Final Report on Project Supported by Paddy Pallin and Royal Zoological Society of NSW Science Grant

1. PROJECT IDENTIFICATION

1.1 Project Title:

The role of calcareous macroalgae *Halimeda* in provision of inter-reef benthic habitat and structural complexity in the northern Great Barrier Reef

1.2 Administering Organisation

Queensland University of Technology

1.3 Project Leader and Participants

Mardi McNeil – Phd Candidate, School of Earth, Environmental and Biological Science
Luke Nothdurft – PhD Supervisor

2. PROJECT DESCRIPTION & OBJECTIVES

2.1 Project Summary

Coral reefs comprise only about 7% of the 344,000 km^2 Great Barrier Reef Marine Park, with much of the remaining area made up of inter-reef seabed habitats. In the northern Great Barrier Reef, vast meadows of the calcareous macroalgae genus *Halimeda* cover over 6000 km^2 of inter-reef benthic habitat, up to 25% of the continental shelf in some areas. *Halimeda* meadows and bioherms are recognised as contributing to the Great Barrier Reef World Heritage Outstanding Universal Value and are:

- The most extensive, actively accumulating *Halimeda* deposits in the world.
- The second largest living structure on the Great Barrier Reef, providing habitat connection between reef and inter-reef areas.
- A vast calcium carbonate sink and an important component of the marine carbon cycle on the reef.
- Potentially a complete archive of chemistry, recording environmental change over the past 10,000 years.

Crucially lacking is baseline data of the benthic biodiversity in this inter-reef habitat, upon which to measure any future impacts due to climate change, ocean acidification, potential disruption to ocean circulation, and changes to nutrient upwelling.

2.2 Summary of original objectives

To assess the benthic invertebrate community composition, relative biodiversity, and habitat structural complexity of *Halimeda* meadows in the northern Great Barrier Reef using marine robotics, geophysics, visual 3D photogrammetry, and ecoacoustics, thus providing reef managers with baseline information to address knowledge gaps identified by the Great Barrier Reef Marine Park Authority in their 2009 and 2014 Outlook Reports.

3. PROJECT OVER DURATION OF FOUNDATION GRANT

3.1 Have there been any changes to the project? If yes give details

There have been no changes to the project aims, research plan, or budget. We have experienced some challenges in the field which are addressed at 3.4, but these have not resulted in any changes of objectives or project direction.

3.2 What were your research plans and objectives for the period covered by this report? (150 words max)

The previous Progress Report documented plans and objectives for the fieldwork which was supported by this funding.
In the period since the Progress Report I have been writing up a manuscript and compiling figures and tables for scientific peer-reviewed publication.

3.3 Did the research project proceed as planned? What have you achieved over this period? Outline the research findings to date

Research findings to date (unpublished):

- The acoustic sonar data show higher reflectance at depth, and lower reflectance on the bioherm tops, meaning harder, rougher surfaces at depth and smoother surfaces on shallower bioherm tops
- A temperature gradient was recorded with depth across the *Halimeda* meadows
- The *Halimeda* meadows are a mix of *Halimeda* species as well as sub-dominant *Caulerpa* (another green macroalgae)
- Invertebrate taxa within *Halimeda* meadows is dominated by sponges, followed by molluscs and echinoderms
- Upright growing macroalgae (*Halimeda* and *Caulerpa*) and sponges provide structural height, complexity, and shelter for other smaller organisms.
- The calcareous sediment within the *Halimeda* meadows is highly bioturbated, indicating high infaunal activity.
- The invertebrate community assemblages on *Halimeda* bioherms is significantly different in composition to inter-reef sites outside of *Halimeda* bioherms at similar latitudes.
- Halimeda bioherms host up to 3.5 times higher benthic biodiversity (species richness) than non-bioherm inter-reef sites.
- We found good evidence of habitat connectivity between Halimeda bioherms and coral reefs for a number of mobile fish species.

3.4 Have you experienced any difficulties that have affected the progress of the research project? If yes give details (150 words max)

No.

3.5 What are your research plans and objectives, including publication plans, for the coming year? (150 words max)

Ongoing work during 2019 includes writing up the physical habitat structural morphometrics and preparing a manuscript and PhD thesis chapter based on this.

4. ACADEMIC OUTPUTS

4.1 Publications and other academic outputs directly related to this project.

My contribution on Halimeda bioherms to the Great Barrier Reef Marine Park Authority 2019 Outlook Report is published.
I have presented work at the Ecology Society of Australia conference and the International Conference on Paleocoeanography
Manuscript for publication is ready to submit.

4.2 Evidence of scholarly impact and contribution. Is there evidence that this research project is having/has had an impact in the research field or the broader public domain? *Include examples of formal training (PhD /Masters) as well as other training.*

If yes, give details

I was invited to present a talk at the “Pint of Science” events in Brisbane this year.
I have been invited to contribute a research article on *Halimeda* bioherms as a sedimentary system, to the Open Access journal “The Depositional Record”.

4.3 End-user interaction and other project outcomes If there are examples of the impact of this research Project not covered in item 4.2 above please provide details.

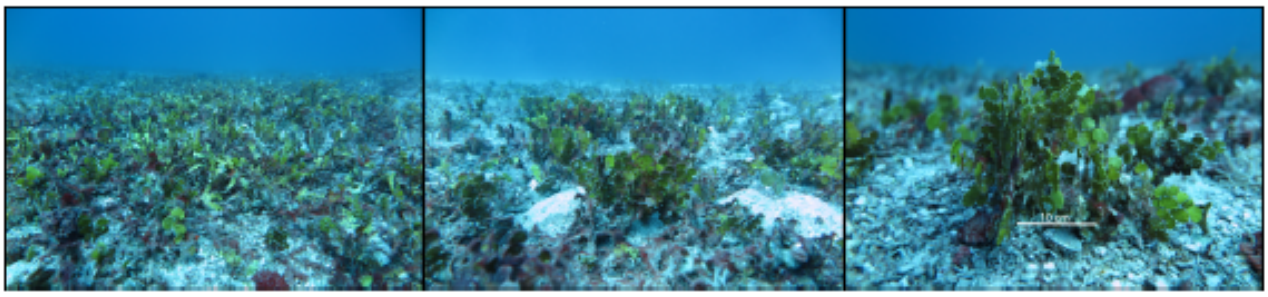
The preliminary work we have done on this project has resulted in the successful granting of ship time for a full marine survey on the CSIRO Marine National Facility R/V *Investigator* in 2020. This will result in a wealth of new data and new sampling in these locations as well as high profile publications and science communication outputs. Additionally, we have been successful in securing a $150K science grant from The Ian Potter Foundation to support the the *RV Investigator* voyage and post-cruise science.

5. ATTACHMENTS & OTHER MATERIAL

I will forward a copy of the current manuscript once it is accepted for publication.
I am happy to provide any images or powerpoint slides to the Society.
I have copied below a draft of an article that appeared in the Australian Coral Reef Society annual newsletter.

Getting to know the neighbours... Halimeda bioherms in the inter-reef seafloor of the GBR

By Mardi McNeil
(Queensland University of Technology)



Coral reef ecosystems are varied and complex, with many connected habitats. Some of these neighbouring inter-reef habitats may be in deeper water, remote, logistically challenging to access and survey, and lack the colourful coral colonies and charismatic fishes of their shallow reef neighbours. Consequently, these deeper inter-reef habitats are not as well-studied, and have been somewhat overlooked as productive and diverse ecosystems. However, the inter-reef seafloor of the Great Barrier Reef Province comprises a variety of geomorphic features, including submerged rocky shoals and pinnacles, carbonate sands, palaeochannels, deltaic fans, submarine canyons, drowned reef terraces, and *Halimeda* bioherms on the outer continental shelf.

Recent efforts to develop a high resolution digital depth model for the entire Great Barrier Reef World Heritage Area (Project 3D-GBR) has combined multibeam sonar, satellite remote-sensing and lidar bathymetry survey data into a single bathymetric grid (gbr30). Development of this high resolution bathymetry DEM has revealed the complex topography and detailed structure of many of the deep inter-reef habitats for the very first time. One such habitat is the vast

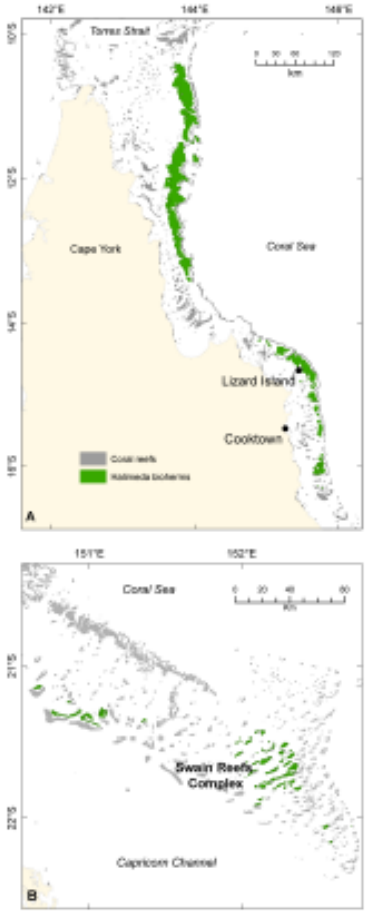


FIGURE 1. DISTRIBUTION OF MAPPED *HALIMEDA* BIOHERMS IN A) NORTHERN GREAT BARRIER REEF, AND B) SWAIN REEFS COMPLEX, SOUTHERN GREAT BARRIER REEF. BIOHERMS WERE IDENTIFIED AND BOUNDARIES DELINEATED FROM HIGH RESOLUTION MULTIBEAM AND LIDAR BATHYMETRY DATASETS FROM PROJECT 3D-GBR. (CREDIT: HTTPS://DOI.ORG/10.6084/M9.FIGSHARE.7506251.V2).

Halimeda algal bioherms of the Great Barrier Reef outer continental shelf (Figure 1), and the subject of my PhD project.

"Bioherm" is a geological term which describes an in situ (grown in place) build-up of biogenic calcium carbonate sediment or limestone, with positive relief above the surrounding seafloor. The *Halimeda* bioherms have built up over millennial timescales since the end of the last ice-age, from the disarticulated skeletons of the calcareous macroalgae genus *Halimeda*. These complex geomorphic features can be up to 20 m thick, span over 6,000 km2 and six degrees of latitude of inter-reef seafloor in the northern GBR, and are the second largest living structure on the Reef. *Halimeda* bioherm morphology is structurally complex, appearing like large fields of donut shaped rings and reticulate honeycomb patterns (Figure 3). This complexity may have the potential to support a more diverse community of benthic fish and invertebrates than has previously been recognised.

The aims of my PhD project include reconstructing the spatial and temporal development of the *Halimeda* bioherms throughout the Holocene using radiocarbon dating

of *Halimeda* sediment cores and analysis of seismic sub-surface data; and investigating the role of *Halimeda* bioherms in the provision of deeper inter-reef habitat for fish and benthic invertebrates. The ACRS Terry Walker Award has provided funding for fieldwork towards this aim. In 2018, I lead two field trips to the Lizard Island Research Station, where *Halimeda* bioherms are located on the continental shelf between the island and the outer barrier reefs. It was a real thrill to finally dive on the *Halimeda* bioherm tops and see the vast green carpet of *Halimeda* algal meadows as far as visibility would allow. During fieldwork we surveyed the surface and sub-surface of the *Halimeda* bioherms using sidescan sonar, acoustic sub-bottom profiling, AUV water chemistry sensors, and ROV video, as well as collecting sediment and water samples for chemical analysis. I am currently writing up my findings from the two Lizard Island field trips, and drafting manuscripts for the first two publications from this work.

A SEA OF YELLOW: PREPARING THE SURVEY EQUIPMENT FOR FIELDWORK AT LIZARD ISLAND RESEARCH STATION; EDGETECH SUB-BOTTOM PROFILER (LEFT) AND IVER ECOMAPPER AND BLUEROV2 (RIGHT). © MARDI MCNEIL

During 2018 I also presented preliminary results of this study at an international sedimentology conference in Quebec, Canada, as well as the Australian Marine Science Association and Ecological Society of Australia conferences. Unfortunately, an attempt to visit the *Halimeda* bioherms known from the southern GBR Swain Reefs was thwarted by bad weather, however our research group has been awarded ship time on the CSIRO Marine National Facility R/V Investigator, to conduct a new survey in mid-2020.

I would like to acknowledge and thank the support of ACRS via the Terry Walker Award, and the Royal Zoological Society of NSW for the valuable contribution to cover fieldwork-related expenses; my PhD supervisors Dr Luke Nothdurft, Dr Jody Webster, and Dr Oliver Gaede; and collaborators Dr Robin Beaman and Dr Dirk Erler. I would also like to thank Dr Lyle Vail and Dr Anne Hogget and acknowledge the Australian Museum Lizard Island Research Station staff for support with fieldwork logistics.

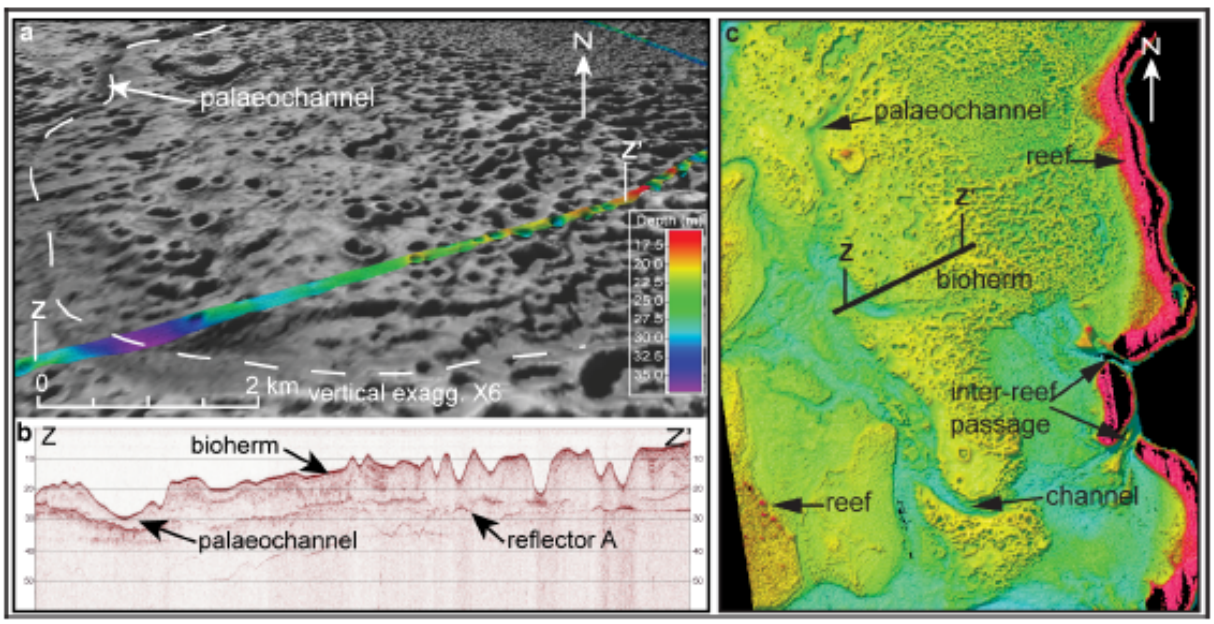


FIGURE 3. THREE-DIMENSIONAL VIEW OF A) *HALIMEDA* BIOHERM COMPLEX IN THE NORTHERN GBR, WITH A 2 M MULTIBEAM DATA (RAINBOW SCALE) OVERLAID ON 25 M LIDAR DATA (GREYSCALE), B) SUB-BOTTOM PROFILE BETWEEN POINTS Z–Z' SHOWS DISTINCT *HALIMEDA* BIOHERM MORPHOLOGY ACCRETING ABOVE A PROMINENT SEISMIC REFLECTOR. C) THE 25 M LIDAR DATA ACROSS THE SAME AREA CLEARLY REVEALS BIOHERMS, REEFS, AND PALAEOCHANNELS. SOURCE: MCNEIL *ET AL.*, 2016. (HTTPS://DOI.ORG/10.1007/S00338-016-1492-2). © MARDI MCNEIL