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Port of Brisbane Mangrove Monitoring

2025 Annual Report

Final

* Chern'ee Sutton Indigenous artist

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Executive Summary

Introduction and Assessment Approach

Extensive mangrove forests and associated intertidal communities occur in the lower Brisbane River and western Moreton Bay. Because these mangrove systems occur adjacent to port infrastructure, shipping channels and reclaimed land, Port of Brisbane Pty Ltd (PBPL) maintains a long-running Mangrove Monitoring Program (MMP) to track mangrove condition, extent and change through time. The program provides an evidence-based framework to distinguish natural variability and climate-driven change from any potential port-related impacts.

The 2025 assessment continues this program, integrating long-term (1988–2025), medium-term (2016–2025) and short-term (2024–2025) analyses to provide a comprehensive evaluation of mangrove condition across port-adjacent and regional background sites.

Key Findings

Overall Mangrove Condition

The 2025 assessment showed that mangrove ecosystems surrounding the Port of Brisbane remained stable and resilient. Across all monitored sites, mangrove canopy condition was comparable to, and often slightly higher than the regional background sites. No evidence of broad-scale mangrove decline associated with current port operations was identified.

Long-term analyses showed that canopy greenness had remained within expected background ranges since the late 1980s, with no progressive downward trends. Interior mangrove forests across all sites consistently exhibited high and stable vegetation greenness, low year-to-year variability and rapid recovery following short dry periods, confirming long-term structural stability.

Spatial Patterns of Mangrove Change

Spatial patterns of mangrove condition were consistent across time and sites. Areas of reduced canopy condition and lower heights were limited in extent and occur predominantly along exposed, erosion-prone shorelines and other hydrodynamically active margins, including southwestern shoreline of Fisherman Islands and parts of Coal Loader and Whyte Island. In contrast, protected and accreting shoreline such as eastern Fisherman Islands supported taller, denser and more continuous mangrove canopies, often with evidence of active regeneration.

Short-term changes observed between 2024 and 2025 were minor and spatially restricted. Where canopy greenness decreased or increased slightly, these changes occurred in locations that have already shown similar patterns through medium- and long-term analyses.

Upper Intertidal and Transitional Zones

The upper-intertidal ecotone, where mangroves transition into saltmarsh and claypan communities, remained the most naturally variable part of the system. Observed changes in this zone reflect rainfall cycles, micro-topography, drainage constraints and episodic recruitment. These fluctuations were consistent with known ecological dynamics across the Port of Brisbane region and do not indicate new or emerging impacts.

Influence of Port Activities

Across long-term, medium-term and short-term analyses, no evidence of broad-scale mangrove decline attributable to current port operations was identified. Areas of reduced canopy greenness were spatially consistent through time, were aligned with natural geomorphic and hydrodynamic processes, and also occurred at regional background sites. Where changes were observed adjacent to port infrastructure, they were highly localised and confined to physically constrained shoreline settings.

Ongoing Monitoring

Overall, the 2025 assessment shows that mangrove ecosystems within the PBPL monitoring area remain structurally robust and ecologically resilient. Geomorphic exposure, hydrology and long-term ecological succession continue to shape canopy condition and patterns of change. Given that eroding and hydrodynamically exposed shorelines consistently show the strongest sensitivity to disturbance, ongoing monitoring should continue to incorporate targeted ground-truthing in these edge environments to detect early signs of change. Monitoring should also continue to account for the natural year-to-year variability within upper-intertidal zones, interpreting shifts in the mangrove saltmarsh ecotone in the context of rainfall patterns, salinity dynamics and recruitment cycles. Based on the spatial patterns observed in 2025, there may also be value in examining whether flooding events correspond with notable changes to shoreline patterns and edge-mangrove condition. Incorporating these into future monitoring interpretation will help distinguish natural geomorphic and climatic variability from potential anthropogenic influences.

Contents

1 Introduction

1.1 Background

To support effective management of these environments, PBPL has maintained a long-running Mangrove Monitoring Program (MMP). The program provides a consistent, evidence-based record of mangrove condition, structure and extent, enabling natural variability and climate-driven change to be distinguished from potential localised effects associated with port development and operations. Continuity in methods and spatial coverage has allowed trends to be assessed with increasing confidence over time.

The MMP has operated for several decades and has generated one of the most comprehensive long-term mangrove datasets in the region (WBM, 1992; BMT WBM, 2016; BMT, 2017–2024). Previous assessments show that mangrove condition in the Port of Brisbane region is primarily influenced by climatic variability—particularly rainfall and large-scale climate oscillations such as the El Niño–Southern Oscillation (ENSO)—together with hydrological and geomorphic processes that control shoreline position, exposure and sediment dynamics (BMT WBM, 2016; Saintilan *et al.*, 2022; BMT, 2024). These drivers operate at different spatial and temporal scales, producing heterogeneous patterns of stability, recovery and decline across the landscape.

Previous assessments indicate that persistent long-term change is most evident along exposed or erosion-prone shorelines, while interior mangrove forests primarily exhibit short- to medium-term variability linked to climate and hydrological conditions. An important question for long-running monitoring programs is how best to interpret short-term change within this context. Short-term fluctuations in canopy condition may reflect transient climatic effects, local disturbance or early stages of recovery, rather than meaningful long-term decline. A key focus of the MMP is therefore whether short-term changes in mangrove condition occur in locations that exhibit persistent medium- and long-term trends. If such spatial consistency exists, long-term datasets provide not only historical context but a reliable framework for interpreting contemporary observations and anticipating where future change is most likely to occur.

1.2 Scope of the 2025 Assessment

For the first time in the MMP, the 2025 assessment integrates long-term (1988–2025), medium-term (2016–2025) and short-term (2024–2025) analyses within a single, spatially explicit framework. It quantifies long-term trends in mangrove canopy condition, evaluates medium-term canopy trajectories, and assesses whether short-term canopy changes align with areas identified as sensitive or persistent through longer-term analyses.

Shoreline dynamics, including erosion, accretion and shoreline migration, are assessed alongside canopy condition to provide geomorphic context for observed patterns in mangrove extent and health. Fine-scale mapping of vegetation extent and structure, including canopy height, is incorporated to support interpretation of spatial variability and to distinguish structural differences from changes in canopy vigour.

Together, these analyses test whether long-term spatial patterns can be used to anticipate where short- and medium-term mangrove change is most likely to occur, and provide a robust basis for interpreting observed changes within a dynamic estuarine environment influenced by both natural processes and long-standing human modification.

1.3 Aims and Objectives

The aim of the 2025 assessment was to evaluate mangrove condition, extent, structural characteristics, and shoreline dynamics across the PBPL operational area, and to characterise temporal patterns in mangrove health and dieback within a broader environmental and climatic context.

The objectives were to:

- Characterise long-term (1988–2025) spatial and temporal trends in mangrove canopy condition, and identify areas of persistent stability or exposure relative to regional background conditions.
- Assess medium-term (2016–2025) canopy trajectories (stable, recovering and non-recovered) and evaluate their spatial consistency with long-term trends.
- Evaluate short-term canopy change (2024–2025) and determine whether observed changes occur in locations identified as sensitive or persistent through longer-term analyses.
- Analyse shoreline dynamics (erosion, accretion and migration) to explain persistent long-term canopy loss and limited recovery along exposed mangrove margins.
- Map fine-scale vegetation extent and structure, including canopy height, to support interpretation of condition patterns.
- Integrate long-, medium- and short-term analyses to test whether long-term trends can be used to anticipate where mangrove change is most likely to occur.

2 Methods

This assessment integrated multi-scale, multi-sensor remote-sensing analyses with biennial ground-truthing surveys to evaluate the extent, drivers, and recovery of mangrove dieback across the study area.

The assessment comprised the following:

- Long term mangrove condition and shoreline change analysis using Landsat imagery, comprising:
  - A multi decadal assessment of mangrove canopy condition using Landsat derived NDVI time series (1988 to 2025), and
  - A long-term shoreline change assessment based on Landsat derived DEA Coastlines to quantify patterns of erosion and accretion and support interpretation of mangrove change.
- Medium-term mangrove dieback analysis using Sentinel-2 normalized difference vegetation index (NDVI) time-series data (2016 to 2025).
- Short-term mangrove condition assessment (July 2024 to 2025), including Sentinel-2 NDVI change detection, biennial field-based validation.
- Fine-scale vegetation structural mapping using WorldView-3 imagery and LiDAR-derived canopy height data.

Further details of the methodology are provided in the sections below.

2.1 Study Area

The study area comprised nine sites across the lower Brisbane River and western Moreton Bay (Figure 2.1) including:

- Control (background) sites – Nudgee Wetlands, Luggage Point, Green Island, St Helena Island and Mud Island
- Test (port-adjacent) sites – Bulwer Island, Pelican Banks (referred to as Coal Loader in this assessment), Fisherman Islands and Whyte Island.

Test sites were selected due to their proximity to PBPL infrastructure, while control sites outside the port's zone of influence provided regional context. Mangrove extent was defined using Queensland Herbarium and Biodiversity Science dataset (2022)[1], derived from 2021 mapping.

Although Luggage Point has been included as a test site in earlier monitoring programs, access constraints have historically limited the extent of ground-truthing that could be undertaken across the site. While remote-sensing analyses provided valuable insight into mangrove condition, the absence of consistent, site-wide field validation restricted the ability to fully integrate ground-based observations with remotely derived patterns. In the current assessment, and given its limited exposure to contemporary PBPL operations, Luggage Point has therefore been reclassified as a background site.

[1] An interactive map viewer that visualises changes in the extent of mangroves and associated communities in Moreton Bay can be seen here.

2.2 Long Term Analysis (1988—2025)

2.2.1 Mangrove Condition

Long-term mangrove canopy condition was assessed using medium-resolution Landsat imagery (30 m) spanning July 1988 to July 2025 (Geoscience Australia 2021), providing a consistent multi-decadal record of vegetation health across all test and background sites.

Mangrove condition was quantified using NDVI, a widely applied indicator of live green vegetation that reflects canopy vigour and density. (NDVI values range from −1 to 1, with higher values indicating denser and/or healthier vegetation). NDVI for each pixel was calculated using the standard formula (Rouse *et al.*, 1974):

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

where NIR is the near-infrared and Red is the red band.

NDVI values were calculated for each available July image and extracted for all mapped mangrove areas within each site boundary to generate site level NDVI time series.

To define background variability, NDVI values from all control sites were pooled into a single reference dataset, from which the 5th and 95th percentile bounds were calculated to represent the expected range of long-term variability under relatively undisturbed conditions. NDVI time series for each test site were then compared against this control envelope, enabling objective identification of periods where mangrove canopy condition at test sites diverged from long-term background behaviour.

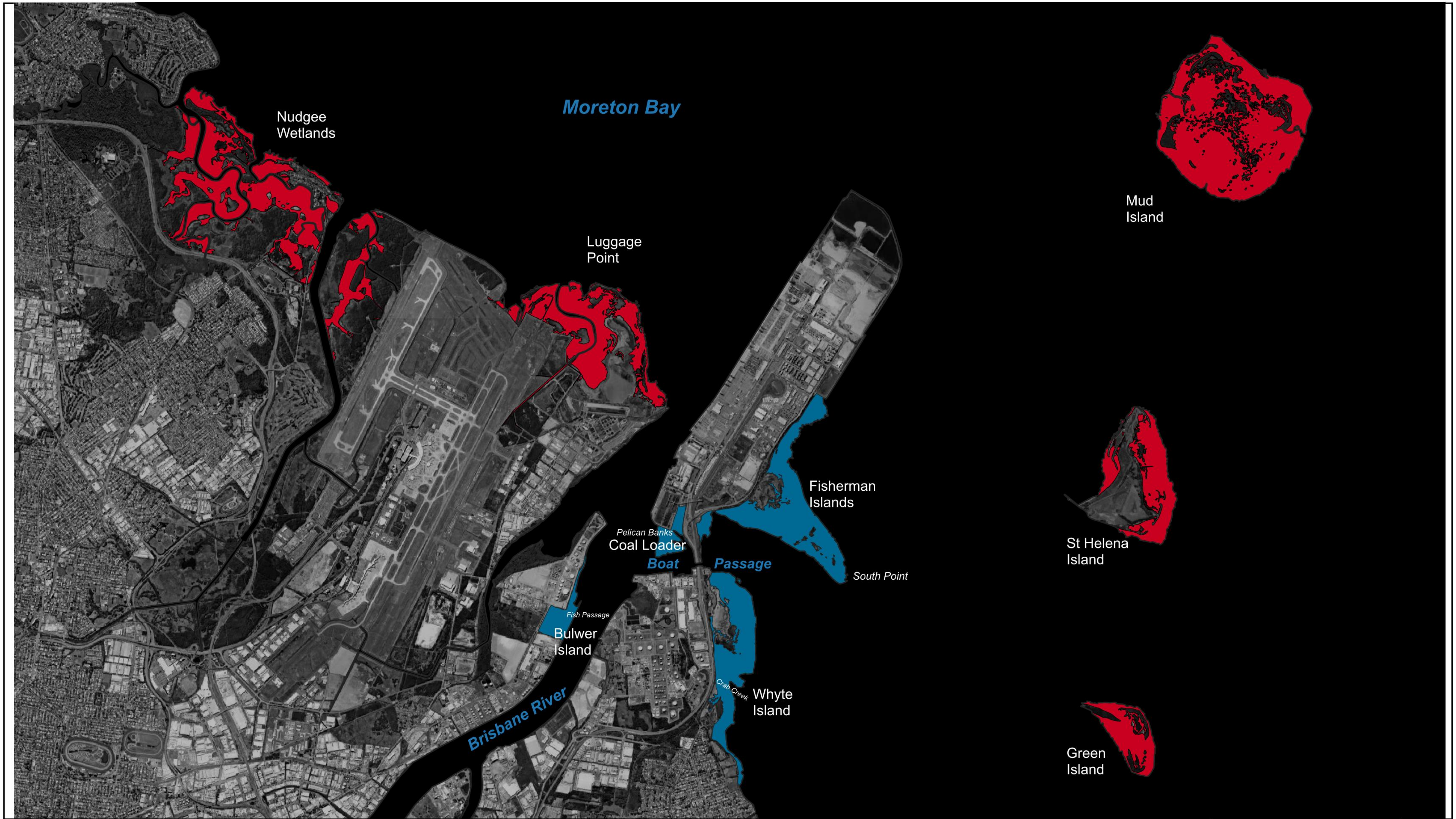
2.2.2 Shoreline Change

Long-term shoreline change statistics were computed for 1988–2024 (latest available) using the DEA Coastlines annual shoreline dataset from the Digital Atlas of Australia. This dataset was derived from medium-resolution (30 m) Landsat imagery and provided a consistent multi-decadal record of shoreline position. The dataset was inputted into a Shoreline Change Analysis Tool to generate the following commonly used shoreline statistics:

- **Net Shoreline Movement (NSM)** – NSM represented the magnitude of shoreline change (in metres) between the oldest (1988) and recent (2024) mapped shorelines. It was calculated as the difference between the shoreline position in the oldest year and the shoreline position in the most recent year. Positive values indicated accretion, while negative values indicated erosion.

- **Linear Regression Rate (LRR)** – LRR represented the rate of shoreline change based on a linear regression fitted across all available shoreline positions. This metric was considered more robust for multiple shoreline observations because it incorporated the full temporal record rather than relying solely on endpoints. LRR was calculated from the slope of a least-squares regression line fitted to all shoreline–transect intersection points. Negative values represented erosion, and positive values represented accretion.

The analysis tool used a workflow similar to the Digital Shoreline Analysis System (DSAS), creating a baseline shoreline from which a series of perpendicular transects were cast. Due to the complexity of the coastlines surrounding the test sites, transects with a length of 300 m and spacing of 5 m were selected. The intersections between these transects and the annual DEA Coastlines positions were then used to calculate the shoreline statistics. Finally, seven representative transects were selected across the test sites to present a detailed year-by-year time-series showing changes in shoreline position.



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- Control (background) sites
- Test (port-adjacent) sites

Title:

Study Area

Figure: **2.1**

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2.3 Medium-Term Analysis (2016-2025)

Mangrove canopy condition was assessed using high-resolution Sentinel-2 multispectral imagery (10 m) covering the period from July 2016 to July 2025 (Geoscience Australia, 2022). NDVI was used as the primary indicator of canopy health. To generate a consistent medium-term dataset suitable for tracking mangrove canopy change, 109 monthly NDVI composites were produced for the nine-year period. All images met an 80 % cloud-free threshold for each site.

2.3.1 Classification of Canopy Condition

Thresholds and statistical rules were then applied to classify each location into one of three canopy-condition trajectories:

- **Stable Condition** – Areas were assigned to the stable category when monthly NDVI values consistently remained above 0.4 for the entire 9-year period, indicating no detectable canopy decline.
- **Recovering Condition** – Recovery was evaluated by comparing the NDVI of the most recent month with the long-term mean NDVI calculated across all 109 months. Recovery was defined where the most recent NDVI value exceeded the long-term mean by more than two standard deviations (mean + 2σ). This threshold represents the NDVI level required for confirmed, statistically significant canopy recovery.
- **Non-Recovered Condition** – Areas were classified as non-recovered when their current NDVI values remained below the recovery threshold (mean + 2σ), indicating that the canopy had not re-established healthy condition by July 2025. To ensure this category captured true lapse-in-recovery rather than long-term degraded areas, only locations that had at least once exceeded the recovery threshold during the monitoring period were included. These areas therefore represent mangroves that showed evidence of improvement but subsequently declined again.

For non-recovered areas, an additional ranking procedure was applied to quantify the severity of non-recovery. The current NDVI value at each location was compared against the recovery benchmark (mean + 2 standard deviations). The difference between the observed NDVI and this benchmark was calculated, with larger deficits indicating more severe non-recovery. The 15 locations with the largest deficits were identified as the most severely affected.

2.4 Short-Term Analysis (July 2024—July 2025)

2.3.1 Canopy Condition (Change Detection)

Short-term canopy change was assessed using Change Vector Analysis (CVA) applied to high-resolution Sentinel-2 imagery (10 m) covering the period from July 2024 and July 2025. CVA was used to quantify the magnitude and direction of spectral change by comparing NDVI values between the two dates. Through this approach, significant shifts in canopy condition such as stress, disturbance, or early recovery could be detected and mapped. This analysis provided a sensitive measure of short-term canopy dynamics that may not yet be evident through changes in mapped extent.

2.3.2 Field Surveys

Field surveys was conducted to verify and support the short-term canopy change results derived from CVA. Based on the NDVI patterns and boundaries identified in the satellite analysis, targeted ground-truthing surveys were carried out on 13–14 October 2025 at the test sites. A differential Garmin GPS unit (horizontal accuracy ±1 m) was used to record field points within each site. At each site, qualitative observations were collected to validate mapped changes, including:

- Dominant mangrove species present
- Evidence of canopy loss, canopy gain, or active revegetation
- Influencing or impacting processes, including bank erosion, litter or debris accumulation, altered surface drainage, sediment characteristics and presence and extent of macroalgae or macroalgal mats

These field observations were used to confirm canopy-change signals detected in the satellite data.

2.3.3 Vegetation Structure and Extent Mapping

Fine-scale vegetation structure and extent were mapped using very high-resolution (VHR) WorldView-3 multispectral imagery acquired on 10 July 2025, which was pre-processed (e.g., atmospherically corrected) and resampled to a 50 cm spatial resolution. An initial multispectral classification was undertaken to delineate broad coastal habitat classes, including mangrove, saltmarsh/saltpan, claypan (including ponding water).

A two-stage classification workflow was applied to refine vegetation extent:

- **Stage 1 CNN-Based Classification** – A Convolutional Neural Network (CNN) was trained using hundreds of expert-labelled samples derived from the WorldView-3 imagery. to distinguish mangrove vegetation from other coastal land-cover types. Standard data augmentation techniques were applied to improve model robustness
- **Stage 2 GEOBIA Object-Based Refinement** – The CNN outputs were incorporated into a Geographic Object-Based Image Analysis (GEOBIA) approach, in which pixels were segmented into objects and rule-based contextual refinement was applied to reduce noise and improve spatial coherence. Ground-truthing points collected during field surveys were used to support refinement and interpretation of mapped classes.

Mapped vegetation areas were further refined using a a normalised Digital Surface Model (nDSM) to incorporate vertical vegetation structure. The nDSM was derived by subtracting a bare-earth Digital Elevation Model (DEM) from a Digital Surface Model (DSM), providing a canopy height-above-ground surface. Canopy height information was used to differentiate structurally distinct mangrove communities that could not be reliably separated using spectral data alone.

Vegetation Classification

Vegetation classes were defined using canopy-height thresholds, ecological characteristics consistent with previous MMP assessments at test sites (BMT 2021; BMT 2020) and established descriptions of northern Australian mangrove assemblages (AIMS 1993; Duke 2006; NVIS 2023; DES 2019). These include:

1. ***Avicennia marina* (grey mangrove) dominated closed to open forest, >10 m canopy height** – Tall, well-developed Avicennia marina stands forming closed to open forest with canopy heights exceeding 10 m. These forests typically occur in mid- to upper-intertidal settings and commonly co-occur with other widespread mangrove species, including *Aegiceras corniculatum, Ceriops australis, Rhizophora stylosa* and *Bruguiera gymnorhiza*.

2. ***Avicennia marina* dominated closed to open forest, 2–10 m canopy height** – Medium-height *A. marina* stands (2–10 m) forming closed to open forest across a range of intertidal settings. These communities often represent younger or more environmentally constrained variants of taller *Avicennia* forests and commonly occur in mixed assemblages with *A. corniculatum*, *C. australis*, *R. stylosa* and *B. gymnorhiza*. Canopy structure is more variable, with patchier cover and greater height heterogeneity.

3. ***Avicennia marina* +/- *Ceriops australis* (yellow mangrove) community** – Mangrove communities comprising a mosaic of *A. marina*, often with *C. australis*, typically forming lower, more uniform canopies. *C. australis* is commonly associated with mid- to upper-intertidal flats and more saline substrates, where it forms even-aged stands. These communities have lower canopy heights, more compact crown structure, and reduced species mixing compared to taller *Avicennia* forests.

4. **Saltmarsh/saltpan community –** Upper-intertidal areas comprising a mosaic of saltmarsh and saltpan vegetation. Due to their fine-scale intermixing and transitional boundaries, these environments were mapped as a combined community to provide a consistent representation of upper-intertidal habitat extent.

5. **Claypan (including ponding water)** – Clay-rich, low-lying intertidal areas that are poorly drained and commonly exhibit surface ponding following rainfall or high-tide inundation.

2.5 Limitations

All analyses were subject to limitations associated with image resolution, cloud and haze, threshold selection and shoreline-mapping generalisation. NDVI thresholds were selected based on previous MMP assessments and ground-truth observations but inevitably simplify the continuous spectrum of canopy condition. DEA Coastlines products derive from 30 m Landsat imagery and may smooth fine-scale shoreline features; the 300 m transect length and 5 m spacing were chosen to balance shoreline complexity and computational efficiency. These constraints were considered when interpreting spatial and temporal patterns, particularly at sharp ecotones and narrow shoreline features.

3 Results

3.1 Long-Term Mangrove Condition

3.1.1 Bulwer Island

The NDVI time –series graph (Figure 3.1) for the Bulwer Island shows a gradual increase in canopy greenness from 1988 to 2025. Throughout the record, Bulwer Island NDVI values generally remained slightly higher than the aggregated control means, with a long-term mean of approximately 0.72 compared with ~0.69 for the controls. Most annual NDVI values for Bulwer Island fell within the 5th–95th percentile control envelope, with short-lived excursions below the lower bound in the early 1990s and around 2007–2008, and brief excursions towards the upper bound between approximately 2010 and 2015 and after 2019.

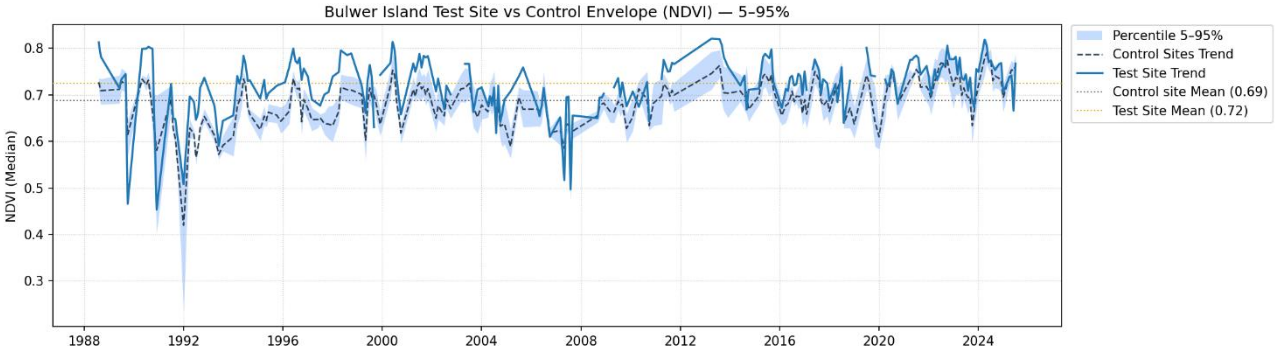

Figure 3.1 Bulwer Island Test Site vs Control Sites Envelope (NDVI) – 5-95 % Percentile

Overall, Bulwer Island NDVI values follow an increasing trend through time, with most values within the control envelope and intermittent departures below the lower envelope (early 1990s; ~2007–2008) and near/above the upper envelope (post-2010).

3.1.2 Coal Loader

The NDVI trend for Coal Loader (Figure 3.2) shows relatively stable canopy greenness from 1988 to 2025. Annual NDVI values generally remained within the 5th–95th percentile control envelope, with a long-term mean comparable to the control mean. Short periods of reduced NDVI occurred intermittently in the early 1990s and during the 2007–2008 interval, after which values returned to within the typical range. A more pronounced uplift occurs after 2010, with NDVI values frequently reaching the upper portion of the envelope, especially between 2011 and 2014.

In the period from 2016 onward, Coal Loader exhibits relatively stable NDVI behaviour, maintaining values consistently within or near the upper half of the control range, though still showing year-to-year variability. Overall, Coal Loader NDVI values are predominantly within the control envelope, with early-period departures below the lower envelope and more frequent values near the upper envelope after ~2010.

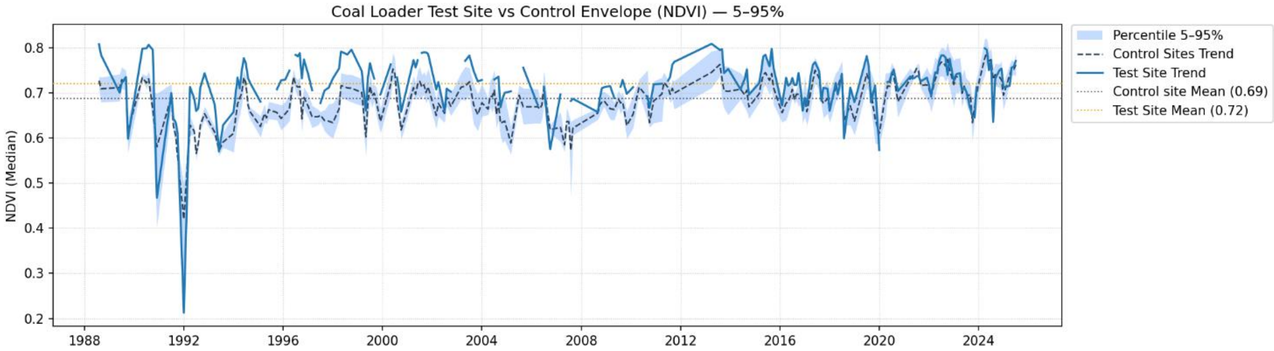

Figure 3.2 Coal Loader Test Site vs Control Sites Envelope (NDVI) – 5-95 % Percentile

3.1.3 Fisherman Islands

The NDVI record for Fisherman Islands (Figure 3.3) indicates a gradual increase in canopy greenness from 1988 to 2025, with annual NDVI values generally falling within the 5th–95th percentile control envelope.

In the early 1990s Fisherman Islands NDVI show sharp dips below the lower percentile boundary. These anomalies were followed by a sustained period of stability through the late 1990s and early 2000s, during which NDVI fluctuates around the control mean without prolonged departures. After 2010, Fisherman Islands exhibits a more pronounced uplift, with NDVI frequently aligning with the upper half of the control envelope and occasionally touching its upper boundary particularly around 2012–2014 and again in the early 2020s.

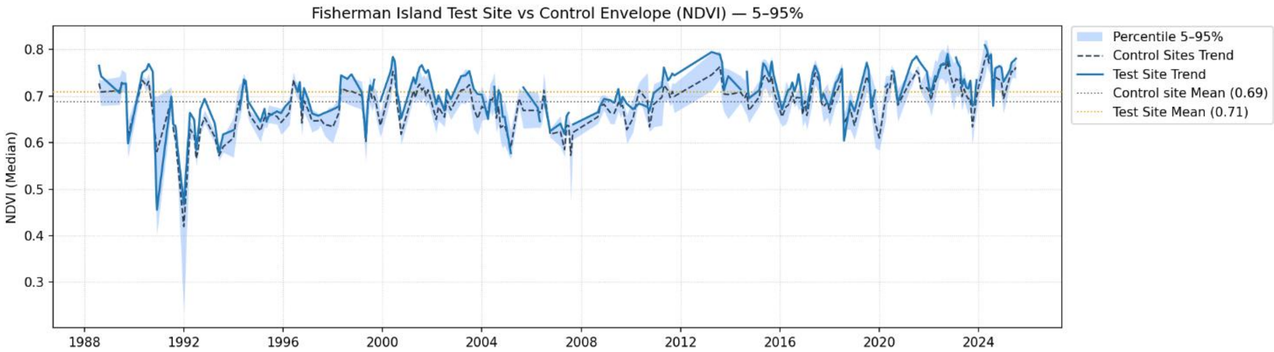

Figure 3.3 Fisherman Islands Test Site vs Control Sites Envelope (NDVI) – 5-95 % Percentile

3.1.4 Whyte Island

The NDVI trend for the Whyte Island (Figure 3.4) displays moderate interannual variability between 1988 and 2025, with most NDVI values remaining within the 5th–95th percentile control envelope. Pronounced negative anomalies occur in the early 1990s, with NDVI briefly falling below the lower envelope boundary.

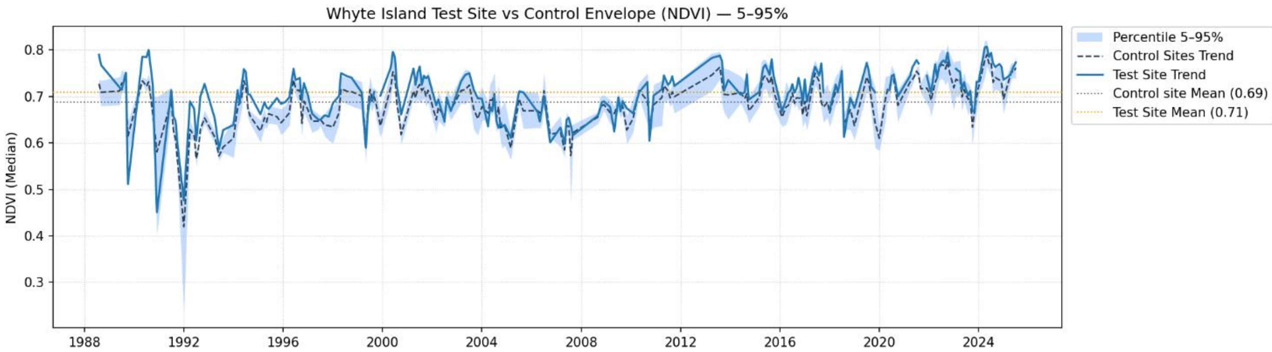

Figure 3.4 Whyte Island Test Site vs Control Sites Envelope (NDVI) – 5-95 % Percentile

Following this period, NDVI stabilises through the late 1990s and early 2000s, oscillating around the control mean without sustained deviations. After 2010, Whyte Island exhibits a clear improvement, frequently tracking the upper half of the control envelope and showing stronger greenness (higher NDVI) during the 2012–2014 period and again in the early 2020s.

3.2 Long-term Shoreline Change

The rates of shoreline change between 1988 – 2024 varied within and between sites (Figure 3.5). The highest rate of erosion (approximately 1.5 m/yr to 1 m/yr) was observed on the western coast of Fisherman Islands, while the highest rate of accretion (up to 5.5 m/yr) occurred on the eastern coast of Fisherman Islands.

At Coal Loader, the shoreline alternates between erosion and accretion, typically at a magnitude of between 0.1 m/yr and 0.5 m/yr. However, more rapid erosion was observed on the southern tip of the Coal Loader (approximately 0.5 m/yr to 1 m/yr), which transitions to accretion to the east (approx. 0.5 m/yr to 1 m/yr). Whyte Island shoreline also alternated between erosion and accretion, with erosion typically dominating the northern areas of the island, and accretion dominating the southern areas. The rates of change were typically below 0.5 m/yr. The shoreline at Bulwer Island was characterized by lower rates of chang, with the rate of change typically remaining below 0.1 m/yr. Sections of erosion occur at the northern tip of the island, as well as two inlets further south, with magnitudes reaching approximately between 0.5 m/yr and 1 m/yr.

Figure 3.6 shows the net shoreline movement (m) for the study areas from 1988 – 2024. Sites with higher erosion rates correspond to larger negative net shoreline movement values. The areas which have experienced the most erosion since 1988 include the western coast of Fisherman Islands, the south-western tip of the Coal Loader, southern tip of Whyte Island, and northern point of Bulwer Island. In these areas, the net shoreline movement is typically between 10 – 50 m. The most erosion experienced during this period was 51 m, which occurred on the western coastline of Fisherman Islands, adjacent to the Port of Brisbane Boat ramp.

The areas which have experienced the most accretion since 1988 include the eastern coastline of Fisherman Islands, the Port of Brisbane Boat ramp, and the southern and western coastlines of the Coal Loader. In these areas, the net shoreline movement is typically between 10 –100 m. The most accretion experienced during this period was 180 m, which occurred on the eastern coastline of Fisherman Islands, adjacent to Lucinda Drive. Whyte Island and Bulwer Island both experience variations in net shoreline movement along their respective coastlines, however, net shoreline movement is predominantly negative across Fisherman Islands and Coal Loader.

To provide more detailed information on the shoreline processes acting within the test sites on an annual basis, seven transects were selected for a timeseries analysis. The locations of these transects are shown in Figure 3.7. Results are presented in the following subsection.

Title:

Rate of Shoreline Change 1988 - 2024

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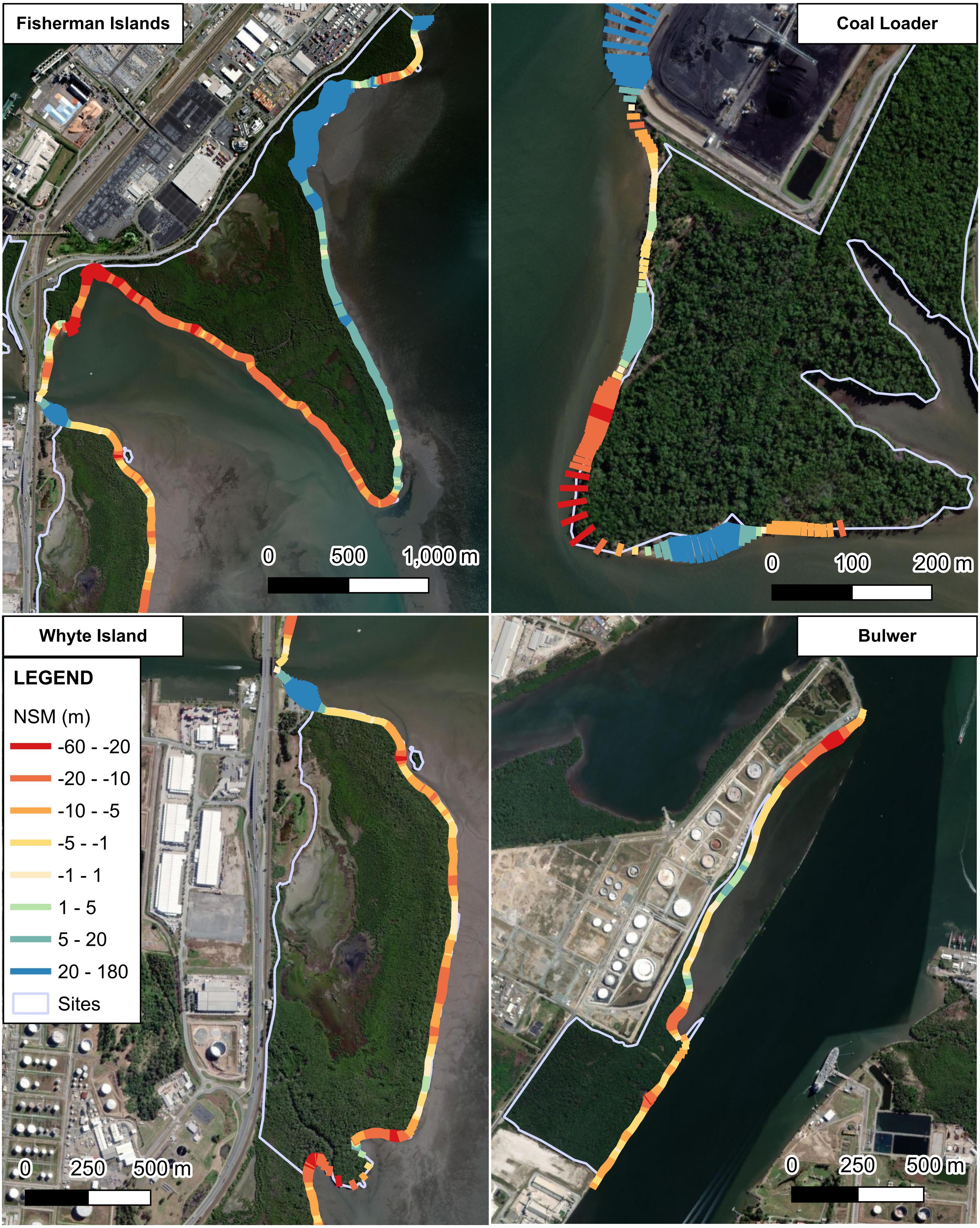

Title:
Net Shoreline Movement 1988 - 2024

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Shoreline Change Transects

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3.2.2 Shoreline Timeseries Analysis

Figure 3.8 presents the timeseries analysis for three transects along the Fisherman Islands coastline. At Fisherman Islands 1 transect (FI1), the distance from baseline has reduced over time from approximately 100 m in 1988 to 50 m in 2024. However, the timeseries shows erosion at FI1 has not been occurring at a constant rate. Between 1992 and 1995, the area experienced accretion (approx. 30 m), which was followed by a period of erosion between 1995 and 2001 (approx. 50 m). Since 2001, the shoreline has stabilised, and total erosion has not exceeded 10 m.

At Fisherman Islands 2 (FI2) transect, the distance from baseline has reduced over time from approximately 74 m in 1988 to 60 m in 2024. Similar to FP1, large amounts of accretion were experienced between 1992 and 1995. However, unlike FP1, this was not followed by a period of significant erosion. Since 1995, the shoreline has experienced alternating periods of erosion and accretion, with an overall erosion trend. At Fisherman Islands 3 (FI3) transect, the distance from baseline has increased over time from approximately 67 m in 1988 to 162 m in 2024. The rate of accretion has been largely consistent over the time period, with the exception of 1991 – 1944, which experienced more rapid accretion (approximately 45 m in four years).

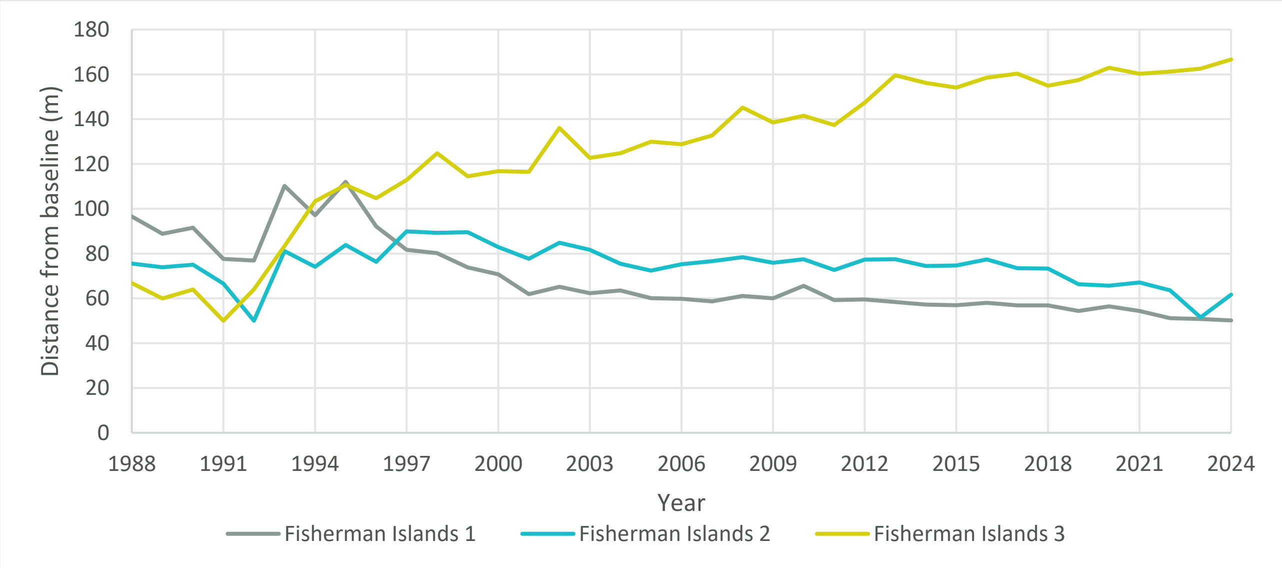


Figure 3.8 Fisherman's Island Timeseries Analysis

Figure 3.9 presents the timeseries analysis for a transect along the southern tip of the Coal Loader. The transect shows a reduction in distance from baseline over time from approximately 80 m in 1988 to 50 m in 2024. The timeseries shows the shoreline has remained dynamic over time, with alternating periods of erosion and accretion occurring since records began. However, following a period of large accretion between 1992 and 1995 (a trend also observed in FI1 and FI2), the shoreline has largely been eroding. The most rapid erosion appears to have occurred between 2019 and 2020, when the shoreline experienced 10 m of erosion in 1 year.

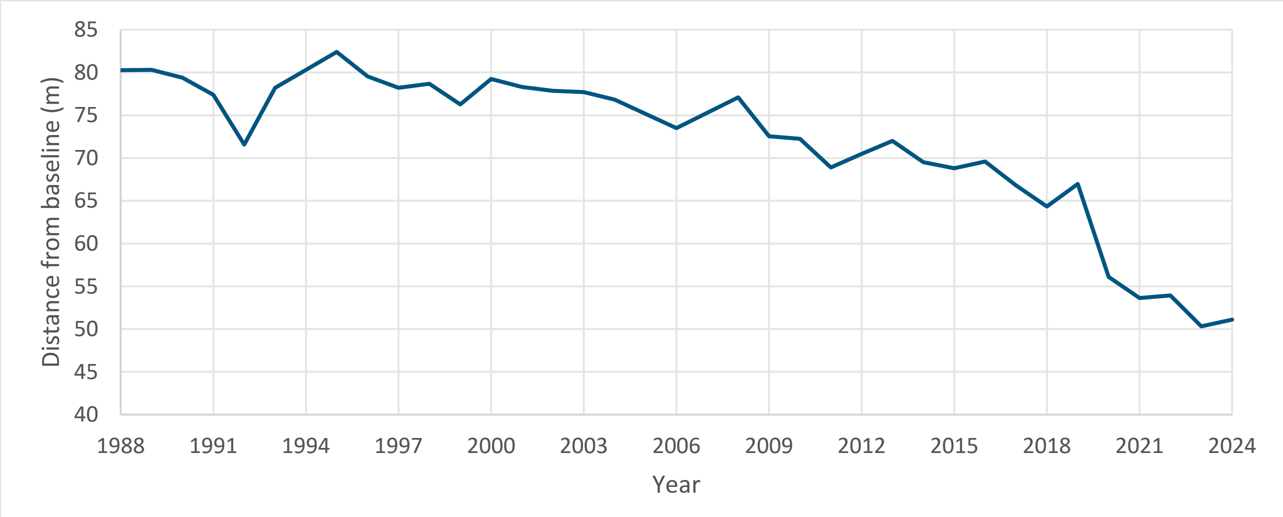


Figure 3.9 Coal Loader Timeseries Analysis

Figure 3.10 presents the timeseries analysis for two transects along the Whyte Island coastline. At Whyte Island 1 transect (WI1), two distinct trends can be observed with regards to the distance from baseline. In the four years prior to 1995, the distance from baseline increased by approximately 23 m, indicating substantial accretion. However, post 1995, there has been an eroding trend, with the distance from baseline decreasing from 80 m in 1995 to 50 m in 2024.

At Whyte Island 2 (WI2) transect, the shoreline position was more variable. Similar to other study areas, WI2 experiences accretion between 1992 and 1995, followed by an eroding trend from 1995 to 2024. Short, rapid accretion events during 1998, 2002 and 2008, in the magnitude of approximately 10 – 15 m occurred. Since 2008, the rate of shoreline erosion has increased (approximately 27 m over 16 years).

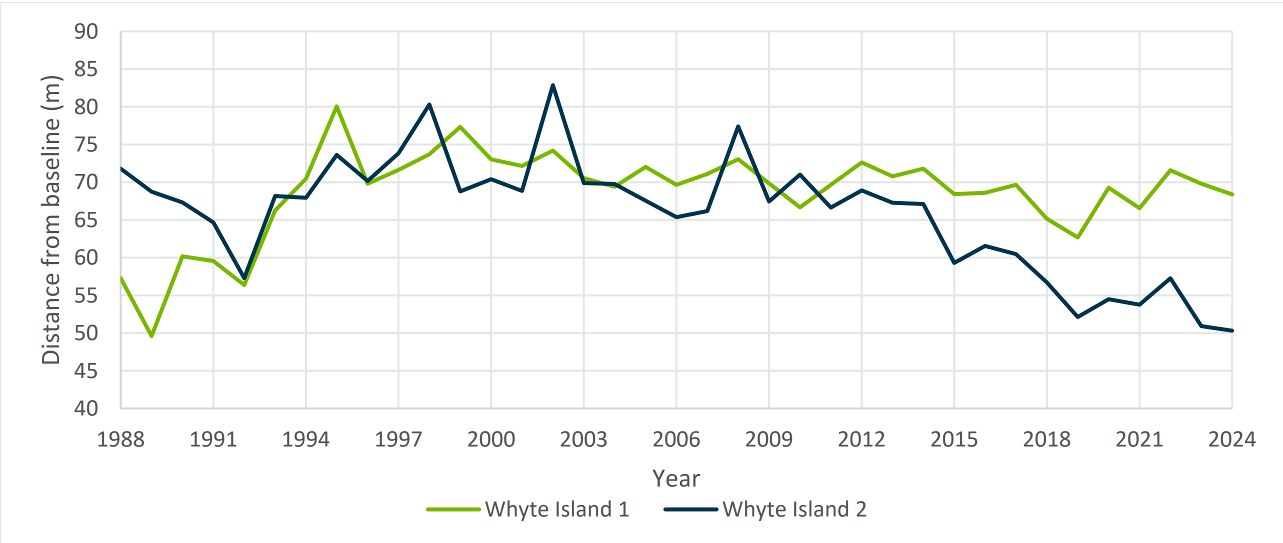


Figure 3.10 Whyte Island Timeseries Analysis

Figure 3.11 presents the timeseries analysis for a transect in the middle of the Bulwer Island coastline. The transect shows a reduction in distance from baseline over time from approximately 72 m in 1988 to 53 m in 2024. The timeseries suggests that the shoreline has remained relatively stable over time, with most of the variation occurring between 1992 and 2004. Similar to other study areas, accretion occurs between 1992 and 1995, extending to 1998 (approximately 30 m over 7 years). This is followed by significant erosion between 1998 and 2001 (approximately 25 m). Other accretion events appear to have occurred in 2002 and 2008. Since 2008, the shoreline position has remained relatively stable, with a slight eroding trend.

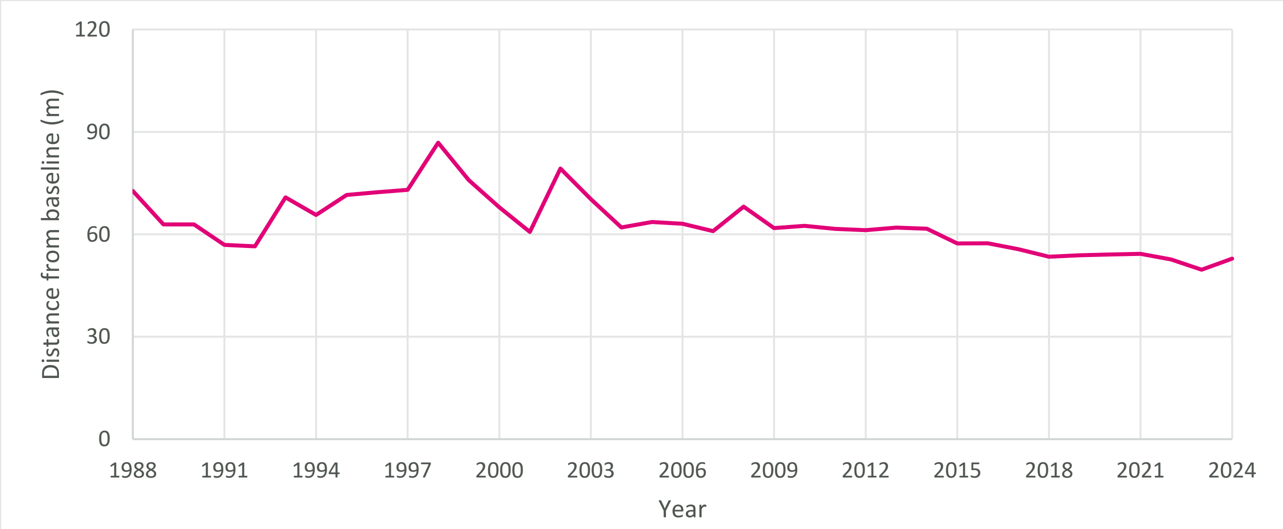


Figure 3.11 Bulwer Island Timeseries Analysis

3.3 Medium-Term Analysis

The nine-year analysis revealed three dominant canopy-condition trajectories across the test sites in relation to mangrove dieback: stable, recovering, and non-recovered. These trajectories occurred across all test sites and are described in the following sections.

3.2.1 Bulwer Island

The five month rolling median NDVI (orange line) remained stable across Bulwer Island from 2016 to 2019, with values closely following the overall site mean of ~0.71 and exhibiting only minor short-term variability (Figure 3.12). A reduction occurred in 2020–2021, after which NDVI values returned to typical levels and remained stable through to 2025.

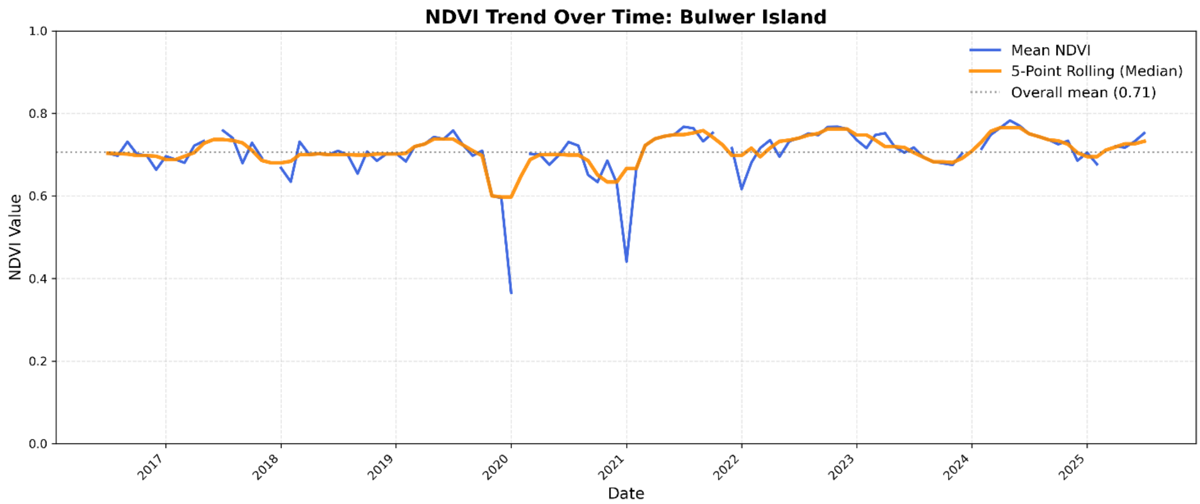


Figure 3.12 NDVI Trend for Bulwer Island (July 2016 – July 2025).

The spatial classification of mangrove canopy condition (Figure 3.13) indicates that the site was dominated by stable vegetation. Stable areas formed a continuous distribution around most of the shoreline, consistent with summary statistics (Table 3.1) indicating that 24.36 ha (96.6 %) of the total 25.23 ha mangrove extent remained above the dieback threshold (NDVI < 0.40) throughout the monitoring period.

Recovered areas occurred in small discrete patches where recent NDVI values meet or exceed the recovery benchmark of 0.56 (Table 3.1). Non-recovered areas were limited in extent and occurred in small, isolated patches corresponding to 0.87 ha (3.4 %) of the mapped mangrove extent. The 15 lowest-performing locations below the recovery threshold are identified in Figure 3.13. Detailed NDVI time-series plots for each ranked location are provided in Annex A.

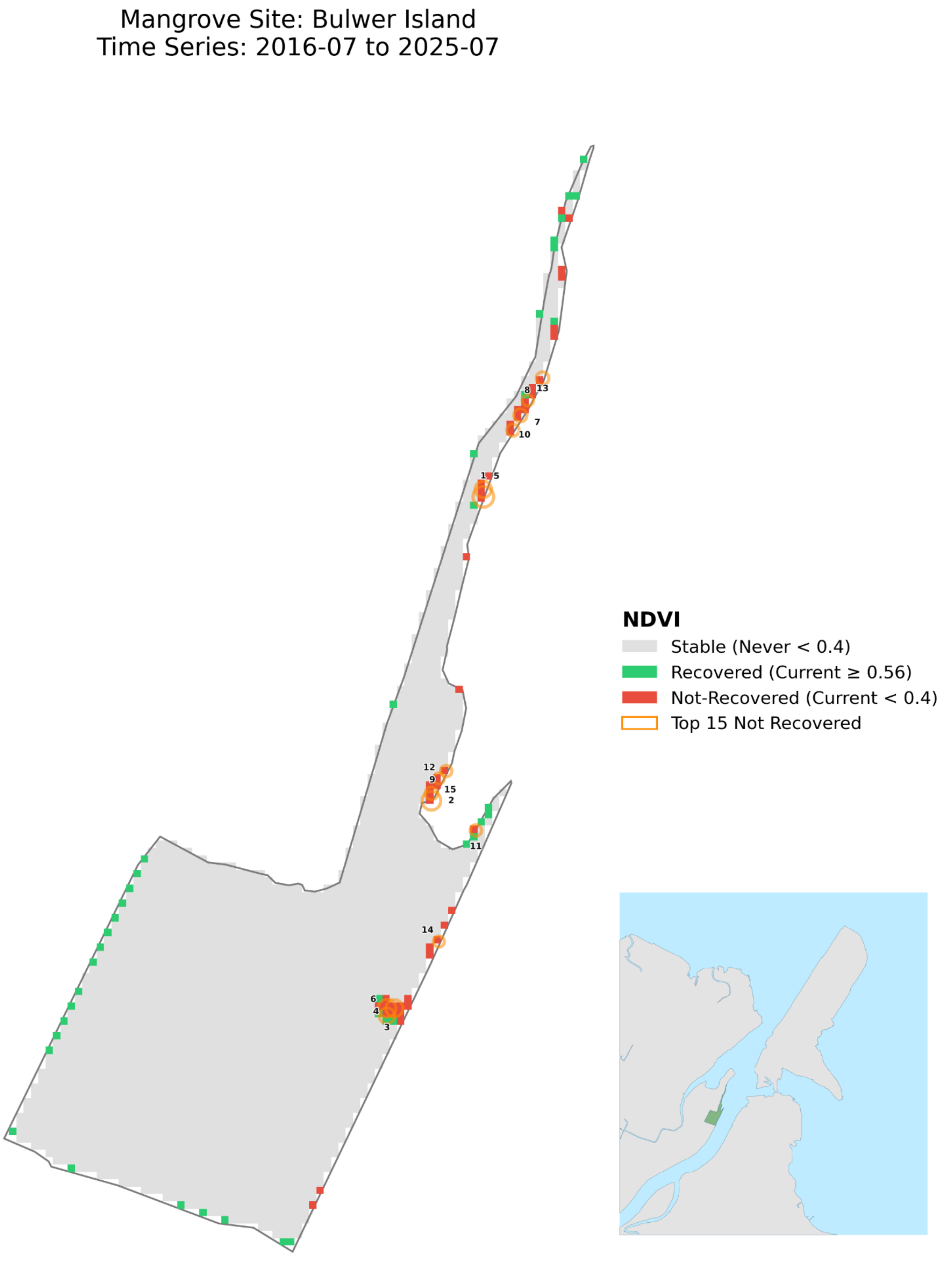


Figure 3.13 Spatial Map of Mangrove Condition Classes and Top-Ranked Non-Recovered Locations at Bulwer Island

Table 3.1 Bulwer Island – Medium-Term Mangrove Dieback Summary (Jul 2016–Jul 2025)

Category	Value	Notes
NDVI Dieback Threshold	NDVI < 0.4	Threshold used to identify areas where canopy condition has declined.
Site Baseline (NDVI < 0.4)	Mean = 0.3250 Std = 0.0817	Represents typical NDVI values observed during dieback conditions.
Recovery Threshold	NDVI >= 0.5634	Calculated as the baseline mean plus 2 standard deviations; indicates the NDVI level required for confirmed recovery.
Total Mangrove Area	25.23 ha	
Stable (Never Disturbed)	24.36 ha	96.6 % of the total mangrove area.
Disturbed (Ever Affected)	0.87 ha	3.4 % of the total mangrove area.
Significantly Recovered	0.41 ha	47.1 % of the disturbed area has improved to above the recovery threshold.
Still Below Recovery Threshold	0.46 ha	52.9 % of the disturbed area has not yet recovered.

3.2.2 Coal Loader

The 5-month rolling median NDVI (orange line) remained close to the overall site mean of ~0.70 from 2016 to 2019, with only minor short-term fluctuations (Figure 3.14). A small decline occurred around 2020, before returning to median levels from 2021 onwards

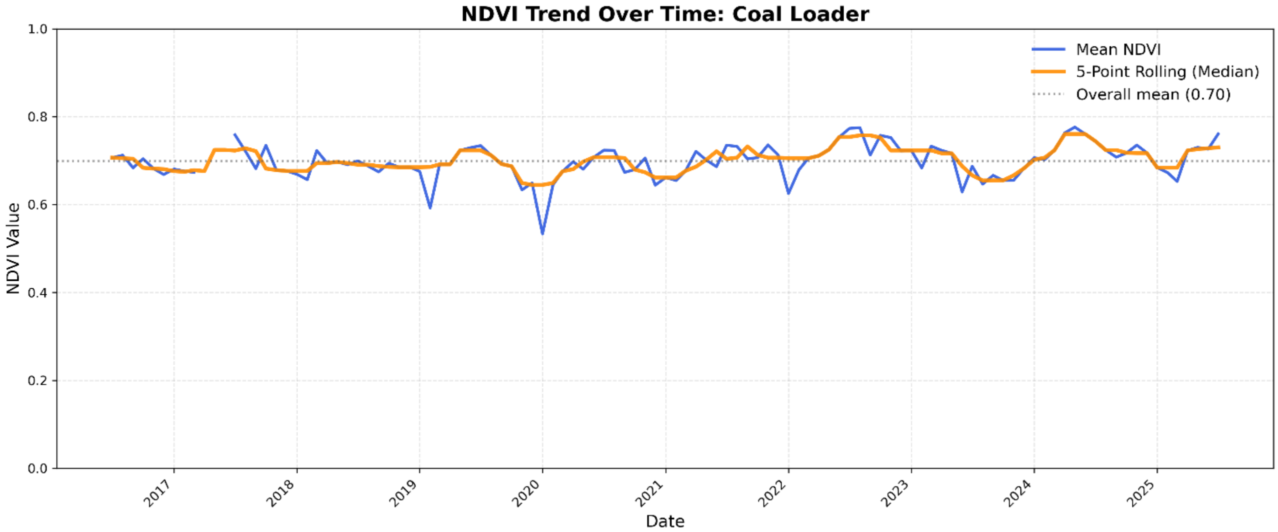


Figure 3.14 NDVI Trend for Coal Loader (July 2016 – July 2025)

Spatial patterns show a near-continuous band of stable canopy along most of the shoreline (Figure 3.15). Stable mangroves account for 19.91 ha (97.4 %) of the total 20.45 ha extent (Table 3.2). Recovered locations (3.56 ha) occurred as small, isolated patches where current NDVI values exceed the recovery threshold of 0.6190, corresponding to the 0.05 ha of significantly recovered mangroves reported in the table. Non-recovered areas appear in more defined clusters along the southern and western margins of the site, corresponding with the 0.49 ha (90.7 % of the disturbed area). Within this non-recovered category, the 15 lowest-performing locations those with the greatest deficits relative to the recovery threshold are highlighted on the map and represent the most severely affected points within the site. Detailed NDVI time-series plots for each ranked location are provided in Annex A.

Table 3.2 Coal Loader – Medium-Term Mangrove Dieback Summary (Jul 2016–Jul 2025)

Category	Value	Notes
NDVI Dieback Threshold	NDVI < 0.4	Threshold used to identify areas where canopy condition has declined.
Site Baseline (NDVI < 0.4)	Mean = 0.2744 Std = 0.1095	Represents typical NDVI values observed during dieback conditions.
Recovery Threshold	NDVI >= 0.6190	Calculated as the baseline mean plus 2 standard deviations; indicates the NDVI level required for confirmed recovery.
Total Mangrove Area	20.45 ha	
Stable (Never Disturbed)	19.91 ha	97.4 % of the total mangrove area.
Disturbed (Ever Affected)	0.54 ha	2.6 % of the total mangrove area.
Significantly Recovered	0.05 ha	9.3 % of the disturbed area has improved to above the recovery threshold.
Still Below Recovery Threshold	0.49 ha	90.7 % of the disturbed area has not yet recovered.

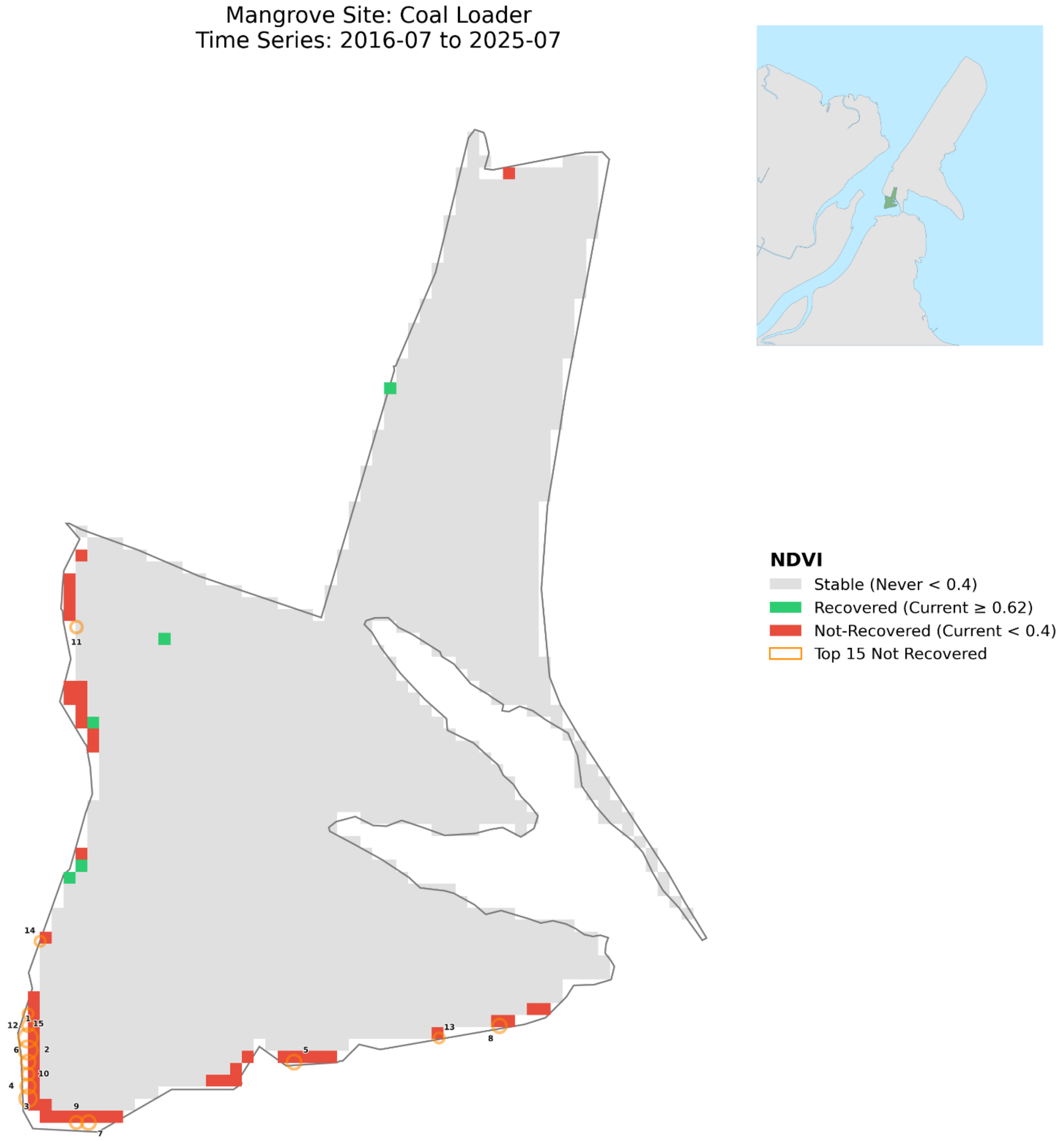


Figure 3.15 Spatial Map of Mangrove Condition Classes and Top-Ranked Non-Recovered Locations at Coal Loader

3.2.3 Fisherman Islands

The 5-month rolling median NDVI (orange line) remained near the overall site long-term mean of ~0.70 from 2016 to 2019, with only minor short-term variability (Figure 3.16). A modest reduction appears around 2020, as also observed at Coal Loader and Bulwer Island. From 2021 onwards, the smoothed NDVI returned to typical levels and remains close to or slightly above ~0.70 through to 2025.

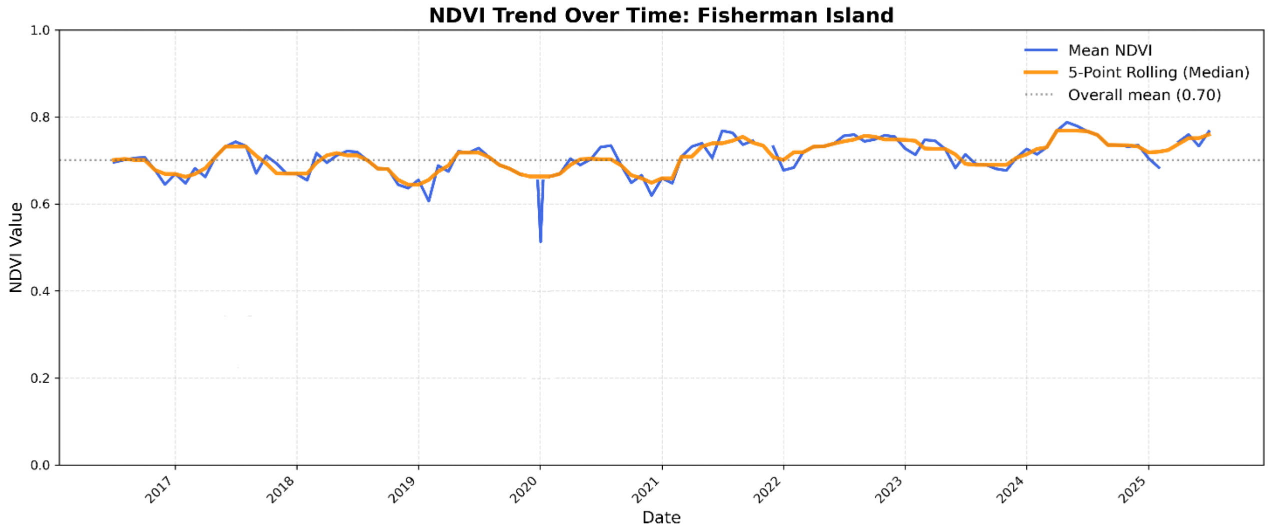


Figure 3.16 NDVI Trend for Fisherman Islands (July 2016 – July 2025).

Spatially, Fisherman Islands was dominated by a stable canopy, with 150.65 ha (95.6 %) of its 157.55 ha in this category (Figure 3.17; Table 3.3). Recovered areas (3.56 ha, 51.6 % of the disturbed area) occurred in several distinct clusters, particularly around the central and southeastern parts of Fisherman Islands. Non-recovered mangroves formed a series of narrow bands around portions of the southern and western shoreline, corresponding to the remaining 3.34 ha (48.4 % of the disturbed area) below the threshold. Among these, the 15 lowest-scoring points those furthest below the recovery benchmark are identified on the map as the most impacted locations. Detailed NDVI time-series plots for each of these ranked points are provided in Annex A.

Table 3.3 Fisherman Islands – Medium-Term Mangrove Dieback Summary (Jul 2016–Jul 2025)

Category	Value	Notes
NDVI Dieback Threshold	NDVI < 0.4	Threshold used to identify areas where canopy condition has declined.
Site Baseline (NDVI < 0.4)	Mean = 0.2117 Std = 0.1257	Represents typical NDVI values observed during dieback conditions.
Recovery Threshold	NDVI >= 0.6515	Calculated as the baseline mean plus 2 standard deviations; indicates the NDVI level required for confirmed recovery.
Total Mangrove Area	157.55 ha	
Stable (Never Disturbed)	150.65 ha	95.6 % of the total mangrove area.
Disturbed (Ever Affected)	6.90 ha	4.4 % of the total mangrove area.
Significantly Recovered	3.56 ha	51.6 % of the disturbed area has improved to above the recovery threshold.
Still Below Recovery Threshold	3.34 ha	48.4 % of the disturbed area has not yet recovered.

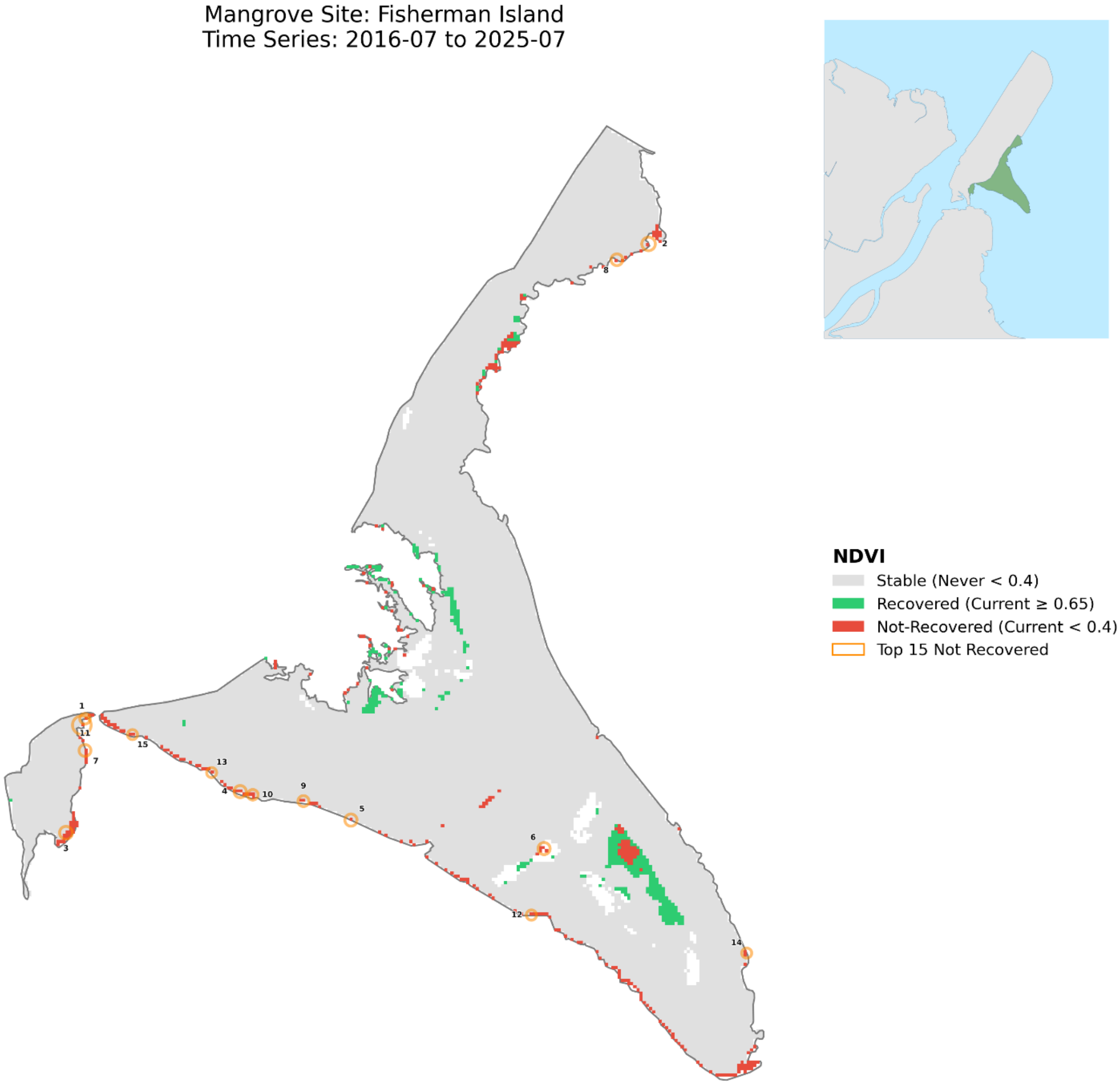


Figure 3.17 Spatial Map of Mangrove Condition Classes and Top-Ranked Non-Recovered Locations at Fisherman Islands

3.2.4 Whyte Island

The 5-point rolling median NDVI (orange line) at Whyte Island followed a similar pattern to other sites, remaining close to the long-term mean of ~0.70 from 2016 to 2019, with minor short-term fluctuations (Figure 3.7). A small decline occurred around 2020, followed by a return to levels comparable with the earlier part of the record. A further reduction occurred around 2022, after which the smoothed NDVI remained stable and close with the ~0.70 mean through to 2025.

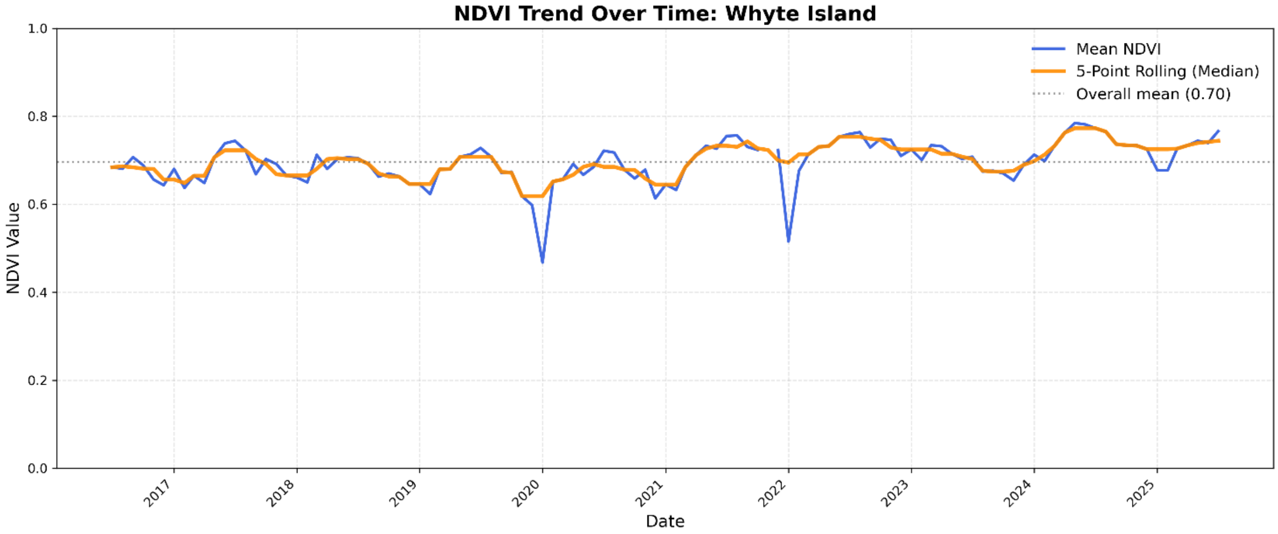


Figure 3.18 NDVI Trend for Whyte Island (July 2016 – July 2025)

Stable mangroves dominated the site, accounting for 100.66 ha (91.3 %) of the 110.30 ha extent (Figure 3.19; Table 3.4). Recovered locations (7.62 ha; 79.0 % of disturbed area) form several well-defined clusters, particularly through central portions of the island. Non-recovered areas (2.02 ha; 21.0 %) occur primarily in smaller pockets along eastern and southern margins. As at other sites, the 15 lowest-performing non-recovered points represent the most affected locations. Detailed NDVI time-series plots for these ranked points are provided in Annex A.

Table 3.4 Whyte Island – Medium-Term Mangrove Dieback Summary (Jul 2016–Jul 2025)

Category	Value	Notes
NDVI Dieback Threshold	NDVI < 0.4	Threshold used to identify areas where canopy condition has declined.
Site Baseline (NDVI < 0.4)	Mean = 0.3197 Std = 0.0693	Represents typical NDVI values observed during dieback conditions.
Recovery Threshold	NDVI >= 0.5387	Calculated as the baseline mean plus 2 standard deviations; indicates the NDVI level required for confirmed recovery.
Total Mangrove Area	110.30 ha	
Stable (Never Disturbed)	100.66 ha	91.3 % of the total mangrove area.
Disturbed (Ever Affected)	9.64 ha	8.7 % of the total mangrove area.
Significantly Recovered	7.62 ha	79.0 % of the disturbed area has improved to above the recovery threshold.
Still Below Recovery Threshold	2.02 ha	21.0 % of the disturbed area has not yet recovered.

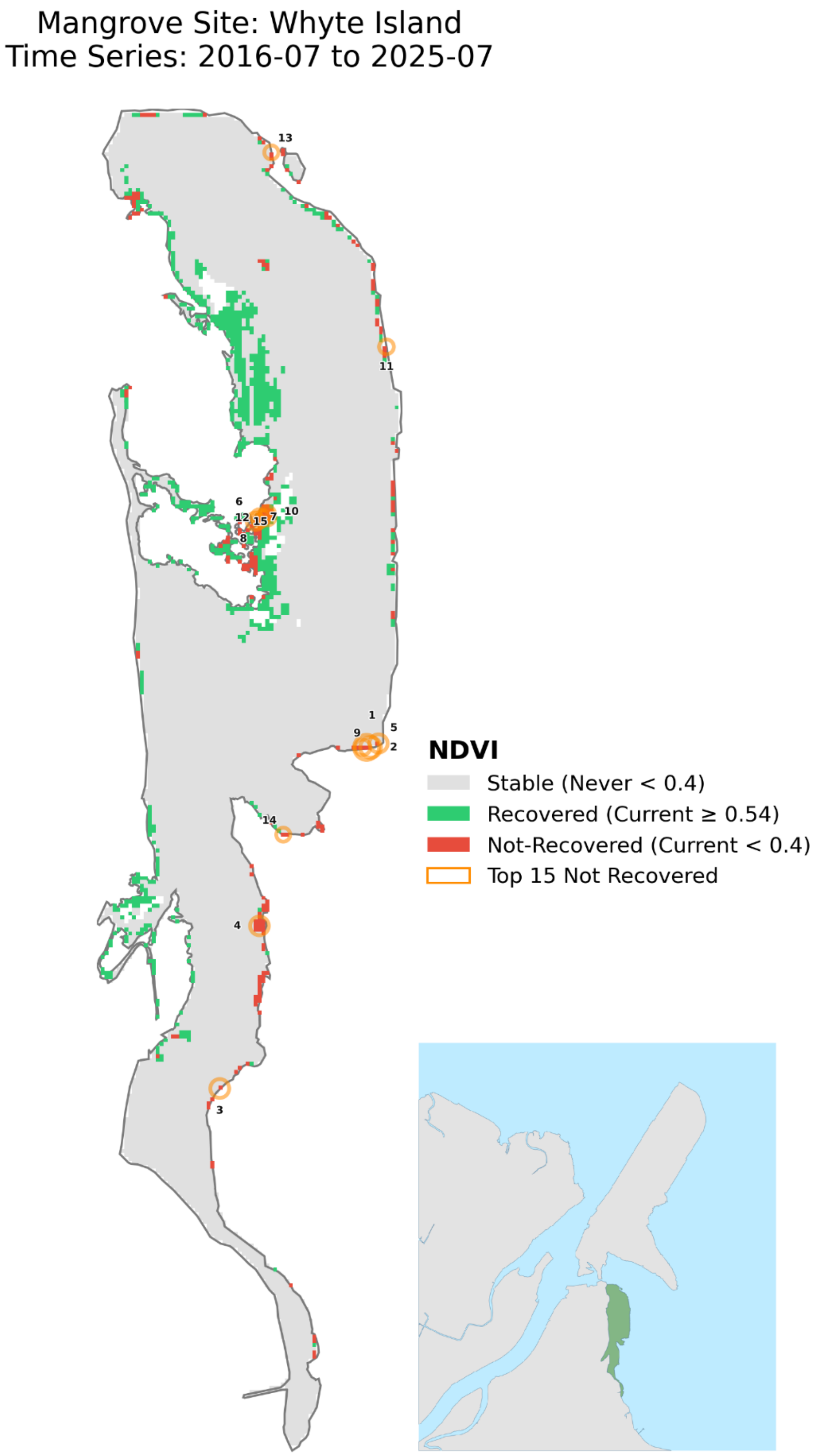


Figure 3.19 Spatial Map of Mangrove Condition Classes and Top-Ranked Non-Recovered Locations at Whyte Island

3.4 Short-Term Mangrove Condition and Structure Analyses

3.4.1 NDVI and Ground-truthing Surveys

Fisherman Islands
The July 2025 NDVI distribution across Fisherman Islands shows spatial variation in mangrove canopy condition (Figure 3.21). Higher NDVI values (>0.9) were predominantly recorded within interior and sheltered zones, while lower NDVI values were more commonly associated with exposed shoreline margins.

Field surveys on the northern margins of Fisherman Islands, which corresponded with areas of higher NDVI, recorded predominantly mature *Avicennia marina* (approximately 10–12 m in height) with a mid and understory of *Rhizophora stylosa* (FI_1–FI_3, FI_5–FI_7) (Figure 3.20). Mangrove condition in this area was generally uniform, with continuous canopy cover observed. Localised disturbance was recorded near the Bird Hide (FI_4) at the Future Port Expansion, where several mature mangroves had fallen along the seaward edge; with epicormic resprouting on adjacent fallen trees. Seagrass wrack was observed accumulated at the base of mangroves in the vicinity of FI_4.

Mangrove communities in the north-eastern and north-western areas similarly aligned with moderate to high NDVI (0.7—0.9) values. These areas were characterised by dense juvenile *Avicennia marina* recruitment, with approximately 60–70 % canopy cover and mangrove heights ranging from 3–7 m. Mangrove condition appeared healthy, with no evidence of canopy stress such as epicormic growth, leaf yellowing, or dieback.

In the south-eastern interior, adjacent to the south-western margin of the saltmarsh/claypan, a distinct and persistent Avicennia marina+/- *Ceriops australis* mosaic was recorded. This area comprised approximately 60–70 % cover of a juvenile mosaic of *Avicennia marina* and *Ceriops australis* mangroves (3–5 m in height) (Figure 3.20).

In contrast, sections of the seaward south –eastern margin exhibited lower NDVI values (≤0.3) and field evidence of reduced canopy condition. Observations in this area included shoreline erosion, exposed *Avicennia marina* root systems (approximately 0.5 m) (Figure 3.20) and dieback of mature mangroves, consistent with the spatial pattern of lower NDVI along this exposed margin.

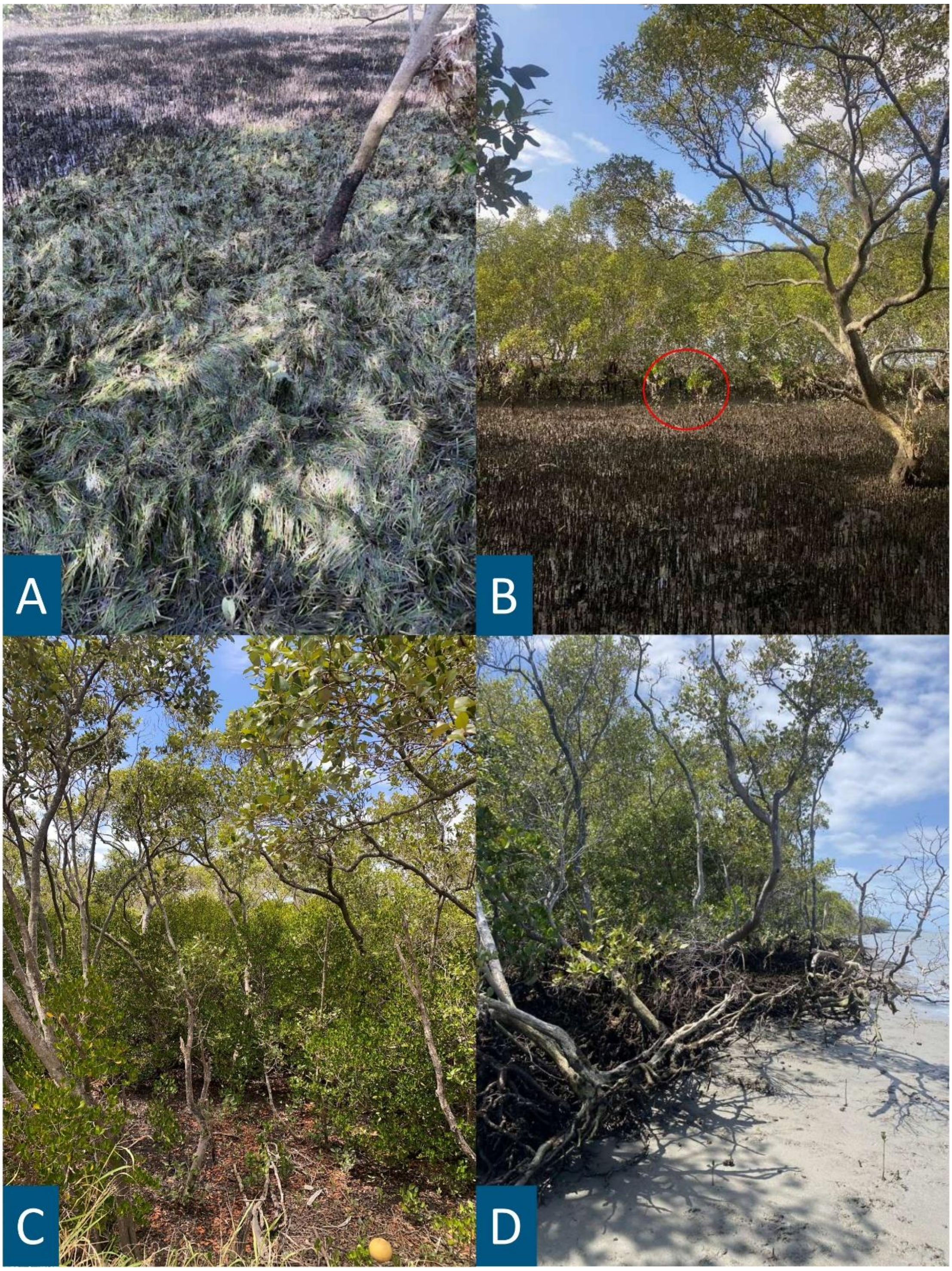
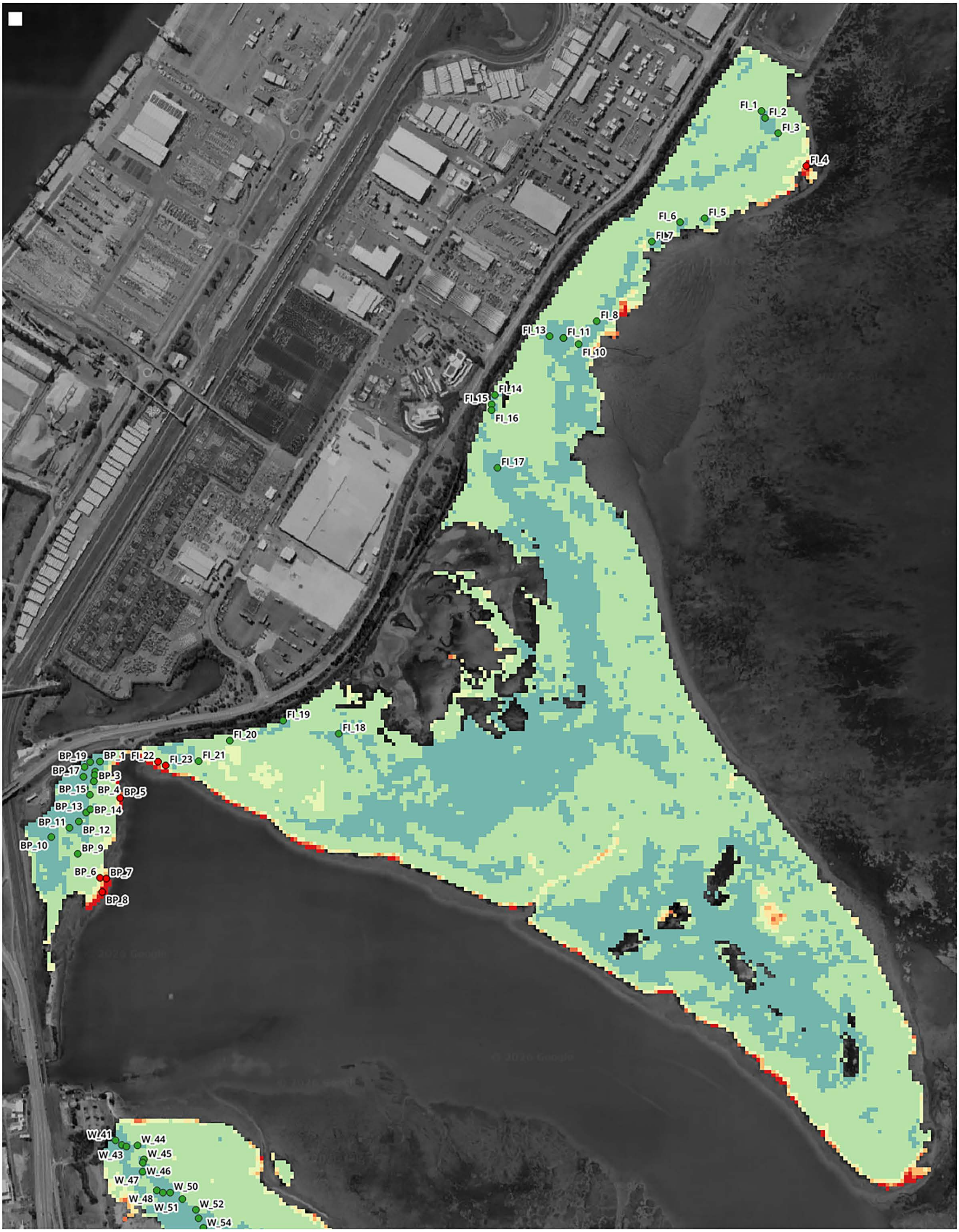


Figure 3.20 (a) Seagrass wrack over pneumatophores (b) *Avicennia marina* near FI_1 with *Rhizophora stylosa* understorey (red circle) (c) *Avicennia marina* with dense *Ceriops australis* understorey in southwest interior (d) Exposed *Avicennia marina* root system on south-eastern margin



Ground Control Points
- Gain
- Loss

NDVI
- <= 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- > 0.9

Title:
Fisherman Island NDVI (Sentinel-2, July 2025) with Field Validation

Drawing: 3.21

Rev: A

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Bulwer Island
The July 2025 NDVI distribution across Bulwer Island indicated relatively uniform canopy condition, with moderate to high NDVI values (approximately 0.7–0.9) in interior and protected areas (Figure 3.23). In contrast, lower NDVI values were observed along parts of the eastern margin of the site.

Ground-truthing surveys across Bulwer Island correspond with these spatial patterns. Most of the site comprised mature *Avicennia marina* with canopy heights of approximately 10–12 m. Tree trunks were generally tall but thin (~30 cm girth at breast height (GBH)), and seedlings were present throughout the site, indicating ongoing recruitment (Figure 3.22).

Localised areas of reduced NDVI were evident where openings in the seawall allow greater hydrological exchange (historically called 'Fish Passage'). These sections were distinct from adjacent areas along the eastern margin that were more protected by the seawall. Observations of oyster baskets were prominent across the Fish Passage.

Figure 3.22 Bulwer Island (a) *Avicennia marina* (tall and thin) with sapling shoots in understorey (b) Oyster baskets (red circle) within Fish Passage

Ground Control Points
- Gain
- Loss

NDVI
- <= 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- > 0.9

Title:

Bulwer Island NDVI (Sentinel-2, July 2025) with Field Validation

Drawing: 3.23

Rev: A

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Coal Loader

The July 2025 NDVI distribution across the Coal Loader site shows some spatial variation in mangrove canopy condition (Figure 3.25). Lower NDVI values (≤ 0.3) were concentrated along the western and south-western margins, while the interior areas generally exhibited moderate to high NDVI values (approximately 0.7–0.9). The north-eastern margin, adjacent to the roadway, showed some of the highest NDVI values (approximately 0.8–0.9) within the site.

Ground-truthing surveys along the western and south-western margins corresponded with areas of lower NDVI. These areas were dominated by *Avicennia marina* with an *Aegiceras corniculatum* understory. Multiple low canopy *Avicennia marina* (approximately 6–7 m in height) were observed along the seaward margin (CL_3 – CL_5). In these areas had sparse understory (~5 %), and evidence of regrowth from fallen mangroves was observed (Figure 3.24).

Interior areas corresponding to moderate to high NDVI values included locations CL_13 and CL_14, which comprised a mixture of *Avicennia marina* stands approximately 12-15 m in height. These areas exhibited approximately 50 % canopy cover, with a dense understory dominated by *Rhizophora stylosa* reaching 3 – 4 m in height.

Evidence of canopy dieback in *Avicennia marina* was observed at the south-western tip of the site (CL_8), consistent with areas of lower NDVI along this margin. In addition, barnacle colonisation was observed on several juvenile mangrove stems (Figure 3.24).

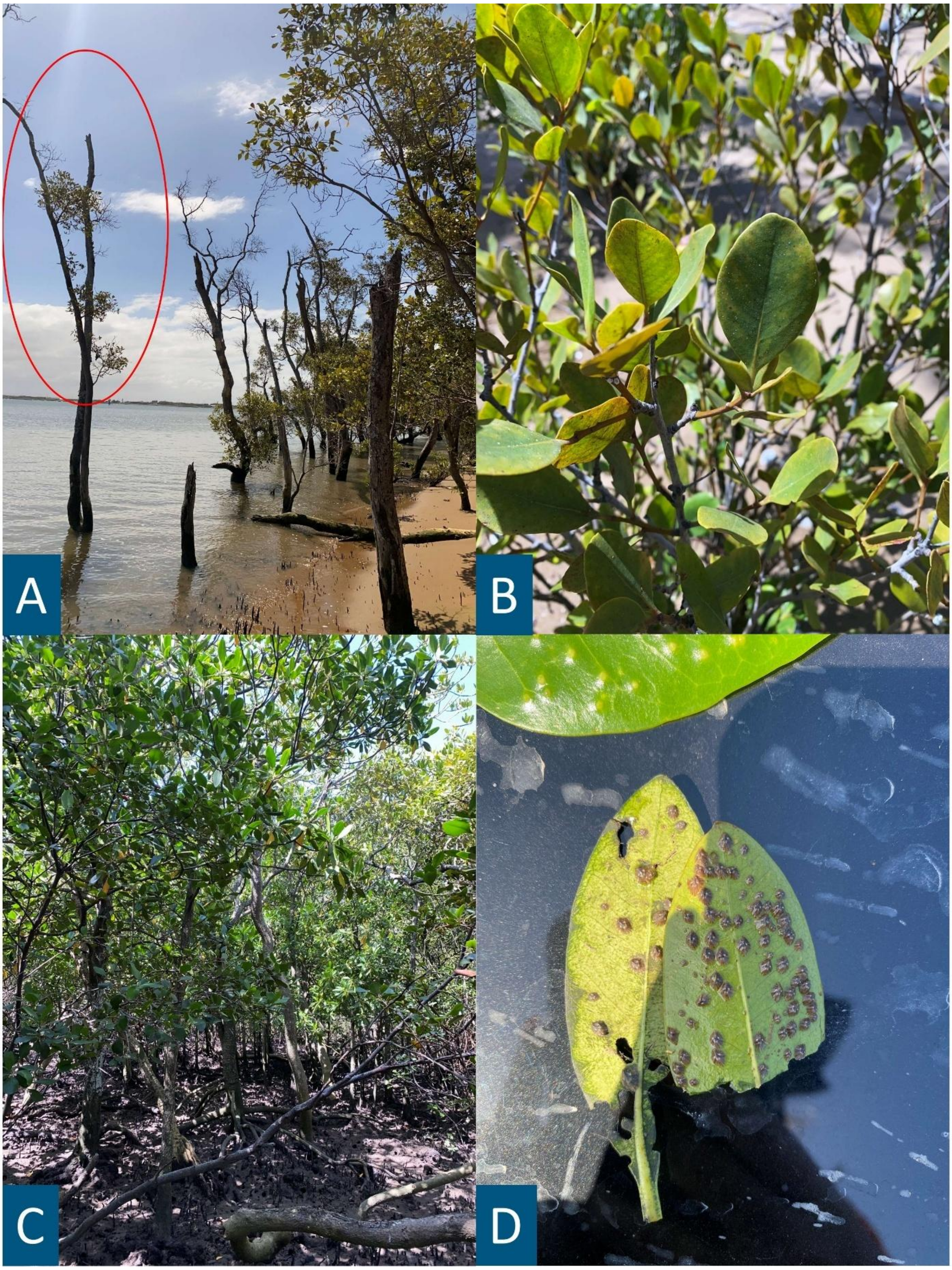
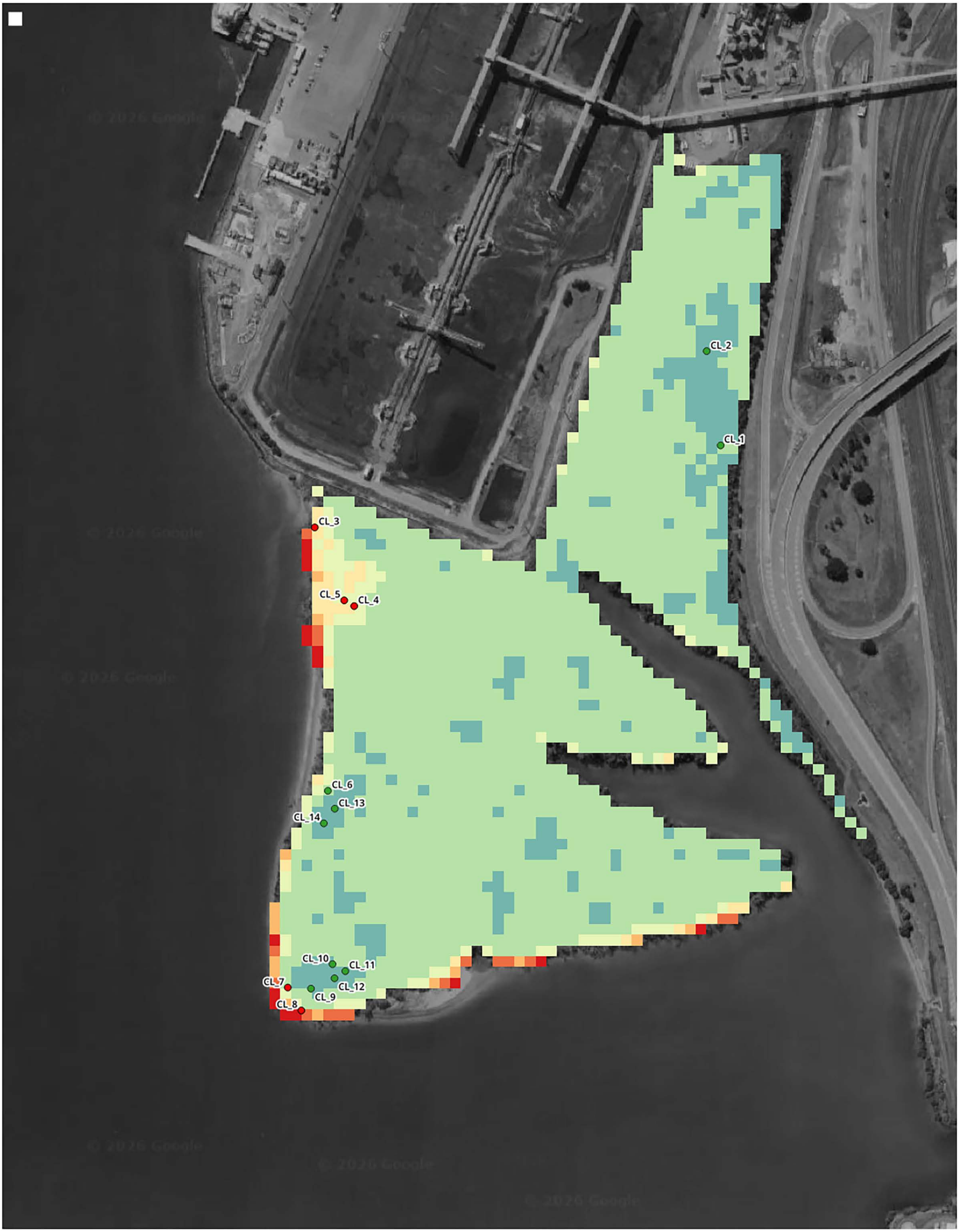


Figure 3.24 Coal Loader (a) Low canopy *Avicennia marina* (CL_3 – CL_5) with evidence of regrowth (red circle) (b) *Aegiceras corniculatum* understorey near CL_3 – CL_5 (c) *Avicennia marina* with *Rhizophora stylosa* understorey (d) Barnacle colonisation



Ground Control Points
- Gain
- Loss

NDVI
- <= 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- > 0.9

Title:
Coal Loader NDVI (Sentinel-2, July 2025) with Field Validation

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Whyte Island

The July 2025 NDVI distribution across Whyte Island shows distinct spatial variation in mangrove canopy condition (Figure 3.27). Moderate to high NDVI values (approximately 0.6–0.9) were prevalent across most of the southern portion of the island, while lower NDVI values (≤ 0.3) were concentrated along parts of the south-eastern shoreline, notably at locations W_31 and W_32. Areas east of the saltmarsh/claypan mosaic generally exhibited high NDVI values (approximately 0.8–0.9), with only localised areas of lower NDVI recorded (e.g. at W_79) (Figure 3.26).

Ground-truthing surveys across Whyte Island correspond with these NDVI patterns. Sites W_1 to W_8 comprised *Avicennia marina*-dominated communities approximately 10–15 m in height, with an understory of *A. marina* saplings ranging from 0.5–4 m in height. During field surveys, sulphurous odours were noted in parts of this area, along with observations of a dark blue-black sheen within the mangrove stand near W_9–W_12 (Figure 3.26). These observations are consistent with naturally occurring reducing conditions and sulfidic mangrove sediments commonly encountered in low-energy tidal environments.

In the south-eastern interior, dense stands of mature *Avicennia marina* were recorded at sites W_14–W_18, corresponding to areas of moderate to high NDVI. These areas had evidence of widespread seedlings and regrowth in the understory. Algal cover was observed at a high percentage (~50-60 %) of pneumatophores in this area.

Along the south-eastern shoreline, areas of lower NDVI corresponded with field observations of *Avicennia marina* canopy dieback at W_30 and W_31, where evidence of regrowth was also recorded. The understory in these locations was sparse (approximately 25 % sapling density), and barnacle growth on mangrove leaves was observed on saplings.

East of the saltmarsh/claypan mosaic, mangrove communities comprised dense stands of juvenile *Avicennia marina* (approximately 3–4 m in height) with a dense *Aegiceras corniculatum* understorey (Figure 3.26).

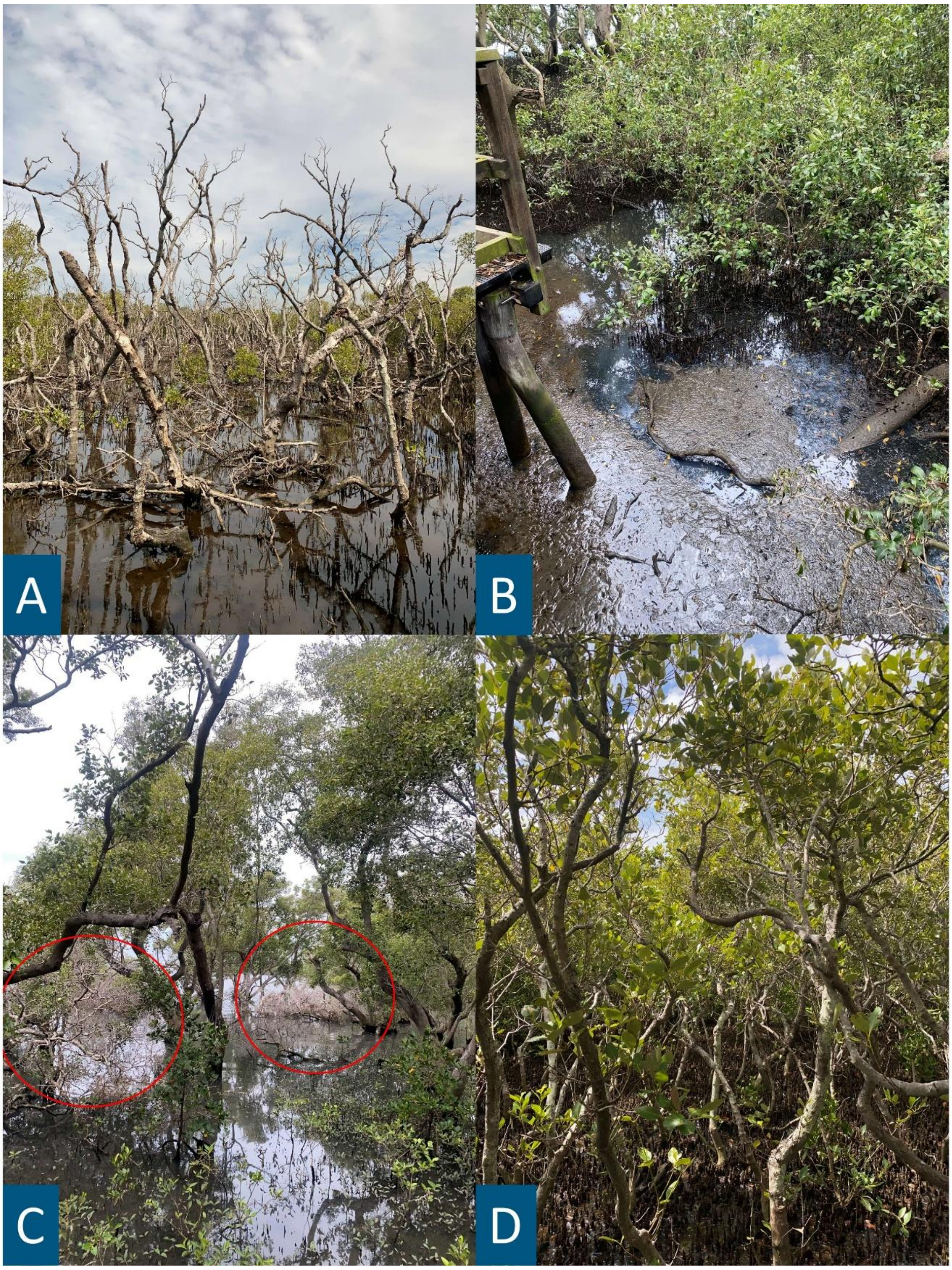
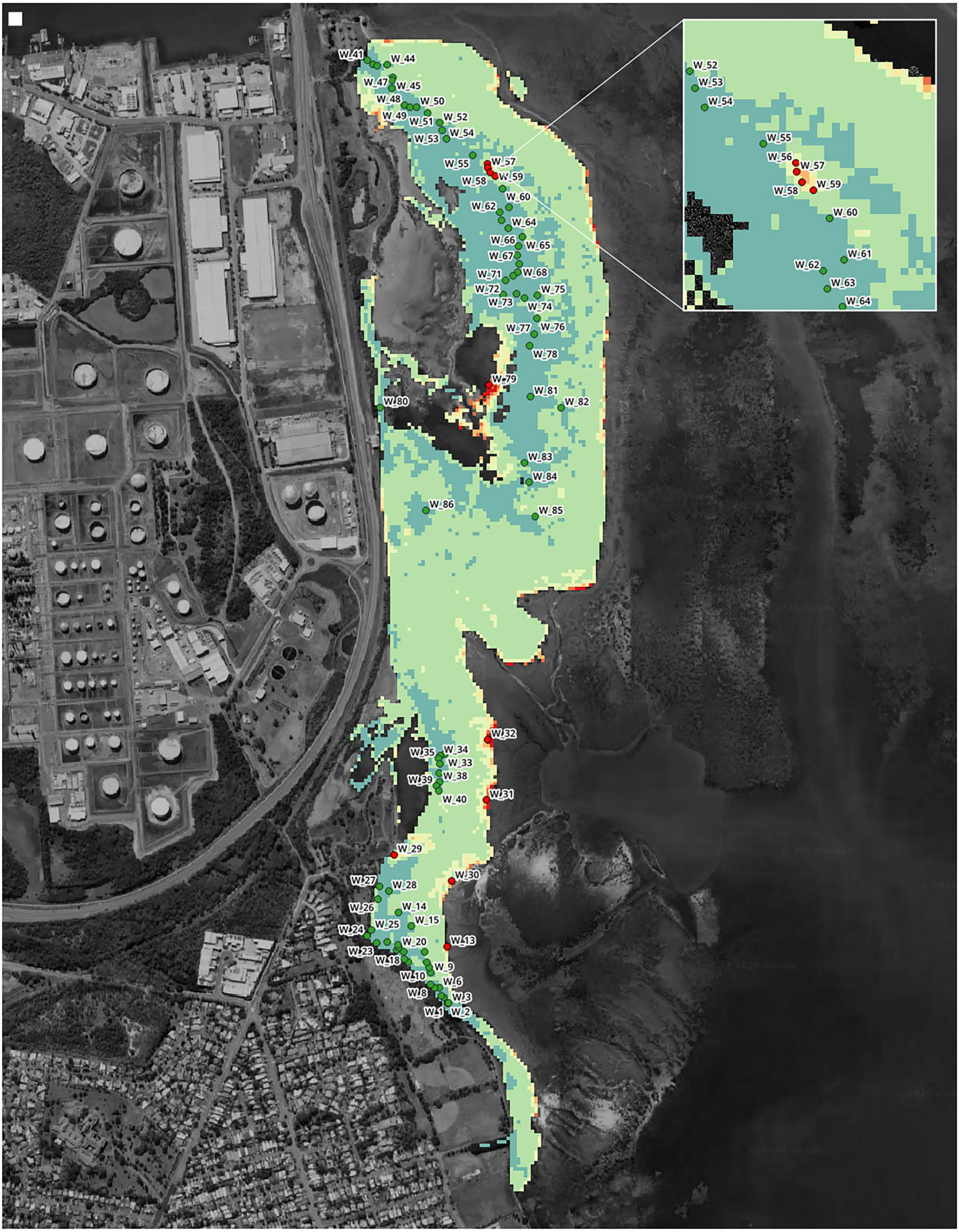


Figure 3.26 Whyte Island (a) Mangrove loss at W_79 (near mangrove/saltmarsh ecotone) (b) Sulfidic mangrove sediments (blue/black sheen) (c) *Avicennia marina* near W_30 and W_31 with some canopy dieback (red circle) but evidence of regrowth (d) Dense *Avicennia marina* with shoots of *Aegiceras corniculatum*



Ground Control Points
- Gain
- Loss

NDVI
- <= 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- > 0.9

Title:

Whyte Island NDVI (Sentinel-2, July 2025) with Field Validation

Drawing: 3.27

Rev: A

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3.3.1 Short-term Canopy Condition

Comparison of NDVI-derived canopy condition between July 2024 and July 2025 shows that most mangrove areas test sites changed very little over this one-year period (Figure 3.28). Small, localised areas of increased NDVI were detected at parts of Fisherman Islands and Whyte Island, indicating areas where canopy greenness increased over the one-year period. Limited areas of reduced NDVI were also identified, occurring mainly along the southern margins of Whyte Island and in small, isolated patches at Bulwer Island and the Coal Loader.

Overall, short-term changes in canopy condition between 2024 and 2025 were minor and spatially restricted, with the majority of mangrove stands showing little detectable change over this period.

LEGEND

Change Vector

- <= -0.20
- -0.20 - -0.15
- -0.15 - -0.05
- -0.05 - 0.00
- 0.00 - 0.05
- 0.05 - 0.15
- 0.15 - 0.20
- > 0.20

Title:

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3.2.3 Fine-Scale Mangrove Structure and Extent Mapping

A high-resolution map of vegetation extent and structural variability was produced, indicating distinct canopy-height-based communities across the test sites. Classification results for the test sites are presented in Figure 3.29 to Figure 3.32. Canopy-height patterns (nDSM) derived from the 2019 LiDAR dataset, which informed the refinement of the mangrove structural classes, are shown in Figure 3.33 and detailed further below.

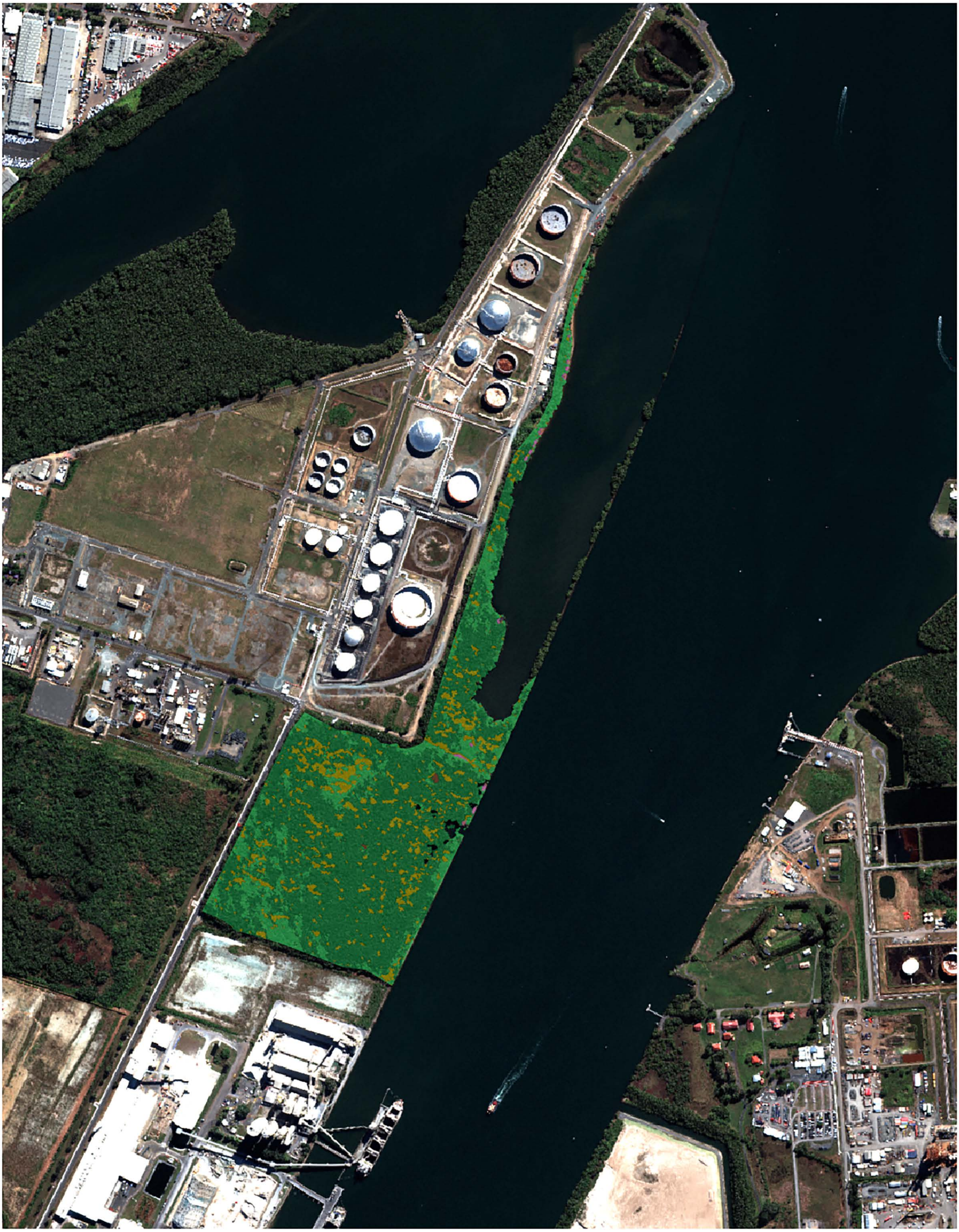
Vegetation Classification

Across all sites, *Avicennia marina*–dominated forest was the most extensive community type, forming large contiguous blocks of closed to open forest. This species occurred in two main structural categories: tall closed to open forest (>10 m) and medium-height closed to open forest (2–10 m). These *Avicennia* classes collectively formed the dominant mangrove canopy along the majority of seaward and mid-intertidal zones, reflecting the widespread distribution and structural variability typical of this species in Moreton Bay. In several locations—most notably Fisherman Islands and Whyte Island—the *Avicennia* canopy formed broad, continuous stands with relatively smooth seaward edges.

Although *Avicennia marina* represented the primary canopy-forming species at each location, areas classified as *Ceriops australis* closed to open forest (2–5 m) were also mapped. These *Ceriops* stands were most extensive at Fisherman Islands and Whyte Island, where they formed distinct patches of low, relatively even-height canopy. In the classification outputs, these patches generally occurred landward of larger *Avicennia* blocks, forming clear zonation patterns. In several areas, *Ceriops australis* was mapped adjacent to, or intermixed with, bare patches and medium-height closed to open forest *Avicennia marina*. The south-western portion of Fisherman Islands and the south-eastern margin of Whyte Island contained the largest continuous areas mapped as *Ceriops australis*. In contrast, at Coal Loader and Bulwer Island, *Ceriops australis* was mapped as smaller, fragmented patches, typically confined to more landward or marginal intertidal positions.

The classification outputs also indicated areas of *Avicennia marina* open forest (sparse encroachment), capturing zones where low-height, widely spaced *A. marina* individuals have begun colonising previously unvegetated or sparsely vegetated intertidal flats. These early-stage encroachment areas were most pronounced at Fisherman Islands and Whyte Island, forming transitional bands between established mangrove forest and adjacent low-lying tidal flats. Their spatial distribution indicates recent expansion of mangrove cover, consistent with encroachment patterns documented in previous assessments. In the imagery, these sparse encroachment classes appeared as thin, discontinuous margins around the main *Avicennia* blocks, often following subtle topographic depressions or edges of shallow ponds.

Across the test sites, noticeable differences in mangrove patch configuration were also evident. Bulwer Island supported a broad, relatively uniform expanse of *Avicennia marina*, with minimal fragmentation and little internal structural complexity. Coal Loader, in contrast, showed a more irregular mangrove boundary, with narrow extensions of *Avicennia* forest protruding along tidal creeks and several small internal breaks in canopy continuity. Fisherman Islands and Whyte Island displayed the highest structural heterogeneity, with alternating patches of tall *Avicennia*, medium *Avicennia*, and low *Ceriops*.



Land Cover Classification

- Avicennia Closed to Open Forest (2-10 m)
- Avicennia Closed to Open Forest (>10 m)
- Avicennia Open Forest (Sparse / Low Canopy)
- Claypan (Pooling Water)
- Ceriops Close to Open Forest (2-5 m)
- Saltmarsh

Title:

Bulwer Island Land Cover Classification (WorldView, 10 July 2025)

Drawing: 3.29

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Land Cover Classification

- Avicennia Closed to Open Forest (2-10 m)
- Avicennia Closed to Open Forest (>10 m)
- Avicennia Open Forest (Sparse / Low Canopy)
- Claypan (Pooling Water)
- Ceriops Close to Open Forest (2-5 m)
- Saltmarsh

Title:

Coal Loader Land Cover Classification (WorldView, 10 July 2025)

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Land Cover Classification

- Avicennia Closed to Open Forest (2-10 m)
- Avicennia Closed to Open Forest (>10 m)
- Avicennia Open Forest (Sparse / Low Canopy)
- Claypan (Pooling Water)
- Ceriops Close to Open Forest (2-5 m)
- Saltmarsh

Title:

Fisherman Island Land Cover Classification (WorldView, 10 July 2025)

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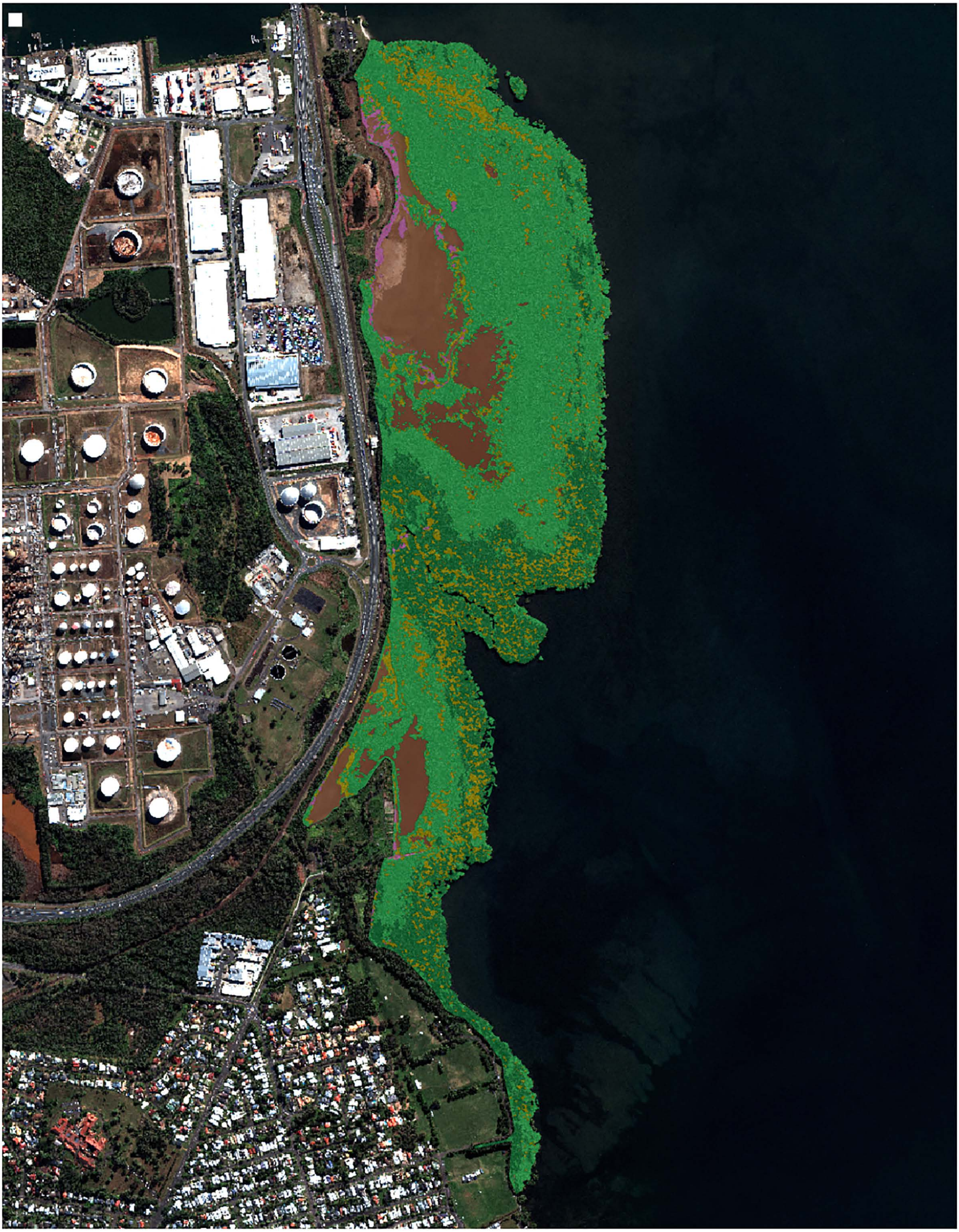

Land Cover Classification

- Avicennia Closed to Open Forest (2-10 m)
- Avicennia Closed to Open Forest (>10 m)
- Avicennia Open Forest (Sparse / Low Canopy)
- Claypan (Pooling Water)
- Ceriops Close to Open Forest (2-5 m)
- Saltmarsh

Title:

Whyte Land Cover Classification (WorldView, 10 July 2025)

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Canopy Height

High-resolution canopy-height mapping identified clear spatial patterns across the test sites (Figure 3.33). The highest mangrove canopies (10—15 m in height) were mapped at Whyte Island, particularly along Crab Creek downstream of the Wynnum wastewater outfall, where continuous bands of elevated canopy height occurred along creek margins. Crab Creek also recorded the highest NDVI values in 2025. Areas adjacent to the Wynnum boardwalk similarly contained extensive stands of tall mangroves.

At Bulwer Island, canopy heights were generally higher than at the other sites, with extensive areas of mangroves reaching 11–17 m. A large block of tall canopy forest was mapped near the Luggage Point wastewater facility, with peak canopy heights concentrated along the inner, landward margins of the site.

At Fisherman Islands, taller mangroves were primarily mapped along the eastern and southern shoreline, forming a narrow but continuous fringe of elevated canopy height (10—12 m in height). In contrast, interior and northern areas of Fisherman Islands were characterised by lower canopy heights (2—8 m in height). Canopy height generally decreased landward, particularly toward the saltmarsh–mangrove ecotone.

At the Coal Loader, higher canopy heights (approximately 11–15 m) were mapped in the north-eastern portion of the site, adjacent to the terrestrial and road interface. Other parts of the site exhibited lower and more variable canopy heights.

Across all sites, canopy height generally decreased landward, particularly toward the saltmarsh–mangrove ecotone.

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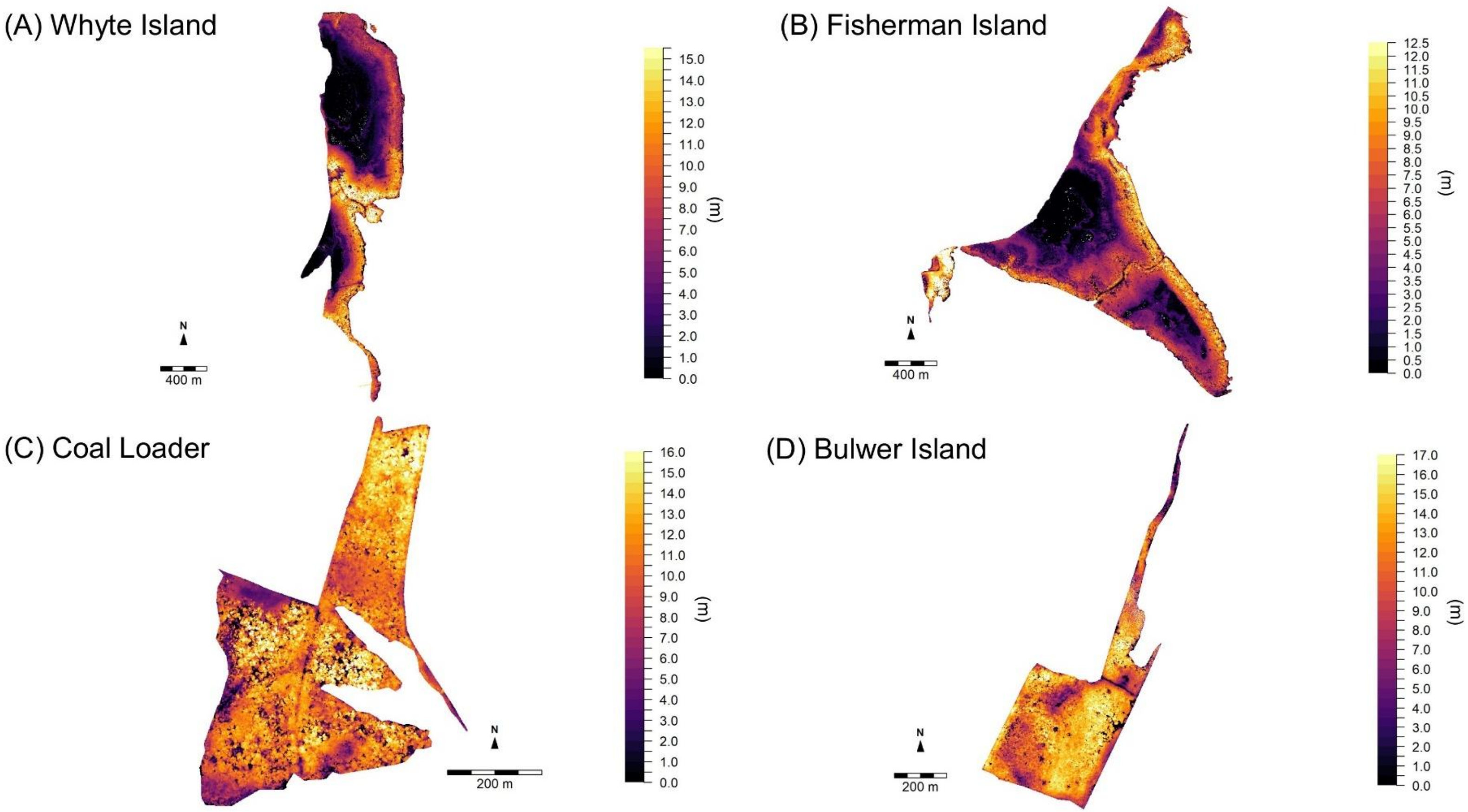


Figure 3.33 Canopy Height Model (nDSM) Derived from LiDAR 2019

3.5 Temporary Variation in Mangrove Extent

Temporal variation in the extent of mangrove and saltmarsh/claypan (including ponding water) communities was assessed using long-term mapping from 1955 to 2022, with the 2025 dataset extending this time series. This mapping allows comparison of both recent (2022–2025) and longer-term (1997–2025) changes across the test sites. The area (ha) of mangrove and saltmarsh/saltpan communities are presented in Figure 3.34, while long term spatial changes (1997–2025) in mangrove extent are shown in Figure 3.35. Mapping methods have been refined over time; accordingly, earlier datasets may under- or over-estimate wetland extent relative to the 2025 dataset, which represents the most recent and internally consistent mapping.

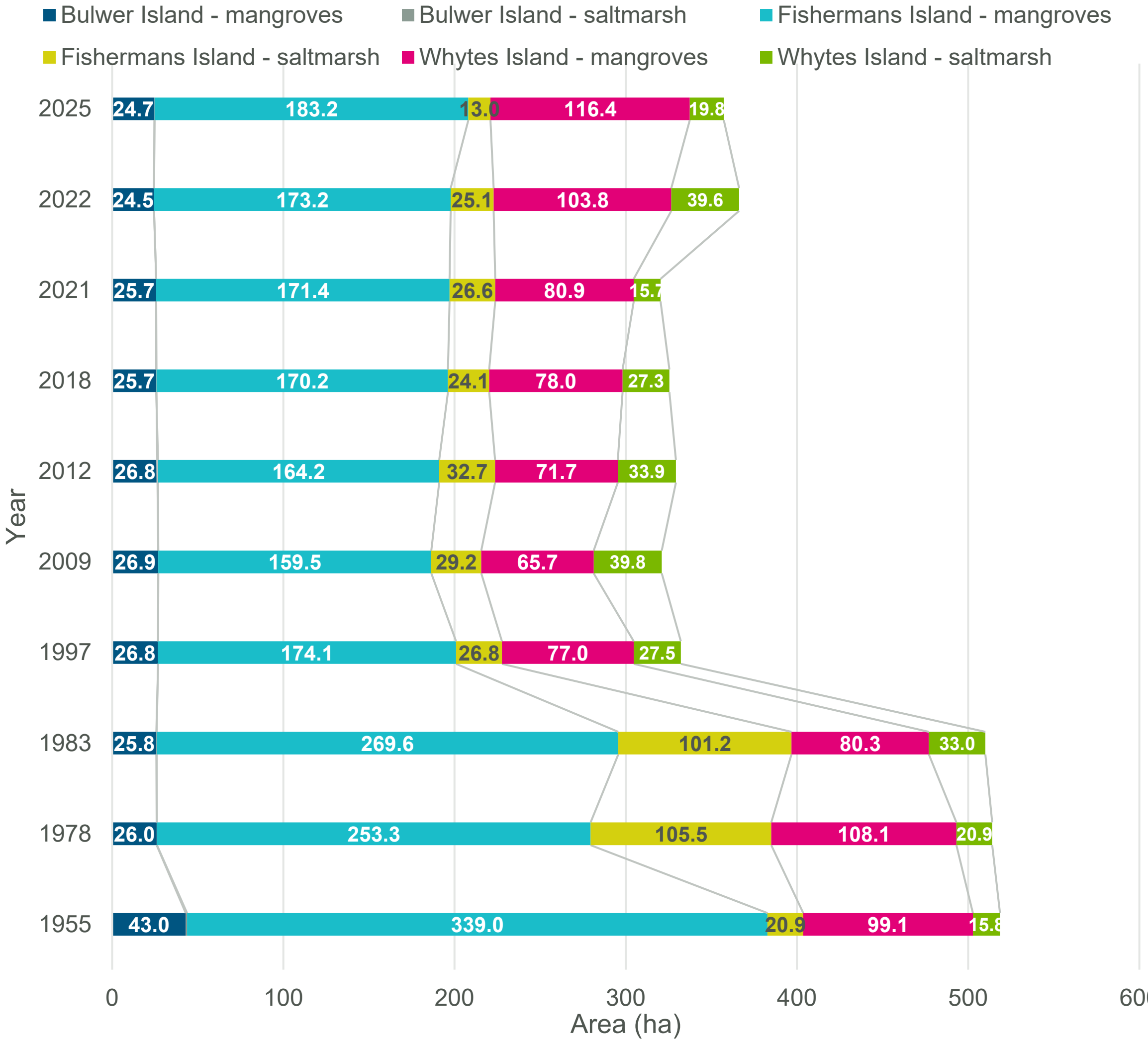
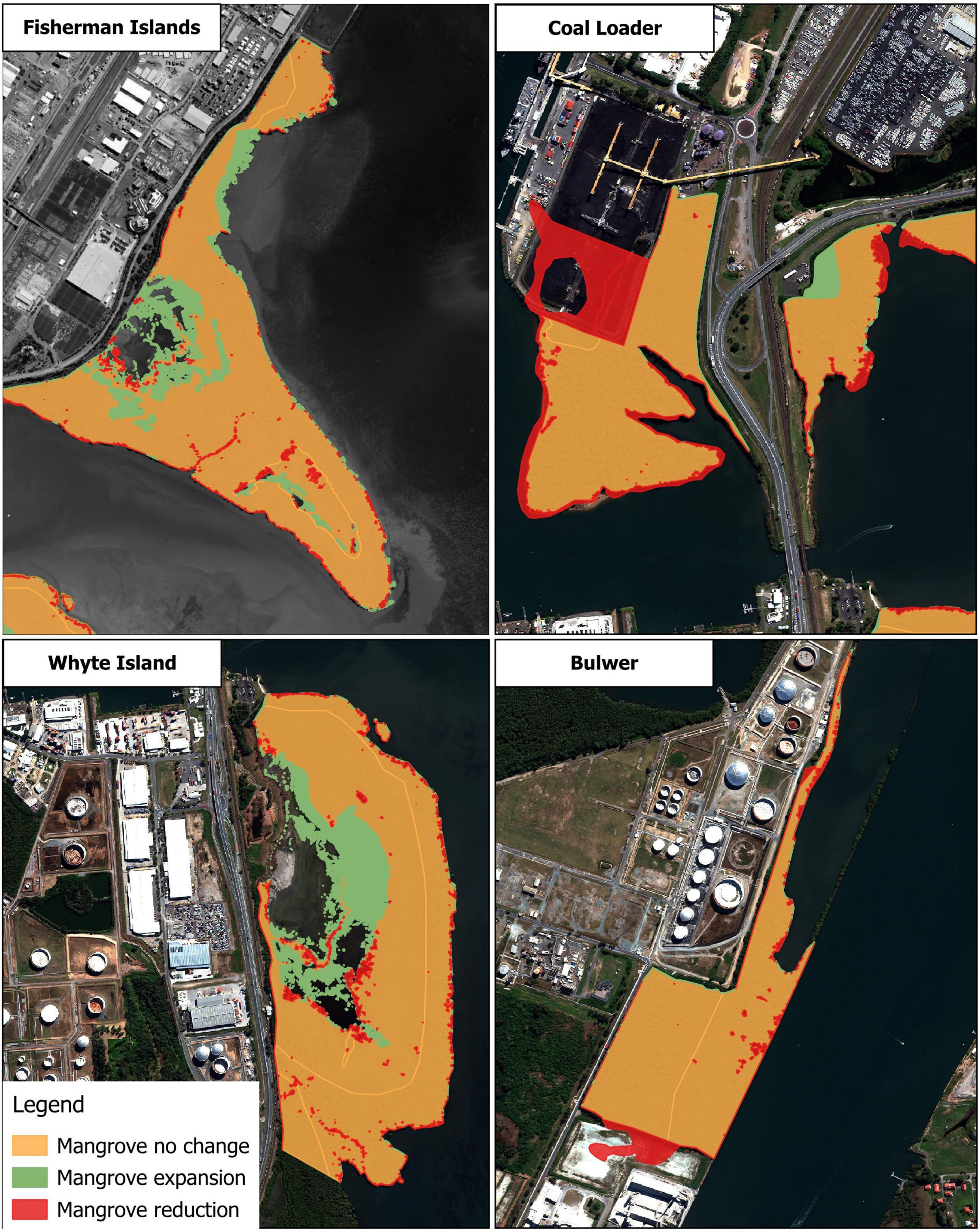


Figure 3.34 Area of mangrove and saltmarsh at Fisherman Islands (including Coal Loader)[2], Bulwer Island and Whyte Island through time. *Note that saltmarsh categories also include claypan and ponded water.*

[2] Historically, Coal Loader formed part of a contiguous mangrove system with Fisherman Island prior to port expansion. Accordingly, historical extent mapping combines both areas as a single area . To ensure consistency with these datasets, Coal Loader is included within the Fisherman Island extent estimate, although they are reported as separate test sites under the current MMP.



Title:

Change in mangrove community extent between 1997 and 2025

Figure: 3.35

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Contemporary Changes (2022–2025)

Between 2022 and 2025, changes occurred in the extent of mangrove and saltmarsh/claypan communities across the test sites (Figure 3.34):

- At Bulwer Island, changes were comparatively minor. Mangrove extent increased slightly from 24.5 ha to 24.7 ha, while saltmarsh/claypan extent changed from 1.0 ha to 1.3 ha, with overall variation remaining below 0.5 ha for both community types.
- At Fisherman Islands (including Coal Loader), mangrove extent increased from 173.2 ha in 2022 to 182.2 ha in 2025, representing a net gain of approximately 10 ha. Over the same period, saltmarsh/claypan extent declined from 25.1 ha to 13.0 ha, a net reduction of around 12 ha.
- At Whyte Island, mangrove extent increased from 103.8 ha to 116.4 ha between 2022 and 2025, a gain of approximately 13 ha. Saltmarsh/claypan communities decreased from 39.6 ha to 19.6 ha, corresponding to a reduction of approximately 20 ha.

Longer Term Changes (1997–2025)

Long term changes from 1997 to 2025, more substantial shifts in wetland community extent were recorded:

- At Bulwer Island, mangrove extent decreased from 26.8 ha in 1997 to 24.7 ha in 2025, a net reduction of roughly 2 ha. Spatially, reductions in mangrove extent were more prominent along the south-eastern margin, including the Fish Passage, and at the north-western tip of the site (Figure 3.35). In contrast, no change in mangrove extent was observed within the interior of Bulwer Island. Saltmarsh/claypan extent remained consistently low throughout the period, staying below 0.5 ha for all mapped years (Figure 3.34).
- At Fisherman Islands (including Coal Loader), mangrove extent increased from 174.1 ha in 1997 to 183.2 ha in 2025, a net gain of approximately 9 ha. Mangrove extent at Coal Loader generally shows a retraction of mangroves on the seaward fringes (Figure 3.35), with the interior of Coal Loader having no change in extent. Spatially, increases in mangrove extent at Fisherman Islands were most evident along parts of the northeastern margins and within and adjacent to the saltmarsh/claypan area, whereas contraction was observed on the seaward fringes on the southwestern margins (Figure 3.35). Saltmarsh/claypan extent declined over this period, decreasing from 26.8 ha to 13.0 ha, representing a reduction of nearly 14 ha (Figure 3.34).
- At Whyte Island, mangrove communities increased significantly, rising from 77.0 ha in 1997 to 116.4 ha in 2025, a net gain of approximately 39 ha. Long-term contractions in mangrove extent occurred primarily around the seaward margins of Whyte Island whereas mangrove expansion occurring within and adjacent to the saltmarsh/claypan area (Figure 3.35). Saltmarsh/claypan extent decreased from 27.5 ha to 19.6 ha, a reduction of about 8 ha (Figure 3.34).

4 Discussion

4.1 Long-term Mangrove Change Analysis

The long-term NDVI record from 1988 to 2025 shows that mangrove canopy condition at all test sites has remained stable or improved over nearly four decades.

Annual NDVI values at Bulwer Island, Coal Loader, Fisherman Islands and Whyte Island were largely contained within the 5th–95th percentile range of the aggregated control sites, with only short-lived departures during the early 1990s and around 2007–2008. These downturns were followed by recovery to typical values within a few years, and no site exhibited a progressive downward divergence from the control envelope.

Long-term mean NDVI values at all test sites were consistently higher than the control site mean (~0.69). Bulwer Island and Coal Loader maintained long-term means of approximately 0.72, and Fisherman Islands and Whyte Island both recorded means of approximately 0.71. These averages demonstrate that canopy greenness at port-adjacent mangrove sites has not lagged behind regional background conditions and has instead remained slightly above the long-term control.

Spatially, the most persistent high NDVI values occurred in interior and mid-intertidal areas, where interannual variability was low and NDVI trajectories recovered quickly after short downturns. Areas with lower NDVI were concentrated along exposed or hydrodynamically active margins, including the southern shoreline of Fisherman Islands, Fisherman Passage at Bulwer Island and the seaward margins of Coal Loader. These correspond to areas identified in the shoreline analysis as experiencing erosion or complex hydrodynamic forcing, and they show greater sensitivity to episodic stress than interior mangroves. More specifically, Fisherman Islands shoreline patterns are likely attributed to the development of super bund and associated drainage channels altering the hydrodynamic processes on the mangrove fringe.

Long-term changes in mangrove and saltmarsh/claypan extent between 1997 and 2025 provide additional context to canopy patterns. Mangrove extent increased at Fisherman Islands and Whyte Island (on the order of +9–10 ha and +13 ha respectively), with gains concentrated in central and landward areas where hydrological and geomorphic conditions favour sediment accumulation and mangrove recruitment. Over the same period, saltmarsh/claypan extent declined at these sites, indicating landward encroachment of mangroves into upper-intertidal habitats. This pattern is consistent with region-wide processes observed in Moreton Bay, where mangrove expansion into saltmarsh has been widely reported in response to long-term sedimentation, stable inundation regimes and favourable hydrological conditions (Saintilan & Rogers 2013; Lovelock *et al.* 2010).

4.2 Medium-Term Canopy Patterns (July 2016–July 2025)

Medium-term NDVI analysis over the period July 2016 to July 2025 identified three consistent canopy-condition trajectories were observed at all test sites.

Stable canopy formed the dominant condition class at every site, occurring mainly in interior mangrove areas where vegetation is shielded from shoreline exposure. These areas maintained consistently high NDVI values throughout the time series, indicating long-term canopy resilience and sustained vegetation vigour.

Recovering areas appear as discrete clusters situated within or adjacent to these stable zones. In these locations, NDVI increased steadily following earlier periods of reduced canopy condition and has since remained at or above typical site values, indicating renewed canopy vigour. These recovering patches often sit in transitional positions neither fully interior nor fully edge-exposed reflecting environments where disturbance pressures have eased sufficiently to allow regrowth.

Non-recovered areas are limited in overall extent but exhibit a consistent spatial configuration across all test sites. These low-NDVI patches formed narrow, linear bands or small clusters tightly aligned with outer shorelines, channel margins, and other exposed site boundaries. Non-recovered areas were not common within interior, sheltered portions of the mangrove area. This repeated edge-focused pattern was particularly pronounced where shoreline geometry was more irregular or where built infrastructure interfaces with the mangrove area such as the eroding shoreline observed at Fisherman Islands.

Time-series patterns of NDVI were broadly aligned across the region. NDVI remained close to long-term means from 2016 to 2019, dipped modestly around 2020–2021, then returned to typical or slightly above-typical values from late 2021 onwards. The brief decrease likely reflects transient satellite-image constraints (e.g. cloud cover), though some sensitivity to climatic variability during this period is also plausible.

At the site level, the same regional pattern is consistent with local variations:

- **Bulwer Island** is stable, with only small, isolated non-recovered patches and scattered pockets of recovery.
- **Coal Loader** shows a near-continuous stable band with small recovering clusters and non-recovered patches concentrated in specific margins rather than spread across the interior.
- **Fisherman Islands** is stable overall but shows linear, non-recovered bands along sections of the southern and western shoreline, with recovery clusters in more central/south-eastern areas.
- **Whyte Island** combines extensive stability with numerous, well-defined recovery clusters, particularly through the central zone, while non-recovered points are scattered in smaller edge pockets, notably along eastern and southern margins.

The spatial configuration of medium-term trajectories is strongly aligned with the 2025 NDVI surface. Areas classified as stable or recovered overwhelmingly exhibit moderate to high NDVI (approximately 0.6–0.8) within interior and mid-shoreline mangrove areas, whereas non-recovered areas retain lower NDVI values (≤0.4–0.5) near seaward eroding margins or hydrodynamic exposure (ie., Fish Passage at Bulwer Island)

This temporal–spatial agreement indicates that short-term variability is not masking deeper trends. The 2024–25 behaviour sits firmly within longer-term trajectories of recovery or decline.

4.3 Short-Term Canopy Change (July 2024–July 2025)

Short-term canopy change between July 2024 and July 2025 indicates that canopy condition across the test sites changed very little over the one-year interval. Most mangrove pixels at all sites were assigned to low-change classes, confirming that NDVI values remained close to 2024 levels across the majority of the mapped mangrove area.

Where short-term changes did occur, they were localised. Increases in NDVI were detected in some interior and mid-shoreline areas of Fisherman Islands and Whyte Island, while small decreases were observed along the southern margins of Whyte Island and in isolated patches at Bulwer Island and Coal Loader. These changes were confined to small portions of each site and did not alter the overall spatial pattern of stable and recovered canopy observed in the medium-term analysis.

Field surveys corroborated these satellite-derived patterns. At Whyte Island, for example, areas with high and stable NDVI were characterised by dense, mature *Avicennia marina* areas and abundant saplings, whereas locations with mapped NDVI decreases corresponded to observed canopy dieback, tree fall, or lower sapling densities near eroding margins or irregular drainage features. Conversely, locations with NDVI increases corresponded to dense regeneration and vigorous understory growth. This ground-truthing confirms that short-term NDVI changes reflect localised disturbance–recovery processes and that no emerging broadscale decline in canopy condition was apparent between 2024 and 2025.

4.4 Climatic and Coastal Context for the Observed Patterns

Interpretation of long-, medium- and short-term canopy patterns mirror the geomorphic and climatic context of the study area, detailed below.

4.4.1 Geomorphic Controls

Shoreline analyses show that the most persistent low-condition areas, including many non-recovered patches, are associated with erosion-prone margins and hydrodynamically active environments. At Fisherman Islands and Coal Loader, non-recovered and low-NDVI zones align with sections of shoreline that have experienced sustained erosion or complex wave and current exposure, whereas interior areas and accreting or stable shorelines support predominantly stable or recovered canopy.

Long-term changes in mangrove extent also reflect these processes, with expansion of mangroves in the north-eastern area of Fisherman Islands occurring in a zone where hydrodynamic energy has been reduced due to sheltering from the Future Port Expansion reclamation. The resulting attenuation of wave exposure and improved sediment stability appear to have created more favourable conditions for mangrove recruitment and establishment in this part of the shoreline.

4.4.2 ENSO/SOI and Rainfall as Context

The spatial and temporal canopy patterns described above can be further understood within the broader climatic setting of the study area. Time-series of the Southern Oscillation Index (SOI), sea level, and cumulative rainfall (Figure 4.1) together with plots showing NDVI and rainfall over the same time periods (Figure 4.2), provide useful context for understanding temporal patterns described above.

Across the assessment period, interior mangrove zones at all test sites predominantly exhibited stable or recovering canopy condition. In summary:

- **Bulwer Island** – Interior canopy was overwhelmingly stable, with only small recovery pockets.
- **Coal Loader** – A continuous interior stable band with scattered recovering areas.
- **Fisherman Islands** – Recovery concentrated across central and southeastern interior zones.
- **Whyte Island** – Widespread interior stability with multiple, well-defined recovery clusters.

These interior-focused patterns are consistent with established ecological links between ENSO phases, rainfall variability, and mangrove canopy condition. Research shows that:

- **Positive SOI / La Niña periods** typically produce higher rainfall, lower salinity stress and improved soil moisture, supporting increased NDVI and canopy vigour (Hickey et al., 2021).
- **Negative SOI / El Niño periods** are associated with reduced rainfall, elevated salinity, and greater physiological stress.
- **Rainfall anomalies** correlate positively with NDVI due to improved leaf-water balance and reduced osmotic stress (Prihantono et al., 2022).

When the canopy patterns are viewed against the SOI and cumulative rainfall time series, the prevalence of interior stability and recovery aligns with wetter La Niña-dominated intervals. These periods increase freshwater inputs, reduce salinity stress, and support hydroperiods favourable for photosynthesis and canopy maintenance. This response is consistent with established eco-physiological understanding that mangrove canopy vigour typically improves under higher moisture availability and relaxed salinity stress, particularly in interior stands buffered from hydrodynamic exposure (Krauss et al., 2008; Hickey et al., 2021). However, ENSO variability should be considered a contributing influence rather than a singular driver of the observed canopy trajectories (Hickey et al., 2021; Prihantono et al., 2022).

Additionally, a major El Niño event occurred immediately prior to July 2016 and may have influenced pre-2016 canopy condition through reduced rainfall and elevated salinity. Due to limited high-resolution satellite data before 2016, the onset and recovery phases of this event cannot be assessed at comparable spatial detail.

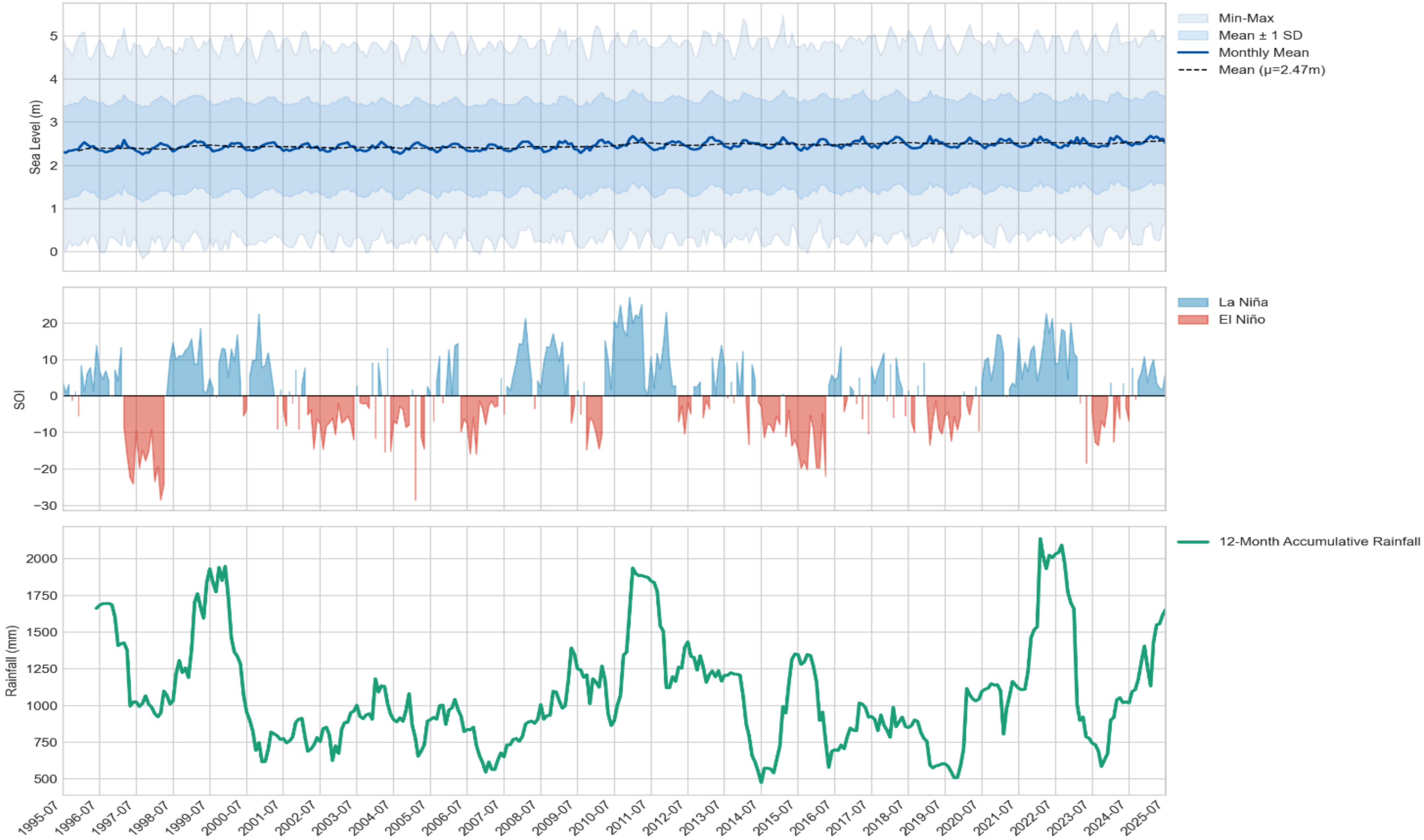

Figure 4.1 Long-term variability in sea level, ENSO (SOI) and rainfall

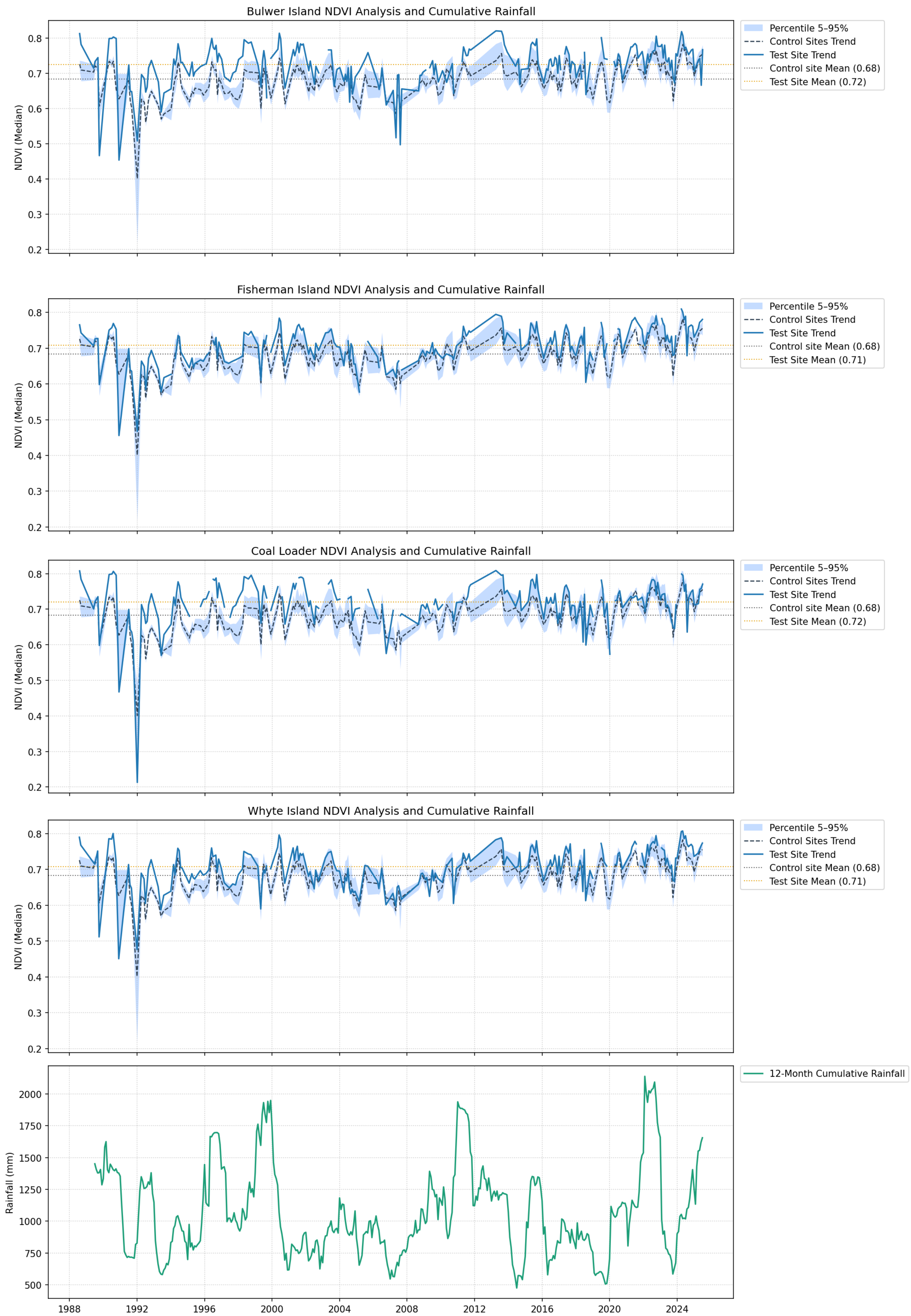

Figure 4.2 Temporal NDVI and cumulative rainfall

4.3.2 Sea-Level and Shoreline Analysis Context

Sea level is a recognised first-order driver of intertidal ecosystem adjustment, with sustained rise typically altering hydroperiods, reorganising sediment pathways and promoting landward migration of mangroves. In systems where sea level is the dominant influence, shoreline behaviour generally exhibits coherent, estuary-wide patterns, such as broad retreat or consistent translation of intertidal zones (Temmerman et al., 2013; Wang et al., 2021). However, the sea-level record for the assessment period is relatively stable, meaning it cannot account for the highly variable shoreline responses mapped across the test sites.

Instead of uniform landward movement, shoreline segments at the test sites alternate over short distances between erosion, stability and rapid accretion, a pattern more characteristic of local-scale hydrogeomorphic controls than of an estuary-wide water-level change (Temmerman *et al.*, 2013; Wang *et al.*, 2021). These local processes include:

- Tidal-current focusing, which intensifies erosion along channel margins and constricted shoreline sections
- Wave-energy exposure, particularly where fetch, vessel wake or flood-tidal currents directly impact the mangrove edge
- Sediment availability and transport, determining whether shoreline segments accrete, stabilise or erode
- Engineered structures, which modify hydrodynamic pathways, influence sediment budgets and alter shoreline stability.

These mechanisms collectively explain the spatial heterogeneity observed at Fisherman Islands, Bulwer Island, Whyte Island and Coal Loader, where erosion and accretion patterns occur in close proximity and cannot plausibly be attributed to sea-level trends alone.

Importantly, the spatial patterns in canopy condition correspond closely with these physical gradients. Across all sites:

- Non-recovered canopy is concentrated along exposed, erosion-prone outer edges and channel margins
- Stable and recovered canopy predominates in interior and semi-sheltered zones, where hydrodynamic forcing is lower, salinity variability is reduced, and substrate cohesion is higher.

These relationships are consistent with established eco-physiological understanding that edge mangroves experience greater physical and salinity stress, more frequent inundation extremes and reduced substrate stability, all of which inhibit canopy recovery relative to interior stands (Krauss et al., 2008). Taken together, the pattern of shoreline behaviour and associated canopy responses indicates that local geomorphic and hydrodynamic processes, not sea level, are the primary controls shaping long-term mangrove trajectories across the PBPL mangrove areas.

Overall, these results indicate a clear separation in mangrove behaviour through time: long-term canopy loss and limited recovery are concentrated along geomorphically unstable shorelines, whereas interior forests exhibit predominantly short- to medium-term, climate-driven variability with high recovery potential.

4.5 Mangrove Community Structure and Zonation Patterns

Mangrove structural patterns across the test sites reflect well-established zonation principles, where inundation frequency, substrate elevation, salinity and hydrological connectivity influence species distribution, canopy height and patch configuration.

The canopy-height data show that *Avicennia marina* dominates the seaward and mid-intertidal zones as tall (>10 m) or medium-height (2–10 m) closed to open forest, consistent with its tolerance for frequent inundation, higher sediment turnover and dynamic hydrodynamic settings typical of Moreton Bay. These tall to medium Avicennia stands form broad, continuous blocks at Fisherman Islands and Whyte Island, while Bulwer Island exhibits a more uniform *Avicennia* canopy with limited internal fragmentation. Coal Loader, in contrast, shows higher structural complexity, with narrow *Avicennia* extensions lining tidal creeks and small internal canopy breaks.

Areas classified as *Ceriops australis* (typically 2–5 m closed to open forest) occur primarily landward of *Avicennia* zones, forming distinct low-height patches most extensive at Fisherman Islands and Whyte Island. This distribution is broadly consistent with the eco-physiological traits of *Ceriops*, which favours higher intertidal positions, less frequent inundation, more stable substrate, and greater salinity tolerance relative to *Avicennia* (Krauss *et al.*, 2008; Perri *et al.*, 2023). However, the classification outputs also map *Ceriops* in several locations where hydrological and geomorphic conditions are less typical for this species, including in proximity to tidal channels, lower-lying flats, and areas of active hydrological flow. These occurrences likely reflect classification artefacts, where spectral and structural signatures resemble *Ceriops* (e.g., low, even-height canopies; substrates with oxidised or desiccated surfaces; or sharp tonal contrast with adjacent *Avicennia*, rather than representing fully established *Ceriops* communities.

Avicennia marina open forest classes (sparse encroachment) capture early-stage colonisation at mangrove–saltmarsh/claypan margins. These transitional bands are most evident at Fisherman Islands and Whyte Island, where low-height, widely spaced *Avicennia* individuals are expanding into shallow depressions and supratidal flats. Their distribution aligns with long-term extent mapping, which shows mangrove expansion into upper-intertidal habitats over several decades. Similar transitions have been observed in other tropical and subtropical coastal systems, where changes in inundation frequency, sedimentation, and freshwater availability favour mangrove recruitment at the expense of saltmarsh communities (Prihantono *et al.,* 2022). The presence of these sparse classes further supports the interpretation that recruitment is occurring in areas where geomorphic and hydrological conditions have recently become more favourable for mangrove species rather than mapping artefacts.

Comparison of canopy height and NDVI patterns shows that structural height does not reliably predict canopy vigour across the test sites. While tall stands in some mangrove systems correlate with high NDVI, the present analysis indicates that canopy condition is more strongly influenced by hydrodynamic stress, salinity variability and disturbance history than by structural development alone. At Whyte Island and Fisherman Islands, both tall and medium-height *Avicennia* stands exhibit a range of NDVI values, and low-height *Ceriops* patches often display moderate NDVI when positioned in hydrologically stable interior environments. Conversely, low NDVI is most consistently associated with exposed edges, eroding margins, or areas with restricted drainage, irrespective of canopy height. The exception remains Crab Creek at Whyte Island, where taller stands express higher NDVI, a pattern not replicated at the other test sites. This creek is the receiving environment of wastewater discharges, which appear to facilitate mangrove growth.

Overall, the mangrove mosaic across the study region is dynamic yet structured, shaped by species traits, disturbance histories, hydrological pathways, and geomorphic controls. This interplay continues to drive the spatial and temporal evolution of canopy condition in these heavily modified estuarine landscapes.

5 Conclusions

Overall, mangrove condition across Bulwer Island, the Coal Loader, Fisherman Islands and Whyte Island is stable and resilient. Mangrove structure and condition are primarily governed by local shoreline position and hydrodynamic setting, rather than by port operations.

Long-term monitoring indicates that mangrove canopy condition has remained stable, and in many areas improved, since the late 1980s. Canopy greenness is consistently comparable to, and often exceeds, regional background levels. High condition is maintained across interior and mid-intertidal forests, while lower canopy condition is confined to exposed shorelines subject to erosion or strong hydrodynamic forcing.

Mangrove extent has increased at Fisherman Islands and Whyte Island over the long term, largely through gradual expansion into adjacent saltmarsh and claypan areas. This pattern is consistent with regional trends and reflects natural responses to sedimentation and hydrological processes rather than anthropogenic impact.

Medium-term analyses confirm that most mangrove areas are stable or recovering. Locations that have not recovered are small, persistent, and closely associated with erosion-prone or exposed margins, indicating spatially constrained physical drivers rather than emerging system-wide decline.

Short-term change between 2024 and 2025 was minimal. Field observations show that detected changes reflect localised disturbance and regeneration, with no evidence of broad-scale canopy stress.

Long-term mangrove change is spatially constrained and primarily associated with erosion-prone shorelines, where canopy loss and limited recovery reflect persistent geomorphic forcing. In contrast, medium- and short-term changes within interior mangrove forests are largely climate-driven, varying from year to year in response to rainfall and hydrological conditions, and are typically followed by recovery. The spatial coincidence of long-term trends, medium-term canopy trajectories and short-term change confirms that long-term monitoring provides a reliable basis for anticipating where future mangrove change is most likely to occur.

Across all sites, geomorphic setting is the dominant control on mangrove condition. Exposed shorelines show greater variability, while interior and sheltered forests remain consistently healthy. Climatic variability influences year to year condition but acts as a secondary modifier rather than a primary driver.

In summary, mangroves surrounding the Port of Brisbane are stable and functioning as expected for this estuarine setting. Observed changes are localised, process-driven, and consistent with natural shoreline dynamics. Contemporary port-related effects were limited to highly localised mangrove loss at Bulwer Island adjacent to the Fish Passage works.

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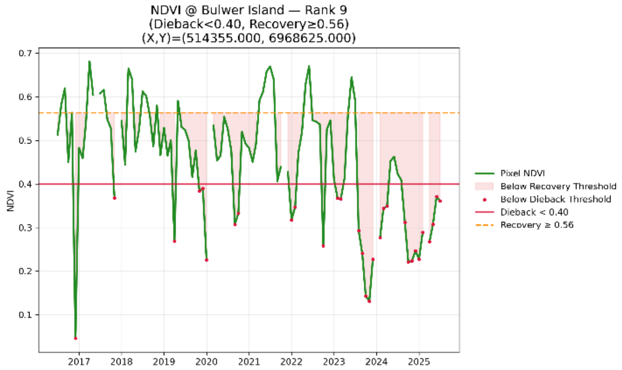
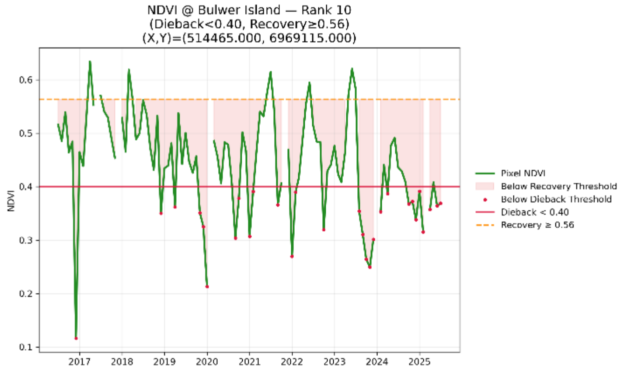
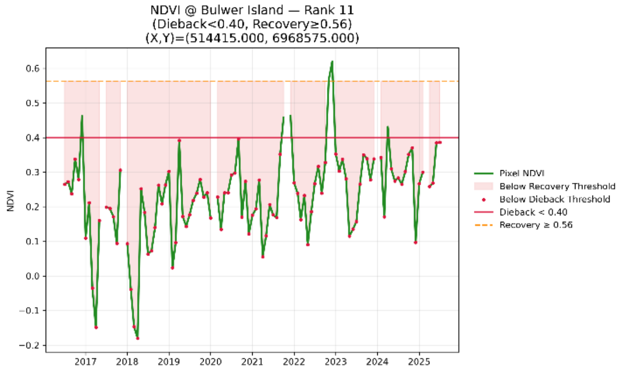
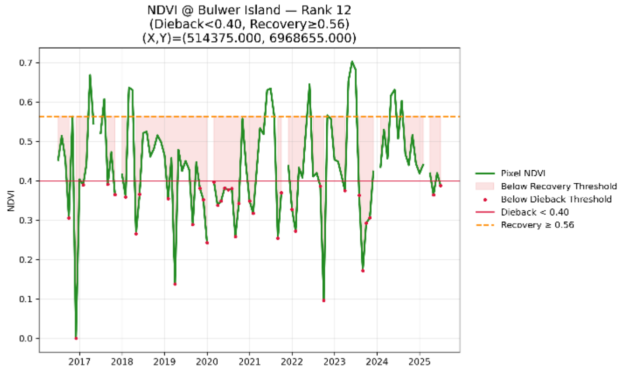
Annex A Detailed NDVI Trajectories for the Top 15 Non-Recovered Mangrove Locations at Each Site

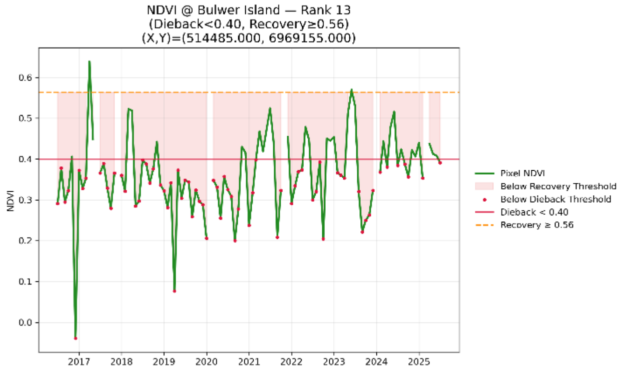
NDVI Time-Series for Ranked Points (Ranks 1–8), Bulwer Island

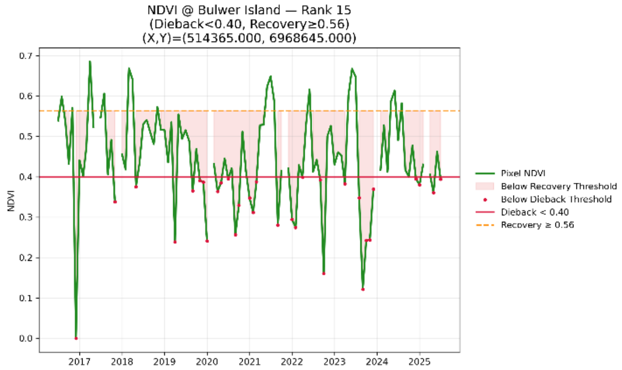


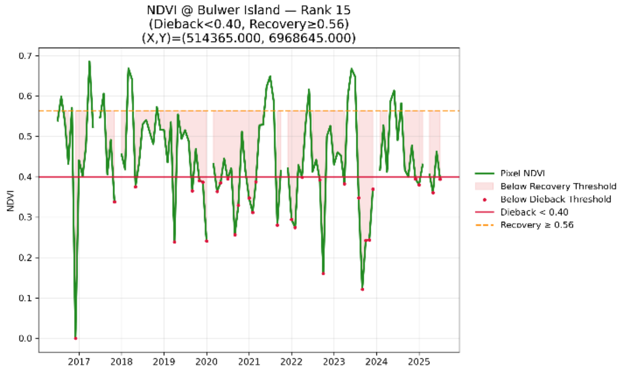




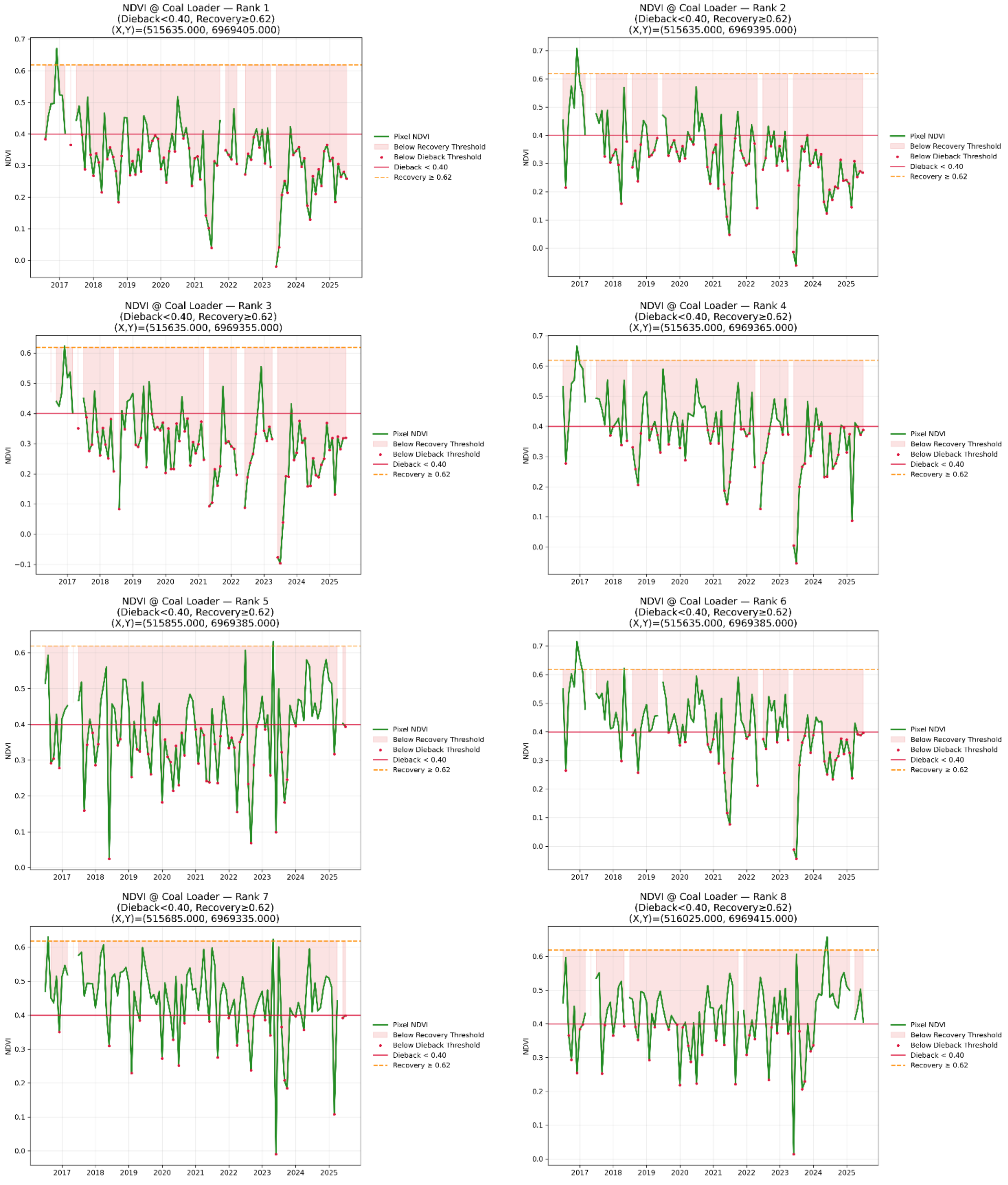








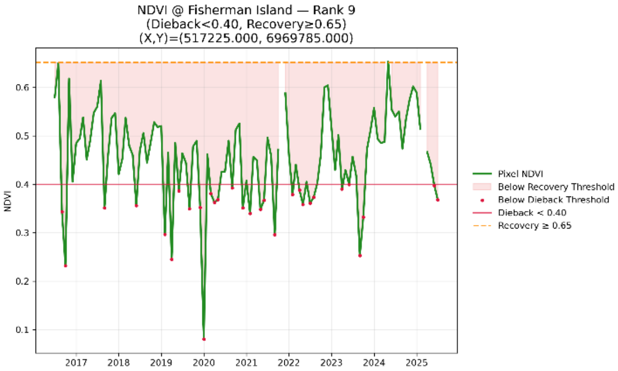
NDVI Time-Series for Ranked Points (Ranks 9–15), Bulwer Island

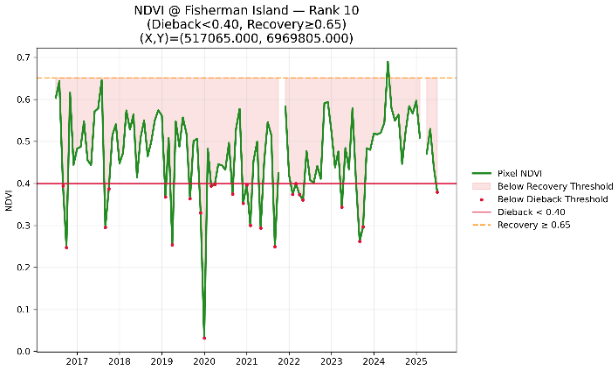


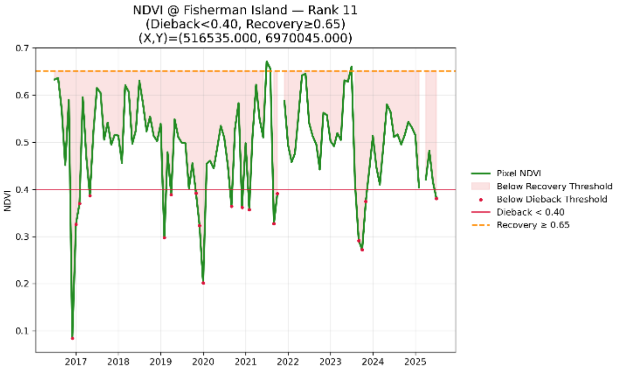
NDVI Time-Series for Ranked Points (Ranks 1–8), Coal Loader

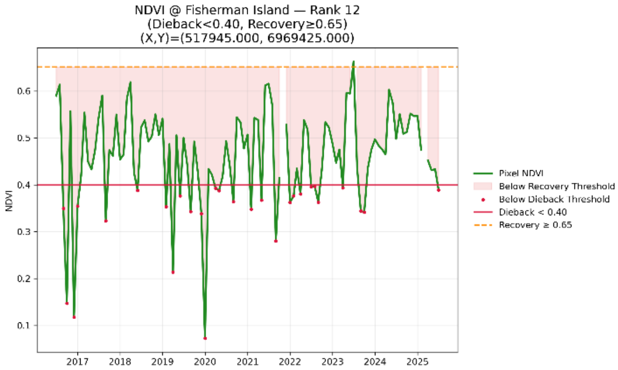
NDVI Time-Series for Ranked Points (Ranks 9–15), Coal Loader

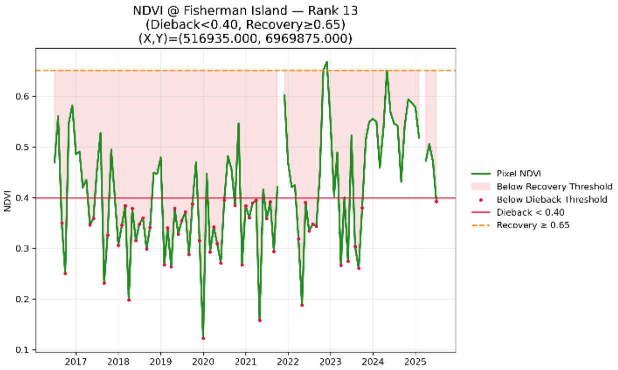
NDVI Time-Series for Ranked Points (Ranks 1–8), Fisherman Islands

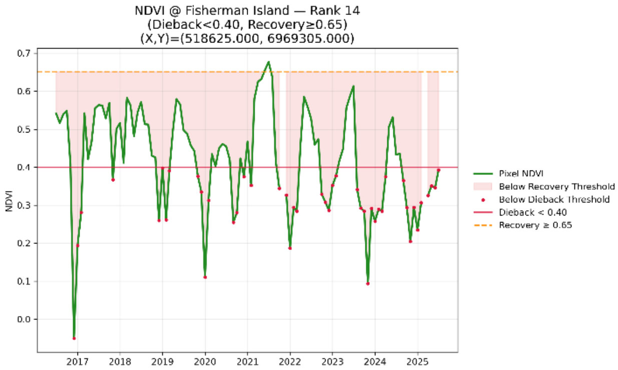


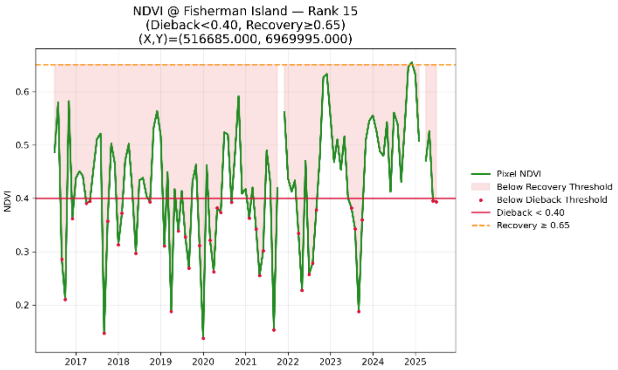








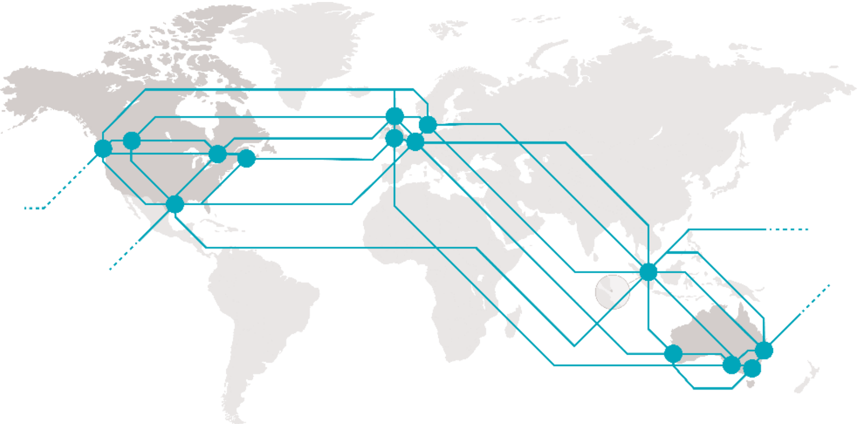




NDVI Time-Series for Ranked Points (Ranks 9–15), Fisherman Islands

NDVI Time-Series for Ranked Points (Ranks 1–8), Whyte Island

NDVI Time-Series for Ranked Points (Ranks 9–15), Whyte Island



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