Port of Brisbane Mangrove Monitoring Program - 2020 Final Report

Reference: R.B23621.007.01.Mangroves 2020.docx
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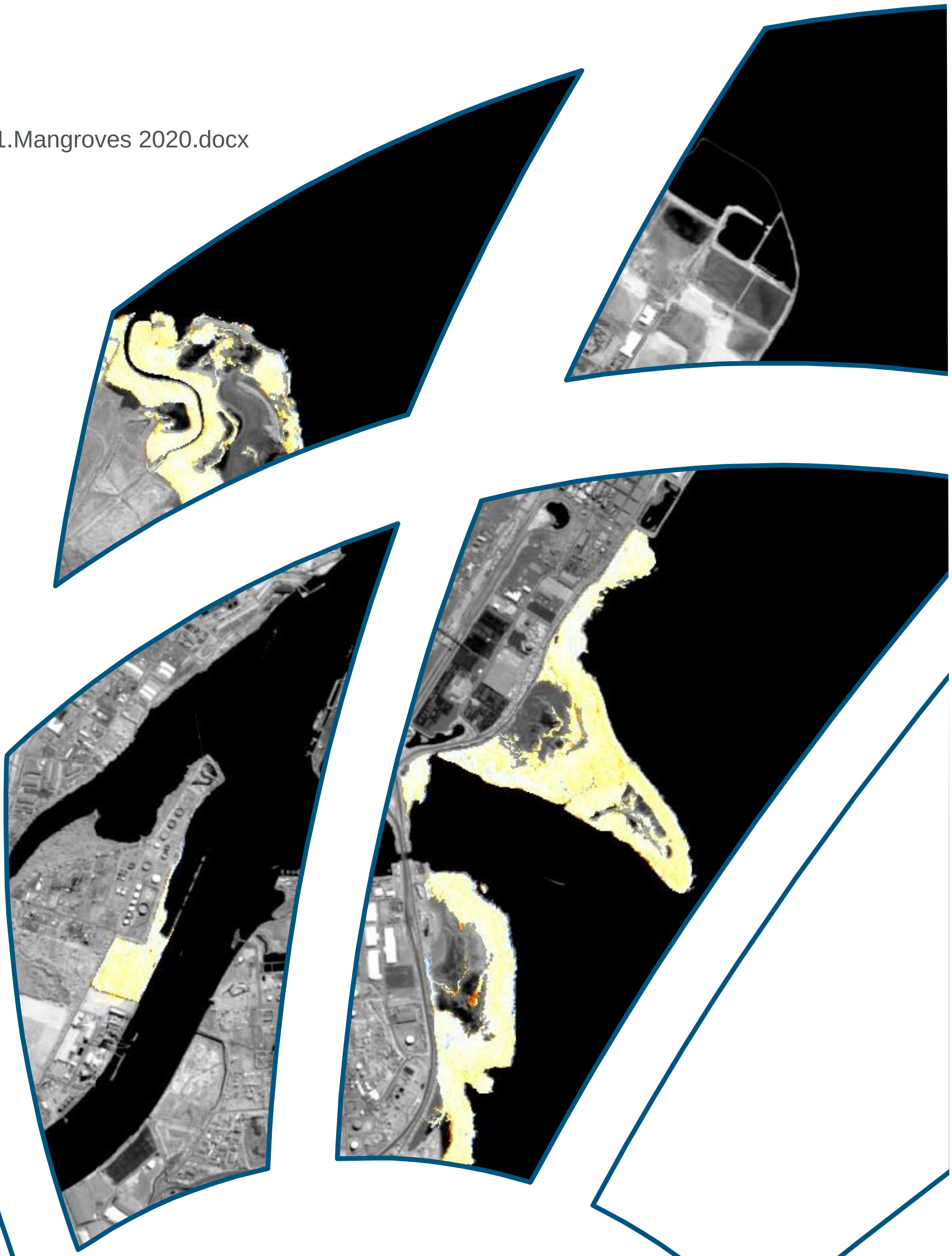

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	Title:	Port of Brisbane Mangrove Monitoring Program - 2020 Final Report
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	Client Reference:	
Synopsis:	**An assessment of mangrove condition at the Port of Brisbane and adjacent environments.**	

REVISION/CHECKING HISTORY

Revision Number	Date	Checked by		Issued by	
0	18th September 2020	DLR		BEH	
1	26th November 2020				

DISTRIBUTION

Destination	Revision										
	0	1	2	3	4	5	6	7	8	9	10
Port of Brisbane Pty Ltd	PDF	PDF									
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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. These vegetation communities are important ecological assets and are among the largest in western Moreton Bay.

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 2020 MMP assessment.

MMP Aims

- Investigate mangrove health using several vegetation indices: normalised difference vegetation index (NDVI), soil-adjusted vegetation index (SAVI) and leaf area index (LAI).
- Map changes in mangrove health between July 2019 and July 2020 using remotely sensed data and validate using aerial imagery.
- Identify potential drivers of mangrove degradation in key investigation areas, namely Fisherman Islands, Whyte Island and Bulwer Island.

Study Approach

Three mangrove condition indices were mapped using remotely sensed data: NDVI, SAVI and LAI. NDVI and SAVI are spectral indices that estimate the amount of green biomass using red and near infrared spectrums while LAI calculates the amount of canopy per unit area. These metrics were calculated for seven periods between and inclusive of July 2019 to July 2020. Aerial imagery was used to investigate areas where changes in mangrove condition were observed over the twelve-month period.

Findings

Long-Term Patterns

- The three condition indicators declined between 2019 and 2020 at all test (Fisherman Island, Whyte Island, Bulwer Island) and control sites. Inspections of aerial photography confirmed that areas of poor mangrove condition had canopy thinning (leaf loss) and/or tree mortality (Figure 1).

Figure 1 Leaf loss and tree mortality of Fisherman Islands inland mangrove communities between July 2019 (A) and July 2020 (B)

- NDVI was lowest in March 2020 during the 2019-2020 monitoring period (Figure 2). This was the fourth lowest NDVI value on record in the period 2016-2020.
- In addition to seasonal cycles described below, there were long term cyclic changes in mangrove health during the 2016-20 monitoring period. Peaks in NDVI values occurred one to three months following rainfall peaks, and there was a significant correlation between the ranks of rainfall and NDVI within seasons for summer ($\rho = 0.98$, $p < .05$) and winter ($\rho = 0.90$, $p < .05$). However, the relationship between rainfall and NDVI was not linear ($r < 0.7$, $p > 0.1$). This was most likely due to confounding influences of seasonality

and possibly variability in the relative influence of surface and groundwater hydrology on mangrove condition.

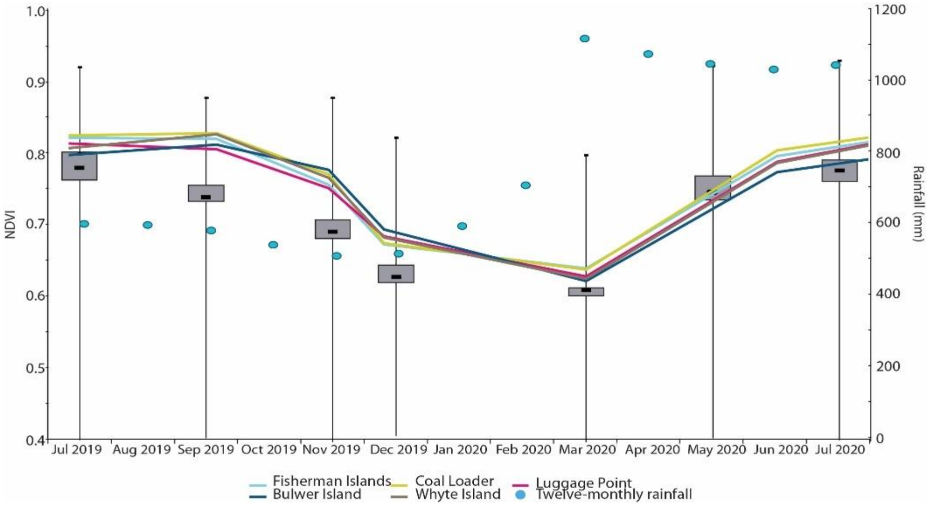

Figure 2 Temporal changes in NDVI and twelve-month cumulative rainfall at test and control (box plot) sites - July 2018 to July 2019

Seasonal Patterns

- There were seasonal changes in NDVI and SAVI during the 2019-20 monitoring period, with a decline over late spring/summer 2019, and improvement in autumn 2020. This pattern was consistent with historical seasonal trends.
- LAI was also lower during summer 2019/20 than winter 2019. However, unlike NDVI and SAVI, LAI did not increase post summer 2019-20. This suggests that while canopy chlorophyll improved post summer, the leaf cover did not change.

Spatial Patterns

- Consistent with previous surveys, mangrove canopy condition was typically greatest in the well-flushed seaward fringes of the forest, and lower in areas near the mangrove-saltpan interface. Water stress is a key driver of this spatial gradient.
- Most of the die-back areas were also observed in previous years, indicating a continuing long-trend trend of mangrove stress in these areas. In most cases, the change in canopy condition was due to leaf loss and/or tree mortality tree fall.

Differences in NDVI Among Community Types

- NDVI values varied among community types.
- However, long-term and seasonal trends in all three condition indicators were broadly consistent among community types.

Conclusions

Mangrove condition decreased over 2019 and 2020, and this trend was consistent across test and control sites. Dry, hot, conditions experienced during this period are predicted to be the main drivers of mangrove stress.

There was a single mangrove fall and areas of poor mangrove condition at Bulwer Island near the fishway works area. Mangrove falls have occurred in this area before and after fishway construction. Further work would be required to establish potential links between mangrove condition and changes to the hydrodynamic regime (i.e. reinstatement of flushing) resulting from fishway works.

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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).

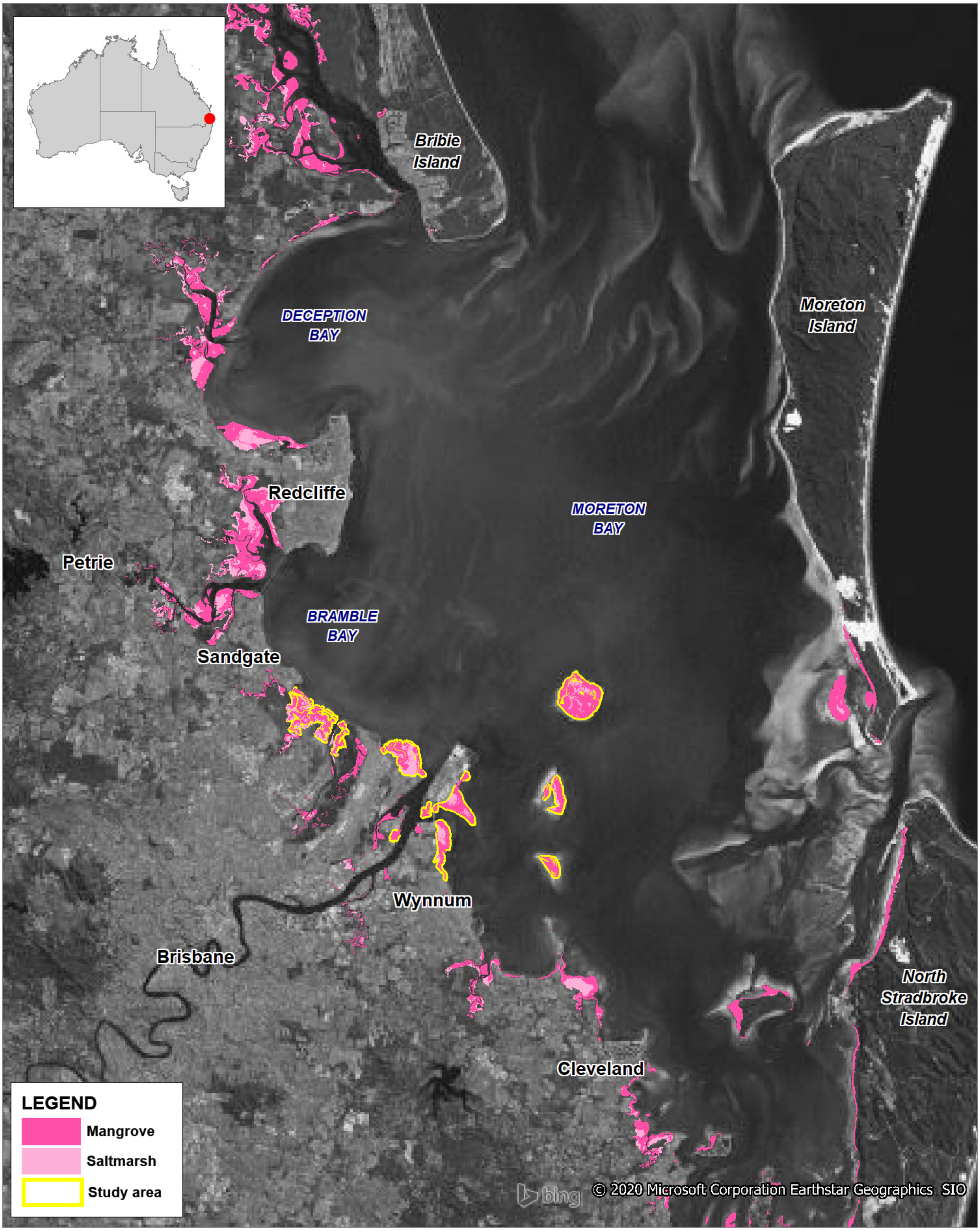
The Port of Brisbane Pty Ltd (PBPL) operates adjacent to these mangrove forests and saltmarsh communities therefore the variation of their health through time and space needs to be monitored and analysed to ensure port activities are not impacting these communities. Monitoring of the mangroves and saltmarsh surrounding the Port of Brisbane has been conducted since the 1990s (WBM 1992; CSIRO 1992; BMT WBM 2016, BMT 2017, BMT 2018, BMT 2019) 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:

- Investigate mangrove health using several vegetation indices: NDVI, soil-adjusted vegetation index (SAVI) and leaf area index (LAI).
- Map changes in mangrove health between July 2019 and July 2020 using remotely sensed data and validate using high resolution aerial imagery.
- Identify potential drivers of mangrove degradation in key investigation areas, namely Fisherman Islands, Whyte Island and Bulwer Island.



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

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2 Methodology

2.1 Remote Sensing

2.1.1 Data Sources

Sentinel-2 imagery (10 m resolution, 12-band) was used to derive vegetation condition metrics for mangrove forests at nine locations (termed investigation areas, refer to Section 2.1.2). Data were acquired for ten periods:

- 5th of July 2019;
- 18th of September 2019;
- 7th of November 2019;
- 2nd of December 2019;
- 1st of March 2020;
- 25th of May 2020; and
- 4th of July 2020.

Due to high cloud cover during the summer months imagery in January and February was not available for analysis. Vegetation mapping in Accad *et al.* (2016) was used to identify mangrove forest boundaries. All other vegetation community types were excluded from the analysis.

2.1.2 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 area (hectares) and pixel counts for mangrove forests in each investigation areas are presented in Table 2-1, and the extent of these areas are shown in Figure 2-1. Sentinel-2 images provided between 2,293 and 44,460 pixels per investigation area (depending on size of the investigation areas), which provided sufficient resolution to assess broad temporal trends in the vegetation health indices.

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Test

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Mangrove health assessment test and control sites

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Table 2-1 Investigation Areas

Treatment type	Investigation area	Area (ha)	Equivalent pixels
Test	Fisherman Islands (main)	181.6	18,161
	Fisherman Islands (Coal Loader)	22.9	2,293
	Whyte Island/Wynnum	143.9	14,389
	Luggage Point	265.8	26,579
	Bulwer Island	29.3	29,25
Control	Nudgee Wetlands	366.6	36,667
	King Island	68.0	6,803
	St Helena Island	126.0	12,596
	Mud Island	444.6	44,460
Total		**1648.7**	**164,873**

2.1.3 Spatial Data Processing

2.1.3.1 Vegetation Indices

Atmospherically-corrected bottom-of-atmosphere (BoA) Sentinel-2 data (Level-2A products) were produced using the Sen2Cor processor (Version 2.4.0), developed by the European Space Agency. Level-1C top of atmosphere products were corrected for atmosphere, terrain, and cirrus cloud density using Sen2Cor within the Sentinel Application Platform (SNAP). Three indices were calculated.

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.

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.

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:

$$LAI = \text{leaf area} / \text{ground area}$$

Band-math and atmospheric correction were performed using SNAP 6.0, Sen2Cor, and the Sentinel-2 toolbox (S2TBX). Raster calculations and area of interest queries were performed using ArcGIS 10.5, and presented in MapInfo 15.0.

2.1.3.2 Vegetation Community Mapping

A light detection and ranging (LiDAR) point cloud was used to derive the community map for all test locations. This LiDAR data was captured as part of the south east Queensland LiDAR project in 2014 and has a vertical accuracy of +/- 0.3 m and a horizontal accuracy of +/- 0.8 m (DNRME 2014). The community classes used for classifying the mangroves were:

- Tall *Avicennia marina* dominated closed to open forest, >10 m canopy height +/- *Aegiceras corniculatum*, *Ceriops australis, Rhizophora stylosa and Bruguiera gymnorhiza;*
- *Avicennia marina* closed to open forest, 3-10 m canopy height +/- *A. corniculatum*, *C. australis, R. stylosa and B. gymnorhiza;*
- Low *Avicennia marina* shrub, 2-3 m canopy height +/- *A. corniculatum*, *C. australis, R. stylosa and B. gymnorhiza;*
- *Ceriops australis* open to closed to open forest, 2-5 m canopy height *+/- A. corniculatum and A. marina*; and
- Saltmarsh/saltpan.

2.1.4 Rainfall data

Rainfall data was accessed from the Bureau of Meteorology from July 2019 to July 2020. The weather station closest to the study area was Brisbane Airport (040842). Twelve monthly cumulative rainfall data were compared with vegetation condition indices.

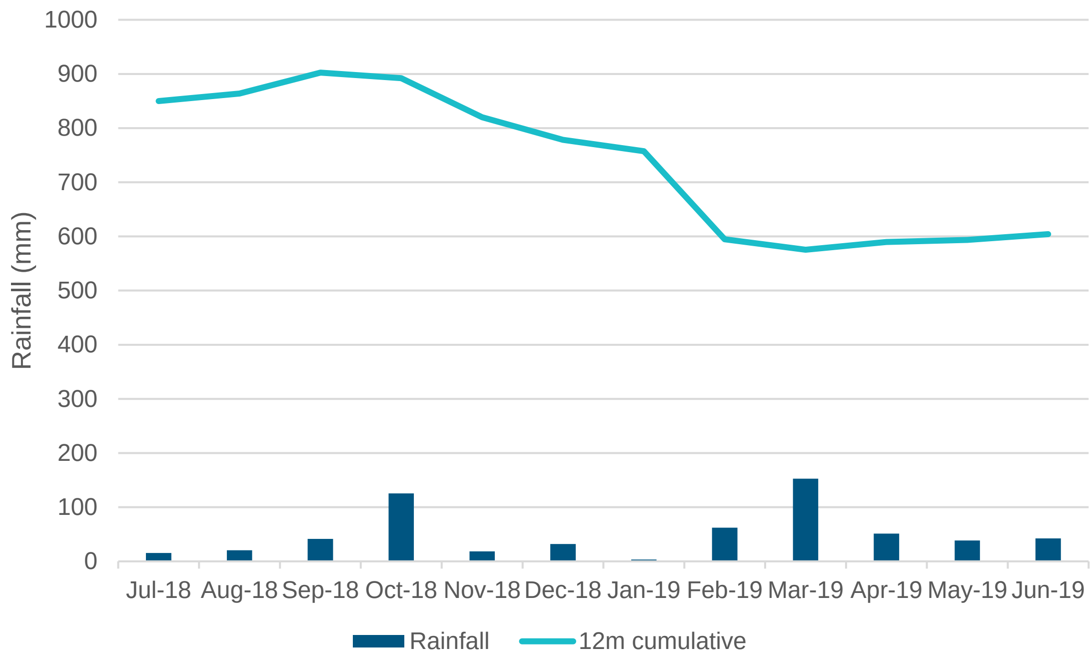


Figure 2-2 Monthly total rainfall and 12-monthly rainfall for the Brisbane Airport (station 040842)

2.1.5 Assumptions and Limitations

The orthorectification of Sentinel-2 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.

3 Results and Discussion

3.1 Spatial Patterns in Condition Indices

3.1.1 Sentinel-2 Imagery – Investigation Areas

Spatial patterns in NDVI, SAVI and LAI are mapped for all investigation areas in Figure 3-1, Figure B-1 and Figure B-2, respectively. The three vegetation indices displayed similar spatial patterns. Both SAVI and NDVI had broadly consistent spatial patterns, whereas there was less temporal variation in LAI. The northern side of Fisherman Islands supported taller (BMT WBM 2016) and healthier mangrove forests than the southern shoreline. The *Ceriops* community on the western side of Fisherman Island has lower vegetation index values for all indices.

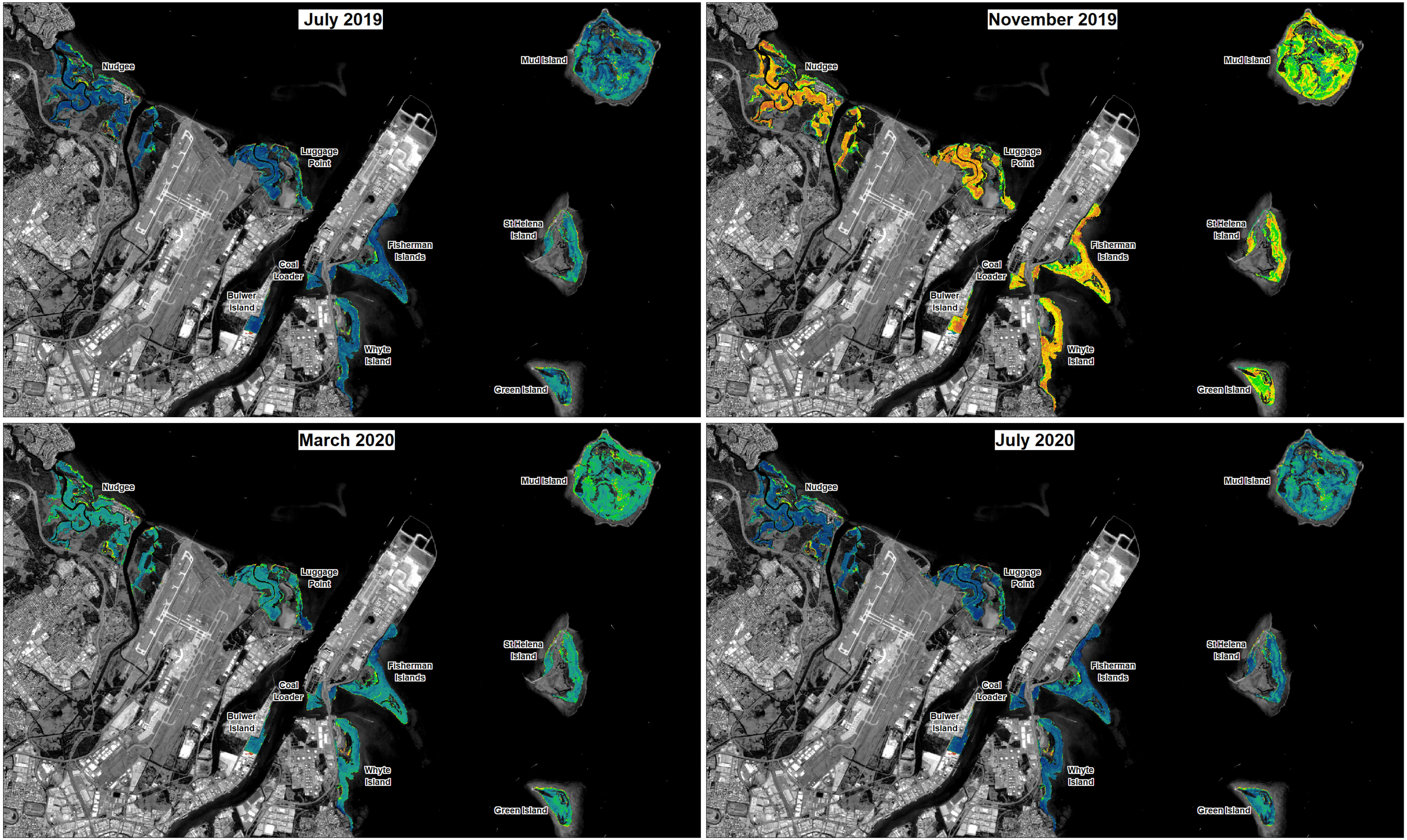
Vegetation community metrics slightly decreased in July 2020 compared to July 2019 across all investigation areas. However, there were a few areas of increased vegetation along the seaward margins and localised interior areas. Key areas of mangrove loss around the port area are shown in Figure C-1 and include:

- There were numerous instances of tree deaths within inland saltmarsh regions at all test and control sites (see Figure C-2 images A/B and G/H for examples). This is likely due to drought conditions and salt stress.
- South-east tip of Fisherman Islands – death of one tree between July 2019 and July 2020, verified by inspection of aerial imagery (Figure C-2 images C/D).
- Eastern seaward edge of Fisherman Islands - death of one tree between July 2019 and July 2020, verified by inspection of aerial imagery (Figure C-2 images E/F). This large dead tree is located 450 m north of the tip of Fisherman Islands.
- Tidal channel bisecting Fisherman Island - Tree death confirmed by inspection of aerial imagery, and some vegetation in poor condition nearby.
- Adjacent to constructed fishway at Bulwer Island - Death of a large tree that was previously displaying leaf loss (see Figure C-3 image I/J). Aerial imagery indicates leaf loss on several other trees nearby.

The areas of loss of Fisherman Island are shown in Figure C-2 and the areas of Bulwer Island, Whyte Island and a Nudgee example are shown in Figure C-3.

Mangrove defoliation and die-back was observed in the interior portions of mangrove forests during the measurement period. This appeared to be in areas that had already begun to see dieback during the previous monitoring period (2018-19). Areas that are not regularly flushed (i.e. inland portions of forests, saltpans) accumulate salts, which can lead to physiological stress to plants. This is termed 'water' stress and is the key control of tidal vegetation community structure, especially at the mangrove/saltpan interface (see review by BMT WBM 2016).

As the decrease in mangrove health was broadscale across all sites including control there is no evidence that these losses of inland mangroves are a result of PBPL activities.



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NDVI Score

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NDVI at investigation sites in July 2019, November 2019, March 2020, and July 2020

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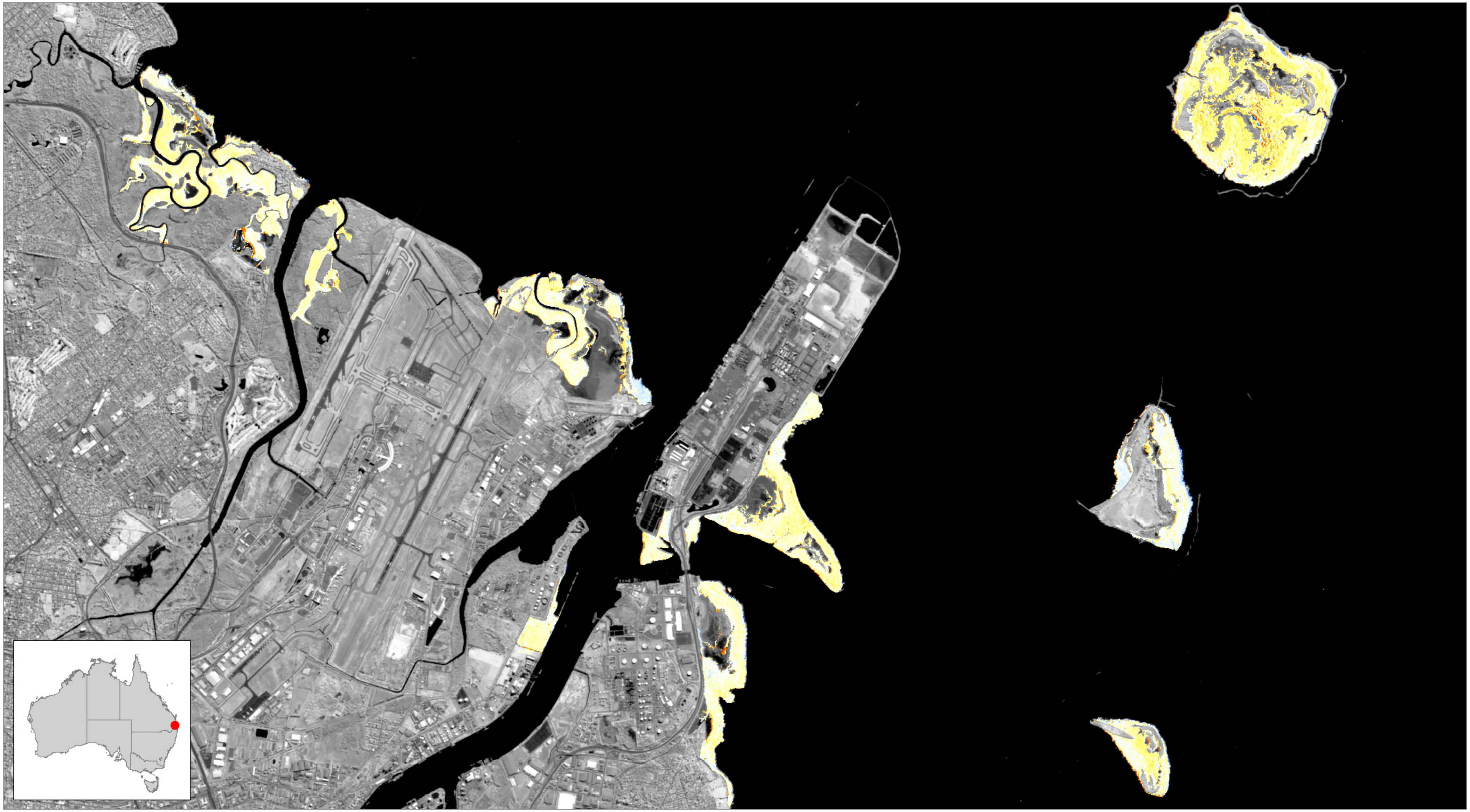

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NDVI Change Between July 2019 and July 2020

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3.1.2 Patterns Among and Within Community Types

Mangrove community mapping is shown in Figure A-1. Mangrove forests of the study area are numerically dominated by the grey mangrove *Avicennia marina*, however yellow mangrove *Ceriops* copses also occur at Fisherman Islands. There were differences in forest height among and within locations - Fisherman Islands and Luggage Point were dominated by moderate (3 to 10 m) *Avicennia* communities, whereas Coal Loader, Bulwer Island and seaward fringes of Fisherman Islands were dominated by tall (>10 m) *Avicennia* communities.

Average NDVI values in each community and test locations in July 2020 are shown in Figure 3-3, and the reporting areas for this are shown in Figure A-2. Patterns in average NDVI in each community type were inconsistent among locations, as follows:

- Saltmarsh/saltpan communities at three sites had low (<0.6) average NDVI values (Fisherman Islands B, Luggage Point, Whyte Island). All other sites supporting this community had NDVI within the range of mangrove forests (typically >0.7). Differences in NDVI among sites reflect variations in the relative proportion of saltmarsh compared to 'unvegetated' saltpan and ponded areas. Individual mangroves were also present in the saltmarsh/saltpan areas, influencing NDVI scores.
- *Avicennia* dominated shrubland generally had NDVI within the range of other mangrove community types. NDVI values ranged from 0.72 to 0.84 (Bulwer Island and Fisherman Islands area D respectively).
- *Ceriops* dominated copses at Fisherman Islands had NDVI of 0.76, which was within the mid-range recorded in other mangrove communities.
- *Avicennia*-dominated communities in the tall and very tall height classes had average NDVI between greater than 0.79 and 0.86. Mud Island had the highest NDVI value of 0.86.

While there are slight temporal variations between community types, they generally follow the prevalent trend of each mapped area.

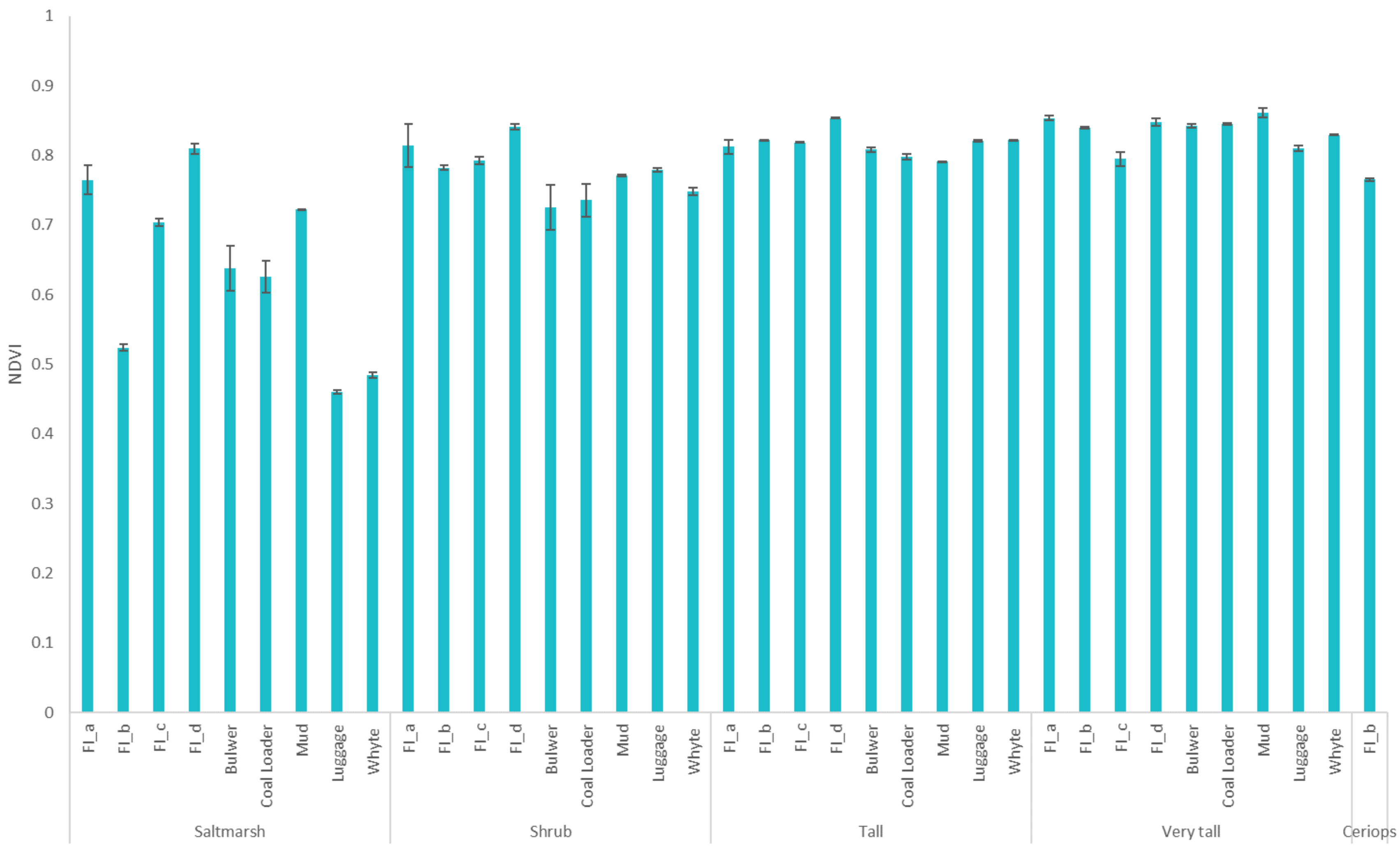

Figure 3-3 Average (± SE) NDVI in July 2020 between locations for community types (including saltmarsh, shrub (2-3 m), tall (3-10 m), very tall (>10 m) and *Ceriops* communities)

3.2 Temporal Patterns in Mangrove Condition

3.2.1 Temporal Trends

Figure 3-5 and Figure 3-6 presents box plots for NDVI, SAVI and LAI for each episode during the 2019-20 monitoring period (all sites and mangrove community types pooled). The following temporal trends in mangrove condition indices were observed:

- A decline in mangrove condition between July 2019 to July 2020;
- A decline in mangrove condition between spring to summer;
- Maximum condition occurred in spring; and
- Minimum condition occurred in summer.

These cyclical trends are consistent with previous observations (BMT WBM 2016; BMT 2017, 2018, 2019), and were also consistent between control and test sites.

Temporal trends between summer 2019-20 and winter 2020 differed among indices, as follows:

- **NDVI** – The NDVI minima occurred in March 2020. Between March 2020 and July 2020 vegetation condition gradually returned to July 2019 levels, resulting in minimum net change between July 2019 and July 2020.
- **SAVI** – The SAVI minima occurred in December 2019. Between December 2019 and July 2020 vegetation condition gradually increased, similar to trends in NDVI. Compared to NDVI, SAVI showed less temporal variation at a community level.
- **LAI** – The LAI minima occurred in December 2019. Between December 2019 and July 2020 LAI was stable, unlike trends in NDVI and SAVI.

Compared to NDVI and SAVI, LAI showed less temporal variation between 2019 and 2020 within community types (Figure D-1). Both *Ceriops* and very tall *Avicennia* dominant communities had a greater range of LAI values in 2020 in comparison to 2019.

3.2.2 Potential Temporal Drivers

As discussed in BMT WBM (2016), temporal cycles in plant health are complex and the drivers not fully resolved. The key temporal trends were:

- The summer-minima/winter-peak seasonal cycle. This cycle is consistent from year to year (BMT WBM 2016; 2017; 2018; 2019, present study). Potential drivers include increased temperature (e.g. heat stress) and solar irradiance (e.g. increased photosynthetically active radiation available for photosynthesis reducing energy demands) during summer.
- Short to medium term responses to rainfall. BMT WBM (2016) found that mangrove condition was highest in wet years and lowest in drought years. Between 2016-20, mangrove condition rapidly increased following rainfall events in some months, whereas in other months there was a lag of several months between rainfall peaks and changes to mangrove condition. Superimposed on these complex long-term cycles were seasonal changes as described. As a result, there was no linear relationship between mangrove condition (NDVI) and rainfall during the 2016-20

measurement period (r = 0.7, p > .05). However, stratifying times by season, there were significant (p < .05) correlations between cumulative rainfall and NDVI ranks (Table 3-1), indicating that mangrove condition was higher during and following wet periods. These complex, non-linear patterns are likely driven by temporal variations in ground water recharge and surface water runoff (BMT WBM 2016). Depending on soil type, vegetation community structure, rainfall and ground water, ground water tables are often recharged in the magnitude of months (Alongi 2009). Surface water runoff, which can reduce soil salinity and deliver nutrients, likely influences mangroves over shorter timescales.

- Long-term responses to rainfall. BMT WBM (2016) found that inter-annual patterns in NDVI tracked El Niño–Southern Oscillation (ENSO) cycle. The period of July 2019 to July 2020 represented weak El Niño conditions. Despite this, the rainfall peak during late summer 2020 appears to have sustained mangroves over late autumn to winter 2020.

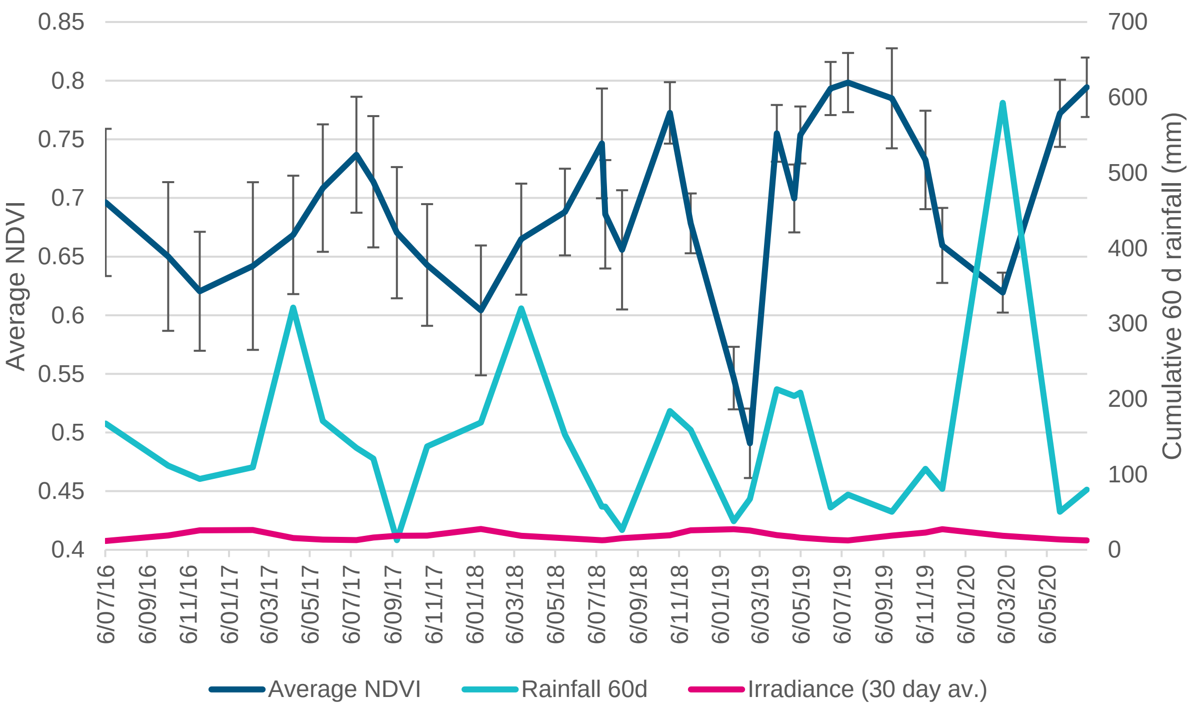

Figure 3-4 NDVI response to rainfall (cumulative 60 day) and irradiance (30 day average) between 2016 to 2020.

Table 3-1 Correlation between seasonal cumulative rainfall NDVI ranks

Season	Spearman rho correlation	*P* value
Summer (6 month cumulative rainfall + 3 months lag)	0.98	<.05
Winter (6 months cumulative rainfall)	0.9	<.05

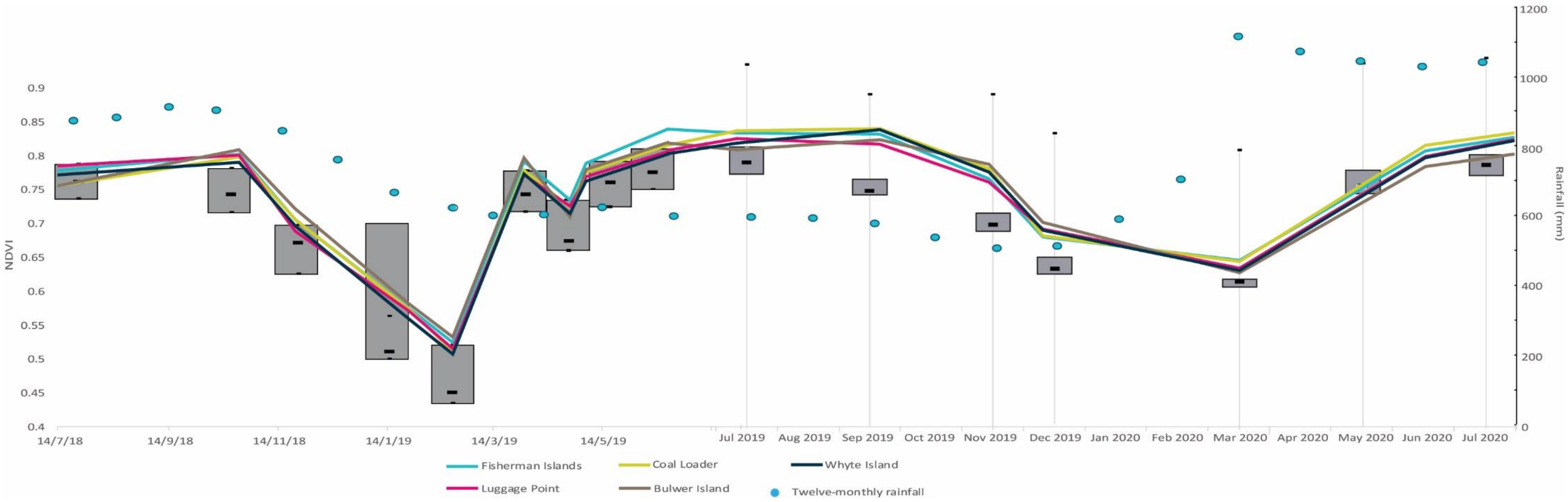

Figure 3-5 Boxplots of NDVI between July 2018 and July 2020 and antecedent 12 month cumulative rainfall

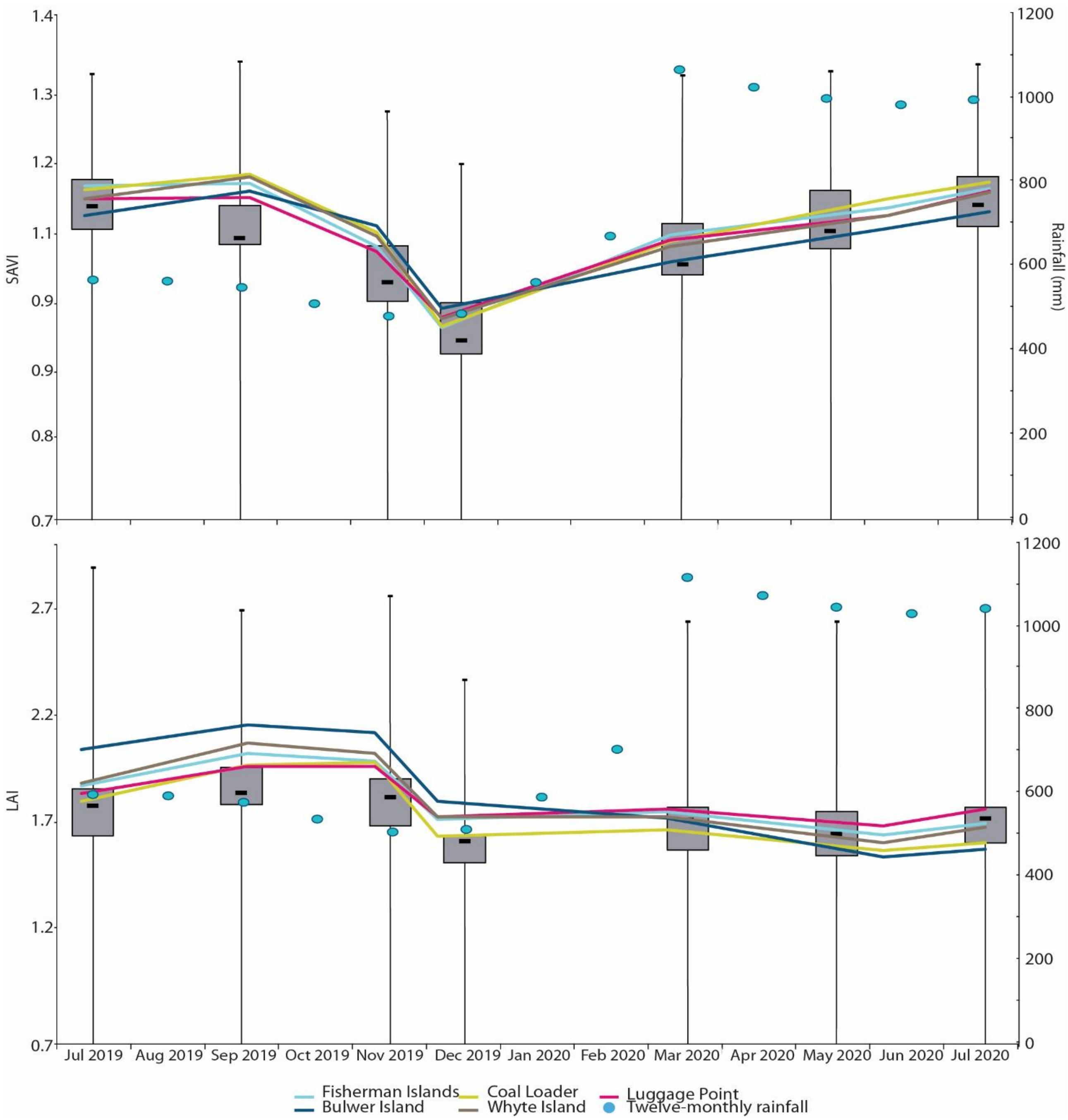

Figure 3-6 Boxplots of SAVI and LAI between July 2019 and July 2020 and antecedent 12 month cumulative rainfall

3.2.3 Associations Among Indices

LAI was inter-correlated with both NDVI and LAI ($p<0.05$) (Table 3-2). NDVI and SAVI are not correlated due to SAVI removing the influence of soil reflectance. As a result of this NDVI saturates faster than SAVI, potentially showing more differentiation of vegetation health within dense vegetation. SAVI and LAI were inter-correlated as SAVI is responsive to variations in the near-infrared spectrum making it receptive to changes in canopy structure, similar to LAI (Huete 1997).

Note that LAI is not linearly related to reflectance and therefore deriving LAI from remote sensing can result in an effective LAI being calculated (the value that may be recorded with the observed remote sensing signal) (INRA 2016).

Table 3-2 Correlation matrix – NDVI, SAVI, LAI

Vegetation Indices	Correlation (R)	P value
NDVI v SAVI	0.0011	0.9
NDVI v LAI	0.019	0.025
SAVI v LAI	0.73	< 0.00001

4 Conclusions

The present study found that:

- There was a broadscale decrease in vegetation health across both test and control sites between July 2019 and July 2020 which was observed to be a result of canopy thinning and/or tree death.
- The areas of mangrove loss were predominately inland regions within the saltmarsh matrix. The dry, hot conditions during the study period are predicted to be the major drivers of mangrove stress.
- There was a single mangrove fall and areas of poor mangrove condition at Bulwer Island near the fishway works area. Mangrove falls have occurred in this area before and after fishway construction. Prior to fishway construction this area was subject ponding, however tidal flushing has been provided by the fishway works. Further work would be required to establish potential links between mangrove condition and changes to the hydrodynamic regime resulting from fishway works (i.e. reinstatement of connectivity and tidal flushing).
- NDVI values varied between community types however seasonal trends were broadly consistent among community types.
- Seasonal changes were observed in NDVI and SAVI during the monitoring period, with a decline over late spring/summer 2019, and improvement in autumn 2020. This pattern was consistent with historical seasonal trends.
- LAI was also lower during summer 2019/20 than winter 2019. However, unlike NDVI and SAVI, LAI did not increase post summer 2019-20. This suggests that while canopy chlorophyll improved post summer, the leaf cover did not change.
- Long-term cyclical trends were observed in addition to seasonal cycles between 2016-20. One to three months lag were observed between rainfall and NDVI peaks. There was a significant correlation between the ranks of rainfall and NDVI within seasons for summer ($\rho = 0.98$, $p < .05$) and winter ($\rho = 0.9$, $p < .05$). The relationship between rainfall and NDVI was not linear ($r < 0.7$, $p > 0.1$) most likely due to confounding influences of seasonality and variability in the relative influence of surface and groundwater hydrology.

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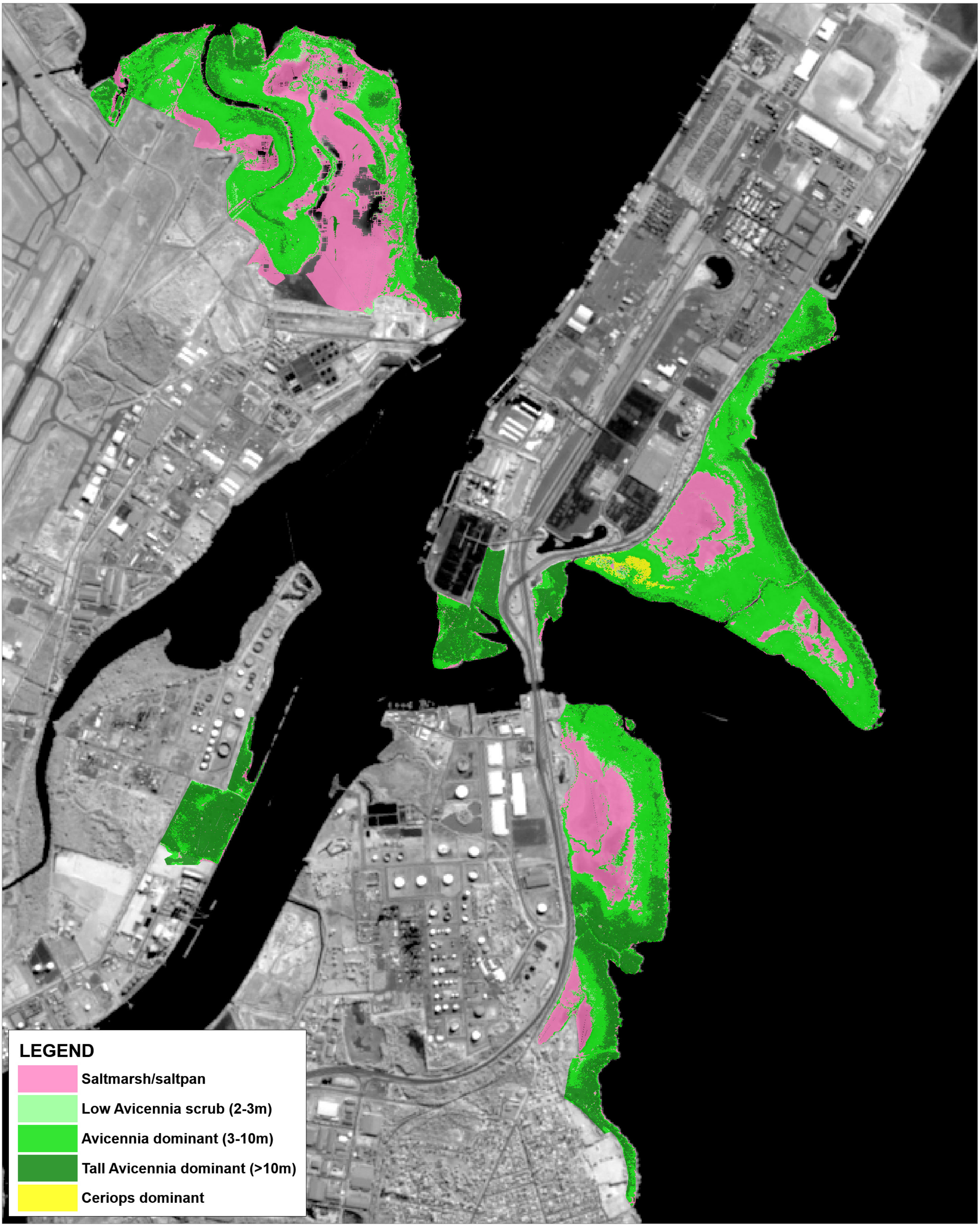
Appendix A Community Reporting Areas



Title:

Mangrove communities at test locations

Figure: A-1

Rev: A

N

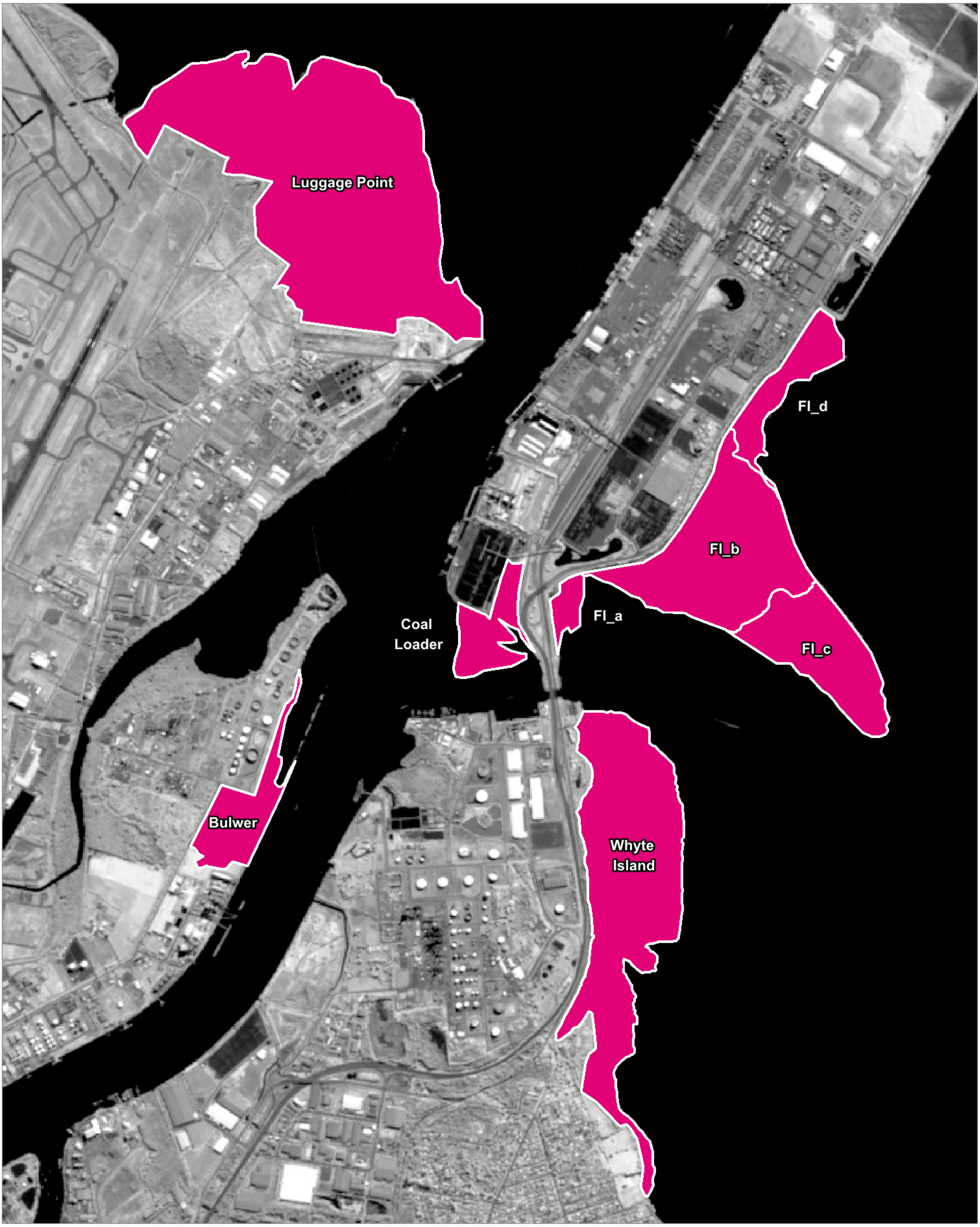
0 0.5 1km

Approx. scale

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2020_Mangroves\ECO_010_190910_Communities



Title:

Reporting boundaries for mangrove community vegetation indices

Figure: A-2

Rev: A

N

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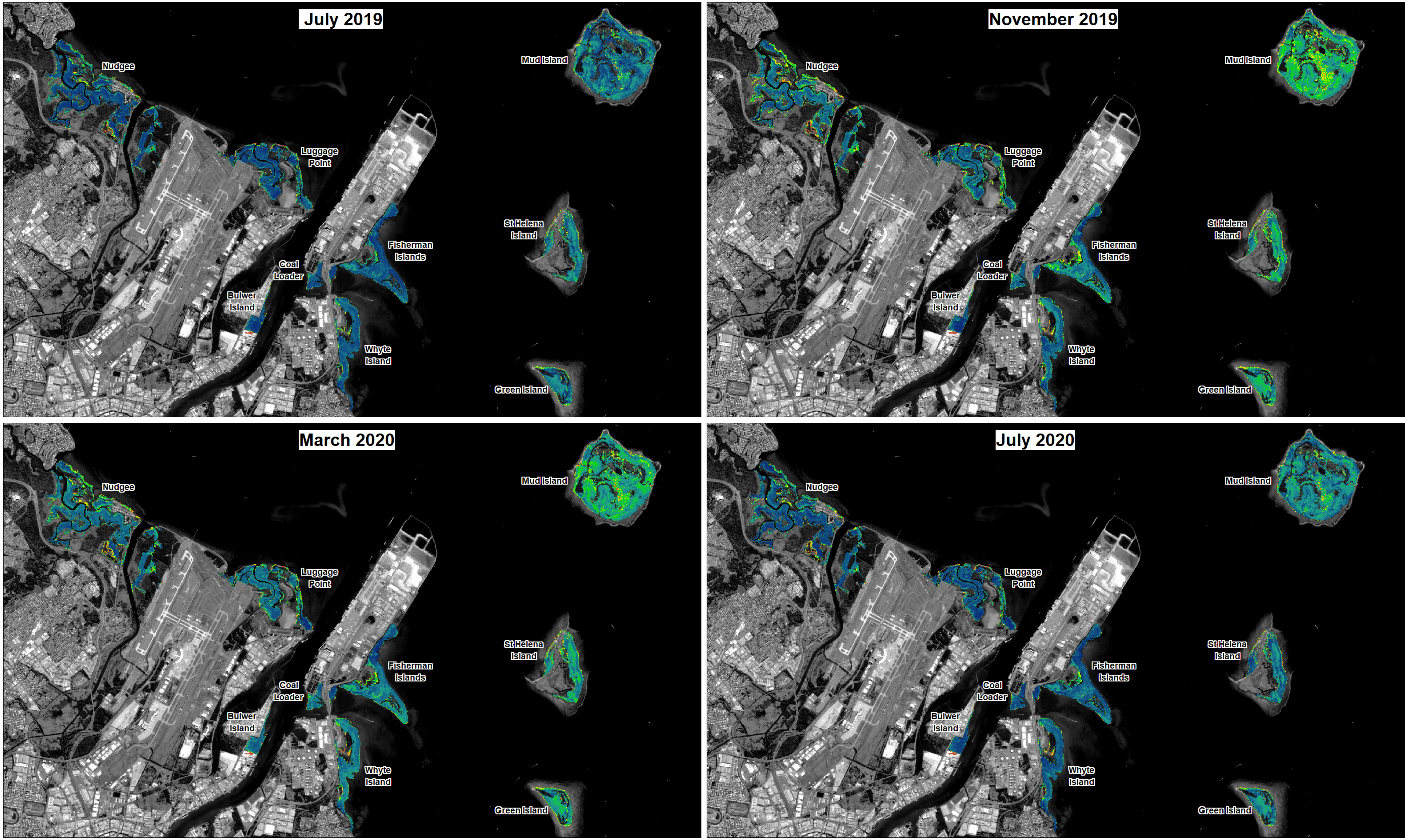
Approx. scale

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2020_Mangroves\ECO_009_190909_Comm_extents.WOR

Appendix B SAVI and LAI Maps



LEGEND

SAVI Score

-1.5 0 1.5

Title:

SAVI at investigation sites in July 2019, November 2019, March 2020, and July 2020

Figure: **B-1**

Rev: **A**

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

N

0 2.5 5km

Approx. Scale

BMT

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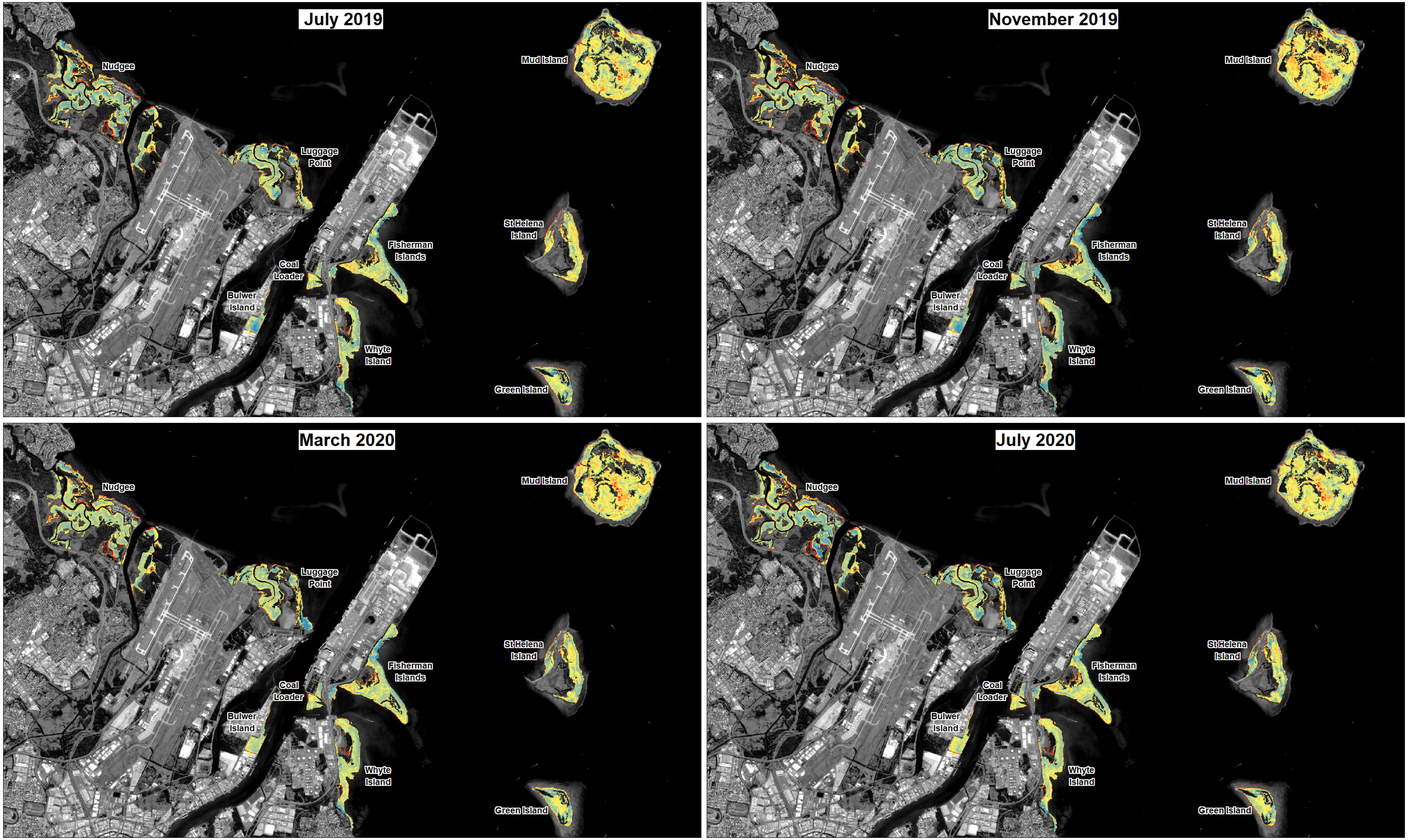

LEGEND

LAI Score

0 — 1.75 — 3.5

Title:

LAI at investigation sites in July 2019, November 2019, March 2020, and July 2020

Figure: B-2

Rev: A

N

0 2.5 5km

Approx. Scale

BMT

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Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2020_Mangroves\ECO_002_200717_LAI_4plot.WOR

Appendix C Aerial Imagery Validation

Title:

Changes in mangrove health between 2019 and 2020 on Nearmap Imagery

Figure: C-1

Rev: A

N

0 2 4km

Approx. scale

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\Mangroves_2020\ECO_012_201126_Nearmap_map.WOR

Figure C-2 Aerial imagery of Fisherman Islands July 2019 and July 2020. Bank erosion causing tree loss (A, B); tree death at the tip of Fisherman Island (C, D); tree death on the eastern fringe (E, F); and tree death in the middle of Fisherman Island (G, H).

Figure C-3 Tree death at Bulwer Island (I, J, K, L); inland tree death at Whyte Islands (M, N, O, P); and inland mangrove death at Nudgee (Q, R).

Appendix D Vegetation Health Per Community Type

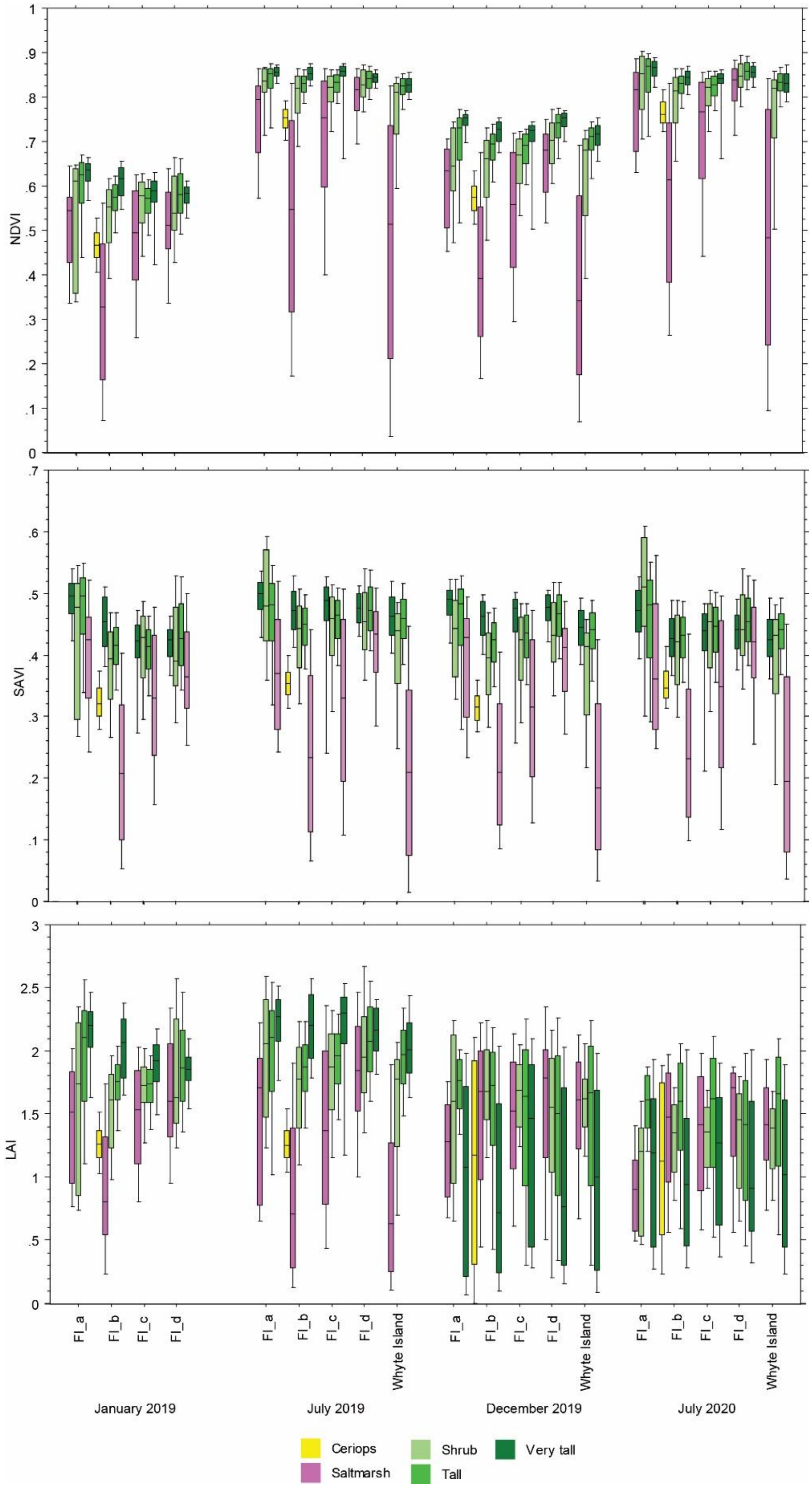

Figure D-1 Vegetation Indices Per Community Type at Fisherman Islands and Whyte Island

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