WATER MOUSE MONITORING PLAN

NORTHERN LAND EXPANSION PROJECT (STAGE 1)
PORT OF GLADSTONE (CO22000089)

Prepared for
Gladstone Ports Corporation Limited

Biodiversity Assessment and Management Pty Ltd
PO Box 1376
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BAAM ECOLOGICAL CONSULTANTS

Specialised ecological knowledge that reduces your risk

Cover Page and Declaration of Accuracy (Proponent)

EPBC number: 2012/6558

Project name: Port of Gladstone Gatcombe and Golding Cutting Channel Duplication Project (CD Project) Stage 1 (Project Stage 1 means any aspect of the construction of the barge unloading facility and the southern reclamation area), Gladstone, Queensland

Approval holder and ABN: Gladstone Ports Corporation Limited, ABN: 96 263 788 242

Approved action: To duplicate the existing Gatcombe and Golding Cutting shipping channel, disposal of capital dredge spoil to land reclamation, and upgrade associated infrastructure in the Port of Gladstone, Queensland (see EPBC Act referral 2012/6558 approved by the Minister on December 2020).

Location of the action: Port of Gladstone, Queensland

Declaration of accuracy

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Signed	
Full name (please print)	RICHARD HAWARD
Organisation (please print)	Gladstone Ports Corporation Limited
Date	20 / 12 / 2024

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Date: 16/12/2024

Dr Penn Lloyd
Principal Ecologist and Director

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Signed

Full name (please print)

Penn Lloyd

Organisation (please print)

Biodiversity Assessment and Management Pty Ltd

Date: 16/12/2024

Glossary

BAAM	Biodiversity Assessment and Management Pty Ltd
CEMP	Construction Environmental Management Plan
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
ERMP	Ecosystem Research and Monitoring Program
GLM	Generalised linear model
GPC	Gladstone Ports Corporation Limited
JCU	James Cook University
NLEP-SRA	Northern Land Expansion Project - Southern Reclamation Area
REMP	Receiving Environment Monitoring Program
TropWATER	Centre for Tropical Water and Aquatic Ecosystem Research
WBRA	Western Basin Reclamation Area

EXECUTIVE SUMMARY

BACKGROUND

In 2020, Gladstone Ports Corporation Limited (GPC) received conditions of approval (EPBC 2012/6558) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the Port of Gladstone Gatcombe and Golding Cutting Channel Duplication Project (CD Project). This project will be conducted in stages, with Stage 1 currently scheduled to commence construction in October 2024. Stage 1 is named as the Northern Land Expansion Project Southern Reclamation Area (NLEP-SRA). The EPBC approval (EPBC 2012/6558) defines Project Stage 1 as meaning any aspect of the construction of the barge unloading facility and the southern reclamation area. However, the construction of the barge unloading facility is not being envisaged at this stage. Consequently, Project Stage 1 for the purposes of this Water Mouse Monitoring Plan is taken to mean any aspect of the construction of the southern reclamation area. A revised plan will be submitted for approval before any aspect of the construction of the barge unloading facility or Stage 3 can commence. Construction of the southern reclamation area involves the construction of a bund wall to create a new 111.12 ha reclamation area that will tie in west of the current Western Basin Reclamation Area for long-term placement of dredged material to the north of Fisherman's Landing. Construction of the barge unloading facility will occur at a later date and is not considered under this Water Mouse Monitoring Plan.

The EPBC Act approval for the Project requires GPC to comply with several conditions with regards to Water Mouse (*Xeromys myoides*) that is listed as a vulnerable species under the EPBC Act. These conditions include a requirement to implement a Water Mouse monitoring program.

PURPOSE

This monitoring plan sets out the monitoring methods, data analysis and reporting framework to ensure the monitoring program is capable of accurately monitoring and quantifying any changes to the extent and location of Water Mouse habitat, including foraging habitat and breeding places, until two years following completion of construction of Project Stage 1.

MONITORING PROGRAM

Water Mouse habitat is confined to mangrove and saltmarsh vegetation communities in the intertidal zone along the mainland shoreline adjacent to the NLEP-SRA project footprint. The western boundary of the construction footprint is separated from Water Mouse habitat by distances of 66 m to 250 m and no direct disturbance of Water Mouse habitat from the construction activities is expected to occur. To address the conditions of approval, the monitoring program has been designed to incorporate the following four components:

- **Mangrove and saltmarsh plot-based monitoring** - detailed monitoring of three representative plots in each of mangrove and saltmarsh vegetation in each of three subareas to detect and quantify change in the extent and condition of Water Mouse habitat, including mangrove vegetation structure (species composition, tree density, basal area) and biomass (kg woody material per hectare) and saltmarsh species composition and cover, running for a period of six years from the start of construction and continuing for 5-years post construction works.
- **Mangrove condition monitoring** - using six 1m^2 litterfall traps and six shoot observation stations (30 tagged canopy leafy shoots) in each subarea to monitor mangrove tree health, running for a period of six years from the start of construction and continuing for 5-years post construction works.
- **Remote-sensing to monitor the extent and condition of mangroves and saltmarsh** - measures of canopy extent and condition of both mangroves and saltmarsh derived from

remote sensing vegetation indices, collected on a monthly basis throughout each of three monitoring subareas during construction works and afterwards for five years.

- **Water Mouse breeding place monitoring** - To monitor the location and extent of Water Mouse breeding places, a survey will be conducted once each year (within period September to April inclusive) during construction and for two years following the completion of construction.

The two plot-based field monitoring components will be used to validate monthly fluctuations in mangrove and saltmarsh vegetation cover and condition detected by the remote-sensing vegetation indices of vegetation condition. The validated remote-sensing indices will be used to monitor mangrove and saltmarsh extent and condition throughout the monitoring areas.

DATA ANALYSIS FRAMEWORK

Potential project impacts on the extent and condition of mangroves and saltmarsh (Water Mouse habitat) will be analysed using an 'alert-to-action' risk matrix and associated triggers for corrective action. Each month, the monthly mapping of canopy density from remote sensing data will be compared to the maximum value previously recorded to derive an index of habitat condition. The value of this index for each of the three monitoring subareas will be interpreted using the 'alert-to-action' risk matrix outlined in **Table 1**, which provides the triggers for corrective action and subsequent management responses.

The implementation of corrective action management responses will depend on whether the impact is assessed as being caused by NLEP construction works, or from an external source such as a severe storm/cyclone. This distinction will be addressed by comparing data from the two monitoring sites adjacent to and therefore potentially impacted by the NLEP (subareas WBSC, WBEA) with the control subarea (WBSC) that is not expected to be impacted by NLEP construction works.

REPORTING

An annual monitoring report will be prepared to report the results of monitoring for the reporting year, comparison with previous results, review of the effectiveness and appropriateness of the monitoring program in meeting the monitoring program objectives, recommendations to inform relevant management plans to adaptively manage and mitigate impacts to Water Mouse habitat where new or increased impacts as a result of the action have been identified, and recommendations to inform the development and delivery of environmental offsets for any significant residual impacts on Water Mouse habitat, where relevant. At the end of the final year of monitoring, the annual monitoring report shall be prepared as a completion report that will be submitted to the Department within 6 months following the completion of the monitoring program.

Table 1. Proposed risk matrix for detecting impacts on mangrove and saltmarsh Water Mouse habitat and triggering corrective actions.

Impact Category	Habitat Impact Description	Green Fraction Trigger (%)	Monitoring subarea	Project Impact Risk	Monitoring Response	Investigative Response	Work Response	Mitigation Response
Normal	Normal seasonal variation in canopy condition	80-100	WBRA	Critical	Continue monitoring	None	Continue work	Continue maintenance
	Normal seasonal variation in canopy condition	80-100	WBEA	Vulnerable	Continue monitoring	None	Continue work	Continue maintenance
	Normal seasonal variation in canopy condition	80-100	WBSC	None (control)	Continue monitoring	None	Continue work	Continue maintenance
Notable	Likely habitat damage	60-80	WBRA	Critical	Continue monitoring	Identify cause	Continue work	Continue maintenance
	Likely habitat damage	60-80	WBEA	Vulnerable	Continue monitoring	Identify cause	Continue work	Continue maintenance
	Likely habitat damage	60-80	WBSC	None (control)	Continue monitoring	Identify cause	Continue work	Continue maintenance
Threatening	Anticipated habitat loss/damage	30-60	WBRA	Critical	Continue monitoring	Identify cause	Reduce work*	Apply mitigation
	Anticipated habitat loss/damage	30-60	WBEA	Vulnerable	Continue monitoring	Identify cause	Reduce work*	Apply mitigation
	Anticipated habitat loss/damage	30-60	WBSC	None (control)	Continue monitoring	Identify cause	Continue work	Apply mitigation
Severe	Moderate habitat loss/damage	10-30	WBRA	Critical	Continue monitoring	Identify cause	Stop work*	Apply mitigation
	Moderate habitat loss/damage	10-30	WBEA	Vulnerable	Continue monitoring	Identify cause	Stop work*	Apply mitigation
	Moderate habitat loss/damage	10-30	WBSC	None (control)	Continue monitoring	Identify cause	Continue work	Apply mitigation
Catastrophic	Extreme habitat loss/damage	0-10	WBRA	Critical	Continue monitoring	Identify cause	Stop work*	Apply mitigation
	Extreme habitat loss/damage	0-10	WBEA	Vulnerable	Continue monitoring	Identify cause	Stop work*	Apply mitigation
	Extreme habitat loss/damage	0-10	WBSC	None (control)	Continue monitoring	Identify cause	Continue work	Apply mitigation

* Work will continue if the change in Green Fraction index is confirmed to be due to external factors unrelated to the Project.

WATER MOUSE MONITORING PLAN

NORTHERN LAND EXPANSION PROJECT (STAGE 1), PORT OF GLADSTONE

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1.0 INTRODUCTION

1.1 BACKGROUND

In 2020, Gladstone Ports Corporation Limited (GPC) received conditions of approval (EPBC 2012/6558) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the Port of Gladstone Gatcombe and Golding Cutting Channel Duplication Project (CD Project). This project will be conducted in stages, with Stage 1 currently scheduled to commence construction in October 2024. Stage 1 is named as the Northern Land Expansion Project Southern Reclamation Area (NLEP-SRA) but was referred to in the EPBC Act approval as the Western Basin Expansion Southern Reclamation Area.

1.2 PROJECT DESCRIPTION

The EPBC approval (EPBC 2012/6558) defines Project Stage 1 as meaning any aspect of the construction of the barge unloading facility and the southern reclamation area. However, the construction of the barge unloading facility is not being envisaged at this stage. Consequently, Project Stage 1 for the purposes of this Water Mouse Monitoring Plan is taken to mean any aspect of the construction of the southern reclamation area. A revised plan will be submitted for approval before any aspect of the construction of the barge unloading facility or Stage 3 can commence. Construction of the southern reclamation area involves the construction of a bund wall to create a new 111.12 ha reclamation area that will tie in west of the current Western Basin Reclamation Area (WBRA; see **Figure 1.1** for location) for long-term placement of dredged material to the north of Fisherman's Landing. The NLEP-SRA will provide additional long-term storage capacity for future capital and maintenance (if required) dredging programs in the Port of Gladstone (e.g. Targinnie Channel, Gatcombe and Golding Cutting Channels).

Figure 1.1: Location of the proposed Northern Land Expansion Project Southern Reclamation Area (NLEP-SRA).

The proposed NLEP-SRA outer bund wall has been designed as a rock filled embankment structure comprising the following key elements:

- an inner bund comprising of hard, durable rock (core material) suitable for use in a marine environment;
- an outer, ocean-side face that will consist of a filter rock layer and armour rock (rip rap revetment) on the face and toe;
- an inner, reclamation-side face that will consist of geotextile layers and a filter sand layer as well as a reshaping rock berm on the face and toe; and
- a compacted (unsealed) surface on the crest of the bund wall composed of wearing course material.

The western boundary of the NLEP-SRA construction footprint is separated from Water Mouse habitat by distances of 66 m to 250 m (**Figure 1.1**) and no direct disturbance of Water Mouse habitat from the construction activities is expected to occur.

1.3 LEGISLATIVE REQUIREMENTS

The EPBC Act approval for the construction of the NLEP associated with the Port of Gladstone Gatcombe and Golding Cutting Channel Duplication Project (EPBC 2012/6558) requires GPC to comply with several conditions with regards to Water Mouse (*Xeromys myoides*) that is listed as a vulnerable species under the EPBC Act. The relevant conditions are outlined in **Table 1.1**, together with a reference to which sections of the Monitoring Plan each approval condition is addressed in.

Table 1.1. Outline of the Project conditions of approval (EPBC 2012/6558) relevant to the Water Mouse Monitoring Plan together with a reference to which sections of the plan each approval condition is addressed in.

Approval condition	Plan reference
(14) The approval holder must implement, commencing prior to the **commencement** of each relevant **Project Stage,** the following monitoring programs in respect of **Project Stage 1** and **Project Stage 3:**	
d. if **Water Mouse habitat**[1] is identified during baseline surveys required under Condition 11(c), a program capable of accurately monitoring and quantifying any changes to the extent, and location of **Water Mouse habitat**, including foraging habitat and breeding places, until 2 years following completion of construction of Project Stage 1 and Project Stage 3.	This plan
(17) All monitoring plans and programs required under conditions 14, 15 and 16 must:	
a. be designed and undertaken by a person suitably qualified to design and/or implement the specific plan or program and who is a **suitably qualified person,** such as a **suitably qualified field ecologist,** or a **marine sediment expert;**	Sections 2.2 and 2.4.6
b. be submitted for the **Minister's** approval prior to the **commencement** of the relevant **Project Stage;**	Stage 1 has not yet commenced
c. include commitments for reporting to the **Department** the relevant findings and outcomes of monitoring, including performance against specified monitoring	Section 3.0

[1] **Water Mouse habitat** means all mangrove communities, intertidal communities, and coastal freshwater wetlands with one or more of the following features:

- Intact hydrology
- Prey resources (crustaceans, marine polyclads and pulmonates and bivalves)
- Active Water Mouse nest structures
- A defined supralittoral bank that could enable construction of nests

As defined in the Referral guideline for the vulnerable Water Mouse *Xeromys myoides*, Commonwealth of Australia (2015).

Approval condition		Plan reference
	objectives, and procedures for undertaking periodic reviews of the effectiveness and appropriateness of the monitoring plan/program;	
d.	commit to submit completion reports to the **Department** within 6 months following the completion of each monitoring program (i.e. the completion of the monitoring in respect of the particular **Project Stage** which is the subject of the monitoring plan or program);	Section 3.0
e.	inform relevant management plans required by this approval to adaptively manage and mitigate impacts to **protected matters;** and	Sections 3.0 and 4.0
f.	be used to inform the development and delivery of environmental offsets for **protected matters.**	Section 3.0

2.0 MONITORING PROGRAM

2.1 OBJECTIVES

This monitoring plan sets out the monitoring methods, data analysis and reporting framework to ensure the monitoring program is capable of accurately monitoring and quantifying any changes to the extent and location of Water Mouse habitat, including foraging habitat and breeding places, until two years following completion of construction of Project Stage 1.

2.2 SUITABLY QUALIFIED ECOLOGISTS

This monitoring plan has been prepared by Dr Penn Lloyd and includes relevant components of a Mangrove and Saltmarsh Monitoring Program developed by Dr Norman Duke and Dr Adam Canning as part of the NLEP Seagrass and Mangrove Monitoring Program to meet conditions prescribed by the Queensland Government Coordinator General. Dr Norman Duke (Senior Research Scientist, Centre for Tropical Water and Aquatic Ecosystem Research, James Cook University) is a mangrove ecologist of more than 40 years standing, a specialist in global mangrove floristics, biogeography, climate change adaptation, vegetation mapping, pollution and coastal habitat condition assessment. Dr Adam Canning (Senior Research Officer, Centre for Tropical Water and Aquatic Ecosystem Research, James Cook University) is experienced in using networks to model the flow of nutrients through ecosystems, species distribution modelling, in sports fish and game bird management, and working at the interface between freshwater science and policy/planning. Dr Penn Lloyd has 30 years of field experience as a terrestrial ecologist, and has undertaken, managed or reviewed a wide variety of baseline studies, terrestrial ecology assessments for Environmental Impact Statements (EIS), and species and offsets management or monitoring plans/programs within the mining, infrastructure industrial and residential sectors, and is a Certified Environmental Practitioner (CEnvP) Ecology Specialist of the Environment Institute of Australia & New Zealand (EIANZ). Projects have included four Water Mouse surveys and habitat assessments completed on Curtis Island.

2.3 MONITORING PROGRAM COMPONENTS

To address the conditions of approval outlined in **Section 1.3**, the monitoring program has been designed to incorporate the following four components:

- **Mangrove and saltmarsh plot-based monitoring** - detailed monitoring of three representative plots in each of mangrove and saltmarsh vegetation in each of three sub-areas to detect and quantify change in the extent and condition of Water Mouse habitat, including mangrove vegetation structure (species composition, tree density, basal area) and biomass (kg woody material per hectare) and saltmarsh species composition and cover, running for a period of six years from the start of construction and continuing for 5-years post construction works.

- **Mangrove condition monitoring** - using six 1m^2 litterfall traps and six shoot observation stations (30 tagged canopy leafy shoots) in each sub-area to monitor mangrove tree health, running for a period of six years from the start of construction and continuing for 5-years post construction works.
- **Remote-sensing to monitor the extent and condition of mangroves and saltmarsh** - measures of canopy extent and condition of both mangroves and saltmarsh derived from remote sensing vegetation indices, collected on a monthly basis throughout each of three monitoring subareas during construction works and afterwards for five years.
- **Water Mouse breeding place monitoring** - To monitor the location and extent of Water Mouse breeding places, a survey will be conducted once each year during construction and for two years following the completion of construction.

The two plot-based field monitoring components will be used to validate monthly fluctuations in mangrove and saltmarsh vegetation cover and condition detected by the remote-sensing vegetation indices of vegetation condition. The validated remote-sensing indices will be used to monitor mangrove and saltmarsh extent and condition throughout the monitoring areas.

2.4 MONITORING METHODS

2.4.1 Background

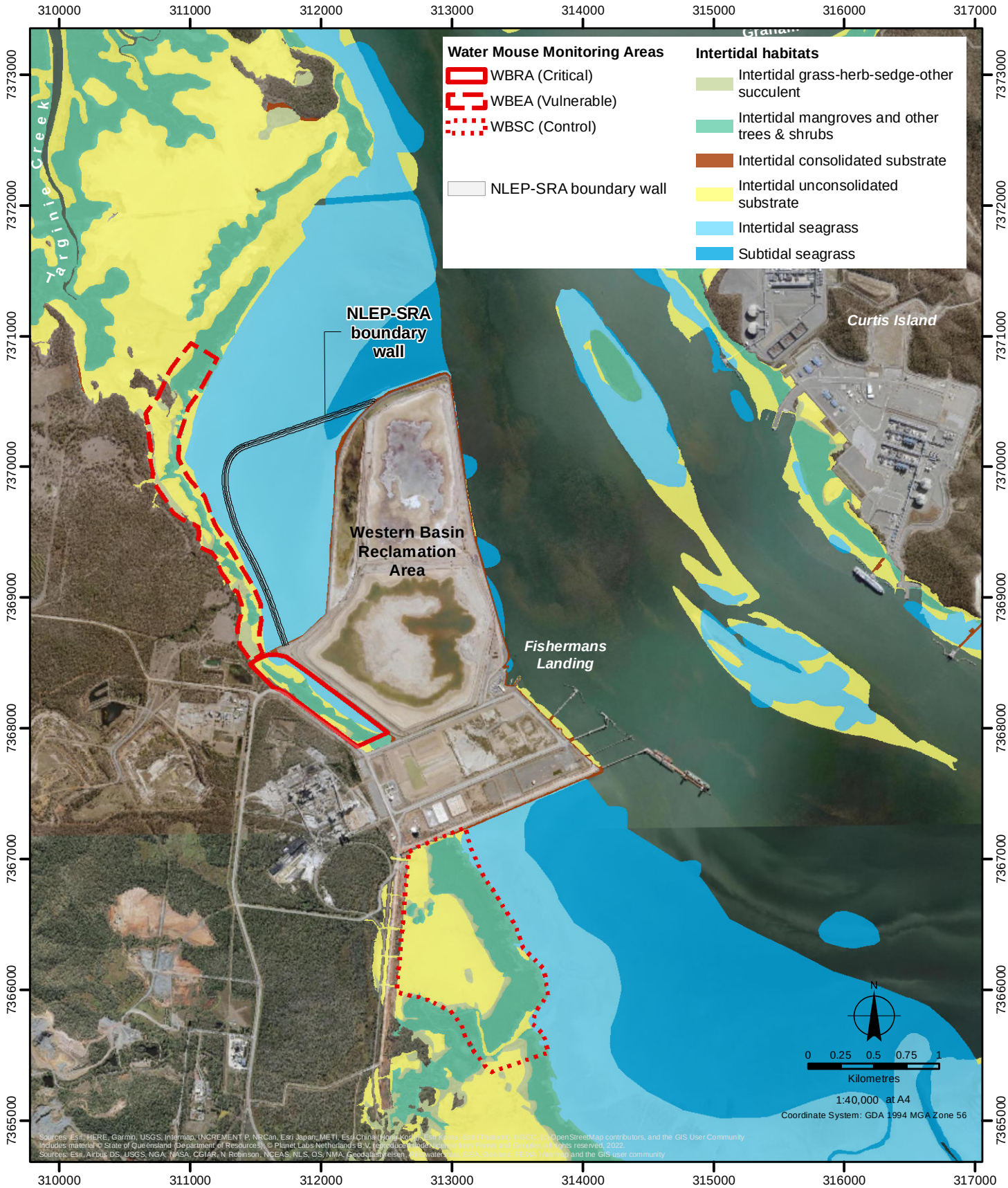
Three baseline surveys for Water Mouse were undertaken in 2020, 2021 and 2023 and reported in detail by Anastasi *et al*. (2024), included as **Appendix 2**. These surveys confirmed that Water Mouse habitat in the NLEP study area was confined to mangrove and saltmarsh vegetation communities in the intertidal zone along the mainland shoreline adjacent to the NLEP project footprint, where abundant prey resources were also present (Anastasi *et al.* 2024). The baseline surveys found evidence of prey remains consistent with those left by Water Mouse but did not find any evidence of characteristic Water Mouse nest structures, shelter sites or breeding places and did not confirm the presence of Water Mouse in the NLEP study area.

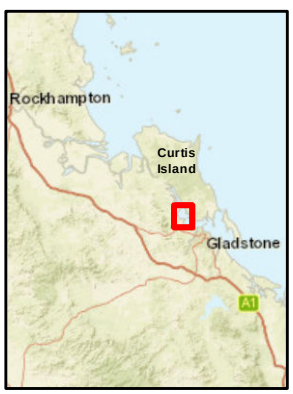
2.4.2 Monitoring Design

Monitoring will be conducted in three representative subareas of local shoreline mangroves (see **Figure 2.1**):

- the bunded area in the immediate vicinity of the Western Basin Reclamation Area (WBRA), which is considered most at risk of NLEP project impacts;
- the nearby area of the Western Basin Expansion Area (WBEA), which is considered vulnerable to NLEP project impacts; and
- a reference area nearby to the south and east, that will serve as a control site away from the construction area (WBSC).

The WBSC reference area is included as a control site to ensure influential factors affecting mangrove condition in the WBRA and WBEA are those associated with construction works rather than from external factors, such as a severe storm or tropical cyclone. The WBSC area has the desired features of proximity whilst suitably distant from construction works. Prior monitoring studies have evaluated the condition of mangroves in these three areas (e.g., Duke 2000; Duke & Burns 1999; Duke et al. 2000, 2003), including studies undertaken from 2011 to 2014 by Southern Cross University (SCU; Stokes and Bucher 2012, 2014), from 2015 to 2016 by Central Queensland University (CQU; Houston *et al.* 2016), and recently re-evaluated and documented in the ERMP final report regarding mangrove and saltmarsh monitoring throughout Port Curtis (Duke *et al.* 2022b). During the period 1996-2021, mangrove canopy density conditions in WBSC sites had maintained at a relatively constant level (~0.6 canopy density) while notable reductions (to ~0.3 canopy density) were recorded in treatment sites nearer to earlier construction works (**Figure 2.2**).





Data Sources:
Roost Sites:
BAAM - Sept 2023
Intertidal Habitats
https://gisservices2.information.qld.gov.au/arcgis/services, Name: WetlandMaps/MapB
Baseline Roads and Tracks - Queensland, Published 01/07/2022
Rail Network - Queensland, Published 17/05/2022
State of Queensland (Department of Resources) 2023

Drawn By: MapLass - KM **Reviewed by: PL** **Date: 25/06/2024**

Figure:	**2.1**
Title:	**Locations of mangrove and saltmarsh monitoring areas**
Project:	**CO22000089 Water Mouse Monitoring Plan**
Client:	**Gladstone Ports Corporation Ltd**

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Document Location: D:\Projects\BAAM\BAAM 2024-006 GPC Water Mouse\Output\0570-005-0001-B (Water Mouse Monitoring Plan).mxdDate: 25/06/2024 7:53:40 AM

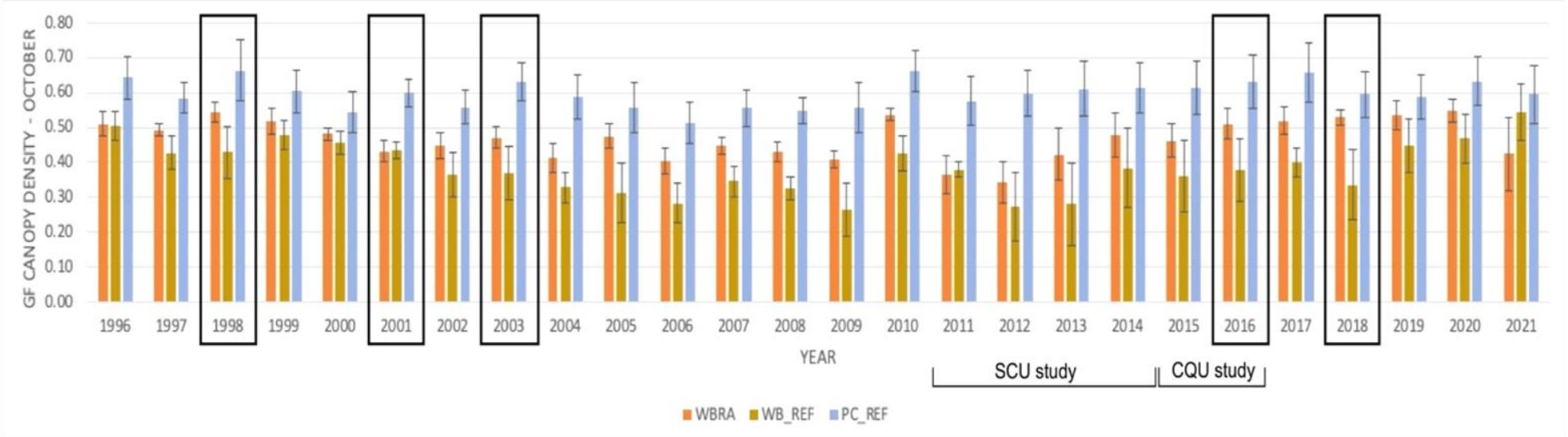

Figure 2.2. Historical time series of Green Fraction canopy density in each of three monitoring subareas: WBRA; WB_REF (now termed the WBEA; and PC_REF (now termed the WBSC) (from Duke *et al.* 2022b).
Mean canopy condition (green fraction NDVI, 1996-2021) was recorded each October for the three subareas. Treatments groupings of three or more replicates show Standard Error bars. Briefly, where bars do not overlap between treatments for any year, there were apparent differences between treatments. The NLEP monitoring program will address differences post 2021 and validate links with field measures. Meanwhile, the historical changes prior to 2021 provide firm evidence of the extent of significant sublethal impacts and their recovery during similar construction works in the recent past (note, black boxes indicating years of prior approved reclamation works). Two relevant monitoring studies mentioned in the text, include: SCU study (Stokes & Bucher 2012, 2014); and CQU study (Houston *et al.* 2016).

Notably, impacted sites had successfully recovered and regained canopy condition by 2021 (**Figure 2.2**). These long-term data and the lessons they provide, have informed the analysis framework outlined in **Section 2.5** below.

2.4.3 Mangrove and saltmarsh plot-based monitoring

To assess the structure and composition of mangroves and monitor mangrove condition, three 20 m x 10 m plots will be established in representative areas of mangrove vegetation within each of three sub-areas (nine plots in total):

- the critical bunded area in the immediate vicinity of the Western Basin Reclamation Area (WBRA), which is more likely to be impacted through reduced tidal flows resulting from change in hydrology from the construction of NLEP-SRA;
- the nearby vulnerable area of the Western Basin Expansion Area (WBEA), which is less likely to be impacted through reduced tidal flows resulting from change in hydrology from the construction of NLEP-SRA; and
- the control site reference area (WBSC).

Within each plot, forest structure (species, tree density, basal area) and biomass (kg woody material per hectare) will be measured prior to the start of construction in year 1, and remeasured in year 5.

To monitor the condition of saltmarsh vegetation, three 10 m x 10 m plots will be established in representative areas of saltmarsh vegetation within each of three sub-areas outlined above (nine plots in total). Within each plot, vegetation cover and condition (species, cover) will be measured prior to the start of construction in year 1 and remeasured in year 5.

2.4.4 Mangrove litterfall and shoot observations

To monitor the condition of mangroves in more detail, six 1 m^2 litterfall traps and six shoot observation stations (30 tagged canopy leafy shoots) will be established in each of the three sub-areas listed above. Litterfall trap contents will be collected each month for a minimum of 12 consecutive months in year 1, repeated in year 5. Each monthly sample will be sorted, dried and weighed as dry weight. Sorting involves separation of leaves, stipules, reproductive parts, wood and debris. Further field canopy condition measures will include below canopy light meter readings. These data are required to quantify variability in canopy condition through annual seasonal cycles, and to validate changes in canopy density when compared with remote-sensing (satellite) data (see under **Section 2.4.5** below). The detailed field data obtained from each 12-month record of canopy condition will be related to remote-sensing data to derive allometric equations to define satellite vegetation indices for use as proxies of the field measures of canopy condition. The confirmation of specific correlative relationships enables satellite measures of canopy condition to be used for the monitoring of mangrove canopy health over the full extent of the vegetation community.

2.4.5 Remote-sensing to monitor the extent and condition of mangroves and saltmarsh

This monitoring component focuses on using vegetation indices derived from remote sensing (captured by satellite) to quantify the extent and condition of both mangroves and saltmarsh vegetation communities. The Normalized Difference Vegetation Index (NDVI) will be used, which quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). NDVI is a proven index of vegetation density and health. Measures will be compiled monthly for a period of six years, starting from the initiation of construction and continuing for five years post-construction. These remote measures will be compared with the field-derived measures of mangrove and saltmarsh structure and condition described in **Section 2.4.3** above. These will provide direct comparison between measures

recorded in the field with remote-sensing measures from satellite data. The use of remote-sensing measures of canopy condition at specific point locations has been developed and proven as a highly beneficial and targeted tool for monitoring canopy condition. This innovative procedure has been called 'green faction' timeseries plots and is a proven method for the detailed assessment of widespread mass dieback of mangroves in the Gulf of Carpentaria (Duke *et al.* 2020a, b; 2022a) as well as for long term monitoring of mangroves in the Port Curtis region (**Figure 2.3**; Duke *et al.* 2022b). The 'green fraction' can be defined as:

$$Green\ Fraction\ (\%) = \frac{NDVI\ t}{NDVI\ max} x\ 100$$

Where: *NDVI t* = the value of NDVI at time *t*; and *NDVI max* = the maximum value of NDVI.

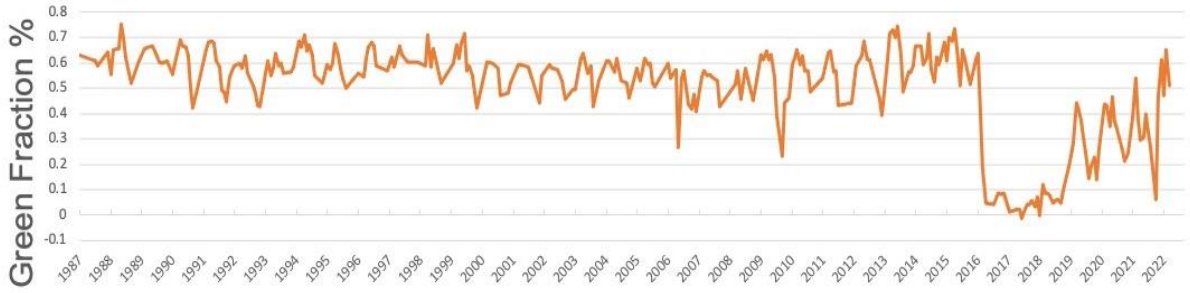

Figure 2.3. Monthly Green Fraction timeseries data (1987-2022) from satellite imagery shows changes in mangrove canopy condition at a Fisherman's Landing site, Site #8 (#PCPA_91), Port Curtis (-23.788089, 151.157345) (reproduced from Duke *et al*., 2022b).

Figure 2.3 illustrates the detection of notable mangrove dieback in March 2016 when the site was reclaimed during approved construction works. The monthly measures of canopy condition show the impact and proportional loss (down to 5-10%, from ~60%) at the time. Such data characterisation will be used to monitor mangrove and saltmarsh condition each month for a period of six years.

2.4.6 Water Mouse breeding place monitoring

To monitor the location and extent of Water Mouse breeding places, a survey will be conducted once each year during construction and for two years following the completion of construction. The survey will be conducted on foot during low tide, whereby a suitably qualified ecologist[2] will search the area of mangroves and saltmarsh and along the supralittoral bank throughout the monitoring area for the characteristic signs of Water Mouse shelter and breeding sites, as outlined in Department of Climate Change, Energy, the Environment and Water (2022). The monitoring area will comprise the Water Mouse habitat within the WBRA and WBEA monitoring subareas (see **Figure 2.1**) that have potential to be impacted by NLEP-SRA construction activities. Since Water Mouse may have reduced activity during the colder winter months (Department of Climate Change, Energy, the Environment and Water 2022), the shelter site surveys will be conducted within the period September to April inclusive. Shelter site searches are a recommended targeted survey method for Water Mouse (Department of Climate Change, Energy, the Environment and Water 2022). The locations of any sites that display characteristics consistent with Water Mouse presence will be recorded using GPS and documented (description of habitat and site, with photographs).

[2] A suitably qualified ecologist is defined by EPBC 2012/6558 as a person who has professional qualifications and at least three (3) years of work experience designing and implementing surveys for the protected matter and their habitat, and can give authoritative assessment and advice on the presence and habitat requirements for the protected matter using relevant protocols, standards, methods and/or literature.

2.4.7 Monitoring schedule and team

The monitoring program outlined in this plan will be implemented by the Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) at James Cook University (JCU) using the extensive knowledge gained by Dr Norman Duke and Dr Adam Canning in the rigorous assessment of mangrove condition and health gained over many decades. The monitoring will start one month prior to the start of NLEP-SRA project construction and the schedule is summarised in **Appendix 1**. JCU researchers will oversee the field program and provide the necessary training and specialized equipment. Land and Sea Rangers from the Gidarjil Development Corporation will be trained for collection of monthly and longer-term data collection and sampling, and their dispatch for sorting and processing. Gidarjil rangers will make monthly collections of litter samples, shoot observations plus the establishment and measurement of long-term plots. Each month, samples and data will be dispatched to JCU for sorting and processing by JCU staff. Where there are opportunities for delegation of higher-level tasks for the rangers in the Port Curtis region (such as the sorting and processing of samples), this will be encouraged, but re-evaluated each monthly period to ensure quality assurance.

2.5 MONITORING DATA ANALYSIS FRAMEWORK

This section outlines the approach to analysing the monitoring data to test whether the Project Stage 1 results in impacts on the extent and location of Water Mouse habitat, including foraging habitat and breeding places, summarised in **Table 2.1**. Potential impacts on the extent and condition of mangroves and saltmarsh (Water Mouse habitat) will be analysed using an 'alert-to-action' risk matrix and associated triggers for corrective action. Each month, the monthly mapping of the Green Fraction will be compared to the maximum value recorded by previous monitoring (Duke et al. 2022b) to derive an index of habitat condition. Monthly monitoring allows early detection (via reduction in NDVI) of sublethal stress that affects plant photosynthesis. The value of this index for each of the three monitoring sub-areas will be interpreted using the risk matrix outlined in **Table 2.2** against the following trigger levels for corrective action:

- **Normal** – Green Fraction 80-100% of the maximum value, indicating normal seasonal variation in habitat condition, with no action required;
- **Notable** – Green Fraction 60-80% of the maximum value, indicating habitat damage has likely occurred, triggering an initial alert to examine potentially harmful work practices that might cause habitat damage unless the change in Green Fraction index is confirmed to be due to external factors unrelated to the Project;
- **Threatening** - Green Fraction 30-60% of the maximum value, indicating anticipated habitat loss/damage, triggering a reduction in potentially harmful work practices that might cause habitat damage unless the change in Green Fraction index is confirmed to be due to external factors unrelated to the Project;
- **Severe** - Green Fraction 10-30% of the maximum value, indicating moderate habitat loss/damage, triggering a halt to construction work and detailed assessment of the cause of damage and appropriate mitigation measures unless the change in Green Fraction index is confirmed to be due to external factors unrelated to the Project; and
- **Catastrophic** – Green Fraction 0-10% of the maximum value, indicating extreme habitat loss/damage, triggering a halt to construction work and detailed assessment of the cause of damage and apply mitigation actions to reduce further harm unless the change in Green Fraction index is confirmed to be due to external factors unrelated to the Project.

Table 2.1. Summary of the monitoring data analysis framework.

Objective	Monitoring indicator	Trigger for investigation	Frequency
Test for an impact of the Project on Water Mouse habitat	Extent and condition of mangrove vegetation, measured using Green Fraction index.	As per the risk matrix in **Table 2.2**.	Monthly for a period of six years, starting one month before the start of construction works.
	Extent and condition of saltmarsh vegetation, measured using Green Fraction index.	As per the risk matrix in **Table 2.2**.	Monthly for a period of six years, starting one month before the start of construction works.

The impact criteria and risk matrix will be reviewed after six months of project start-up. While the hierarchy of severity ratings will remain, it is anticipated that management responses will need to be re-evaluated and amended in agreement with key stakeholders. The objective will be to ensure that altered mangrove conditions in the pertinent treatment groups have the appropriate type and degree of management response to minimise and avoid longer term and/or catastrophic environmental harm from NLEP-SRA construction works.

The implementation of corrective action management responses will depend on whether the impact is assessed as being caused by NLEP construction works, or from an external source such as a severe storm/cyclone. This distinction will be addressed by comparing data from the two monitoring sites adjacent to and therefore potentially impacted by the NLEP (subareas WBSC, WBEA) with the control subarea (WBSC) that is not expected to be impacted by NLEP construction works. Where the mangrove canopy loss is unrelated to the project activities (cyclone/storm or other) then stopping or amending the works would not be required.

Table 2.2. Proposed risk matrix for detecting impacts on mangrove and saltmarsh Water Mouse habitat and triggering corrective actions. This matrix will be reviewed and finalised within the first six months after project start up.

Impact Category	Habitat Impact Description	Green Fraction Trigger (%)	Monitoring subarea	Project Impact Risk	Monitoring Response	Investigative Response	Work Response	Mitigation Response
Normal	Normal seasonal variation in canopy condition	80-100	WBRA	Critical	Continue monitoring	None	Continue work	Continue maintenance
	Normal seasonal variation in canopy condition	80-100	WBEA	Vulnerable	Continue monitoring	None	Continue work	Continue maintenance
	Normal seasonal variation in canopy condition	80-100	WBSC	None (control)	Continue monitoring	None	Continue work	Continue maintenance
Notable	Likely habitat damage	60-80	WBRA	Critical	Continue monitoring	Identify cause	Continue work	Continue maintenance
	Likely habitat damage	60-80	WBEA	Vulnerable	Continue monitoring	Identify cause	Continue work	Continue maintenance
	Likely habitat damage	60-80	WBSC	None (control)	Continue monitoring	Identify cause	Continue work	Continue maintenance
Threatening	Anticipated habitat loss/damage	30-60	WBRA	Critical	Continue monitoring	Identify cause	Reduce work*	Apply mitigation
	Anticipated habitat loss/damage	30-60	WBEA	Vulnerable	Continue monitoring	Identify cause	Reduce work*	Apply mitigation
	Anticipated habitat loss/damage	30-60	WBSC	None (control)	Continue monitoring	Identify cause	Continue work	Apply mitigation
Severe	Moderate habitat loss/damage	10-30	WBRA	Critical	Continue monitoring	Identify cause	Stop work*	Apply mitigation
	Moderate habitat loss/damage	10-30	WBEA	Vulnerable	Continue monitoring	Identify cause	Stop work*	Apply mitigation
	Moderate habitat loss/damage	10-30	WBSC	None (control)	Continue monitoring	Identify cause	Continue work	Apply mitigation
Catastrophic	Extreme habitat loss/damage	0-10	WBRA	Critical	Continue monitoring	Identify cause	Stop work*	Apply mitigation
	Extreme habitat loss/damage	0-10	WBEA	Vulnerable	Continue monitoring	Identify cause	Stop work*	Apply mitigation
	Extreme habitat loss/damage	0-10	WBSC	None (control)	Continue monitoring	Identify cause	Continue work	Apply mitigation

* Work will continue if the change in Green Fraction index is confirmed to be due to external factors unrelated to the Project.

3.0 REPORTING

An annual monitoring report will be prepared, which will include the following information at a minimum:

- EPBC approval number;
- results of monitoring for the reporting year, including:
    - results of mangrove and saltmarsh plot-based monitoring;
    - results of mangrove litterfall and shoot observation monitoring;
    - total area (in hectares) and condition (Green Fraction index) of Water Mouse habitat (mangroves and saltmarsh) in each of the three monitoring areas (WBRA, WBEA, WBSC), including mapping and temporal trends; and
    - results of Water Mouse breeding place monitoring;
- comparison of the monitoring results for the current year of reporting with the monitoring results from the previous years of reporting, including comparison of mangrove and saltmarsh extent and condition with the pre-construction (baseline) monitoring results that extend back to at least 1990 (Duke et al. 2003, 2022b);
- review of the effectiveness and appropriateness of the monitoring program in meeting the monitoring program objectives outlined in **Section 2.1**;
- recommendations to inform relevant management plans required by EPBC 2012/6558 to adaptively manage and mitigate impacts to the extent, and location of Water Mouse habitat, where relevant (see **Section 4.0**); and
- recommendations to inform the development and delivery of environmental offsets for any significant residual impacts on Water Mouse habitat, where relevant.

At the end of the final year of monitoring, the annual monitoring report shall be prepared as a completion report that will be submitted to the Department within 6 months following the completion of the monitoring program.

4.0 LINKAGES WITH OTHER PLANS

GPC is required to develop and implement several other management and monitoring plans to address the full requirements of approval conditions under both Commonwealth and Queensland legislation. The interaction between the Water Mouse Monitoring Plan and these other plans is summarised in **Table 4.1**.

Table 4.1 Description of other management plans and linkages with the Water Mouse Monitoring Plan.

Management Plan	Purpose	Link to legislation or approval	Link to Water Mouse Monitoring Plan
Construction Environmental Management Plan (CEMP)	Systems and controls for minimising the risk of environmental impacts associated with the construction of the NLEP-SRA outer bund wall.	EPBC approval Condition 20 Development Permit DA2022/10/01 Condition 27 Environmental Authority PA-EA-100261837	Informs interpretation of ecological triggers, monitoring and management through adaptive processes set out in the CEMP.

Management Plan	Purpose	Link to legislation or approval	Link to Water Mouse Monitoring Plan
Receiving Environment Monitoring Program (REMP)	Describes the receiving environment attributes, environmental monitoring and related adaptive management actions designed for the NLEP-SRA.	EPBC approval Conditions 14-17 Development Permit DA2022/10/01 Condition 27 Environmental Authority PA-EA-100261837	Links with the overarching REMP and informs interpretation of ecological triggers, monitoring and management through adaptive processes set out in the REMP.
NLEP-SRA Offset Strategy	To deliver environmental offsets to compensate for significant residual impacts of the NLEP-SRA on matters of national environmental significance.	EPBC approval Conditions 19 and 31	Will inform the significant residual impact report prepared within six months of the completion of the monitoring program and any necessary updates to the NLEP-SRA Offset Strategy.

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APPENDIX 1

Monitoring Schedule

Table A1. The six-year schedule of the Water Mouse monitoring plan. Project participants: JCU team, ND = Norm Duke, AC = Adam Canning; and Gidarjil Development Corporation (GDC): G3 = 3 Gidarjil rangers (1 senior, 2 junior).

Mangroves & Saltmarsh	**Year 1**		**Year 2**		**Year 3**		**Year 4**		**Year 5**		**Year 6**	
	JFMAMJ	JASOND	JFMAMJ	JASOND	JFMAMJ	JASOND	JFMAMJ	JASOND	JFMAMJ	JASOND	JFMAMJ	JASOND
1A) Field site selection & setup	ND/AC/G3											
1B) Field plots long-term biomass	ND/AC/G3								ND/AC/G3			
1C) Field monthly litterfall collection	ND/AC/G3	ND/G3	ND/G3						ND/G3	ND/G3		
1D) Field data processing	ND/AC	AC	AC						AC	AC		
2) Remote sensing data acquisition	ND/AC	AC	AC	AC	AC	AC	AC	AC	AC	AC	AC	AC
3) Water Mouse breeding place monitoring	ND/AC/G3		ND/AC/G3		ND/AC/G3		ND/AC/G3		ND/AC/G3		ND/AC/G3	ND/AC
4A) Reporting 6-monthly	ND/AC	ND/AC	ND/AC	ND/AC	ND/AC	ND/AC	ND/AC	ND/AC	ND/AC	ND/AC	ND/AC	ND/AC
4B) Reporting Final												ND/AC

APPENDIX 2

Western Basin Expansion (WBE) reclamation area (southern area) and barge unloading facility (BUF) – Water Mouse (Yirrkoo) Survey

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Western Basin Expansion (WBE) reclamation area (southern area) and barge unloading facility (BUF) – Water Mouse (Yirrkoo) Survey

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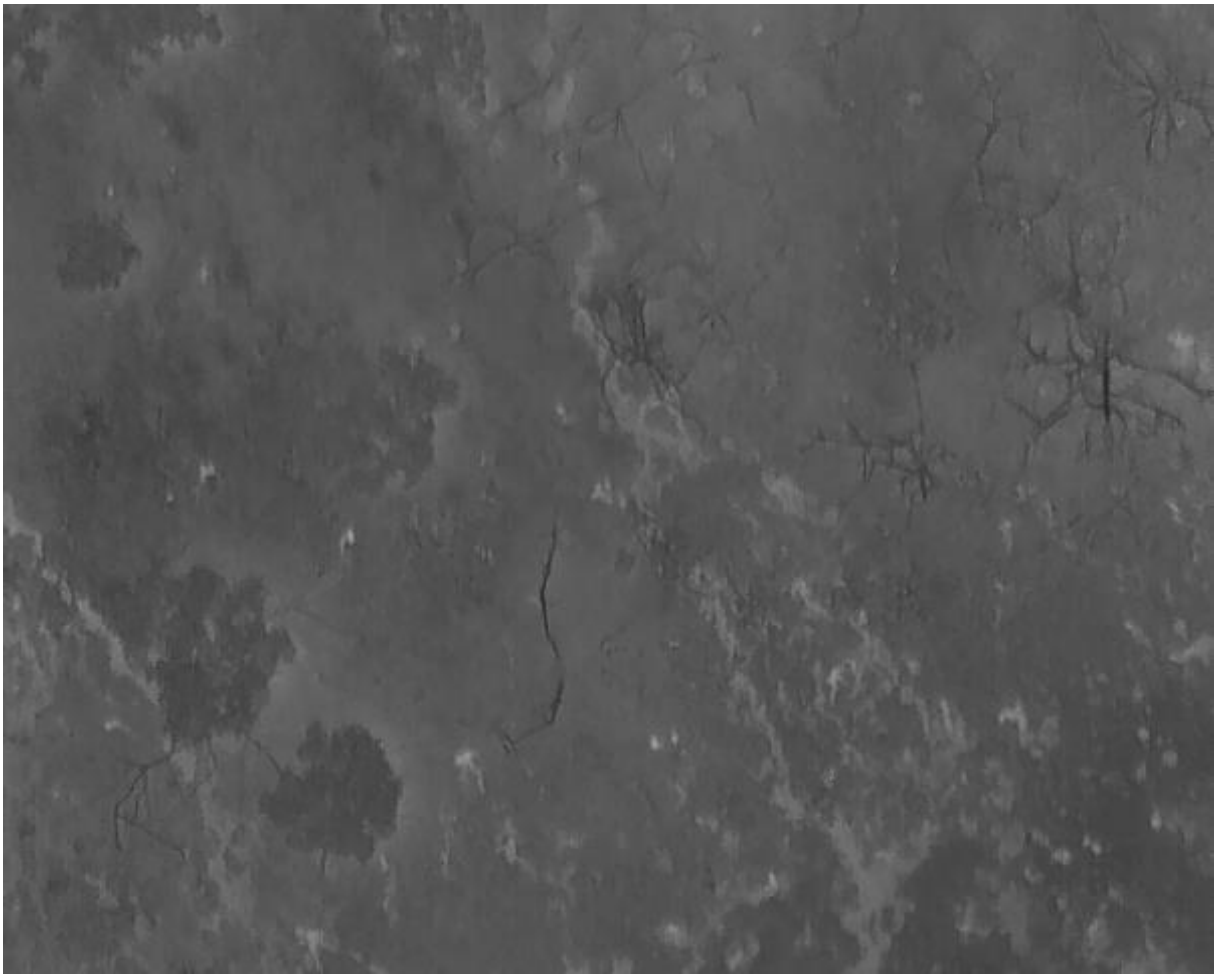

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1.4	06/08/2021	Final	AA	AA, SG, RM, DJ, ELJ	ELJ	ELJ

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Acronyms

AGL	Above Ground Level
CD	Channel Duplication
WBE	Western Basin Expansion
BUF	Barge Unloading Facility
EIS	Environmental Impact Statement
WBRA	Western Basin Reclamation Area
GPCL	Gladstone Ports Corporation Limited

Executive summary

To validate the results of the 2020 Yirrkoo survey, an additional Yirrkoo survey, to be completed in Autumn 2021, was recommended. It was recommended that camera trapping should be undertaken to verify the potential Yirrkoo nesting site identified in the WBE adjacent survey area during the 2020 Yirrkoo survey. Additionally, the possible nest structure incidentally observed in the WBRA bunded area during the mangrove and other foreshore marine plants survey during late 2020 was also recommended to be investigated as Yirrkoo may disperse to the WBE adjacent survey area from the WBRA bunded area.

During the 2020 Yirrkoo survey, no observations of Yirrkoo were made, though suitable habitat and abundant prey resources were present within the survey area.

Potential threats to Yirrkoo and Yirrkoo habitat were also observed during the 2020 Yirrkoo survey. The site is heavily impacted by cattle and evidence of predator species was evident. These disturbances have the potential to impact on the nesting habits of the Yirrkoo.

Additional camera trapping was undertaken to verify the possible Yirrkoo nesting site identified in the WBE adjacent survey area during the 2020 Yirrkoo survey and the possible nest structure incidentally observed in the WBRA bunded area during the 2020 mangrove and other foreshore marine plants survey. In a novel approach, a combination of ground truthing and radiometric thermal mapping were utilised to allow for targeted placement of day/night motion triggered camera traps within the survey areas.

Radiometric thermal mapping identified numerous possible small mammal hot spots throughout the survey areas. Many of these hot spots were identified as non-target species (kangaroos, birds, pigs etc.), however, 10 of the hot spots were the right size, shape, and location to be potential Yirrkoo signature hot spots. These 10 sites, along with the two potential nest sites identified during the 2020 surveys were used as the basis for placing the camera traps.

Over the course of the 13 day/nights that the camera traps were deployed, a total of 23,384 photos were taken. The majority were accidental triggering of the camera by tree or water movement. Additionally, photos of pest species were also captured. Many of these pest species are also Yirrkoo predators (pigs, foxes etc.). Some small animal activity was captured by one camera in the WBE adjacent survey area. Eye shine from multiple small animals was observed moving around fallen trees. Definitive identification of the animals was not available. It is possible that the animals in the photo are Yirrkoo but is also equally possible that they are another small native, or invasive, rodent, or other small animal. No definitive images of Yirrkoo were captured by any camera at any time.

Radiometric thermal mapping was successfully used to map the survey area and identify potential Yirrkoo hotspots. This method was also proven useful for other small and large animal species (kangaroos, pigs, birds), and may be of use in future animal-based surveys of the area.

Camera trapping identified several species of animal in the survey area, native and pest, as well as an unidentified small animal that was only observable via the shine from its eyes being present in the camera images.

No observations of Yirrkoo were made during the survey.

1 Introduction

1.1 Background

Gladstone Ports Corporation Limited (GPC) is currently progressing the Port of Gladstone Gatcombe and Golding Cutting Channel Duplication Project (CD Project) beyond the Environmental Impact Statement (EIS) phase. As part of these works, GPC has initiated commencement of engineering design, post-EIS studies and associated regulatory approvals for the Western Basin Expansion (WBE) reclamation area (southern area) and barge unloading facility (BUF) components of Stage One (1) of the CD Project.

Included within the post-EIS studies scope is the need to undertake a range of ecological monitoring prior to start of construction activities inclusive of mangrove and foreshore vegetation, pest and weed, vegetation survey and the animal breeding place survey. All monitoring was conducted in areas adjoining the WBE reclamation area (southern area) and the hauls road (as required).

During 2020, a pre-construction animal breeding place survey inclusive of Water Mouse (Yirrkoo, *Xeromys myoides*) and their potential habitat was carried out in areas adjacent to the direct impact area of the Western Basin Expansion (WBE) reclamation area (southern area) of the CD project (Anastasi et al., 2020). This included the intertidal area adjacent to the direct impact area of WBE reclamation area and extended to 100 m within the patches of terrestrial vegetation intersected by the indicative survey area (WBE adjacent survey area) (Figure 1).

Figure 1: Location of the CD Project mangrove and foreshore vegetation survey area. WBE adjacent survey area (red dashed lines) and WBRA bunded area (solid red line).

In accordance with the Referral Guidelines for the Vulnerable Water Mouse (Department of Environment, 2015) (Yirrkoo, *Xeromys myoides*), the extent and location of Yirrkoo habitat, including foraging habitat and breeding places and an estimate of the likely current population present, within the area that could be indirectly impacted by Project Stage 1 and/or Project Stage 3 was preliminarily determined. Yirrkoo are a nocturnal, carnivorous rodent. Adults are between 8 and 13 cm body length with a tail of 7 to 10 cm, and about 4 cm high. Yirrkoo require mangrove communities and associated saltmarsh, sedge lands, clay pans, heathlands and freshwater wetlands with intact hydrology that provide adequate nest sites and prey resources. Where present, it may also use a supralittoral zone (with or without supralittoral bank) for the construction of nest mounds. The species can construct nests in trees, hollows, simple tunnels excavated in elevated banks and freestanding mud mounds (Burnham 2000, Russell and Hale 2009).

In 2020, an initial Yirrkoo survey of the length of supralittoral zone within the WBE adjacent survey area was searched for potential Yirrkoo nesting banks. To minimise disturbance to the area, the transects that were previously established for mangrove vegetation surveys were also used to further assess for Yirrkoo breeding places. Surveys were conducted during the day, with a team of four travelling parallel to each other on foot through the intertidal zone 10 m apart in thick vegetation and 20 m apart in thinner vegetation. Each transect was searched for potential nest structures including nest mounds, tree, and log hollows. Potential nest sites in larger mature mangroves such as *Avicennia marina* and the base of trees with buttress roots such as *Ceriops tagal* were also examined for mud ramp-like structures associated with Yirrkoo nesting sites. Areas of higher ground in and around the mangrove, mudflat and saltpan areas were also searched. Other potential indicators of the presence of Yirrkoo were also noted, included the availability of food resources such as crustaceans such as grapsid crabs and mud lobsters, worms, and molluscs. Particular attention was also paid to the floor of the littoral zone and hollows at the bases of trees to identify shell middens, another key indicator of Yirrkoo nesting areas.

During the 2020 Yirrkoo survey, no direct observations of Yirrkoo were made, though suitable habitat and abundant prey resources were present within the survey area. As Yirrkoo are a fully nocturnal species, direct observation during daylight surveys is not expected and previous surveys focused on identification of potential nest sites.

Throughout the WBE adjacent survey area, there is an absence of a supralittoral bank suitable for Yirrkoo nesting, except for two small areas which had no sign of nest structure. There are limited areas of elevated marine couch (*Sporobolus virginicus*) grassland which provide suitable Yirrkoo habitat, though a vehicular access track disturbs the key transitional zone between the mangrove/couch interface along parts of the site. Throughout the site, there are wide claypan and saltpan areas behind the mangrove community where food resources for the Yirrkoo are usually less abundant.

A supralittoral bank is often absent in Central Queensland. Yirrkoo habitat in the Central Queensland area may be more diverse than generally observed elsewhere and include similar habitat types to those utilised by Yirrkoo in Southeast Queensland (DAWE, 2019). In Central Queensland Yirrkoo has been captured from a permanent weed swamp one mile from a beach and in Southeast Queensland a variety of habitats including 25 m from a stream fringed with Casuarina and inside a 5-year-old slash pine plantation (DAWE, 2019).

Ceriops tagal (yellow mangrove) and *Avicennia marina* (grey mangrove) and some *Aegialitis annulata* (club mangrove) edge the landward margins across the survey site with larger stands of *Rhizophora stylosa* (red mangrove) the dominant species to the seaward margins. The landward mangrove margins provide suitable habitat for Yirrkoo. The areas of *R. stylosa* are dense, with few hollows and due to the height of the tide in the seaward margin, Yirrkoo are unlikely to nest here as the nests would need to be very high to escape the water.

Throughout the WBE adjacent survey area, there were elevated areas of coarse material consisting mostly of shells. Although the coarse substrate is generally less suitable for nesting and foraging for Yirrkoo, in this area the substrate is suitable habitat as tidal influence on nests built in this area would be much less. Trees were searched for hollows in these areas, but no evidence of prey middens or nest structures were observed amongst them.

There are a few larger grey mangroves (*Avicennia marina*), some with hollows, and yellow mangroves (*Ceriops tagal*) near the supralittoral edge. One possible nest structure was observed here between buttress roots, however, fresh mud plastering/ daubing characteristic of Yirrkoo was not evident. No odour was observed and there was no evidence of prey middens in the vicinity of this possible nesting site.
An abundance of live prey items suitable for Yirrkoo foraging were observed, particularly within the mangrove stands, including a variety of grapsid crabs and mud lobsters. Some prey remains/remnants of grapsid crabs carapaces were observed, however, these were randomly spread out throughout the littoral zone. No remains were observed in formation of prey middens, feeding areas, on feeding platforms or near nest structures which could be an indicator of Yirrkoo presence.

To validate the results of the initial survey, additional camera trapping was undertaken to verify the potential Yirrkoo nesting site identified within the WBE adjacent survey area during the 2020 Yirrkoo survey, and the possible nest structure incidentally observed in the Western Basin Reclamation Area (WBRA bunded area) (Figure

1) during the mangrove and other foreshore marine plants survey during late 2020. In a novel approach, a combination of ground truthing and radiometric thermal mapping were utilised to allow for targeted placement of day/night motion triggered camera traps within the survey areas. Thermal mapping has been used previously for other large mammals at larger resolutions (Gooday et al. 2018, Kays et al. 2019). In a wildlife survey by Focardi et al. (2001) thermal infrared imaging was compared to spotlighting. They found that thermal imaging was, on average, more efficient than spotlighting, which detected only 53.8% of the animals observed by thermal imaging. Thermal mapping has been suggested, and previously used for less invasive detection of threatened nocturnal animal species (Vinson et al. 2020).

1.1 Scope and aims

To validate the results of the 2020 Yirrkoo survey, an additional Yirrkoo survey, to be completed in Autumn 2021, was recommended. It was recommended that camera trapping should be undertaken to verify the potential Yirrkoo nesting site identified in the WBE adjacent survey area during the 2020 Yirrkoo survey. Additionally, the possible nest structure incidentally observed in the WBRA bunded area during the mangrove and other foreshore marine plants survey during late 2020 was also recommended to be investigated as Yirrkoo may disperse to the WBE adjacent survey area from the WBRA bunded area.

1.2 Site description

The survey area is approximately 30 ha of mangrove community, saltpan, mudflats, and sclerophyll woodlands. The mangrove areas are patchy and not continuous throughout the survey area and vary in depth from the landward to seaward margin (2 m - 50 m). There is a distinct ecotone between the dry sclerophyll woodlands directly behind the tidal saltpan and mangrove communities.

Potential threats to Yirrkoo and Yirrkoo habitat are present within the survey area. The site is heavily impacted by cattle and predator species frequent the area. Suitable Yirrkoo habitat is present within the survey area, and prey resources are abundant.

The survey area has a macro-tidal range (> 4 m), during the survey period, the maximum tidal range was 4.07 m on 24 June.

2 Methods

Low altitude radiometric thermal mapping was undertaken on 21-22 May 2021 and 8-9 June 2021.

Camera trapping was undertaken between 18 June – 1 July 2021.

To validate the results of the 2020 Yirrkoo survey, further surveys were carried out in areas adjacent to the direct impact area of the Western Basin Expansion (WBE) reclamation area (southern area) of the Channel Duplication (CD) project. This included the intertidal area adjacent to the direct impact area of WBE reclamation area and extended to 100 m within the patches of terrestrial vegetation intersected by the indicative survey area (Figure 1), where these areas are relevant to the Yirrkoo. As a possible Yirrkoo nest structure was also incidentally observed within the WBRA bunded area, this survey was extended to include the WBRA bunded area (Figure 1).

The information and data gathered during the 2020 Yirrkoo survey, as part of the Pre-Construction Animal Breeding Place Survey: Spring 2020 (Anastasi et al. 2020), was used to inform the basis of this survey. Given the lack of positive indicators of Yirrkoo at the location, site selection for nocturnal camera trapping was informed using high resolution thermal imaging drone cameras.

2.1 Radiometric thermal mapping

Mapping was carried out under two different conditions to account for different potential activity periods of the Yirrkoo. Firstly, just after last light on a falling tide and then at low tide in the middle of the night. Licensed drone pilots from Queensland Aerial completed low altitude radiometric thermal mapping of the extended survey area (WBE adjacent survey area and WBRA bunded area) to map nocturnal Yirrkoo activity (Figure 2). The surveys were carried out over a total of four (4) nights.

The WBE adjacent survey area was mapped on 21 May 2021 between the hours of 1800 and 2100 (last light: 1742, low tide: 2321; 1.33 m). The weather was calm and clear with an average temperature of 16 °C. The drone

was flown at an altitude of 50 m above ground level (AGL), giving a ground resolution of 5 cm per pixel. Approximately 3000 photographs were taken.

The WBRA bunded area was mapped the following day (22 May 2021) between 1815 and 2000 (last light: 1742, low tide: 0022 (23 May); 1.07 m), under similar conditions, at an altitude of 40 m AGL giving a slightly higher resolution of 4 cm per pixel.

To account for variations in activity later in the night and at low tide a second set of flights were undertaken at an altitude of 40 m AGL giving a slightly higher resolution of 4 cm per pixel. The WBE adjacent survey area was mapped on 8 June 2021 between the hours of 0000 and 0400 (low tide: 0158; 1.19 m) with approximately 3000 photos taken, and the WBRA bunded area was mapped the following day (9 June 2021) between the hours of 0000 and 0200 (low tide: 0233; 1.12 m) with approximately 2600 photos taken. This mapping period provided greater contrast in temperature between mammals and ambient ground temperature.

All photographs were inspected for thermal hotspots (pixel temperature more than 5 degrees greater than surrounding ambient temperature) and less than 20 cm in length.

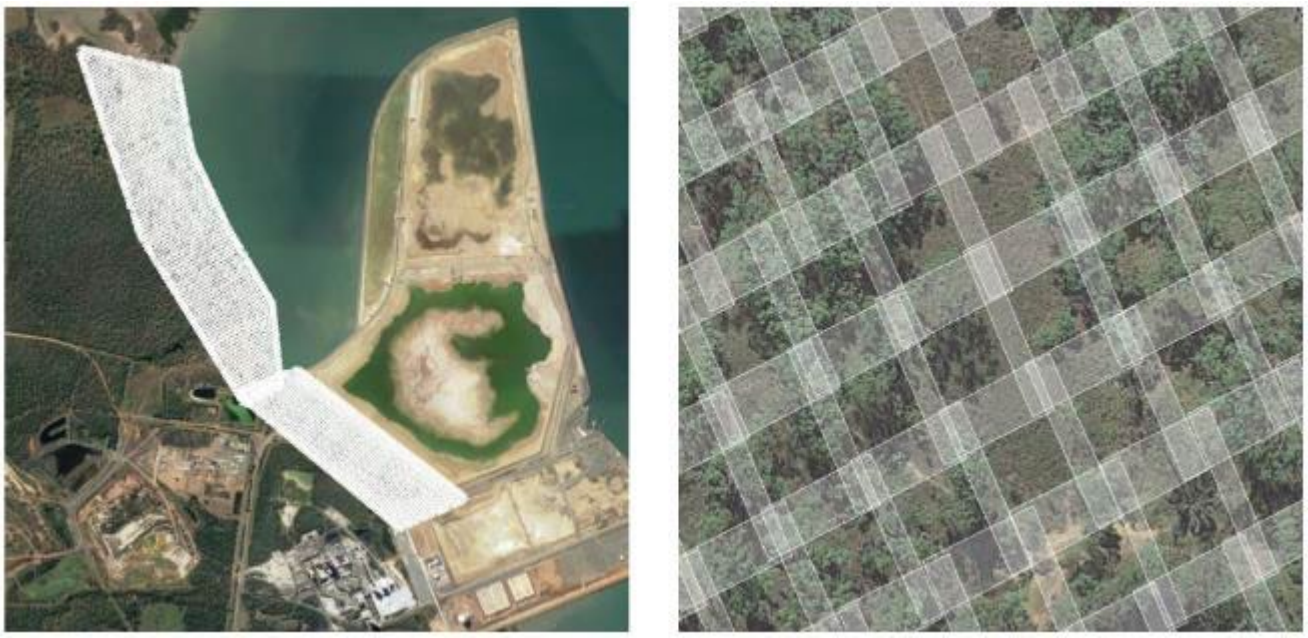

Figure 2: Flight footprint of the drone path and a zoom in of the overlap between images.

2.2 Camera trapping

The coordinates of possible small mammal 'hot spots' identified from the radiometric thermal mapping, in conjunction with the possible sites identified during the 2020 surveys were used to inform sites for deployment of trail cameras (Figure 3). A total of 11 trail cameras were used: five (5) black Nextech trail cameras and six (6) Bushnell Core DS cameras. All cameras were battery operated, had external SD cards, night sensors, are motion activated, and took pictures day and night when activated by movement.

CMERC staff visited the mangrove sites on 18 June 2021, using a handheld GPS device to find the coordinates of the selected hot spot sites and deploy the cameras. An appropriate location to deploy the camera was chosen to face the hotspot, usually this involved attachment to a trunk of a reasonably sturdy tree. The camera was turned on and activated to ensure it was working. The cameras were revisited on 25 June to download the photos. On 28 June, one camera was replaced as it had suffered water damage, and one camera was relocated. All cameras were collected on 1 July and the photos downloaded for review and identification.

Figure 3: Location of camera traps

2.3 Persons

The Yirrkoo surveys were coordinated by Dr Amie Anastasi, a CQUniversity researcher with over 14 years' experience in environmental studies, and, Associate Professor Emma Jackson, CMERC director and marine ecologist with over 19 years' experience in ecological studies.

The radiometric thermal mapping was completed by Darren Jeacocke and his team from Queensland Aerial.

Camera trapping was completed by CQUniversity staff Rory Mulloy, Hannah Russell, Chris Aiken, and Matt Pfeiffer.

2.4 Permits and approvals

The following permits and approvals are in place for this research:

- Animal Ethics Approval (CQUniversity Animal Ethics Committee; Approval Number 22754).
- Field Work Risk Assessment (CQUniversity OHS Unit).
- GPC Rapid Global inductions (for access to bunded area and GPC sites).

2.5 Limitations and assumptions

Whilst every effort has been made to target and identify the presence of any Yirrkoo in the survey area, presence varies with seasonal and climatic conditions.

3 Results and discussion

3.1 Radiometric thermal mapping

Radiometric thermal mapping identified numerous possible small mammal hot spots throughout the survey areas (Figure 4). Many of these hot spots were identified as non-target species (kangaroos, birds, pigs, e.g., see Figure 5), however, 10 of the hot spots were the right size, shape and location to be potential Yirrkoo signature hot spots

(Figure 6). These 10 sites, along with the two potential nest sites identified during the 2020 surveys were used as the basis for placing the camera traps.

Size and shape were primarily used in the identification of hot spot signatures. While the thermal images provide such detail, other detail, such as height, is not possible. From the thermal images, it is not possible to indicate height of hot spot above the ground, so it is possible that many of the hot spots may be birds, bats, or flying foxes etc.

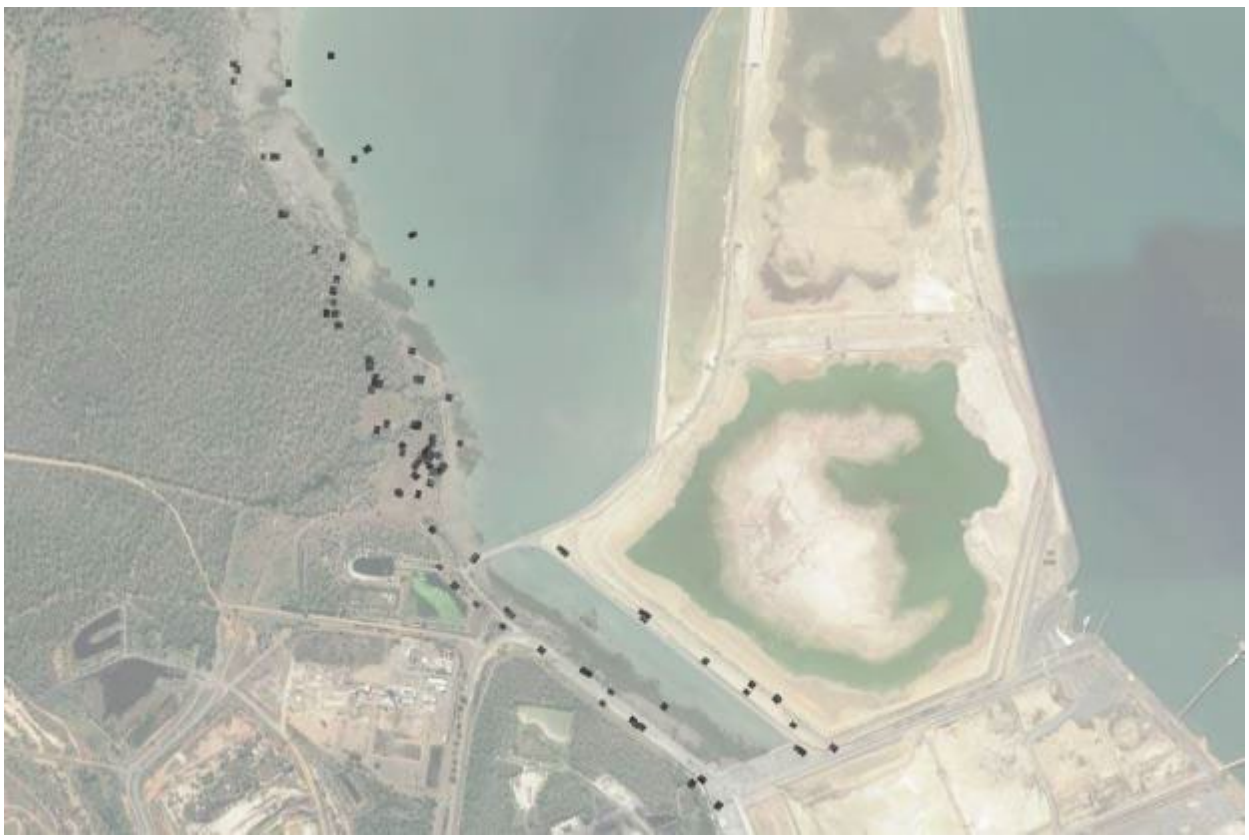

Figure 4: Radiometric thermal mapping hotspots

Figure 5: Thermal signature of kangaroos (length of heat signature ~ 1 m)

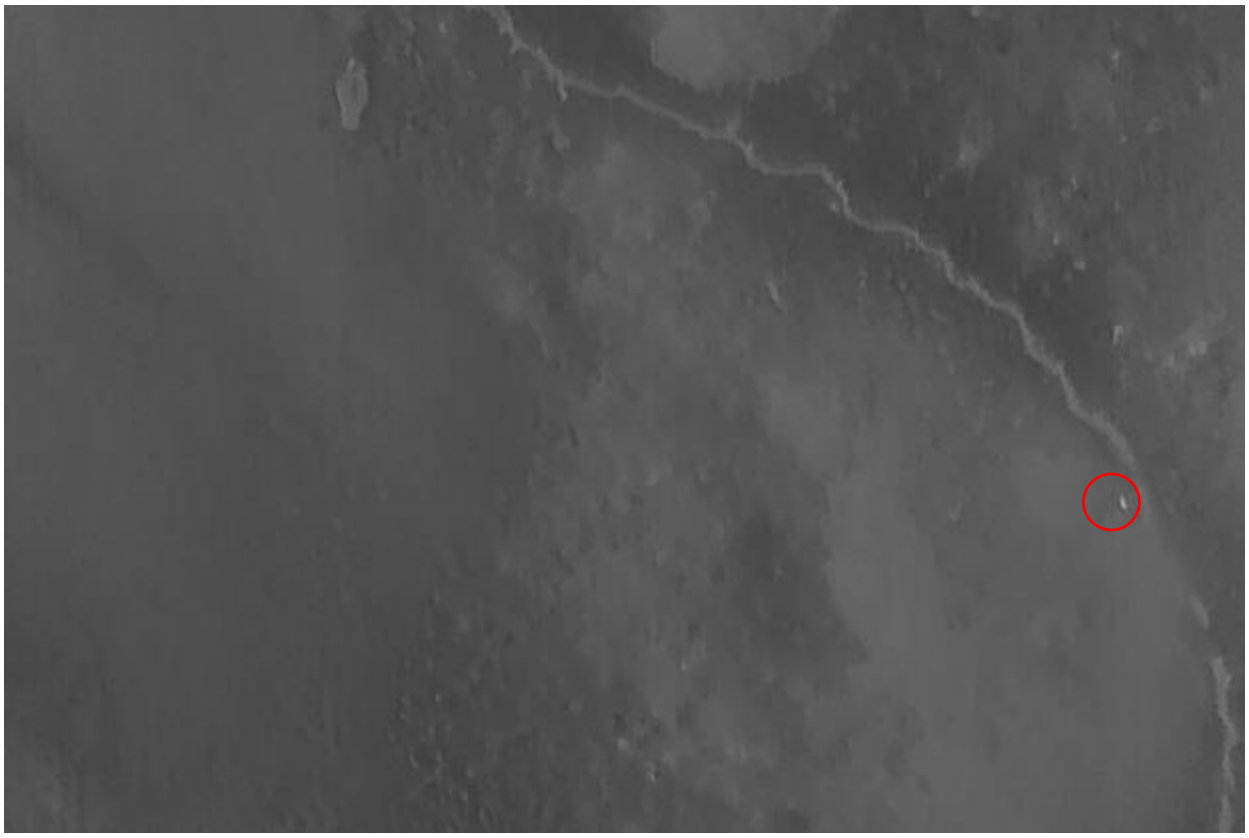

Figure 6: Example of possible Yirrkoo heat signature (length of heat signature ~ 0.2 m)

3.2 Camera trapping

Over the course of the 13 day/nights that the camera traps were deployed, a total of 23,384 photos were taken. The majority were accidental triggering of the camera by tree or water movement. Additionally, photos of pest species were also captured. Many of these pest species are also Yirrkoo predators (pigs, foxes etc.). Some small animal activity was captured by one camera in the WBE adjacent survey area (Figure 7). Eye shine from multiple small animals was observed moving around fallen trees (Figure 8). Definitive identification of the animals is not available. It is possible that the animals in the photo are Yirrkoo but is also equally possible that they are another small native, or invasive, rodent, or other small animal.

No definitive images of Yirrkoo were captured by any camera at any time.

Figure 7: Location of small animal activity

Figure 8: Small animal eye shine (circled in red)

4 Conclusion

Radiometric thermal mapping was successfully used to map the survey area and identify potential Yirrkoo hotspots. This method was also proven useful for other small and large animal species (kangaroos, pigs, birds), and may be of use in future animal-based surveys of the area.

Camera trapping identified several species of animal in the survey area, native and pest, as well as an unidentified small animal that was only observable via the shine from its eyes being present in the camera images.

No observations of Yirrkoo were made during the survey.

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