3. Lastly, differences in coral composition between Mooloolaba Reef sites were compared with other regions surveyed by Reef Check Australia, and UniDive in the Southeast Queensland region such as: Point Lookout, and Flinders Reef

2.4. 3D complexity surveys (Photogrammetry)

2.4.1. Photogrammetry Data Collection

To understand the three-dimensional complexity of the different study sites, photogrammetric data collection surveys were conducted, and 3D mosaics created to derive information on rugosity and complexity(Dustan et al. 2013). We used three GoPro Hero 3 black edition cameras on a 1.5 m long aluminium pole to enable the capture of multiple viewing angles and consequent depth of field. One camera was focusing straight down and two from the side with a 10-15 degree angle. The optimal angle for the tilted cameras was determined using a custom Python script (Figure 10c) and consequent dry trials at UQ.

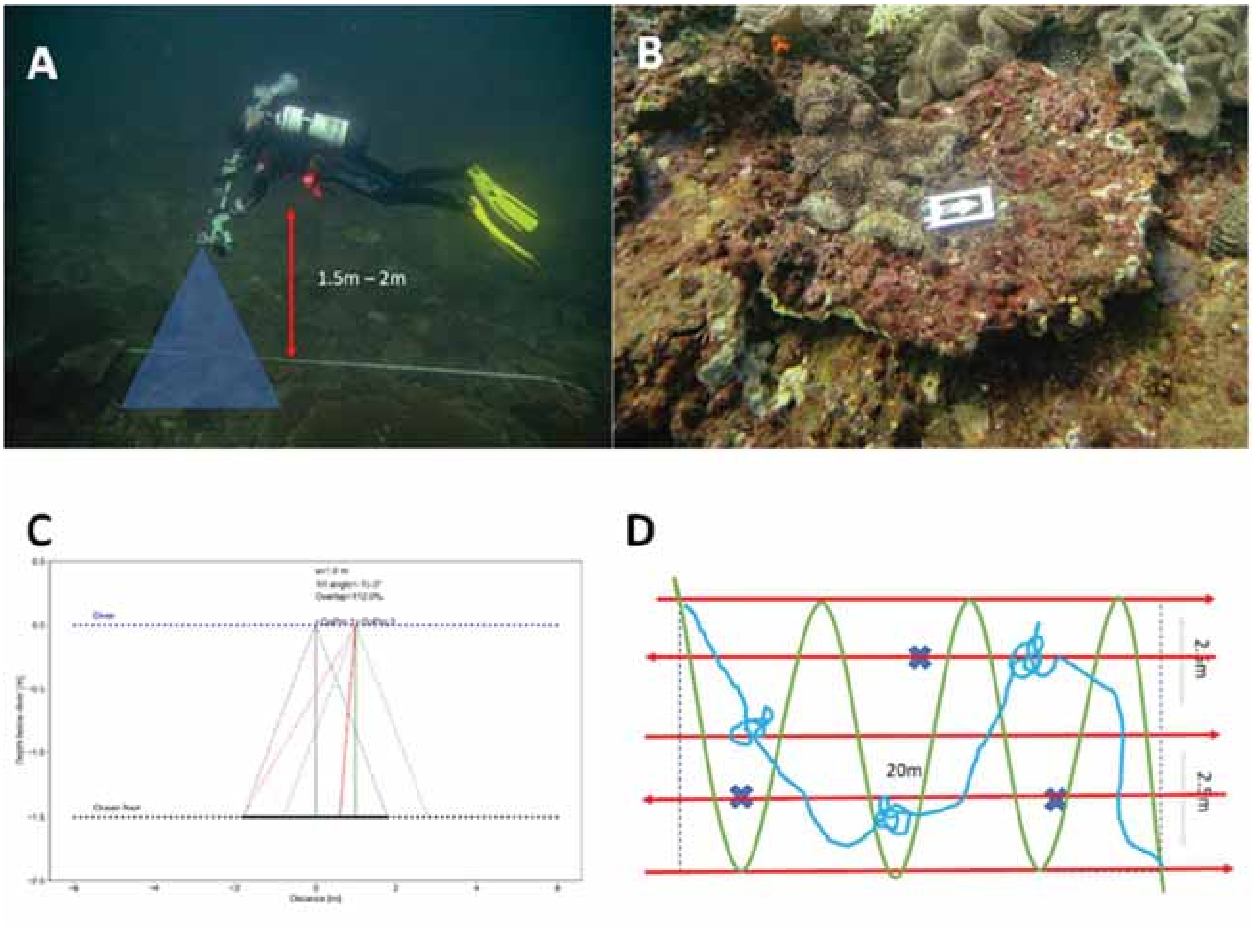

Figure 10: A) Volunteer collecting photogrammetry footage along the survey transect. The rough viewing angle is indicated in blue. The desired distance from the ground is indicated with the red arrow. B) Example of marker placed on the reef C) Schematic of overlap generated by tilted camera. D) Schematic of the sampling sequence across each 20 m transect segment. First, three markers were placed at random positions across the transect (blue crosses), then five straight repeats (red) of obtaining images were done, followed by a zig-zag pattern (green) and, finally, a 'clean-up' run to capture overhangs, crevices, and larger objects in detail.

At the beginning of each 20 m segment on a transect, the cameras were set to take two pictures per second. Before taking the footage of each segment, three markers (Figure 10b) were placed at random positions within each 20 m segment. This was done to aid in image alignment for the 3D model construction as well as potential scaling of the models at a later stage. Each 20 m segment produced about 2,000-3,000 images (Figure 10b). Roughly 10 citizen scientist volunteers were trained in data acquisition and software use in two dedicated practical workshops and with online presentations.

2.4.2. Photogrammetry Data Analysis

All images were manually screened for quality and any images out of focus were removed from the data. The images were then colour & contrast calibrated, noise levels reduced and sharpened using Adobe Lightroom. 3D models were created using Agisoft Metashape Standard licence (Agisoft LLC 2022). Using access to a free 30-day trial of an Agisoft professional licence we calculated the rugosity of each 20 m segment. This was achieved by calculating the ratio between the surface area of each 3D model to the projected area underneath it, relative to the best fitted level plane.

The median rugosity of each part of the survey area (Mudjimba Island, Inner Gneerings, Outer Gneerings) was calculated and correlations between rugosity and coral cover investigated across all sites.

2.5. Environmental Data

2.5.1. Data Type and Sources

Historical environmental data has been collected and reviewed to understand the potential influences of these factors on the Mooloolaba reef and provide insight into future environmental impacts. The environmental data analysed included atmospheric and sea data.

Atmospheric data: localised precipitation, air temperature, minimum and maximum, solar exposure, localised wind speed and direction. Atmospheric data was sourced from the Bureau of Meteorology, Station number 040861 (Climate statistics for Australian locations (bom.gov.au). The Station is located approximately 3 km to the north-west of Mudjimba Island, and 11 km North-west of the outer Gneerings.

Sea data consisted of sea surface temperature, and wave height. Sea data was sourced from the Queensland Government wave monitoring site for Mooloolaba (Mooloolaba wave monitoring | Environment, land and water | Queensland Government (www.qld.gov.au)). The wave buoy is located approximately 8 km to the north-east of Mudjimba Island, and 9 km North of the outer Gneerings.

Historical environmental data was collected to understand potential influencing factors on the Mooloolaba Reefs. The data included atmospheric temperature, precipitation, wind (direction and speed) and solar exposure. The weather station provided Minimum and Maximum temperatures, Total Rain and Average Daily global solar exposure (MJ/m*m) per day from January 1994 to July 2022.

Global solar exposure is the total amount of solar energy falling on a horizontal surface. The daily global solar exposure is the total solar energy for a day. Typical values for daily global solar exposure range from 1 to 35 MJ/m 2 (megajoules per square metre).

2.5.2. Environmental Analysis

Due to a lack of completeness of atmospheric and sea data in periods prior to 2006, it was decided that analysis would only use data from January 2006 to July 2022. To allow comparisons and analysis of atmospheric data monthly figures have been calculated. In the case of month-by-month comparisons from January 2006 to July 2022.

- Precipitation - rainfall has been totalled per month,
- Air temperature, both for each month:
    - highest maximum temperature and lowest minimum temperature are taken,
    - average minimum and average minimum temperatures are calculated,
- solar exposure - daily recordings are averaged over the month.
- Wave height:
    - the average wave height for a month is calculated,
    - the minimum and maximum wave heights for each month are recorded.

To understand the potential influences of weather factors on the Mooloolaba reef over the survey period, data for years 2021 and 2022 are compared to averaged data for the years 2006 to 2020.

2.6. Species List

Flora and fauna species lists were created through a literature review (Appendix C), by:

1) Identification of flora and fauna from photos and videos taken by divers at the dive sites during and outside the survey weekends.
2) Those volunteers with detailed knowledge of the local flora and fauna recorded any non-surveyed species.
3) Previous data sets collected by volunteers on the project, such as the dataset collated by Terry Farr and Julie Schubert(Farr and Schubert 2022), who have done hundreds of dives at the sites in the last two decades photographing and noting species.

The species list has been compiled in Appendix C and represents all marine species that have been observed at the Mooloolaba reefs.

3. Results

3.1. General Overview

3.1.1. Participants

The project took at least 8,000+ hours in volunteer time, that included 34 online meetings (academic training/planning), six pool training sessions, 60 training dives, and 132 survey dives, conducted between October 2020 and November 2022. Over 60 members participated in various activities and 20 were trained/certified or 20 were refreshed in Reef Check Australia, CoralWatch and mapping survey techniques. There were two training weekends, and 11-day trips organised, 23-day trips were organised but cancelled at the last moment due to COVID restrictions or weather conditions.

3.1.2. Survey Considerations

Dives were conducted over a total of two training weekends and eight survey days from June 2021-Jan 2022. Table 1 summarises the environmental conditions documented during the survey dates. For the duration of the study, the water temperature at the surface (SBT) ranged from 20 °C in July to 25 °C in February. Based on divers observation, the visibility varied between 5-15 m. Figure 11 shows a significant variation from the average for November 2021 and February 2022. Both these months show a significantly higher rainfall than the long-term average**.** Rainfall is also below average for the winter months. Figure 12 shows a significant variation from the average wave height for January, February, and May 2022, however 2021 does not show significant variation. The higher wave height impacted on the survey work with many trips being cancelled due to adverse diving conditions or poor visibility**.**

Table 1: Environmental conditions during each of the survey weekends (Source: Bureau of Meteorology, Wave Rider Buoy).

Mooloolaba Survey Dive	Recording point	Rain 24 hour (milimeters)	Max. Daily Sea Surface Temperature (Celcius)	Maximum Wave Height (metre)	Air Temperature (Celcius)	Wind Direction	Wind Speed (Km/h)	Cloud Cover (%)	Sea Surface Tempurature (Celcius)	Wave Height (meters)
Saturday, 24 April 2021	Daily	0.0	24.8	1.6						
	Morning 9am				NA	NA	NA	NA	24.60	0.66
	Afternoon 3pm				NA	NA	NA	NA	24.70	0.57
Saturday, 31 July 2021	Daily	0.0	20.5	1.6						
	Morning 9am				17.1	NW	9.0	0.0	20.30	0.68
	Afternoon 3pm				21.1	NNE	26.0	0.0	20.50	0.74
Sunday, 1 August 2021	Daily	0.0	20.4	2.0						
	Morning 9am				19.7	NW	19.0	0.0	20.30	0.69
	Afternoon 3pm				22.6	NNE	30.0	0.0	20.35	0.79
Sunday, 19 September 2021	Daily	0.0	21.9	2.4						
	Morning 9am				23.7	NW	24.0	0.0	21.60	1.01
	Afternoon 3pm				23.8	NNE	24.0	0.0	21.85	0.92
Saturday, 25 September 2021	Daily	0.0	21.6	1.7						
	Morning 9am				23.7	NNW	15.0	0.0	21.15	0.66
	Afternoon 3pm				24.4	NE	26.0	0.0	21.55	0.87
Saturday, 6 November 2021	Daily	0.0	NA	2.8						
	Morning 9am				23.6	ESE	17.0	7.0	NA	1.28
	Afternoon 3pm				23.0	ENE	17.0	8.0	NA	1.23
Saturday, 20 November 2021	Daily	0.0	NA	2.2						
	Morning 9am				26.5	NW	11.0	0.0	NA	0.75
	Afternoon 3pm				25.7	NNE	28.0	0.0	NA	0.79
Saturday, 19 February 2022	Daily	0.0	NA	2.0						
	Morning 9am				27.1	SE	15.0	7.0	NA	0.96
	Afternoon 3pm				28.2	SE	24.0	1.0	NA	0.82

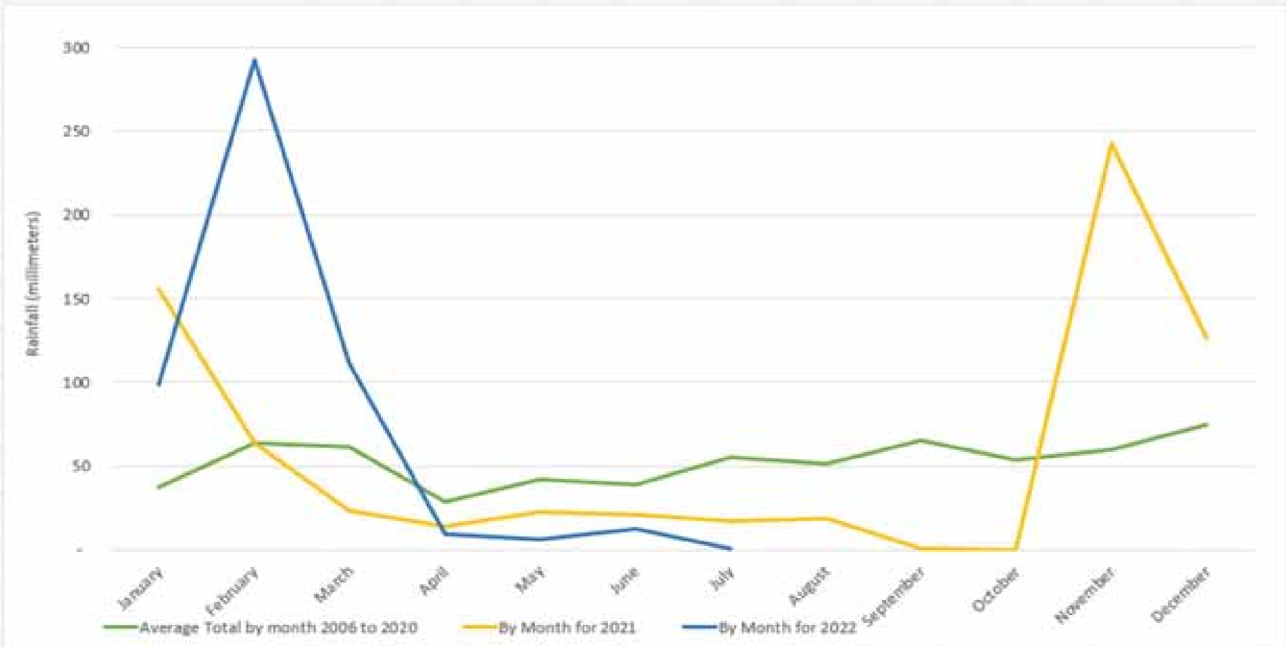

Figure 11: Monthly rainfall averaged for 2006 to 2020 compared to 2021 and the first 6 months of 2022.

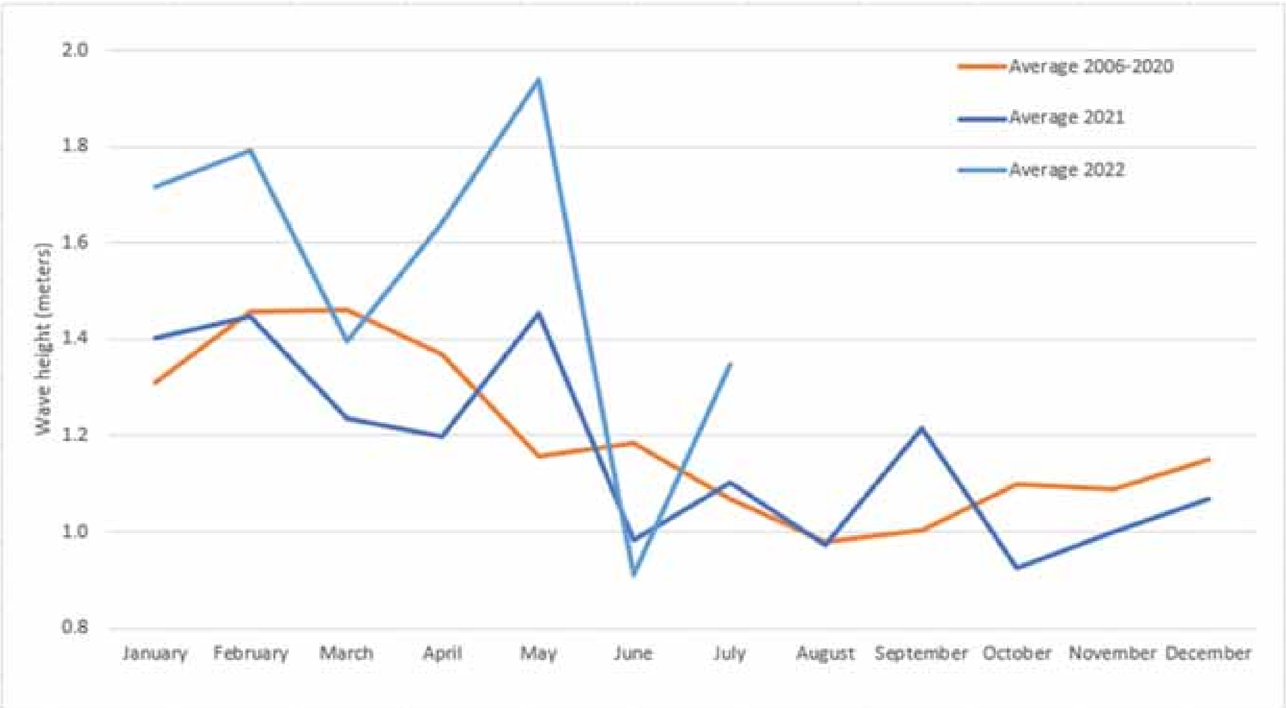

Figure 12: Monthly average wave heights and compares the average of 2006-2020 to the month average for 2021 and 2022.

3.1.3. Mapping

Georeferenced habitat maps (UTM-WGS84) were created for Mooloolaba reefs, which described the substrate type, water depth, and significant features. Mooloolaba was further divided into three sub regions, the Mudjimba Island, Inner Gneerings and Outer Gneerings (Figure 13).

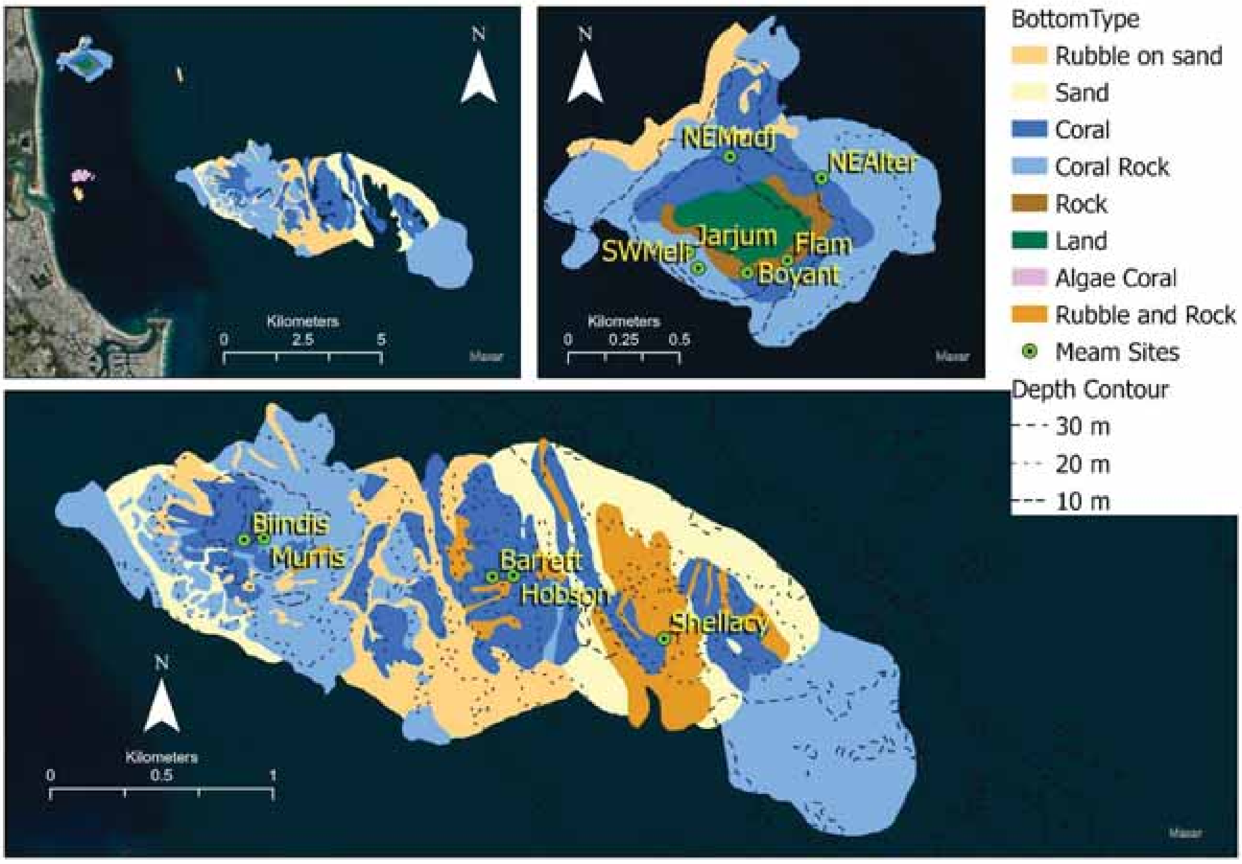

Figure 13: Prominent substrate features at Inner and Outer Gneerings, Mooloolaba Reef, Sunshine Coast Australia. Depth sourced from Beaman 2010. Worldview 2 satellite imagery used as backdrop.

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3.1.4. Species Desktop Study

Species present at the Mooloolaba Reefs was completed on 29th May 2022. The search revealed there has been limited research on species of the Mooloolaba Reefs in scientific articles (n=3). Observations within the Mooloolaba Reef area from the iNaturalist database within the pastfive years were included in the species list (n=159). Additionally, avid citizen scientists Terry Farr and Julie Schubert, who have done hundreds of dives at the sites in the last two decades have photographed and noted hundreds of species. We were provided access to their private observation database. Species were recorded from each source and duplicates were removed to leave a total of 1,192 species Table 2.

Table 2: Species data sources identified in literature search

Species	Source
1	Cribb, A.B., 1954. Records of marine algae from south-eastern Queensland (p. 1954). Brisbane: University of Queensland Press.
598	Farr, T., Schubert, J., Ocean Observation Database 2010-2022
118	iNaturalist search by area
9	Jeff Johnson personal communication
12	nudibranch.com.au
91	Queensland Museum 2014, Queensland Museum fishes collection records
363	Schlacher-Hoenlinger, M.A., Walker, S.J., Johnson, J.W., Schlacher, T., Hooper, J.N.A., Ekins, M., Banks, I.W. and Sutcliffe, P.R., 2009. Biological monitoring of the ex-HMAS Brisbane Artificial Reef: Phase II-Habitat Values. Technical Reports of the Queensland Museum Issue 003. University of the Sunshine Coast, Queensland.

The literature review identified 403 fish species from 66 families, 26 hard coral species, 41 soft corals species and 326 nudibranch species within the Mooloolaba Reefs region. In comparison, of the 463 species reported in the Point Lookout Ecological Assessment (Grol et al. 2019), 280 fish species were reported from 35 families, with 36 hard coral and 4 soft coral species and 4 nudibranchs.

3.2. Ecological Surveys

3.2.1. Substrate and Benthos

Hard coral cover was generally uniform across all three sites: Mudjimba Island (41%), Inner Gneerings (40%) and Outer Gneerings (37%). Hard coral was the dominant benthos for Mudjimba Island and Outer Gneerings (Figure 13). Rock was the dominant substrate cover for Inner Gneerings (46%) followed by hard coral. Soft coral varied at each site with 32% at Outer Gneerings, 11% at Mudjimba Island and 3% at Inner Gneerings. Recently killed coral was present at Mudjimba Island and Inner Gneerings with <1% cover for both. Coral rubble was only present at the Mudjimba Island sites. Mudjimba island had the highest diversity in substrates and benthos (n=10) compared with Inner Gneerings (n=8) and Outer Gneerings (n=7).

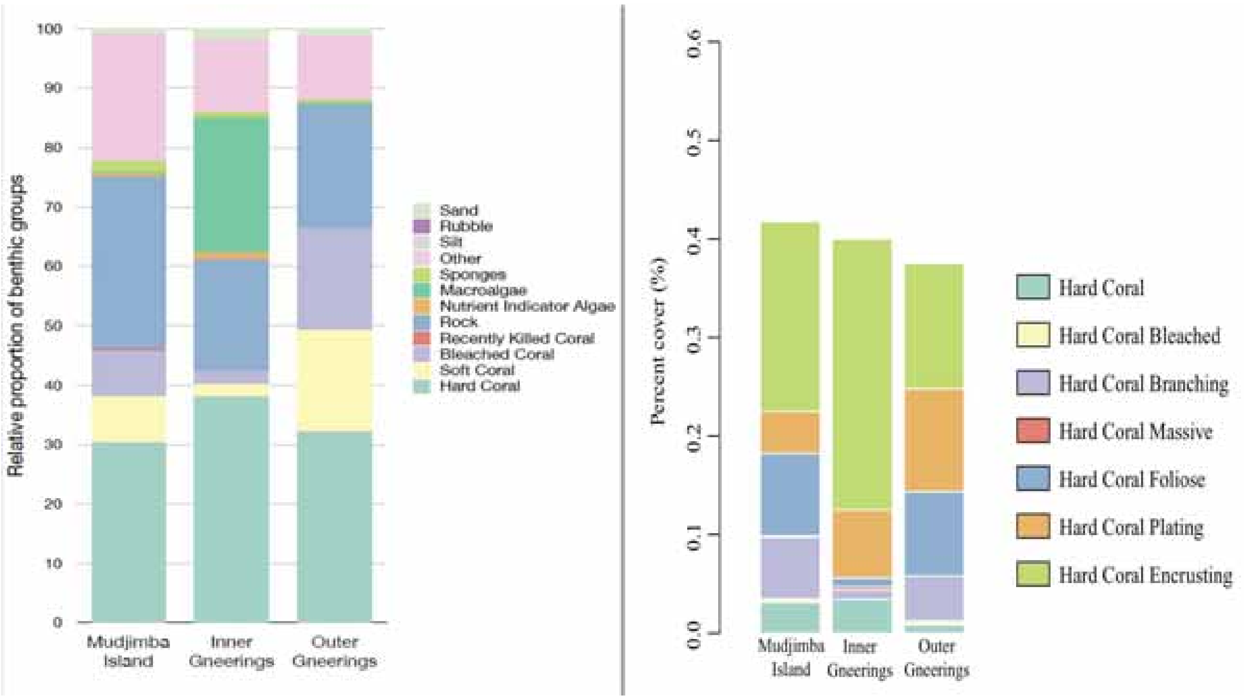

Figure 14: Stacked barplot of relative proportion of benthic groups per Mooloolaba area(left). Values are averaged from each area's sites. Stacked barplot of averaged hard coral cover per area and per hard coral type (right). Values are percent cover and averaged from each area's sites.

Hard coral cover was the most dominant benthos for half of the sites (Northeast Alternate, Southeast FLAM, Southeast Boyant, Barrett and Shellacey) with soft coral dominant at Hobson. Rock was the dominant substrate for four sites (Southwest Meli, Southwest Jarjurn, Murri, Bindi) (Figure 15). Both Outer Gneerings sites (Hobson and Shellacey) had the lowest diversity in benthos and substrates present (n=5) with the highest diversity (n=8) occurring in Northeast Alternate and Southwest Meli (Mudjimba Island) and Murri (Inner Gneerings). Bleached coral was present at three sites, Northeast Alternate (Mudjimba Island) and both Barrett and Shellacey (Outer Gneerings).

Hard encrusting coral was the most dominant hard coral present across the sites, ranging from 13-28% of the total cover of hard corals (Figure 14). Massive hard coral was the least abundant hard coral and located both at Southeast Boyant and Bindi (1% of total hard coral cover) (Figure 15).

Bleached hard coral was present at Mudjimba Island (Northeast Alternate 2%) and Outer Gneerings (Barett and Shellacey both 1%) (Figure 14).

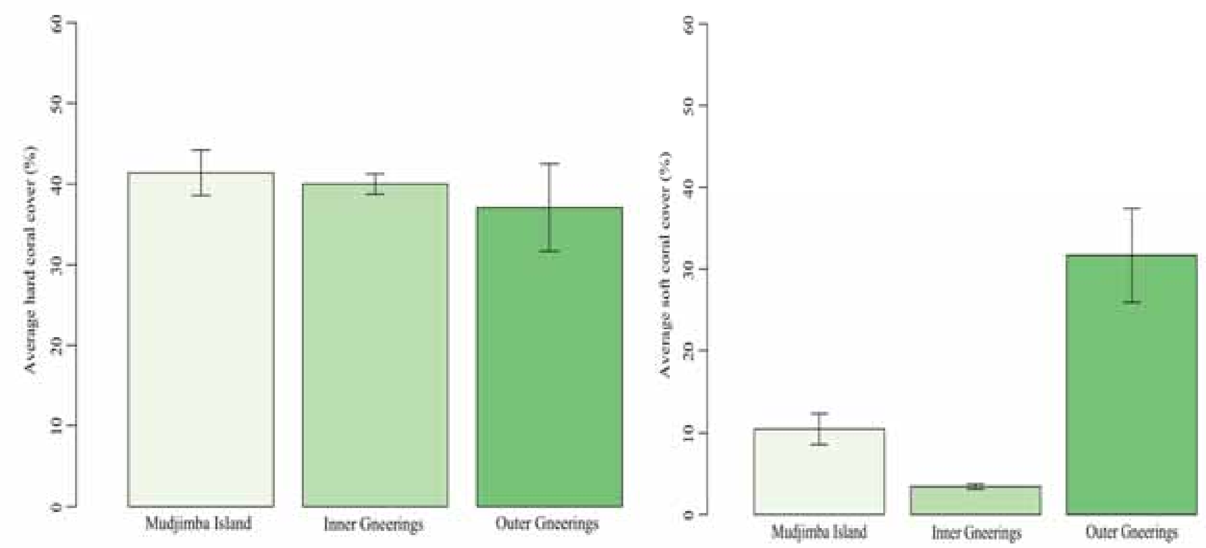

Figure 15: Barplot of averaged hard coral (left) and soft coral (right) cover per area with Standard Error. Values are percent cover and averaged from each area's sites.

3.2.2. Fish Abundance and Diversity

Overall fish abundance

Fish species were surveyed in this study based on the Reef Check Australia fish survey guidelines (Figure 16). Fish were only surveyed once at each site, and in most cases the number of fish observed was averaged across transects at each site. Overall, fish abundance was highest at Shellacy, and Jarjum, while some fish species were completely absent from several sites including Flam, Murris, Northeast Alternate and Northeast Mudjimba. Notably, overall abundance was lowest at the Inner Gneerings sites.

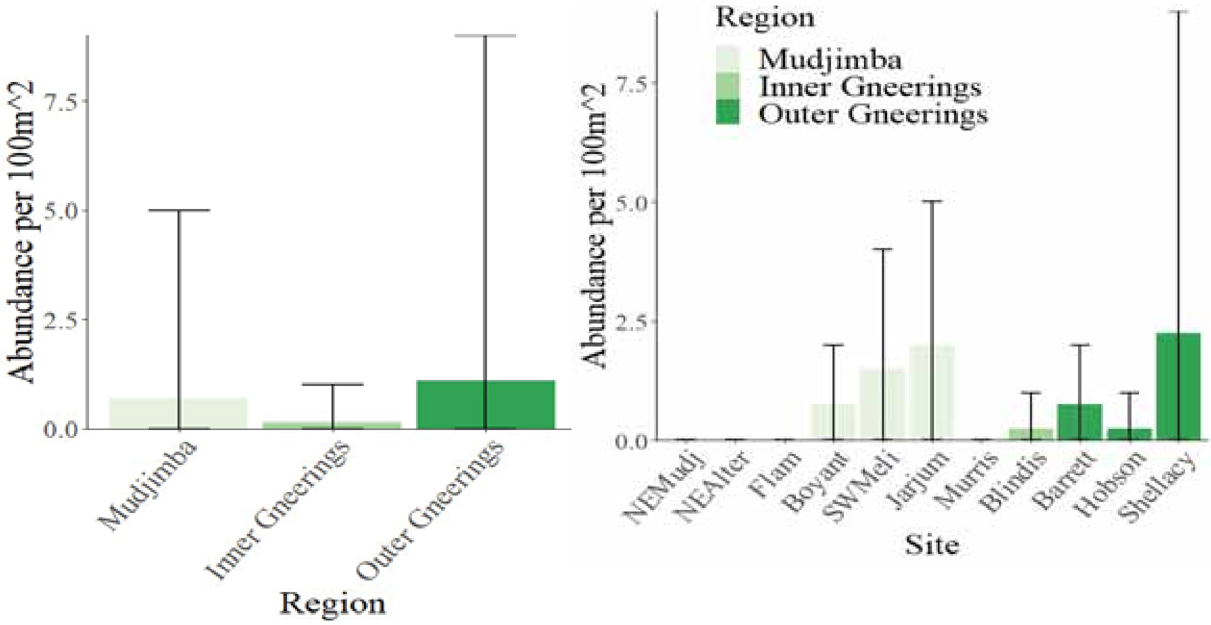

Figure 16: Average abundance of surveyed fish across the three main regions (right) and at each survey site (left) within the Mooloolaba reefs. Error bars indicate standard deviation.

Fish taxa

Several key groups of tropical and subtropical fish species were surveyed in this study. After the butterfly fish, snappers were the most observed fish, particularly at Jarjum, Shellacy, and Southwest Meli, (*Figure 17*). Interestingly, Moray eels, which are usually rare and hard to spot, were recorded on several occasions with sightings at Bindis, Boyant, Hobson and Jarjum (*Figure 17*).

Overall trends are similar across regions, which can be seen in Figure 17. This figure shows the total abundance of each taxon across the three surveyed regions. In the Outer Gneerings, snapper were the dominant group and the second most common taxon at Mudjimba (with Parrotfish being the dominant group at Mudjimba). Fish abundance and diversity was lowest at the Inner Gneerings, with only one Moray eel observed.

Butterflyfish

Overall, butterfly fish exhibited the highest total abundance at all sites. This group was omitted from Figure 17 (above) as their high abundances obscured trends in other groups. Butterflyfish abundance was highest at Shellacy, Southwest Meli and Murris, and lowest at Flam and Northeast Alternate. Overall, their abundance was higher at the Inner and Outer Gneerings than at Mudjimba. However, there was a high degree of variability in butterflyfish abundance across sites as evidenced by the error bars shown below (Figure 18). Butterflyfish abundance was higher at the Inner and Outer Gneerings as compared to Mudjimba Island. However, there was a high degree of variability in butterflyfish abundance as evidenced by the error bars (Figure 18).

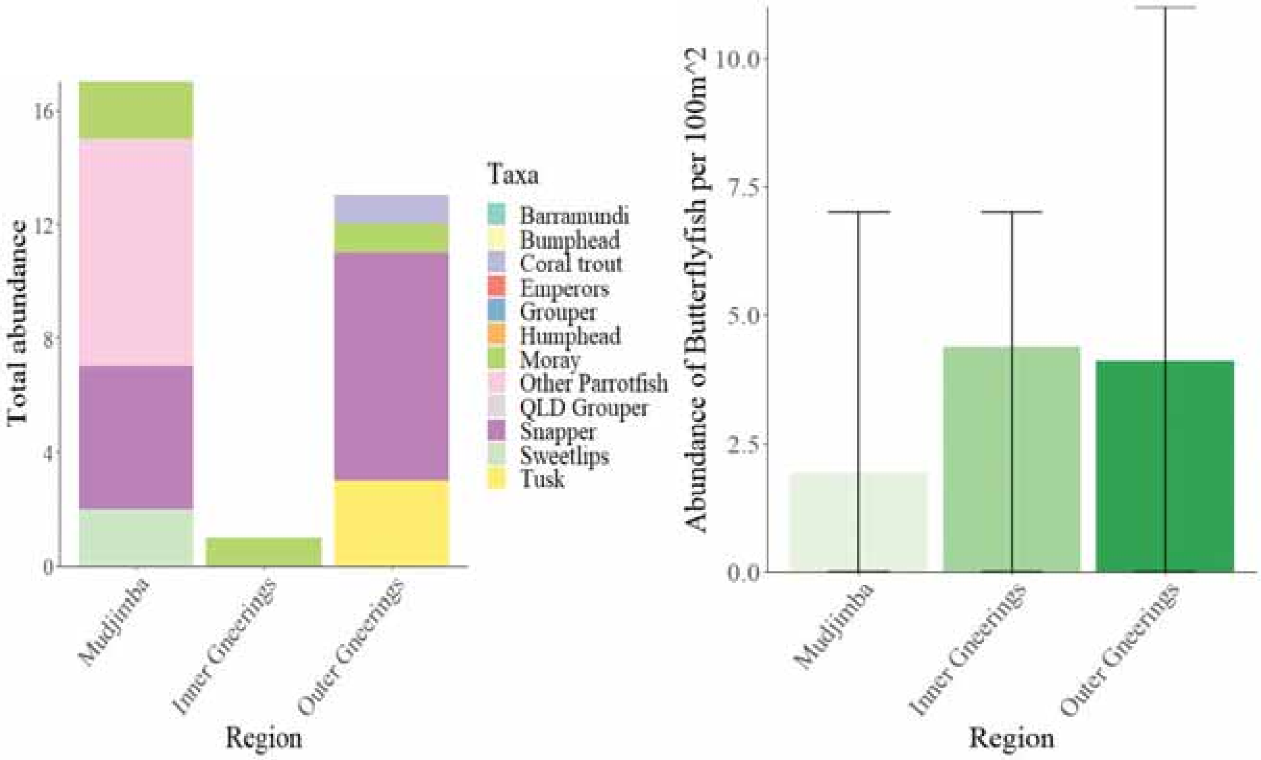

Figure 17: Abundance of targeted fish taxa across the three regions surveyed (Left) and average number of butterfly fish (100m2) across the three regions surveyed (right). Error bars indicate standard deviation.

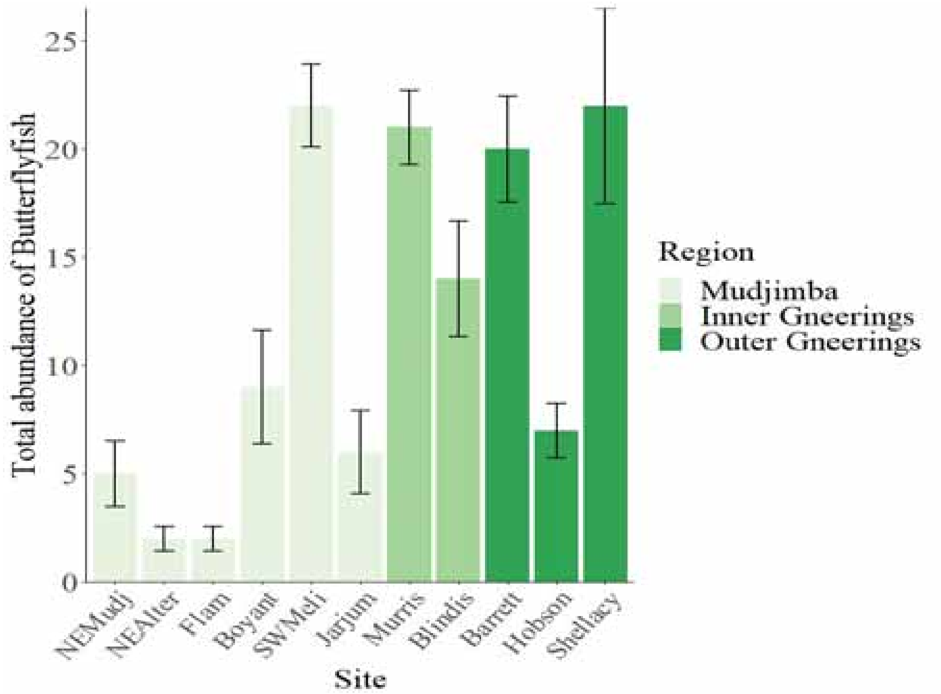

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Figure 18: Average abundance of butterfly fish for the eleven sites surveyed. Error bars indicate standard deviation.

3.2.3. Invertebrates

In total, 258 invertebrates were recorded at the areas around Mooloolaba, 170 nudibranch species and 88 individuals of indicator invertebrates from Reef Check Australia. Particularly, a total of 99 individuals were recorded at Mudjimba (2400 m^2) with an average of ~4 invertebrates per 100m^2 (0.38 SE), 75 individuals were recorded at Inner Gneerings (800 m^2) with an average of ~9 invertebrates per 100 m^2 (0.60 SE), and 84 individuals were recorded at Outer Gneerings (1200 m^2) with an average of ~7 invertebrates per 100 m^2 (1.35 SE) (Figure 19).

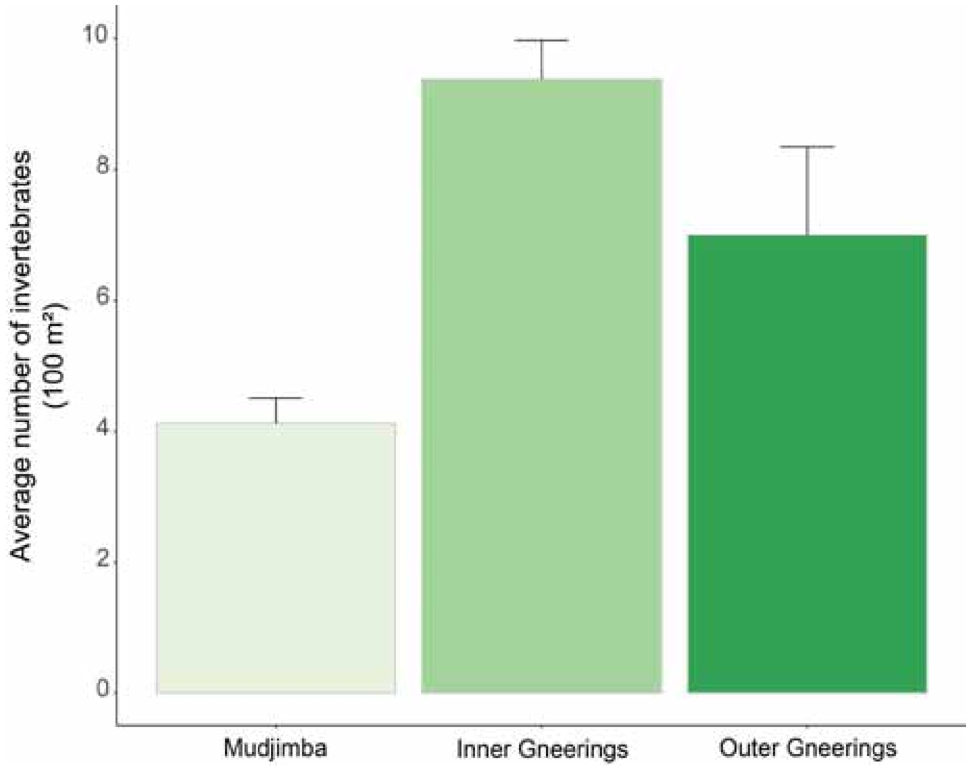

Figure 19: Average number of indicator invertebrates recorded per area including nudibranch species. Number of surveyed sites (100m2) differed among areas such as Inner Gneerings had two sites, Outer Gneerings had three sites, while Mudjimba had six sites. Note error bars indicate standard error.

Invertebrate sightings were on average below 10 individuals per 100 m^2 transects at all sites. Nudibranch species, *Drupella* snails, and clams were found in all three areas (Figure 20). The average observed abundance of nudibranch species was higher at Inner Gneerings than at any other area (~7/100 m^2), whilst *Drupella* snails had the highest average abundance at Outer Gneerings (~3/100 m^2). Excluding nudibranch species and *Drupella* snails, the average abundance of the recorded invertebrates was below 1/100 m^2 (Figure 20). Collector and pencil urchin were only sighted once at Mudjimba. Lobsters were low and only sighted at Inner and Outer Gneerings. Overall, five clams were recorded, two at Inner Gneerings, two at Mudjimba, and one at Outer Gneerings. Finally, most anemones were found without anemone fish at all areas, and only two anemones were found with fish at Mudjimba.

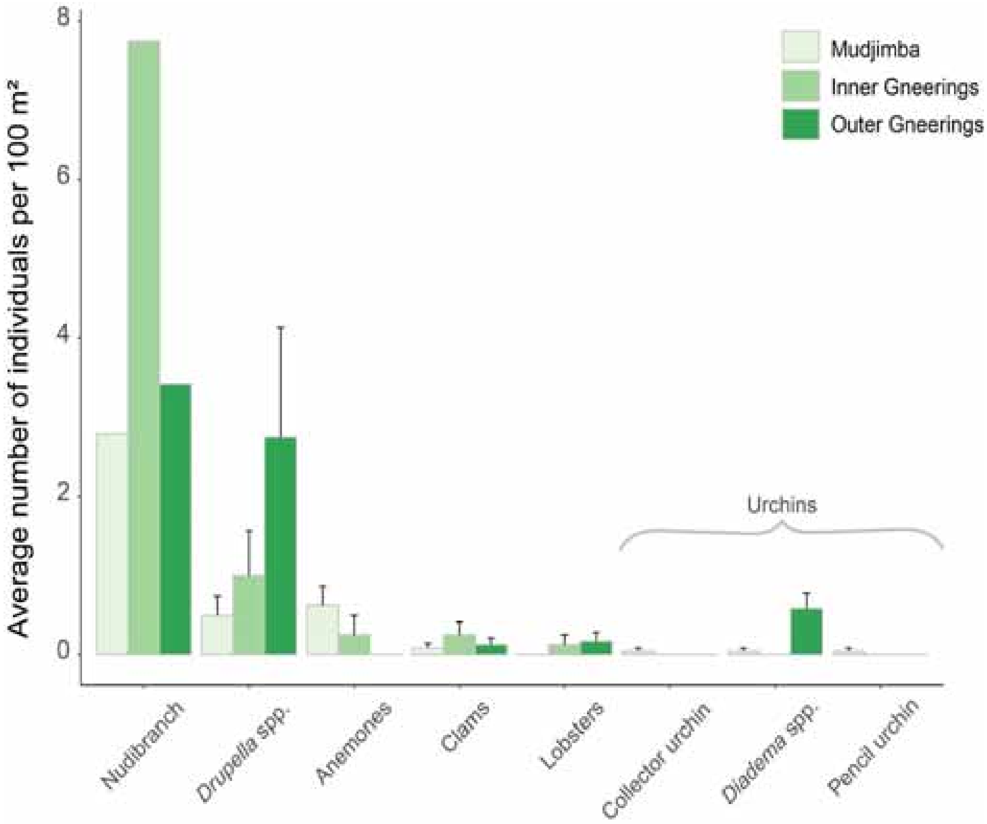

Figure 20: Average abundance of indicator invertebrates including nudibranch species recorded per 100 m2 transects in each site. Note error bars indicate standard error.

3.2.4. Reef Impacts

Reef Health Impacts

Coral damage, disease and marine debris were observed at all three Mooloolaba sites with marine debris having the highest count of any impact (Mudjimba Island n=3.0, Inner Gneerings n=1.6, Outer Gneerings n=3.7) (Figure 21). All impacts were present at both Mudjimba Island and Outer Gneerings, whereas no scars (*drupella* or unknown) or coral bleaching was observed at Inner Gneerings. Of the 11 Mooloolaba sites, five sites did not have *Drupella* scars present. Within the Outer Gneerings sites, marine debris had the highest count per square metre for each site.

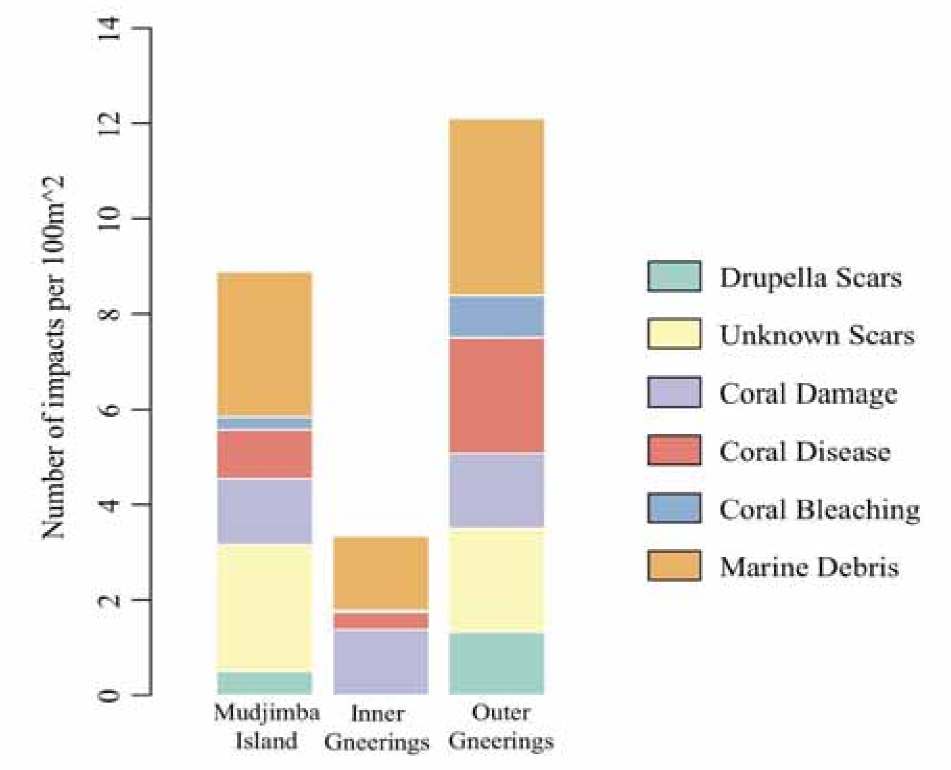

Figure 21: Stacked barplot of the number of impacts per 100 m^2 from the MEAM areas. Values are occurrence data and averaged per each area's sites.

Coral Health (bleaching)

A total of 140 corals were surveyed using the Coral Health Chart during the MEAM Project. For the period of observation, the recorded coral health was relatively high with all average values above four, and minimal recorded bleaching. Across all the seven sites surveyed, there was only one coral with a Coral Health score of 1 (bleached). The Inner Gneerings had an average colour health score of 4.61 (σ = 1.16). The Outer Gneerings had an average colour health score of 4.3 (σ = 0.65). Sites at Mudjimba has an average colour health score of 4.06 (σ = 0.70) (Figure 22).

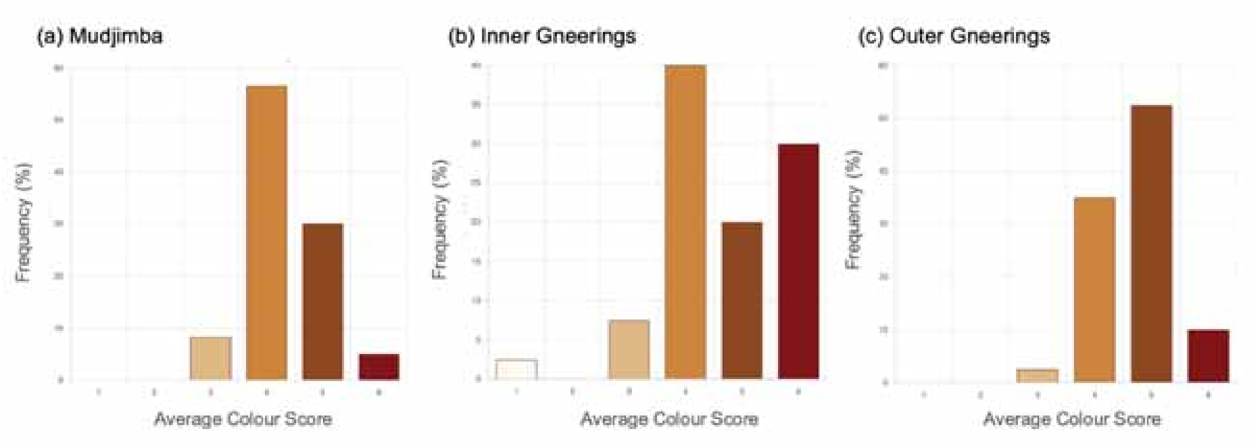

Figure 22: Coral Health Score for corals surveyed at (a) Mudjimba (n=60), (b) Inner Gneerings (n=40), and (c) Outer Gneerings (n=40)

Coral Health Score has fluctuated over time at the Gneerings (2015-2021). The lowest values occurred in October 2017 with a coral health score of 3.12, with the highest values recorded in November 2016 (4.33). The most recent data in 2021 shows a Coral Health score sitting around 4.06 (Figure 23).

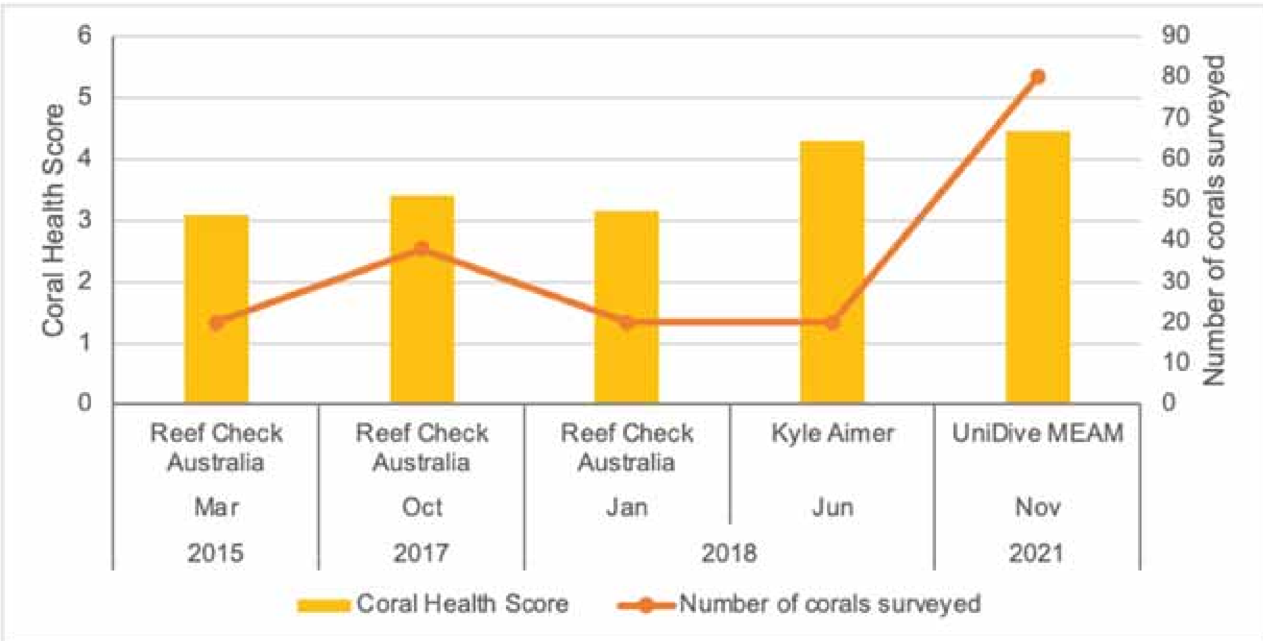

Figure 23: Coral Health Score and the number of corals surveyed over time for Mudjimba, Sunshine Coast.

Coral Health Score has been improving over time at Mudjimba (2015-2021). Coral health score has increased from a minimum of 3.08 in 2015 to a high of 4.46 in 2021.

3.2.5. Coral Cover Over Time (2008 – 2022) and Space (South East Queensland)

Hard coral cover has generally increased from 2008-2022 at both Mudjimba Island and Inner Gneerings (Figure 24). The surveys completed as part of the MEAM project generally continue the positive linear trend of increasing cover as observed from previous Reef Check Australia surveys. The Outer Gneerings have not previously been considered in the Reef Check Australia surveys and so the MEAM data has established a baseline. According to the most recent surveys, hard coral cover was on average highest at Flinders (32% in 2019) and lowest at Point Lookout (18.5% in 2021).

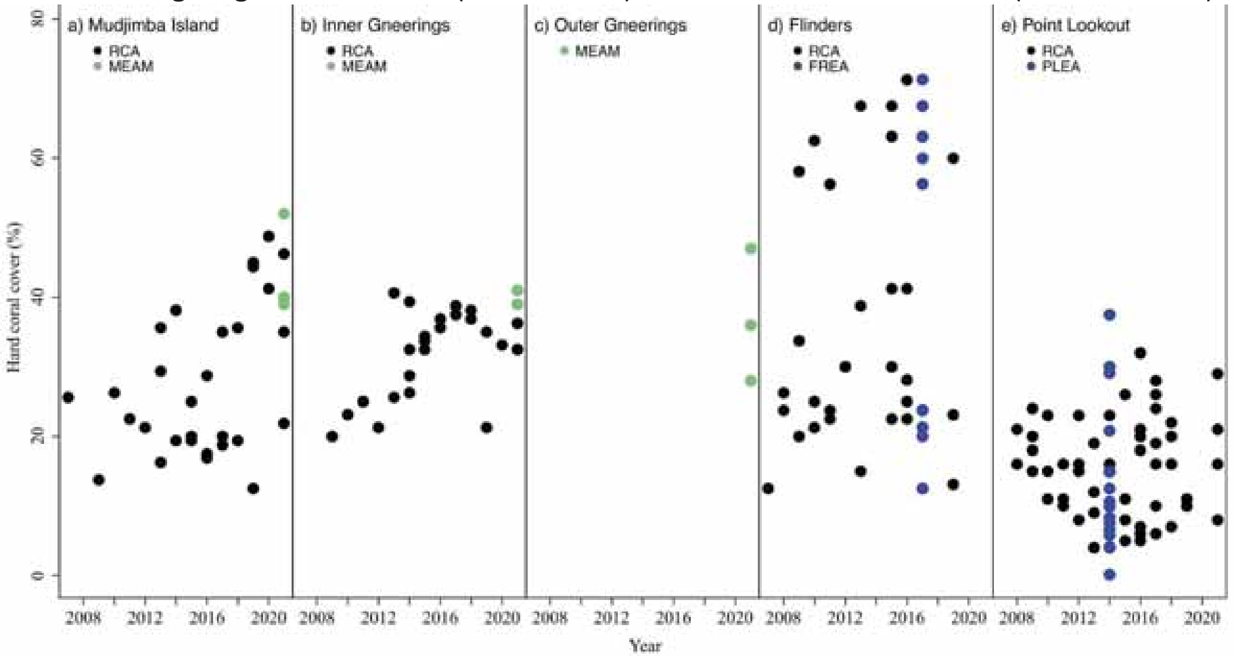

Figure 24: Temporal comparisons of hard coral cover (%) between Reef Check Australia (RCA) data and MEAM, Flinders (FREA) and Point Lookout (PLEA) data.

Hard coral cover per area was most abundant at the Mooloolaba sites compared with Flinders and Point Lookout (Figure 25). Hard encrusting coral was the most abundant hard coral at all three sites; Mooloolaba (19%), Flinders (16%) and Point Lookout (6%). Massive hard coral cover was <1% at all locations and absent from the Outer Gneerings. Bleached hard corals were not observed at Flinders and Point Lookout but were found at Mudjimba Island and Outer Gneerings (both <0.5%).

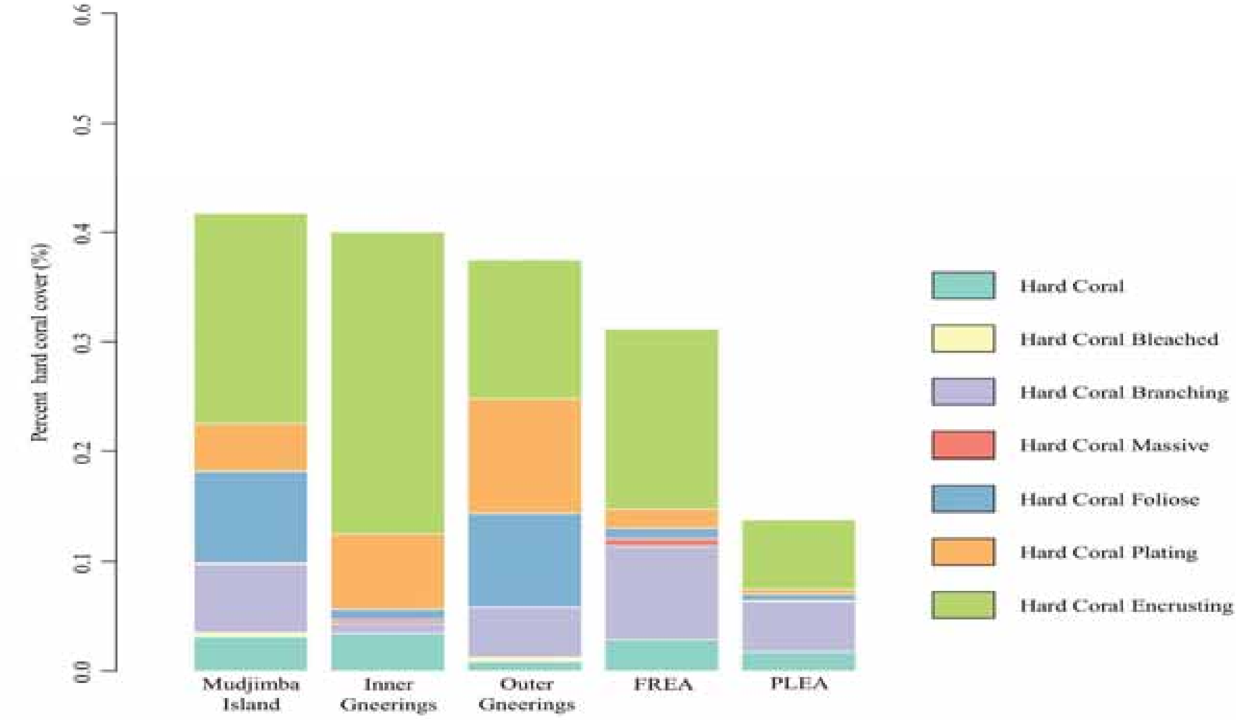

Figure 25: Stacked barplot of averaged hard coral cover per area and per hard coral type with comparisons to the FREA (Flinders) and PLEA (Point Lookout) data. Note FREA data is the combined average of all sites at Flinders reef or for Point Lookout reefs.

3.3. 3D Complexity

A total of 36 3D models of 20m segments along survey transects were created, covering a total of 3.6 km^2 (Figure 25). Additionally, two 100 m transects were modelled to visualise the extend of an entire survey transect (Figure 26). The original and edited images, as well as all 3D models have been made available online (van de Berg 2022). A record of 4K videos highlighting some of the models can be found at: vimeo.com/user88153375.

Rugosity (or complexity of the shape of the bottom surface) analysis found that all sites had a similar level of structural complexity (Figure 27). However, sites around Mudjimba island showed a much larger variation in rugosity than the Gneerings and sites on the outer Gneerings were, on average, minimally more rugose. Importantly, we did not find any clear relationships between rugosity and coral cover (Figure 27b-d). Interestingly, the outer Gneerings showed a visibly larger degree of coral cover than the inner Gneerings, driven by the abundance of soft coral (Figure 27b-d). Mudjimba Island showed variability in coral cover and rugosity at the combined scale of the inner and outer Gneerings, reflecting the highly variable conditions around the island.

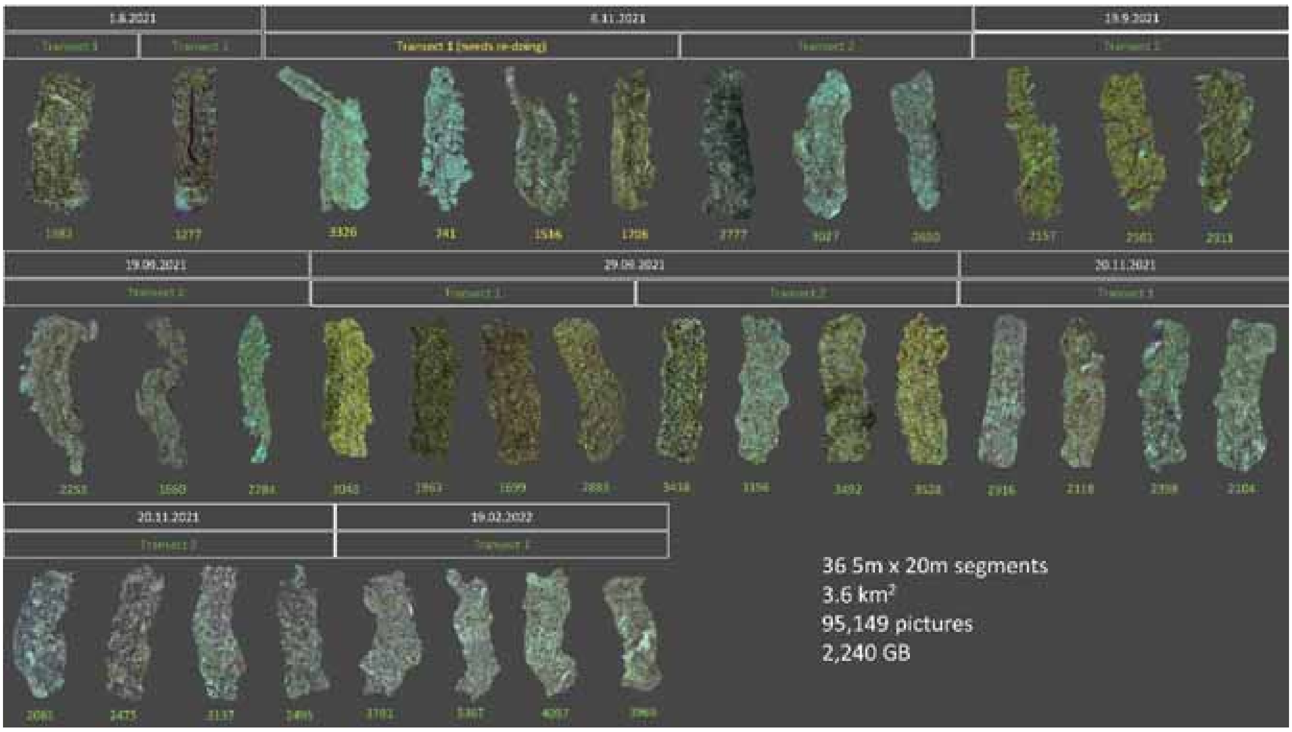

Figure 26: Top-down captures of each 20 m transect segment listed according to survey date and site. Headers in green indicate models available for rugosity analysis, yellow headers indicate models which did not align sufficiently well. Numbers underneath each segment indicate the number of images used to create the model.

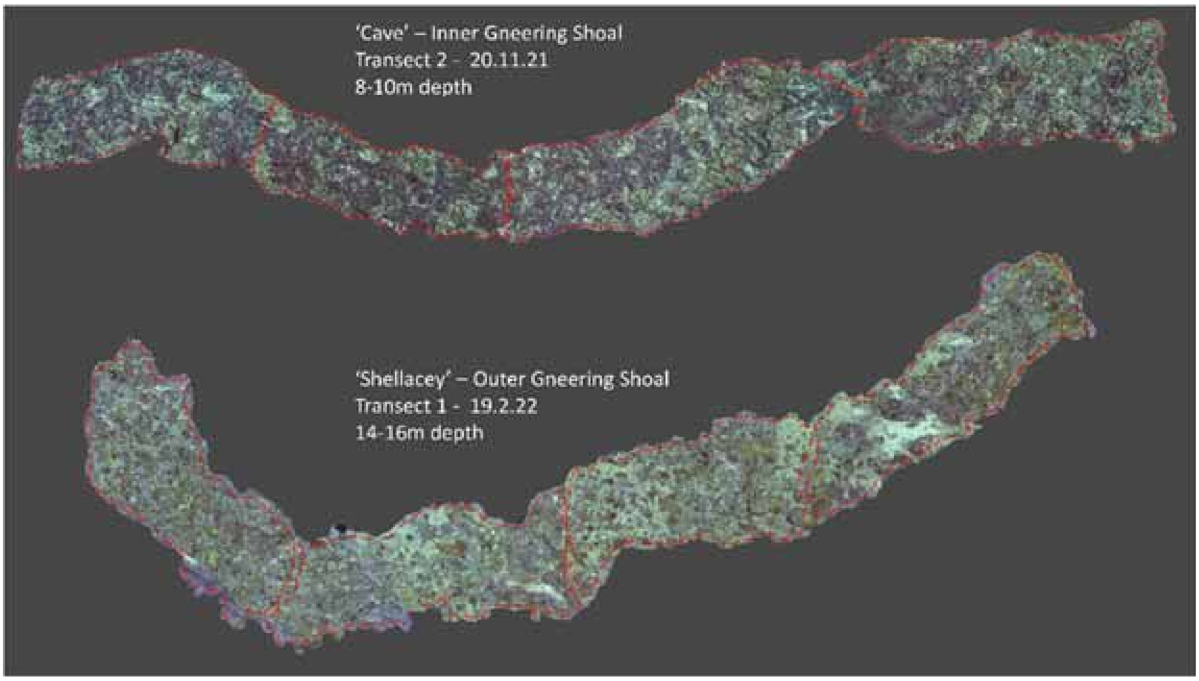

Figure 27: Top-down captures of two complete 100 m survey transect models with individual 20 m segment model outlines indicated with red dashed lines.

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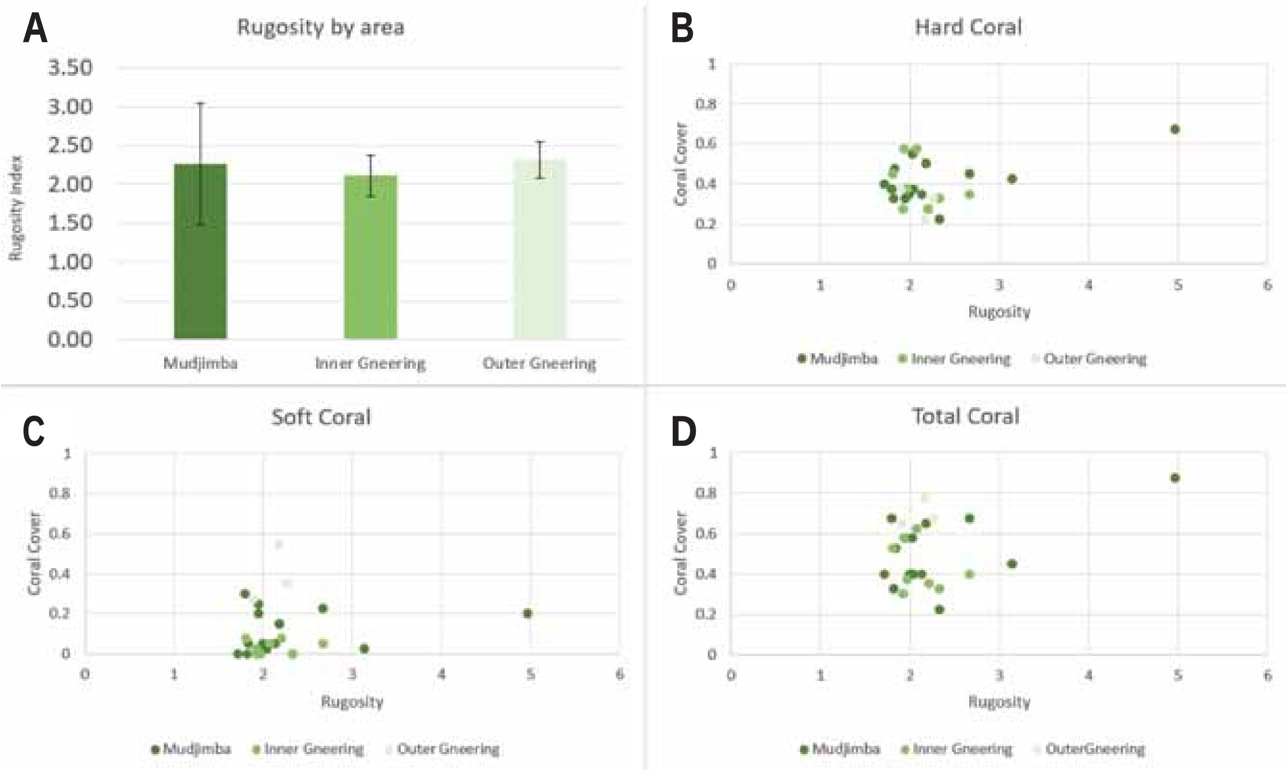

Figure 28: Summary of Photogrammetry results and comparisons with coral cover. A) Mean rugosity between sites. Error bars show standard deviation. B) Correlation between rugosity and hard coral cover. C) Correlation between rugosity and soft coral cover. D) Correlation between rugosity and total coral cover (hard & soft). B- D does not include all available survey data.

3.4. Review of the Adjusted Survey Methods

The survey methods applied provided the opportunity to assess the ability to collect additional information and introduce new methods.

The additional information was collected for the substrate, invert, and fish Reef Check Australia Surveys. For substrate point surveys the four macro algae (*Sargassum spp. Padina spp. Turbenaria spp. Asparogopsis spp.*) were now marked along the transect if present. The volunteers required no additional skills but did provide more insight on what algae is occurring along the transects. For fish surveys, the additionally classes were easy to be identified, as they were commonly occurring fish species (e.g. Morwong, Wobbegong Sharks). For the invertebrates, a similar experience was noted, where the two changes included identifying and counting any sea cucumbers, other than the previously targeted sea cucumbers; and secondly counting of sea slugs that included flatworms and nudibranchs.

Next to the substrate Reef Check Australia survey, photo quadrat surveys were captured along the transect. Photos were analysed through machine learning for benthic composition and the results presented show that more categories were identified through photo quadrat survey compared to the traditional point intercept survey.

Although more analysis is required to fine tune the different categories for comparison, the results are promising (Figure 29). Additionally, the photos provided more information since the photos were captured at 1 m interval.

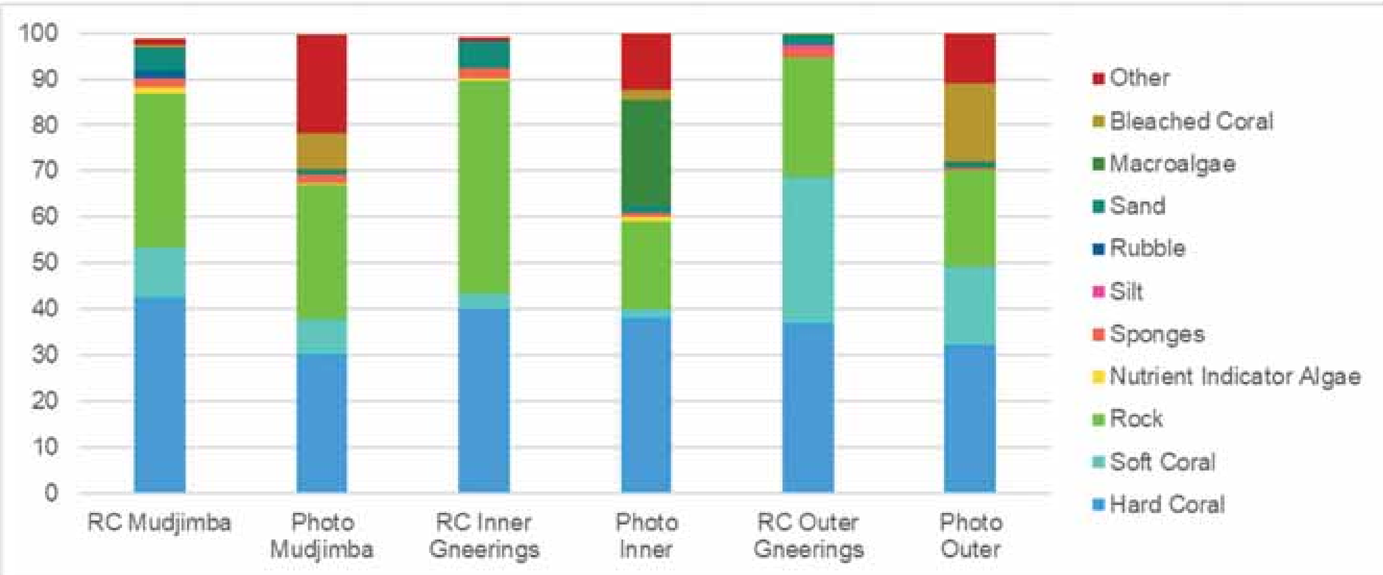

Figure 29: Example of photo quadrat surveys vs substrate reef check survey results summarised for the three main survey areas.

4. Discussion

4.1. Setting the Scene

The project was impacted by COVID restrictions and environmental conditions. However, when surveys were conducted, data was secured in a high-quality manner. Surveys were supposed to be completed between June and September 2021, but due to weather and COVID restrictions pushed our timeline to February 2022. In February and March 2022, flooding caused a significant run-off and associated reductions in water visibility. This together with limited access to the boat and continuing strong winds the decision was made to stop survey activities from this point. Although less surveys were conducted than expected the distribution of sites and the local knowledge together provided sufficient information to warrant this in-depth report.

4.2. Hard Coral and Rocky Substrate Dominance

A notable result of this study was the observed high proportion of hard and soft corals at Mudjimba Island, Inner Gneerings and the Outer Gneerings. The coral cover for the Mooloolaba sites was relatively high compared to previous work by the team at both Point Lookout and at Flinders Reef. This is especially encouraging given the large area the Mooloolaba reefs extend over and that they are also important habitat for both commercial and recreational users. The analysis of coral cover trends over time revealed a general increase, which is considered positive due to ongoing environmental pressures (e.g. coral bleaching). However, the specific taxonomic assignment of the coral cover was not known and there is limited temporal data, especially for Outer Gneerings.

As coral cover has become an important metric to monitor on coastal reefs, these high cover findings are positive and therefore important. Climate change and the direct effects of anthropogenic inputs have caused severe reductions in coral cover and habitat complexity globally. Such reductions not only cause harm to the aquatic environment, but also led to reduced capacity for coral reefs to act as important break waters for adjacent coastlines.

The specific growth forms of coral observed showed that encrusting forms were the most abundant at all three sites, followed by plating and foliose. Similar trends were also observed at both Flinders Reef and Point Lookout (Roelfsema et al. 2016, Grol et al. 2019). This is encouraging given that foliose, plating, and encrusting corals are generally hardier than branching corals. Although it was surprising to see the general lack of massive corals, which are perhaps the most resilient to thermal stress. Mooloolaba is an exposed reef area prone to strong sea conditions and large swell based on the information we gathered. Coral growth forms may follow suit given the strong hydrodynamics experienced within the reef system. Encrusting, plating and foliose growth forms can adhere to substrate better and are not as easily dislodged as compared to branching or delicate coral growth forms, and this may explain the observed patterns.

The abundance of hard and soft corals and the partition of their growth forms also warrant further monitoring. Future monitoring should aim to not only compare overall hard and soft coral cover, but also how the relative proportion of coral growth forms change through time. Much research has shown many coral reefs have also transitioned from being hard coral dominated to being soft coral and algal dominated. Given the abundance of soft corals, it would be interesting to observe how these dynamics change or remains stable through time.

Rock was also a very abundant benthic type. This is encouraging as rock covered in crustose coralline algae is an important settlement space for hard coral recruits. In tandem, the general lack of macro algae and nutrient indicator algae is also encouraging since these algal types generally take over the benthos and can outcompete coral recruits for settlement space. What would be interesting to monitor is how these benthic types change through time and monitoring the abundance, type, and survivorship of coral recruits.

4.3. Fish Abundance and Diversity

In this study, tropical and sub-tropical fish species, commonly found in this region (Johnson 2010), were observed at all survey sites. **Overall fish abundance and diversity was greatest at Mudjimba reef, which is not surprising since the Mudjimba sites are more sheltered than the Gneerings sites, and thus provide more suitable habitats for smaller reef fishes (Depczynski and Bellwood 2005).** Snapper, Parrotfish and Butterfly were the most commonly observed taxa, which is consistent with previous RCA surveys and accounts for this region (Salmond and Schubert, 2021). These taxa also tend to be the most easily identifiable given their discrete colouration and morphology (Johnson 2010). It is certainly comforting that Snapper and Parrotfish were observed on a few occasions, despite being popular taxa targeted by recreational and commercial fishers. However, Sweetlips, Coral Trout and Red Emperor, which are also targeted by fishers, were less abundant, which suggests that more thorough monitoring is needed for this region.

It is also interesting to note that Moray eels were observed on several occasions during our surveys, given that they are often rare and hard to spot (Buhlke and McCosker 2001). Our ability to frequently observe Moray eels speaks to the effectiveness of the in-water survey methods and highlights Mooloolaba as a potential hotspot for rarer organisms such as Nudibranchs (See section 4.4 below) and Moray eels.

Fish diversity was lowest at the Inner Gneerings, which exhibited the highest abundance of Butterfly Fish. This observation could be a result of environmental conditions on the days on which the Inner Gneerings sites were surveyed. Thus, continual monitoring of these sites would be particularly useful to gain a better understanding of the fish assemblages in the region and to explore temporal dynamics in fish presence and habitat use.

4.4. Nudibranch (Sea Slug) Paradise

Mooloolaba has been previously highlighted as a region which contains a high number of nudibranch species and individuals. Not surprisingly, within our surveys they were the most numerous invertebrates. **Their intrinsic beauty and cryptic nature further add to the value of Mooloolaba reefs. The next most numerous invertebrates were the *Drupella* snails.** While both nudibranchs and *Drupella* are corallivores (i.e., they fed on corals), the latter have the potential to become hyper numerous on a reef and become a real issue. In our surveys, *Drupella* never enumerated to more than a few individuals per coral head, but previous RCA surveys in Mooloolaba have encountered far greater numbers than during MEAM surveys, and *Drupella* have denuded reefs along the southern Great Barrier Reef (GBR). As such, our systematic surveys highlighted the importance of Mooloolaba reefs for charismatic invertebrates such as nudibranchs, but also reveal the potential for *Drupella* outbreaks, which could cause severe mortality to coral populations.

Anemones and clams were the next most abundant groups of invertebrates within the Mooloolaba reef system. However, they were again uncommon, with no more than a few individuals per site. This is not too unsurprising, given other citizen science efforts in Flinders Reef and Point Lookout (Roelfsema et al. 2016, Grol et al. 2019) also did not document high numbers of these groups. Both anemones and clams are photosynthetic and just as vulnerable to thermal stress as compared to their coral counterparts. As such, continual monitoring can reveal whether populations of anemones and clams are stable or ephemeral within the region.

Lastly, urchins and lobsters were very uncommon across all three sites. While Mooloolaba reefs did confer a relatively high level of rugosity (i.e., a measure of habitat complexity), there perhaps was not much preferential habitat for lobsters. In addition, the region does contain commercial vessels which target these invertebrates. As for urchins, it was surprising their numbers were so low. They are important herbivores and can consume algae which preferentially clears settlement space for coral recruits. We cannot offer a clear explanation for their low numbers, although they are also cryptic invertebrates, often found underneath coral heads and within overhangs and crevices. As such, a purely top-down visual survey may overlook their numbers. Indeed, as with other difficult to see invertebrates, such surveys may underestimate their numbers. These are also nocturnal creatures, and night-time surveys may reveal higher numbers of both lobsters, crabs and other mobile invertebrates.

4.5. Prevalent Impacts

Coral damage, coral disease and marine debris were observed at all three Mooloolaba sites. Marine debris was the most common impact, with higher counts at the Outer Gneerings and Mudjimba Island, suggesting that there could be actions taken to reduce debris loads. However, what was most encouraging was the general lack of coral bleaching. As climate continues to warm, the most direct and visually apparent effect is when corals become stressed, expel their endosymbiotic zooxanthellae, and become ghost white – bleaching. Coral bleaching has caused drastic reductions in coral cover from both the Caribbean and Indo-Pacific. The lack of observed bleaching, and the minimal reporting on recently dead coral at Mooloolaba is a welcome sight.

Mooloolaba reefs occur at high latitude, ~26-27 S, much research has shown high latitude reefs may be able to withstand the onslaught of thermal stress given their geographic position, and generally cooler ambient water temperatures. Thus, high latitude reefs like Mooloolaba may be important coral refugia for both tropical and sub-tropical corals into the future as climate continues to warm.

Another welcoming find at Mooloolaba was the lack of crown of thorn starfish (COTs) and the limited number of *Drupella* snails. Both echinoderms are known coral killers. Although COTS are more uncommon in higher latitudes, as water temperature continues to warm, monitoring for impacts may start to detect more COTS soon. Further, previous reporting by Reef Check Australia (RCA) has found considerable numbers of *Drupella* snails. The lack of snails in our surveys is encouraging, but their prevalence as detected from other surveys in the Mooloolaba region warrant concern. Targeted approaches have been developed to remove COTS directly from coral reefs, especially along the central and southern GBR, however removal or control of *Drupella* outbreaks is more difficult due to *Drupella* being more cryptic and often burrowing deep inside coral branches. While the general trends observed from our impact surveys are encouraging, further monitoring for impacts need to occur to be able to influence potential management actions.

Coral damage, rubble and overturned corals occurred within most surveyed transects. Rubble formation is not necessarily a concern for coral reefs, as rubble if stabilized, is important for seeding growth and substrate for coral recruits. However, if Mooloolaba experiences an increase in inclement weather, especially cyclonic activity as climate continues to warm, then rubble production and coral damage may increase. For now, this does not seem to be problematic for the region but should be carefully observed into the future.

Coral disease was also encountered on most surveyed sites. Coral disease has been shown to increase in prevalence in areas prone to coastal modification and resultant outflow of nutrients and pollutants. The shoreline of Mooloolaba is heavily modified with large construction occurring on adjacent beaches and the potential of sewage waste. Such direct effects can not only lead to eutrophication of the coastal marine habitats, but also act as a disease vector potentially harming coral population. While disease incidence was low within all three sites at Mooloolaba, further monitoring is essential to detect if peaks in disease occur, pinpoint where they occur and what coral types are most affected.

Lastly, Mooloolaba is not a green zone and there anecdotal it is intensive resource extraction from both commercial and recreational fishers. Not surprisingly, fishing line and marine debris were the most numerous impacts encountered within surveyed transects. While we did not record anchor damage, there are no permanent moorings within the surveyed sites and many recreational and commercial boats continually anchor in the area.

Thus, several different impacts were recorded within the surveyed sites of Mooloolaba. However, they are not yet numerous enough to warrant concern. But continual urbanization and modification of the adjacent coastline, as well as the effects of a warming climate do warrant the need for continual monitoring.

4.6. 3D Projections of The Mudjimba Complex and Outer Gneerings.

The largest variation in rugosity was shown at Mudjimba Island based on the photogrammetric survey data. This does not come as a surprise, as the survey sites were located on all sides of the Island, with the underwater geometry and benthic growth being strongly influenced by exposure to wave energy based on our environmental data collection. For example, the sheltered side of the island is known among local divers to have a distinct seabed morphology and benthic growth when compared to the exposed outer side of the island.

Our data further shows that, although similar in complexity to sites surrounding Mudjimba island, sites on the Inner Gneerings shoal were slightly less rugose than sites on the Outer Gneerings. This could be driven by both, the structure of the rocky substrate or the presence of benthic growth, namely hard and soft corals. The Inner Gneerings are closer the mainland and are substantially shallower than the Outer Gneerings. As such, the environmental conditions for benthic cover are likely substantially different with the inner Gneerings being subject to increased levels of wave energy and coastal runoff, consequently influencing the mechanical forces impacting benthic growth as well as light levels, temporal stability, and nutrient availability. It is hard to make a meaningful comment of the overall rock morphology between the inner and outer Gneerings as the surveys were intentionally placed on rather flat parts of the ocean floor at either site. However, the Outer Gneerings are home to much more pronounced geological features such as gullies and drop-offs than the Inner Gneerings. This, together with the difference in benthic cover explains the location of the most famous and popular dives sites on the reef. Indeed, the Inner Gneering showed a similar level of hard coral cover than the Outer Gneerings, however, the sites on the Outer Gneering had substantially higher cover of soft corrals, driving the difference in absolute coral cover between the inside and the outside of the shoal despite only a moderate difference in the rugosity between sites. Despite the preliminary nature of these data, our results indicate that survey and conservation efforts of local reefs at the Sunshine Coast need to be approached with careful consideration of the local differences between distinct areas of the local underwater ecosystems.

In addition to these empirical insights, our project has produced an impressive and permanent geolocated visual record of the state of almost four square kilometres of underwater landscapes off the coast of Mooloolaba. Lastly and importantly, this project provides a crucial and pioneering example of the implementation of photogrammetry into large-scale citizen science efforts.

4.7. Project and Data Limitations

The MEAM surveys were carried out successfully by volunteer divers certified in Reef Check Australia, and all volunteers were trained in CoralWatch Survey and mapping techniques (Appendix A). Whilst a high number of volunteers was imperative for project engagement, there was some variation in the results due to data that could not be explained through seasonality (e.g., Hard Coral cover) as the surveys were originally planned over to take place over three months instead of 12 months. Likely some of the variation arises from data being collected by different divers on different surveys. To reduce this variation, divers were trained to a high standard (pass mark ≥85% on written survey ID exams, and 95% for in water exams) and core divers were appointed to survey activities across trips for consistency, where feasible. Of the 44 Reef Check certified divers, 24 were certified previously and had past survey experience (PLEA, FREA or RCA), and the remaining 20 undertook the Reef Check Australia certification course. All had participated in academic and practical exams, and their diving skills were reviewed.

The substrate survey utilised a point intercept transect method. Some differences were also evident on comparison of field-based substrate data and photo transect data. The photo transect-based substrate survey allowed for rapid data collection in the field, and compared to previous analysis methods, they were analysed automatically through machine learning, speeding up data processing. Also in this study, the photo transect method provided a higher level of consistency in assessment of benthic composition as the photo analysis was done using machine learning and questionable analyses could be reassessed.

Surveys were carried out over a roughly 12-month period (see Appendix I). The environmental conditions (e.g. wind, swell, tides, visibility and temperature) during the surveys varied due to normal to extreme weather patterns, which could have influenced the flora and fauna present. Therefore, ongoing surveys are especially valuable to provide better knowledge of what is present or absent at different times of the year and in different conditions. Due to natural changes mentioned, notable variability would have been inherent and could contribute to potential intra-season differences as was noted in previous studies (Roelfsema et al. 2016, Grol et al. 2019). This was especially relevant for the fish survey, where transient or migratory schools of fish could greatly affect the overall counts. Surveying the entire Mooloolaba Reef region on a seasonal basis helps to differentiate between real changes such as seasonal migrations or regional preferences, as opposed to local transient populations.

5. Recommendations for Management and Community

This citizen science project provides an opportunity to further consider ways to work collaboratively to understand, protect and manage the unique subtropical reefs of the Sunshine Coast. This is particularly important given the limitations in comprehensive marine monitoring, the intensive use of this area, and growing threats from climate change and population growth in the region. Some opportunities that have been identified through this project are outlined below.

5.1. Continued and improved Monitoring of the Mooloolaba Reefs

Continuing annual reef health monitoring on a select number of sites and habitat mapping every five years for all reef areas, may be beneficial for an increased ecological understanding and for management and conservation. The results of this project build on the existing dataset for the region, with Reef Check Australia undertaking annual surveys at four sites since 2009. The more intensive seasonal survey approach used in this project expanded four of the number of locations with monitoring baselines, provided greater understanding of seasonal variation trends and augmented ongoing monitoring through photogrammetry and detailed habitat maps. Regular monitoring of reefs can improve understanding of ecological changes, including whether they are natural variations or caused by external factors such as fishing, pollution or physical damage.

There are also opportunities to further strengthen citizen science data applications. Integration of benthic imagery into Reef Check Australia citizen science surveys offers efficiencies, long-term benthic records, and new opportunities for broader data applications. Data analysis revealed that photo transect data was more consistent in documenting benthic composition across seasons but was not as strong as diver recorded data in picking-up variability. Beyond potential data processing benefits, adding complementary photo records to data recorded in situ offers an opportunity for other interested parties to access photo records for additional applications. This suggests that integrating this approach is worthwhile for the future.

Although the 3D photogrammetry mosaic provided a good source and record of detail information of the substrate, currently the method to create the mosaic and conduct the analysis would require a dedicated skilled volunteer to conduct that process.

This project and the ongoing efforts of Reef Check Australia reef health monitoring and reporting have shown that citizen science efforts are especially strong at reporting general trends in both coral cover and coral type. Beyond that, citizen science offers a cost-effective approach that also offers numerous social benefits through building community capacity, growing meaningful community engagement, generating educational outcomes and supporting cross-sector collaboration. We have expanded what is known about these reefs, as to our knowledge, this is the first time any systematic survey had been done at the Outer Gneerings. As such, continued citizen science monitoring efforts across all three Mooloolaba reef areas would be beneficial. In doing so, we can track how reefs change through time to contribute to efforts that inform management and community actions to protect these sites.

5.2. Strengthening Ways to Care for Mooloolaba Reefs

Educating divers, spear fishers, snorkelers, fishers, and vessel skippers in practical ways to reduce physical damage and limit marine debris may help to reduce pressures on reef sites. Coral damage, coral disease and marine debris were observed at the outer Gneerings, Inner Gneerings and Mudjimba Island. While encrusting coral was the most common growth form, these sites also host delicate branching, plating and foliose corals, which are more vulnerable to physical damage. Anchor damage was not recorded on surveys, but snorkellers, divers and boat anchors may be attributing to unidentified coral damage recorded on surveys. Promoting boat anchoring practices and skills that use sandy patches and avoid coral dense areas could be beneficial for reducing pressure on reefs from physical damage. Divers should be encouraged, or ideally required, to follow a code of conduct that highlights the need for good buoyancy control to avoid touching the bottom, and the streamlining of dive gear to avoid entanglement in corals. Snorkelers should be encouraged not to touch or get close to the bottom, reducing their impact. Best practice fishing guidelines could be supported to avoid fishing near or close to the bottom to avoid line entanglement and/or loss of fishing gear and associated damage to corals.

Collecting and sharing targeted information about reef health and values can enable discussions about further options for protecting the values of Mooloolaba reefs. The HMAS Brisbane shipwreck is the only marine protected area within the Sunshine Coast region, despite Mudjimba Island being acknowledged as having cultural significance and the Outer Gneerings (Wobbe Rock) being an identified Grey Nurse Shark habitat (a critically endangered species). Protecting the unique cultural, social, ecologic and economic values of this area may require new approaches. Citizen science can help to activate these discussions and bring together diverse groups of people and organisations who care about this place to find solutions.

Installing moorings at sites like Mudjimba Island could be considered to reduce direct site-use pressures. Even though no anchor damage was recorded, the high coral cover could easily be damaged by frequent visitors, such as fisherman, snorkelers, and divers. Based on the ecological assessment and mapping activities, the project found that all sites are favourable for diving, however they do not have moorings and anchoring could be hard due to the observed reef complexity. Moorings can be an effective tool for managing visitation to high use areas.

5.3. Building Awareness of the Value of Local Reefs

Engaging residents and visitors of the Sunshine Coast reefs in citizen science and education efforts can help grow awareness about these unique reefs and encourage more people to understand how they can care for and protect these places for the future. Anecdotal feedback collected from community engagement in the region (2007-present) indicates that many people are not aware of the presence and values of the unique subtropical reefs of Mooloolaba. Increasing knowledge about these special places and how personal actions can support their protection will be critical to help in the conservation of these ecosystems for the future. Further efforts to identify key audiences and actions could help to tailor targeted ways that people can take meaningful action.

Community members can contribute to improving understanding of Sunshine Coast reefs through citizen science. Already, many residents and visitors have a deep local knowledge and attachment to these reefs and the wildlife they support. Promoting and supporting multiple pathways for the broader community to get involved in citizen science can help to generate useful data and continue to strengthen community understanding about habitats and wildlife. Some relevant citizen science initiatives to consider include:

- Reef Check Australia (http://www.reefcheckaustralia.org/)
- CoralWatch (http://www.coralwatch.org/)
- Project Manta (https://www.facebook.com/ProjectMANTA)
- Spot the Leopard Shark (http://www.uq.edu.au/whale/spot-the-leopard-shark)
- iNaturalist (https://www.inaturalist.org/)
- Tangaroa Blue Foundation (https://www.tangaroablue.org/)
- Turtle Care: https://www.sunshinecoast.qld.gov.au/Environment/Native-Animals/TurtleCare/TurtleCare-Volunteering

5.4. Supporting Conservation of Sunshine Coast Reefs Through Sharing Knowledge

Learning about cultural connections and value of Mooloolaba reefs and connected habitats can help to support shared understanding and care. The Sunshine Coast holds deep cultural value for the Gubbi Gubbi people, who have a long and rich connection to country. Building a shared understanding and learning from long term custodianship can benefit the flora, fauna and people using and depending on these habitats. Fostering opportunities to learn about Traditional Knowledge, cultural connections and values of the Sunshine Coast land and sea country can assist in efforts to support more holistic understanding and conservation of the reefs and grow meaningful partnerships with Traditional Owners.

Collaborating and sharing knowledge to generate open access scientific information to fill key information needs can help strengthen partnerships and understanding to care for Mooloolaba reefs. The scientific community, non-governmental organisations, management authorities, local area councils and interested citizens can use the findings of this research and future research projects to help support management decisions and guide further monitoring of the reefs. Growing active dialogue across groups and individuals who care for the local marine environment can help to strengthen collaboration for positive impact.

6. Reference and Publicly Accessible Project Data sets

- Substrate, Fish, Invert and Impact data accessible through Reef Check Australia Data Portal https://www.reefcheckaustralia.org/data
- CoralWatch Survey data is accessible through CoralWatch Data Portal https://biocollect.ala.org.au/coralwatch
- 3D Photogrammetric data models are available through (van de Berg 2022) https://espace.library.uq.edu.au/view/UQ:2be1b1d
- Photo quadrates will be made accessible through Pangaea Data Portal (in Progress).
- Maps will be made accessible through Pangaea Data Portal (in Progress).

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Appendices

Appendix A: Participants List

First name	Last name	Grants/funding/sponsorship	Organisation/logistics	Reef Check Certified	Training weekends March 2021	Boating/diving and/or survey jobs	Science/data analysis team	Report writing
Alexandra	Lau			x	x			
Alice	Twomey						x	x
Amber	Moran		x	x	x	Surveys	x	
Andrew	O'Hagan		x	x	x	Surveys		
Andy	Holland		x	x	x	Surveys		
Boeke	Elbers				x			
Breanne	Vincent		x	x	x	Surveys		
Bruce	McLean		Treasurer	x	x	Boathandler, Surveys		
Catherine	Kim	x		x	x	Surveys	x	x
Cedric	van den Berg	x		x	x	Photogrammetry	x	x
Cheryl	Tan		x	x	x	Surveys	x	
Chris	Roelfsema	x	Project lead	x	x	Photos	x	x
Chris	Klaas			x				
Chris	Adams			x				
Christina	Lapid			x	x	Surveys		
Clarissa	Elakis							
Damien	Shrier		x	x	x	Surveys		

First name	Last name	Grants/funding/sponsorship	Organisation/logistics	Reef Check Certified	Training weekends March 2021	Boating/diving and/or survey jobs	Science/ data analysis team	Report writing
Delphine	**Gonchond**		Secretariat, admin, website	x	x	Surveys		x
Devin	**Rowell**		Social media, photos	x	x		x	x
Diana	**Kleine**		Design, merch, publications	x	x	CoralWatch, Surveys		x
Donna	**Easton**	x	x	x	x			
Douglas	**Stetner**		x	x	x			x
Elliot	**Peters**		x					
Emily	**Gregory**			x			x	x
Fei	**Yang**							
Hannah	**Barrenger**			x	x	Surveys		x
Henri	**Decoeur**			x	x	Surveys		
Hisatake	**Ishida**						x	
Ilha	**Byrne**			x	x		x	x
Isabelle	**Derouet**		x	x	x	Surveys		
Jenni	**Calcraft**			x				
Jennifer	**Loder**			x	x	Surveys	x	x
Jodi	**Salmond**			x	x	Surveys	x	x
Jody	**Kreuger**			x	x	Boathandler, surveys		
Joop	**Sassen**						x	x
Jörn Guy	**Süß**	x			x			

First name	Last name	Grants/funding/sponsorship	Organisation/logistics	Reef Check Certified	Training weekends March 2021	Boating/diving and/or survey jobs	Science/data analysis team	Report writing
Josh	Passenger		Data team lead	x	x	Surveys	x	x
Kade	Chambers			x			x	
Kane	James							
Karen	Johnson			x	x	Surveys		x
Katharine	Prata			x	x		x	
Leah	Clarke							
Lucas	de Castro			x	x		x	
Mark	Stenhouse		x	x	x	Boathandler		
Monique	Grol			x	x		Science team lead	
Nataly	Gutierrez Isaza	x	x	x	x	Surveys	x	x
Nicholas	Hammerman	x	x	x	x	Surveys	x	x
Philip	Dunbavan			x		Surveys	x	
Rachel	McVeigh		x	x	x	Surveys	x	x
Ranishka	Hewavisenthi		x	x	x			
Rikki	Andersen			x				
Robert	Mactaggart			x	x			
Ryan	Booker	x	x	x	x	Boathandler	x	x
Sophie	Kalkowski-Pope			x	x		x	x
Tania	Kenyon			x				
Tania	Alajo	x		x	x	Surveys	x	x

First name	Last name	Grants/funding/sponsorship	Organisation/logistics	Reef Check Certified	Training weekends March 2021	Boating/diving and/or survey jobs	Science/data analysis team	Report writing
Trevor	**Barrenger**		x	x	x	Boathandler		x
Vincenzo	**Montalbano**	x		x				
Zoe	**Meziere**						x	

Appendix B: Data Sheets

UNIDIVE MEAM REEF CHECK	Reef Check Belt Transact – Substrate SEQ	
	Dive site name:	Reef name:
	Date:	Depth
	Time:	Habitat:
	Data recorded by:	Site number:
	Camera ID:	Team leader:

HC – Hard Coral HCB – Bleached hard coral HCBR – Branching hard coral HCM – Massive hard coral HCF – Foliose hard coral HCP – Plate hard coral HCE – Encrusting hard coral	SC – Soft Coral SCL – Leathery soft coral SCZ – Zoanthids SCB – Bleached soft coral OT – Other OTC – Corallimorph	RKC – Recently Killed Coral RKCNIA – Recently killed coral & NIA RKCTA – Recently killed coral & turf algae NIA – Nutrient Indicator Algae
SP – Sponge SPE – Encrusting sponge	RC – Rock RCTA – Turf algae RCCA – Coralline algae	SI – Silt/Clay RB – Rubble SD – Sand

0-20m				25-45m				50-70m				75-95m			
0		10		25		35		50		60		75		85	
0.5		10.5		25.5		35.5		50.5		60.5		75.5		85.5	
1		11		26		36		51		61		76		86	
1.5		11.5		26.5		36.5		51.5		61.5		76.5		86.5	
2		12		27		37		52		62		77		87	
2.5		12.5		27.5		37.5		52.5		62.5		77.5		87.5	
3		13		28		38		53		63		78		88	
3.5		13.5		28.5		38.5		53.5		63.5		78.5		88.5	
4		14		29		39		54		64		79		89	
4.5		14.5		29.5		39.5		54.5		64.5		79.5		89.5	
5		15		30		40		55		65		80		90	
5.5		15.5		30.5		40.5		55.5		65.5		80.5		90.5	
6		16		31		41		56		66		81		91	
6.5		16.5		31.5		41.5		56.5		66.5		81.5		91.5	
7		17		32		42		57		67		82		92	
7.5		17.5		32.5		42.5		57.5		67.5		82.5		92.5	
8		18		33		43		58		68		83		93	
8.5		18.5		33.5		43.5		58.5		68.5		83.5		93.5	
9		19		34		44		59		69		84		94	
9.5		19.5		34.5		44.5		59.5		69.5		84.5		94.5	
MA Tally				MA Tally				MA Tally				MA Tally			
Air		Time		Air		Time		Air		Time		Air		Time	


MAA – Asparagopsis


MAP – Padina


MAS -- Saragassum


MAT -- Turbinaria

Comments about 'other' category:

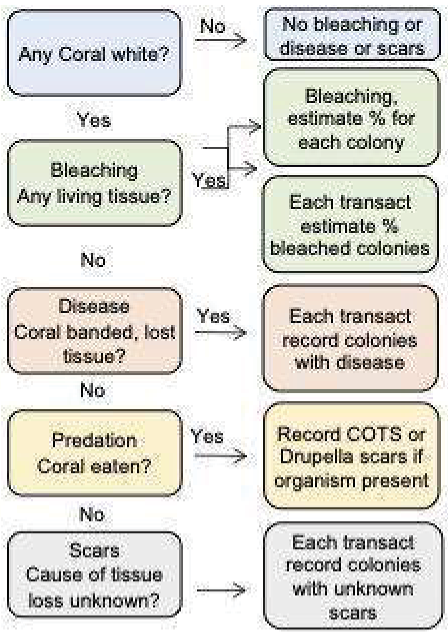
Rare Animals:

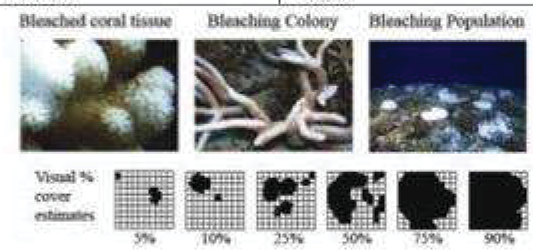
Circle SI category for site: N L M H
N – None
L – Low some SI
M – Medium, Surface have thin SI layer
H – High, Surface have thick SI layer

Reef Check Belt Transact – Impacts SEQ	
Dive site name:	Reef name:
Date:	Depth
Time:	Habitat:
Data recorded by:	Site number:
Camera ID:	Team leader:

		0-20m	25-45m	50-70m	75-95m	Photo No.*
Bleaching	Estimate % impact for each bleached colony					
	Estimate % totals coral population					
Damage	Boat / Anchor					
	Coral Upside down					
	Other					
Coral Disease						
Coral Scars	Crown of Thorns					
	Drupella					
	Unknown/Other					
Trash	Fishing Line					
	Fish Nets					
	General Plastic					
	General not plastic					
Rare Animals						
	Air					
	Time					

Three dominant algae	1. Photo #	2. Photo #	3. Photo #





Other Photos	
Subject	Photo #

UNIDIVE MEAM REEF CHECK	Reef Check Belt Transact – Inverts SEQ	
	Dive site name:	Reef name:
	Date:	Depth
	Time:	Habitat:
	Data recorded by:	Site number:
	Camera ID:	Team leader:

		0-20m	25-45m	50-70m	75-95m	Photo No.*
Anemone	With Fish					
	No Fish					
Banded Coral Shrimp						
COTS	< 6cm					
	6-15cm					
	15-25cm					
	>25cm					
Giant Clam	<10cm					
	10-20cm					
	20-30cm					
	30-40cm					
	40-50cm					
	>50cm					
Lobster, spiny & slippery						
Sea slugs						
Shells	Drupella					
	Triton					
	Trochus					
Sea Cucumbers	Pinkfish					
	Prickly Greenfish					
	Prickly Redfish					
	Other					
Sea Urchins	Collector					
	Diadema					
	Pencil					
	Rare Animal					
	Air					
	Time					
			Dominant Algae	1)	2)	3)

Reef Check Belt Transact – Fish SEQ

UNIDIVE MEAM REEF CHECK AUSTRALIA

Dive site name:	Reef name:
Date:	Depth
Time:	Habitat:
Data recorded by:	Site number:
Camera ID:	Team leader:

			0-20m	25-45m	50-70m	75-95m	Photo No.*
Barramundi Cod							
Butterfly							
Grouper	Coral Trout	30-40cm					
		40-50cm					
		50-60cm					
		>60cm					
	Grouper	30-40cm					
		40-50cm					
		50-60cm					
		>60cm					
	Queensland						
Wrasse	Eastern Blue Groper						
	Tuskfish						
	Humphead						
Moray Eel							
Parrotfish	Bumphead						
	Other	0-20cm					
		> 20cm					
Snapper / Emperor	Snapper (generic)						
	Pink snapper						
	Emperor (generic)						
Morwong							
Sweetlip							
Rare animals (turtle, ray, octopus, zebra, wobbie, other shark, etc)							
		Air					
		Time					

Appendix C: Species List

Key: PHYLUM, *Species Name*, Common name

ANIMALS

ANNELIDA (Worms)

Bispira porifera	Spongy Fanworm
Chloeia sp. 1	
Choleia sp. 2	
Eurythoe complanata	Orange Fire Worm
Filograna implexa	Tube worm
Hesione splendida	Splendid Worm
Lepidonotus melanogrammus	Dark-marked Scale Worm
Odontosyllis sp. 1	
Sabellastarte indica	Tube worm
Sabellastarte sp. 6	
Spirobranchus giganteus	Christmas tree worm

ARTHROPODA (Crustaceans/Barnacles)

Aethra scruposa	Stealth Crab
Allogalathea elegans	Elegant Crinoid Squat Lobster
Aretha edentata	Smooth Elbow Crab
Camposcia retusa	Blunt Decorator Crab
Ciliopagurus strigatus	Halloween Hermit Crab
Cymothoid sp. 1	
Etisus demani	
Hamodactylus sp. 3	
Hymenocera picta	Harlequin Shrimp
Lissocarcinus orbicularis	Sea Cucumber Crab
Majidae sp. 1	
Nerocila sp. 1	Dark Stripe Fish Isopod
Panulirus ornatus	Ornate Rock Lobster
Panulirus versicolor	Painted spiny lobster
Rhynchocinetes durbanensis	Dancing Shrimp
Scyllarides squammosus	Blunt Slipper Lobster
Stenopus hispidus	Banded coral shrimp
Thor amboinensis	Squat Shrimp

BRYOZOA (Moss Animals)

Bilustra sp. 1	
Celleporaria sp.1	
Idmidronea sp.1	
Philodoridae sp.	
Reteporella graeffei	
Triphillozoon sp. 1	

CHORDATA

Angelfish

Centropyge bicolor	Bicolor angelfish
Centropyge tibicen	Keyhole angelfish
Centropyge vroliki	Pearlscale angelfish
Chaetodontoplus meredithi	Queensland Yellowtail Angelfish
Pomacanthus semicirculatus	Blue Angelfish

Barracudas

Sphyraena obtusata	Yellowtail Barracuda
Sphyraena qenie	Blackfin Barracuda

Bigeyes

Heteropriacanthus carolinus	Red Big-eye

Blennies

Aspidontus dussumieri	Lance blenny
Aspidontus dussumieri	Lance Blenny
Aspidontus taeniatus	False Cleanerfish
Cirripectes castaneus	Chestnut Blenny

Cirripectes chelomatus	Lady Musgrave Blenny
Cirripectes sp.	
Crossosalarias macrospilus	Triplespot blenny
Ecsenius bicolor	Combtooth blenny
Ecsenius stictus	Smallspotted Combtooth Blenny
Istiblennius meleagris	Peacock Blenny
Laiphognathus multimaculatus	Many Spotted Blenny
Meiacanthus lineatus	Lined Fangblenny
Omobranchus punctatus	Muzzled Blenny
Parablennius intermedius	False Tasmanian Blenny
Parenchelyurus hepburni	Bluespotted Blenny
Petroscirtes fallax	Yellow sabretooth blenny
Plagiotremus rhinorhynchos	Bluestriped pigfish
Plagiotremus tapeinosoma	Piano fangblenny

Butterflyfish

Chaetodon auriga	Threadfin butterflyfish
Chaetodon citrinellus	Citron Butterflyfish
Chaetodon flavirostris	Dusky Butterflyfish
Chaetodon guentheri	Guenther's butterflyfish
Chaetodon kleini	Klein's Butterflyfish
Chaetodon lavirostris	Dusky butterflyfish
Chaetodon lunulatus	Pinstripe Butterflyfish
Chaetodon plebeius	Bluespot Butterflyfish
Chaetodon rainfordi	Rainford's Butterflyfish
Chaetodon trifascialis	Chevron butterflyfish
Chaetodon unimaculatus	Teardrop butterflyfish
Chelmon muelleri	Muller's Coralfish
Chelmon rostratus	Beaked Coralfish
Chelmonops truncatus	Eastern talma
Coradion altivelis	Highfin coralfish
Forcipiger flavissimus	Forceps Butterflyfish
Heniochus acuminatus	Longfin bannerfish
Heniochus chrysostomus	Pennant bannerfish
Heniochus diphreutes	Schooling Bannerfish
Heniochus monoceros	Masked bannerfish
Heniochus varius	Horned bannerfish
Parachaetodon ocellatus	Ocellate Butterflyfish

Cardinalfish

Apogon capricornis	Capricorn Cardinalish
Apogon crassiceps	Little Red Cardinalfish
Apogon doederleini	Fourline cardinalfish
Apogon lavus	Yellow cardinalfish
Apogon limenus	Sydney cardinalfish
Apogon properuptus	Coral cardinalfish
Cheilodipterus isostigma	Toothy Cardinalfish
Cheilodipterus macrodon	Tiger cardinalfish
Ostorhinchus capricornis	Capricorn Cardinalfish
Ostorhinchus doederleini	Fourline Cardinalfish
Ostorhinchus limenus	Sydney Cardinalfish
Ostorhinchus properuptus	Coral Cardinalfish
Rhabdamia gracilis	Slender Cardinalfish
Taeniamia fucata	Painted Cardinalfish
Taeniamia zosterophora	Girdled Cardinalfish

Clinids

Heteroclinus nasutus	Large-nose Weedfish
Heteroclinus whiteleggii	Banded Weedfish

Cods/Groupers/Anthiases

Cephalopholis argus	Peacock Cod
Cephalopholis miniata	Coral rockcod
Cromileptes altivelis	Barramundi Cod
Diploprion bifasciatum	Barred soapfish
Epinephelus coioides	Gold spotted rockcod
Epinephelus cyanopodus	Purple rockcod
Epinephelus fasciatus	Blacktip rockcod
Epinephelus maculatus	Highfin groper
Epinephelus malabaricus	Blackspotted Rockcod
Epinephelus quoyanus	Longfin Rockcod
Epinephelus undulostriatus	Maori rockcod

Plectropomus leopardus	Common coral trout
Pseudanthias squamipinnis	Orange basslet
Rainfordia opercularis	

Cornetfish/Fluemouths

Fistularia commersonii	Smooth Flutemouth
Fistularia petimba	Rough flutemouth

Damselfish/Clownfish

Abudefduf bengalensis	Bengal sergeant
Abudefduf sexfasciatus	Sissortail Sergeant
Abudefduf sordidus	Black-spot Sergeant
Abudefduf vaigiensis	Indo-pacific sergeant
Abudefduf whitleyi	Whitley's Sergeant
Amblyglyphidodon curacao	Staghorn damsel
Amphiprion akindynos	Barrier reef anemonefish
Amphiprion clarkii	Clark's Anemonefish
Amphiprion latezonatus	Wideband anemonefish
Amphiprion polymnus	Saddleback Anemonefish
Chromis atripectoralis	Blackaxil puller
Chromis margaritifer	Whitetail puller
Chromis nitida	Yellowback puller
Chromis weberi	Weber's puller
Chrysiptera biocellata	Two-spot Damselfish
Chrysiptera lavipinnis	Yellowfin demoiselle
Chrysiptera rollandi	Bluehead demoiselle
Chrysiptera talboti	Talbot's demoiselle
Dascyllus reticulatus	Headband humbug
Dascyllus reticulatus	Reticulated Dascyllus
Dascyllus trimaculatus	Three-spot Humbug
Mecaenichthys immaculatus	Immaculate Damsel
Neoglyphidodon melas	Black damsel
Neoglyphidodon nigroris	Scarface damsel
Neopomacentrus azysron	yellowtail demoiselle
Neopomacentrus bankieri	Chinese demoiselle
Neopomacentrus cyanomos	Regal pigfish
Parma oligolepis	Bigscale scalyfin
Parma unifasciata	Girdled Scalyfin
Plectroglyphidodon apicalis	Australian Gregroy
Plectroglyphidodon dickii	Dick's damsel
Plectroglyphidodon lacrymatus	Jewel Damsel
Plectroglyphidodon leucozona	Whiteband damsel
Pomacentrinae	
Pomacentrus amboinensis	Ambon damsel
Pomacentrus australis	Australian damsel
Pomacentrus bankanensis	Speckled damsel
Pomacentrus brachialis	charcoal damsel
Pomacentrus coelestis	Neon damsel
Pomacentrus lepidogenys	Scaly damsel
Pomacentrus moluccensis	lemon damsel
Pomacentrus nagasakiensis	Blue-scribbled damsel
Pomacentrus wardi	Ward's damsel
Pristotis obtusirostris	Gulf damsel
Stegastes apicalis	yellowtip gregory
Stegastes fasciolatus	Pacific gregory
Stegastes gascoynei	Coral sea gregory

Dottybacks

Ogilbyina novaehollandiae	Multicoloured Dottyback

Dragonet

Calliurichthys ogilbyi	Ogilby's Stinkfish
Diplogrammus goramensis	Goram dragonet
Eocallionymus papilio	Butterfly Dragonet

Driftfish

Cubiceps whiteleggii	Coastal Cubehead

Emperors

Lethrinus genivittatus	Threadfin Emperor
Lethrinus laticaudis	Grass emperor

Lethrinus miniatus	Redthroat emperor
Lethrinus nebulosus	Spangled emperor

Flatfish

Pardachirus hedleyi	Peacock Sole
Zebrias scalaris	Many-band Sole

Flatheads

Cymbacephalus nematophthalmus	Fringe-eye Flathead
Platycephalus fuscus	Dusky Flathead
Platycephalus grandispinis	Long-spine Flathead
Thysanophrys cirronasus	Rock Flathead

Flounders

Engyprosopon grandisquama	Largescale Flounder
Engyprosopon maldivensis	Olive Wide-eye Flounder

Foolfish/Leatherjackets/Shingles

Anacanthus barbatus	Bearded Leatherjacket
Cantherhines pardalis	Honeycomb leatherjacket
Cantheschenia grandisquamis	largescale leatherjacket
Oxymonacanthus longirostris	Harlequin filefish

Foolfish/Leatherjackets/Shingles

Aluterus monoceros	Unicorn File-fish
Aluterus scriptus	Scrawled Filefish
Anacanthus barbatus	Bearded Leatherjacket
Arotrolepis filicauda	Threadfin Leatherjacket
Cantherhines pardalis	Honeycomb leatherjacket
Cantheschenia grandisquamis	largescale leatherjacket
Oxymonacanthus longirostris	Harlequin filefish
Pervagor janthinosoma	Blackbar Filefish
Pseudomonacanthus peroni	Potbelly Leatherjacket

Frogfish

Antennarius commerson	Giant Frogfish
Antennarius pictus	Painted Anglerfish
Antennarius striatus	Blotched Anglerfish
Histiophryne maggiewalker	

Fusiliers

Caesio cuning	Yellowtail Fusilier
Pterocaesio chrysozona	Yellowband fusilier
Pterocaesio digramma	Doubleline fusilier

Goatfish

Mulloidichthys vanicolensis	Goldstripe Goatfish
Parupeneus multifasciatus	Banded goatfish
Parupeneus spilurus	Blacksaddle goatfish
Upeneus tragula	Bartail goatfish

Gobies

Amblyeleotris periophthalma	Broad-banded shrimpgoby
Amblyeleotris wheeleri	Burgundy shrimpgoby
Bathygobius cocosensis	Cocos Frillgoby
Bathygobius krefftii	Frayedfin Goby
Bathygobius laddi	Brownboy Goby
Bryaninops amplus	Large Whipgoby
Bryaninops loki	Loki Whipgoby
Callogobius depressus	Flathead Goby
Eviota	Greenies
Eviota albolineata	Whitelined eviota
Eviota cf. teresae	Whitelined Eviota
Eviota teresae	Terry's Pygmygoby
Fusigobius neophytus	Neophyte Sandgoby
Gobiodon quinquestrigatus	Fiveline Coralgoby
Istigobius decoratus	Decorated sandgoby

Istigobius nigroocellatus	Blackspotted sandgoby
Priolepis nuchifasciata	Orange Reef-goby
Valenciennea immaculata	Immaculate glidergoby
Valenciennea puellaris	Orange-dashed Goby
Valenciennea strigata	Blueband glidergoby

Hawkfish

Cirrhitichthys aprinus	Threadfin Hawkfish
Cirrhitichthys falco	Dwarf Hawkfish
Cirrhitichthys oxycephalus	Pixy Hawkfish

Lion/Stonefish

Dendrochirus zebra	Zebra lionfish
Parascorpaena aurita	Golden Scorpionfish
Parascorpaena picta	Painted Scorpionfish
Pterois volitans	Common Lionfish
Scorpaena	
Scorpaena cardinalis	Eastern Red Scorpionfish
Scorpaena jacksoniensis	Eastern Red Scorpionfish
Scorpaenopsis papuensis	Papuan Scorpionfish
Scorpaenopsis venosa	Raggy scorpionfish
Scorpis lineolata	Silver sweep
Sebastapistes cyanostigma	Yellowspotted Scorpionfish
Taenianotus triacanthus	Leaf Scorpionfish

Lizardfish

Saurida undosquamis	Large-scaled Grinner
Synodus dermatogenys	Banded lizardfish
Synodus jaculum	Tailspot Lizardfish
Synodus variegatus	Variegated lizardfish
Trachinocephalus myops	Painted Lizardfish

Longfins

Belonepterygion fasciolatum	Banded Longfin
Paraplesiops poweri	Northern Blue Devil
Trachinops taeniatus	Eastern Hulafish

Marblefish/Sea Carp

Aplodactylus lophodon	Cockatoo Fish

Monos/Moonfish

Monodactylus argenteus	Diamondfish
Schuettea	
Schuettea scalaripinnis	Eastern Pomfred

Moray Eels

Echidna nebulosa	Starry Moray
Gymnothorax cribroris	Crib Moray
Gymnothorax eurostus	Stout Moray
Gymnothorax favagineus	Tessellate Moray
Gymnothorax meleagris	Whitemouth Moray
Gymnothorax pseudothyrsoideus	False Spotted Moray
Strophidon sathete	Long-tailed Eel

Morwongs

Cheilodactylus fuscus	Red Morwong
Cheilodactylus vestitus	Crested morwong
Goniistius vestitus	Eastern Morwong

Mullet

Myxus elongatus	Black Spot Mullet

Parrotfish

Scarus frenatus	Sixband Parrotfish
Scarus rubroviolaceus	Redlip Parrotfish
Scarus sp.	Parrotfish

Pipefish

Festucalex cinctus	Girdled Pipefish
Stigmatopora nigra	Wide-bodied Pipefish

Porcupinefish

Didemnium sp.1	
Didemnium sp.2	
Diodon hystrix	Spotted porcupinefish
Lissoclinum bistratum	
Lissoclinum sp.1	

Pufferfish

Arothron hispidus	Stars and stripes puffer
Arothron mappa	Map Puffer
Arothron stellatus	Black-lined Pufferfish
Canthigaster valentini	Blacksaddle toby
Lagocephalus cheesemanii	Cheeseman's Puffer
Marilyna pleurosticta	Banded Toadfish
Tetractenos hamiltoni	Common Toadfish
Torquigener whitleyi	Whitley's Toadfish

Rabbitfish

Siganus argenteus	Forktail Rabbitfish
Siganus canaliculatus	Whitespotted Rabbitfish
Siganus fuscescens	Black rabbitfish

Ray-finned fish

Alectis ciliaris	African Pompano
Alepes	
Carangoides fulvoguttatus	Turrum
Carangoides gymnostethus	Bludger Trevally
Caranx sexfasciatus	Bigeye Trevally
Gnathanodon speciosus	golden Trevally
Platycaranx chrysophrys	Longnose Trevally
Selaroides leptolepis	Yellowstripe Scad
Seriola dumerili	Greater Amberjack
Seriola lalandi	Yellowtail Kingfish
Trachinotus coppingeri	Swallowtail Dart
Turrum fulvoguttatum	Yellow spotted trevally

Sandperches

Parapercis clathrata	Spothead Grubfish
Parapercis queenslandica	Blacktail Grubfish
Parapercis stricticeps	Whitestreak grubish

Sea Bream

Acanthopagrus australis	Yellowin bream
Chrysophrys auratus	Snapper
Rhabdosargus sarba	Tarwhine

Sea Chubs

Kyphosus bigibbus	Brown Chub
Microcanthus strigatus	Stripey

Sea Robins

Chelidonichthys	
Lepidotrigla umbrosa	Blackspot Gurnard

Shark

Carcharhinus obscurus	Black Whaler
Carcharodon carcharias	Great White Shark

Sharks

Brachaelurus waddi	Blind Shark
Orectolobus maculatus	Spotted Wobbegong
Orectolobus ornatus	Banded wobbegong
Orectolobus ornatus	Banded Carpet Shark
Stegostoma fasciatum	Zebra Shark

Snake Eels

Malvoliophis pinguis	Half-banded Snake-eel

Snappers

Dipterygonotus balteatus	Mottled Fusilier

Lutjanus argentimaculatus	Mangrove jack
Lutjanus bohar	Red bass
Lutjanus carponotatus	Sydney snapper
Lutjanus fulviflamma	Blackspot Snapper
Lutjanus kasmira	Lutjanus kasmira
Lutjanus monostigma	Onespot Snapper
Lutjanus quinquilineatus	Fiveline Snapper
Lutjanus rivulatus	Blubberlip Snapper
Lutjanus russelli	Moses' snapper
Lutjanus russellii	Moses' Snapper
Lutjanus sebae	Red Emperor
Symphorichthys spilurus	Sailfin Snapper

Spadefish/Batfish

Platax batavianus	Batavia Batfish
Platax teira	Roundface Batfish

Squirrelfish/Soldierfish

Myripristis murdjan	Crimson soldierfish
Sargocentron diadema	Crown Squirrelfish
Sargocentron melanospilos	Blackspot squirrelfish
Sargocentron praslin	Brownspot Squirrelfish
Sargocentron rubrum	Red squirrelfish

Stargazers

Ichthyscopus nigripinnis	Blackfin Stargazer
Ichthyscopus sannio	Northern Stargazer

Stripeys

Microcanthus joyceae	East-Australian Stripey

Surgeonfish/Tangs/Unicornfish

Acanthurus dussumieri	Pencil surgeonfish
Acanthurus lineatus	Striped Surgeonfish
Acanthurus mata	Pale surgeonfish
Acanthurus nigricans	Velvet surgeonfish
Acanthurus nigrofuscus	Dusky surgeonfish
Acanthurus triostegus	Convict Surgeon
Acanthurus xanthopterus	Ring-tailed Surgeonfish
Naso annulatus	Ringtail unicornfish
Naso tonganus	Bluntnose Unicornfish
Naso unicornis	Bluespine unicornfish
Prionurus maculatus	Spotted Sawtail
Prionurus microlepidotus	Australian sawtail
Zebrasoma scopas	Brown tang

Sweepers

Parapriacanthus ransonneti	Golden bullseye
Pempheris afinis	Blacktip bullseye
Pempheris analis	Bronze Bullseye
Pempheris ypsilychnus	Ypsilon Bullseye

Sweetlips

Diagramma labiosum	Painted Sweetlips
Diagramma pictum labiosum	Painted sweetlips
Plectorhinchus chaetodonoides	Spotted Sweetlips
Plectorhinchus flavomaculatus	Goldspotted Sweetlips
Plectorhinchus gibbosus	Brown sweetlips
Plectorhinchus lavomaculatus	Goldspotted sweetlips
Plectorhinchus picus	Dotted sweetlips

Threadfin bream/Whiptail Bream/False Snappers

Pentapodus aureofasciatus	Yellowstripe threadfin
Pentapodus paradiseus	Paradise threadfin
Scolopsis bilineatus	Two-line monocle bream
Scolopsis lineata	Green-lined Spine-cheek
Scolopsis monogramma	Rainbow monocle bream

Tonguefish

Paraplagusia bilineata	Doublelined Tonguesole

Triggerfish

Balistoides conspicillum	Clown Triggerfish
Rhinecanthus aculeatus	Hawaiian Triggerfish
Sufflamen chrysopterum	Eye-stripe Triggerfish
Sufflamen chrysopterum	Halfmoon triggerfish
Sufflamen fraenatus	Masked triggerfish

Tripplefin Blennies

Enneapterygius atrogulare	Black Triple-fins
Enneapterygius rufopileus	Blackcheek Threefin
Enneapterygius similis	Blacktail Triplefin
Enneapterygius sp.	Enneaptyerygius
Norfolkia squamiceps	Lord Howe Scaly-headed Triplefin

Trumpetfish

Aulostomus chinensis	Trumpetfish

Trunkfish/Boxfish

Lactoria cornuta	Cow-fish
Ostracion cubicum	Yellow Boxfish
Ostracion cubicus	Yellow boxfish
Tetrosomus reipublicae	Smallspine Turretfish

Venemous ray-finned fish/Wasfish

Inimicus caledonicus	Bearded Ghoul
Minous versicolor	Black-banded Wasp-fish

Viviparous brotula

Dinematichthys	

Wasfish/Sailback Scorpionfish

Centropogon australis	Eastern Fortescue

Whiptail Stingrays

Taeniura meyeni	Blotched fantail Ray

Whiting

Sillago ciliata	Blue Nose Whiting

Wobbegongs

Orectolobus maculatus	Spotted Wobbegong
Orectolobus ornatus	Banded wobbegong

Wrasse

Achoerodus viridis	Eastern Blue Groper
Anampses caeruleopunctatus	Diamond wrasse
Anampses geographicus	Scribbled wrasse
Anampses neoguinaicus	Blackback wrasse
Austrolabrus maculatus	Blackspotted Parrotfish
Bodianus axillaris	Coral pigfish
Bodianus dictynna	False diana's pigfish
Bodianus mesothorax	Eclipse Pigfish
Bodianus perditio	Goldspot Pigfish
Cheilinus chlorourus	Floral maori wrasse
Choerodon fasciatus	Harlequin tuskfish
Choerodon graphicus	Graphic tuskfish
Choerodon schoenleinii	Blackspot tuskfish
Choerodon venustus	Venus tuskfish
Cirrhilabrus punctatus	Finespot wrasse
Coris aurilineata	goldlined wrasse
Coris batuensis	Variegated wrasse
Coris pictoides	Pixy wrasse
Gomphosus varius	Birdnose wrasse
Gomphosus varius	Bird Wrasse
Halichoeres margaritaceus	Pearly Wrasse
Halichoeres prosopeion	Twotone Wrasse
Hemigymnus fasciatus	Fiveband Wrasse
Labroides dimidiatus	Common cleanerfish

Labropsis australis	Southern tubelip
Leptojulis cyanopleura	shoulderspot wrasse
Macropharyngodon	Choati choat's wrasse
Macropharyngodon choati	Choat's Wrasse
Macropharyngodon meleagris	leopard wrasse
Macropharyngodon negrosensis	Black leopard wrasse
Notolabrus gymnogenis	Crimson-banded Parrot-fish
Oxycheilinus bimaculatus	Little maori wrasse
Oxycheilinus diagrammus	Violetline maori wrasse
Pseudocheilinus hexataenia	Sixline wrasse
Pseudolabrus guentheri	Gunther's wrasse
Scarus ghobban	Bluebarred Parrotfish
Stethojulis bandanensis	Redspot wrasse
Stethojulis interrupta	Brokenline wrasse
Suezichthys gracilis	Slender rainbow wrasse
Thalassoma amblycephalum	Indo-Pacific Bluehead Wrasse
Thalassoma lunare	Moon wrasse
Thalassoma lutescens	Green moon wrasse
Thalassoma nigrofasciatum	Jansen's wrasse

Fish - Other

Alabes parvula	Eel Clingfish
Anguilla reinhardtii	Australian Long-finned Eel
Centroberyx affinis	Nannygai
Diploprion bifasciatus	Barred Soapfish
Epinephelus	Rockcods
Latropiscis purpurissatus	Sergeant Baker
Pataecus fronto	Red Foreheadfish
Pseudanthias fasciatus	Redstripe Basslet
Pseudanthias rubrizonatus	Redbar Anthias
Scatophagus argus	Butterfish
Solenostomus paradoxus	Ornate Ghostpipefish
Synanceia horrida	Estuarine Stonefish

Turtles

Caretta caretta	Loggerhead Sea Turtle
Chelonia mydas	Green Sea Turtle
Cheloniidae	Typical Sea Turtles
Emydura macquarii	Macquarie Turtle
Eretmochelys imbricata	Hawksbill Turtle

Chordata - Other

Ascidia latesiphonica	Ascidia latesiphonica
Ascidia sp. 2 (undet.)	Ascidia latesiphonica
Cnemidocarpa stolonifera	Orange-spouted Sea Squirt
Eusynstyela latericius	
Gomophia sp. 1	Coleman's Sea Star
Herdmania momus	Pink Trumpet Sea Squirt
Microcosmus exasperatus	Orange Leather Sea Squirt
Phallusia arabica	
Phallusia julinea	
Phallusia obesa	
Polycarpa ovata	
Polycitor giganteus	
Pyura stolinifera	
Rhopalaea crassa	
Salpa fusiformis	Torpedo salp
Zanclus cornutus	Moorish idol

<u>CNIDARIA</u> (Corals, Anemones, Jellyfish, Sea Firs)
Anemone

Boloceroides mcmurrichi	Swimming anemone
Heteractis crispa	Sebae anemone

Jellyfish

Versuriga anadyomene	Giant Crinkled Jellyfish

Sea Fir

Macrorhynchia philippina	White Stinging Sea Fir
Macrorhynchia phoenicea	Orange Stinging Sea Fir
Plumularia sp. 1	
Sertularella diaphana	

Hard Corals

Acanthastrea echinata	
Acanthastrea lordhowensis	
Acropora muricata	
Acropora solitaryensis	
Acropora sp.	
Aulactinia sp. 1	
Cyphastrea serailia	
Echinophyllia sp.1	
Entacmaea quadricolor	Bubble-tip Sea Anemone
Favia speciosa	
Favites sp.	
Goniastrea sp.	
Goniopora	
Goniopora djiboutiensis	Goniopora djiboutiensis
Heteractis aurora	Beaded Sea Anemone
Heteractis magnifica	Magnificent Anemone
Heteractis malu	Delicate Anemone
Lobophylliidae sp. 1	
Oulophyllia crispa	
Pocillopora damicornis	
Seriatopora hystrix	
Stylasterid	
Tubastrea faulkneri	
Tubastrea micrantha	
Tubinaria mesenterina	
Turbinaria peltata	

Soft Corals

Acanthogorgia sp.	
Capnella sp.1	
Carijoa sp.1	
Carijoa sp.2	
Cespitularia sp.1	
Chironephtya sp.1	
Chironephtya sp.2	
Cladiella sp.1	
Clavularia sp.1	
Dendronephthya sp.2	
Dendronephthya sp.3	
Dendronephthya sp.4	
Dendronephthya spp.	Prickly Tree Coral
Dichotella spp.	Dichotella Sea Whips
Dipsastraea danai	
Dipsastraea favus	
Echinogorgia sp.1	
Echinogorgia sp.2	
Echinogorgia sp.3	
Echinogorgia sp.4	
Echinogorgia sp.5	
Echinogorgia spp.	Maze Sea Fans
Goniastrea australensis	Australian Brain Coral
Goniastrea favulus	Goniastrea favulus
Iciligorgia sp.1	
Isis hippuris	
Junceella sp.1	
Klyxum sp.1	
Lobophytum sp.	
Menella spp.	Menella Soft Coral
Mopsella sp.1	
Paraplexaura spp.	Paraplexaura Soft Coral
Plumigorgia spp.	
Rumphella sp.1	
Sansibia sp.1	
Sarcophyton sp.	
Sarcophyton spp.	
Sinularia sp.	
Tubastraea diaphana	Black Cup Coral
Tubipora sp.	
Turbinaria mesenterina	Meso Turbinaria

Other

Antipathes sp. 1	Black coral
Palythoa sp.1	Zooanthid

CTENOPHORA

Coeloplana astericola	Seastar Benthic Ctenophore
Ocryopsis sp. 1	

ECHINODERMATA (Urchins, Cucumbers, Starfish)

Acanthaster planci	Crown-of-Thorns Starfish
Anthenea sp. 2	
Asthenosoma periculosum	Stinging sea urchin
Astrobrachion adhaerens	Grasping Brittle Star
Astrobrachion constrictum	
Cenolia sp.	
Cenolia tasmaniae	Tasmanian Feather Star
Clypeaster virescens	Clypeaster virescens
Comanthina nobilis	
Diadema savignyi	Savigny's Spined Sea Urchin
Echinaster callosus	Warty seastar
Echinaster luzonicus	Luzon seastar
Echinostrephus aciculatus	Burrowing sea urchin
Echinothrix calamaris	Banded Sea Urchin
Fromia indica	Indian seastar
Gomophia mamillifera	Ornamented seastar
Holothuria dificilis	Sea cucumber
Jacksonaster depressum	Depressed Sand Dollar
Linckia laevigata	Blue Sea Star
Linckia multifora	Multipore Sea Star
Massinium magnum	Magnum Sea Cucumber
Nepanthia belcheri	Belcher's Sea Star
Oligometrides adeonae	
Ophidiaster sp.	Banded starfish
Ophidiaster sp. 1	Dark Sea Star
Ophiomastix endeani	Ophiomastix endeani
Ophiothela sp.	
Oxycomanthus bennetti	
Pentagonaster dubeni	Vermillion seastar
Petricia vernicina	Velvet Sea Star
Pseudoboletia maculata	Spotted Sea Urchin
Tamaria sp.	
Tripneustes gratilla	Collector Sea Urchin

MOLLUSCA (Bivalves)
Clam

Gafrarium dispar	Gafrarium dispar
Lamarcka avellana	Flying-Bird Ark
Lioconcha castrensis	Zigzag Venus
Pinna deltodes	Razor clam
Placamen lamellatum	Placamen lamellatum
Plicatula	Kittenpaw Shells
Solen vaginoides	Southern Razor Shell
Trapezium oblongum	Oblong Trapezium Clam
Tridacna crocea	Burrowing Giant Clam
Tridacna gigas	Giant Clam

Cockle

Glycymeris grayana	Glycymeris grayana
Vasticardium vertebratum	Vasticardium vertebratum

Oyster

Dendostrea folium	Leaf oyster
Hyotissa hyotis	Giant Coxcomb Oyster
Pictada maculata	Spotted pearl oyster
Pinctada imbricata	New South Wales Pearl Shell
Pteria lata	Red wing oyster
Pteria penguin	Penguin wing oyster
Saccostrea scyphophilla	Cupped Rock Oyster
Spondylus squamosus	Spinous Thorny Oyster
Spondylus violacescens	Cliff Oyster

Scallop

Pascahinnites coruscans	Pascahinnites coruscans
Pecten fumatus	Pecten fumatus

Octopuses, Squid, Cuttlefish, Nautilus

Hapalochlaena fasciata	Blue-lined Octopus
Metasepia pfefferi	Flamboyant Cuttlefish
Nautilus pompilius	Chambered Nautilus
Octopus cyanea	Day Octopus
Sepia latimanus	Broadclub Cuttlefish
Sepia plangon	Mourning Cuttlefish
Sepioteuthis lessoniana	Bigfin Reef Squid

Mollusca - Other

Abronica sp. 1	
Abronica sp. 2	
Actinocyclus verrucosus	
Adamantia concinna	Diamond Ovulid
Aegires cf. citrinus	
Aegires citrinus	
Aegires exeches	
Aegires flores	
Aegires gardineri	
Aegires hapsis	
Aegires incusus	
Aegires minor	
Aegires villosus	
Aldisa pikokai	
Amoria zebra	Zebra Volute
Aplysia concavia	
Ardeadoris angustolutea	
Ardeadoris averni	
Ardeadoris egretta	
Ardeadoris electra	
Ardeadoris rubroannulata	
Ardeadoris sp. 1	
Ardeadoris symmetrica	
Astralium tentoriiforme	Tent Turban
Atagema albata	
Atagema ornata	
Atagema sp. 2	
Atagema spongiosa	
Atys semistriatus	
Atys sp. 2	
Atys sp. 7	
Austrocochlea porcata	Zebra Top Snail
Austrolittorina unifasciata	Little Blue Periwinkle
Babakina indopacifica	
Baeolidia variabilis	
Bembicium	Bembicium
Berthella martensi	
Berthellina delicata	
Bistolida stolida lorrainae	Bistolida stolida lorrainae
Biuve fulvipunctata	
Bornella anguilla	
Bornella sp. 1	
Bornella stellifer	
Bouchetriphora aspergata	
Bouchetriphora pallida	Pallid Sinistral Creeper
Bulbaeolidia alba	
Bulla vernicosa	
Cadlina sp. 1	
Cadlinella ornatissima	
Callistochiton antiquus	Antique Chiton
Callochiton crocinus	Red-marked Chiton
Caloria indica	
Calpurnus verrucosus	Toenail Cowry
Carminodoris flammea	
Carminodoris pustulata	
Carminodoris sp. 1	
Cellana tramoserica	Variegated limpet
Ceratosoma sp. 1	
Ceratosoma sp. 2	
Ceratosoma tenue	
Ceratosoma trilobatum	
Cerithium echinatum	Spiny Cerith

Cerithium novaehollandiae	New Holland Cerith
Charonia tritonis	Giant Triton
Chelidonura electra	
Chelidonura hirundinina	
Chicoreus ramosus	Giant murex
Chromodoris	Chromodoris
Chromodoris annae	
Chromodoris aspersa	
Chromodoris burni	
Chromodoris cf. magnifica	
Chromodoris colemani	
Chromodoris elisabethina	
Chromodoris kuiteri	
Chromodoris lochi	
Chromodoris magnifica	
Chromodoris sp. 2	
Chromodoris sp. 3	
Chromodoris sp. 5	
Chromodoris splendida	
Chromodoris strigata	
Chromodoris willani	
Clavus unizonalis	One-zoned Turrid
Colinatys sp. 1	
Colpodaspis thompsoni	
Conuber incei	Conuber incei
Conus ammiralis	Admiral Cone
Conus catus	Conus catus
Conus chaldaeus	Conus chaldaeus
Conus coronatus	Coronated Cone
Conus miles	Soldier Cone
Conus musicus	Music Cone
Conus omaria	Omaria Cone
Conus sp.	Cone shell
Conus textile	Textile Cone
Conus varius	Freckled Cone

Coralliophila monodonta	Coralliophila monodonta
Coriocella nigra	Black Velvet Snail
Coriocella tongana	Tonga Lamellaria
Coryphellina exoptata	
Coryphellina lotos	
Coryphellina pannae	
Costasiella formicaria	
Costasiella kuroshimae	
Cratena affinis	
Cratena lineata	
Cratena simba	
Crenavolva tinctura	Tinted Crenavolva
Cribrarula cribraria	Sieve Cowry
Crimora edwardsi	
Crimora sp. 1	
Cyerce kikutarobabai	
Cyerce sp. 2	
Cylichnatys campanula	
Cymatium parthenopium	Broad-ripped triton
Cypraea sp.	Cowrie shell
Cypraea tigris	Tiger Cowry
Dendrodoris albobrunnea	
Dendrodoris coronata	
Dendrodoris denisoni	
Dendrodoris fumata	
Dendrodoris nigra	
Dendrodoris sp. 4	
Dendrodoris sp. 6	
Dendrodoris sp. 7	
Dermatobranchus	Dermatobranchus
Dermatobranchus cf. tuberculatus	
Dermatobranchus fasciatus	
Dermatobranchus fortunatus	

Dermatobranchus oculus	
Dermatobranchus ornatus	
Dermatobranchus rodmani	
Dermatobranchus semilunus	
Dermatobranchus sp. 13	
Dermatobranchus sp. 5	
Dermatobranchus sp. 7	
Dermatobranchus sp. 8	
Dermatobranchus sp. 9	
Dermatobranchus tuberculatus	
Diacavolinia longirostris	
Diminovula margarita	Margarita Pearl-ovulid
Discodorid sp. 2	
Discodoris coerulescens	
Discodoris lilacina	
Diversidoris aurantionodulosa	
Diversidoris crocea	
Diversidoris flava	
Diversidoris sp. 1	
Diversidoris sp. 2	
Diversidoris sp. 3	
Dolabrifera dolabrifera	
Doriprismatica atromarginata	
Doriprismatica dendrobranchia	
Doris sp. 1	
Doto racemosa	
Doto rosacea	
Doto ussi	
Drupella rugosa	Purple-mouthed Drupe
Elysia maoria	
Elysia pusilla	
Elysia sp. 11	
Elysia sp. 12	
Elysia sp. 13	
Elysia sp. 14	
Elysia sp. 17	
Elysia sp. 2	
Elysia sp. 24	
Elysia sp. 4	
Elysia sp. 5	
Elysia sp. 6	
Elysia sp. 9	
Engina zonalis	Engina zonalis
Epidendrium	Epidendrium
Erronea errones	Erroneous Cowry
Erronea xanthodon	Erronea xanthodon
Eubranchus mandapamensis	
Eubranchus sp. 11	
Eubranchus sp. 3	
Eubranchus sp. 6	
Euselenops luniceps	
Fabellina rubrolineata	
Facelina bourailli	
Facelina sp. 3	
Facelina sp. 6	
Facelina sp. 7	
Favorinus japonicus	
Favorinus sp. 1	
Favorinus sp. 2	
Favorinus sp. 3	
Flabellina sp. 9	
Geitodoris sp. 2	
Glaucus atlanticus	Sea Swallow
Glossodoris aeruginosa	
Glossodoris atromarginata	
Glossodoris cincta	
Glossodoris hikuerensis	
Glossodoris rufomarginata	
Glossodoris sp. 3	
Glossodoris sp. 4	

Glossodoris sp. 5	
Glossodoris vespa	
Goniobranchus albonares	
Goniobranchus albopunctatus	
Goniobranchus alius	
Goniobranchus aureopurpureus	
Goniobranchus coi	
Goniobranchus collingwoodi	
Goniobranchus daphne	
Goniobranchus decorus	
Goniobranchus geometricus	
Goniobranchus kuniei	
Goniobranchus leopardus	
Goniobranchus roboi	Tooth-edged Nudibranch
Goniobranchus rufomaculatus	
Goniobranchus sp. 1	
Goniobranchus sp. 2	
Goniobranchus sp. 6	
Goniobranchus sp. 7	
Goniobranchus sp. 8	
Goniobranchus splendidus	
Goniobranchus splendidus	Splendid Goniobranch
Goniobranchus tinctorius	
Goniobranchus verrieri	
Goniodoridella savignyi	
Gymnodoris alba	
Gymnodoris amakusana	
Gymnodoris okinawae	
Gymnodoris sp. 10	
Gymnodoris sp. 3	

Gymnodoris sp. 7	
Gymnodoris sp. 9	
Gyrineum lacunatum	Isasa-bora Triton
Halgerda albocristata	
Halgerda aurantiomaculata	
Halgerda elegans	
Halgerda sp. 1	
Halgerda sp. 3	
Halgerda tessellata	
Halgerda willeyi	
Halichoeres hortulanus	chequerboard wrasse
Halichoeres marginatus	Dusky wrasse
Halichoeres melanurus	Hoeven's wrasse
Halichoeres nebulosus	Cloud wrasse
Haliotis melculus	Haliotis melculus
Hallaxa translucens	
Haloa sp. 7	
Haminoea sp.	
Haminoeid long-tail sp. 1	
Hexabranchus sanguineus	
Hiatavolva depressa	Depressed Ovulid
Hydatina physis	
Hypselodoris	Hypselodoris
Hypselodoris apolegma	
Hypselodoris bullocki	
Hypselodoris decorata	
Hypselodoris emma	
Hypselodoris imperialis	
Hypselodoris jacksoni	
Hypselodoris lacuna	
Hypselodoris maculosa	

Hypselodoris maritima	
Hypselodoris melanesica	
Hypselodoris obscura	
Hypselodoris roo	
Hypselodoris sagamiensis	
Hypselodoris sp. 2	
Hypselodoris sp. 4	
Hypselodoris sp. 6	
Hypselodoris sp. 9	
Hypselodoris tryoni	
Hypselodoris whitei	
Hypselodoris zephyra	
Ischnochiton elongatus	Elongated Chiton
Jorunna parva	
Jorunna ramicola	
Jorunna sp. 2	
Jorunna sp. 3	
Jorunna sp. 4	
Jorunna sp. 6	
Kabeiro sp. 1	
Kaloplocamus acutus	
Lambis truncata	Giant Spider Conch
Liloa brevis	
Limenandra confusa	
Littorinidae	Periwinkle Snails
Lobiger sp. 1	
Lobiger viridis	
Luria isabella	Queen Isabella Cowry
Lyncina carneola	Carnelian Cowry
Mancinella alouina	Yellow-mouthed Rock Shell
Mariaglaja inornata	
Mariaglaja inornata	Headband Headshield Slug
Marianina rosea	
Marionia cf. rubra	
Marionia rubra	
Marionia sp. 2	
Marionia sp. 3	
Marionia sp. 5	
Marionia sp. 6	
Martadoris limaciformis	
Menathais tuberosa	Menathais tuberosa
Mexichromis aurora	
Mexichromis festiva	
Mexichromis macropus	
Mexichromis mariei	
Mexichromis pusilla	
Mexichromis trilineata	
Miamira magnifica	
Miamira moloch	
Miamira sinuata	
Micromelo guamensis	Micromelo guamensis
Micromelo undatus	
Mnestia sp.	
Monetaria caputserpentis	Snakehead Cowrie
Monophorus nigrofuscus	
Montfortula rugosa	Cap-shaped False Limpet
Murphydoris adusta	
Murphydoris cobbi	
Murphydoris puncticulata	
Murphydoris sp. 1	
Naria erosa	Eroded Cowry
Naria labrolineata	Pitted-margin Cowry
Nassa serta	Garland Thaid
Nassarius gaudiosus	Pointed Dogwhelk
Nassarius papillosus	Pimpled Dog Whelk
Nembrotha lineolata	
Nembrotha purpureolineata	
Nerita albicilla	blotched nerite
Niparaya sp. 2	
Niparaya sp. 4	
Niparaya sp. 9	
Notodoris gardineri	Gardiner's Banana Nudibranch
Nucleolaria nucleus	Madagascar Nucleus Cowry

Okenia hallucigenia	
Okenia rhinorma	
Onchidoris sp. 1	
Orania ficula	
Ovula costellata	Pink-mouth Egg Cowry
Ovula ovum	Common Egg Cowry
Oxynoe jacksoni	
Oxynoe viridis	
Palmadusta asellus	Little Ass Cowry
Pardalinops testudinaria	Tortoise Dove Shell
Phalium bandatum	Banded Bonnet Snail
Phanerophthalmus anettae	
Phenacovolva rosea	Many-host Phenacovolva
Phestilla melanobrachia	Cup Coral Nudibranch
Philine angasi	
Philine orca	
Philinopsis falciphallus	
Philinopsis lineolata	
Philinopsis orientalis	
Phyllidia cf. elegans	
Phyllidia coelestis	
Phyllidia elegans	
Phyllidia exquisita	
Phyllidia guamensis	
Phyllidia madangensis	
Phyllidia ocellata	
Phyllidia picta	
Phyllidia sp. 3	
Phyllidia sp. 4	
Phyllidia varicosa	
Phyllidiella annulata	
Phyllidiella cooraburrama	
Phyllidiella hageni	
Phyllidiella lizae	
Phyllidiella meandrina	
Phyllidiella pustulosa	
Phyllidiopsis burni	

Phyllidiopsis cardinalis	
Phyllidiopsis fissurata	
Phyllidiopsis krempfi	
Phyllidiopsis loricata	
Phyllidiopsis shireenae	
Phyllidiopsis xishaensis	
Phyllodesmium acanthorhinum	
Phyllodesmium colemani	
Phyllodesmium crypticum	
Phyllodesmium hyalinum	
Phyllodesmium macphersonae	
Phyllodesmium magnum	
Phyllodesmium opalescens	
Phyllodesmium sp. 2	
Phyllodesmium sp. 7	
Placida kevinleei	
Platydoris formosa	
Platydoris sanguinea	
Pleurobranchus peronii	
Pleurolidia juliae	
Polycera sp. 1	
Polycera sp. 2	
Primovula rosewateri	Rosewater's Primovula
Prionovolva brevis	Short Prionovolva
Procalpurnus lacteus	Netted Milky Ovulid
Pteraeolidia semperi	
Purpuradusta gracilis	Purpuradusta gracilis
Pyrene flava	Pyrene flava
Retusa sp.	
Ringicula sp.	
Rissoina ambigua	

Roboastra luteolineata	
Rostanga lutescens	
Roxaniella leucampyx	
Sabia conica	Bonnet Limpet
Sagaminopteron ornatum	
Sagaminopteron psychedelicum	
Sakuraeolis nungunoides	
Samla bicolor	
Samla macassarana	
Samla sp. 1	
Santia sp. 2	
Sclerodoris coreacia	
Sclerodoris sp. 4	
Sclerodoris sp. 8	
Scutus antipodes	Elephant Snail
Sebadoris fragilis	
Siphopteron sp. 1	Siphopteron sp. 1
Staphylaea staphylaea	Staphylaea staphylaea
Stiliger aureomarginatus	
Strigatella scutulata	Strigatella scutulata
Talparia talpa	Mole Cowry
Tambja amakusana	
Tambja caeruleocirrus	
Tambja morosa	
Tambja tenuilineata	
Tambja victoriae	
Tenellia diversicolor	
Tenellia melanobrachia	
Tenellia ornata	
Tenellia sibogae	
Tenellia sp. 1	
Tenellia sp. 11	
Tenellia sp. 13	
Tenellia sp. 20	
Tenellia sp. 23	
Tenellia sp. 24	
Tenellia sp. 3	
Tenellia sp. 33	
Tenellia sp. 35	
Tenellia sp. 36	
Tenellia sp. 39	
Tenellia sp. 4	
Tenellia sp. 40	
Tenellia sp. 41	
Tenellia sp. 44	
Tenellia sp. 45	
Tenellia sp. 50	
Tenguella marginalba	Mulberry Whelk
Terenolla pygmaea	Pygmy Auger
Thordisa tahala	
Thorunna australis	
Thorunna daniellae	
Thorunna florens	
Thorunna furtiva	
Thorunna halourga	
Thorunna sp. 3	
Thorunna sp. 4	
Thorunna sp. 5	
Thorunna sp. 7	
Thuridilla albopustulosa	
Thuridilla carlsoni	
Thuridilla carlsoni	
Thuridilla cf. splendens	
Thuridilla gracilis	
Thuridilla hoffae	
Thuridilla livida	
Thuridilla neona	
Thuridilla sp. 1	
Thuridilla sp. 5	
Thuridilla sp. 6	
Thuridilla sp. 7	
Thuridilla splendans	
Thuridilla vatae	
Tornatina avenaria	
Tornatina sp. 1	
Tornatina sp. 4	
Trapania brunnea	
Trapania gibbera	
Trapania reticulata	

Trapania vitta	
Tritoniopsis elegans	
Trivirostra oryza	Sulcate Bean Cowry
Turbo militaris	Military Turban
Turbo petholatus	Cat's Eye Turban
Tutufa bubo	Large Frog Snail
Tylodina corticalis	
Tyrannodoris luteolineata	Tyrannodoris luteolineata
Verconia alboannulata	
Verconia cf. varians	
Verconia decussata	
Verconia haliclona	
Verconia laboutei	
Verconia norba	
Verconia romeri	
Verconia simplex	
Verconia sp. 2	
Verconia sp. 3	
Verconia verconiforma	
Vexillum daedalum	Vexillum daedalum
Volculla rostrata	
Weinkauffia reliqua	

Nemertea

Baseodiscus hemprichii	Dark-striped Ribbon Worm

PLATYHELMINTHES (Flatworms)

Acanthozoon sp. 16	
Cycloporus sp. 10	
Maritigrella eschara	Scarred Flatworm
Maritigrella fuscopunctata	Dark-spotted Flatworm
Maritigrella virgulata	Red-striped Flatworm
Pericelis sp. 1	
Pericelis sp. 3	
Phrikoceros fritillus	Spotted Flatworm
Pseudobiceros apricus	Orange Flatworm
Pseudobiceros bedfordi	Persian Carpet Flatworm
Pseudobiceros gloriosus	Glorious Flatworm
Pseudobiceros gratus	Pleasing Flatworm
Pseudobiceros hancockanus	Hancock's Flatworm
Pseudobiceros sp. 13	
Pseudobiceros sp. 19	
Pseudobiceros sp. 21	
Pseudobiceros sp. 22	
Pseudobiceros sp. 3	
Pseudobiceros splendidus	Splendid Flatworm
Pseudoceros bimarginatus	Bimargined Flatworm
Pseudoceros laticlavus	Black and White Flatworm
Pseudoceros leptostictus	Thinspotted Flatworm
Pseudoceros paralaticlavus	Broadstriped Flatworm
Pseudoceros scintillatus	Scintillated Flatworm
Pseudoceros sp. 25	
Pseudoceros sp. 29	
Pseudoceros sp. 49	
Pseudoceros sp. 51	
Pseudoceros sp. 7	
Pseudoceros sp. 8	

PORIFERA (Sponges)

Acanthella carvernosa	
Agelas mauritiana	
Amphimedon sp. 2776	
Aplysilla sulfurea 224	
Aplysinella sp.1194	
Batzella sp. 2175	
Batzella sp. 4217	
Batzella sp. 4407	
Callyspongia (C.) sp. 3148	

Callyspongia (C.) sp. 4328	
Callyspongia manus	
Callyspongia sp. 7	
Carteriospongia sp.	
Ceratopsion clavata	
Chondropsis sp. 4131	
Cinachyrella enigmatica	
Cliona orientalis	
Cribrochalina sp. 2666	
Dactylia sp. 1	Mauve Finger Sponge
Dactylia sp. 1823	
Didiscus aceratus	
Dysidea sp. 16	
Echinochalina (E.) sp. 272	
Euryspongia deliculata	
Grantiopsis sp. 1582	
Halichondria (H) sp.	
Halichondria (H.) 3764	
Haliclona (H.) sp. 2584	
Ianthella quadrangulata	
Iotrochota coccinea	
Ircinia sp. 1255	
Leucetta chagosensis	
Myrmekioderma granulata	
Neopetrosia paciica	
Pericharax heterographis	Abnormal Needle Sponge
Phyllospongia papyracea	
Phyllospongia sp. 2899	
Psammocinia bulbosa	
Psammocinia sp. 1191	
Pseudoceratina clavata	
Pseudoceratina sp. 1247	
Pseudoceratina sp. 2973	
Siphonochalina deiciens 582	Tubular Beautiful Sponge
Siphonochalina sp.	Sponge
Spheciospongia cf. vagabunda	
Sycon sp. 1	
Trachycladus laevispirulifer	
Xestospongia testudinaria	

Plantae

Chlorophyta (Green Algae)

Codium sp.	Green algae
Halimeda discoidea	Green algae
Ulva	Sea Lettuces
Valonia aegagropila	

Ochrophyta

Lobophora variegata	Brown algae

Rhodophyta (Red Algae)

Corallinales	Coralline algae
Delisea pulchra	Red algae
Mesophyllum mesomorphum	Red algae leafy
Metagoniolithon sp.	Red algae segmented
Peyssonnelia capensis	Encrusting red algae

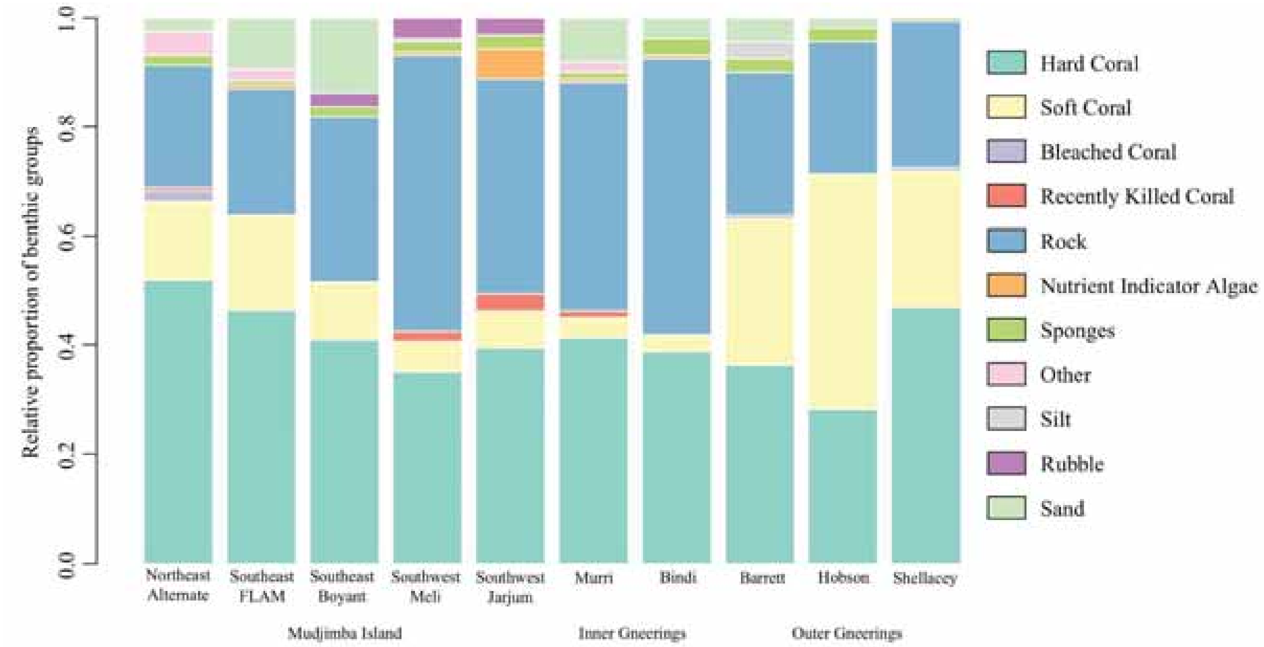
Appendix D: Transect Coordinates

Site Name	Coordinates Start	Coordinates End
Inner Gneerings Bindi	153.159611E -26.645321S	153.159611E -26.645321S
Inner Gneerings Murri's	153.160675E -26.645514S	153.161576E -26.645171S
Mudjimba, North East	153.117079E -26.613983S	153.117959E -26.614127S
Mudjimba N.E. Alternative	153.114493E -26.611941S	153.117079E -26.613983S
Mudjimba SE Boyant	153.116153E -26.616047S	153.115212E -26.616112S
Mudjimba SE Flam	153.116169E -26.616062S	153.116886E -26.615489S
Mudjimba SW Jarjum	153.113345E -26.615858S	153.114290E -26.616016S
Mudjimba SW Meli	153.113270E -26.615787S	153.114216E -26.615879S
Outer Gneerings Barrett	153.182933E -26.648672S	153.183888E -26.648672S
Outer Gneerings Hobson	153.182933E -26.648672S	153.181989E -26.648672S
Outer Gneerings Shellacey	153.200951E -26.654217S	153.200952E -26.654051S

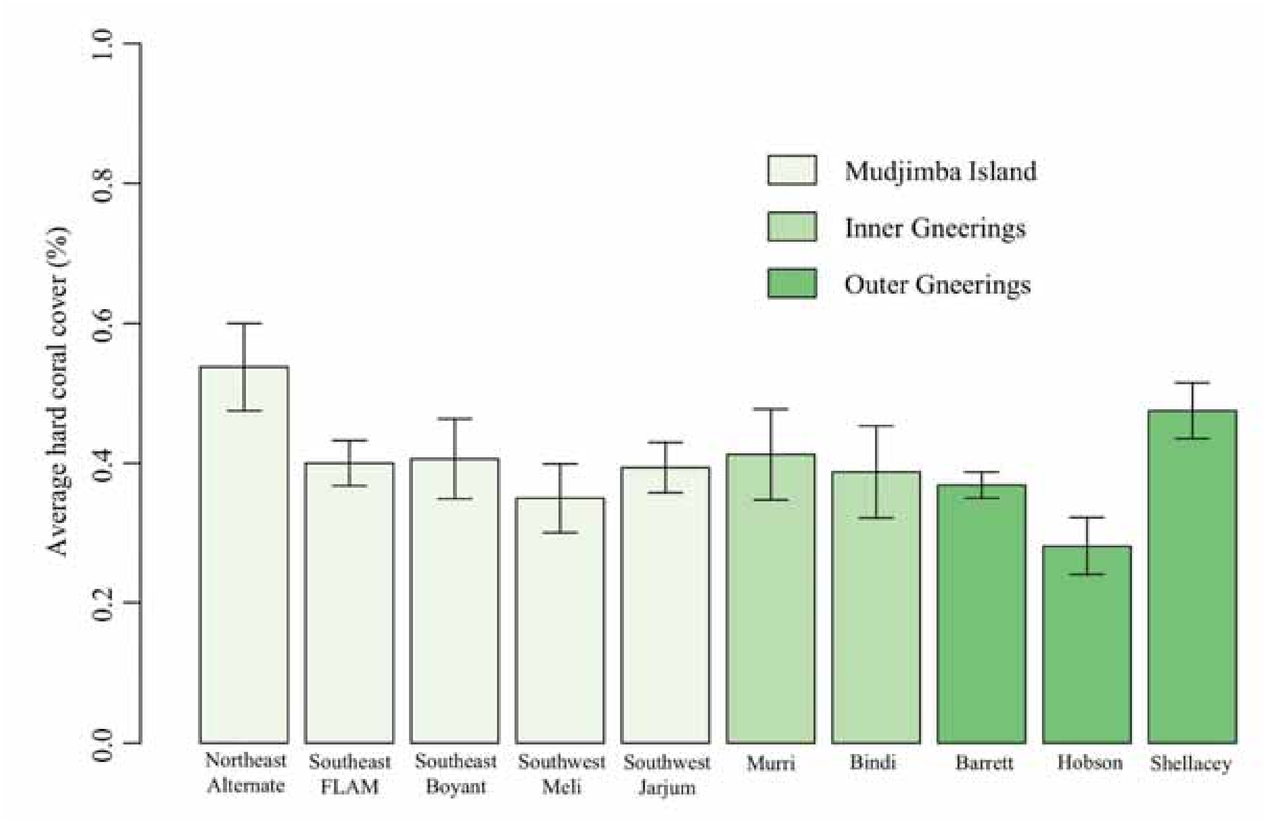
Appendix E: Dive Statistics

Dates	Number of divers	Dive location	Type of dive
13/03/2021 and 14/03/2021 (weekend)	19	North Stradbroke Island (Point Lookout)	training dives
27/03/2021 and 28/03/2021 (weekend)	22	North Stradbroke Island (Point Lookout)	training dives
24/04/2021	10	Mooloolaba	exploratory dive
30/07/2021 and 01/08/2021 (weekend)	10	Mooloolaba	surveys, mapping
19/09/2021	10	Mooloolaba	surveys, mapping
25/09/2021	10	Mooloolaba	surveys, mapping
06/11/2021	10	Mooloolaba	surveys, mapping
20/11/2021	10	Mooloolaba	surveys, mapping
19/02/2022	10	Mooloolaba	surveys, mapping

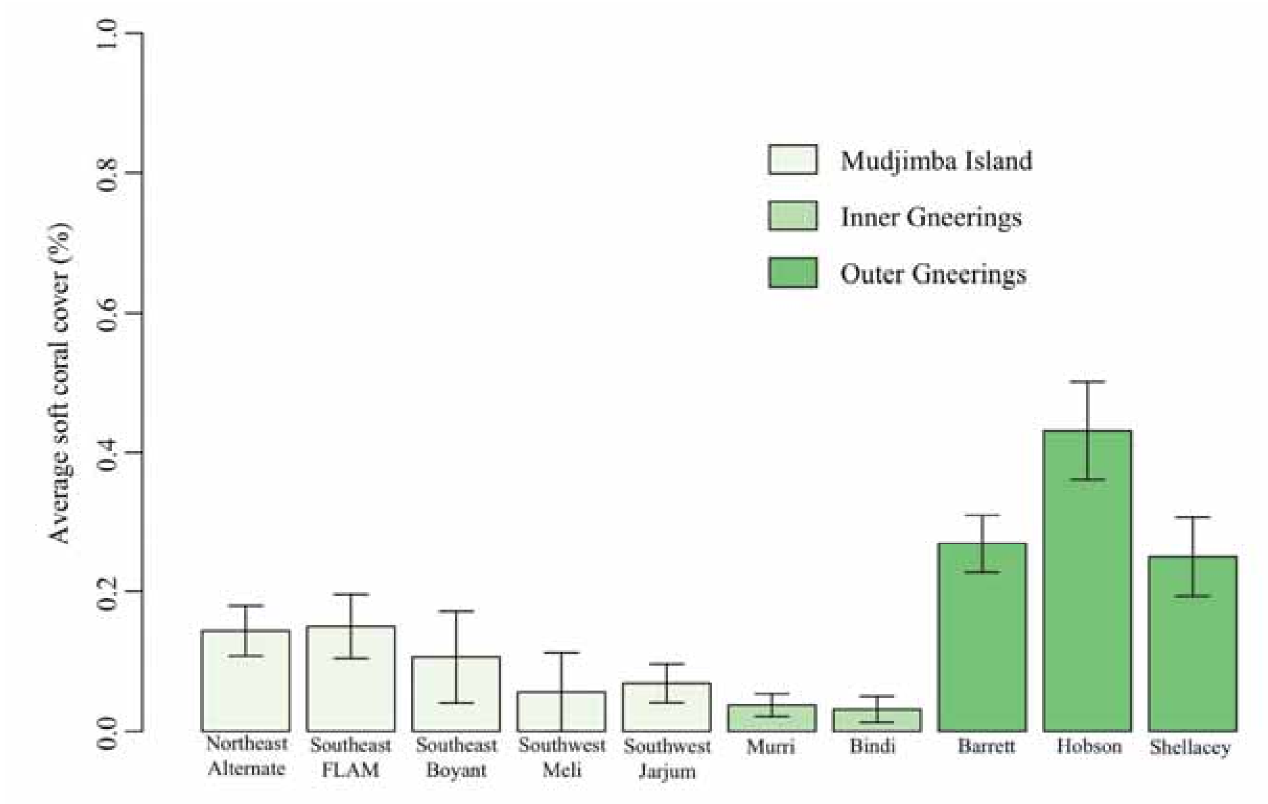
Appendix F: Additional Results Figures



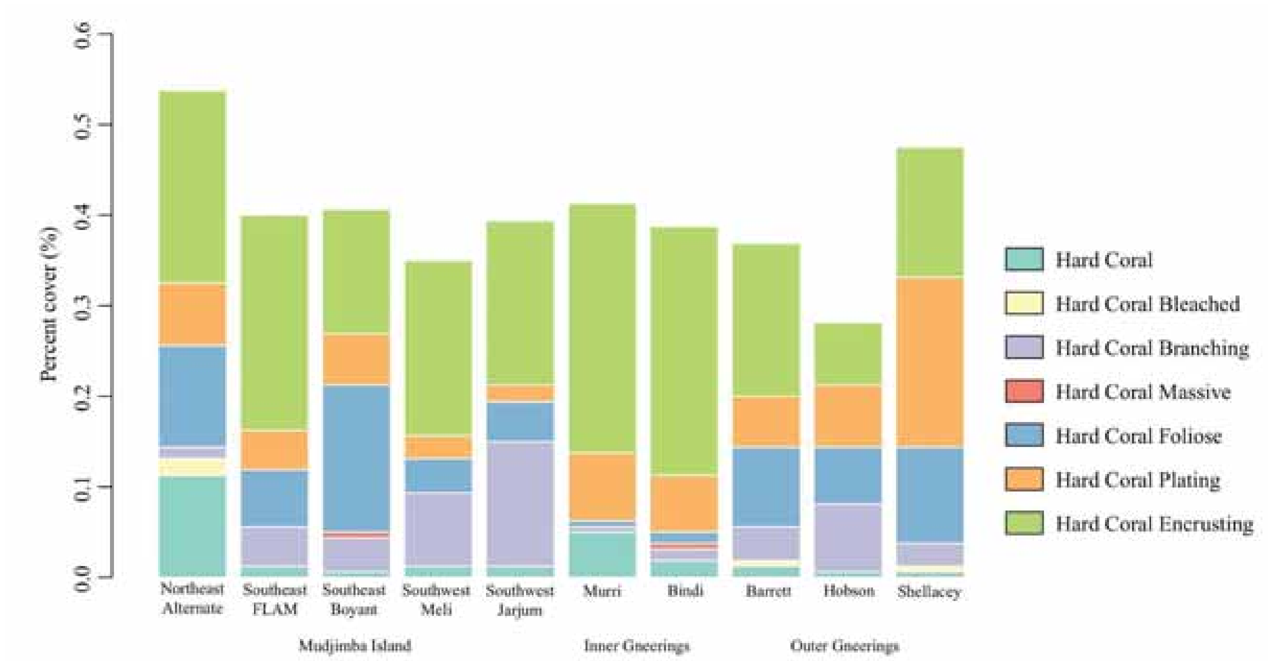
Stacked barplot of relative proportion of benthic groups per site. Values are averaged from each site's transects.



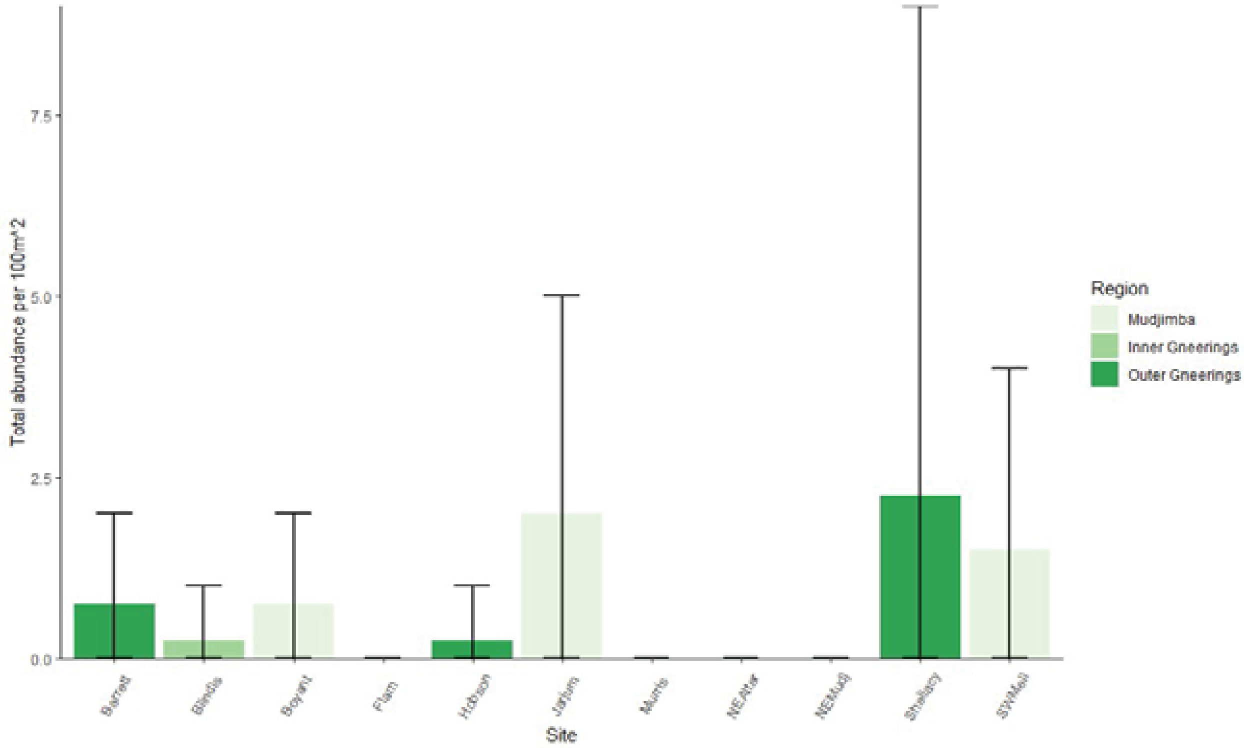
Barplot of averaged hard coral cover per site with Standard Error. Values are percent cover are averaged from each site's transects.



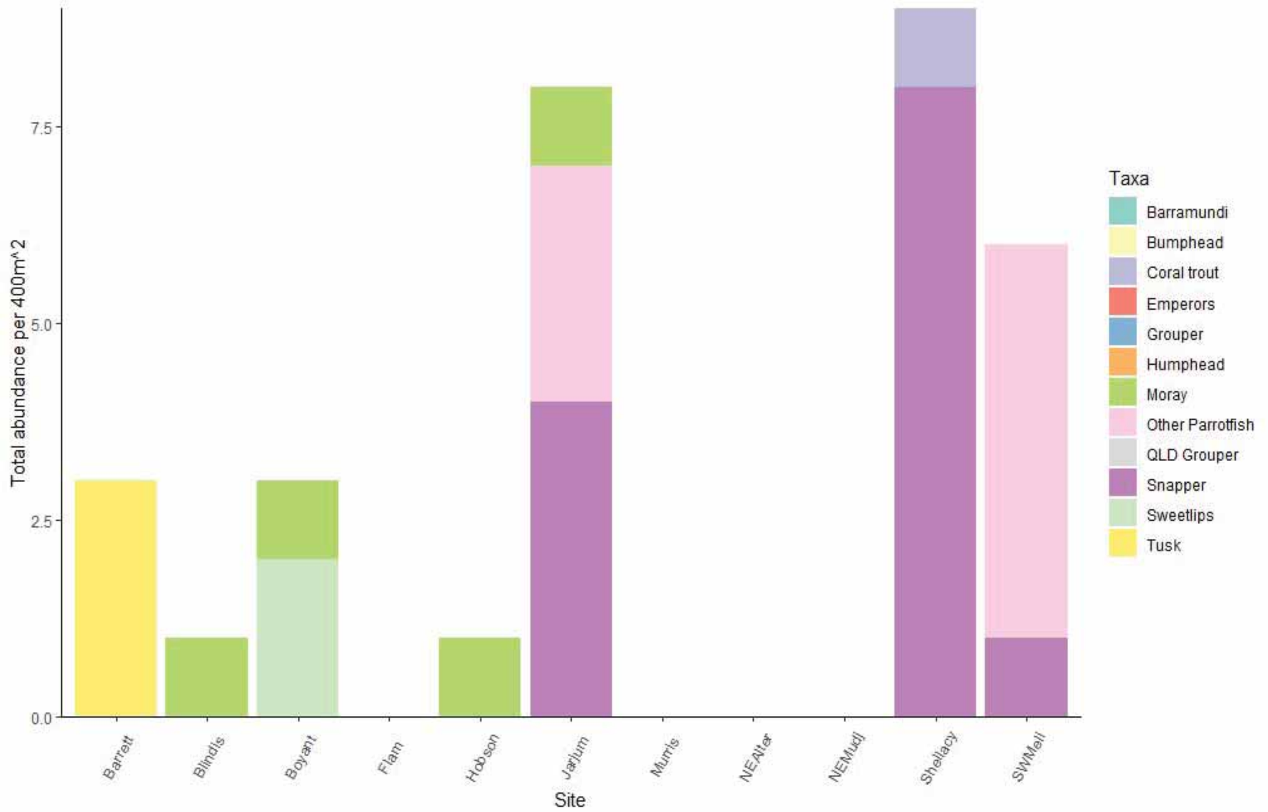
plot of averaged soft coral cover per area with Standard Error. Values are percent cover and averaged from each site's transects.



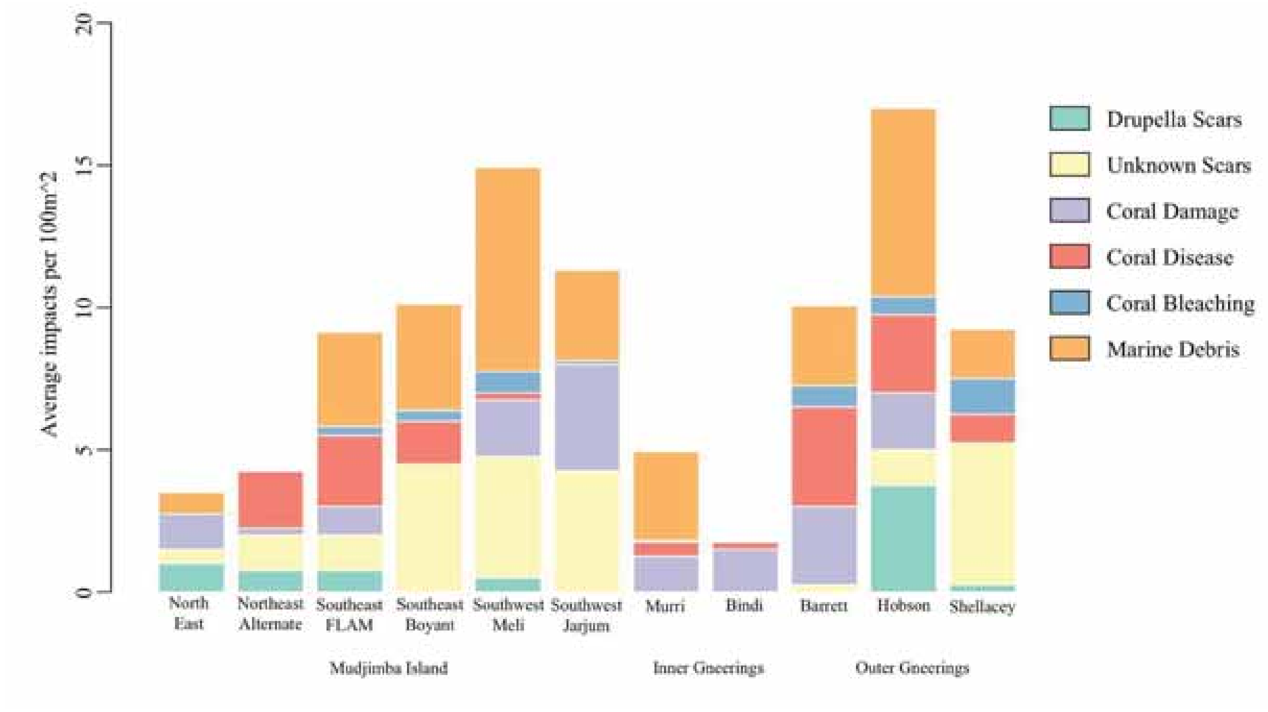
Stacked barplot of averaged hard coral cover per site and per hard coral type. Values are percent cover and averaged from each site's transects.



Average abundance of surveyed fish for the eleven sites at Mooloolaba reef (error bars indicate standard deviation).

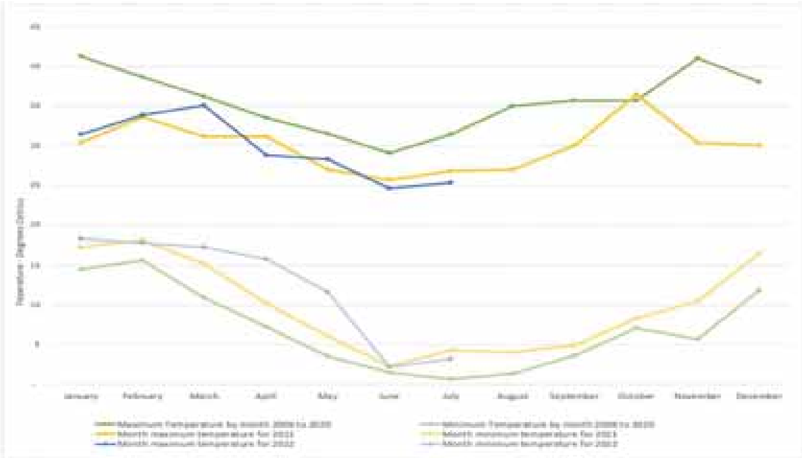


Total abundance of targeted fish taxa at each site surveyed



Stacked barplot of the number of impacts per MEAM site per 100m^2. Values are occurrence data and averaged per each site's transects.

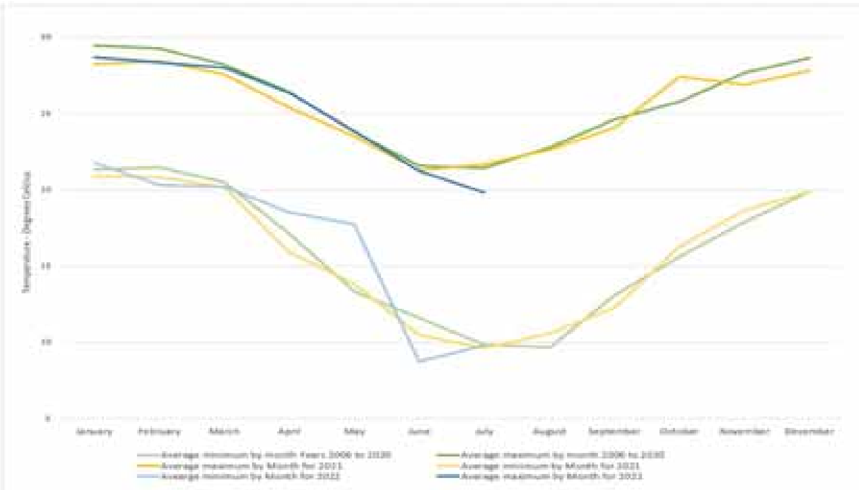
Appendix G: Environmental Parameters.



The graph shows the minimum and maximum temperatures recorded for each month over the period 2006 to 2020, along with the minimum and maximum per month for 2021 and 2022. i.e. this is the peak max and min for the month.

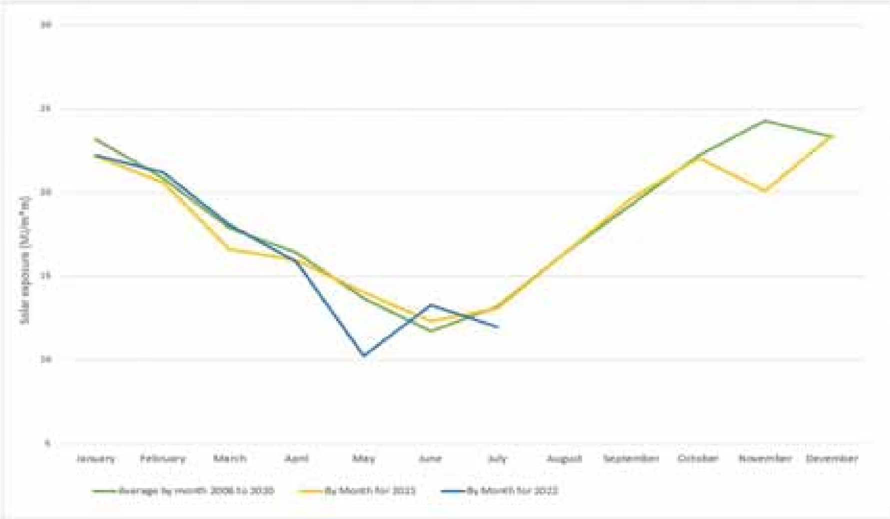
2021 and 2022 are broadly in-line with the long term recordings. Of note:

- A peak in October 2021, where the maximum October temperature exceeded the 2006-2020 recordings, and
- the period of March to May 2022 where the minimums are well above the 2006-2020 recordings. There is a corresponding dip in solar exposure, figure ??.



The graph shows the average minimum and maximum temperatures recorded for each month over the period 2006 to 2020, along with the average minimum and maximum per month for 2021 and 2022.

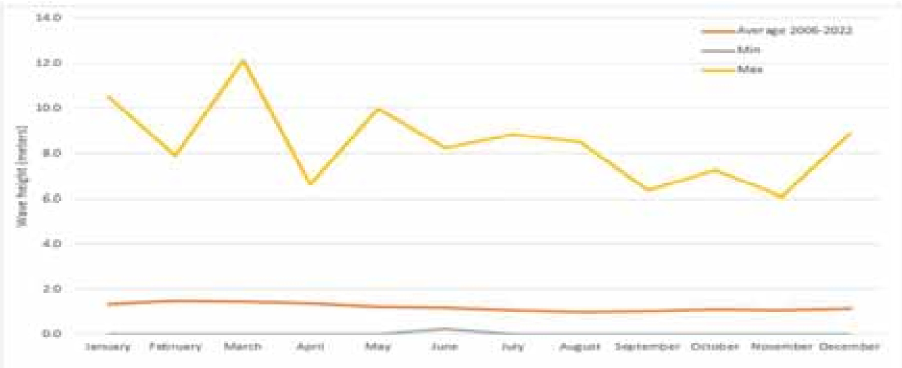
As per the peak maximum and minimum temperatures in figure above temperature for 2021 and 2022 are broadly in-line with the long term recordings. As per the peak graph this graph also shows the minimum for 2022 particularly in May higher than the long term average. Again this corresponds to the dip in solar exposure, figure above



The graph shows the long-term (2006-2020) monthly average solar exposure compared to the monthly average solar exposure for 2021 and 2022.

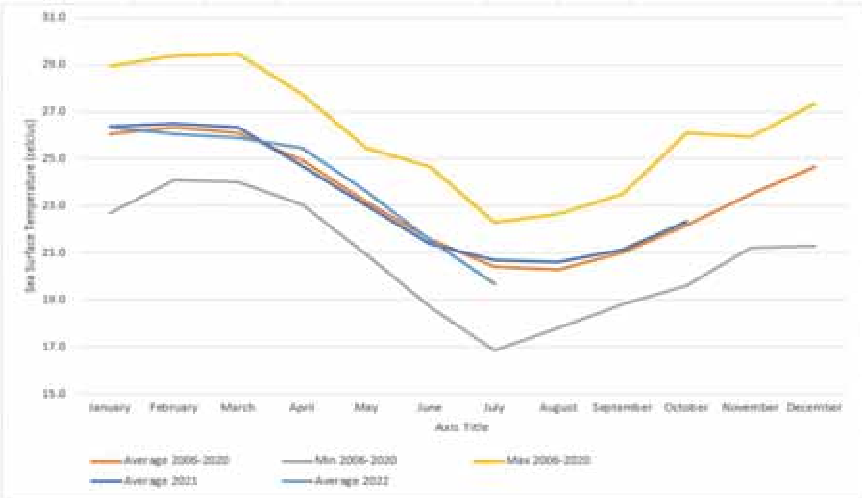
2021 and 2022 are broadly in-line with the long term recordings. Of note:

- November 2021 show a dip in average solar exposure and this does coincide with the significant rainfall of that month.
- May 2022 shows a dip in average solar exposure, this alings to a higher average minimum temperature for that month. Further analysis could show an alignment to cloud cover.



:The graph shows average wave height per month from 2006 to 2022, along with minimum and maximum wave heights recorded per month over the same period.

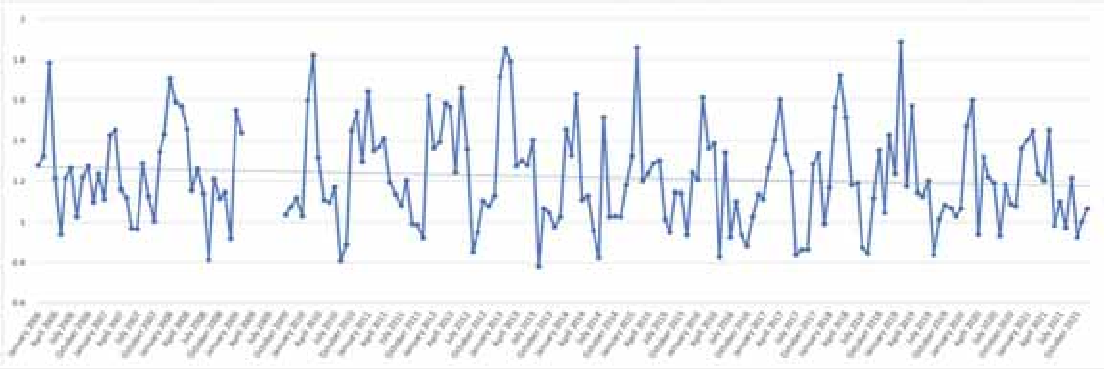
The average is under 2 metres for all months. Most months show there are times with no waves, June being the exception, but the minimum is still very low. The maximum wave heights are well above the average, so are likely evident for short time periods, ie during storms. There appears to be greater height and variance in the summer period, December to March.



The graph shows the long term average (2006-2020) sea surface temperature (SST) along with the monthly minimum and maximum SST for 2006-2020. This is compared to the monthly average for 2021 and 2022.

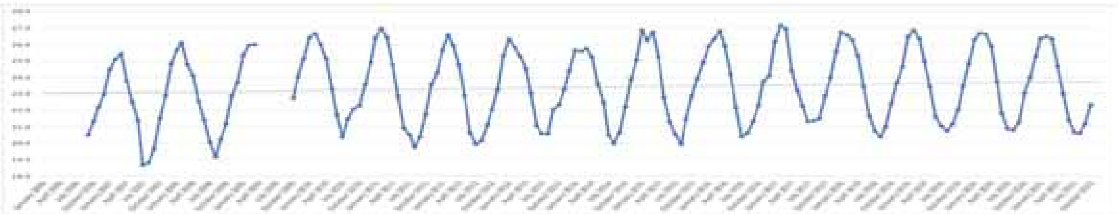
The average SST for long term, 2021 and 2022 show no significant variation to the long term average.

Appendix I: Long Term Charts (Trevor)



The graph shows the average wave height per month for 2006 to 2021.

The average monthly wave height shows that typically there is greater wave action over the summer months. Most waves will fit to a 1 metre to 1.5 metre range.



The graph shows the average sea surface temperature per month for 2006 to 2021.

The average monthly sea surface temperature shows, as expected, that the temperature has a constant seasonal variation, with summer (December to March) having the warmest temperatures. The trend line shows that there is an increase in sea surface temperature over the 2006 to 2021 period of about 1.5 degrees.

Appendix H: Mooring Options

Placing a private mooring on Mooloolaba reefs requires a marine park permit (from Queensland Parks and Wildlife Service- QPWS) and a buoy mooring authority (from Maritime Safety Queensland - MSQ). QPWS approval will depend on justification that the mooring, its installation and operation will cause the least damage to substrate when compared to alternatives. MSQ approval will depend on the mooring's location not causing a navigation hazard. Both mooring applications should be lodged together. Given its location, it would be beneficial to have a registered professional engineer or naval architect certify that the design is fit for purpose.

The Marine Park permit if approved, will require the permit holder to have public liability insurance of $20 million.

There are three mooring options to consider: 1. Private, 2. Public but privately funded, and, 3. Public.

Mooring Type	Private	Public (Privately Funded)	Public
Owner (liable)	Trust, joint dive shops, one dive shop, or dive club etc.	QPWS,	QPWS
Funding	Whoever is interested and wants to use the mooring	Money is donated privately sufficient to fund at least three years maintenance and installation	QLD Government
Maintenance (responsibility of owner)	Given its environmentally sensitive location, the marine park permit may specify who, (e.g. someone who belongs to the Board of Professional Engineers (RPEQ)) can carry out and/or certify the maintenance	Every three months, by appropriate service provider	Every three months, by appropriate service provider
Liability Insurance (Paid by owner)	$20 million	$20 million	$20 million
Mooring type: (refer to below)	Any class as approved by MSQ.	C class mooring	C class mooring
Users:	Only those with approval from the mooring owner; mooring is marked as limited access	Any user	Any user

Mooring Class	Colour Band	Max Wind Strength	Monohull Maximum Length	Multihull Maximum Length
Tender (T)	Brown	24 knots	6 metres	6 metres
Class A	Yellow	24 knots	10 metres	9 metres
Class B	Orange	34 knots	20 metres	18 metres
Class C	Blue	34 knots	25 metres	22 metres
Class D	Red	34 knots	35 metres	30 metres

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