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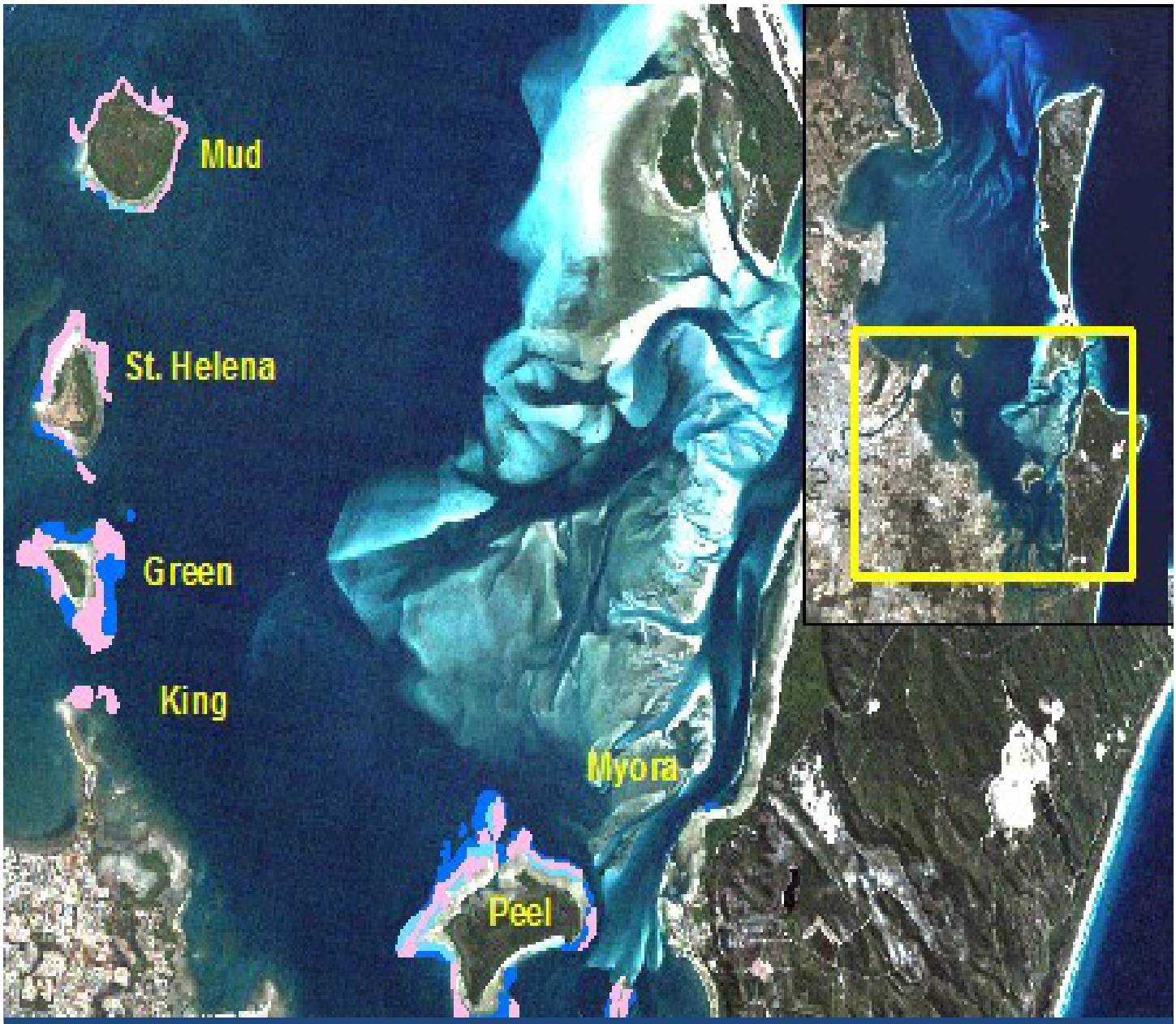

Phase 1: Benthic Inventory of Reefal Areas in Central Moreton Bay, Queensland, Australia

Report prepared for: Healthy Waterways

By: Chris Roelfsema[1,2], Jennifer Loder[2], Rachel Host[2], and and Eva Kovacs[1,2]

1) Remote Sensing Research Centre (RSRC), School of Geography, Planning and Environmental Management, The University of Queensland, Brisbane, Queensland, AUSTRALIA, 4072

2) Reef Check Australia, Level 2 183 North Quay Brisbane, Queensland, AUSTRALIA 4000

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Project Aim and Deliverables

Project Aim:

This collaborative citizen science project between Reef Check Australia, The University of Queensland Remote Sensing Research Centre and Healthy Waterways will produce benthic inventories for eight key subtropical reefal areas in Central Moreton Bay.

Objectives:

- Train volunteers to collect field data that describes reef composition of some of the notable reefal areas within Central Moreton Bay, using adapted Reef Check Australia benthic habitat categories.
- To produce an inventory of reef habitats for Central Moreton bay (winter 2015) using spot check field data and a 2014 ZY-3 satellite image, following a similar approach to that conducted in 2004 (Roelfsema et al 2009).
- Compare findings for 2015 with baseline coral extent maps developed in 2004.

Deliverables:

- A report describing the methods used to produce benthic habitat inventories for the reef areas in central Moreton Bay.
- A digital GIS ready file in WGS84, UTM zone 56 outlining the extent of the reef inventory areas.

Executive Summary

Overview

Moreton Bay is a transitional area where tropical, sub-tropical and temperate marine species coexist, resulting in unique habitat and wildlife communities (Harriot et al. 1999, Perry and Larcombe 2003, Beger et al. 2014). The subtropical reefs of Moreton Bay are considered marginal and the building of reef structures is generally limited (Fellegara & Harrison 2008), yet the region hosts notable coral communities (Harrison et al 1998, Wallace et al 2009).

The health of Moreton Bay corals are key indicators of water quality and overall catchment health. However, more data is needed regarding the spatial distribution and condition of this important natural resource. The proximity of these reefs to the rapidly growing South East Queensland (SEQ) region highlights the need to understand linkages and impacts across the catchment.

The 2004 Moreton Bay coral reef maps (source: Queensland Environmental Protection Agency) form a key component of natural resource management decisions for the area. In 2015, a collaborative project to re-map key coral habitat areas was undertaken by Reef Check Australia, The University of Queensland Remote Sensing Research Centre and Healthy Waterways (Queensland Environmental Protection Agency in 2004). The 2015 project engaged trained volunteers to collect benthic habitat field data that allowed for review and revision of the 2004 coral spatial extent baseline.

Results

Benthic habitat inventories were conducted for eight reef areas in Central Moreton Bay. These eight sites do not cover the full extent of the areas mapped in 2004, but capture some of the notable areas of reef in Central Moreton Bay. The inventories for each reefal area were based on georeferenced spot check field data collected by volunteer teams, which was overlayed on the ZY-3 imagery by Remote Sensing Research Centre staff. Polygons were digitised around reefal areas and then manually assigned one of three categories (Coral on reef matrix, Soft Coral on Sand/Rubble, and, Algae on sand/rubble) based on field data and expert image interpretation. High resolution satellite imagery, more advanced mapping software and increased field knowledge enabled more refined habitat assessments than the 2004 baseline maps.

This citizen science project has generated a multi-purpose dataset describing the spatial extent and inventories of several of the key reefs in Moreton Bay. Reef Check Australia reef health condition surveys were conducted at 8 locations across 5 reef areas, providing additional information regarding habitat condition. This data will contribute directly to the Healthy Waterways Report Card, helping to evaluate the effectiveness of catchment-level natural resource management investments and support evaluation of NRM project outcomes. The revised spatial data set can offer a practical tool for best-practice decisions relating to management in the catchment and the Bay. Images of habitat maps, as well as a digital GIS-ready file will be made available to the public though on line data portal (e.g. www.pangaea.de, www.acef.tern.org.au/portal/) or on request.

Recommendations

- The 2015 benthic inventory of reefal areas from this study should not be directly compared with the 2004 inventory to document change. Efforts were made to visit similar locations and collect comparable information in 2015, but visual inspection of the 2004 study suggests courser digitising, resulting in less fine-scale detail and the exclusion of some habitat areas in the 2004 inventory. It is expected that the 2015 results more closely represent the spatial extent of coral areas and should be treated as a revised baseline. Additional investigations could be made to seek high spatial resolution imagery from 2004 (if available), in order to strengthen opportunity for comparison.

- Phase 1 of the project focused on eight reefal areas within the central Moreton Bay, hence some reefal areas have not been mapped. Additional areas to map in the future include fringing reef around the Redland area (Wellington Point, Raby Bay, Victoria Point and Coochimudlo) and reef habitat around Redcliffe. There appears to be both science and management support for access to a dataset that covers all reefal areas surveyed in 2004. This activity should be undertaken within 2016 to provide a more comprehensive account of reefal areas. To provide maximum value and context for science and management applications, this dataset should sit within a larger and more comprehensive habitat map for Moreton Bay.

- Whilst coral habitats do not expand at rapid rates, their decline may be rapid, dependent upon the stressors placed upon them. The SEQ region has a rapidly growing population, and pressures upon the Bay (such as pollution, extreme events, tourism, etc) are likely continue growing into the future (Gibbes et al 2014). As such, repeat monitoring of these areas is recommended to enable prevention, intervention or prediction of loss of these natural resources. This should include annual detailed monitoring to assess reef condition (e.g. Reef Check Australia and CoralWatch surveys), and repeating an extensive habitat mapping program every 5 years, such as presented in this report.

- The inventories of reefal areas in Central Moreton Bay should be distributed and utilised to inform science, management and community. Potential applications include integration in the annual Healthy Waterways Report Card and/or SEQ Catchments natural resource management planning. Communications activities to share these resources with the wider community would be beneficial to promote appreciation, awareness and conservation of these habitats.

1 Background

Moreton Bay encompasses unique subtropical reefs and a Ramsar wetland. The subtropical reefs here are considered marginal (Perry & Larcombe 2003) and the building of reef structures is generally limited by environmental factors such as light, temperature, water chemistry and/or turbidity (Fellegara & Harrison 2008, Kleypas, McManus & Menez 1999). Yet the region hosts notable coral communities (Harrison et al 1998, Wallace et al 2009).

Moreton Bay is a transitional area where tropical, sub-tropical and temperate marine species coexist (Harriot et al. 1999, Beger et al. 2014), resulting in unique habitat and wildlife communities. The Bay is internationally recognized for biodiversity and ecological significance. There have been 64 species of scleractinian corals (including 59 reef building species) recorded in the inner Bay, (enclosed by North and South Stradbroke, Moreton and Bribie Islands) and 125 species recorded in the outer bay (on the ocean side of the islands) (Narayan and Pandolfi 2010). Beyond the unique species assemblages and seasonal marine life aggregations (including mantas, leopard sharks and grey nurse sharks) Moreton Bay has critical cultural, social and economic value making it an important natural resource

Moreton Bay's reefs are located adjacent to one of Australia's fastest growing cities, with a current population of two million. Conditions in the bay have been classified as "modified" or "extensively modified," with sediment and nutrients being the major pollutants of concern (Gibbes et al 2014). Several rivers flow into the bay, and over 30 major sewage plants and industrial wastewater treatment plants discharge directly into the bay (Gibbes et al 2014). The majority of sediment inputs (suspended silts and clays) into the bay are released through episodic flows caused by high rainfall events. This results in western and southern areas having the highest sediment content, highest nutrient availability, and lowest water clarity (Fellegara et al 2013).

Long term exposure to eutrophication, sedimentation and heavy fishing pressure may have selected for ecological resistance in corals and improved the capacity of the reefs to withstand disturbances (Olds et al 2014). Moreton Bay was previously dominated by *Acropora* species until European settlement rapidly increased the input of nutrients into the bay, but now massive corals (*Cyphastraea, Favia* and *Goniopora* species) dominate (Zann et al 2012).

Compounding pressures from both local influences and climate change result in complex interactions with unclear implications for reef communities, perhaps particularly so for subtropical communities (Munday et al. 2009, Figueira & Booth 2010, Graham et al. 2010, Lybolt et al. 2011). These issues will intensify with population growth in SEQ, as the population is projected to reach four million people by 2026 (QOESR 2011). As such, long-term monitoring of these habitats is critical (Wallace et al. 2009).

The proximity of these reefs to a developing catchment supports the need to understand impacts and interconnectivity across the catchment. The health of the coral's in Moreton Bay provide an indication of the water quality in the Bay and the overall health of the catchment. However, limited long-term data on the distribution and health of the coral's is available.

Maps of the coral areas of inshore Moreton Bay (1500 km^2) were produced in 2004 (source: Queensland Environmental Protection Agency). These maps were based on a combination of spot check surveys and manual digitising using Landsat satellite imagery as a guide. The 2004 coral spatial extent maps have formed a key component of natural resource management decisions for the region, but have not been updated for more than a decade.

Since 2009, Reef Check Australia has conducted reef health surveys at five sites in the central Moreton Bay (Goat Island, Peel Island (North and East), Macleay Island, and Myora Reef). Trained surveyors assessed substrate cover (e.g. coral, algae, rock), invertebrate composition, and reef impacts (Hill & Loder 2013) using the globally standardised reef health survey method. The findings from these surveys are summarised in annual reports which are made publically available online via the Reef Health Database (http://www.reefcheckaustralia.org/data.html). It was determined that additional information regarding spatial distribution of reef habitats would complement this reef condition assessment approach and that Reef Check substrate categories could be adapted to suit field data collection and classification.

2 Study Site, Data Collection and Methodology

2.1 Overview of Methods, Study Site and Data Sets

Moreton Bay is located in South East Queensland, Australia (27°15' S, 153°15' E), and covers an area of 1,582 km^2. It is a partially enclosed, relatively shallow embayment, bounded to the east by Moreton and Stradbroke Islands (Figure 1). The Brisbane metropolitan area has a current population of two million and is located on the western shores of the Bay. The water depth in Moreton Bay varies and can be up to 30 m deep in some shipping channels, with a semi-diurnal tidal range of approximately 1.7 m.

Coral habitats are distributed mainly in the central Bay, predominantly in shallow water (above 3 m Lowest Astronomical Tide (LAT)), and they are characterised by mixture of soft/hard coral and algae types. The largest area of reef in Moreton Bay is located around Peel Island (Figure 1). Relatively small fringing reefs occur (compared to the Great Barrier Reef) around the islands of the central Moreton Bay. The focus of this study was the reef areas around Mud, Saint Helena, Green, King, Macleay, Goat, and Peel Islands, and, Myora Reef.

The study involved the creation of maps that present a benthic inventory for reefal habitat areas in Central Moreton Bay. In this report, the term maps is used to describe spatial presentations of benthic inventories for reefal habitats only. These maps do not present benthic inventory information for other habitat types, and this should be considered in interpretation. The maps displayed in this report were created through manual digitising and class assignment of reef areas guided by overlaying field data on satellite imagery.

Figure 1: Red lines represent the extent of Moreton Bay reef areas mapped in 2004 (Queensland Environmental Protection Agency 2004, Olds et al 2012)

2.2 Field Data Collection

Field data was collected using spot check surveys. Data collectors included volunteers trained in Reef Check Australia survey techniques, with demonstrated ability of the identification of benthic habitat types. Training for spot check survey methodology was provided by the staff from the Remote Sensing Research Centre, whom are also trained in Reef Check Australia survey methods.

Spot check surveys were carried out at 350 sites to provide information for benthic habitat mapping at eight reef areas. Spot check surveys were carried out by trained volunteers who recorded the major benthic cover categories and the percentage composition of those categories at each site based on modified Reef Check Australia survey methodologies. Observations were conducted by snorkellers, or, from the boat using a drop video camera or underwater viewer (depth dependent).

Site locations were chosen by revisiting the 2004 survey sites where an assessment was made to determine the edge between habitats. At this location, a spot check was performed and a GPS waypoint created to record exact location and to enable overlay of the field data on the satellite imagery during the mapping process.

At each spot check location a snorkeler entered the water and swam 10-20 m and estimated percent composition of the three dominant substrate types present at that site (from a possible 30 substrate types) to the nearest 5%. The presence of coral, even if <5%, was recorded. The condition of the corals at each of the sites was noted (bleaching, damage, etc). Where feasible, areas between individual spot check locations were observed from the boat if water clarity permitted, or alternatively, by using a viewing bucket to identify habitat changes and bottom composition.

The major categories observed included:

- **Hard Coral form:** branching (HCBR), encrusting (HCE), foliose (HCF), massive (HCM), plate (HCP) or other hard coral if form undetermined or mixed growth forms (HC)
- **Soft Coral form**: ornate (SC), leathery (SCL) or Zoanthid (SCZ)
- **Sponge**: (SP)
- **Algae type**: *Asparagopsis* (ASP), *Lobophora* (MAL), *Padina* (MAP), *Turbinaria* (MAT), *Sargassum* (MAS), Epiphytic (MAE), other (MA)
- **Substrate type**: Rock (RC), rock with turf algae (RCTA), rock with coralline algae (RCCA), rubble (RB), sandy rubble (SDRB), sand (SD), silty sand (SISD), silt (SI), sandy silt (SDSI)
- **Seagrass**: *Cymodocea serrulata* (SGCS), *Halodule uninervis* (SGHU), *Halophila ovalis* (SGHO), *Halophila spinulosa* (SGHS), *Syringodium isoetifolium* (SGSI), *Zostera muelleri* (SGZM)
- **Percentage cover** of bottom type which was estimated to the nearest 5%.

The major benthic categories and their percent cover were recorded in the field and entered into a spread sheet with the GPS position for each spot check location.

2.3 Mapping Method

Georeferenced spot check field data collected by volunteer teams was provided in spreadsheets to Remote Sensing Research Centre staff for mapping. The field data was overlayed on a 2014 ZY-3 satellite image, and, guided by the field data and expert analysis of the satellite imagery, polygons were digitised around reef areas (defined as areas where coral had been sighted). Although the ZY-3 imagery was captured in June 2014, it was assumed that the reef areas had not changed dramatically over a 12 month period. ZY-3 imagery was considered ideal as it has pixel size of 5 m x 5 m and revealed a high level of detail. Additionally, it has a swath with of 50 km, hence all of the central Moreton Bay sites are captured within one image.

Each of the digitised polygons were assigned one of three categories, based on field data and expert image interpretation. These categories were:

1) **Coral on reef matrix:** These included areas where spot check field data points were assigned a category of moderate or higher hard coral cover (roughly >25%) on a consolidated surface (e.g. reef matrix / rock) present in areas that are homogenous in colour and texture identified in the Zy3 satellite imagery at the specific field location.
2) **Soft Coral on Sand/Rubble:** These included areas where spot check field data points were assigned a category of moderate or higher soft coral cover (roughly >25%) on an un-consolidated surface (e.g. on a sandy/rubble) present in areas that are homogenous in colour and texture identified in the ZY3 satellite imagery at the specific field location.

3) **Algae on sand/rubble** These included areas where spot check field data points were assigned a category of moderate or algae cover (roughly >25%) on a un-consolidated surface (e.g. on a sandy/rubble) present in areas that are homogenous in colour and texture identified in the ZY3 satellite imagery at the specific field location. There may be patchy coral in these locations.

3 Results

3.1 Spot Check Survey Data

Spot check survey sites were distributed across the reefal areas (Figure 2). The spot check sites showed a composition of different benthic and substrate cover types for each reef habitat, providing valuable information for the manual digitisation procedure (Figure 3-8).

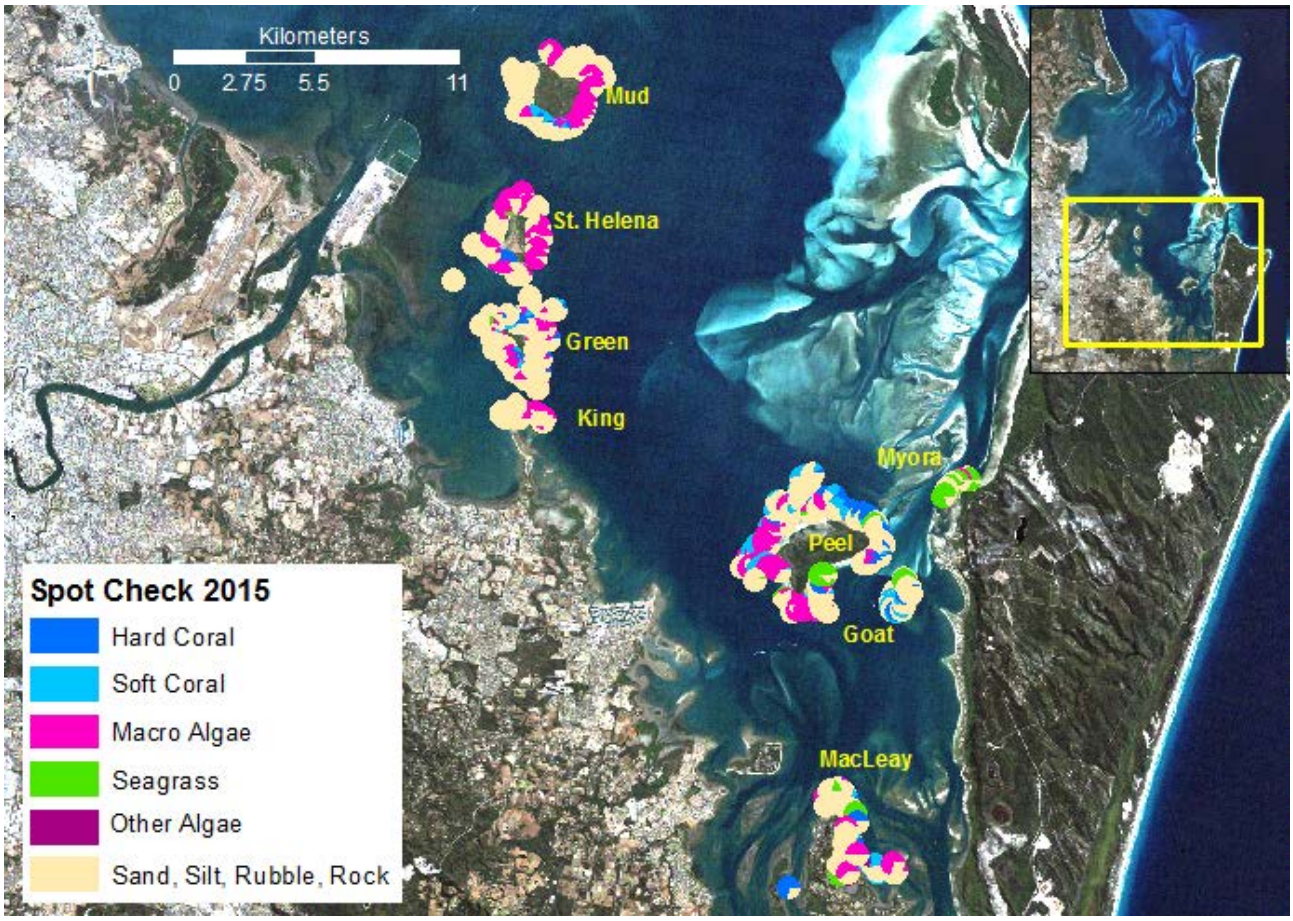

Figure 2: Central Moreton Bay spot check survey sites showing the pie charts indicating benthic composition at each reef area overlayed on the 2014 Landsat L8 (30 m x 30 m pixel) satellite imagery.

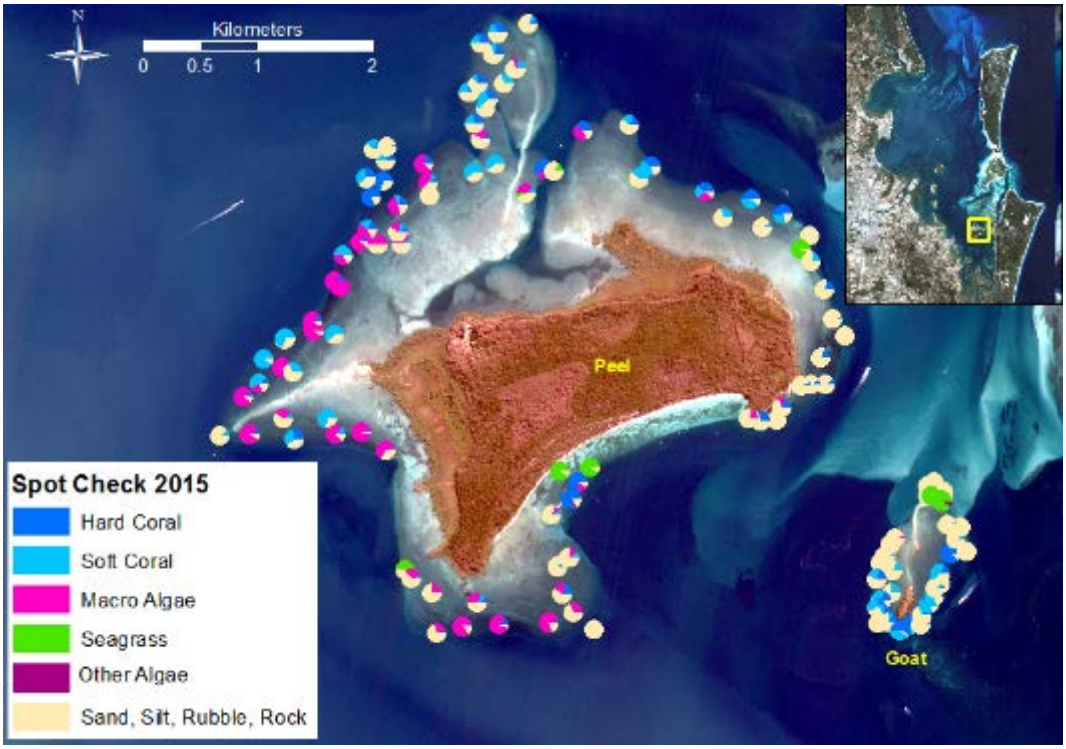

Figure 3: Peel and Goat Island spot check survey sites showing the pie charts indicating benthic composition at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.

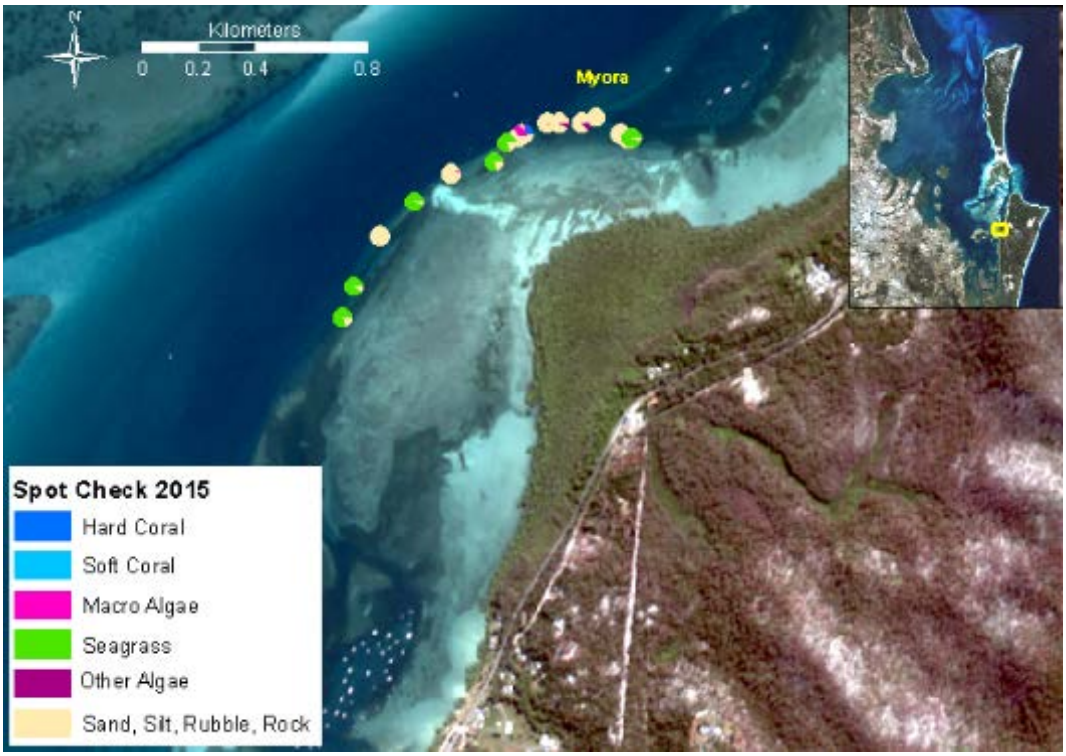

Figure 4: Myora spot check survey sites showing the pie charts indicating benthic composition at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.

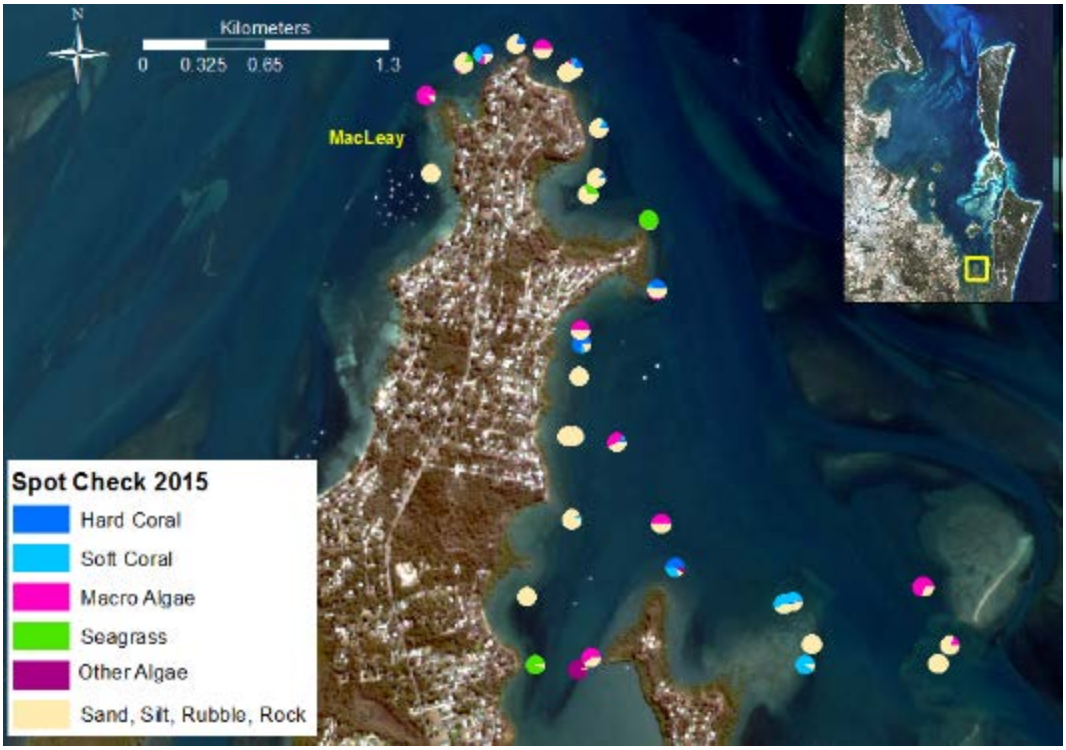

Figure 5: Macleay spot check survey sites showing the pie charts indicating benthic composition at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.

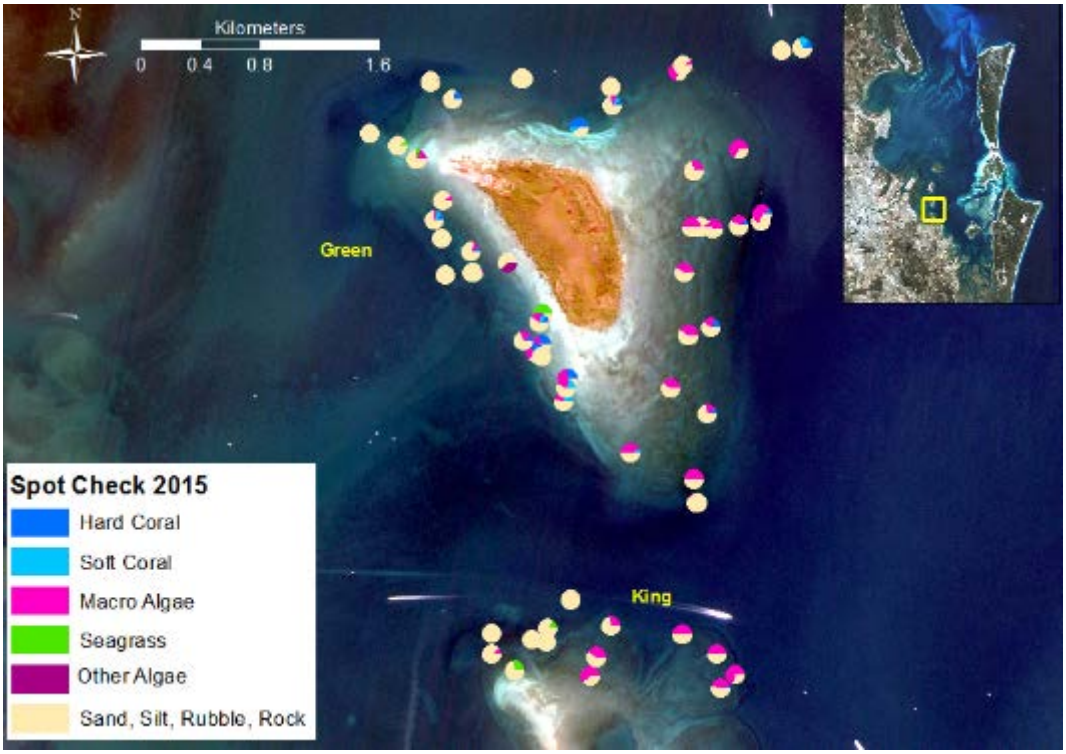

Figure 6: Green and King Island spot check survey sites showing the pie charts indicating benthic composition at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.

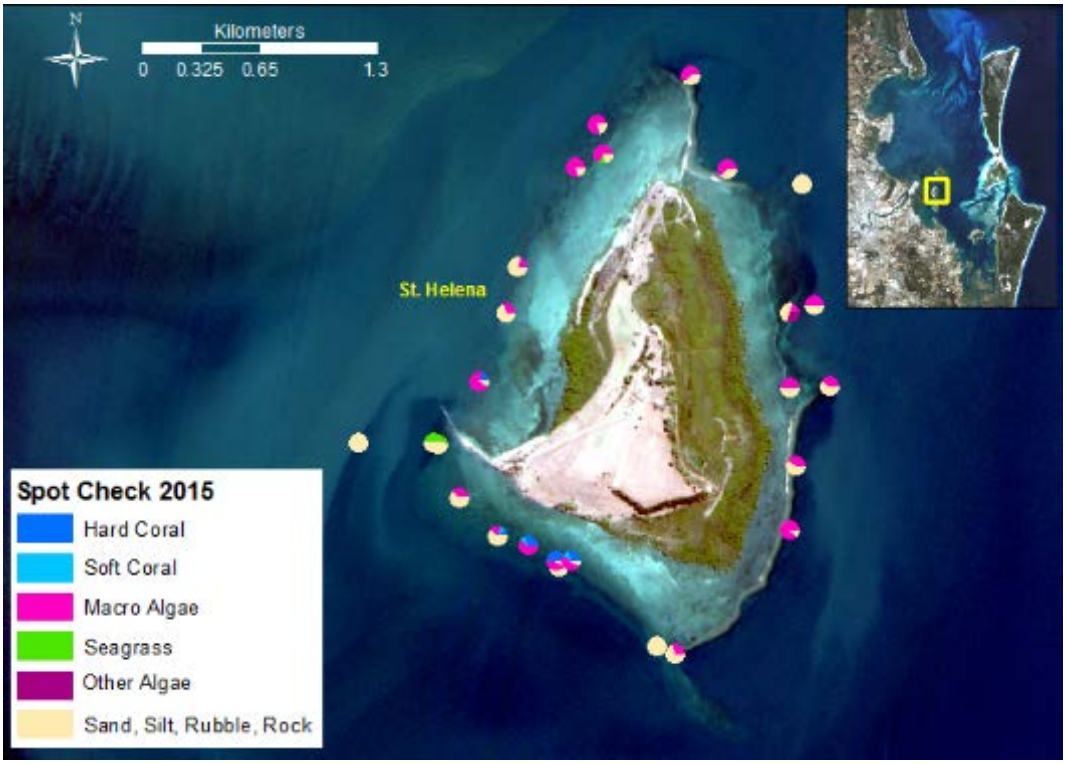

Figure 7: St. Helena spot check survey sites showing the pie charts indicating benthic composition at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.

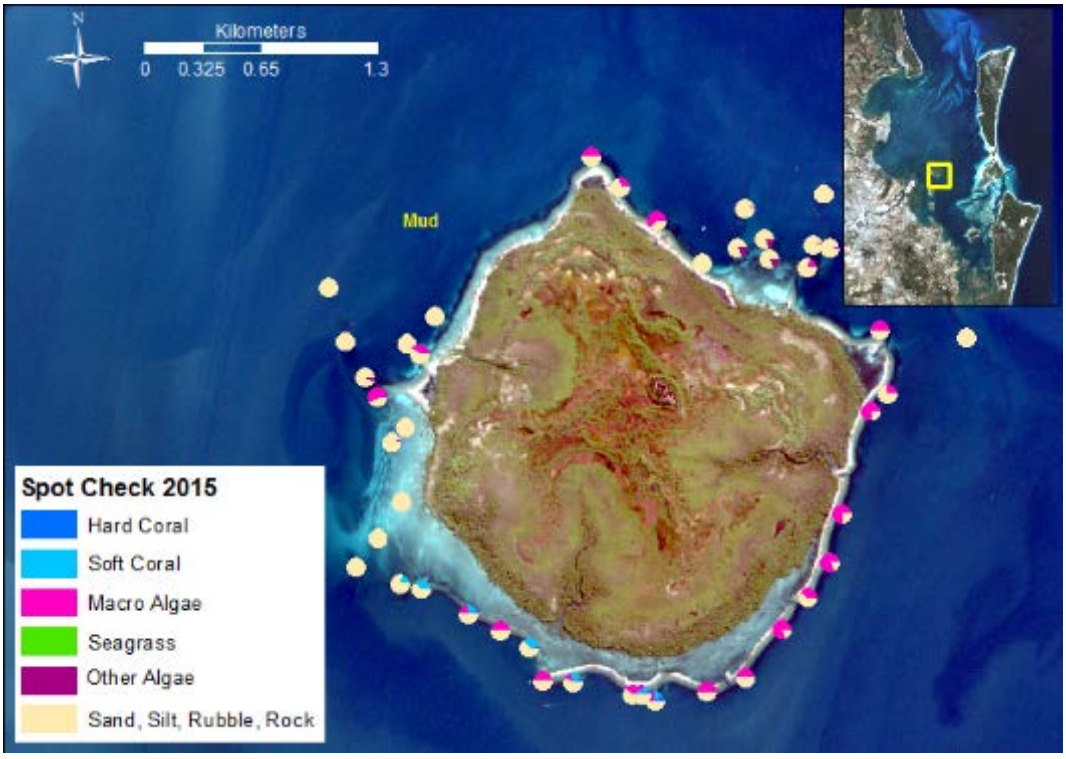

Figure 8: Mud Island spot check survey sites showing the pie charts indicating benthic composition at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.

3.2 Reef Habitat Maps

Reefal areas where coral was present were mapped on the satellite imagery, guided by the field data (Figure 9). Differentiation of reef habitat types was possible due to the availability of spot check field data and the high spatial resolution of the ZY-3 image, enabling clear distinction of reef areas from non-reef areas (Figure 10-15). Only areas of dense coral (>25%) were mapped. Smaller patches of coral are present across the entire reefal area (including areas designated as Algae on sand rubble in Figure 9).

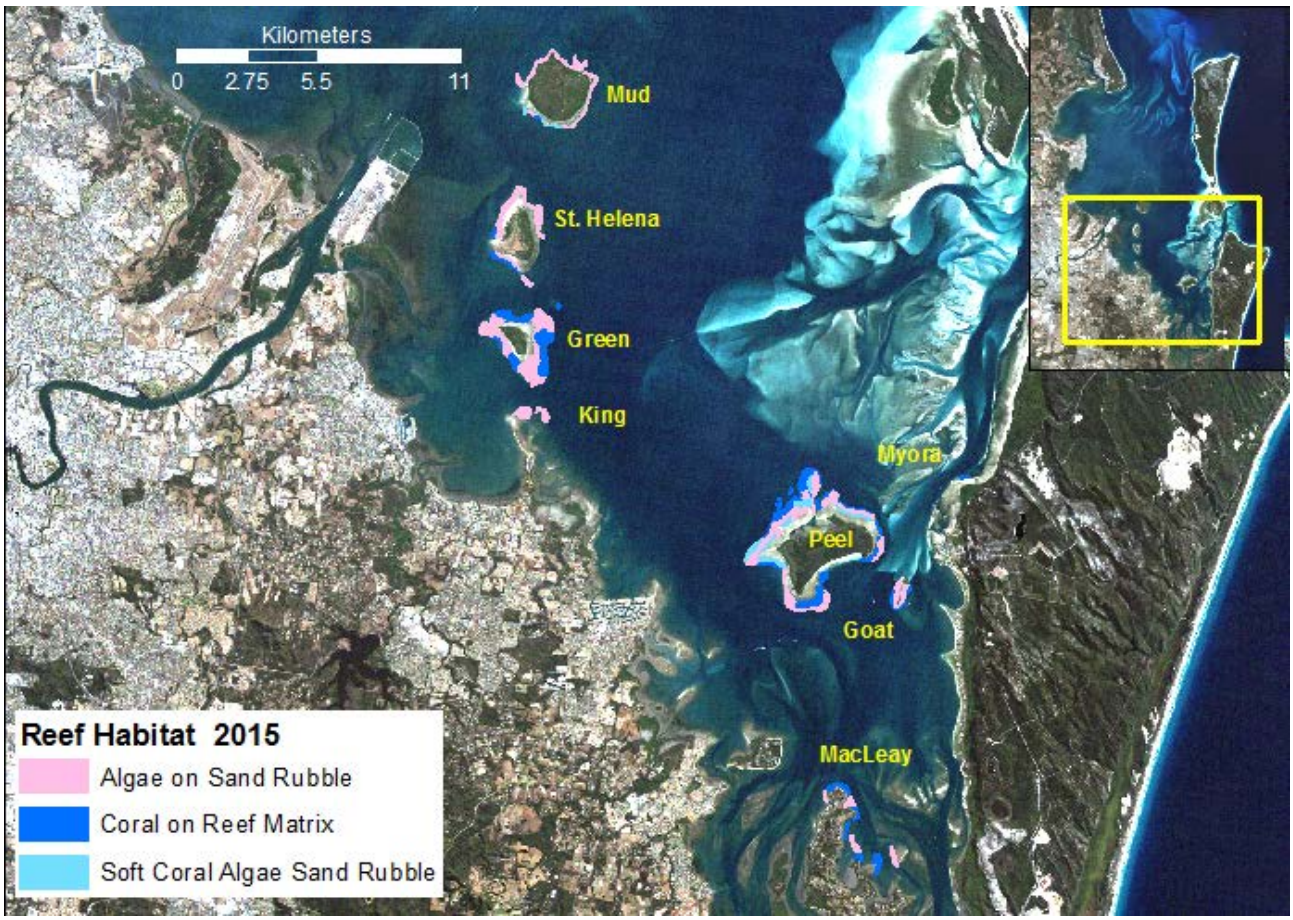

Figure 9: Central Moreton Bay reefal areas, derived through manual digitsation guided by 2014 ZY-3 satellite image (5 m x 5 m pixel) as a backdrop overlayed with spot check field data for interpretation. Polygons are in this figure overlayed on a 2014 Landsat L8 (30 m x 30 m pixel) satellite imagery.

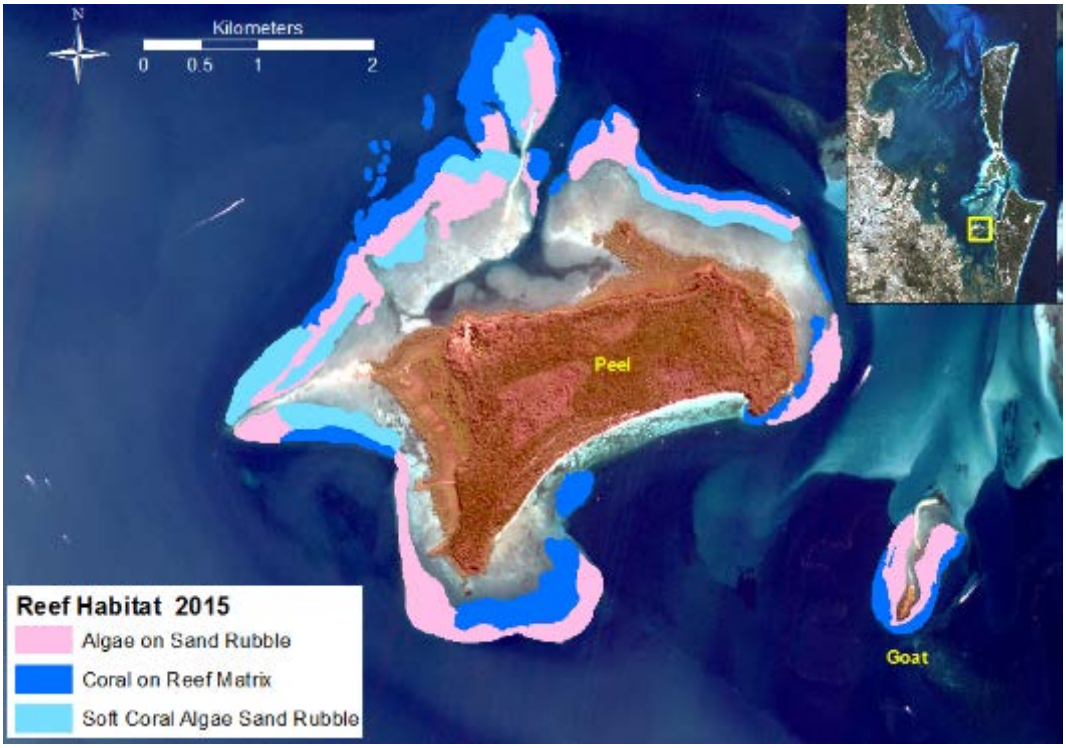

Figure 10: Peel and Goat Island reefal areas, derived through manual digitsation guided by 2014 ZY-3 satellite image (5 m x 5 m pixel) as a backdrop overlayed with spot check field data for interpretation.

Figure 11: Myora reefal areas, derived through manual digitsation guided by 2014 ZY-3 satellite image (5 m x 5 m pixel) as a backdrop overlayed with spot check field data for interpretation.

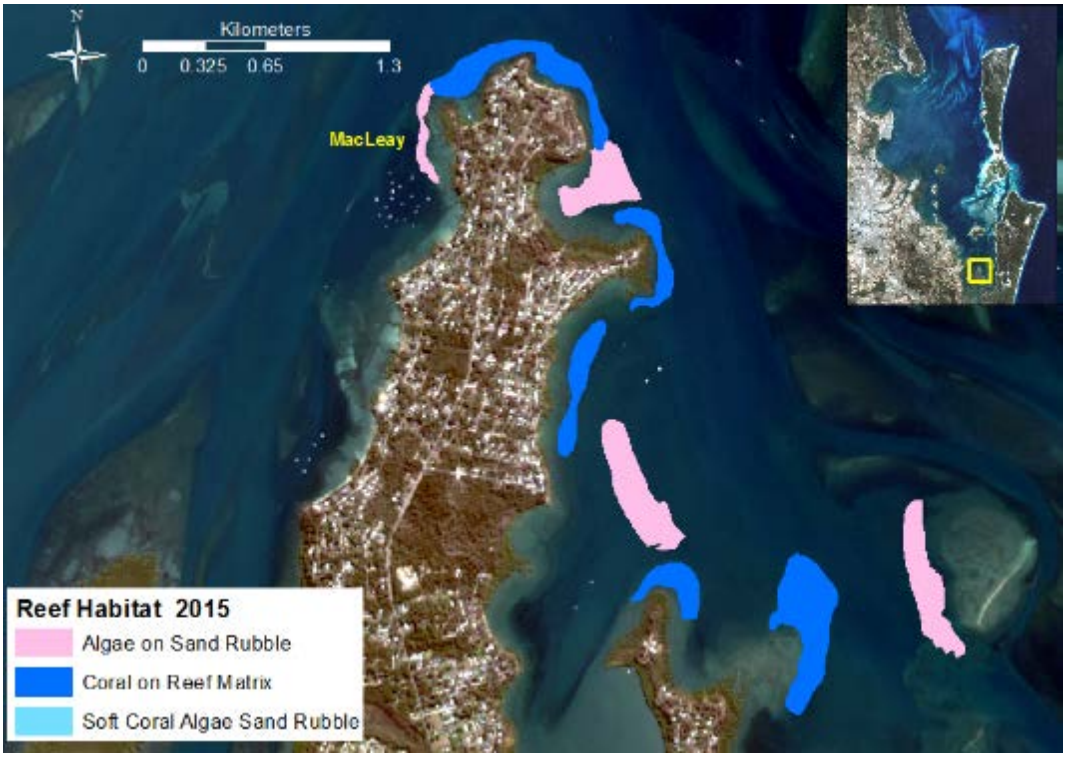

Figure 12: Macleay island reefal areas, derived through manual digitsation guided by 2014 ZY-3 satellite image (5 m x 5 m pixel) as a backdrop overlayed with spot check field data for interpretation.

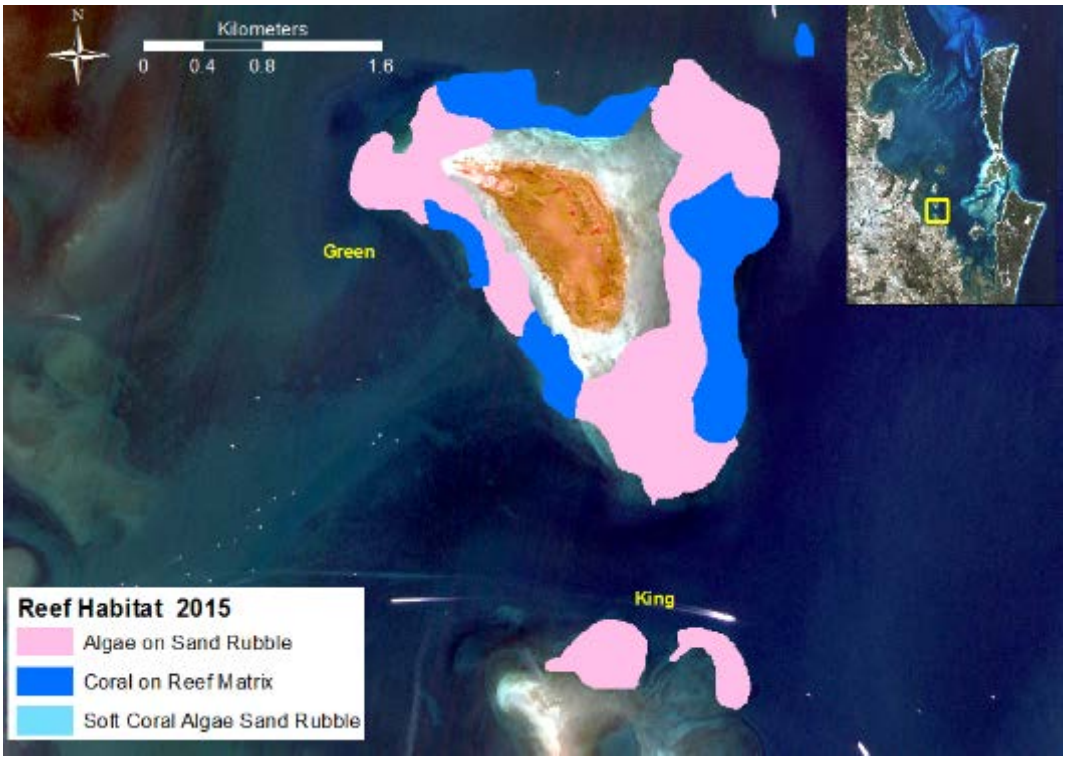

Figure 13: Green and King Island reefal areas, derived through manual digitsation guided by 2014 ZY-3 satellite image (5 m x 5 m pixel) as a backdrop overlayed with spot check field data for interpretation.

Figure 14: St. Helena Island reefal areas, derived through manual digitsation guided by 2014 ZY-3 satellite image (5 m x 5 m pixel) as a backdrop overlayed with spot check field data for interpretation.

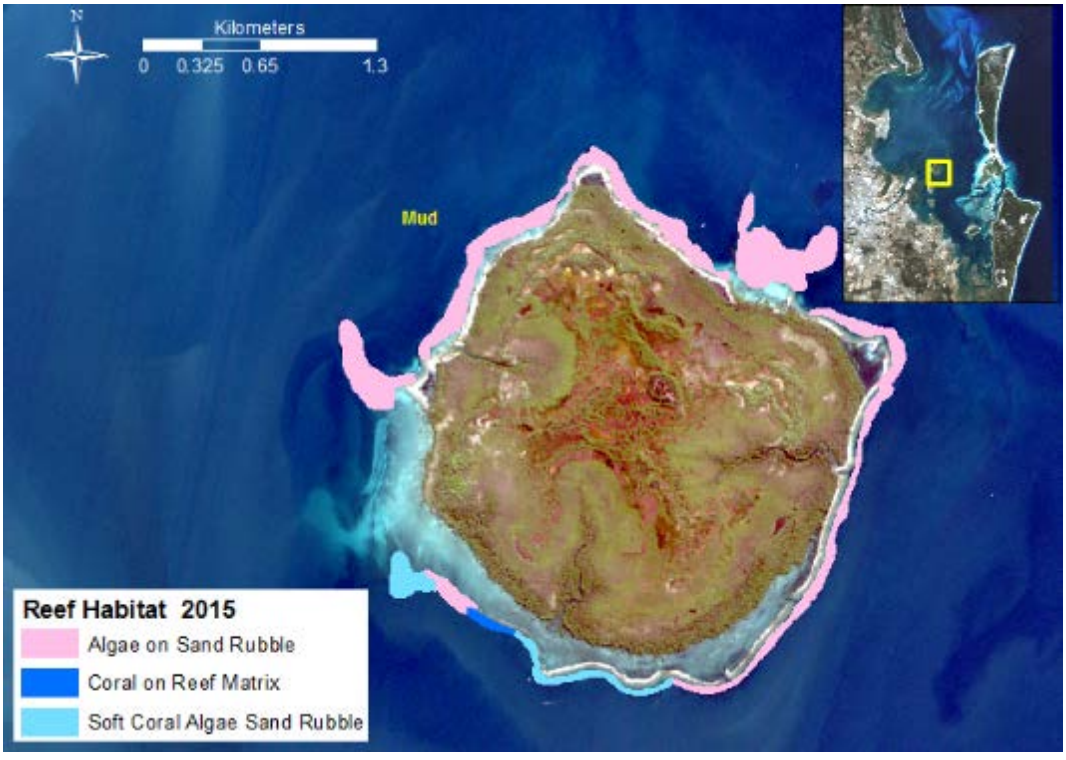

Figure 15: Mud Island reefal areas, derived through manual digitsation guided by 2014 ZY-3 satellite image (5 m x 5 m pixel) as a backdrop overlayed with spot check field data for interpretation.

3.3 Benthic inventory of reefal areas Map 2015 versus Coral Map 2004

The 2015 benthic inventory from this study should not be directly compared with 2004 data set to document change in coral cover. For completeness, an example of a visual comparison of the 2004 and 2015 maps has been included (Figure 16).

The 2004 maps offer a lower level of detail, as some areas have not been mapped or other areas have been mapped coarsely in comparison to the 2015 maps. In 2004, large areas were interpreted as coral, however the 2015 results suggest that these coral areas are more appropriately categorised as reefal areas and may not host notable coral cover. It is not likely that areas covered by coral in 2004, but not mapped as coral in 2015, have degraded to algae or rubble. The more likely explanation for varying boundaries and classifications is that improved high resolution satellite imagery and advanced mapping software has allowed for more sophisticated habitat assessment. Therefore, in this recent study, the coral areas have been refined and it is expected that the 2015 results more closely represent their spatial extent.

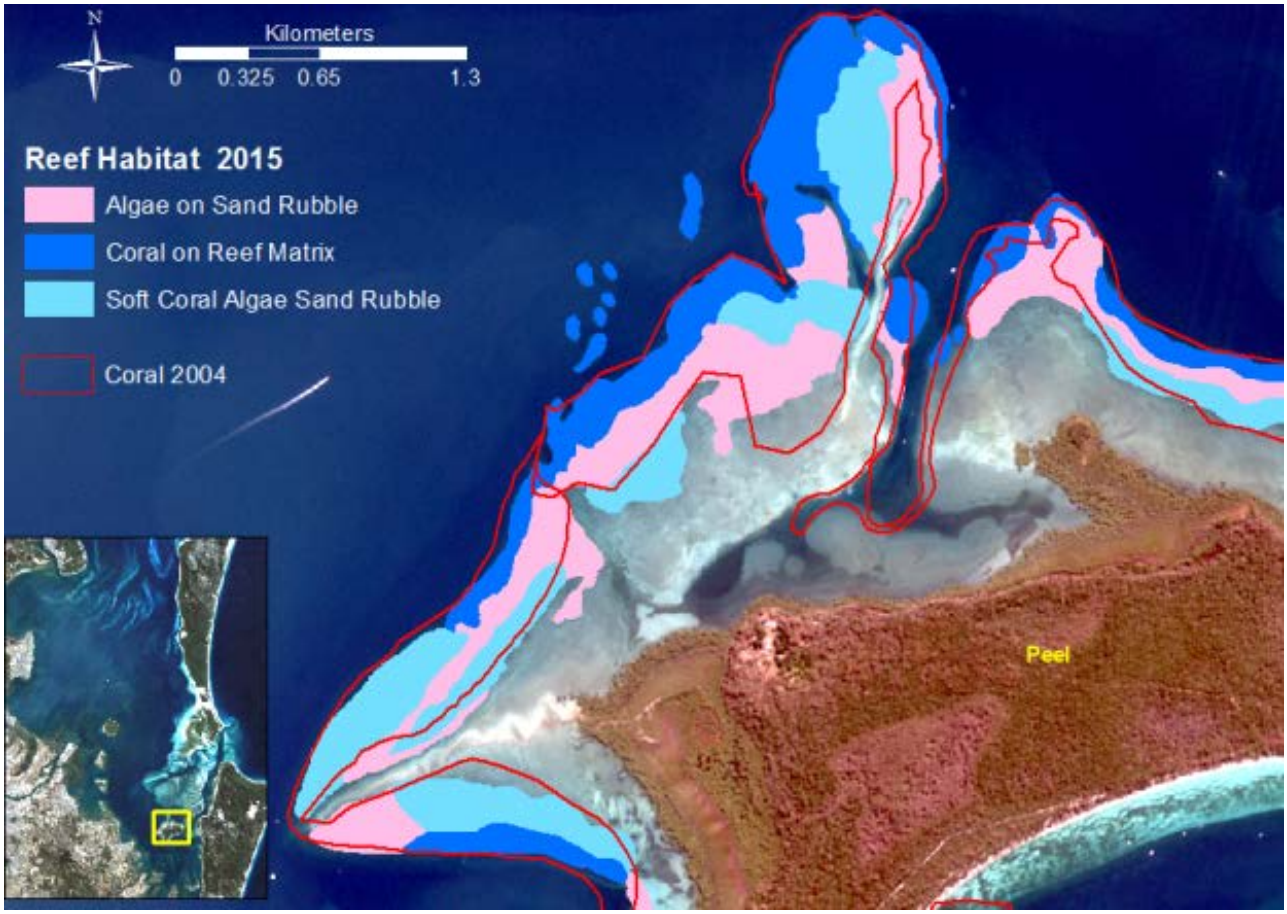

Figure 16: Peel Island benthic inventory of reefal areas for 2015 overlayed with the 2004 coral map. The 2015 reef habitat map was created through manual delineation of spot check field data overlayed on satellite imagery, 2014 ZY-3 (5 m x 5 m pixel).

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