Port of Brisbane Mangrove Monitoring Program - 2022

Customer	Port of Brisbane Pty Ltd
Project	B23621
Deliverable	018
Version	00
	17 October 2022

Document Control

Document Identification

Title	Port of Brisbane Mangrove Monitoring Program - 2022
Project No	B23621
Deliverable No	018
Version No	00
Version Date	17 October 2022
Customer	Port of Brisbane Pty Ltd
Customer Contact	Michael Linde
Synopsis	An assessment of mangrove condition at the Port of Brisbane and adjacent environments.

Author	Darren Richardson and Brianna Heeley
Reviewed By	Darren Richardson
Project Manager	Darren Richardson

Amendment Record

The Amendment Record below records the history and issue status of this document.

Version	Version Date	Distribution	Record
00	17 October 2022	Port of Brisbane Pty Ltd	Draft report

This report is prepared by BMT Commercial Australia Pty Ltd ("BMT") for the use by BMT's client (the "Client"). No third party may rely on the contents of this report. To the extent lawfully permitted by law all liability whatsoever of any third party for any loss or damage howsoever arising from reliance on the contents of this report is excluded.
Where this report has been prepared on the basis of the information supplied by the Client or its employees, consultants, agents and/or advisers to BMT Commercial Australia Pty Ltd ("BMT") for that purpose and BMT has not sought to verify the completeness or accuracy of such information. Accordingly, BMT does not accept any liability for any loss, damage, claim or other demand howsoever arising in contract, tort or otherwise, whether directly or indirectly for the completeness or accuracy of such information nor any liability in connection with the implementation of any advice or proposals contained in this report insofar as they are based upon, or are derived from such information. BMT does not give any warranty or guarantee in respect of this report in so far as any advice or proposals contains, or is derived from, or otherwise relies upon, such information nor does it accept any liability whatsoever for the implementation of any advice recommendations or proposals which are not carried out under its control or in a manner which is consistent with its advice.

© BMT 2022

Executive Summary

Background

Extensive mangrove forests and saltmarsh communities occur at and near the Port of Brisbane at Fisherman and Whyte Islands, and on the northern side of the Brisbane River mouth. Port of Brisbane Pty Ltd (PBPL) has implemented a mangrove monitoring program (MMP) to measure trends in the condition and extent of mangroves potentially affected by Port activities. This report outlines the findings of the 2022 MMP assessment.

The major element of the MMP was to quantify of patterns in mangrove canopy condition using medium resolution (Landsat) and high resolution (Sentinel -2) satellite data. Three mangrove condition indices (NDVI, SAVI and LAI) were mapped for the periods of 1988-2022 (Landsat) and 2015-2022 (Sentinel-2) using analysis-ready data. Potential relationships between vegetation indices and environmental data (rainfall, Southern Oscillation Index, and temperature) were examined. Aerial imagery was used to investigate and validate areas where changes in mangrove condition were observed over the twelve-month period.

Findings

Long-term Patterns

Long-term patterns in mangrove condition (NDVI) were positively correlated with rainfall, with declines in mangrove condition during drought years and improved mangrove condition during wet periods. The 2021-22 monitoring period had above average annual rainfall and major flooding in the Brisbane River, and the 12 month rolling average NDVI value was greater than the long-term average across sites (Figure 1).

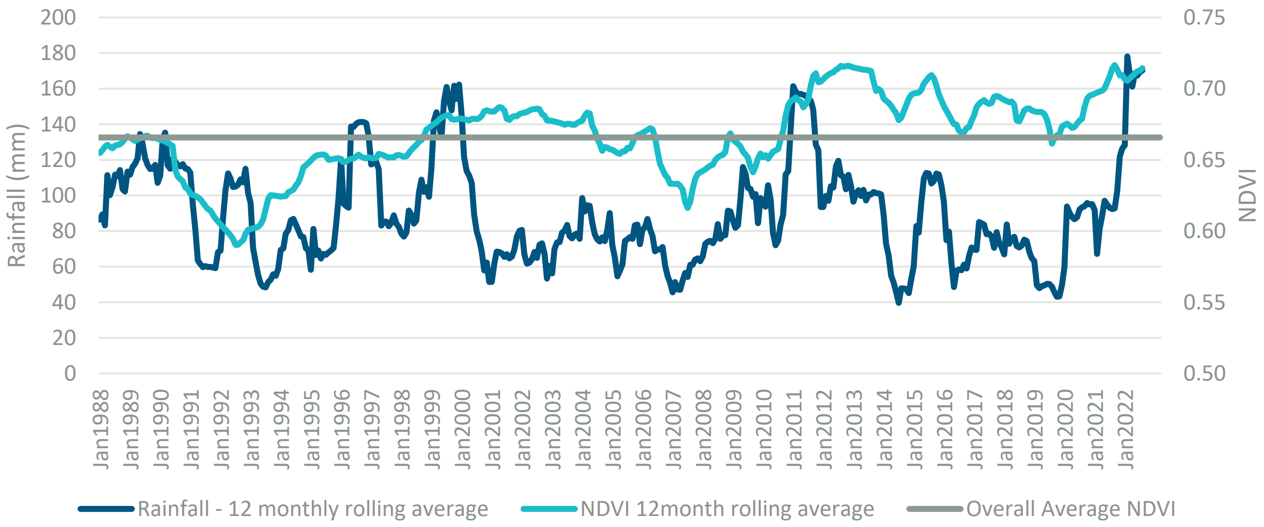


Figure 1. 12-month rolling average NDVI score and monthly rainfall 1988 and 2022

© BMT 2022

Contemporary Changes (2021-2022)

While mangrove condition in 2022 was higher than the long-term average, there was not a broad-scale improvement in mangrove condition between 2021-2022. Figure 2 is a map of NDVI changes between July 2021 and July 2022. The direction (i.e. improvement, stable, decline) and magnitude of change varied among and within locations. At broad scales, mangroves along Bramble Bay (Luggage Point and Nudgee) and Coal Loader/Pelican Banks had improved condition (NDVI change generally >+0.15), whereas mangroves at Bulwer and south of the Brisbane River entrance (Fisherman Islands, Whyte Island, St Helena Island, Mud Island, Green Island) were stable (<0.15 change) or declined in condition (Figure 2). Patterns at finer spatial scales were as follows:

- Fisherman Island:
  - mangrove condition slightly increased slightly along Boat Passage. Unlike in previous years, there was no evidence of tree fall and bank erosion in the 2021/22 monitoring year.
  - the landward portion of Coal Loader/Pelican Banks had a slight increase in mangrove condition, whereas the seaward fringe experienced a decrease in mangrove condition due to ongoing erosion and tree fall.
  - mangrove condition decreased slightly on the south-east tip of the island and areas north of the tip. Some inland areas of mangrove also had canopy loss, but mangrove recruitment also occurred in some parts of the claypan, which resulted in a net expansion in mangrove forest and between 2021 and 2022 of approximately two hectares. There was also a net expansion in saltmarsh/claypan of 1.9 hectares.
- Bulwer had an overall trend of decrease in mangrove condition, especially in the south-west margin of the mangrove forest. Mangrove extent remained stable.
- Trends in mangrove condition at Whyte Island varied spatially:
  - There were areas of improved mangrove condition at the mangrove-claypan interface on the northern claypan. This was the result of mangrove canopy improvement and recruitment onto the saltpan.
  - There were areas of reduced mangrove condition in the inland sections of southern Whyte Island. At this location a band (up to 40 m wide by 700 m long) of mangroves between Port Drive to the northern end of the Wynnum mangrove walk experienced canopy loss. There were also areas of mangrove decline in the central claypan, separate to the areas of reduced health.
  - Overall, there was a net loss of mangrove forest and a commensurate net gain of saltmarsh/claypan at Whyte Island of five hectares.

The results of the present study suggest that mangrove forests of the study area do not display a uniform response to high rainfall. The mangrove canopy declines in parts of the inland portions of Fisherman Islands and Whyte Island may be a result of one or more drivers, such as water stress (e.g. ponding, raised water-tables etc.) or water quality changes (e.g. pollutant discharges). Further investigation would be required to investigate potential causes of mangrove degradation.

© BMT 2022

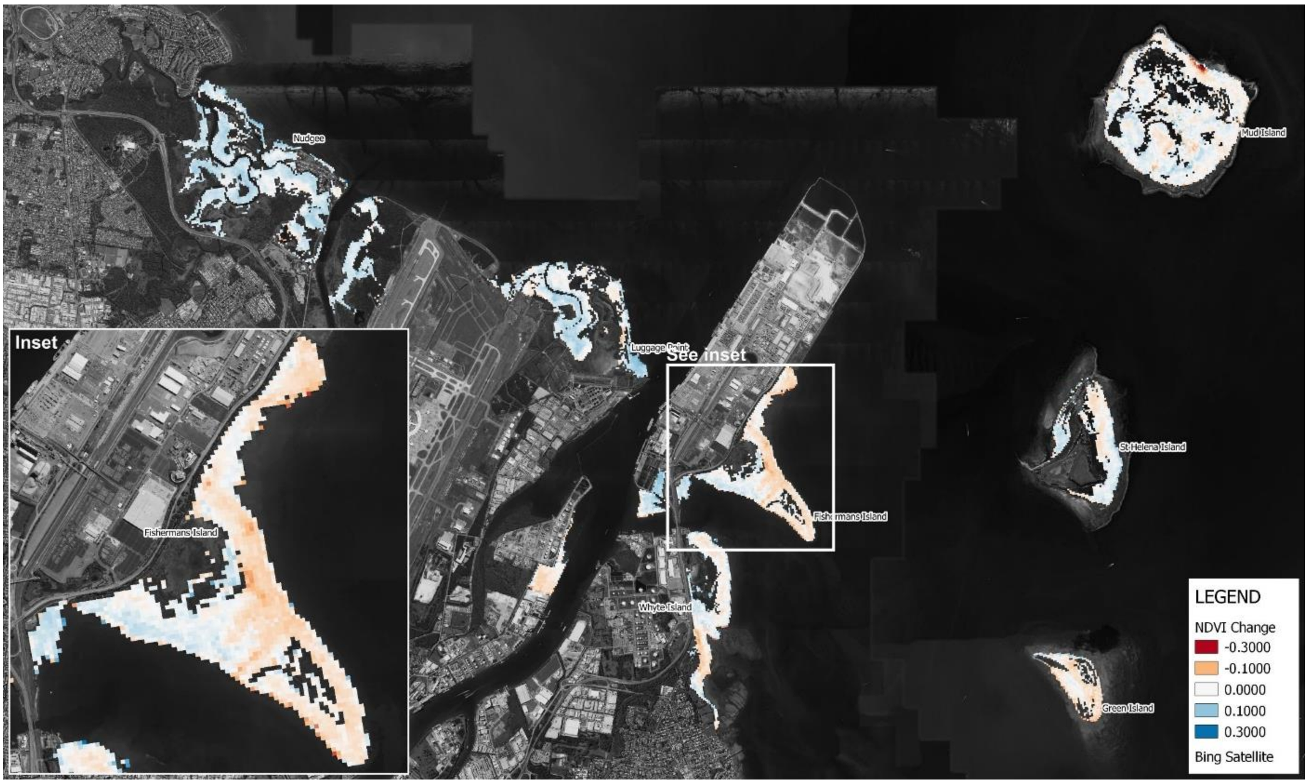


Figure 2. Differences between July 2022 and July 2021 geomeans (Landsat)

Contents

Tables

Figures

1 Introduction

1.1 Background

Extensive areas of mangrove forests and saltmarsh communities are located at the mouth of the Brisbane River. The mangrove forests of Fisherman Islands and Whyte Island (see Figure 1 1) are among the largest in western Moreton Bay (Accad et al. 2016), and the structure and form of these communities is unique to this area (Davie 2011).

The Port of Brisbane Pty Ltd (PBPL) operates adjacent to these mangrove forests and saltmarsh communities therefore the variation of their health through time and space needs to be monitored and analysed to ensure port activities are not impacting these communities. Monitoring of the mangroves and saltmarsh surrounding the Port of Brisbane has been conducted since the 1990s (WBM 1992; CSIRO 1992; BMT WBM 2016, BMT 2017, BMT 2018, BMT 2019, BMT 2020, BMT 2021) but variable assessment techniques and observer bias made long-term health assessments difficult. The Port of Brisbane Mangrove Monitoring Program was revised in 2016 to provide a more robust objective means for mapping and characterising patterns in mangrove condition (BMT WBM 2016).

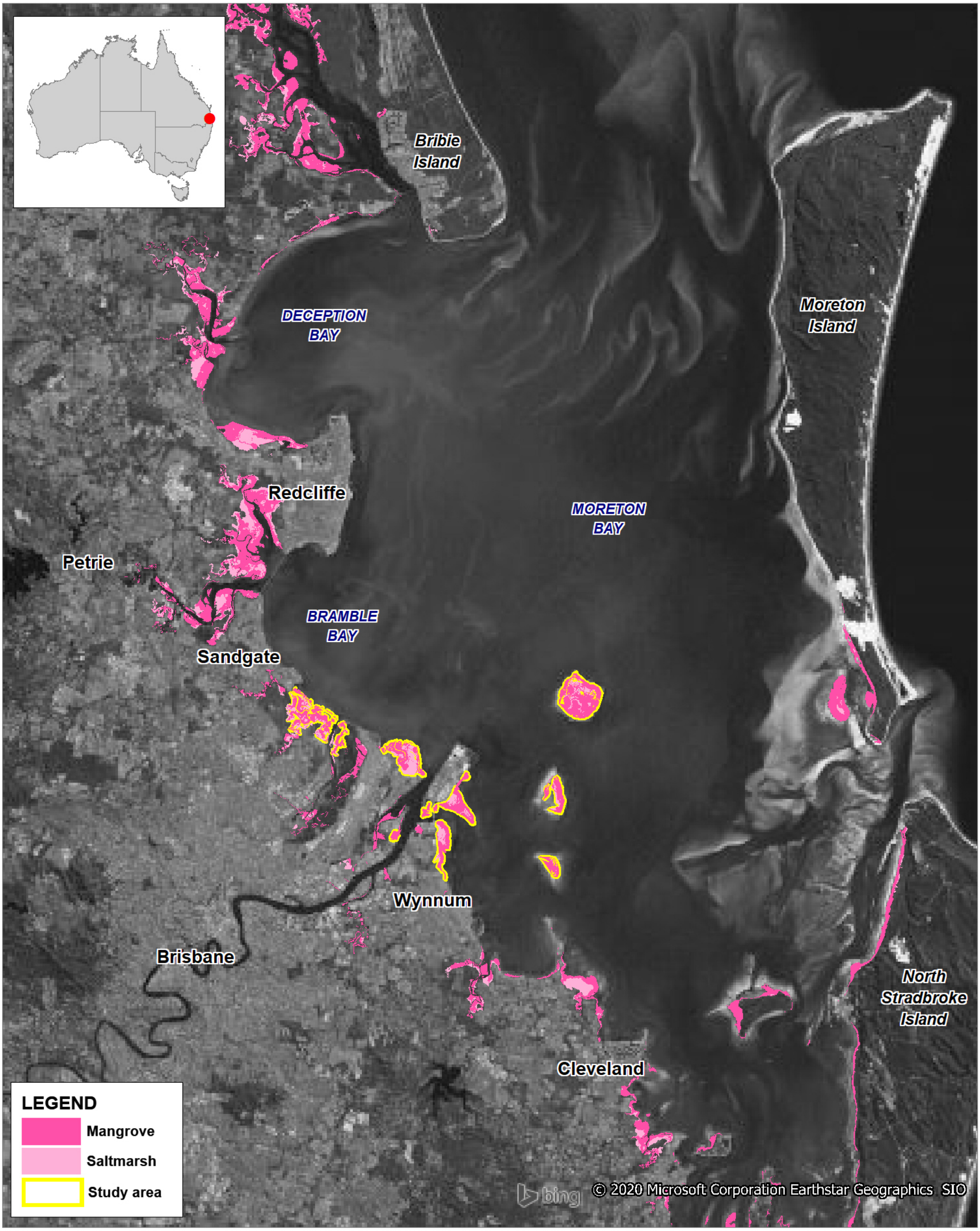
Previous monitoring programs have found strong associations with weather and climate variations and changes in mangrove health. Cumulative rainfall has been found to relate to normalized difference vegetation index (NDVI) while longer term health has been associated with the El Niño–Southern Oscillation (ENSO) cycle (BMT WBM 2016). The medium-term trends show a decrease in mangrove health that coincided with strong La Niña conditions (1987-1989) and during the Millennium Drought (2006-2008).

1.2 Aims and Objectives

The aim of the present study is to describe spatial and temporal patterns in mangrove vegetation condition, and potential drivers controlling these patterns. The specific objectives of this study were to:

- Quantify long-term changes in the spatial extent of mangrove and saltmarsh/saltpan between 1950s and 2022 based on analysis of aerial photography and satellite data
- Map and quantify temporal patterns in mangrove green biomass (NDVI) using satellite data at the following temporal scales:
  - seasonal patterns for 2022 monitoring period
  - contemporary changes for the period 2021-22, based on remotely sensed data and validate using high resolution aerial imagery.
  - long-term patterns between 1988 and 2022
- Identify potential drivers of mangrove degradation in key investigation areas (Fisherman Islands, Whyte Island and Bulwer Island).

© BMT 2022



Title:
Locality plan showing 2012 mangrove and saltmarsh extent based on data in Accad et al. (2016)

Figure: 1-1

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 5 10km
Approx. scale

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2020_Mangroves\ECO_008_190909_LocalityPlan.WOR

2 Methodology

2.1 Remote Sensing

2.1.1 DEA Data Cube

Analysis was performed on the Open Data Cube, where Sentinel, Landsat and other freely available remote sensing data are available for the Australian continent, catalogued by Digital Earth Australia (DEA). The DEA open data cube was accessed and analysed using code modified from Krause et al (2021). The data cube contains analysis-ready datasets (ARD) for Sentinel 2A, 2B and Landsat 5, 7 and 8 sensors. ARD datasets have been geometrically corrected and stacked consistently so that sequential observations can be used to track changes over time. Surface reflectance are corrected for sensor gains, biases and offsets, and include adjustments for terrain illumination, atmosphere and sensor viewing angle per pixel.

Nadir-corrected, Bidirectional reflectance distribution function, Adjusted Reflectance with Terrain illumination (NBART) imagery was used from Landsat and Sentinel-2 sensors.

2.1.2 Data Sources

Sentinel-2 imagery (10 m resolution) and Landsat 5, 7, and 8 (30 m resolution) were gathered for individual study sites and the combined mangrove region. Sentinel-2 masking near port infrastructure reduced the number of available scenes at the Coal Loader and Bulwer Island otherwise a large number of scenes were available for analysis (Table 2.1). For Landsat 5,7, 9, a minimum of 98% good data was used as a filter. For Sentinel-2, data quality filters were relaxed to between 50% and 90% to increase temporal coverage due to a large number of masked pixels.

Table 2.1 Scene availability for different sensors and time periods

Site	Sentinel 2 (July 2017-July 2022))	Landsat 5,7, 8 (Aug 1988 – July 2022)
Pelican Banks / Coal Loader	16	525
Nudgee Wetlands	331	383
Luggage Point	382	440
Bulwer Island	35	374
Whyte Island	317	449
St Helena Island	371	592
Green Island	333	577
Mud Island	399	310
Fisherman Islands	281	407

2.1.3 Investigation Areas

Two treatments were adopted:

- Test treatment – which are mangrove areas direct adjacent to Port operations (i.e. Fisherman Islands, Coal Loader and Whyte Island/Wynnum foreshore) or occur in the vicinity of operational works undertaken by PBPL (i.e. habitat restoration works at Bulwer Island, cruise ship construction works at Luggage Point).
- Control treatment – these are mangrove areas outside the direct influence of PBPL activities and provide contextual information on background variability. These sites encompass minimally disturbed environments (e.g. St Helena Island) and areas subject to historical (e.g. coral dredging at Mud Island) and/or ongoing human disturbance.

The extent of these areas are shown in Figure 2.1.

© BMT 2022

LEGEND

- Test
- Control

Title:

Mangrove health assessment test and control sites

Figure: 2-1

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 2 4km

Approx. scale

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2019_Mangroves\Methodology\ECO_002_190826_Test_v_control.WOR

2.1.4 Spatial Data Processing

Vegetation Indices

Atmospherically-corrected bottom-of-atmosphere (BoA) analysis-ready products for Sentinel-2 and Landsat 5, 7, and 8 products were used to derive the following three vegetation indices, using the calculate indices function within the DEA data cube:

1. The normalized difference vegetation index (NDVI), which is the difference between near-infrared (which chlorophyll in vegetation strongly reflects) and red light (which chlorophyll absorbs), and essentially represents greens (i.e. chlorophyll found in leaves). NDVI for each of the pixels was calculated using the following formula:

   $$NDVI = (NIR - Red) / (NIR + Red)$$

   Where *NIR* is the near-infrared BOA reflectance and Red is the BoA reflectance of the red band.

2. Like NDVI, the soil adjusted vegetation index (SAVI) is based on the difference between red and near infrared wavelengths, and therefore provides a measure of chlorophyll content in leaves. SAVI also compensates for the confounding effects of soil moisture and soil colour (i.e. changes in 'soil brightness'). SAVI was calculated for each pixel using the following formula:

   $$SAVI = ((NIR - Red) / (NIR + Red + L) \times (1 + L))$$

   Where *NIR* is the near-infrared BOA reflectance, Red is the BoA reflectance of the red band and L is the vegetation correction factor.

3. Leaf area index (LAI) is a biophysical index that as the name suggests measures the area of leaves in the visible canopy. LAI was calculated for each pixel using the following formula from Boegh et al. (2002) utilising the Enhanced Vegetation index of Huete et al. (2002):

   $$LAI = (3.618 * 2.5 * (Green * ((NIR - Red) / (NIR + SWIR * Red - 7.5 * Blue + 1))) - 0.118$$

Only NDVI was applied to the Landsat dataset due to its relative consistency across sensors, and similarity to other indices.

Vegetation Community Mapping

Vegetation communities were mapped using a combination of recent aerial imagery and known species locations. Previous field surveys of mangrove condition have shown distinct community areas across Fisherman Islands. This data was used as training data within ArcGIS v10.8. High resolution Nearmap imagery was used for classification. This image was classified into the following classes: Mangrove communities and saltmarsh/saltpan.

2.1.5 Rainfall data

Rainfall data were accessed from the Bureau of Meteorology from January 1988 to July 2022. The weather station closest to the study area was Brisbane Airport (040842), but this provided an incomplete record of rainfall. Missing data were filled using nearby Fort Lytton (040320). Twelve monthly cumulative rainfall data were compared with vegetation condition indices.

© BMT 2022

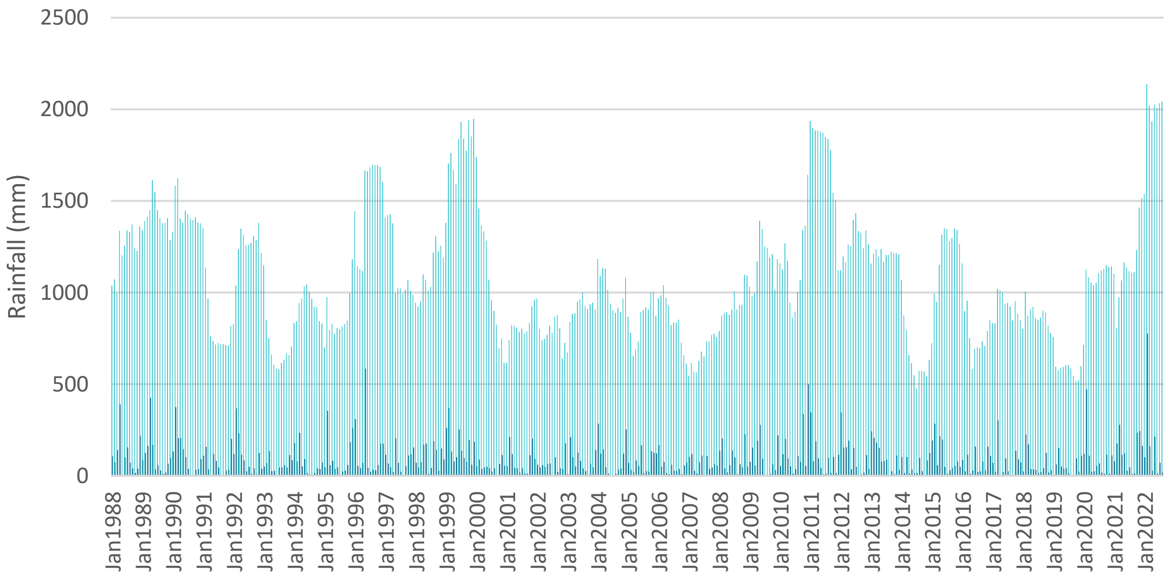


Figure 2.2 Monthly total rainfall (dark blue) and 12-monthly rainfall (light blue) for the study area in millimetres (based on Brisbane Airport station 040842 and Fort Lytton station 040320)

2.1.6 Assumptions and Limitations

Analysis-ready Sentinel-2 and Landsat imagery can have up to 12.5 m geolocational error, meaning that up to two 10 m pixels from each capture may be misaligned. Therefore, rectification errors can occur within two pixels and contribute to errors along edge of mangrove forests. It is also noted that where the canopy is sparse (saltpans and dieback regions), variable soil moisture can dominate the signal. Therefore, some interpretation is required in such areas.

Various minimum-good data thresholds (based on cloud filtering) between 70 and 98% were applied to each analysis based on the availability of data. For long-term Landsat analyses, scene counts were always relatively high and minimum good data thresholds were maintained at 98%. Some of the Landsat ARD scenes included heavy clouds that had not been effectively filtered. These were removed by filtering out mean NDVI scene values less than 0.40.

For Sentinel-2, ARD pixel masking tended to be adversely affected by nearby infrastructure, particularly near the Coal Loader and at Bulwer Island. At these locations, where scene counts were low, the thresholds of minimum good data were lowered to 70%. Despite this, scene counts for Sentinel-2 data were relatively low at these two sites.

NDVI represents and extremely robust vegetation index for long-term comparisons in vegetation community due its relative simplicity and similarities in central wavelengths for the red and NIR bands among sensors. Inter-sensor comparisons (AVHRR, SPOT, MODIS SeaWiFS, Landsat) typically differ by less than 0.05 NDVI units over most of the non-polar regions of the world (Brown et al 2000).

Comparisons of NDVI among various Landsat sensors since 1988 are potentially prone to small changes in sensors, orbit and sensor drift. Orbit changes in Landsat 5 over the 27 year record resulted in 0.0006 NDVI / year, equivalent to about a 0.016 NDVI change over the entire Landsat 5 TM data record (Zhang and Roy 2016). These issues for long-term assessments have been resolved by the introduction of analysis-ready data where atmospheric correction, spatial alignment and radiometric calibration allow estimation of the remotely sensed surfaces without sensor, atmospheric, or geolocation artefacts (Dwyer et al 2018).

© BMT 2022

3 Findings

3.1 Wetland Community Extent

The wetland community extent remained relatively consistent between 2021 and 2022 (Figure 3.1). The following changes were observed:

- Fisherman Island: There has been a net increase in mangroves which is a result of recruitment in mangroves on the interface between the saltpan and the existing mangrove community (Figure 3.2). Despite this there has also been some areas of mangrove dieback at the claypan interface and some other inland areas. There was also a slight increase in saltmarsh and clay pan in the areas at Fisherman Islands inland at the main claypan.

- Whyte Island: There was a slight loss of mangrove extent at Whyte Island which is due to tree death on the landward areas of Whyte Island on the fringe between claypan/saltmarsh and mangroves (Figure 3.2). These areas in 2021 were noted as mangroves with declining health which have since died. The increase in saltmarsh and claypan at Whyte Island was in these areas of tree loss.

- Bulwer Island: mangrove extent remained consistent between years (Figure 3.2).

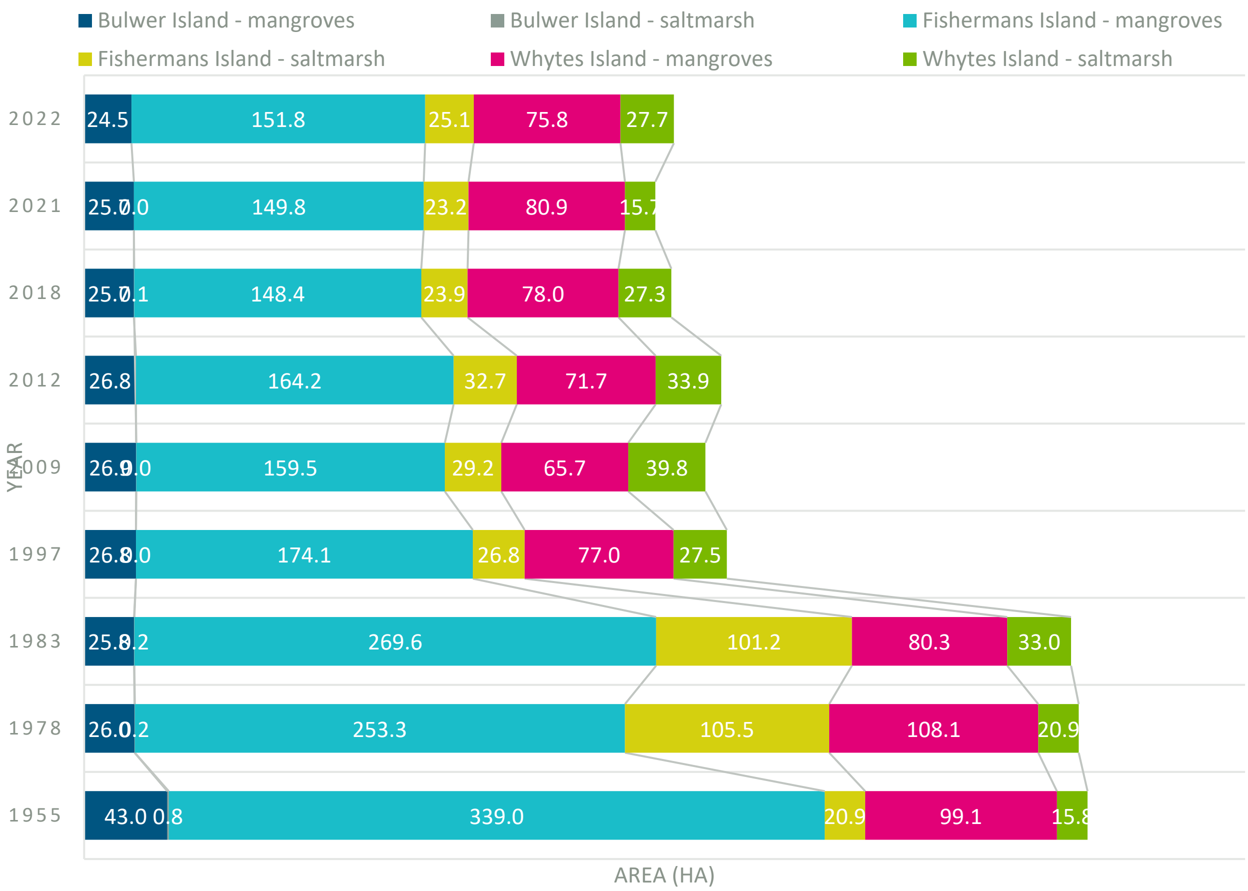


Figure 3.1 Area of mangrove and saltmarsh at Fisherman Islands, Bulwer Island and Whyte Island through time

© BMT 2022

Title:

Change in mangrove extent between July 2021 and July 2022

Figure: 3-2

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 500 1,000 m

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2022_Mangroves\ECO_003_220930_MangroveExtentChange_21_22.qgz

3.2 Mangrove Condition

3.2.1 Temporal trends

The overall condition of mangroves at both the test and control sites between 2021 and 2022 were highly variable with some locations in each treatment increasing and some decreasing overall (Figure 3.3). All sites had means within the historical ranges and slightly greater than the long-term average NDVI value. Within the test sites, between 2021 and 2022 the overall condition of Fisherman Islands and Coal Loader mangrove forests decreased while the Whyte Island, Luggage Point and Bulwer increased overall.

There was a positive association between mangrove condition and rainfall (Figure 3.4). A weak positive correlation was found between rainfall ranks and rolling average NDVI ($r = 0.23$, $p < 0.0001$) as well as between the rolling 12-month average rainfall and average NDVI ($r = 0.25$ $p = < 0.0001$). This indicates that while there was a positive relationship between rainfall and mangrove condition, it was not strongly linear, suggesting that other factors may interact with rainfall to control mangrove condition.

Water availability is the key driver of mangrove condition and community structure (Hutchings and Saenger 1987), and rainfall is just one factor determining water availability. As discussed by BMT WBM (2016), water availability is a function of tidal inundation, ground water recharge, surface water runoff, and the relationship between these processes varies in time and space. Ground water tables are often recharged in the magnitude of months, depending on soil type, vegetation community structure, rainfall and ground water (Alongi 2009). Consequently, there may be a lag between rainfall, groundwater recharge and mangrove response measured in months. Superimposed on this groundwater process are (i) regular tidal flushing (diurnal near sea level, less frequent higher in the profile); (and (ii) irregular surface water runoff. Both processes affect soil salinity and nutrient delivery, and may influence mangrove condition over shorter timescales. Refer to BMT WBM (2016) for a review of these processes.

The El Niño - Southern Oscillation (ENSO) is a key driver of rainfall in the region, therefore relationships between mangrove condition and the Southern Oscillation index (SOI) were explored. For the period of 1988 to July 2022, 12 month rolling averages of monthly SOI and NDVI were positive correlated (Figure 3.4, $r = 0.47$, $p < 0.0001$). BMT WBM (2016) did not find a correlation between these variables, as only linear associations were examined, and sample sizes were smaller.

SOI is linked to rainfall and temperature with periods of positive SOI bringing higher than average rainfall, and lower temperatures. Conversely, lower SOI results in warmer drier conditions. The relationship between the average monthly maximum temperature (maximum daily temperatures averaged across each month) was weakly inversely correlated to the 12-month rolling average of NDVI across the study area NDVI (Figure 3.4, $r = 0.1$, $p < 0.05$).

Time series of NDVI, SAVI, and LAI for the entire Sentinel-2 capture history (2015-2022) show the same annual patterns observed in recent Landsat data (Annex A). Each site shows a relatively consistent pattern with strong correlations among all three indices, a generally flat to slightly inclined trajectory, and the most recent overall minima occurring late in 2019 coinciding with very low rainfall and high temperatures.

© BMT 2022

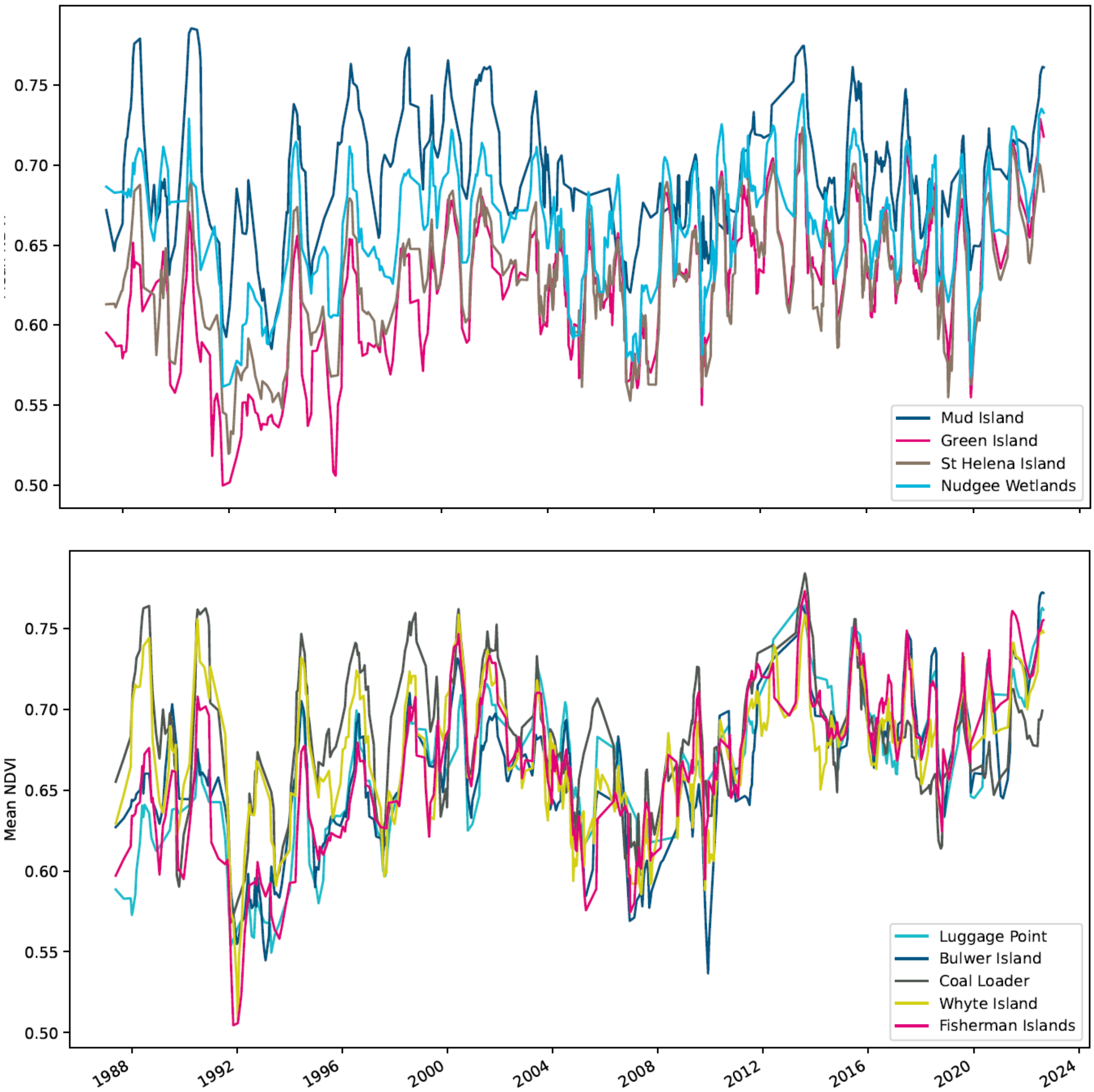


Figure 3.3 Mean NDVI scores for control (above) and test sites (below) from 1988 to July 2022

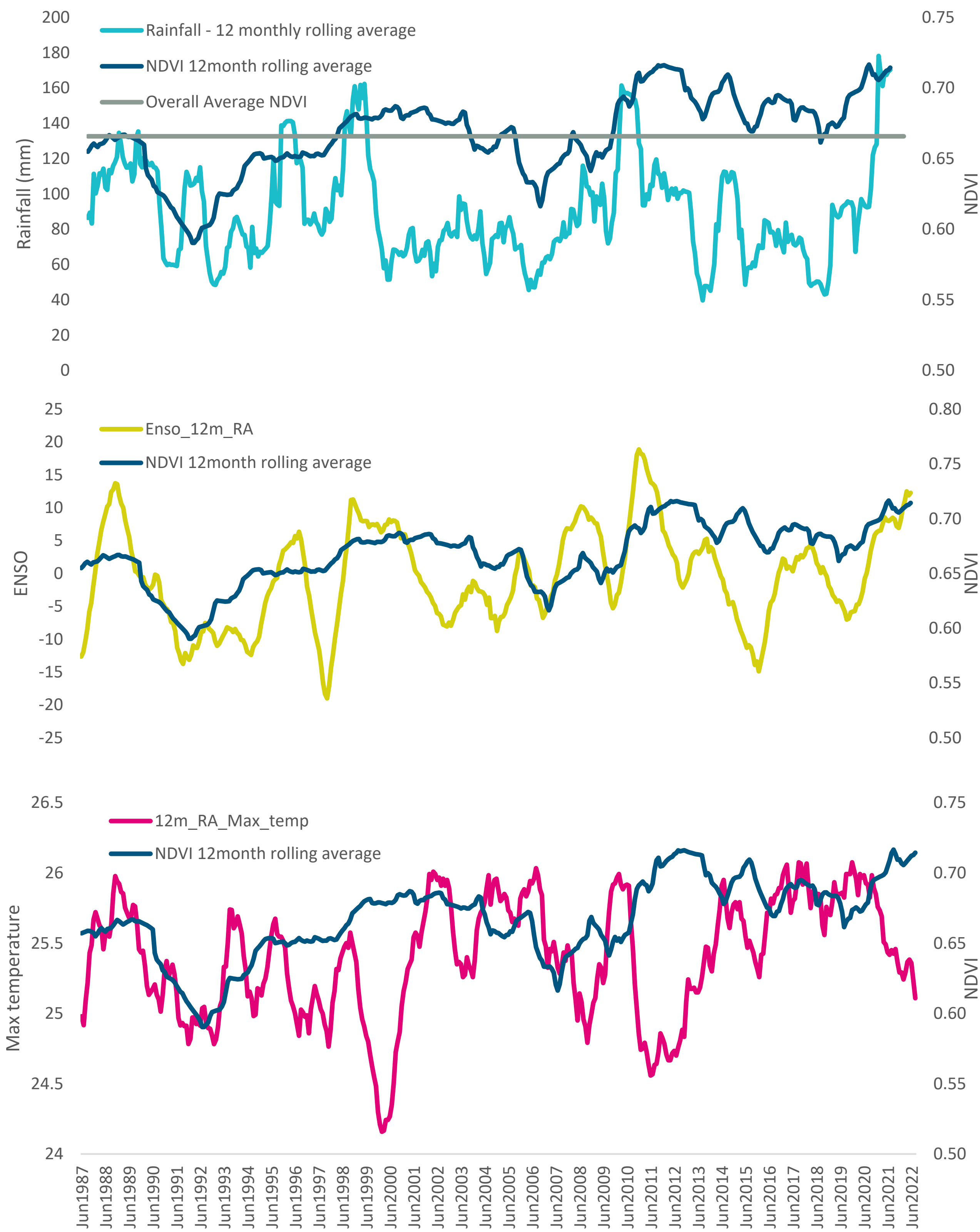


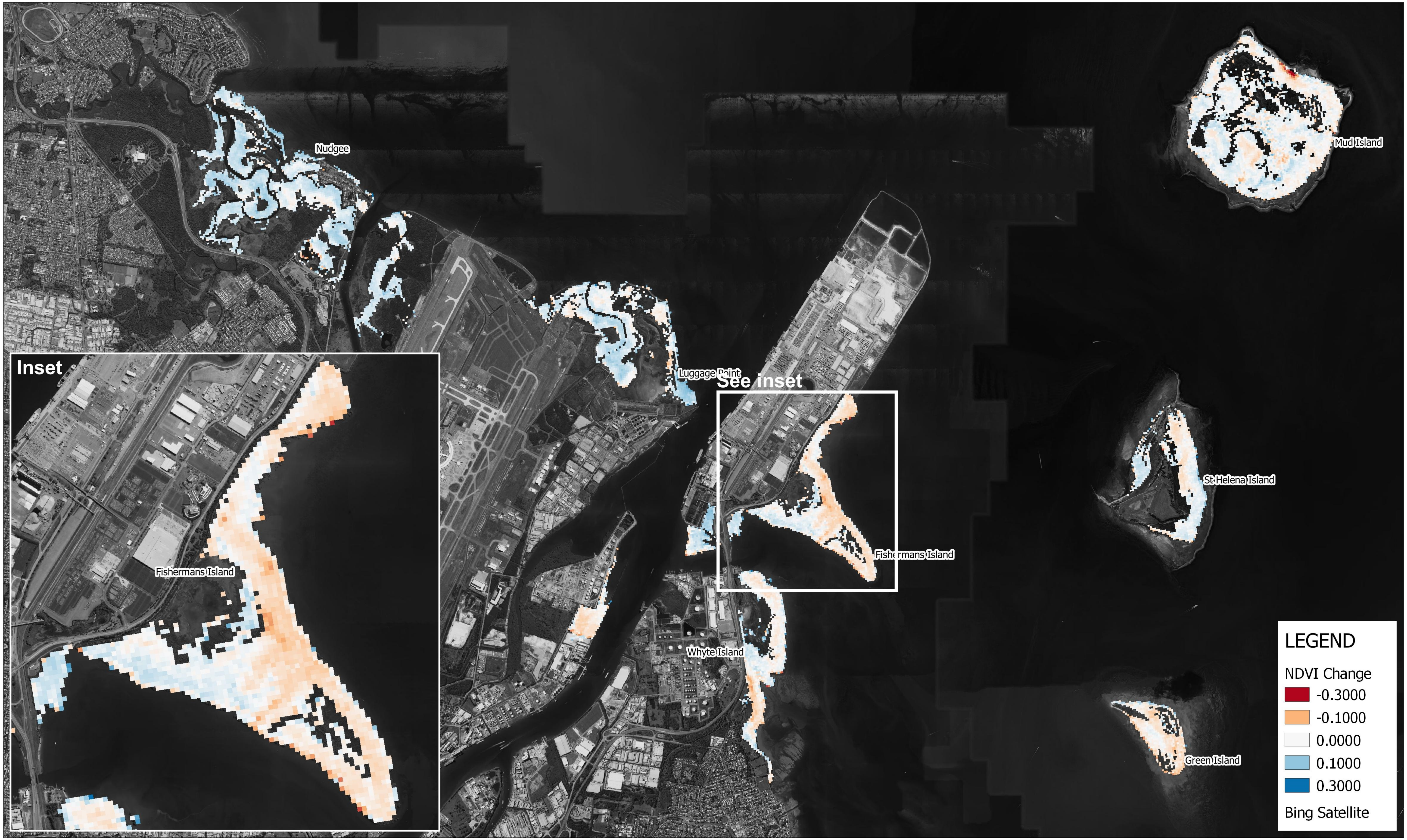
Figure 3.4 Relationships between the 12-month rolling average of NDVI score and monthly rainfall (top); 12 month rolling average of SOI (middle); and the rolling average of maximum monthly temperature (bottom)

© BMT 2022

3.2.2 Spatial trends

While mangrove condition in 2022 was higher than the long-term average, there was not a broad-scale improvement in mangrove condition between 2021-2022. Figure 2 is a map of NDVI changes between July 2021 and July 2022. The direction (i.e. improvement, stable, decline) and magnitude of change varied among and within locations. At broad scales, mangroves along Bramble Bay (Luggage Point and Nudgee) and Coal Loader/Pelican Banks had improved condition (NDVI change generally >+0.15), whereas mangroves at Bulwer and south of the Brisbane River entrance (Fisherman Islands, Whyte Island, St Helena Island, Mud Island, Green Island) were stable (<0.15 change) or declined in condition (Figure 3.1).

Aerial imagery showing specific comparison between 2021 and 2022 is shown in Annex B.



Title:
Differences Between July 2021 and July 2020 (Landsat Geomeans)

Figure: 3-5

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2022_Mangroves\ECO_001_220916_LandsatChange_22_21.qgz

Fisherman Islands

At Fisherman Islands, the eastern fringe observed an overall decrease whereas areas on the western fringe typically observed an overall slight increase in health. Within the eastern edge some areas of leaf loss were noted in bands of *Avicenna* across Fisherman Islands in landward areas or in central areas of the island. These decreases in health are observable on aerial imagery as shown in Figure 3.6.

Boat Passage

Overall there was a slight increase in vegetation health at Boat Passage. This area noted some issues with erosion in previous monitoring years that had resulted in tree fall which was no observed in the 2021/22 monitoring year.

Coal Loader

Overall there was a slight increase in mangrove health at Coal Loader between 2021 and 2022. This was observed as a slight increase in canopy cover and health. However, the seaward fringe of Coal Loader continued to experience ongoing erosion, resulting in a decrease in vegetation health.

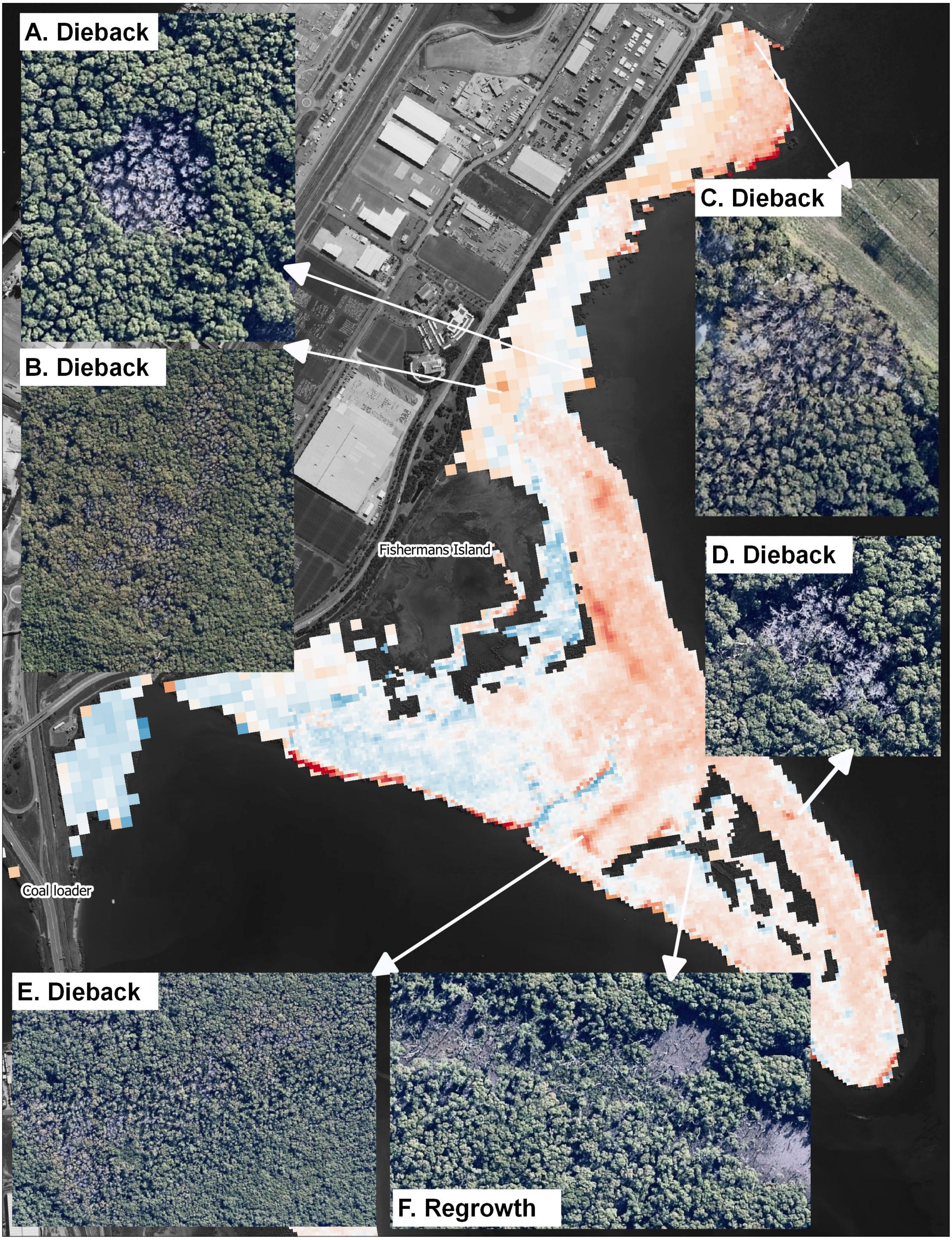
Bulwer

Bulwer had an overall trend of decrease in vegetation health, which was concentrated in the south-west corner of the mangrove patch. Investigation of aerial imagery shows that majority of the area is relatively consistent except for the southern boundary of Bulwer which has observed some canopy loss on individual trees.

Whyte Island

The vegetation health trend was variable across Whyte Island in the monitoring period. Some inland areas fringing the northern claypan observed an increase in vegetation health which can be seen on aerial imagery to be a result of growth of existing mangroves and recruitment of new mangroves. The major notable area of change at Whyte Island was the decrease in vegetation health in the south on the landward side (see Figure 3.8). At this location a large band (up to 40 m wide by 700 m long) of mangroves have experienced leaf loss. Aerial imagery reveals that this leaf loss began in early 2022 at the edge of Port Drive and has continued to track south over time. The leaf loss has now spanned from Port Drive to the northern end of the Wynnum mangrove walk. This is further discussed below.

© BMT 2022



Title:

Areas of observed changes in mangroves July 2021 to July 2022

Figure: 3-6

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2022_Mangroves\ECO_001_220916_LandsatChange_22_21.qgz

3.2.3 Health reduction in inland mangroves, particularly Whyte Island

During the 2021-2022 monitoring year, pockets of landward mangroves at both Fisherman Islands and Whyte Island experienced leaf loss. As mangroves live in a dynamic interface between land and sea, as well as typically being adjacent to dense urbanised or industrial area, it is difficult to determine if there is a singular factor resulting in the leaf loss or whether it is multiple interacting factors. Duke *et al.* (2021) have conducted a review on the factors that determine mangrove health which are listed in Table 3.1.

As summarised in Table 3.1, the potential factors that currently cannot be ruled out to be causing the leaf loss are acute and chronic rainfall, hydrology issues through blocked drainage resulting in ponding and pollution or excessive nutrients.

Despite the consistent finding of positive correlation between rainfall and vegetation health in the MMP, acute or chronic rainfall events can also lead to a decrease in mangrove health (Duke *et al.* 2021). This negative relationship was also observed by DERM (2012) following the 2011 Brisbane floods where excessive rainfall caused erosion and siltation of mangroves which lead to leaf loss and death. Some of these mangroves were observed to recover following the short-term reduction in health. One of the potential causes is ponding of water as a result of high rainfall and hydrology issues. The ground elevation profile at Whyte Island is shown in Figure 3.8. The elevation in the dieback areas is not notably different to the adjacent areas other than a general increase in elevation to the west of the dieback. However even a small change in elevation could cause ponding and this cause cannot be ruled out.

To further investigate the potential leaf loss a small site inspection was conducted at Whyte Island at the Wynnum mangrove boardwalk. The inspection confirmed the copse of mangroves were leafless as shown in Figure 3.7. The potential pollution reported by the community, as shown in Figure 3.7, is likely to be what is referred to as marine or cyanobacteria ‘scum’. Further laboratory testing of the water and sediment would be required for a definitive conclusion.

The mangroves at the southern edge of the leaf loss had an excess of algae growing on the pneumatophores and on the ground. This suggests that either the water is ponding in this area and/or that there is an increase in nutrients within the water. Either of these factors could also be contributing to the mangrove leaf loss.

It is recommended that a further investigative study be conducted into the cause of this health decline. The future investigation should involve water and sediment testing, observing some of the mangrove dieback areas at low tide to determine if there is any water ponding, and identifying any obstructions to drainage that may be causing hydrological issues.

© BMT 2022

Table 3.1 Factors that influence mangrove health according to Duke et al. (2021) and evaluation of whether they may be contributing to inland mangrove leaf loss at Fisherman and Whyte Islands

Factor	Disturbance	Response	Evaluation for Fisherman Islands and Whyte Island	Rating
Soil condition	Soil stability influences	Loss or gain due to erosion scouring & burial deposition	As the impacted mangroves are in inland areas it is unlikely that soil stability would be the cause of the leaf loss.	Unlikely
Temperature	Extremes in evapotranspiration reduce habitat resilience	High- or low-temperature stress reduces biodiversity	Temperature stress can result in the death of inland mangroves however the rolling maximum temperature observed in the monitoring year was not higher than other years therefore, it is unlikely that this is the cause.	Unlikely
Rainfall	Incremental shift towards high or low biomass vegetation	Wet or dry conditions reduce biodiversity with dramatic impacts on	Rainfall has been particularly high during the current monitoring year in both short-term acute events and prolonged chronic rainfall events. Therefore, this has the potential to be impacting mangrove health.	Likely
Flooding events	Inundation, erosion, burial cause plant damage & death in small patch areas	Inundation, erosion, burial cause plant damage & death across broad areas	Rainfall has been particularly high during the current monitoring year in both short-term acute events and prolonged chronic rainfall events. Therefore, this has the potential to be impacting mangrove health.	Likely
Salinity	Incremental shift towards high or low biomass vegetation	Hypersaline to hyposaline extremes reduce biodiversity	No evidence that salinity has changed.	Unlikely
Storm severity	High winds, large waves cause plant damage & death in small patch areas	High winds, large waves cause plant damage & death across broad areas	There have been no major storms in the monitoring years and the vegetation decline is not consistent with a single acute wind damage event.	Unlikely
Pollutant incident	Toxic/smothering oil spill, chemical, nutrients cause plant damage & death in small patch areas	Toxic/smothering oil spill, chemical, nutrients cause plant damage & death across broad areas	Due to the distribution of leaf loss across Whyte Island and Fisherman Islands it is unlikely that a pollutant would be the cause however, as multiple factors may be to blame further studies would be required to test the water and sediment in the area of leaf loss.	Possible

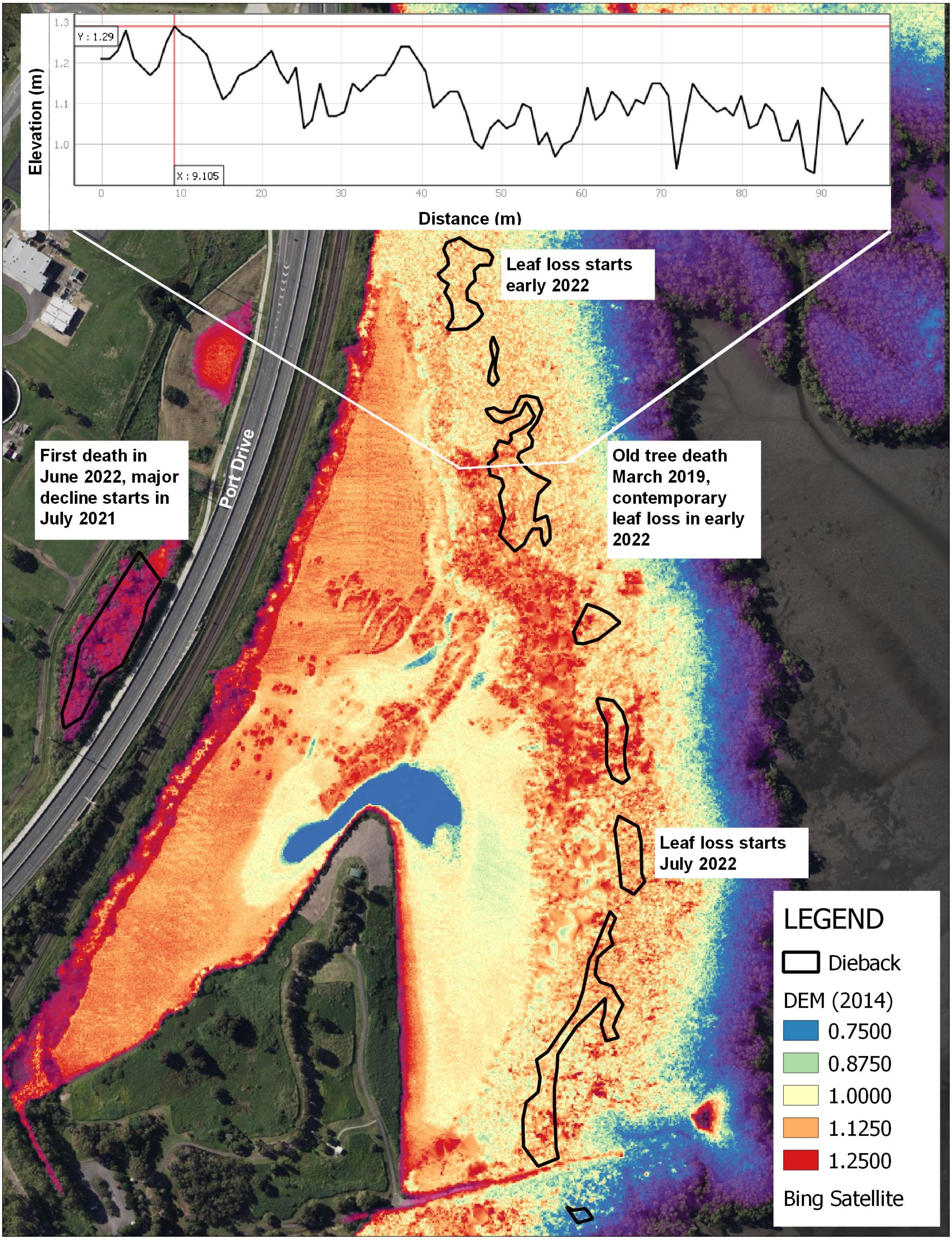
© BMT 2022

Factor	Disturbance	Response	Evaluation for Fisherman Islands and Whyte Island	Rating
Direct damage	Harvest, trampling, landfill of small patch areas	Harvest, trampling, landfill of broad areas	There is no evidence of direct damage therefore this is unlikely.	Unlikely
Herbivore damage or pathogen attack	Plant death and recovery in small patch gaps	Plant death and recovery of broad areas	Due to the distribution of leaf loss across Whyte Island and Fisherman Islands it is unlikely that a herbivore/pathogen would be the cause however, as multiple factors may be to blame further studies would be required to ground-truth some areas of leaf loss.	Unlikely

© BMT 2022

Figure 3.7 Wynnum mangrove boardwalk at Whyte Island field observations of loss of canopy along the elevated path (top left), a band of canopy loss (top right), white floating sum along the boardwalk (bottom left) and excess macroalgae growth on pneumatophores (bottom right)

© BMT 2022



Title:

Whyte Island dieback areas, ground elevation and leaf loss timeline

Figure: 3-8

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 50 100 m

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2022_Mangroves\ECO_002_220930_WhyteDieback.qgz

4 Conclusions

The present study found that:

- The overall condition of mangroves at both the test and control sites between 2021 and 2022 were highly variable with some locations in each treatment increasing and some decreasing overall. All sites had means within the historical ranges. Within the test sites, the overall condition of Fisherman Islands and Coal Loader decreased while the Whyte Island, Luggage Point and Bulwer increased overall.
- The overall spatial trend was that the mangroves north of the Brisbane River entrance increased in health (Luggage Point and Nudgee) whereas the mangroves along the Brisbane River (Bulwer) or to the south of the Brisbane River entrance (Fisherman Island, St Helena Island, Mud Island, Green Island) had overall stable or decrease in health (Figure 2).
- At Fisherman Island, the eastern fringe observed an overall decrease whereas areas on the western fringe typically observed an overall slight increase in health. Some inland areas of mangrove showed notable patches of leaf loss.
- Boat Passage had an overall slight increase in vegetation health. This area noted some issues with erosion in previous monitoring years that had resulted in tree fall which was no observed in the 2021/22 monitoring year.
- Coal Loader had a slight increase in mangrove health however, the seaward fringe is experiencing ongoing erosion which resulted in a decrease in vegetation health.
- Bulwer had an overall trend of decrease in vegetation health, which was concentrated in the south-west corner of the mangrove patch.
- Whyte Island had a variable trend of vegetation health with some areas of growth and recruitment at the northern claypan and a decrease in vegetation health in the south on the landward side. At this location a large band (up to 40 m wide by 700 m long) of mangroves have experienced leaf loss spanning from Port Drive to the northern end of the Wynnum mangrove walk.
- This decline in mangrove health may be a result of a single or multiple interacting factors including acute and chronic rainfall, hydrology issues through lack of drainage and/or pollution/excessive nutrients. Further study is recommended to investigate potential causes.

© BMT 2022

5 References

Accad A, Li J, Dowling R, Guymer G (2016). 'Mangrove and associated communities of Moreton Bay, Queensland, Australia: change in extent 1955-1997-2012.' Queensland Herbarium, Department of Science, Information Technology and Innovation, Brisbane.

Alongi DM (2009) 'The Energetics of Mangrove Forests.' (Springer Netherlands).

Australian Government (2022) Supplement to the Carbon Credits (Carbon Farming Initiative – Tidal Restoration of Blue Carbon Ecosystems) Methodology Determination 2022. Clean Energy Regulator, Canberra.
http://www.cleanenergyregulator.gov.au/DocumentAssets/Documents/Supplement%20to%20the%202022%20blue%20carbon%20method.pdf

BMT WBM (2016) Mangrove Health Assessment: 2016 Monitoring Results. September 2016. Prepared for Port of Brisbane Pty Ltd by BMT WBM, Brisbane.

BMT WBM (2018) Port of Brisbane Mangrove Health Monitoring Program 2018 – Final Report. December 2018. Prepared for Port of Brisbane Pty Ltd by BMT WBM, Brisbane.

Boegh E, Soegaard H, Broge N, Hasager CB, Jensen NO, Schelde K, Thomsen A (2002) Airborne multispectral data for quantifying leaf area index, nitrogen concentration, and photosynthetic efficiency in agriculture. Remote Sensing of Environment 81 (2002) 179– 193

Brown ME, Pinzon JE, Didan K, Morisette JT, Tucker CJ (2000) Evaluation of the consistency of long-term NDVI time series derived from AVHRR, SPOT-vegetation, SeaWiFS, MODIS, and Landsat ETM+ sensors. IEEE Transactions on Geoscience and Remote Sensing. 44 (7): 1787-1793

Davie P (Ed.) (2011) 'Wild Guide to Moreton Bay and Adjacent Coasts.' (Queensland Museum: Brisbane).

Department of Environment and Resource Management (DERM) (2012). Report on the Effects of the January 2011 Flood on the Mangrove Communities Along the Brisbane River. Available online at: https://wetlandinfo.des.qld.gov.au/resources/static/pdf/ecology/mangroves/effects-jan-2011-flood-mangroves-brisr.pdf

Department of Natural Resources, Mines and Energy (2014). Queensland LiDAR Data - SE Queensland 2014 Project. Available at: https://elevation.fsdf.org.au/

Diaz BM, Blackburn GA (2003) 'Remote sensing of mangrove biophysical properties: Evidence from a laboratory simulation of the possible effects of background variation on spectral vegetation indices.' International Journal of Remote Sensing 24: 53-73.

Duke, N.C., Hutley, L.B., Mackenzie, J.R., Burrows, D. (2021). Processes and Factors Driving Change in Mangrove Forests: An Evaluation Based on the Mass Dieback Event in Australia's Gulf of Carpentaria. In: Canadell, J.G., Jackson, R.B. (eds) Ecosystem Collapse and Climate Change. Ecological Studies, vol 241. Springer, Cham. https://doi.org/10.1007/978-3-030-71330-0_9

Dwyer JL, Roy DP, Sauer B, Jenkerson CB, Zhang HK, Lymburner L (2018). Analysis ready data: Enabling analysis of the landsat archive. Remote Sensing. 10. 10.3390/rs10091363.

Green EP, Mumby PJ, Edwards AJ, Clark CD, Ellis AC (1998) 'The Assessment of Mangrove Areas using High Resolution Multispectral Airborne Imagery.' Journal of Coastal Research 14: 433-443.

Huete AR, Didan K,Miura T, Rodriguez EP,Gao X, Ferreira LG (2002) Overview of the radiometric and biophysical performance of the MODIS vegetation indices. Remote Sensing of Environment 83 (2002) 195-213 doi:10.1016/S0034-4257(02)00096-2.

Huete AR, Liu HQ, Batchily KV, Van Leeuwen, WJDA (1997). 'A comparison of vegetation indices over a global set of TM images for EOS-MODIS.' Remote sensing of environment, 59: 440-451.

Hutchings PA, Saenger P (1987) 'Ecology of Mangroves.' (University of Queensland Press: St Lucia)

Institut national de la recherche agronomique (INRA) (2016). 'S2ToolBox Level 2 products: LAI, FAPAR, FCOVER.' Available at: https://step.esa.int/docs/extra/ATBD_S2ToolBox_L2B_V1.1.pdf

Krause C, Dunn B, Bishop-Taylor R, Adams C, Burton C, Alger M, Chua S, Phillips C, Newey V, Kouzoubov K, Leith A, Ayers D, Hicks A (2021) DEA Notebooks contributors 2021. Digital Earth Australia notebooks and tools repository. Geoscience Australia, Canberra. https://doi.org/10.26186/145234

WBM (1992) Fisherman Islands Tidal Wetland Study. April 1992. Prepared for Port of Brisbane Corporation by WBM Oceanics Australia, Brisbane.

WBM (1998) Review of Potential Impacts Associated with the Superbund Construction. August 1998. Prepared for Port of Brisbane Corporation by WBM Oceanics Australia, Brisbane.

WBM (2000) Assessment of the Health, Viability and Sustainability of Mangrove Communities at Fisherman Islands. Prepared for Port of Brisbane Corporation by WBM Oceanics Australia, Brisbane.

WBM (2002a) Assessment of the Health and Viability of Mangrove Communities at Fisherman Islands. Prepared for Port of Brisbane Corporation by WBM Oceanics Australia, Brisbane.

WBM (2002b) Assessment of the Health and Viability of Mangrove Communities at Whyte Island. Prepared for Port of Brisbane Corporation by WBM Oceanics Australia, Brisbane.

WBM (2003) Mangrove Rehabilitation Works at Luggage Point - Success Determination Monitoring Report Year 2. Prepared for Brisbane City Council by WBM Oceanics Australia, Brisbane

Zhang HK, Roy DP (2016) Landsat 5 Thematic Mapper reflectance and NDVI 27-year time series inconsistencies due to satellite orbit change, Remote Sensing of Environment. 186: 217-233, https://doi.org/10.1016/j.rse.2016.08.022.

© BMT 2022

Annex A Vegetation indices

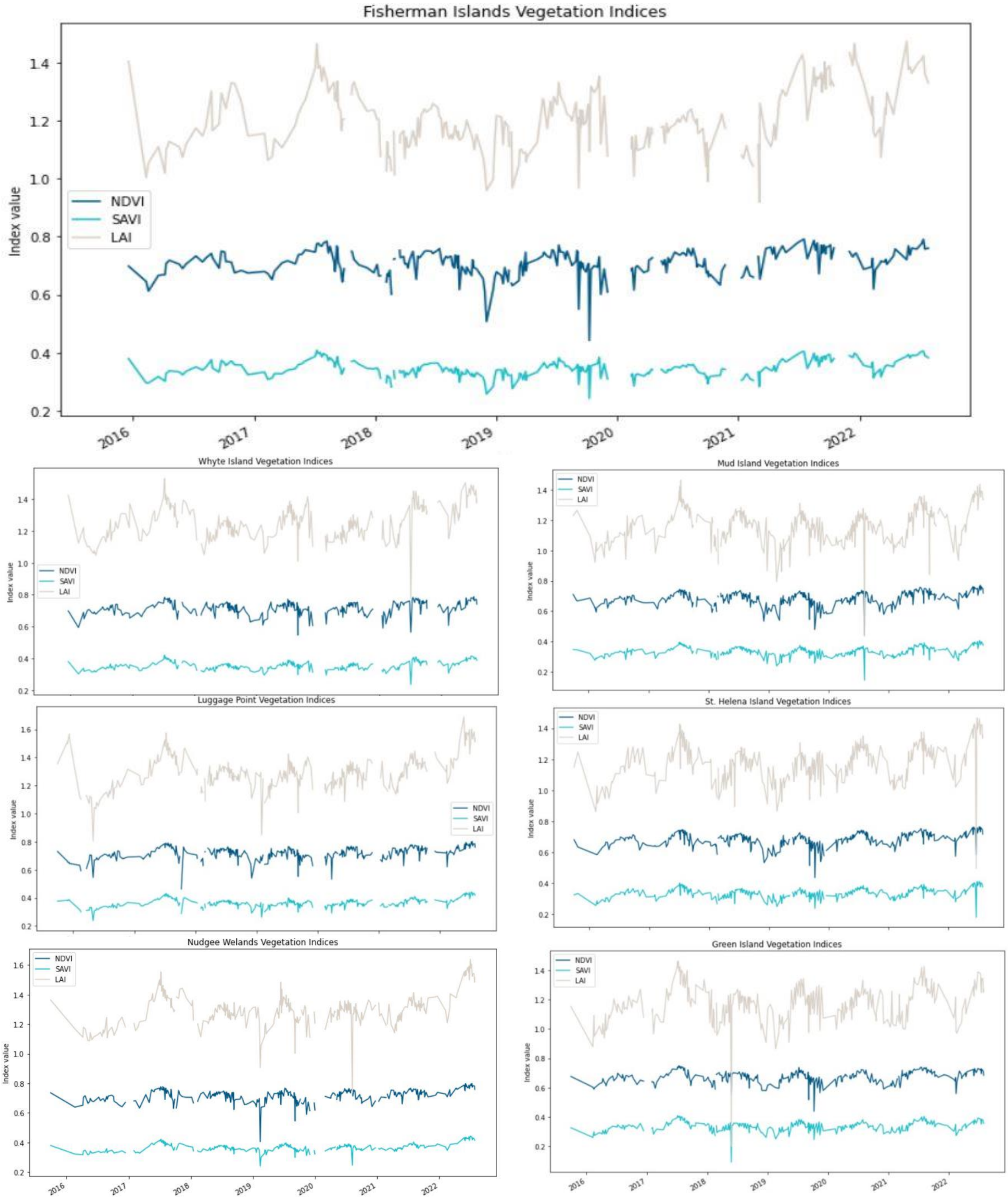


Figure A.1 Time-series of NDVI, SAVI, and LAI for all sites derived from Sentinel-2 between 2015 and 2021

Annex B Aerial imagery investigations

Figure B.1 Dieback of mangroves at Fisherman Islands between July 2021 (middle) and July 2022 (right)

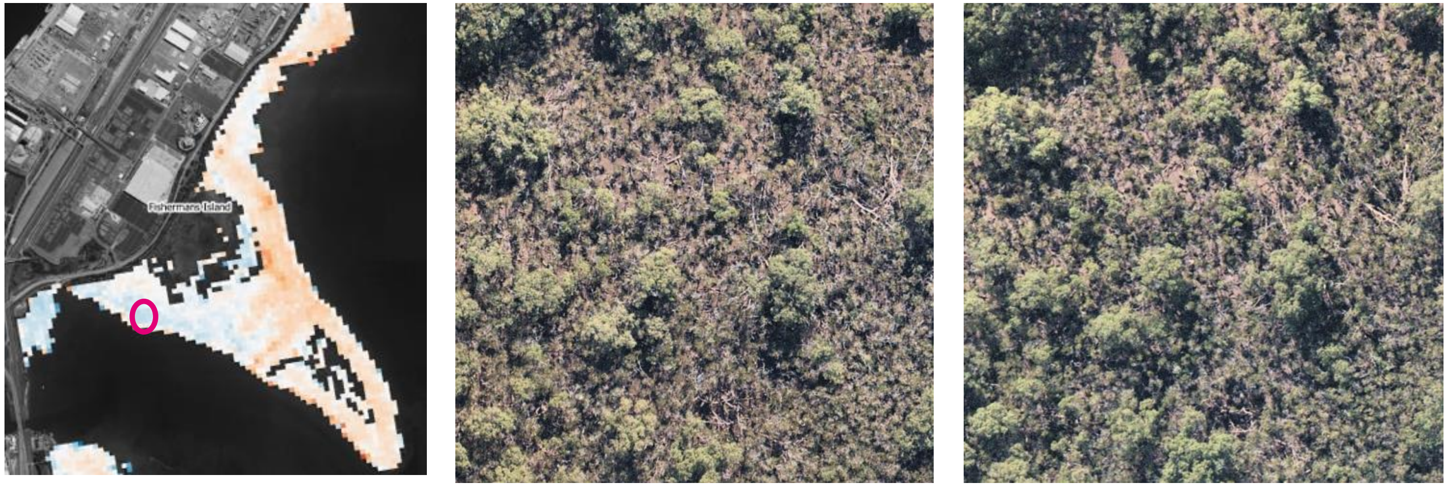


Figure B.2 Recruitment of juvenile mangroves between July 2021 (middle) and July 2022 (right)

© BMT 2022

Figure B.3 Tree fall at the tip of Coal Loader between July 2021 (middle) and July 2022 (right)

Figure B.4 Increase in canopy cover at Coal Loader between July 2021 (middle) and July 2022 (right)

© BMT 2022

Figure B.5 Dieback on fringing mangroves at Whyte Island between July 2021 (middle) and July 2022 (right)

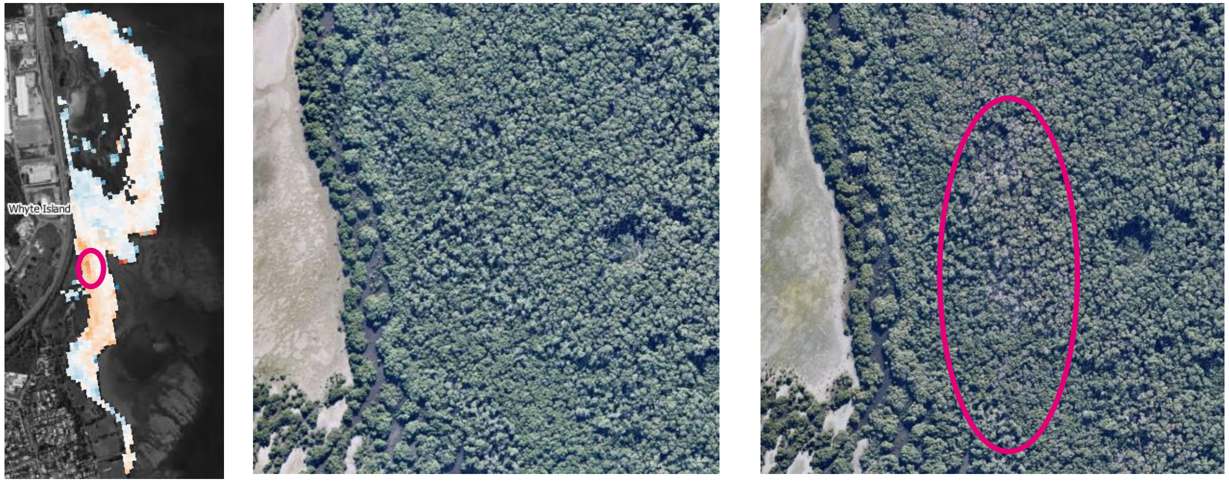
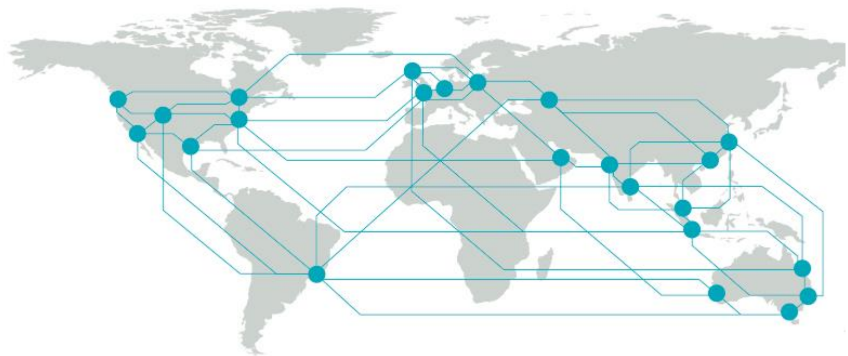


Figure B.6 Dieback on mangroves at Whyte Island between July 2021 (middle) and July 2022 (right)

Figure B.7 Growth on inland mangroves at Whyte Island between July 2021 (middle) and July 2022 (right)

Figure B.8 Defoliation of southern fringing trees at Bulwer Island between July 2021 (middle) and July 2022 (right)

© BMT 2022



BMT is a leading design, engineering, science and management consultancy with a reputation for engineering excellence. We are driven by a belief that things can always be better, safer, faster and more efficient. BMT is an independent organisation held in trust for its employees.

Level 5
348 Edward Street
Brisbane
QLD 4000
Australia
+61 7 3831 6744

Registered in Australia
Registered no. 010 830 421
Registered office
Level 5, 348 Edward Street,
Brisbane QLD 4000 Australia

For your local BMT office visit www.bmt.org

Contact us

enquiries@bmtglobal.com

www.bmt.org

Follow us

www.bmt.org/linkedin

www.bmt.org/youtube

www.bmt.org/twitter

www.bmt.org/facebook