Benthic Inventory of Reefal Areas of Inshore Moreton Bay, Queensland, Australia

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Place Names of Quandamooka

Aboriginal place names for locations mentioned in this report include:

Cleveland – Nandeebie / Indillie

Coochiemudlo – Goochie Goochie-Pa / Goochie mudlo

Dunwich – Goompie

Green Island – Milwarpa / Danggar / Tangeera

Macleay Island – Jencoomercha

Manly – Narlang

Moreton Bay – Quandamooka

Mud Island – Bangamba

Myora Springs – Capeemba / Kapembah

North Stradbroke Island – Minjerribah / Terangeri

Peel Island – Jercroobai

Redland Bay – Talwalpin

St Helena Island – No-gun / Nugoon

Tingalpa – Tingal / Tangulba / Tangul / Dinggalba

Victoria Point – Warrer warrer

Wellington point—Cullen-cullen

Wynnum – Winnam / Winam / Winim / Wynyem

Executive Summary

Overview

Moreton Bay hosts unique subtropical reefs habitats. While these reefs are considered marginal due to their high-latitude location, and the building of reef structures is generally limited (Fellegara & Harrison 2008), the region hosts notable coral communities (Harrison et al 1998, Wallace et al 2009).

The health of Moreton Bay corals is a key indicator of water quality and overall catchment health. 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.

Coral extent maps for Moreton Bay were last produced in 2004 (source: Queensland Environmental Protection Agency). These maps form a key component of natural resource management decisions for the area. It was identified that updated data regarding the spatial distribution and condition of this important natural resource was fundamental to improve understanding and management of these important habitats.

In 2015 and 2016, a collaborative citizen science 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 and Catchments (Queensland Environmental Protection Agency in 2004). The project engaged trained volunteers to collect benthic habitat field data that allowed for review and revision of the 2004 coral spatial extent baseline to produce updated benthic habitat inventories for key subtropical reefal areas of inshore Moreton Bay.

Results

- In 2015 and 2016, trained Reef Check Australia volunteers helped to collect 610 geo-referenced spot-checks of benthic/substrate field data across 8 inshore Moreton Bay reef areas and along the fringing reef areas from sites stretching from Wellington Point to Coochiemudlo Island.

- The University of Queensland Remote Sensing Research Centre Staff overlayed spot-check data on ZY-3 imagery to manually assign one of three habitat inventory categories: Coral (>20% cover) on reef matrix, Soft Coral on Sand/Rubble, and, Algae on sand/rubble+patchy coral) to digitised polygons through expert image interpretation. Images of habitat maps, as well as a digital GIS-ready file will be made available for non-commercial use on request.

- High resolution satellite imagery, more advanced mapping software and increased field knowledge enabled more refined habitat assessments than the 2004 baseline maps, creating an improved baseline for reef habitat extent in inshore Moreton Bay.

- The 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 offers a practical tool for best-practice decisions relating to management in the catchment and the Bay.

Recommendations

- The updated comprehensive reefal habitat spatial dataset provides a critical resource for science and management applications in Moreton Bay. It should be noted that this reefal dataset is focused on areas with coral cover and should sit within a larger and more comprehensive marine habitat map for Moreton Bay to more accurately illustrate connectivity and context.

- The benthic inventory of reefal areas from the 2015/16 study should not be directly compared with the 2004 inventory to document change. While efforts were made to allow for comparability, higher spatial resolution imagery (5 m x 5 m pixels) and advanced technology resulted in an enhanced level of detail for spatial and for benthic composition results in 2015/16. The 2016 results more closely represent the spatial extent of coral areas in Moreton Bay and should be treated as a revised baseline.

- Repeat monitoring of these areas is recommended to enable prevention, intervention and/or prediction of changes to these critical natural resources. This should include annual monitoring to assess reef condition (e.g. Reef Check Australia, Reef Health Impact Surveys and CoralWatch surveys), and repeating an extensive spatial habitat mapping project every five years, such as presented in this report.

- Phase 1 (2015) and Phase 2 (2016) included spot-checks across key reefal habitat areas in central Moreton Bay and the fringing reef around the Redland area (Wellington Point, Raby Bay, Victoria Point and Coochimudlo). Reefal areas around Redcliffe and the western shores of North Stradbroke Island could be further explored.

- The inventories of reefal areas in inshore Moreton Bay should be distributed and utilised to inform science, management and community. Applications include integration in the annual Healthy Waterways and Catchments Report Card, Moreton Bay Marine Park zoning and South East Queensland Natural Resource Management (SEQ NRM) Plan. Communications activities to share these resources with the wider community are essential to promote appreciation, awareness and conservation of these habitats. These coral habitats are not well-known by many community members and provide a notable opportunity to demonstrate how human activities in the catchment affect Moreton Bay health.

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 (Lybolt et al. 2011), but now massive corals (*Cyphastraea, Favia* and *Goniopora* species) dominate reefal habitats (Wallace et al, 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 between the marine and terrestrial environments. 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 (moderate spatial resolution of 30 m x 30 m) as 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.

This citizen science project is a collaboration with Reef Check Australia, The University of Queensland Remote Sensing Research Centre, and Healthy Waterways and Catchments, to produce updated benthic habitat inventories for key subtropical reefal areas of inshore Moreton Bay.

Since 2009, Reef Check Australia has conducted reef health surveys at five sites in the inshore Moreton Bay (Goat Island, Peel Island, Macleay Island, and Myora Reef). Trained surveyors assess 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.

Objectives of the project included:
- Train and coordinate volunteers to collect field data to describe the composition of key inshore Moreton Bay reef habitat areas using adapted Reef Check Australia benthic habitat categories and comparable methodology to mapping conducted in 2004 (Roelfsema et al 2009).
- Produce an updated and refined inventory of reefal habitats for Inshore Moreton Bay from 2004 utilising spot-check field data collected in 2015 and 2016, integrated with a 2014 ZY-3 satellite image (Roelfsema et al 2009).
- Compare findings for 2016 with baseline coral extent maps produced in 2004.
- Share findings with stakeholders to support increased knowledge for science, management, and community awareness applications.

This report describes the findings and the methods used to produce benthic habitat inventories and key findings for the extent of reef habitat areas in inshore Moreton Bay (additional information regard methods available in *Field Methods for Benthic Habitat Mapping Methodology* (Roelfsema et al 2015). A digital GIS ready file in WGS84, UTM zone 56 outlines the extent of the reef inventory areas will be made available via http://www.pangaea.de.

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 inshore 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 inshore 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, as well as fringing reef areas stretching from Wellington Point to Coochiemudlo Island.

The study involved the creation of maps that present a benthic inventory for reefal habitat areas in inshore 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. A *Field Methods for Benthic Habitat Mapping Methodology* outlines a coordinated approach using Reef Check Australia methods with standardised benthic habitat mapping and geo-referenced photo-transect protocols (Roelfsema et al 2015).

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). Data collection took place in two phases: April-June 2015 (central Moreton Bay reefs) and August-September 2016 (fringing reefs close to mainland).

Site locations were chosen based on the 2004 survey sites, and additional sites were chosen by assessment of high spatial resolution satellite imagery, as well as anecdotal information. In addition to pre-defined spot-checks, field teams tried to define the edge between habitats. At these locations, 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 (**Figure 2**).

Figure 2. **Spot-check surveys conducted by Reef Check teams using: viewing bucket, drop camera, snorkel transects and note-taking (source: C. Roelfsema 2016).**

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 field 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 Excel 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 (compared to 2004 data that used 30m x 30 m pixel size). Additionally, it has a swath with of 50 km, hence all of the inshore 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:

Category name	Description	Photo
Coral (>20% cover) on reef matrix	These included areas where spot-check field data points were assigned a category of moderate or higher hard coral cover (>20%) 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.	
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	
Algae on sand/rubble + patchy coral	These included areas where spot-check field data points were assigned a category of moderate or algae 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. There may be patchy coral in these locations.	

3 Results

3.1 Benthic Inventory Map 2016

Spot-checks of benthic composition, in combination with satellite imagery, were used to digitise habitat boundaries of the reefal areas (see example for Peel Island Figure 3). Further detail for each in individual reef is listed in the Appendix.
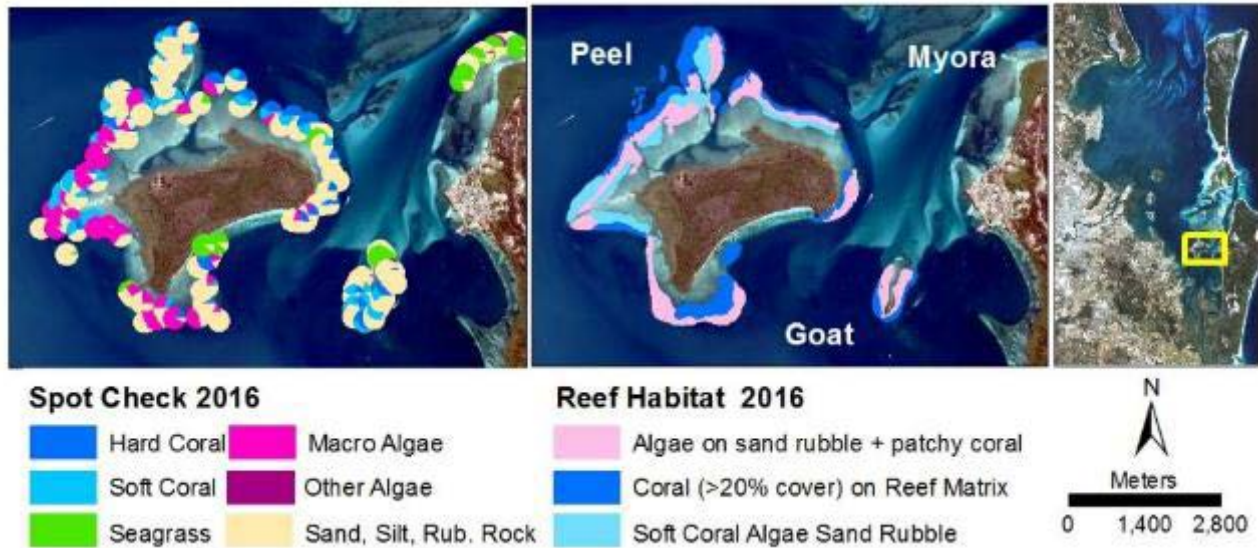
Figure 3: Peel and Goat Island spot-check survey sites showing the pie charts indicating benthic composition and 2016 reef habitat at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.

Spot-check survey sites were distributed across the reefal areas, with particular focus on identifying boundaries between habitat types (Figure 4). 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 (Appendix).

Reefal areas where coral was present were mapped on the satellite imagery, guided by the field data (Figure 5). 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 (see Appendix). Only areas of dense coral (>20%) were mapped. This does not represent consistent cover across the entire area, due to patchy nature of reefal habitats, but does indicate areas of concentrated coral cover. Smaller patches of coral are present across the entire reefal area (including areas designated as Algae on sand rubble).
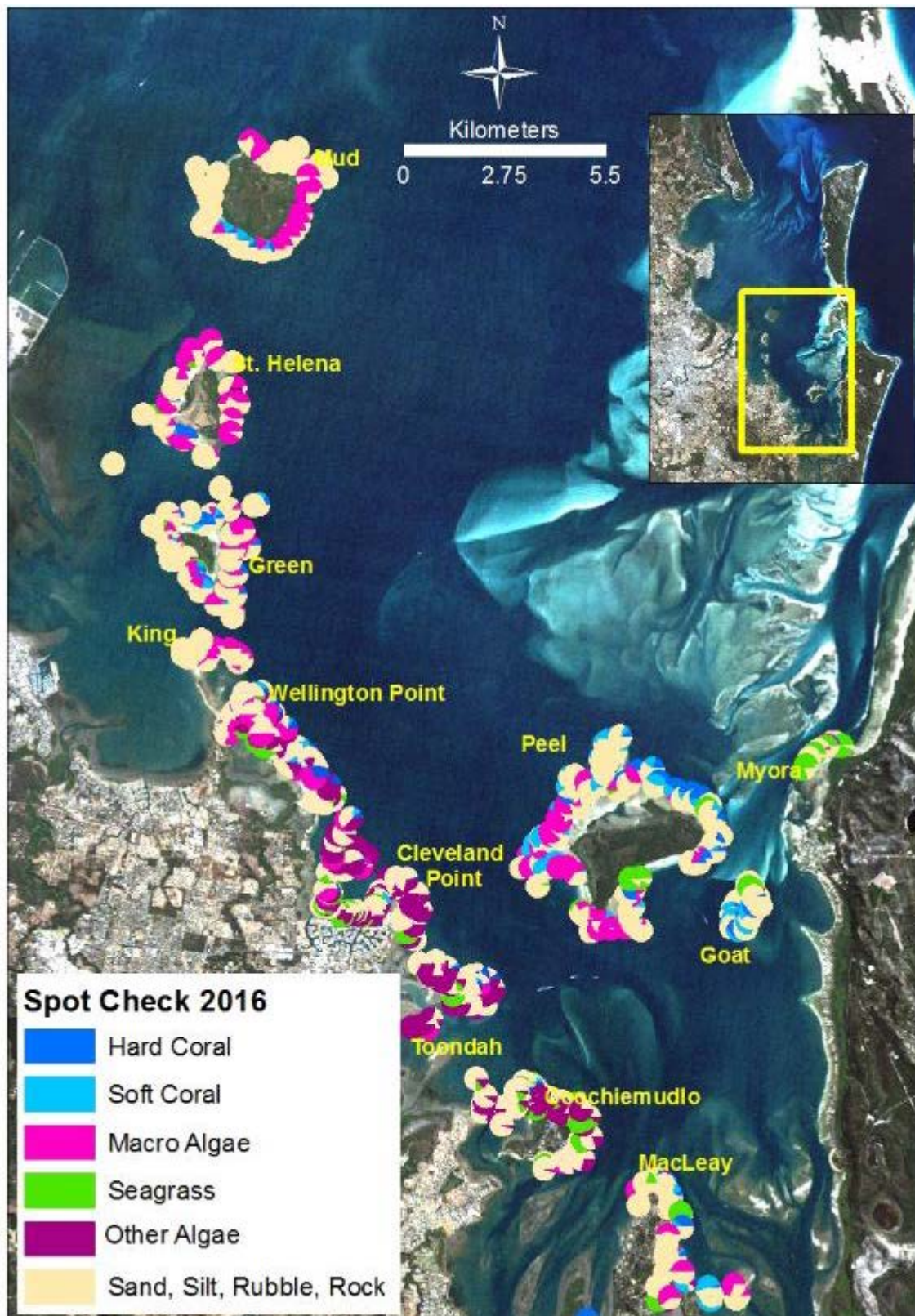
Figure 4: Moreton Bay spot-check survey sites for 2015 and 2016 showing the pie charts indicating benthic composition at each reef area overlayed on the 2014 Landsat L8 (30 m x 30 m pixel) satellite imagery.
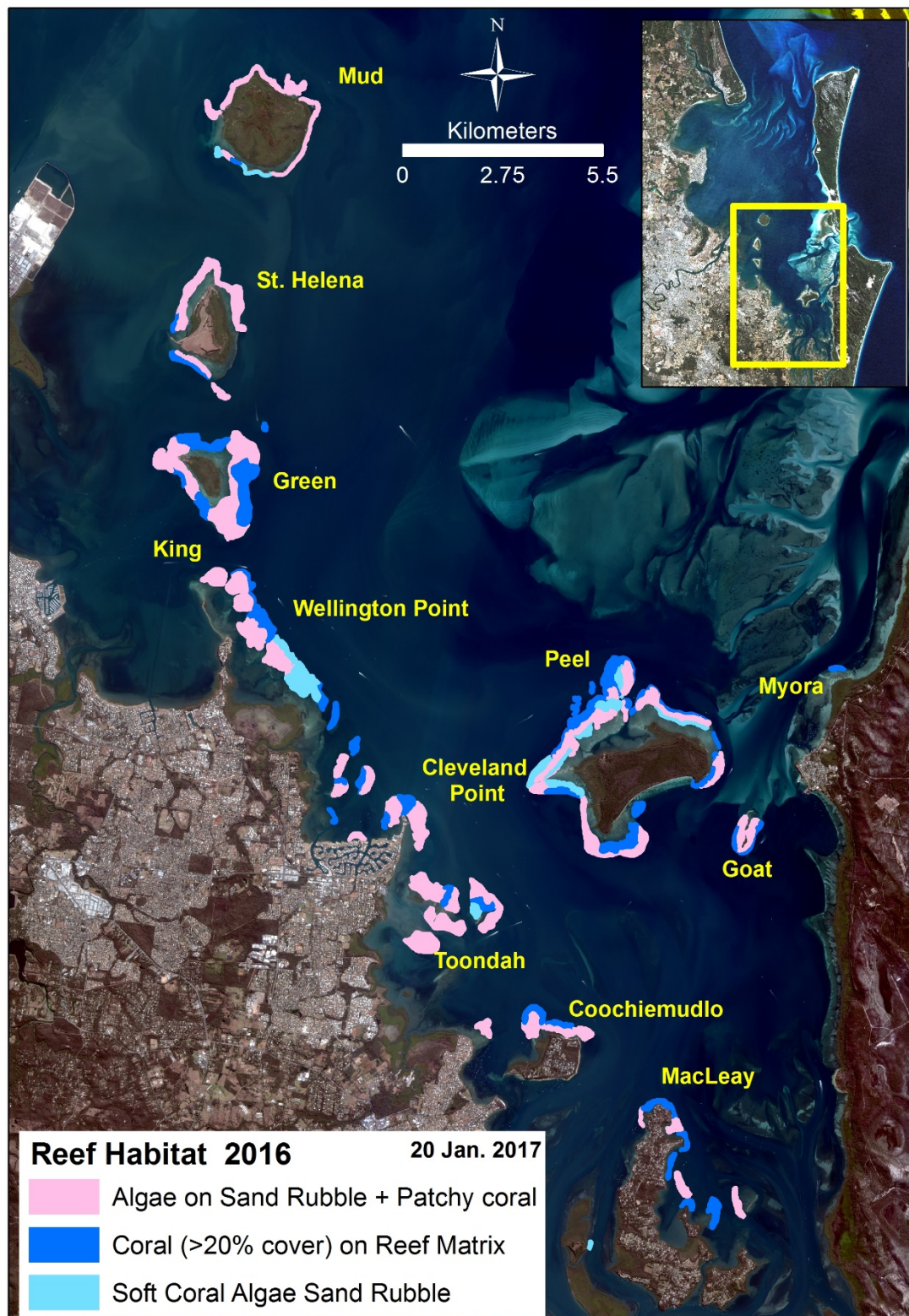
Figure 5: Inshore Moreton Bay reefal areas, derived through manual digitsation guided by 2014 ZY-3 satellite image (5 m x 5 m pixel) as a backdrop overlayed with spot-check field data collected in 2015 and 2016, for interpretation. Polygons are in this figure overlayed on a 2014 Landsat L8 (30 m x 30 m pixel) satellite imagery.

4 Discussion

The updated comprehensive reefal habitat spatial dataset describing an updated spatial extent and benthic habitat inventory of most key reef habitat areas in Moreton Bay, previously mapped in 2004. This is a critical resource for science and management applications for inshore Moreton Bay.

4.1 Benthic inventory of Reefal Areas Map 2016 versus Coral Map 2004

The 2016 benthic inventory from this study should be considered a revised baseline for reef habitat extent in inshore Moreton Bay, and not be directly compared with the 2004 data set to document changes in coral cover. Data collection for 2015/16 was intentionally designed to visit similar locations and collect comparable information, however differences in spatial resolution and technology do not allow for accurate comparison of change in coral extent over time.

The 2004 study used a courser digitising approach based on moderate resolution satellite imagery (30 m x 30 m pixels), resulting in less fine-scale detail and the exclusion of some habitat areas for the 2004 inventory. In 2004, large areas were interpreted as coral, however the 2016 results suggest that these coral areas are more appropriately categorised as reefal areas (with quite patchy coral cover), and may not host notable coral cover. The 2015/16 project used higher resolution satellite imagery (5 m x 5 m pixels) more advanced mapping software and increased field knowledge, resulting in an enhanced level of detail for spatial and for benthic composition results.

The project attempted to re-visit 2004 data for re-analysis, however there is limited high spatial resolution imagery covering all reef areas mapped from 2004, hence a refined map for 2004 could not be created to strengthen the comparison. For completeness, an example of a visual comparison of the 2004 and 2016 maps has been included (Figure 5).

It is not expected that areas covered by coral in 2004, but not mapped as coral in 2016, 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 2016 results more closely represent their spatial extent and should be considered a revised baseline.

This project focused on larger areas of known concentrated coral communities. It does not represent all of the coral habitat in Moreton Bay, as there are many scattered coral communities throughout the Bay that are not large enough to identify via high resolution imagery.
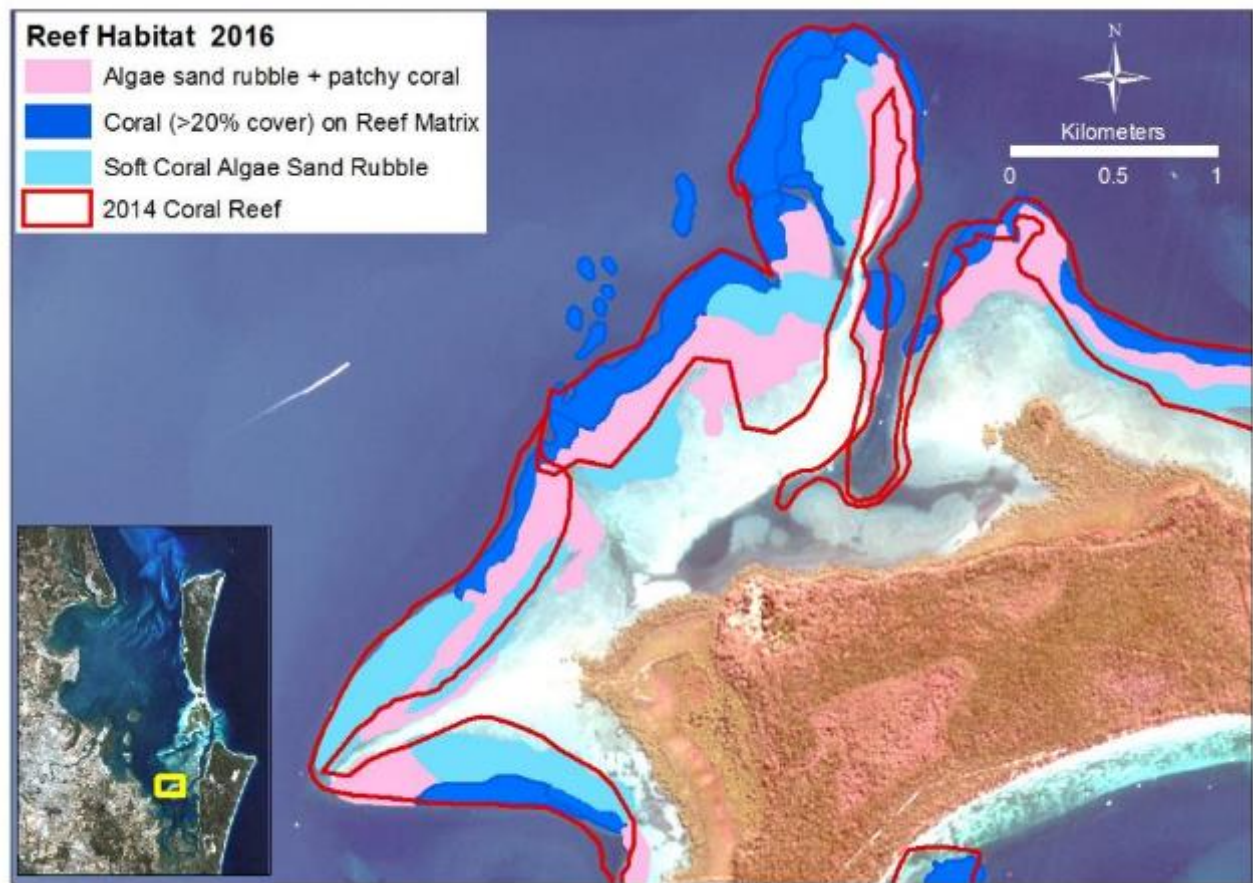
Figure 6: Peel Island benthic inventory of reefal areas for 2016 overlayed with the 2004 coral map. The 2016 reef inventory map was created through manual delineation of spot-check field data overlayed on satellite imagery, 2014 ZY-3 (5 m x 5 m pixel).

4.2 Citizen science supports reef science and management

This collaborative project highlights the complementary role that strategic citizen science can play within the context of marine science and management. The project was prompted by an identified data gap, which citizen science programs in the region were-placed to fill with small modifications to existing training and resources, as well as strong support from science advisors. Protocols were implemented to support data alignment with past projects and ensure robust quality assurance and control.

The leveraging of existing resources, strong science and management support and volunteer contributions allowed for a cost-effective project. The project provides extensive benefits beyond data collection through capacity-building and community education.

The project helped to bring together multiple agencies and researchers through consultations. This of ongoing consultation process not only ensured that data could be utilised for science and management applications, but also prompted new collaborative dialogue and outcomes.

4.3   Information sharing and applications

The revised spatial data set offers a practical tool for best-practice decisions relating to management in the catchment and the Bay. The inventories of reefal areas in inshore Moreton Bay should be distributed and utilised to inform science, management and community.

Data applications include integration in the annual Healthy Waterways and Catchments Report Card, Moreton Bay Marine Park zoning and South East Queensland Natural Resource Management (SEQ NRM) Plan. The data was specifically collected to contribute 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.

Communications activities to share these resources with the wider community are beneficial to promote appreciation, awareness and conservation of these habitats. A community survey indicated that a quarter of people surveyed were not aware that there were reefs in the waters of South East Queensland (Reef Check Australia 2010). Those that are aware of these inshore reefs may benefit by increasing knowledge about coral habitat areas, such as areas to visit for snorkelling or areas to avoid for anchoring.

The maps also provide a notable opportunity to demonstrate how human activities in the catchment affect Moreton Bay health, as well as an opportunity to celebrate the unique marine environments of the region.

4.4   Future monitoring and mapping regime

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, extraction and use) are likely continue growing into the future (Gibbes et al 2014).

As such, repeat monitoring of these areas is recommended to enable prevention, intervention and/or prediction of changes to these critical natural resources. This should include annual monitoring to assess reef condition (e.g. Reef Check Australia monitoring, Reef Health Impact Surveys and CoralWatch surveys), and repeating an extensive habitat mapping program every five years, such as presented in this report.

This reefal dataset is focused on areas with coral cover and should sit within a larger and more comprehensive marine habitat map for Moreton Bay to more accurately illustrate connectivity and context.

Future areas of study could expand on the 2004 baseline by conducting ground-truthing and habitat mapping on reefal areas around Redcliffe and fringing North Stradbroke Island.

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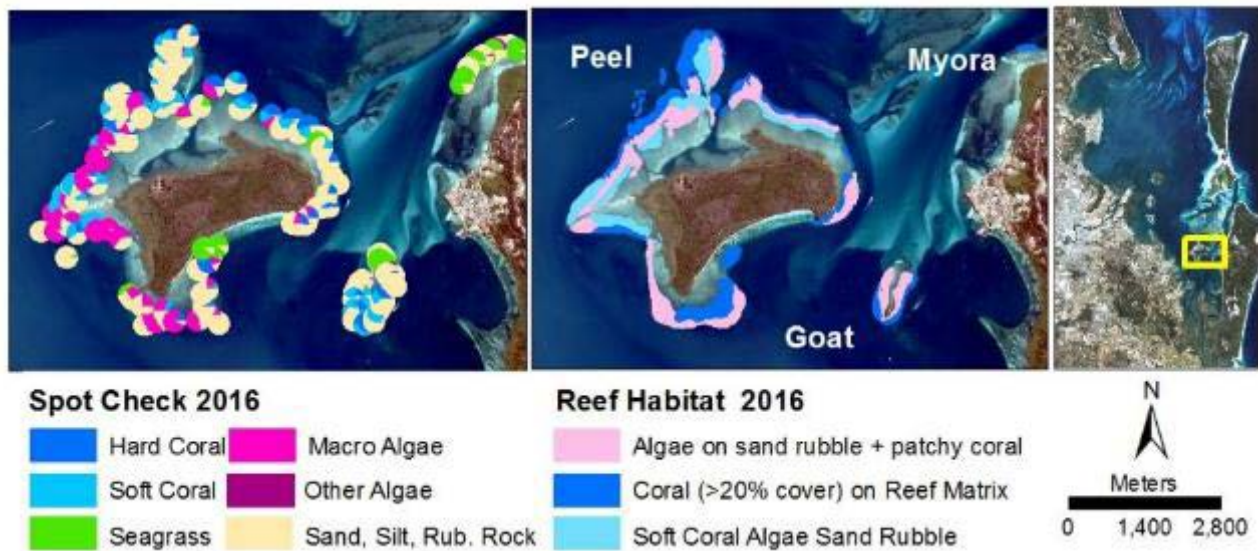
Appendix

Figure 7: Peel Island, Goat Island and Myora Reef spot-check survey sites showing the pie charts indicating benthic composition and 2016 reef habitat at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.
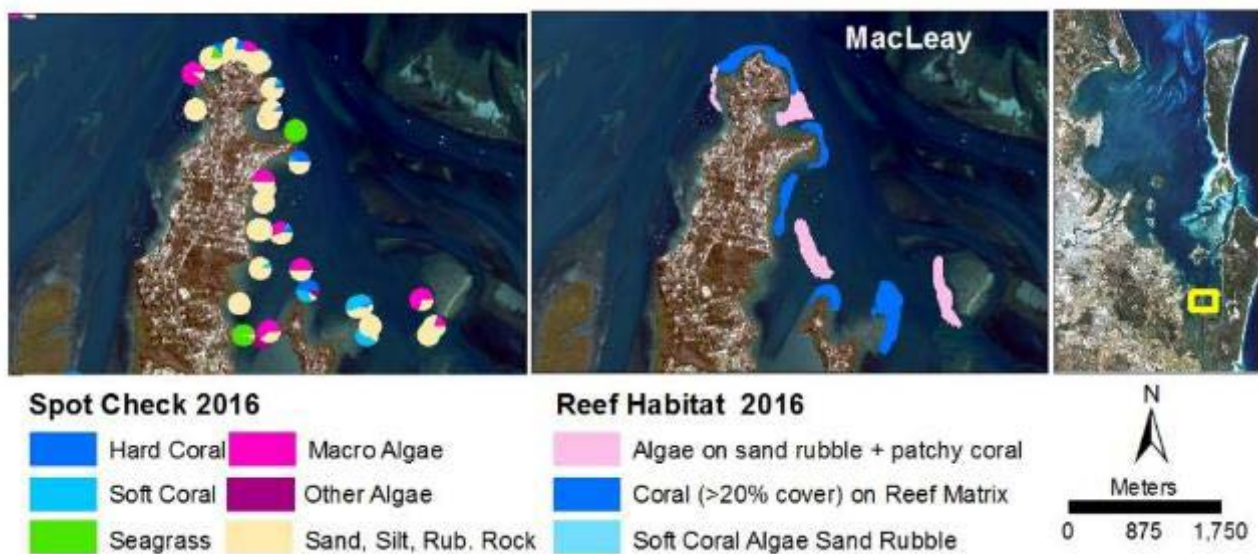

Figure 8: Macleay Island spot-check survey sites showing the pie charts indicating benthic composition and 2016 reef habitat at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.
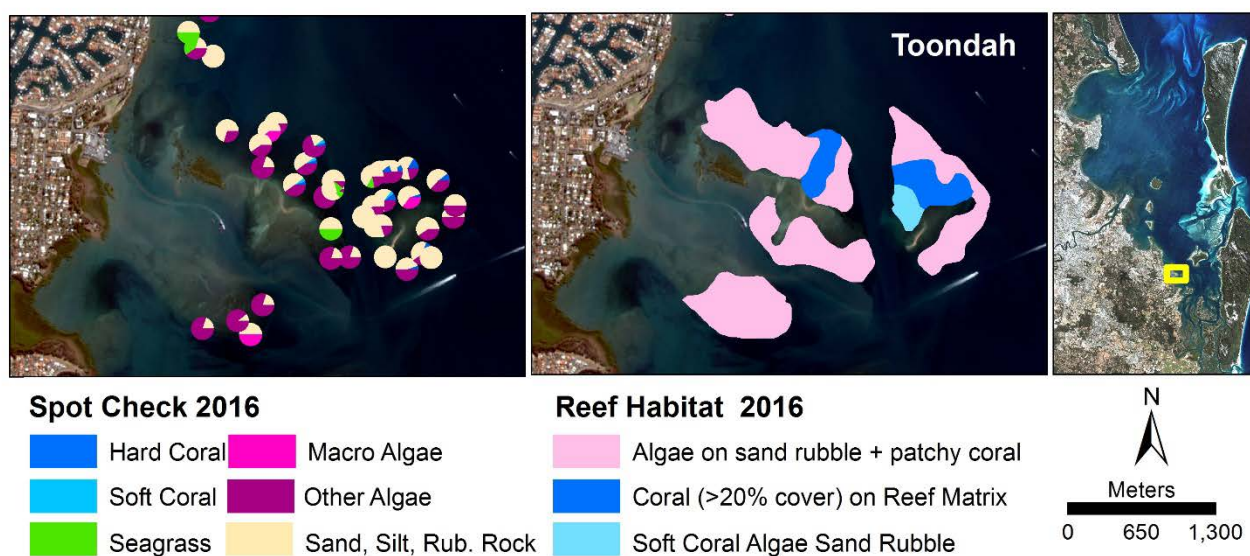
Figure 9: Toondah spot-check survey sites showing the pie charts indicating benthic composition and 2016 reef habitat at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.

Figure 10: St. Helena Island spot-check survey sites showing the pie charts indicating benthic composition and 2016 reef habitat at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.
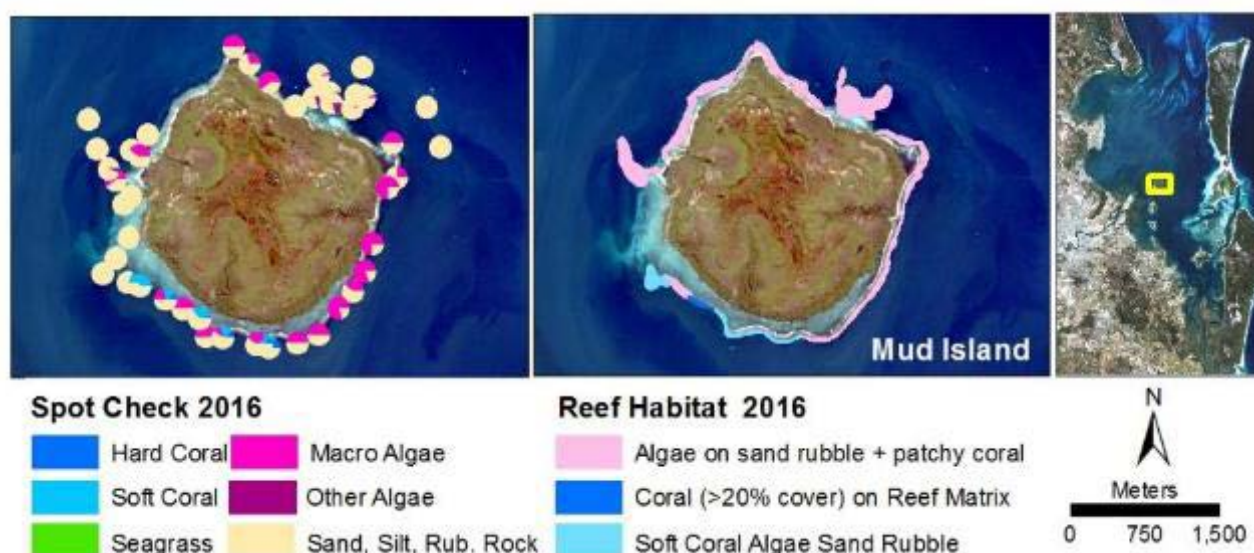
Figure 11: Mud Island spot-check survey sites showing the pie charts indicating benthic composition and 2016 reef habitat at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.
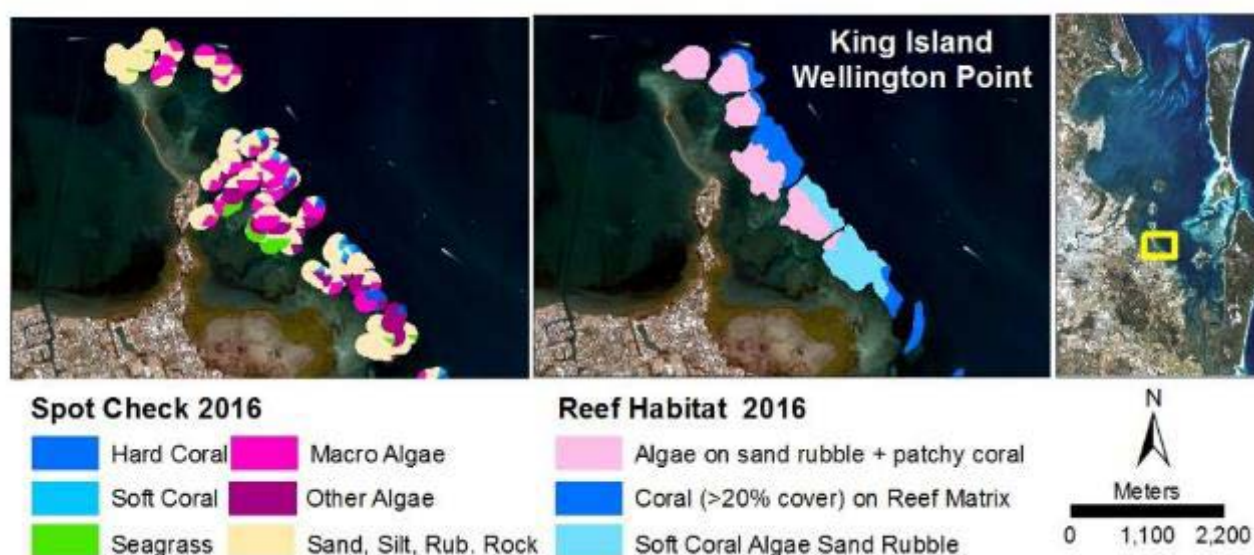

Figure 12: Wellington Point and King Island spot-check survey sites showing the pie charts indicating benthic composition and 2016 reef habitat at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.

Figure 13: Green Island spot-check survey sites showing the pie charts indicating benthic composition and 2016 reef habitat at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.

Figure 14: Raby Bay spot-check survey sites showing the pie charts indicating benthic composition and 2016 reef habitat at each reef area overlayed on the 2014 ZY-3 (5 m x 5 m pixel) satellite imagery.