# PCPA CHAMP

## Port Curtis and Port Alma Coastal Habitat Archive and Monitoring Program

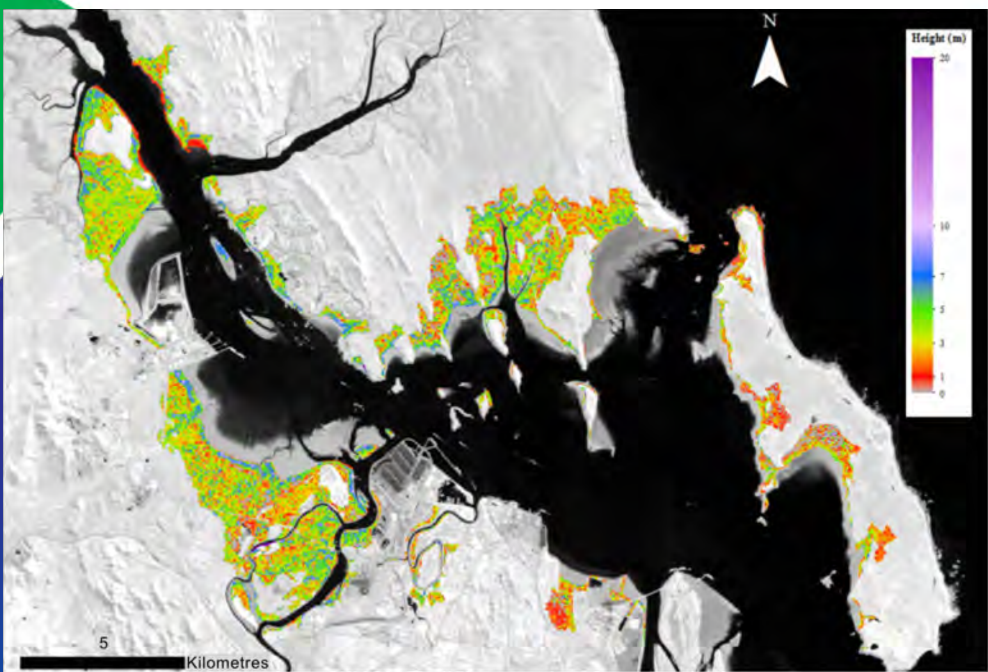
### 2016-2017 Annual Report

CA14000114: Monitoring the survival and recovery of shorelines, specifically Tidal Wetlands (Mangroves/Saltmarsh/Saltpans)

**Norman C Duke, Jock Mackenzie, John Kovacs, Duncan Hill, Dylan Carder, Franz Eilert, Ian Atkinson and Steven van der Valk**

**Report No. 17/56**

**14 July 2017**



# PORT CURTIS AND PORT ALMA COASTAL HABITAT ARCHIVE AND MONITORING PROGRAM

## 2016-2017 Annual Report for the Environmental Research and Monitoring Program Advisory Panel as part of the Gladstone Ports Corporation's Ecosystem Research and Monitoring Program

**Report No. 17/56**
**14 July 2017**

**Prepared by Norman C Duke, Jock Mackenzie, John Kovacs, Duncan Hill, Dylan Carder, Franz Eilert, Ian Atkinson, Mat Wyatt and Steven van der Valk**

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*"We acknowledge the traditional owners of this land wherever we walk.
We pay our respects to the elders both past and present and to the future generations yet to come."*

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This report has been produced for the Ecosystem Research and Monitoring Program Advisory Panel as part of Gladstone Ports Corporation's Ecosystem Research and Monitoring Program. The study was undertaken through a Consultancy Agreement (CA14000114) between Gladstone Ports Corporation (GPC) and James Cook University (JCU) to monitor the condition, survival and recovery of shorelines, specifically tidal wetlands (Mangroves/Saltmarsh/Saltpans) in the Port Curtis and Port Alma region; in field surveys conducted by researchers, traditional owner rangers and community members.

This publication has been compiled by the Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER), JCU.



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# EXECUTIVE SUMMARY

1) This 2016-2017 Annual Report documents the status and key current findings from the program of works for 2016-2017 (commencing in mid-November 2014) directed by Dr Norm Duke and Jock Mackenzie from James Cook University (JCU) with key project partners: Prof John Kovacs of Nipissing University in Canada, Rangers of the Gidarjil Development Corporation, and Prof Ian Atkinson with the eResearch Centre at JCU.

2) Project Components 1 & 2 - High Resolution Mapping and Change Detection and Ecological Condition Mapping. Prof Kovacs and team acquired high-resolution satellite imagery and elevation data from which the 2016 baseline condition of tidal wetlands was mapped. The classifications of vegetation are to be compared and checked for future field observation validation. Further comparisons with existing map units demonstrate how mapping with this project has improved on the accuracy achieved in prior efforts. In particular, this applies to upstream estuarine stands, along landward margins throughout the study area, and generally for narrow zones and smaller stand occurrences. Vegetation indices have been reviewed along with other indicators of change to tidal wetland habitat – to better inform site selection, starting with the 2018-2019 field surveys. No boat or aerial surveys were budgeted for 2017-18. One further practical development is the selection and designation of three comparative areas, as Port Curtis, Port Alma and Rodds Bay. The aim will be to develop the sampling design and experimental comparisons further in order to adequately evaluate likely impacts caused by port activities, particularly dredging.

3) Project Component 3 - Aerial shoreline surveys. No additional aerial field surveys were undertaken during this period. Data from the 2015 survey have been processed and partly analysed. Some outcomes are displayed in the trial and development of the ShoreView online facility, as well as for the mapping and assessment component.

4) Project Component 4 - Boat-based shoreline surveys and field studies. Boat-based surveys were undertaken by the Gidarjil Rangers for the Boyne River in March 2017. These S-VAM surveys continue to add significant new data on the extent and condition of tidal wetland shorelines around the study area.

5) Project Component 5 - Public access online data archive. This milestone marks the completion of the first functional prototype website for the ShoreView online facility. Further work is being undertaken by the JCU eResearch team to develop additional functionality in the site over the next year. A demonstration of the current online prototype is scheduled for the next ERMP meeting in late 2017.

6) Updated assessment of data and observations of shoreline change and condition in the PCPA study area. Our studies show notable issues with shoreline retreat, along with comparisons in shoreline condition.

# ACRONYMS USED IN THIS REPORT

ALOS – Advanced Land Observation Satellite
ArcGIS – a geographic information system (GIS) for working with maps and geographic information
ATCOR – a software application designed to process remote sensing data
AVNIR – Advanced Visible and Near Infra-Red
BMRG – Burnett Mary Regional Group
CHAMP – Coastal Habitat Archive and Monitoring Program
DEM – Digital Elevation Model
DSAS – Digital Shoreline Analysis System developed by USGS (United States Geological Survey Office)
DSM – Digital Surface Model
DNRM - Queensland Department of Natural Resources and Mines
DSITI - Queensland Department of Science, Information Technology and Innovation
DSLR – Digital Single Lens Reflex camera
ERMP – Ecosystem Research and Management Program
ETM – Enhanced Thematic Mapper sensor with Landsat remote sensing satellites
FBA – Fitzroy Basin Association
GBR – Great Barrier Reef
GDC – Gidarjil Development Corporation
GPC – Gladstone Ports Corporation
GPS – Global Positioning System
HAT – Highest Astronomical Tide levels
HD – High Definition
HR – High Resolution
JCU – James Cook University
LIDAR – Light Detection And Ranging - a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth
MSS – Multispectral Scanner System - satellite line scanning devices observing the Earth perpendicular to the orbital track
NDVI – Normalized Difference Vegetation Index
NDWI - Normalized Difference Water Index
NIR – near infrared
NRM – Natural Resource Management
OLI – Operational Land Imager sensor with Landsat remote sensing satellites - measures visible, near infrared, and shortwave infrared portions of the spectrum.
PCI Geomatica – a remote sensing desktop package for processing earth observation data
PCPA – Port Curtis Port Alma, includes, Port Alma, the Narrows, Western Basin, Gladstone Harbour and Rodds Bay
QCIF – Queensland Cyber Infrastructure Foundation
SO-IAM - Shoreline Oblique-Image Assessment Method – developed with this project
SPOT – Satellite for observation of Earth
SPSS – Statistical Package for Social Sciences
SRTM - Shuttle Radar Topography Mission - a digital elevation model that is derived from radar
S-VAM – Shoreline Video Assessment Method
TM – Thematic Mapper sensor with Landsat remote sensing satellites - a multispectral scanning radiometer operating in the visible and Infra-Red regions of the Electromagnetic Spectrum
TropWATER – Centre for Tropical Water and Aquatic Ecosystem Research
TUMRA – Traditional Use of Marine Resources Agreement
WBDDP - Western Basin Dredging and Disposal Project

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# 1 INTRODUCTION

This is the 2016-2017 Annual Report of the Port Curtis Port Alma (PCPA) Coastal Habitat Archive and Monitoring Program (CHAMP) lead by scientists from James Cook University (JCU) TropWATER Centre. The work program includes monitoring the condition, survival and recovery of shorelines, specifically tidal wetlands, as outlined in the scope of works for tender CA14000114.

As noted in the previous Annual Reports, this project forms part of Gladstone Ports Corporation's (GPC) Ecosystem Research and Monitoring Program - a compliance requirement under GPC's approval for the Western Basin Dredging and Disposal Project (WBDDP). The PCPA CHAMP project commenced around mid-November 2014.

This third annual report, plus appendices, describes current project achievements, with their status in this six year program of assessment and monitoring of mangrove tidal wetlands in the PCPA study area, including Gladstone Harbour in Port Curtis (see Fig. 1). The PCPA study area extends from Port Alma to Rodds Bay and includes 3 core study areas, Port Alma, Port Curtis (of which the Western Basin is included) and Rodds Bay. Over the project period, 2014-2020, the plan is to generate essential baseline data, including comparisons with historical information, as the basis for on-going evaluations of environmental condition and change in the region.


**Figure 1.** Map of the study area for the PCPA CHAMP projects showing the key study areas north of Gladstone to Port Alma, and south to Rodds Bay.

The information presented in this third report describes on-going project logistics, mapping, ranger engagement and training, with project results to date. The five component tasks continue to be fundamental to meeting the objectives of this program.

Current data presented are the result of project findings that further extend on prior project achievements. Surveys and mapping have been most beneficial in our on-going establishment of baseline information, noting that we are now getting the benefit of prior efforts in the establishment of organisational facilities, like the Gladstone office, and with the training and familiarisation workshops with our partners, the Gidarjil rangers.

As previously noted, the program commitment is to undertake and complete the five components listed in the project scope of works for the PCPA study area, as:

1. High resolution maps of tidal wetlands, plus historical assessment (change detection);
2. Normalised Difference Vegetation Index (NDVI) mapping of tidal wetlands;
3. Shoreline condition monitoring using oblique aerial image data acquisition;
4. Shoreline condition monitoring using boat based video image data acquisition and community volunteers; and
5. Public access and data entry portal for display of current and past mapping.

The integration of these components is fundamental to the success of the program. All efforts continue to be made to ensure each component is connected with each other component. And, the methodologies applied to the mapping, the aerial surveys, the field works, and the public outreach are all linked to the central archive database now in advanced development.

As noted previously, the program is chiefly lead by science specialists in tidal wetlands, who are characterising shoreline environmental values for the PCPA study area as compared to neighbouring reference areas. This is being achieved through the mapping and evaluation of natural tidal wetland resources using the Shoreline Video Assessment Method (S-VAM) and all linked to the integrated monitoring and archiving program, bringing together partners in field research, remote sensing, information technology and teaching skills.

While TropWATER at JCU is the lead agent for the purposes of contracting with GPC, we are collaborating with partner organisations through individual sub-contracting/partnership arrangements, as appropriate:

a. Gidarjil Development Corporation (GDC) Indigenous Sea Rangers along with community volunteers in the Gladstone region, are assisting in the monitoring and assessment of coastal tidal wetland habitats (Component 4 chiefly, plus 3);
b. Collaboration with Prof John Kovacs lab team at Nipissing University, Canada, for dedicated remote sensing assessments and mapping of tidal wetland habitats in the region (Components 1 & 2 primarily, plus using 4 for opportunities in ground truth and data validation);
c. Partnership with Queensland Cyber Infrastructure Foundation (QCIF) and the JCU e-Research Centre for the development and implementation of the planned online facility (Component 5 primarily, plus all other components eventually).

This project is considered an important opportunity to achieve world best practice for compilation and dissemination of data and expert advice gathered from tidal wetland field surveys and meetings with key stakeholders from industry, government, universities and with indigenous rangers and community volunteers. These particular works build on prior surveys like Duke et al. (2003; 2010).

The program is planned to raise awareness amongst communities about the values, condition and threats to coastal tidal wetlands. In addition, by encouraging best practice management of these fragile ecosystems, human communities can contribute to the preservation of high value coastal nursery habitat and coastal shoreline buffering from erosion and deposition, as well as the protection of neighbouring coastal habitats, like seagrass meadows and coral reefs.

# 2 BACKGROUND REVIEW

This program is an integrated package, called CHAMP (Coastal Habitat Archive & Monitoring Program), being delivered as five Project Components with a variety of contributing, specialist partners applying their specific skills to address the objectives of each.

## 2.1 Project Component 1. High resolution mapping and change detection

| | |
|---|---|
| **Criteria:** | Generate high resolution maps of tidal wetlands with historical change detection to identify areas of net loss and gain in key habitat components (mangroves, saltmarsh and saltpans) |
| **Project Lead:** | Dr Norm Duke, TropWATER JCU |
| **Partners:** | Prof. John Kovacs lab, Nipissing University, Canada |

**Specific Tasks**

Suitably fine-scaled Image data will be acquired from a number of sources starting with the remote sensing archives spatial imagery housed by the Queensland Herbarium and the Remote Sensing Centres with Queensland Department of Science, Information Technology and Innovation (DSITI), and the Queensland Department of Natural Resources and Mines (DNRM). These and other spatial data, like that held by the Fitzroy Basin Association (FBA), will be identified and sought for use with this project prior to the project team making purchases to meet listed project objectives.

The key methodology being employed is:

1. Identify and collect source imagery based on a combination of high definition satellite imagery (0.5-1.0m) and aerial photographs.
2. Ensure adequate historical cover is captured by using imagery back to 2000.
3. Create the mapping using the tools for difference and record, notable occurrences of vegetation dieback and expansion and overall changes to habitat condition (health) reflected in canopy condition.
4. These outcomes will provide guidance for Components 3 and 4.
5. The maps will be uploaded and displayed on the dedicated, online public access website and data entry portal under Component 5, combining historical and current information on the condition of mangrove and tidal wetland vegetative communities in the region.

## 2.2 PROJECT COMPONENT 2. Ecological condition mapping

| | |
|---|---|
| **Criteria:** | Normalised Difference Vegetation Index (NDVI) mapping of tidal wetland with historical change detection to identify areas of net loss and gain in key habitat components (mangroves, saltmarsh and saltpans); |
| **Project Lead:** | Dr Norm Duke, TropWATER JCU |

**Partners:** Prof. John Kovacs lab, Nipissing University, Canada

**Specific Tasks**
Suitably fine-scaled, multispectral image data will be acquired as described for Component 1. It is expected that the key imagery will be suitable for both components.

The methodology that will be employed is:
1. Identify and collect source imagery based on a combination of high definition satellite imagery (0.5-1.0 m) of suitable multispectral bands for NDVI analyses and mapping detection of sublethal change in canopy condition. Corrections and classifications will be made to image data based on field measures of *in situ* Leaf Area Index (LAI) measured during field surveys described in Component 4.
2. Ensure adequate cover is captured by using imagery specifically dated in at least two time periods each around 2014 and 2018. Additional time periods will be assessed where image availability and funding permits. The choice of suitable image data will be determined by availability, suitably high definition, and lack of cloud cover.
3. Create mapping using tools for difference and record, notable occurrences of zonal margins of vegetation dieback or expansion and overall changes to habitat condition (health) reflected in canopy condition.
4. These outcomes will provide guidance for Components 3 and 4.
5. The maps will be uploaded and displayed on the dedicated, online public access website and data entry portal under Component 5, combining historical and current information on the condition of mangrove and tidal wetland vegetative communities in the region.

## 2.3 PROJECT COMPONENT 3. Aerial shoreline surveys

**Criteria:** Shoreline condition monitoring using oblique aerial image data acquisition and current assessment criteria for quantification of key ecological processes

**Project Lead:** Dr Norm Duke, TropWATER JCU
Jock Mackenzie, TropWATER JCU

**Partners:** GDC Land and Sea Rangers

**Specific Tasks**
The methods used in these surveys are geo-referenced videography. All imagery is processed and used both to visually describe coastlines, and to be used to make ecological assessments of shoreline composition, status and condition.

The methodology that will be employed is:
1. Collect source video and still imagery taken obliquely from aircraft flown at around 150 m altitude, covering entire shorelines of estuarine areas and embayments. The extent of shorelines filmed will comprise continuous coverage of most mainland and island shorelines (as chiefly mangrove seaward margins, but not restricted to them) in the study area.
2. Ensure adequate temporal cover is captured by using imagery taken in at least two time periods around 2014, and 2018. Additional time periods will be assessed if funding permits. The choice of days for flying surveys will be determined by the suitable weather conditions, time of day, coupled with periods of relatively low tide.
3. Records will initially be made of baseline conditions, followed by difference records in subsequent surveys. Records will note occurrences of habitat type, condition and change. Specifically, these include key processes of change, like shoreline retreat, erosion,

dieback of vegetation, encroachment of vegetation, and other indicators/evidence of changes to the shoreline.
4. These outcomes will provide guidance for site selections made in Component 4.
5. The information will be mapped based on background maps developed in Components 1 and 2. These will be uploaded and displayed on the dedicated, online public access website and data entry portal under Component 5, combining historical and current information on the condition of mangrove and tidal wetland vegetative communities in the region.

## 2.4 Project Component 4. Boat-based shoreline surveys and field plots

| | |
|---|---|
| **Criteria:** | Shoreline condition monitoring using boat based video image data acquisition and community volunteers**.** |
| **Project Lead:** | Dr Norm Duke, TropWATER JCU<br>Jock Mackenzie, TropWATER JCU |
| **Partners:** | GDC Land and Sea Rangers<br>MangroveWatch Ltd<br>Gladstone MangroveWatch Community Volunteers |

**Specific Tasks**

The methods used in these surveys are geo-referenced videography. All imagery is collected by either indigenous rangers or by community volunteers. All participants are trained by the project team. In the PCPA study area, the indigenous rangers are already trained and operationally ready to conduct surveys in the study area. Processing of image data collected by community members is assessed by the project team at the Mangrove Hub at JCU TropWATER. Data taken from imagery and from survey diaries are used to visualise and describe coastlines, to make ecological assessments of shoreline composition, status and condition.

The methodology that will be employed is:
1. Collect source video and still imagery taken laterally from small boats around 50 m distance to shoreward margins. Filming will be undertaken such that it covers continuous shorelines of specific sections of estuarine areas and embayments. The intent of the project team is to cover all seaward margins in the study area, but limitations of funding dictate that only about 200 km of shoreline will be filmed and assessed. Ideally, the extent of shorelines filmed will include continuous coverage of most mainland and island shorelines (as mangrove seaward margins mostly, but not restricted to them) in the study area.
2. Training has been given to the Gidarjil Rangers by the MangroveWatch project team in 2012-13 to specifically develop their skill base for the effective, independent gathering of imagery and other data for development of shoreline profiles relevant to this scope of work.
3. The project team would prefer to make annual temporal coverages, but the extent of work will be determined fully, as soon as possible after commencement of the project. There is sufficient funding support in the budget proposed to make at least three surveys during the six project years working with the Gidarjil Rangers with surveys in at least three time periods around 2014, 2016 and 2018. To fill intervening periods and to enhance the existing program, a number of strategies will be employed: 1) additional funds will be sought with selected grant applications to further employ Gidarjil Rangers; and 2) community volunteers will be enlisted and trained. This depends on the level of interest shown by community volunteers for increased shoreline coverage and filling time intervals (notably years 2015, 2017, 2019 and 2020). It is proposed that the community

volunteer engagement be facilitated by our support of a community coordinator position for one day per week each year until 2020.

4. The choice of days for boat surveys will be determined by the suitability of weather conditions, the time of day, coupled with periods of relatively low to mid tide.
5. Initial records will represent baseline conditions. Subsequent records will provide the means to measure differences from baseline. Project observations will describe occurrences of habitat type, condition and change; specifically noting: specific vegetative conditions, like species type, biomass, dieback condition, presence of plant mutations, notable erosion, root/bank exposure, sediment deposition, presence of seedlings, and seasonal changes along with verified combinations of species present in each habitat assemblage.
6. As part of this component, field surveys will be conducted in early 2015 and early 2017 to provide specific ground truth to support the mapping and remote sensing (Components 1 and 2), plus each of the videographic surveys (this Component and Component 3). Information gathered will include confirmation of habitat structure, biodiversity, condition, presence of fauna, and soil character.
7. The information from video tracks and sites will be mapped based on background maps developed in Components 1 and 2. These will be uploaded and displayed on the dedicated, online public access website and data entry portal under Component 5, combining historical and current information on the condition of mangrove and tidal wetland vegetative communities in the region.
8. The community coordinator position and office location in Gladstone is considered an important role for the delivery of this component outcomes. The position will be funded from the project at one day per week. The positions work role will be to coordinate community engagement in all MangroveWatch activities combining contributions from the Gidarjil Rangers along with community volunteers and school students. With this, the Gidarjil Rangers are working with the Boyne Island Environmental Education Centre (BIEEC) for collaboration in MangroveWatch surveys. This involves boat support used with project surveys. An additional role of the Coordinator will be to organise community workshops, training sessions, plus outreach activities, like the MangroveWatch art gallery shows.

## 2.5 PROJECT COMPONENT 5. Public access open data archive

**Criteria:** Public access and data entry portal for display of current and past mapping.
**Project Lead:** Dr Norm Duke, TropWATER JCU
Jock Mackenzie, TropWATER JCU
**Partners:** Prof. Ian Atkinson, eResearch JCU
Franz Eilert
Queensland Cyber Infrastructure Foundation (QCIF)
MangroveWatch Ltd

### Specific Tasks

The JCU eResearch Centre, with direction from Dr Duke, is developing a highly engaging and effective, interactive public access website featuring contributor links, along with assessments of risk and vulnerability of the study area shoreline - including estuaries, channels and islands. This system will be able to store, display, organise and archive the data sets and outputs from components 1 to 4 above and provide a single source interface to the programs activities.

This facility is to be an online Digital Asset Management system (DAM) containing all of the digital observations and products developed in components 1-4. This includes the map data with the facility to add/upload future mapping from Component 1 and shoreline profiles (Component 3 & 4). It will also permit the combining of historical and current information on the condition of mangrove and tidal wetland vegetative communities, including any significant impacts of episodic change during the study period to be displayed. The website will have the facility for ready access and uploading of data for the display of the data and imagery from Component 1-4.

The public-access website prototype was available in late June 2017, and functionality will be added in subsequent years in direct response to on-going feedback and emerging requirements. All data, video and other assets will be managed and securely stored in the DAM and relevant metadata will be uploaded to the national Research Data Australia (RDA) repository to enable discovery of the raw and processed data by public search engines such as Google. The website will be updated and reviewed biannually.

The products generated by the proposed project offer tangible long-term benefits, including:

1) A constantly renewed and expanding archive of geo-referenced maps and imagery, available online with assessments of past and current condition of coastal and estuarine habitats, aided by the ShoreView platform (see http://mangrove.hpc.jcu.edu.au/home/)
2) A specific stakeholder network supporting industry, government and community initiatives for improved environmental management of coastal and estuarine habitats, with awareness raising, public workshops and targeted publications and training manuals;
3) A robust, best practice, standardised program, methodology and reporting framework for the systematic assessment and monitoring of the condition and health of coastal and estuarine habitats, involving community volunteers and indigenous rangers.

# 3 2016-2017 UPDATE AND RESULTS

## 3.1 Project Components 1 & 2. High Resolution Mapping, Change Detection and Ecological Condition Mapping

### Current works

Prof. Kovacs has been working with Dr Duke in an on-going collaboration to deliver the mapping outcomes for this project.

The key overall aims of the project are to take the following steps:
1) to develop a HR baseline map using recent imagery to show accurate vegetation extent and condition;
2) to make comparisons with prior historical mapping (like Duke et al. 2003) to show longer term changes in extent, and where possible the canopy condition of key vegetative units of tidal wetlands;
3) to map changes in extent for selected representative areas of each of the three primary areas around Port Alma, Port Curtis and Rodds Bay of the PCPA study area;
4) to tabulate changes in extent based on selected representative areas for at least each of the three primary areas around Port Alma, Port Curtis and Rodds Bay.

The focus of this current milestone report has been on the development of the baseline high resolution map (item #1 above) depicting current day extent and condition of tidal wetlands including mangroves, tidal saltmarsh and saltpans. These are the vegetation units that occupy the zone/niche between mean sea level and the highest astronomical tides.

### Method Using Landsat imagery for NDVI change detection within target areas

**Image acquisition:** For Rodds Bay a total of 31 Landsat images were acquired from 1975 until 2016 (Table 1).

**Table 1.** Landsat imagery acquired for Rodds Bay (Path 91, Row 77).

| *Sensor Name* | *Image Date and Time* | *Spatial Resolution (m)* |
|---|---|---|
| ***Landsat-8 OLI_TIRS*** | 2016-08-07 23:53:42 | 30 |
| ***Landsat-8 OLI_TIRS*** | 2015-08-05 23:53:18 | 30 |
| ***Landsat-8 OLI_TIRS*** | 2014-08-18 23:53:45 | 30 |
| ***Landsat-8 OLI_TIRS*** | 2013-08-15 23:55:41 | 30 |
| ***Landsat-5 TM*** | 2011-09-11 23:42:14 | 30 |
| ***Landsat-5 TM*** | 2010-06-04 23:44:21 | 30 |
| ***Landsat-5 TM*** | 2009-08-04 23:42:50 | 30 |
| ***Landsat-5 TM*** | 2007-08-31 23:46:52 | 30 |
| ***Landsat-5 TM*** | 2005-08-09 23:41:40 | 30 |
| ***Landsat-5 TM*** | 2004-08-22 23:36:54 | 30 |
| ***Landsat-5 TM*** | 2003-08-20 23:30:44 | 30 |
| ***Landsat-7 ETM*** | 2002-09-10 23:41:37 | 30 |
| ***Landsat-7 ETM*** | 2001-08-22 23:42:28 | 30 |
| ***Landsat-7 ETM*** | 2000-08-03 23:44:49 | 30 |
| ***Landsat-5 TM*** | 1996-09-01 23:10:40 | 30 |
| ***Landsat-5 TM*** | 1995-08-30 22:56:23 | 30 |
| ***Landsat-5 TM*** | 1993-08-08 23:16:04 | 30 |
| ***Landsat-5 TM*** | 1991-08-19 23:17:15 | 30 |
| ***Landsat-5 TM*** | 1990-08-16 23:13:38 | 30 |
| ***Landsat-5 TM*** | 1989-08-13 23:20:25 | 30 |
| ***Landsat-5 TM*** | 1988-08-10 23:24:22 | 30 |
| ***Landsat-5 TM*** | 1987-08-24 23:19:59 | 30 |
| ***Landsat-5 MSS*** | 1986-08-05 23:15:40 | 60 |
| ***Landsat-5 MSS*** | 1985-08-18 23:23:18 | 60 |
| ***Landsat-5 MSS*** | 1984-08-15 23:23:29 | 60 |
| ***Landsat-4 MSS*** | 1983-08-21 23:22:58 | 60 |
| ***Landsat-4 MSS*** | 1982-08-18 23:20:05 | 60 |
| ***Landsat-3 MSS*** | 1980-08-03 23:01:07 | 60 |
| ***Landsat-2 MSS*** | 1977-09-15 22:45:23 | 60 |
| ***Landsat-2 MSS*** | 1976-10-08 23:01:21 | 60 |
| ***Landsat-1 MSS*** | 1975-06-28 23:11:06 | 60 |

Port Alma and Port Curtis are found in the same Landsat scene and a total of 31 Landsat images were also acquired for these target areas but the data ranged from 1972 until 2016 (Table 2). All images were selected from near-anniversary dates with the majority collected from the month of August. The earlier MSS sensor has a much coarser spatial resolution (60 m) in comparison to the more recent 30m spatial resolution of the TM, ETM and OLI sensors (1984-2016). A Queensland 5m LIDAR digital surface model (https://data.gov.au/dataset/digital-elevation-model-dem-of-australia-derived-from-lidar-5-metre-grid), a Queensland HAT dataset and an ALOS 30m derived digital surface model (http://www.eorc.jaxa.jp/ALOS/en/aw3d30/) were also collected for the three target areas.

**Table 2.** Landsat imagery acquired for the Port Curtis and Port Alma areas (Path 91, Row 76).

| *Sensor Name* | *Image Date and Time* | *Spatial Resolution (m)* |
|---|---|---|
| ***Landsat-8 OLI_TIRS*** | 2016-08-07 23:53:18 | 30 |
| ***Landsat-8 OLI_TIRS*** | 2015-08-05 23:52:54 | 30 |
| ***Landsat-8 OLI_TIRS*** | 2014-08-02 23:53:16 | 30 |
| ***Landsat-8 OLI_TIRS*** | 2013-07-30 23:55:17 | 30 |
| ***Landsat-5 TM*** | 2011-09-11 23:41:50 | 30 |
| ***Landsat-5 TM*** | 2010-06-04 23:43:58 | 30 |
| ***Landsat-5 TM*** | 2009-08-04 23:42:27 | 30 |
| ***Landsat-5 TM*** | 2007-10-02 23:46:12 | 30 |
| ***Landsat-5 TM*** | 2006-11-16 23:47:43 | 30 |
| ***Landsat-5 TM*** | 2005-08-09 23:41:16 | 30 |
| ***Landsat-5 TM*** | 2004-08-22 23:36:30 | 30 |
| ***Landsat-5 TM*** | 2003-09-05 23:30:37 | 30 |
| ***Landsat-7 ETM+*** | 2002-09-10 23:41:13 | 30 |
| ***Landsat-7 ETM+*** | 2001-08-22 23:42:04 | 30 |
| ***Landsat-7 ETM+*** | 2000-08-03 23:44:25 | 30 |
| ***Landsat-7 ETM+*** | 1999-09-18 23:46:09 | 30 |
| ***Landsat-5 TM*** | 1996-09-01 23:10:16 | 30 |
| ***Landsat-5 TM*** | 1995-08-30 22:55:59 | 30 |
| ***Landsat-5 TM*** | 1994-08-27 23:10:18 | 30 |
| ***Landsat-5 TM*** | 1993-08-24 23:15:39 | 30 |
| ***Landsat-5 TM*** | 1991-08-19 23:16:51 | 30 |
| ***Landsat-5 TM*** | 1990-08-16 23:13:14 | 30 |
| ***Landsat-5 TM*** | 1989-08-29 23:19:42 | 30 |
| ***Landsat-5 TM*** | 1987-08-24 23:19:35 | 30 |
| ***Landsat-5 TM*** | 1986-08-21 23:14:40 | 30 |
| ***Landsat-5 MSS*** | 1985-08-18 23:22:54 | 60 |
| ***Landsat-5 MSS*** | 1984-08-15 23:23:05 | 60 |
| ***Landsat-4 MSS*** | 1983-08-21 23:22:34 | 60 |
| ***Landsat-2 MSS*** | 1980-08-30 23:09:55 | 60 |
| ***Landsat-2 MSS*** | 1975-08-21 23:09:29 | 60 |
| ***Landsat-1 MSS*** | 1972-08-27 23:21:48 | 60 |

**Landsat Image processing:** All of the Landsat images were converted to surface reflectance using *PCI Geomatica's ATCOR* module. The NDVI was then calculated for each date of imagery. To narrow the focus of analysis a study area mask (HAT Zone) was created. The area below the HAT line (HAT Zone) mask was produced by first converting the vector polyline HAT dataset to a binary bitmap. Water masks were then produced from each image using a threshold NDWI = Green−NIR Green + NIR. The union of the binary water masks was then used to delineate the area of surface water at its maximum extent. The maximum water extent mask was then used to erase areas of surface water from the HAT Zone mask. Using the HAT Zone mask, a time series of NDVI maps were then produced to examine historical changes for each of the target areas. To create an estimated height for the mangroves LIDAR DEM was first resampled to a 30m spatial resolution in order to match that of the ALOS data. Once resampled the LIDAR DEM could then be subtracted from the ALOS digital surface model to provide an estimated canopy height for all three locations.

## SPOT Image processing methods

**Data Acquisition:** To cover the entire study area for the baseline image and map, three separate scenes of SPOT imagery were collected between August 7 and September 23 of 2016. Once collected, these data were radiometrically and geometrically corrected. Since several swaths of imagery were needed to cover the entire PCPA study area, the many surface reflectance images may also be mosaicked. For each scene, this included four bands of multi-spectral imagery at a 6m spatial resolution and one panchromatic band at 1.5m spatial resolution.

**Image Pre-Processing:**

*Pan-sharpening and orthorectification of pan-sharpened products*

For each scene an additional set of pan-sharpened bands were created using a Toutin model. This resulted in four bands of multi-spectral imagery at a 1.5m spatial resolution. These data were then ortho-rectified using Ground Control Points (GCPs) collected manually from the geo-referenced Queensland 5m LIDAR digital surface model and using the SRTM 30m DEM for terrain correction. The ortho-rectified products were corrected to a sub-pixel root mean square error accuracy.

*Multi-spectral surface reflectance and orthorectification*

For each scene, the original 6m multi-spectral images were atmospherically corrected using Geomatica's ATCOR module without cloud and water masking or haze removal. This resulted in multi-spectral bands with surface reflectance values. These new data were then ortho-rectified (Toutin's model) using GCPs automatically collected from the corrected pan-sharpened products (1.2.1). The SRTM 30m DEM was again used for terrain correction.

*Mask creation for subsequent image classification procedures*

The target area vector polygons provided were first converted into target area bitmap binary masks. Using the ortho-rectified surface reflectance bands (1.2.2) the NDWI was calculated for each of the three scenes. Values above approximately 0.0 are considered water and values below approximately 0.0 considered land. For this investigation, it was determined that a threshold value of -0.2 or greater represented areas of water. Consequently, the NDWI was employed to create a surface water binary bitmap mask. A final classification mask was created using the surface water binary bitmap masks, the target area bitmap binary masks and a HAT area binary mask. Specifically, the HAT area binary mask areas within the target area mask were selected and then edited by removing those areas identified as surface water based on the surface water binary bitmap mask.

**Image Classification:** Using the classification masks an iterative unsupervised classification procedure was applied for all three target areas. Specifically, all four pan-sharpened bands were classified only under the classification mask areas using a K-means classification algorithm. Ancillary data were then used to assist in post-classification manually editing of the output maps.

The NDVI will be produced from each surface reflectance mosaic. NDVI is calculated using the following formula: $NDVI = \frac{(NIR - Red)}{(NIR + Red)}$. The NDVI images can then be used to monitor changes in the health of the vegetation by comparing them with future NDVI images collected of the same locations. Finally, using more recent ancillary data (e.g., our project field surveys), an updated per pixel classification procedure will be applied to the newly acquired imagery in order to map the most recent areas of mangrove and saltpan/saltmarsh land cover.

**Queensland Wetlands Mapping**: Mangrove areas are defined by the mapped polygons (DSITI 2015) where mangroves (RE 12.1.3) are the dominant vegetation type. Dataset is titled as Queensland wetland data version 4 - wetland areas. The dataset provides mapping of water bodies and wetland regional ecosystems at 1:100,000 scale across Queensland.

The positional accuracy of wetland data mapped at a scale of 1:100 000 is +/-75m is described as: the minimum polygon size depicted is 5 ha or 75m wide for linear features, except for areas along the east coast which are mapped at the 1:50 000 scale with a positional accuracy of +/-50m, with a minimum polygon size of 1 ha or 35m wide for linear features. Wetlands smaller than 1 ha are not delineated on the wetland data. Note that consideration of the effects of mapped scale is necessary when interpreting data at a larger scale (eg: 1:25,000). For property assessment, digital line work should be used as a guide only.

## A preliminary look at image data now available to the project

**Mangrove vegetation maps – SPOT 2016:** While mangrove vegetation dominates shoreline areas across PCPA study area, there are notable differences from north, to central and southern sections. The light grey-blue saltpan/saltmarsh areas are more dominant in the north with a trend to greater mangrove dominance in the south (see Figs. 2 to 4). The key correlate with these differences is annual rainfall, being much lower in the north than towards the south.

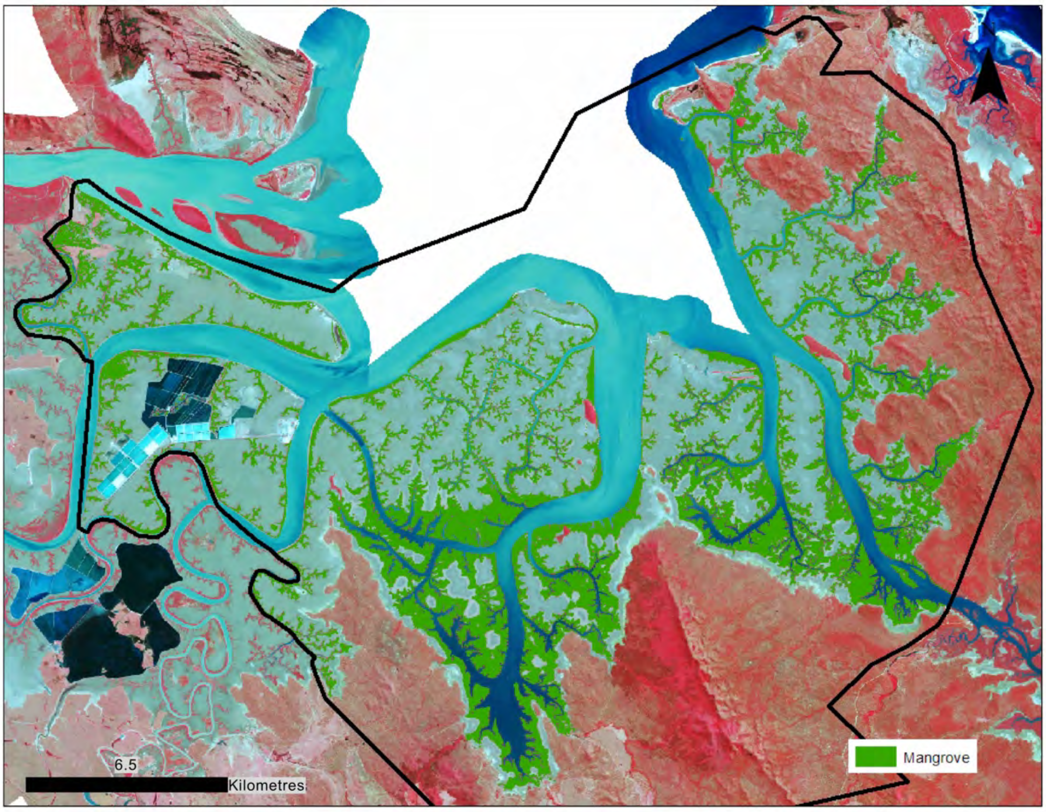


**Figure 2.** Mangrove vegetation (green) mapped from SPOT 2016 – Port Alma in the northern part of the PCPA study area.

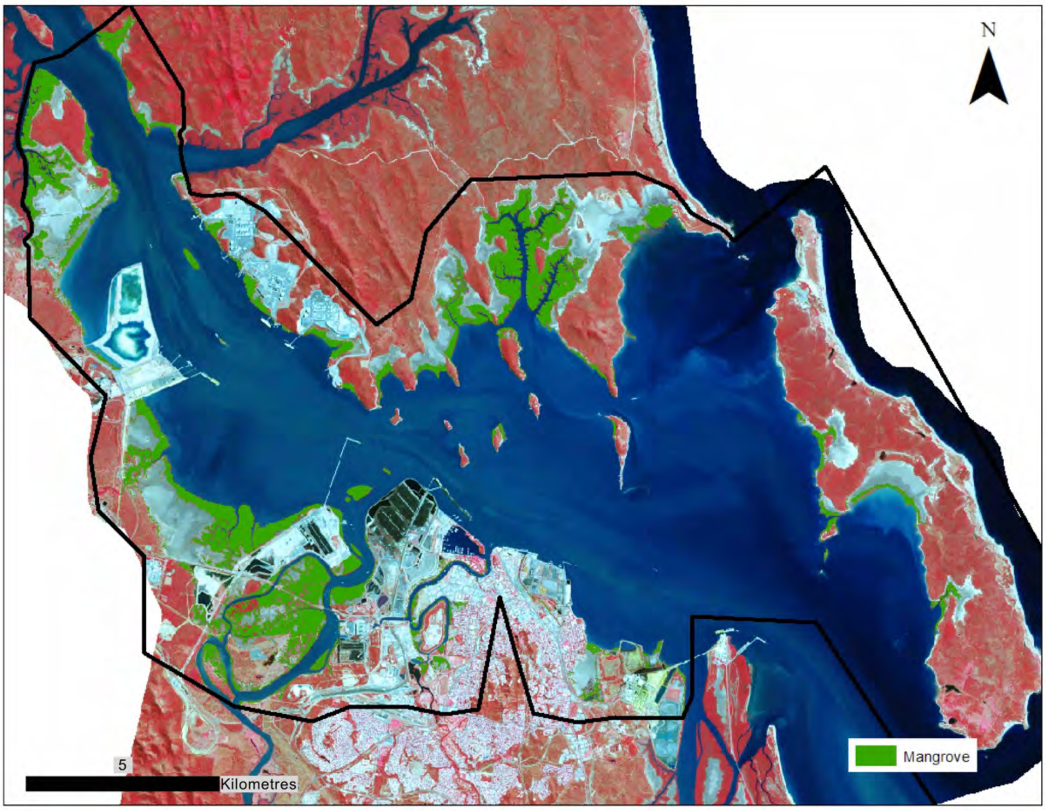


**Figure 3.** Mangrove vegetation (green) mapped from SPOT 2016 – Port Curtis and the Western Basin in the central part of the PCPA study area.

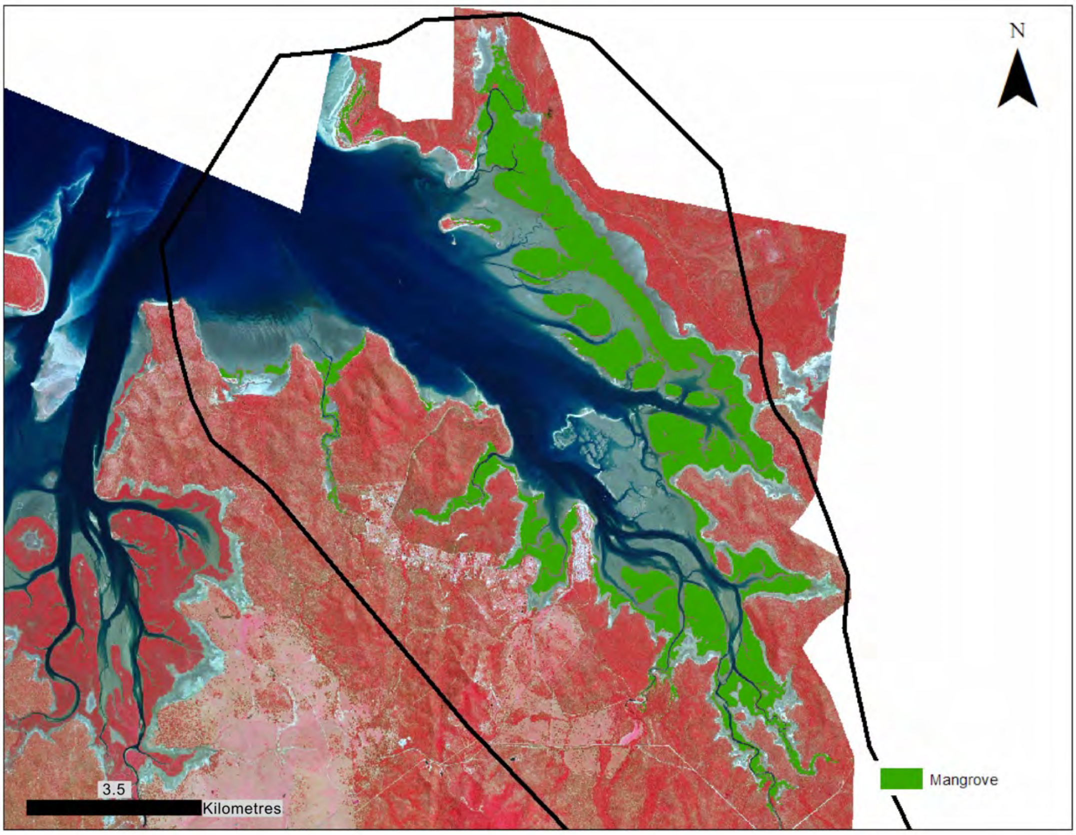


**Figure 4.** Mangrove vegetation (green) mapped from SPOT 2016 – Rodds Bay in the southern part of the PCPA study area.

## Comparison of mangrove vegetation maps - SPOT 2016 versus prior mapping

**Comparing prior mapping of mangrove vegetation:** Mangrove vegetation maps from high resolution SPOT 2016 mapping show notable improvements from prior mapping done from our 2015-2016 mapping and Queensland Wetland mapping.

In Figure 5, note detail showing three notable improvements to the mapping:
1) greater definition and description of detailed, fine patterns and edges;
2) correct determination of mangrove mistaken for terrestrial vegetation; and
3) correct determination of terrestrial vegetation mistaken for mangrove vegetation.

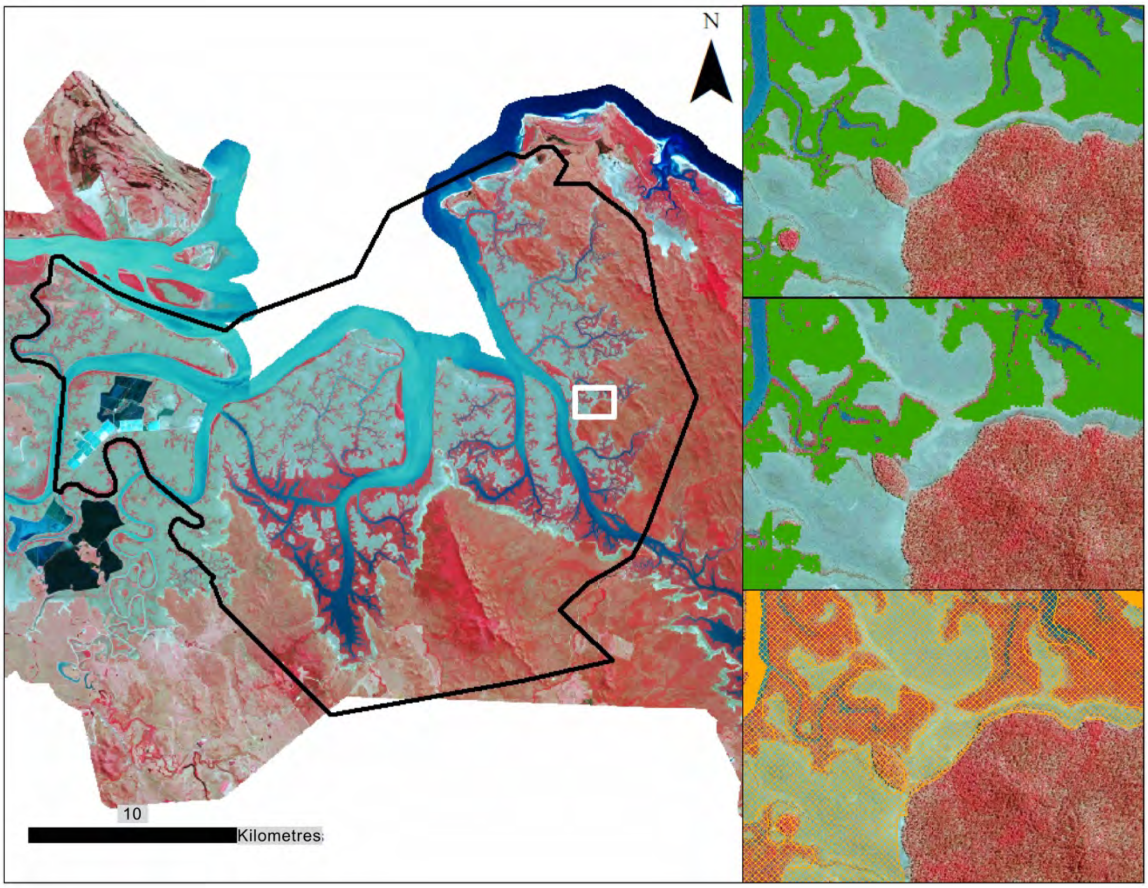


**Figure 5.** Mangrove vegetation mapped from SPOT 2016 compared with other mangrove maps of the Port Alma northern area. Inset images on the right side from top to bottom include SPOT 2016; ALOS AVNIR 2013 and the Queensland Wetland V4.

Table 3 shows overall estimates of mangrove areas for the three scenes of the study area (Figs. 2 -4) taken from each of the three instances of mapping.

**Table 3.** Comparisons of mangrove area estimates (in ha) taken from different sourced imagery – as SPOT 2016 (this report), ALOS AVNIR (2015-2016 report) and Queensland Wetland V4.

| *Mapped Mangrove Area* | *SPOT (ha)* | *AVNIR (ha)* | *QLD Wetland V4 (ha)* | *Area Difference SPOT vs. AVNIR +ve* | *Area Difference SPOT vs. AVNIR -ve* |
|---|---|---|---|---|---|
| ***Port Alma*** | 7919 | 8451 | 8891 | 1050 | 1581 |
| ***Port Curtis*** | 1907 | 1554 | 2174 | 610 | 257 |
| ***Rodds Bay*** | 1708 | 1565 | 1860 | 252 | 108 |

Despite notable variability due to the different spatial resolutions of the sensors, there are further differences in estimations of areas for each of the three sections. There are additional issues when comparing vector-based data sets (like Queensland Wetland V4; = Version 4.0— released September 2015 based on 2013 imagery) with the raster-based SPOT imagery (satellite imagery). However, regardless of such issues, the recent mapping for this project using the high-resolution SPOT data is more accurate than has been possible previously.

## Biomass distribution maps

***A notable trend in mangrove canopy height:*** Mangrove canopy heights overall vary notably from north to south. Those in the north range are shortest, around 1-3 m tall (Fig. 6). While those in the Port Curtis area are ~3-5 m tall (Fig. 7), and those around Rodds Bay range around 5-7 m tall (Fig. 8).

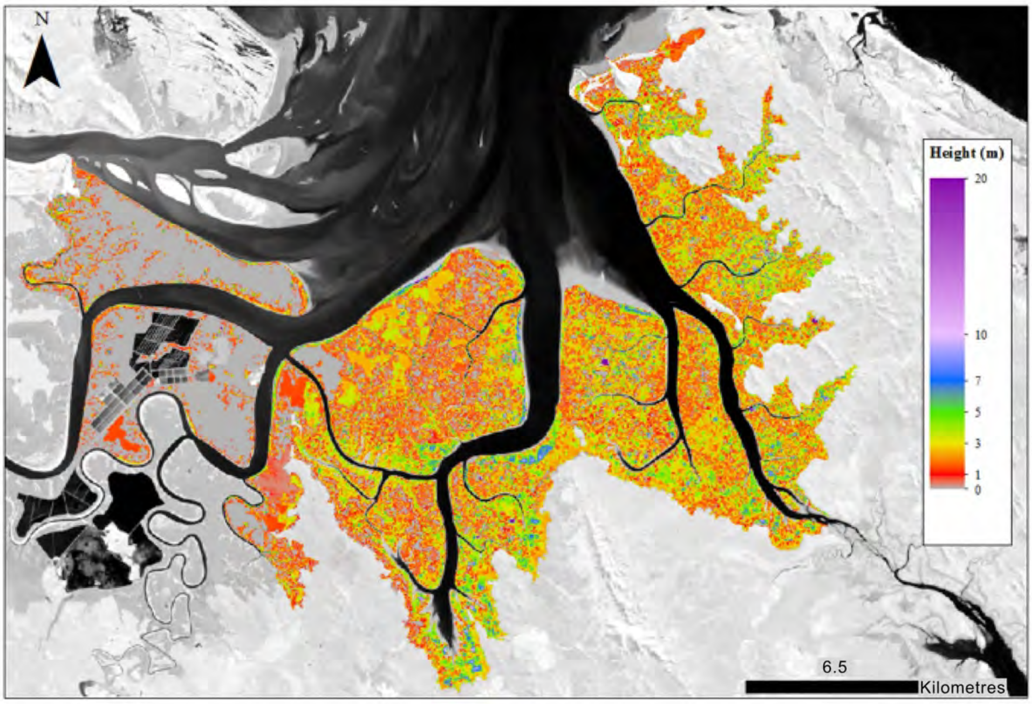


**Figure 6.** Vegetation height from ALOS DSM 2016 – Port Alma in the northern part of the PCPA study area.

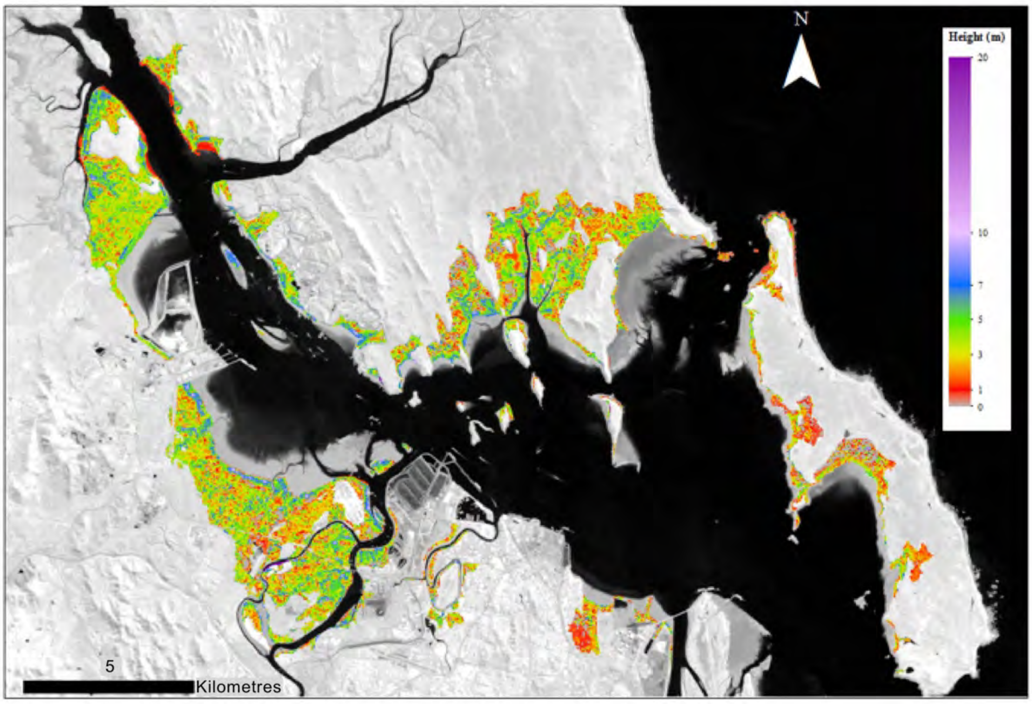


**Figure 7.** Vegetation height from ALOS DSM 2016 – Port Curtis and Western Basin in the central part of the PCPA study area.

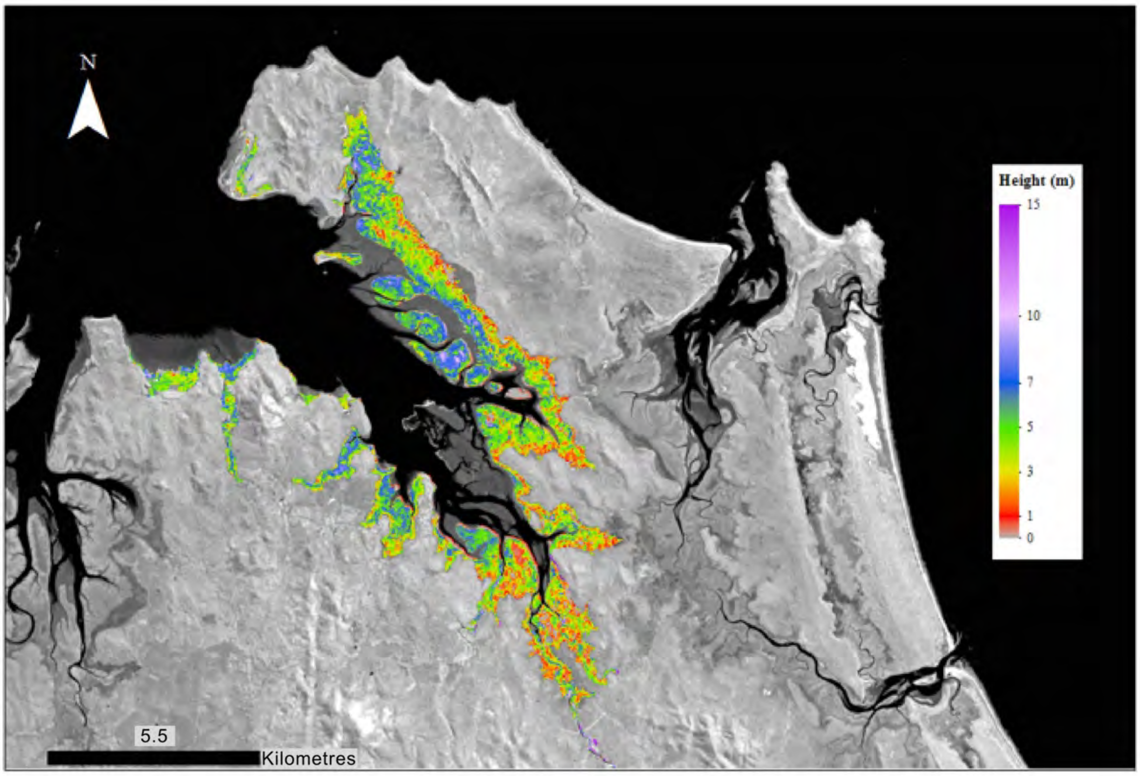


**Figure 8.** Vegetation height from ALOS DSM 2016 – Rodds Bay in the southern part of the PCPA study area.

## Canopy density maps

***A notable trend in canopy condition – 2016:*** Canopy density was quantified using the NDVI estimated from the Landsat Thematic Mapper for 2016 data. These can be taken as measures of condition but this must be used advisedly.

NOTE: the NDVI describes the relative density of vegetation canopy. For mangroves, NDVI can be used as a proxy for vegetation condition. At the spatial scale of $30m^2$, low NDVI represent low mangrove canopy cover and high values depict dense healthy mangrove cover. Low NDVI values may be attributed to either low vegetation stem density (stems $m^{-2}$) or low density, canopy relating to physiological stress. Both instances represent poor mangrove 'condition' as healthy mangrove areas are characterised by having continuous canopies with dense canopy cover.

Those in the north (Fig. 9; 0.1-0.3) had lower canopy condition (refer to Fig. 6), compared with those in the central area (Fig. 10; 0.2-0.5), and those in the south (Fig. 11; ~0.5).

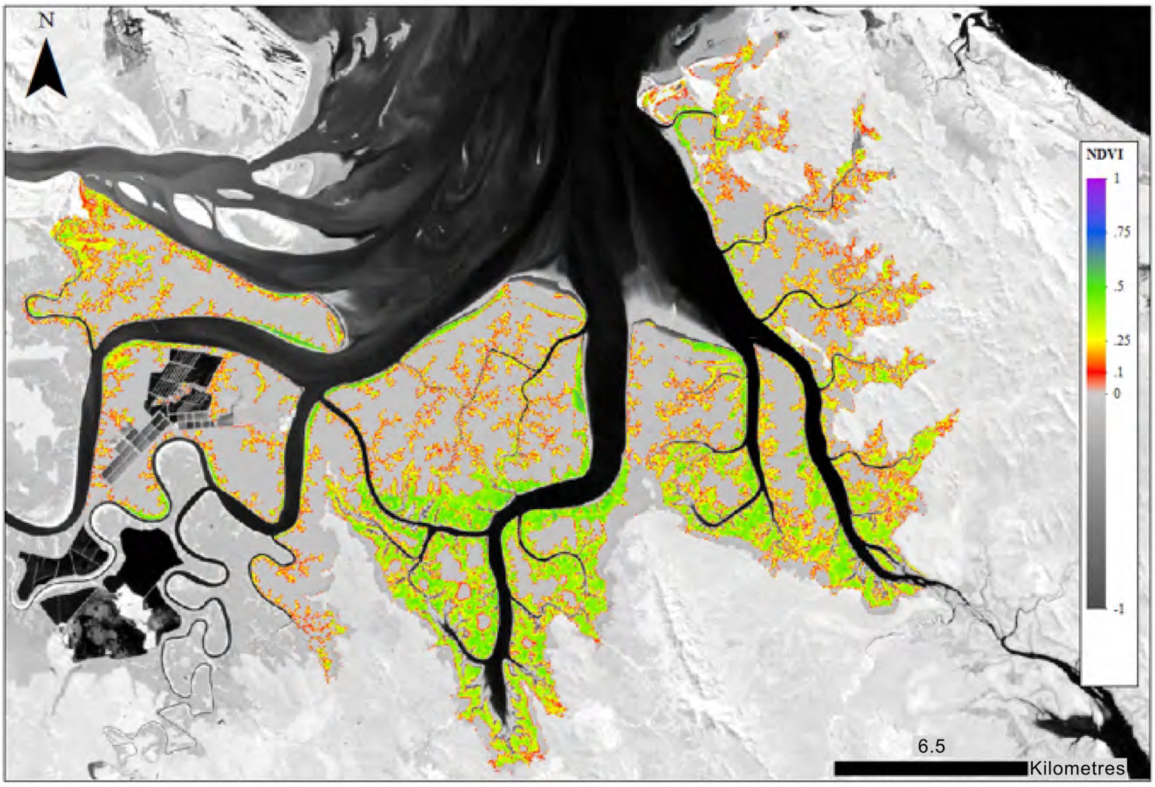


**Figure 9.** Canopy condition from Landsat NDVI 2016-08-07 – Port Alma in the northern part of the PCPA study area.

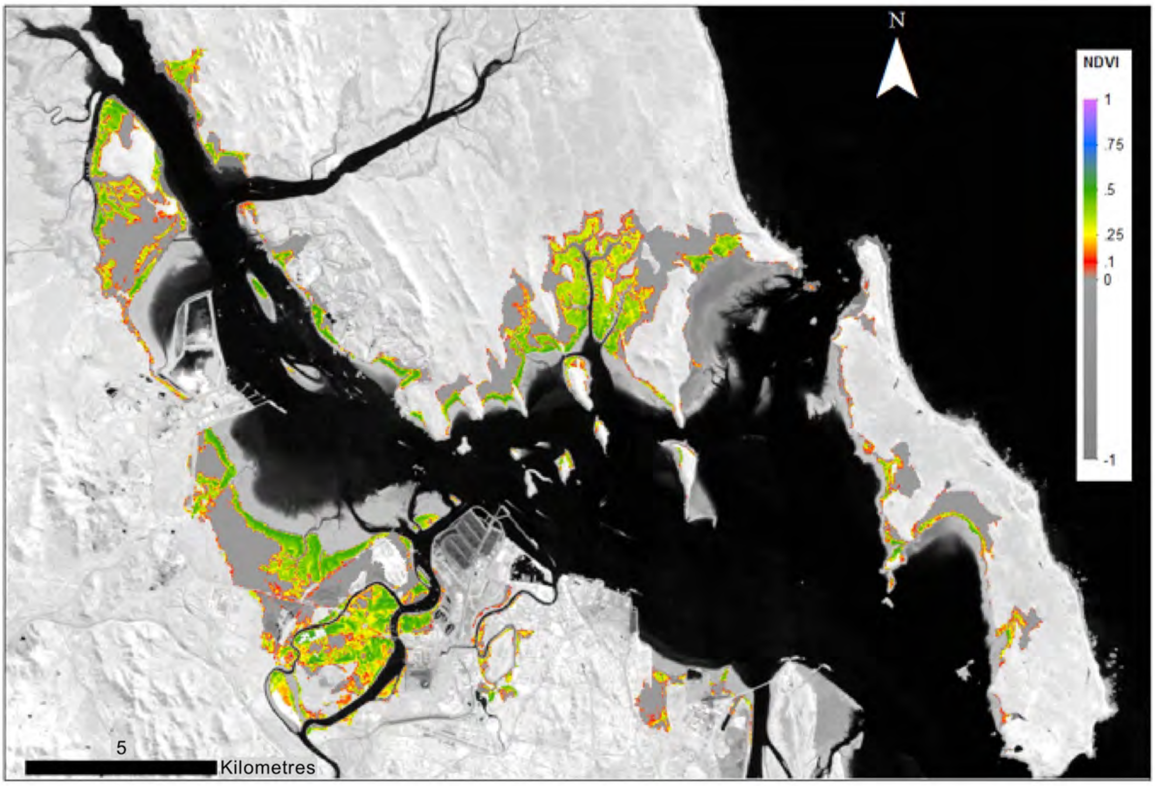


**Figure 10.** Canopy condition from Landsat NDVI 2016-08-07 – Port Curtis and the Western Basin in the central part of the PCPA study area.

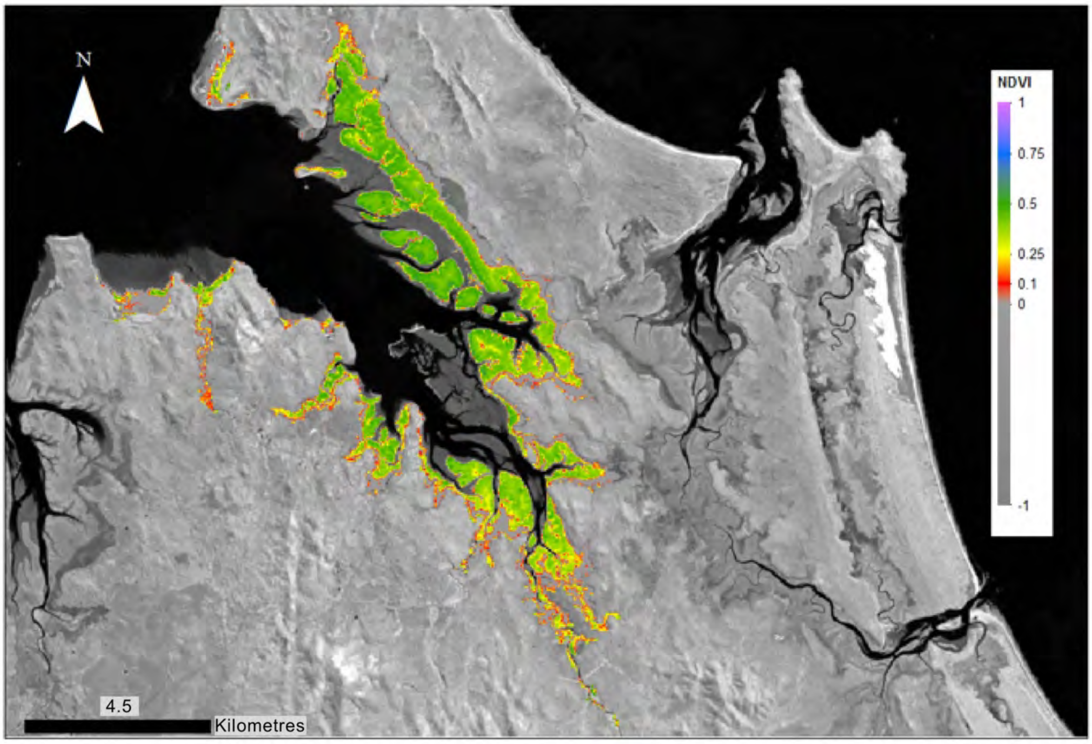


**Figure 11.** Canopy condition from Landsat NDVI 2016-08-07 – Rodds Bay in the southern part of the PCPA study area.

***A comparable trend in canopy condition – 1980:*** Canopy condition was quantified using the NDVI estimated from the Landsat Thematic Mapper for 1980 data. The overall trend was the same as that shown for 2016. Those in the north (Fig. 12; 0.1-0.3) were more stressed, compared with those in the central area (Fig. 13; 0.1-0.4), and those in the south (Fig. 14; 0.2-0.5).

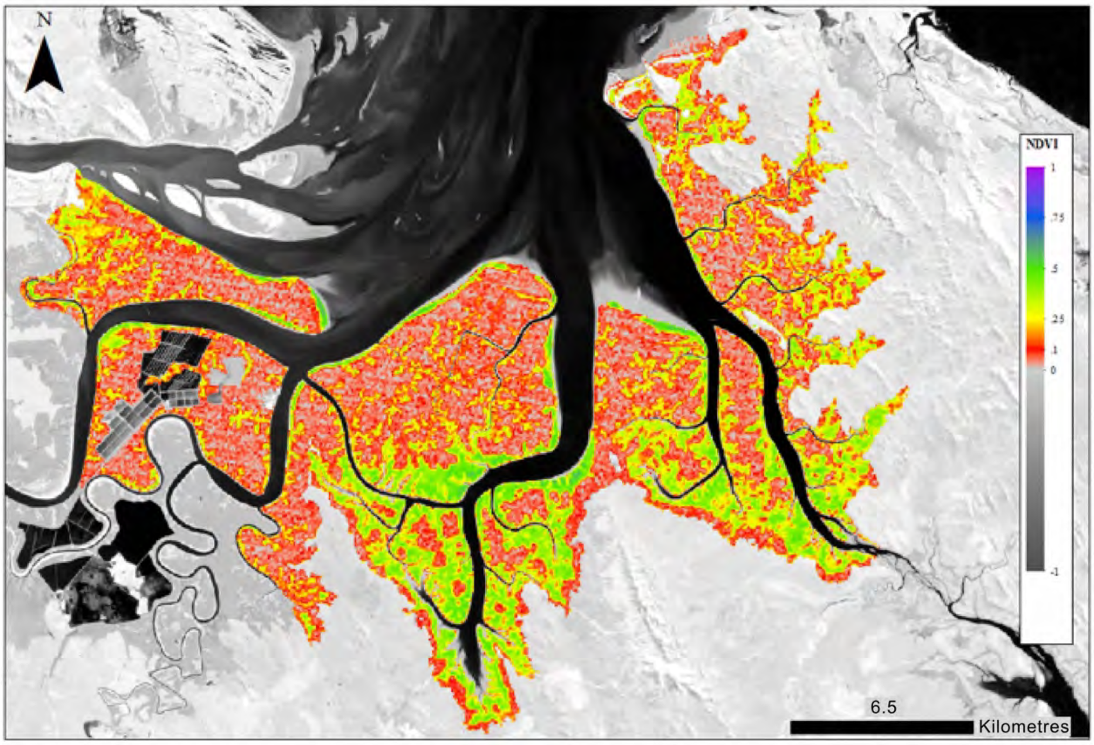


**Figure 12.** Canopy condition from Landsat NDVI 1980-08-30 – Port Alma in the northern part of the PCPA study area.

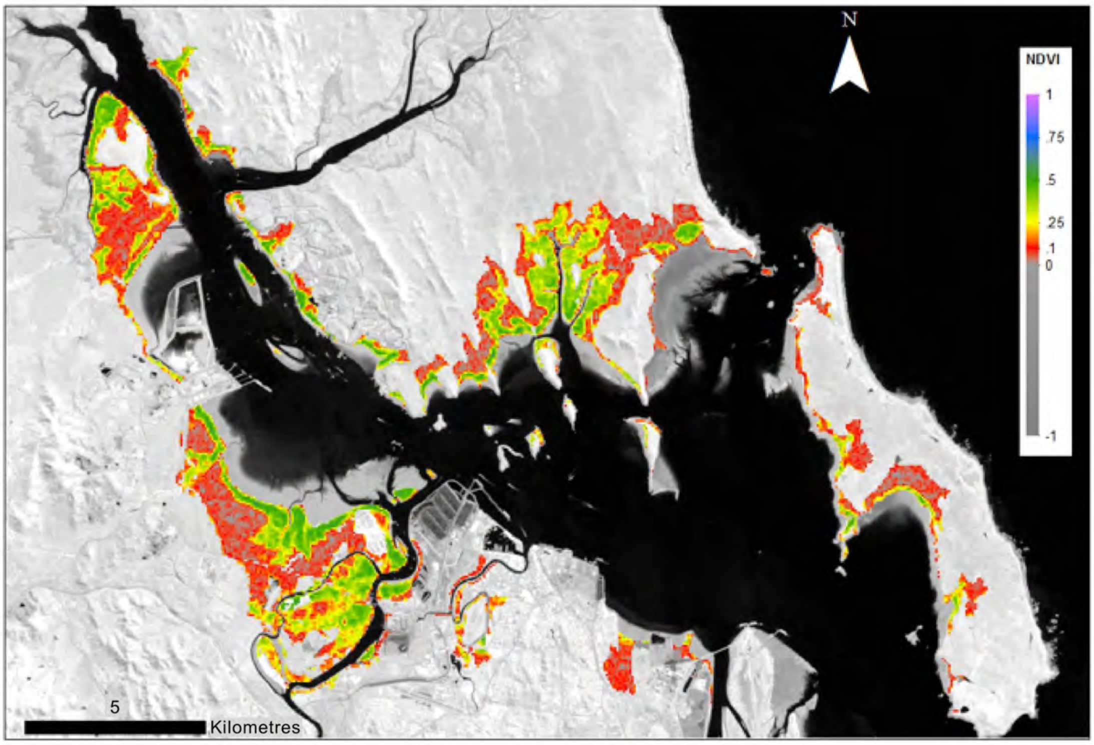


**Figure 13.** Canopy condition from Landsat NDVI 1980-08-30 – Port Curtis and the Western Basin in the central part of the PCPA study area.

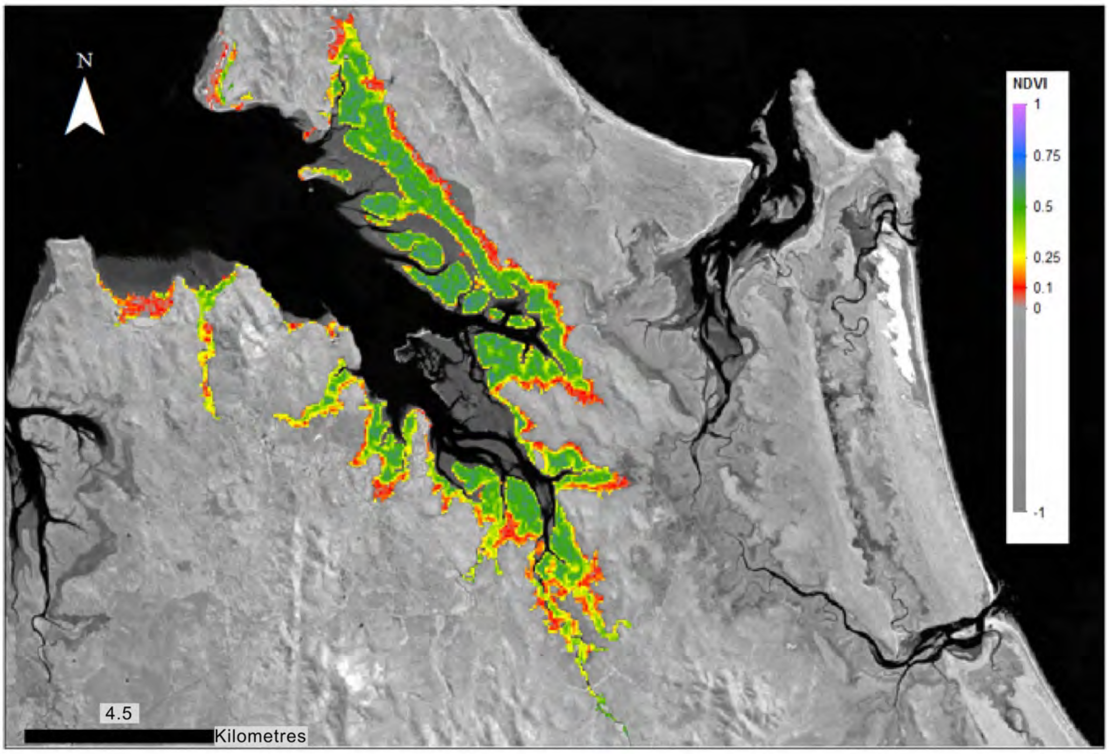


**Figure 14.** Canopy condition from Landsat NDVI 1980-08-30 – Rodds Bay in the southern part of the PCPA study area.

## 3.2 Project Component 3. Aerial shoreline surveys

No aerial surveys were conducted during this reporting period. Refer to Table 4 for scheduled aerial survey periods (#4 survey activity).

## 3.3 Project Component 4. Boat-based shoreline surveys and field work

Scheduling of boat-based field surveys are listed in Table 4 (see survey activities #3 & #5).

**Table 4.** Project field schedule for S-VAM surveys in the southern GBR region as of June 2017 including both ERMP PCPA & the associated NESP (#6) surveys. Surveys focus on specific estuarine systems for the PCPA (ERMP project) and southern GBR (SGBR NESP project) projects as listed.

**GIDARJIL Shoreline Video Assessment Surveys**
**PCPA & SGBR CHAMP project study sites**

COMPLETED (2012-2013 to 2015-2016) | current (2016-2017) | JCU boat ERMP / Gidarjil boat ERMP (2017-2018 to 2019-2020)

| # | NRM regior | PCCC Systen | 2012-2013 | 2013-2014 | 2014-2015 | 2015-2016 | 2016-2017 | 2017-2018 | 2018-2019 | 2019-2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | FBA | Fitzroy River | | | | | | 6 > | 4 | |
| 2 | FBA | Balaclava Island | | | 3 | | | 5 | 3+4 | 5 |
| 3 | FBA | Port Alma | | | 3 | | | 5 | 3+4 | 5 |
| 4 | FBA | Maria Inlet | | | | | | | 4 | |
| 5 | FBA | Barker Ck | | | | | | | 4 | |
| 6 | FBA | Mosquito Ck | | | | | | | 4 | |
| 7 | FBA | Deception Ck | | | | | | | 4 | |
| 8 | FBA | Badger Ck | | | | | | | 4 | |
| 9 | FBA | Monte Christo Ck | | | | | | | 4 | |
| 10 | FBA | Middle Ck | | | | | | | 4 | |
| 11 | FBA | The Narrows Ck | | | | | | | 4 | |
| 12 | FBA | Black Swan | | | | | | | 4 | |
| 13 | FBA | Graham Ck | | | | | | 5 | 4 | 5 |
| 14 | FBA | Targinie Ck | | | 5 | 5 | | 5 | 4+5 | 5 |
| 15 | FBA | Endfield Ck | | | | | | 5 | 4 | 5 |
| 16 | FBA | Port Curtis | | | 3 | | | | 3+4 | |
| 17 | FBA | Calliope (Upper +Lower) | | | 5 | 6 | 6 | 5 | 4+5 | 5 |
| 18 | FBA | Auckland Ck | | | | | | | 4 | |
| 19 | FBA | W Facing Island | | | | | | 5 | 3+4 | 5 |
| 20 | FBA | South Trees | | 2 | | | | 5 | 4 | 5 |
| 21 | FBA | Boyne R | | 2 | 5 | 5 | 5 | 5 | 4+5 | 5 |
| 22 | BMRG | Wild Cattle Ck | | | | | | | 4 | |
| 23 | BMRG | Pancake Ck | | | | | | | 3+4 | |
| 24 | BMRG | Rodds Bay | | | 3 | | | 5 | 3+4 | 5 |
| 25 | BMRG | Eurimbula | | | | | | | | |
| 26 | BMRG | Round Hill Ck | | | | | 6 | | | |
| 27 | BMRG | Deepwater | | | | | | | | |
| 28 | BMRG | Baffle | | | | | 6 | | | |
| 29 | BMRG | Littabella | | | | | | | | |
| 30 | BMRG | Kolan | 1 | | | 6 | | | | |
| 31 | BMRG | Burnett | 1 | | | 6 | | 6 > | | |
| 32 | BMRG | Elliott | 1 | | | 6 | | 6 > | | |
| 33 | BMRG | Coonarr | | | | | | | | |
| 34 | BMRG | Theodilite | | | | | | | | |
| 35 | BMRG | Burrum | 1 | | | 6 | 6 | 6 > | | |
| 36 | BMRG | Gregory | | | | 6 | | | | |
| 37 | BMRG | Isis | | | | 6 | | | | |
| 38 | BMRG | Cherwell | | | | | | | | |
| | | Survey #'s | 4 | 2 | 7 | 9 | 5 | 10 | 15 | 10 |

| Legend - survey activities | |
|---|---|
| 1 | JCU boat BMRG |
| 2 | JCUboat C-4-C |
| 3 | JCU PCPA boat ERMP |
| 4 | JCU PCPA aerial ERMP |
| 5 | GDC PCPA boat ERMP |
| 6 | GDC SGBR boat NESP |

Boat-based surveys lead by Gidarjil rangers were conducted for the ERMP project in the Boyne River estuary (Table 4; #5) over 2 days during March 2017.

The timing of boat surveys was made to maximise favourable light conditions in conjunction with the midday period of neap tides; to observe exposed tidal wetlands and their vegetation at low tide while being able to navigate safely (Mackenzie et al. 2016). The survey crew operated two cameras along with a portable GPS device to record the survey track. The cameras were synchronised for time reference, and with GPS records. Data are being combined, assessed and evaluated as part of the overall analysis of condition of tidal wetland habitat throughout the PCPA study area.

## 3.4 Project Component 5. Public access and data entry portal for display - current and past mapping and S-VAM surveys

This project component involved on-going collaboration between the JCU TropWATER project coordinators along with the JCU eResearch Centre and the QCIF.

The key goal had been the development of an online public database for uploading, managing, processing and displaying imagery and other data collected and produced in Components 1-4 of the PCPA CHAMP project. This will hold all S-VAM images (Mackenzie et al. 2016) from aerial and boat-based surveys, plus scenic imagery collected along with the sequential imagery of shorelines. Data referenced from these imagery will describe all features visible as well as estimates and measures (like tree height & density), plus indicators of condition and drivers of change (Duke 2014). At a latter date, such data will be used to quantify condition states for particular shoreline locations and summed for larger shoreline sections, and estuarine systems. These data will form the basis for reliable evaluations of shoreline health and risk.

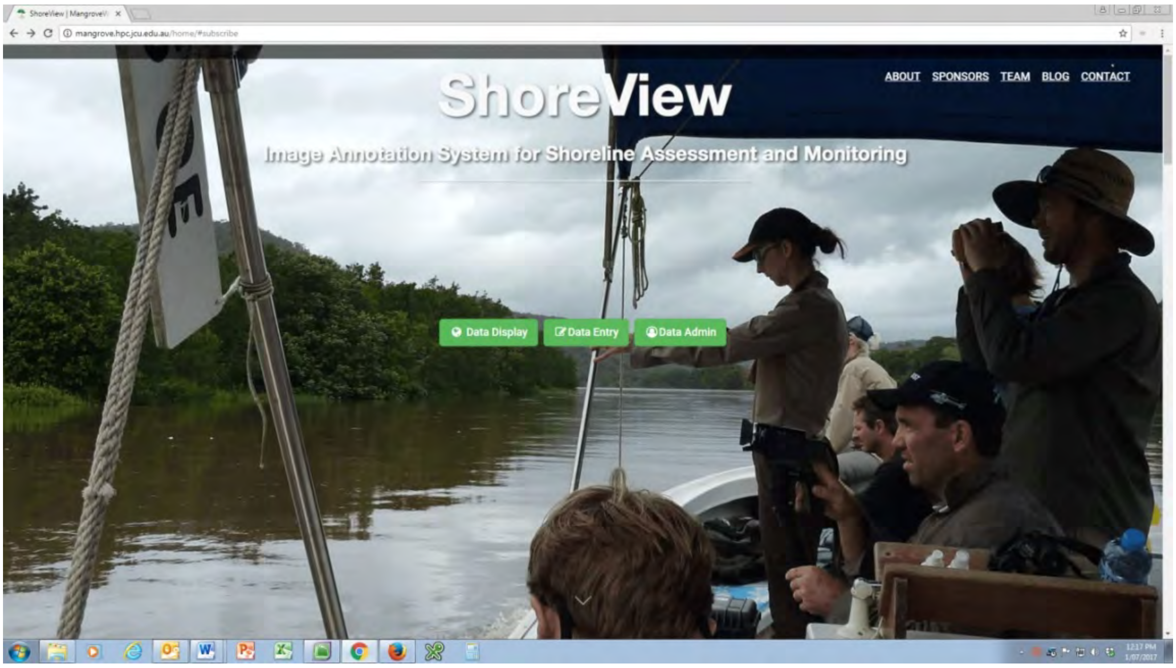


**Figure 15.** ShoreView. Primary landing page (see http://mangrove.hpc.jcu.edu.au/home/)

## Release of the prototype ShoreView Website

The new ShoreView Website (Fig. 15) has been designed using the latest design techniques to provide a platform that is both desktop and mobile friendly and is available for public access. The site provides links to the package of ShoreView Data Portals which provide image management including the display views for ShoreView. The simplified front page identifies the Gladstone Ports Authority as a prominent sponsor of ShoreView, and provides information on the participants and latest news. A demonstration presentation is planned for the next ERMP Advisory Panel meeting in late 2017.

## Architecture and Design

The core of ShoreView is the imagery and assessments conducted on the imagery. In this prototype facility, various types of imagery are displayed for the Boyne River estuary shorelines consisting of:

a. 2015 Boat-based lateral imagery as acquired using S-VAM;

b. 2015 Helicopter aerial oblique Imagery, as S-VAM and Scenic; and

c. 2016-17 Boat-based lateral Imagery, as S-VAM and Scenic.

The curation and processing of these imagery from the raw imagery taken in the field can be a time-consuming procedure since the imagery needs to be extracted as single frames with each needing to be locked to a co-ordinate along the shoreline. With the frame located by its shoreline co-ordinate, other imagery from previous years and imagery from helicopter and boat can be seen at the same time. Ideally the user would be able to look at many images of the same point on the shore at different times and angles.

A simplified representation of the operating architecture is shown below (Fig. 16). Due to the size of the data loading is done via a specific process into the storage area and this is described in the Shoreview Data Upload section.

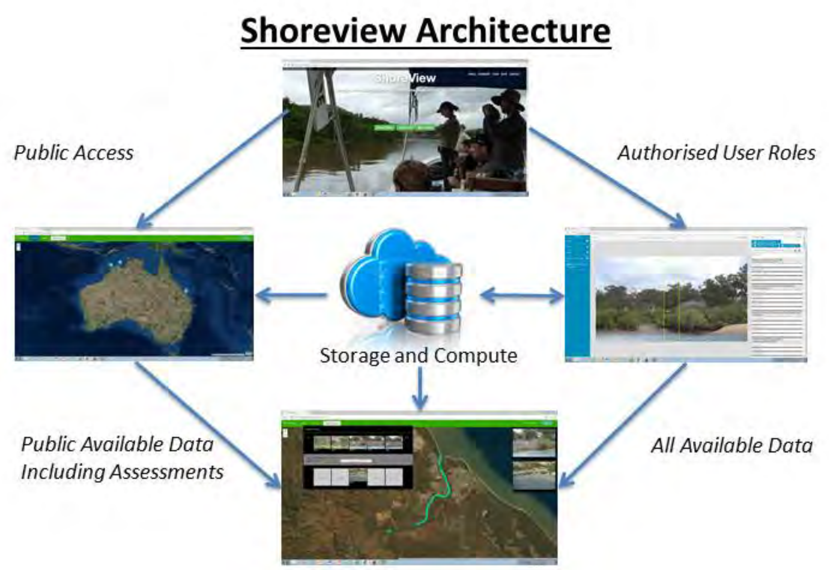


**Figure 16.** ShoreView overall site layout and architecture

## Public Access – Data Collections

Each data collection or survey track is identified by a pin icon on the map. Each pin represents the data collection that is available for that area. This can be seen in the architecture diagram above. The other way to look at data collections is by their project. Currently there are two projects on ShoreView (Fig. 17):

a. Montara Labels – the original imagery from the 2009 Montara project (Duke et al., 2010) as the first display portal prototype developed for ShoreView; and

b. Proj2 – examples of 2015 & 2016 image data collected during the PCPA CHAMP Project.

The naming of such projects will be modified once a naming convention is decided upon and when more projects are added in the future. These enhancements will come as the online facilities development advances in conjunction with the richness and volume of data available.

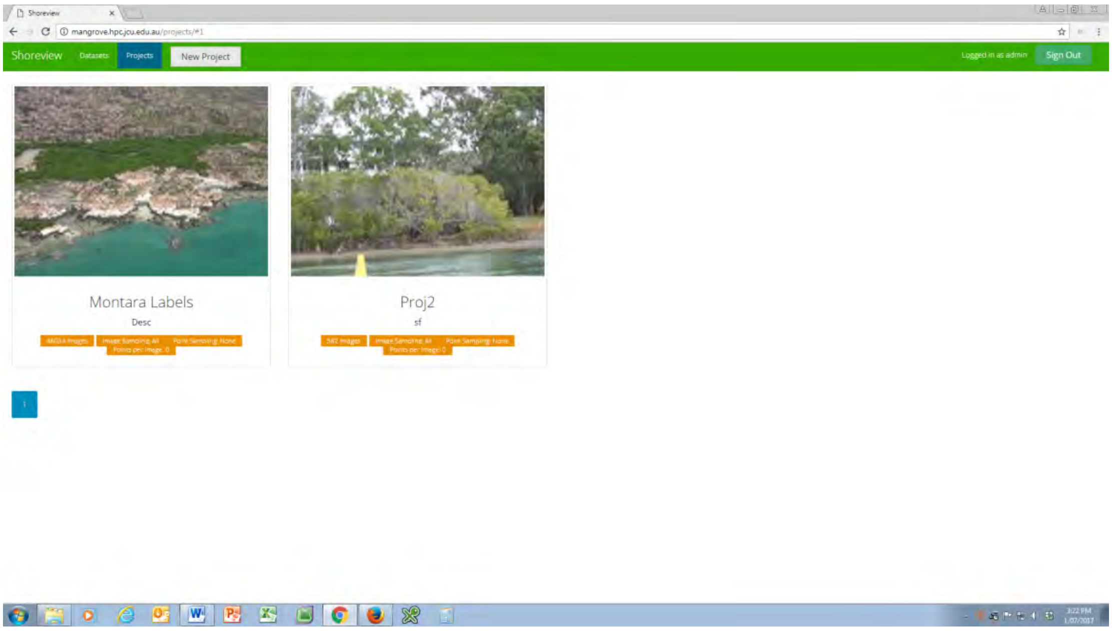


**Figure 17.** ShoreView Data available for display as indicated by individual survey.

## Data Portal - Available for Public Access

The display portal views show example data for a small number of surveys conducted from both small boats and a helicopter (aerial) for Port Curtis. Additional example imagery and data from the earlier survey of the North West Australian coastline from Darwin to Broome is included for comparison to show how larger datasets might apply. The screenshot shown below (Fig. 18) shows both a boat view and a helicopter view of the same location for the Boyne River estuary – just south of Port Curtis. It must be noted that there are notable differences between helicopter and boat images, where these mostly differ in the resolution and distance from the shore.

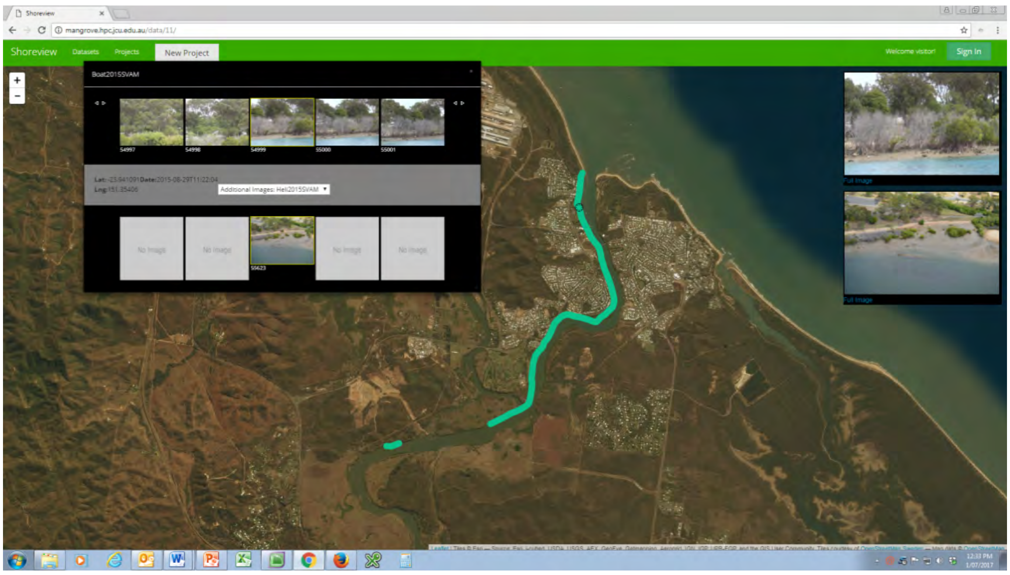


**Figure 18.** ShoreView Display Portal image data along with survey tracks in the Boyne River estuary case study.

## Authorised User Services

Public users will just have access to view the data whereas the authorised users will be able to modify the data. The next screenshot (Fig. 19) demonstrates the power and complexity of the image annotation tool. The user can provide large number of attributes to each image. The attributes are searchable in the data collection making research investigation easier when looking for specific attributes eg, Mangroves over 20m in height.

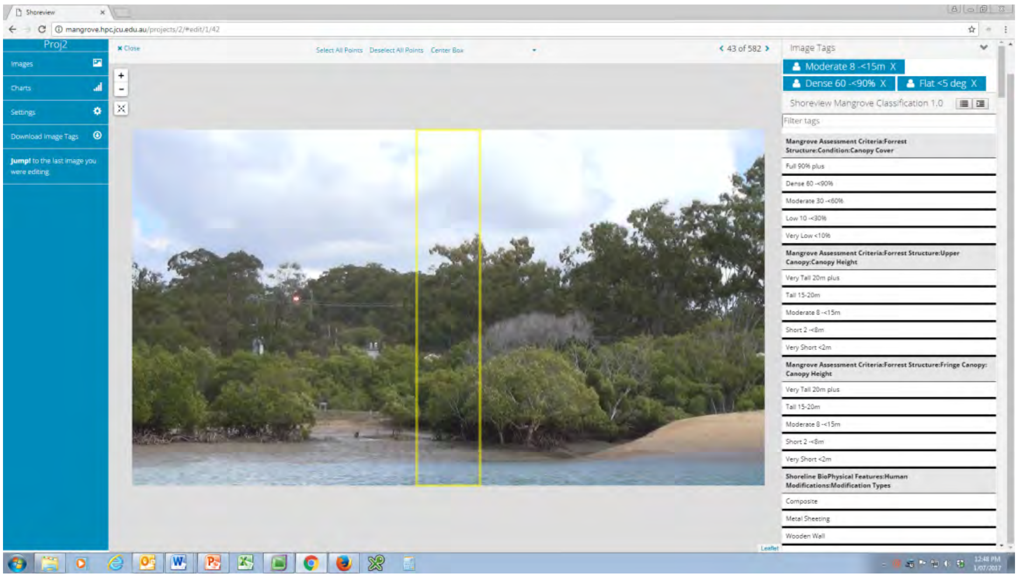


**Figure 19.** ShoreView Assessment Portal showing the assessment reference frame (yellow bordered area) and typical shoreline view for boat-based data acquisition. On the right side is a partial view of the menu of indicators and measures used in resource and condition classifications.

## ShoreView Data Upload Platform and Methodology

### Overview

The ShoreView project requires the movement of multi-gigabyte datasets of high resolution imagery from researchers in various locations to the ShoreView server located at James Cook University, Townsville. To make transfers efficient in both time and band width used, ShoreView utilises Aspera software. Aspera uploads very large datasets from a researcher's home internet connections without wasted bandwidth and waiting days that accompanies traditional transfer techniques.

### Aspera

The Aspera transfer platform is the most advanced software solution for file transfer, synchronisation and streaming of digital assets, allowing users and enterprises secure high speed movement of all of their data over any distance, to any environment, with none of the waiting. Covering a wide range of server, desktop and mobile operating systems, Aspera provides the most modern and flexible option for data transfer available.

**Methodology**

In the ShoreView project, researchers at various locations in Australia use Aspera desktop software to simply drag and drop datasets of mangrove imagery and annotations to upload to the central database at James Cook University. The database notifies the ShoreView application which automatically ingests the imagery and displays on the ShoreView Display portal. This workflow enables effective data upload at scale for the ShoreView project.

## Stage 2 Enhancements

The current ShoreView platform provides the data and ability to view and annotate, however there are further capabilities and enhancements planned for the next year:

1. Automated classification of the Coastline – unclassified data would be Pink and once it is classified (checked by an authorised person) then it changes to green;
2. New streamlined business process to allow imagery to be loaded easily and quickly rather than the current labour intensive imagery management. The new process will be trialled in December;
3. Creating a trial set of mangrove shoreline assessments to judge the capability of the assessor and then apply to the dataset they have assessed.
4. Enhanced security with contributors having the capability to manage the access to the data and who annotates the data; and
5. New models for storing the data and managing in the cloud environments.

The longevity of ShoreView will depend on a sustainable business model. A business model will be developed to ensure this important research and environmental tool grows and continues to contribute major environmental information.

# 4 DISCUSSION. UPDATED ASSESSMENT OF PCPA SHORELINES

## 4.1 Combined Findings Assessment

Shoreline mangrove condition was assessed in three comparative portions of the PCPA study area using the Shoreline Oblique-Image Assessment Method (SO-IAM). The target areas included sites in northern, central and southern PCPA areas - as Rodds Bay, the Western Basin Area of Port Curtis, and Port Alma. These areas were chosen to enable comparative assessment of mangrove condition in each region to test the working hypothesis that mang

roves might be less healthy in and around Port Curtis (Fig. 21) compared to adjacent areas.

**Figure 21. A development site shoreline fringed by dense mangroves on southern Curtis Island bordering Port Curtis.**

**Mangrove Shoreline Retreat in the PCPA Study Area**

Baseline assessment of mangrove shorelines throughout the PCPA study area have identified evidence for the recent retreat of mangrove shorelines. The greatest extent of retreat was observed in and around the Gladstone Harbour Western Basin region. This area is the location of recent port development and capital dredging which may have altered local hydrodynamics and potentially impacted mangrove shoreline stability.

This evidence was tested in an hypothesis where mangrove retreat was greater in the central PCPA region (Fig. 22) compared to elsewhere within the PCPA area. A statistical assessment of mangrove shoreline retreat was undertaken, and preliminary results are presented.

The information described here is a precursor to more detailed assessment of change and on-ground field assessments of mangrove retreat and coastal dynamics within the PCPA study area.

**Figure 22. Shoreline of the central area of the PCPA study area - viewed from Port Curtis towards the Narrows to the north.**

## 4.2 Methods Update

**Shoreline Oblique-Image Assessment Method (SO-IAM)**

The SO-IAM approach used here is a modification of the MangroveWatch S-VAM monitoring (Mackenzie, Duke et al. 2016). For the SO-IAM, categorical visual assessments of shoreline habitat features along shoreline interfaces are made from geotagged oblique still image series collected from an aircraft, rather than geotagged video imagery collected from a boat.

Shoreline imagery was collected from R44 Helicopter flying parallel and shoreward of shoreline margins at ~100 km/hr, offset at an angle of approximately 45$^o$ at a height of ~400 ft. Shoreline margins were photographed with a 1/3 image overlap using a *Nikon* D800E DSLR camera with GPS attachment. Images were taken as close as possible to 90$^o$ to the direction of travel. Each image represents an individual randomly stratified sampling point of shoreline margins. Imagery was collected over two days in late August 2015.

During PCPA-CHAMP field surveys, a total of 15,548 oblique still images were taken of tidal wetland habitats within the PCPA study area. Images within the target sub-region were selected based on image coordinates in ArcGIS 10.5. Images were further sorted using manual visual classification to identify suitable shoreline images and images with visible shoreline mangrove forest.

Each image represents a randomly stratified sampling point of the shoreline margin. Shoreline mangrove condition was assessed for each image within the image subset using a criteria-based visual classification to identify the presence and extent of mangrove dieback and dead mangroves. For classification criteria and example images see Table 5 and Fig. 23.

Mangrove condition was assessed at the centreline of each image (see Fig. 5). Only the fringe mangrove forest, identified by species composition and canopy height, up to ~100 m of the shoreline was assessed. Care was taken to ensure no images had exact centreline reference points to avoid duplicate sampling.

Differences in shoreline mangrove condition score were compared between the three target regions using a Kruskal-Wallis test in SPSS v24.

**Table 5.** Mangrove Forest Condition Score Visual Classification Criteria.

| | *Variable Descriptor* | *Assessment Criteria* |
|---|---|---|
| ***Shoreline Mangrove Forest Condition Score*** | The condition of mangroves determined by canopy retreat and exposed branches and twigs (dieback) and dead trees. | 0) Healthy Trees<br>Healthy trees or only minor dieback present<br><br>1) Severe Dieback<br>Est. >25% Canopy Loss in fringing forest<br><br>2) Dead Mangrove Presence<br>1-3 recently dead mangroves present. Dieback may or may not be present.<br><br>3) Many Dead Mangroves<br>>3 recently dead mangroves present<br><br>4) Total Loss<br>Entire fringing forest is dead/missing |


**Figure 23.** Example images showing different mangrove condition score classifications (see Table 5) for the five PCPA shorelines: 1) healthy; 2) mostly healthy; 3) 1-3 dead mangroves present; 4) many dead mangroves to severe dieback; and 5) severe loss to total loss.

During field surveys, mangrove shoot leaf counts of *Rhizophora stylosa* were also conducted across 21 sites within Port Alma (9) and Port Curtis (12) (Duke et al., 1984). At each site, the number of leaves present on 25 randomly selected sun-exposed terminal *R.stylosa* shoots from across five individual trees were counted. Mean shoot-leaf count (~6-10 leaves per shoot) was compared between both regions using an independent-samples T-test.

**Rates of Shoreline Change**

To determine rates of recent mangrove shoreline change (2011 to 2015) and identify erosion hotspots within the PCPA study area, a digital shoreline analysis of change was undertaken using DSAS v4.3 (Thieler et al. 2009) using ArcGIS 10.5.

***Generating Shoreline Position***

Mangrove shoreline polylines for 2011 and 2015 were generated by manual digitisation of shoreward mangrove position of mangroves visible in geo-referenced aerial imagery using ArcGIS 10.5. Aerial imagery was sourced from Nearmap (11$^{th}$ July, 2011 & 7$^{th}$ May, 2015) at a resolution of 1.194 m. Nearmap imagery from 2011 and 2015 was availaasble for the majority of the PCPA target project area from north of Black Swan Island in The Narrows through to Tannum Sands (Fig. 24**)**. The year 2011 was chosen as the starting date for assessment as this was the year capital dredging activity started within the Western Basin area for the WBDDP.

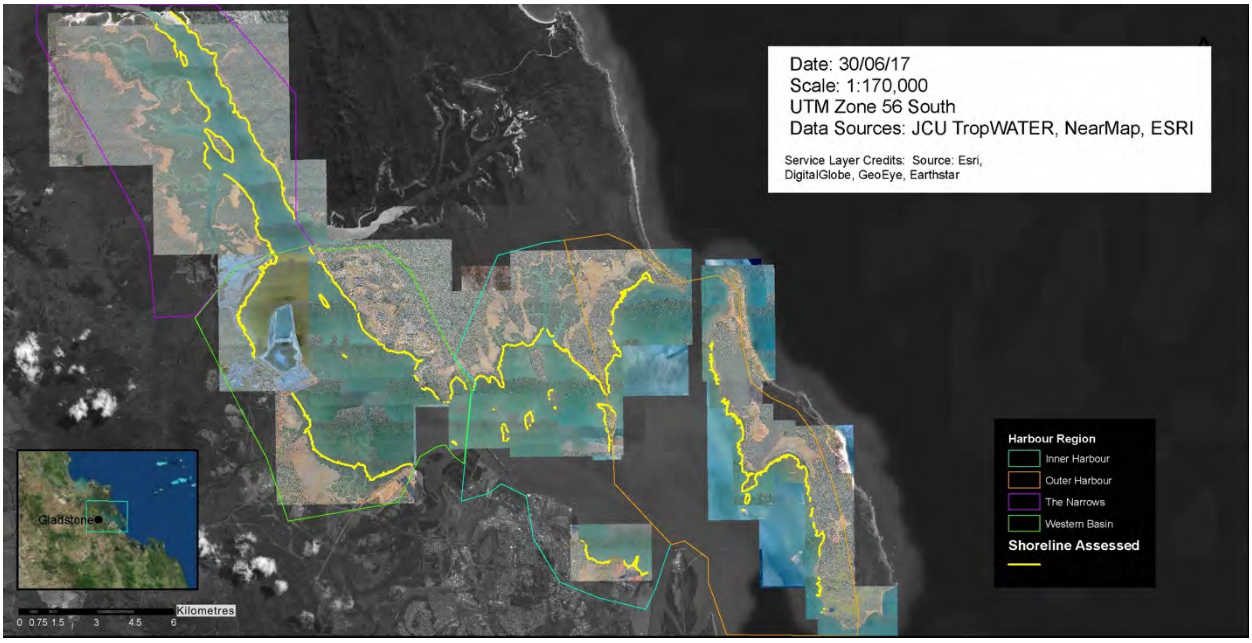


**Figure 24.** Area assessed for shoreline mangrove retreat (also see Fig. 1).

Due to the highly fragmented nature of the target area coastline and recent hydrological changes in the region, it was difficult to determine an exact shoreline position representing mean sea level. To assist shoreline digitisation, a series of 10m interval perpendicular transects was generated from a mean sea level (0m) contour using a 5m DEM, such that transects crossed the mangrove-shoreline interface. A line was drawn connecting the shoreward most position of visible mangroves that intercepted transect lines such that the mangrove shoreline represents a 10m point-intercept transect of mangrove shoreward position. Separate lines were drawn for both 2011 and 2015. Shorelines were generated at a 1:1000 scale.

### *Estimating Shoreline Change*

Change in mangrove shoreward position between 2011 and 2015 was compared using a digital shoreline analysis of change using DSAS v4.3 (Thieler et al. 2009) in ArcGIS 10.5. The DSAS approach calculates the linear distance difference between shorelines using transects spaced at regular intervals along a baseline. Here we used the original 10 m interval transects from the 0m contour to assess change in shoreline position. The DSAS approach enables quantification of the net shoreline movement (NSM) for each transect and the annual rate of shoreline change.

### *Identifying Erosion Hotspots*

Transects showing shoreline retreat greater than 1.5 standard deviations from the mean rate of shoreline movement were selected to identify locations of severe erosion.

***Comparing Shoreline Change between Regions***

Shorelines were roughly sub-divided into four regions based on the Gladstone Healthy Harbour Partnership (GHHP) Report Card regions (McIntosh and Poiner 2014; also see Queensland DEHP and PCIMP) as: The Narrows; Western Basin; Inner Harbour; and Outer Harbour (Fig. 25). Differences in net shoreline movement were compared between these regions using a Kruskal-Wallis test in SPSS v24.

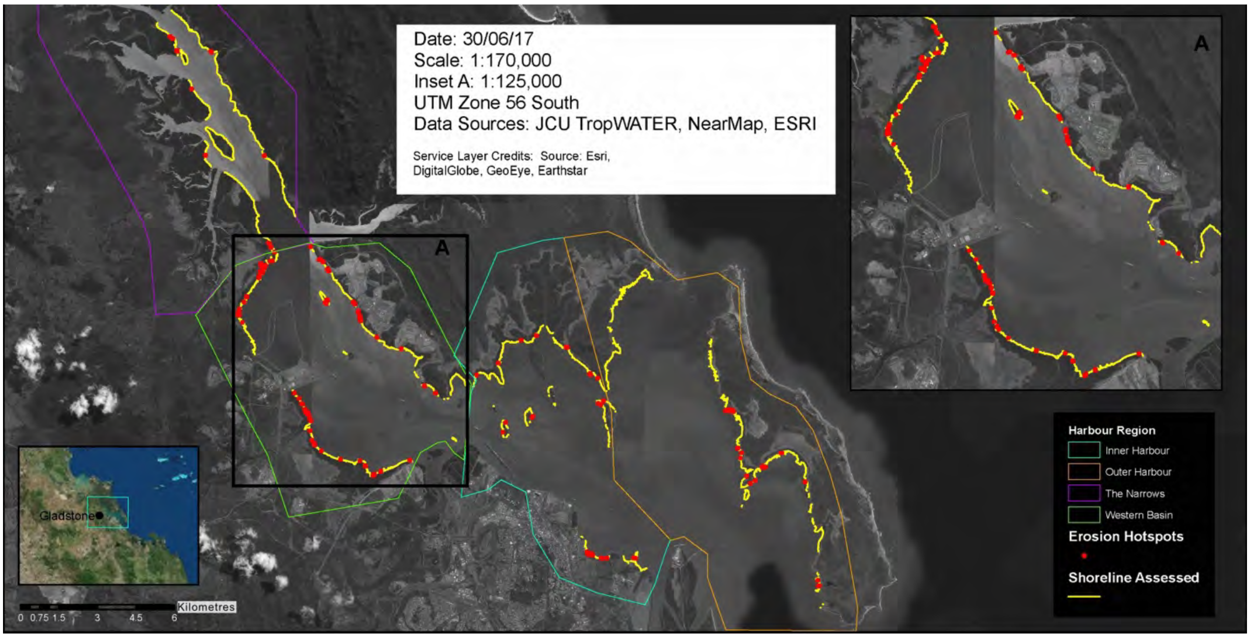


**Figure 25.** Erosion hotspots within the central part of the PCPA study area (also see Fig. 1).

## 4.3 Preliminary Outcomes

**Shoreline Mangrove Forest Cover Extent**

Of the 3,236 oblique images from within the three target sampling areas, 2,360 images represented shoreline habitat. Fringe mangrove forest was present within 85% (*n*=1998) of images. The Port Alma region had the highest extent of mangrove cover with ~97% of shoreline assessed having fringe forest present. The lowest shoreline fringe mangrove forest cover extent was in the Western Basin area (~74%).

**Shoreline Mangrove Forest Condition**

The majority (~60%) of shoreline mangrove image points assessed in the three sample target areas exhibited indicators of stress and poor habitat condition, including severe dieback (41%) and or dead shoreline mangroves (19%). Of the shoreline mangrove forest with dead trees, a total of 7% had multiple recently dead mangroves visible.

A Kruskal-Wallis H test was conducted to determine if there were differences in shoreline mangrove forest condition (SMFC) scores between the three different regions of Port Curtis (Western Basin area), Port Alma and Rodds Bay. Distributions of SMFC scores were not similar for all groups, as assessed by visual inspection of a boxplot. SMFC scores were statistically significantly different between the different areas, $\chi2(2) = 99.57$, $p = <0.001$. Subsequently, pairwise comparisons were performed using a Bonferroni correction for multiple comparisons. Adjusted p-values are presented. This post hoc analysis revealed statistically significant differences in condition score between Rodds Bay (845) and Western Basin (1099) ($p = <0.01$), and Rodds Bay (845) and Port Alma (1090) (Table 6). There was no statistically significant difference in mangrove condition scores between Western Basin (1099) and Port Alma (1090).

**Table 6.** Summary of shoreline change as determined from the DSAS.

| *Region* | *No. of Image Points* | *Mean SMFC score*[a] | *SE* | *Mean Rank*[b] | *% Healthy* | *% Dieback* | *% Dead* |
|---|---|---|---|---|---|---|---|
| ***Port Alma*** | 881 | 1.00 | 0.03 | 1090 | 31 | 48 | 22 |
| ***Western Basin*** | 365 | 1.08 | 0.06 | 1099 | 38 | 28 | 34 |
| ***Rodds Bay*** | 752 | 0.61 | 0.03 | 845 | 51 | 40 | 9 |
| ***Grand Total*** | 1998 | 0.87 | 0.02 | | 40 | 41 | 19 |

[a]Shoreline Mangrove Forest Condition [b]Mean Ranks determined by Kruskal-Wallis analysis of distributions.

There was a higher proportion of shoreline mangrove forest with dead mangroves in Western Basin (34%) compared to Port Alma (22%), with both areas having much higher representation of dead mangroves relative to Rodds Bay (9%) (Fig. 26).

### *Rhizophora stylosa* leaf-shoot counts

Leaf count values per shoot may be used as correlates for forest canopy density – as such, they are useful indicators or proxies of forest canopy condition.

Mean leaf-shoot counts of *R. stylosa* were similar between Port Alma and Port Curtis. An independent samples T-test comparing mean leaf-shoot count between the two regions showed no statistically significant difference in leaf-shoot counts between Port Alma (7.5 ± 0.3) and Port Curtis (7.8 ± 0.2), $t(19) = 0.712$, $p = 0.485$. However, both estimates were lower than the 8.2 ± 0.3 leaves per shoot scored earlier for Hinchinbrook Island (Duke et al., 1984). As such, while mangroves in the PCPA study area displayed greater stress overall than those in the wetter Hinchinbrook region – this was consistent with differences in climatic conditions between regions.

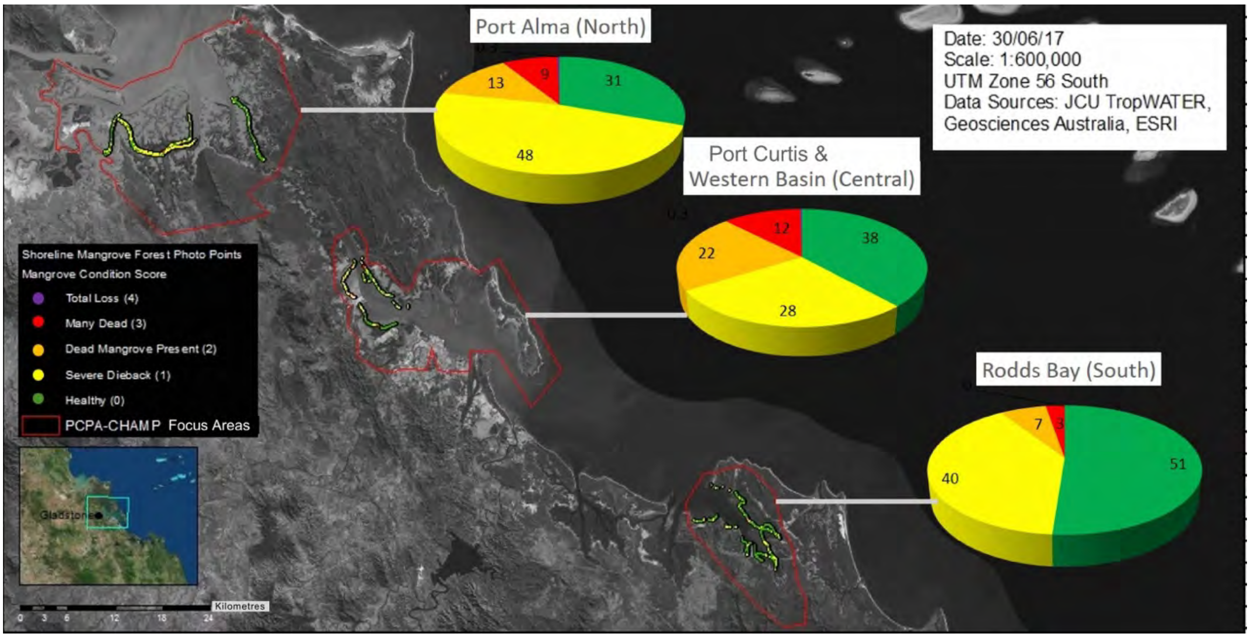


**Figure 26.** Shoreline mangrove forest condition in the three sample areas of Rodds Bay, Port Curtis and Port Alma.

### Shoreline Change Assessment

Shoreline erosion was the dominant shoreline process in the target area between 2011 and 2015, with a mean net shoreline movement of -1.67 (±0.1) m. A total of 31% of all transects showed some degree of erosion and mangrove retreat, with only 11% of transects showing mangrove shoreward expansion. Nearly half (43%) of transects with mangrove retreat were within the Western Basin region (Fig. 27). This pattern was similar for locations identified as having extreme mangrove retreat (>1.5 standard deviations from the mean).

A total of 2.5% (n=81) shoreline transects represented extreme retreat, with the majority (51%) present within the Western Basin region. The most stable shoreline was present in The Narrows, where less than ~1% of shoreline transects were either eroding (0.7%) or expanding (0.4%).

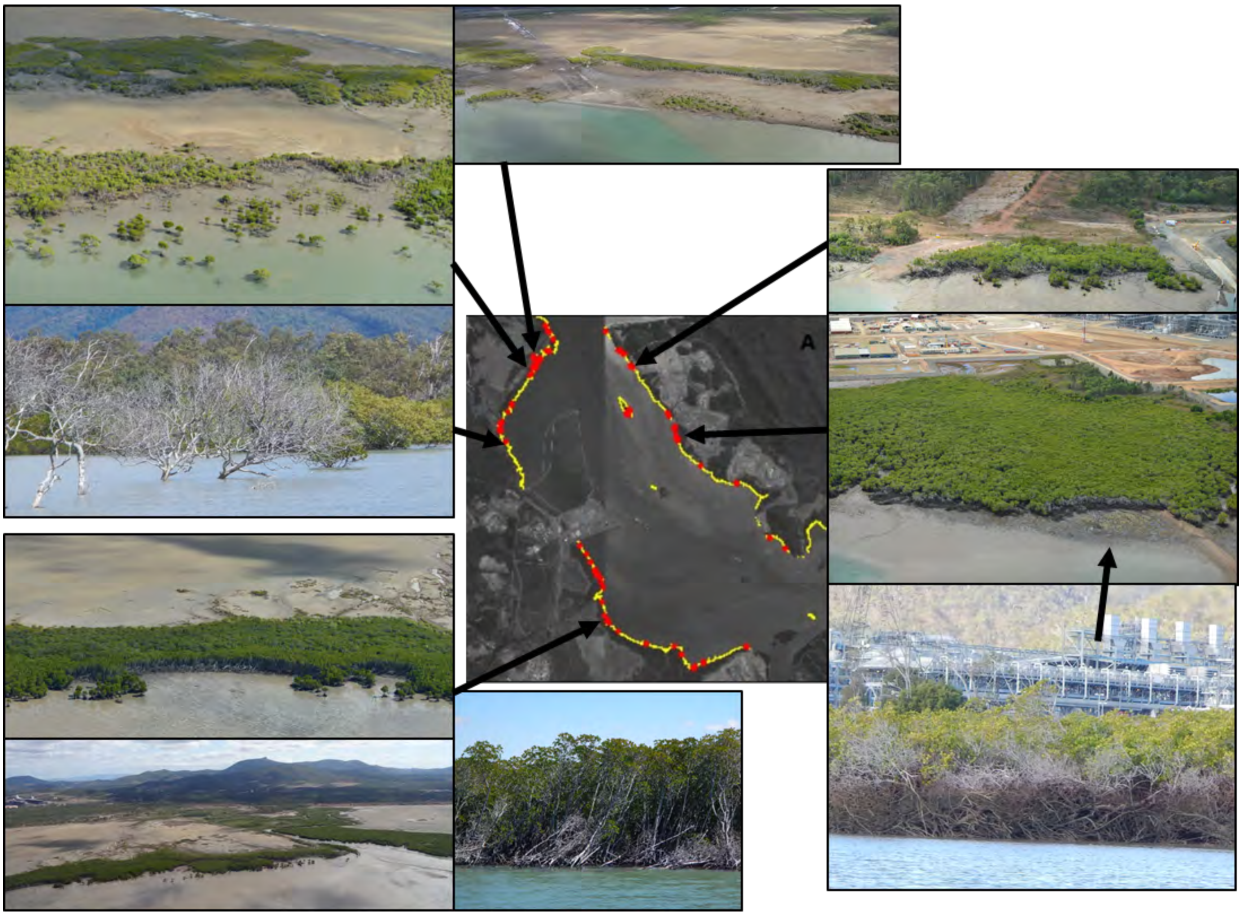

**Figure 27.** Examples of mangrove retreat within the Port Curtis central part of the PCPA study area.

In total ~27.9 km of the 90.6 km mangrove shoreline assessed is eroding. The mean rate of retreat for shoreline experiencing mangrove retreat is -1.9m per annum, with the overall mean annual rate of retreat for all shoreline being 0.44 m per annum.

A Kruskal-Wallis test was conducted to determine if there were differences in NSM for 10m shoreline transects between different shoreline regions of the central part of the PCPA study area following the Gladstone Healthy Harbours Partnership reporting zones: "Narrows" (n = 2509), "Western Basin" (n = 2199), "Inner Harbour" (n = 2203) and "Outer Harbour" (n = 2145). Distributions of NSM values were not similar for all groups, as assessed by visual inspection of a boxplot. NSM values were statistically significantly different between the different shoreline regions, $\chi^2(3) = 349.92$, $p = <0.001$. Subsequently, pairwise comparisons were performed using a Bonferroni correction for multiple comparisons. Adjusted p-values are presented. This post hoc analysis revealed statistically significant differences ($p = <0.01$) in NSM values between all shoreline regions (Table 7).

**Table 7.** Summary of shoreline change as determined from the DSAS.

| *Shoreline Region* | *No. of Transects* | *Mean NSM[a] (m)* | *SE* | *Min NSM (m)* | *Max NSM (m)* | *Mean Rank[b]* | *% >16.6 m[c]* | *% >11.6 m[d]* | *Loss to Gain Ratio* |
|---|---|---|---|---|---|---|---|---|---|
| ***Narrows*** | 2509 | -0.44 | 0.06 | -39.35 | 21.61 | 4857 | 0.7 | 0.4 | 1.7 |
| ***Western Basin*** | 2199 | -3.45 | 0.32 | -280.5 | 155.89 | 3869 | 5.2 | 2.2 | 2.3 |
| ***Inner Harbour*** | 2203 | -1.86 | 0.16 | -175.66 | 48.46 | 4310 | 2.6 | 0.7 | 3.6 |
| ***Outer Harbour*** | 2145 | -1.09 | 0.17 | -146.06 | 45.3 | 5044 | 1.6 | 0.3 | 5.8 |
| ***Grand Total*** | 9056 | -1.67 | 0.10 | -280.5 | 155.89 | | 2.5 | 0.9 | 2.8 |

[a]Net Shoreline Movement [b]Mean Ranks determined by Kruskal-Wallis analysis of distributions. [c,d] Percentage greater and less than 1.5 Standard Deviations from the mean (-1.67).

## 4.4 Conclusions and Recommendations To Date

**Shoreline Retreat**

Mangrove shoreline retreat resulting from coastal erosion is one of the major issues threatening mangrove habitats within the PCPA study area. Based on the findings of this assessment, the shoreward extent of mangroves is retreating at an average of 0.44 m per annum within the central section of the study area. The 27.9 km of shoreline identified as retreating is retreating at an annual rate of 1.9 m per annum. Shoreline retreat is not being offset by deposition with only 9.7 km of mangrove shoreline identified as expanding at a mean annual rate of 1.3 m per annum. Based on these results we propose that mangrove retreat and shoreline erosion is a significant source of sediment to the Port Curtis area and may be contributing to high turbidity levels reported in the region with potential impacts on adjacent seagrass, coral and other benthic marine habitats. If shoreline mangrove retreat results in a loss of 30cm of surface elevation, a conservative estimate based on mangrove root depth, shoreline erosion between 2011 and 2015 may have contributed ~60,000m$^3$ of sediment or 108,000 tonnes sediment (based on an estimated 1.8 tonnes/m$^3$ for marine sediment (Brodie 2014)) to the southern Great Barrier Reef. Further detailed work is required to more accurately quantify these estimates.

The majority of shoreline mangrove retreat and associated shoreline erosion is occurring within the central part of the PCPA study area (Fig. 27), with the Port Curtis (Western Basin) area having significantly higher rates of erosion and proportionally more shoreline compared to other adjacent areas.

It is not possible at this stage to identify the key causal factors driving mangrove retreat within the Western Basin area. Elsewhere, mangrove shoreline retreat is linked to five primary factors: 1) extreme weather events such as storms, cyclones and floods; 2) sea level rise; 3) altered coastal hydrodynamics resulting from coastal construction and human modification; 4) increased wave action from boating and shipping activity; and 5) coastal subsidence.

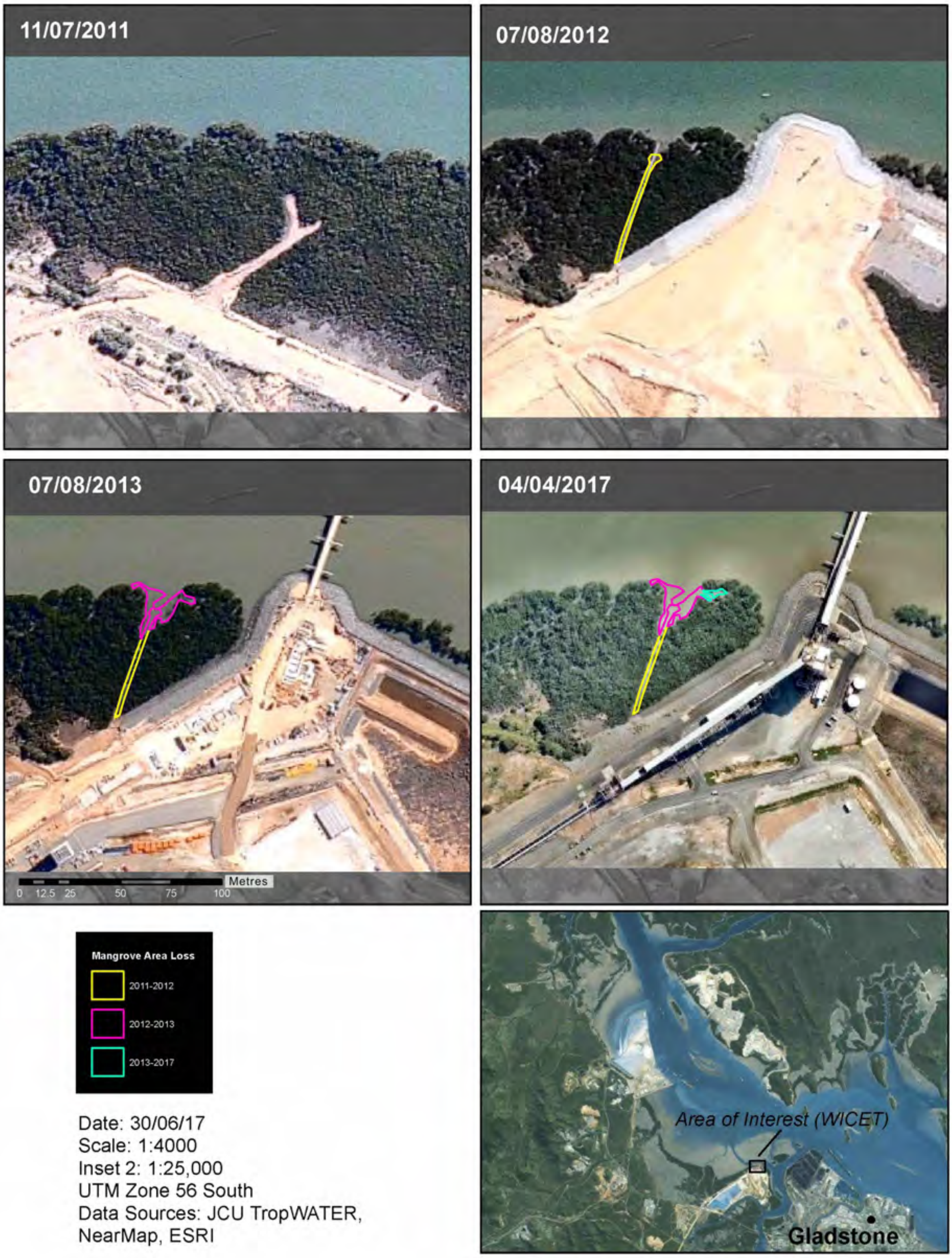


**Figure 28.** Mangrove loss associated with drain construction at WICET, 2011-2017.

Of these factors, natural factors such as storm impacts, sea level rise and coastal subsidence are likely to be influential at a regional scale, with anthropogenic impacts more likely to result in localised shoreline retreat as observed in central parts of the PCPA study area, particularly in the Western Basin area. Alternatively, it is possible that natural drivers have been impacting shoreline mangroves throughout the region, but mangrove resilience to physical forces need to have been reduced in the central area for this to happen. This will be investigated further during the project.

Marine structures, altered hydrodynamics from channel dredging, increased wave action from shipping, habitat fragmentation and altered hydrological connectivity are unlikely to reduce mangrove retreat and may be exacerbating factors in combination with natural stressors. This is exemplified by an area of mangrove loss at Golding Point, near Wiggins Island Coal Export Terminal (WICET) (Fig. 28). The construction of a drainage channel through the mangrove fringe in 2012 resulted in a small (390.5 $m^2$) and confined area of mangrove loess. After the 2013 flood events, the area of loss had increased by 1.6 times to 1018.5 $m^2$. Mangrove loss continues to occur in this area at a rate of 22$m^2$ per annum. As of April 2017, the area of loss had expanded to 1100 $m^2$ which was nearly three times the original loss due to construction (Fig. 29).

**Figure 29.** Oblique aerial image of WICET drain and associated mangrove loss. Image: 27/08/2015.

**Recommendations based on Current Observations**

Regardless of the cause of coastal erosion within the Western Basin area, it is clear that this is an issue requiring increased management oversight and intervention. The construction of breakwaters, wave protections structures and mangrove enhancement need to be considered. We recommend the use of a 'living shorelines' approach, integrating re-establishment of seagrass, oyster reefs, saltmarsh, mangroves and artificial structures to create a shoreline 'mangrove gardens' © that have multiple ecosystem service functions including shoreline protection, fish habitat enhancement and water quality improvement. Sites within central parts of the PCPA study area present unique opportunities to trial such an approach that demonstrates the capacity of port infrastructure and industry to create positive integrative solutions to the dilemma of coastal erosion and change facing vulnerable shoreline ecosystems and habitats.

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