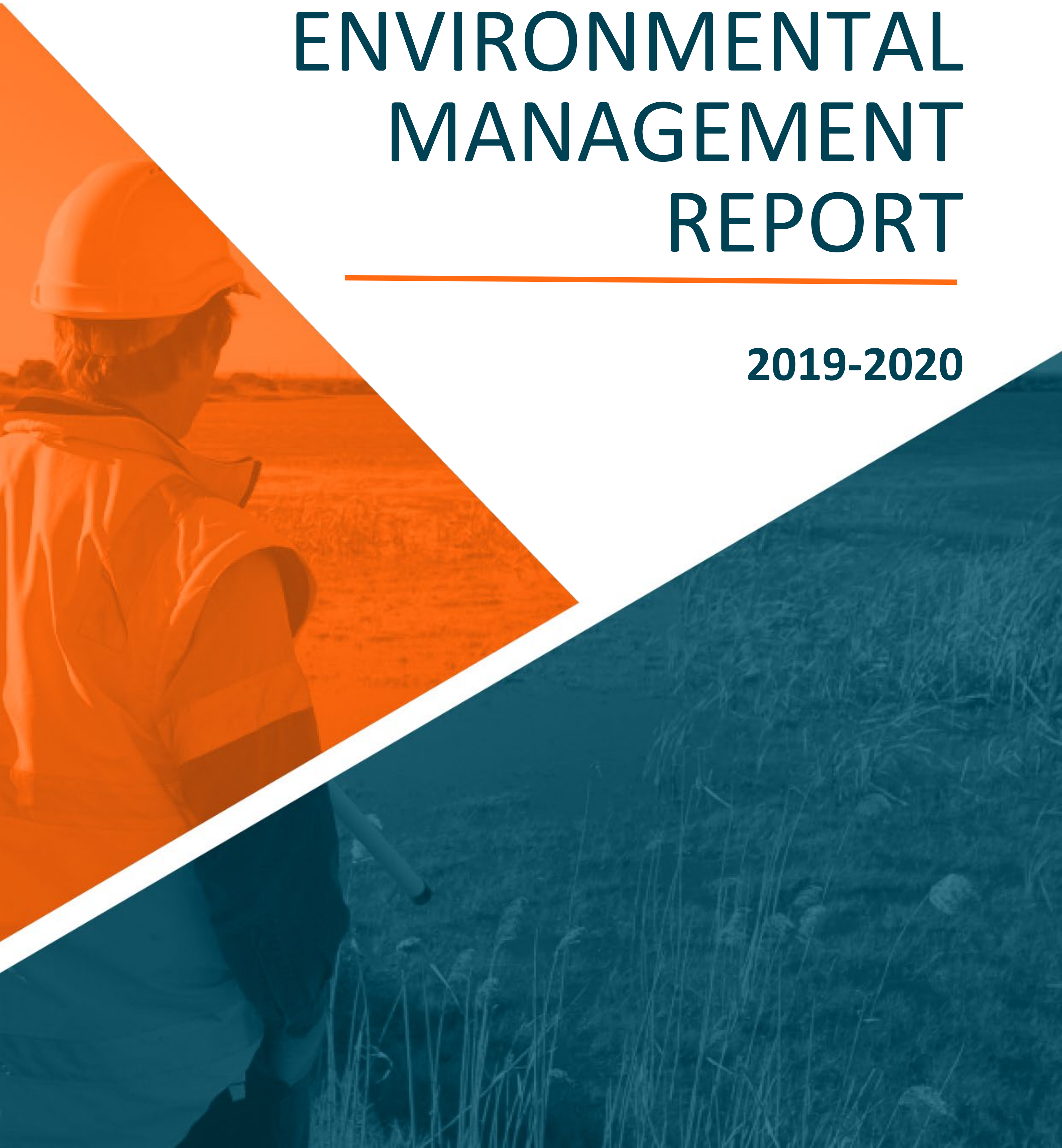
Newcastle Coal
INFRASTRUCTURE GROUP

ANNUAL ENVIRONMENTAL MANAGEMENT REPORT

2019-2020



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Approved by	**Fiona Robinson**
Description	**This Annual Environmental Management Report (AEMR) has been prepared for the Newcastle Coal Infrastructure Group (NCIG) Coal Export Terminal project. The AEMR reviews the performance of the Terminal against the requirements of the Project Approval and provides an overview of environmental management actions and summarises monitoring results over the 12-month reporting period (July 2019 to June 2020).**

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ACRONYMS AND ABBREVIATIONS

AEMR	Annual Environmental Management Report
ANZECC 2000	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
ANZG 2018	Australian and New Zealand Fresh and Marine Water Quality Guidelines
AQMN	Air Quality Monitoring Network
ARI	Annual recurrence interval
BAMs	Beta Attenuation Monitors
BC Act	NSW *Biodiversity Conservation Act 2016*
BCD	NSW Biodiversity Conservation Division
CEG	Community Engagement Group
CET	Coal Export Terminal
CHEMP	Compensatory Habitat and Ecological Monitoring Program
CMR	Capture-Mark-Recapture Surveys
DEC	Department of Environment and Conservation
DECC	Commonwealth Department of Environment and Climate Change
DO	Dissolved Oxygen
DoEE	Commonwealth Department of the Environment and Energy
DPIE	NSW Department of Planning, Industry and Environment
EC	Electrical conductivity
ELMP	Ecological and Land Management Plan
EMS	Environmental Management System
EPA	NSW Environment Protection Authority
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
EPL	Environmental Protection Licence
ESCP	Erosion and Sediment Control Plan
g/m^2/month	Grams per square metre per month
GGBF	Green and Golden Bell Frog
GGBFMP	Green and Golden Bell Frog Management Plan
HCCDC	Hunter and Central Coast Development Corporation
HSEC	Health, Safety, Environment and Community.
HVAS	High Volume Air Sampling
IEA	Independent Environmental Audit
kg	Kilograms
KIWEF	Kooragang Island Waste Emplacement Facility
L	Litre

Landcom 2004	Managing Urban Stormwater: Soils and Construction – Volume 1
LOR	Limit of reporting
MERI	Monitoring Evaluation Reporting and Improvement Plan
mm	Millimetres
MOU	Memorandum of Understanding
Mtpa	Million tonnes per annum
NCIG	Newcastle Coal Infrastructure Group
NEPM	National Environment Protection (Ambient Air Quality) Measure
NP&WS	NSW National Parks and Wildlife Service
NSW	New South Wales
ODAQMP	Operation Dust and Air Quality Management Plan
OEMP	Operation Environmental Management Plan
ONMP	Operation Noise Management Plan
OSCMP	Operation Spontaneous Combustion Management Plan
OWMP	Operation Water Management Plan
PA	Project Approval
PAH	Polycyclic aromatic hydrocarbons
PIT	Passive Induction Transponder
PM_{10}	Particulate Matter <10 µm
$PM_{2.5}$	Particulate Matter <2.5 µm
PWCS	Port Waratah Coal Services
Ramboll	Ramboll Australia Pty Ltd
SSGV	Site-specific guideline value
SSTV	Site-specific trigger values
TDS	Total dissolved solids
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSP	Total Suspended Particles
TSS	Total suspended solids
UNSW	University of New South Wales
UoN	University of Newcastle
VES	Visual Encounter Surveys
WHS	Work Health and Safety
WMP	Waste Management Plan

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1. INTRODUCTION

This Annual Environmental Management Report (AEMR) has been prepared for the Newcastle Coal Infrastructure Group (NCIG) Coal Export Terminal project (the Terminal) in accordance with the conditions of the approved Operation Environmental Management Plan (OEMP). The OEMP was prepared in accordance with Condition 7.5, within Schedule 2 of the Project Approval (PA) (06_0009) which was granted on 13 April 2007.

This is the twelfth AEMR prepared for the Terminal which includes the tenth year of terminal operation and covers the period July 2019 to June 2020 (inclusive) (the reporting period).

The AEMR reviews the performance of the Terminal against the requirements of the Project Approval and provides an overview of environmental management actions implemented and summarises monitoring results for the reporting period. The AEMR will be distributed to relevant government agencies and stakeholders, and copies provided to other interested parties, if requested.

1.1 APPROVALS, LEASES, LICENCES AND PERMITS

Site operations are being undertaken within the approvals, leases, licences and permits presented in **Table 1-1.**

Table 1-1: Project Approval, Leases, Licences and Permits

INSTRUMENT	RELEVANT AUTHORITY	DATE GRANTED	DURATION OF APPROVAL
PA 06_0009	NSW Department of Planning and Environment (now Department of Planning, Industry and Environment (DPIE))	13 April 2007	5 years unless substantially commenced
Modification of Minister's Approval MP06_0009	DPIE	27 November 2007	N/A (conditions appended to the PA)
Modification of Minister's Approval MP06_0009 MOD2	DPIE	13 May 2013	N/A (conditions appended to the PA)
Modification of Minister's Approval MP06_0009 MOD3	DPIE	Submitted April 2020 and approved 21 August 2020 (granted outside this reporting period)	N/A (conditions appended to the PA)
Project Lease	State Property Authority	22 January 2008	35 years (until 21 January 2043)
Environmental Protection Licence (EPL) (No. 12693)	NSW Environment Protection Authority (EPA)	26 October 2007	Until the Licence is surrendered or revoked. The Licence is subject to review every 5 years.
Environment Protection and Biodiversity Conservation Act 1999 Particular Manner Decision (EPBC 2006/2987)	Commonwealth Department of the Environment and Energy (DoEE)	11 October 2006	Perpetuity
Maritime Services Act 1935 s13JE	NSW Roads and Maritime Services (now Transport for NSW)	02 October 2007	Perpetuity
Environmental Representative	DPIE	03 October 2007	Perpetuity
Project Ecologist	DPIE	02 May 2007 & 25 October 2007	Perpetuity
Licence for Minor Operations – Green and Golden Bell Frog Compensatory Habitat	NP&WS	31 March 2014	5 years (currently in process of renewal)
Determination Notice for External Proponents – Green and Golden Bell Frog Compensatory Habitat (Ref No. CCHR 1317_17)	NP&WS	7 March 2013	Perpetuity

INSTRUMENT	RELEVANT AUTHORITY	DATE GRANTED	DURATION OF APPROVAL
Deed for the provision of compensatory habitat for migratory shorebirds on Kooragang Island (Area E)	(the Minister for) NP&WS	22 February 2016	Cessation of NCIG Coal Export Terminal (CET), surrender of PA 06_0009 or expiry of the lease
Determination (NP&WS) – Shorebird Compensatory Habitat project at Fish Fry Flats (Appl No. CCHR 1415_21)	NP&WS	28 June 2015	Perpetuity
Licence for Minor Operations – Shorebird Habitat Compensation Area E, Kooragang Island	NP&WS	15 December 2015	Up to 35 years (until 14 December 2050)

1.2 MANAGEMENT PLANS AND MONITORING PROGRAMS

In accordance with the PA 06_0009, the Terminal is currently being operated consistent with the following approved environmental management plans and monitoring programs:

Operations Management Plans

- Operation Environmental Management Plan (OEMP)
- Operation Dust and Air Quality Management Plan (ODAQMP)
- Operation Noise Management Plan (ONMP)
- Operation Spontaneous Combustion Management Plan (OSCMP)
- Operation Water Management Plan (OWMP)

Other Management Plans and Programs

- Ecological and Land Management Plan (ELMP)
- Waste Management Plan (WMP)
- Spill and Pollution Incident Response Management Plan (SPIRMP)
- Compensatory Habitat and Ecological Monitoring Program (CHEMP)
- Compensatory Habitat Management Plan
- Monitoring, Evaluation, Reporting and Improvement (MERI) Plan for the Migratory Shorebird Habitat Establishment
- Compliance Tracking Program
- Coordinated Environmental Monitoring and Management Protocol (with Port Waratah Coal Services (PWCS))
- Materials Transport Procedure
- Biosecurity Incident Response Procedure (BIRP)
- Community Engagement Plan

Monitoring Programs

- Environmental Monitoring Program (contained within the OEMP)
- Green and Golden Bell Frog Monitoring Program (contained in the ELMP)
- Deep Pond Bird Monitoring Program (contained in the ELMP)

1.3 TERMINAL BACKGROUND

The Terminal is located on Kooragang Island in Newcastle, New South Wales (NSW) (**Figure 1-1**).

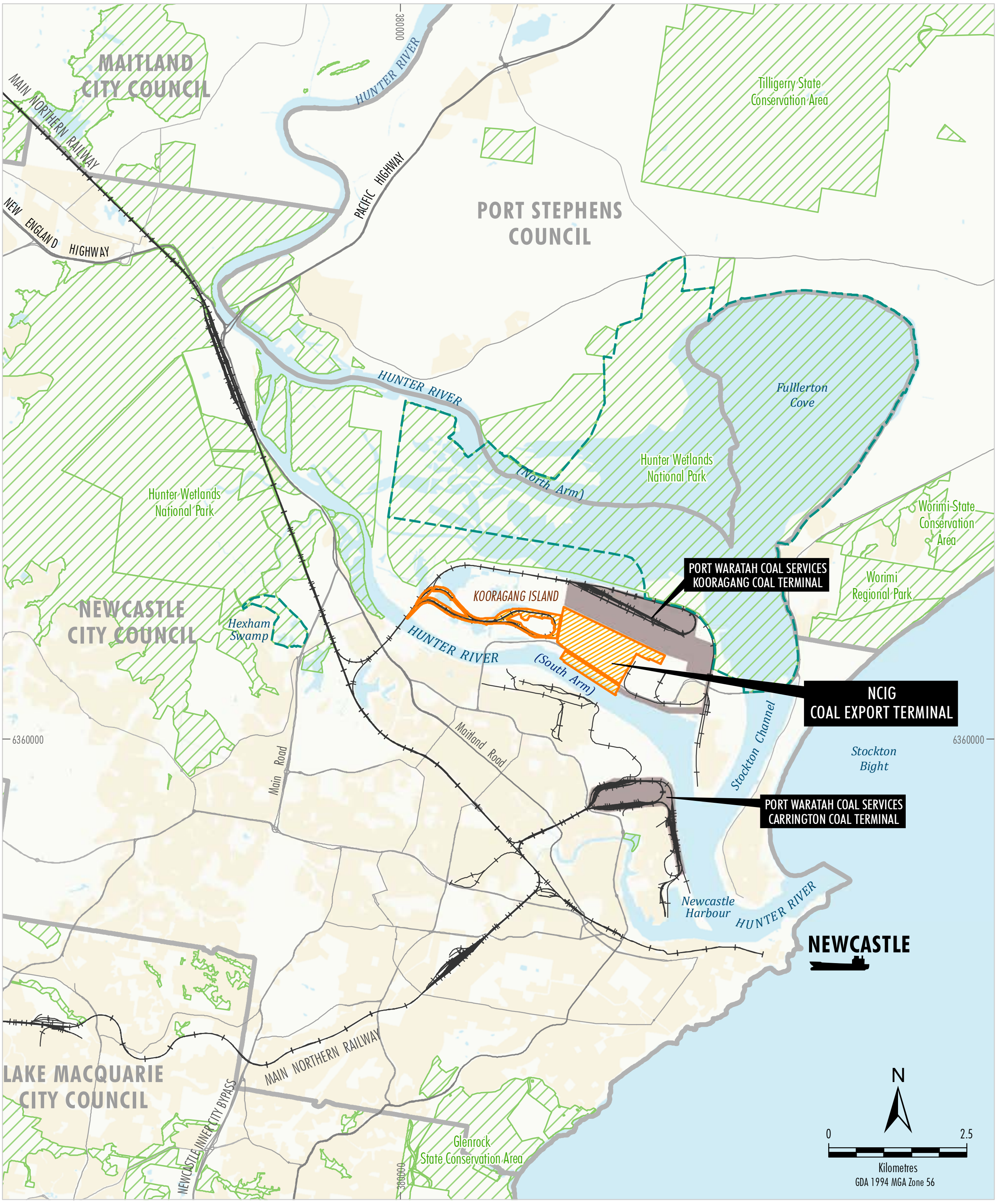
NCIG operates the coal export terminal with approval to export up to 66 million tonnes per annum (Mtpa), including associated rail and coal handling infrastructure and wharf/ship loading facilities on the south arm of the Hunter River. All construction activities associated with PA 06_0009 have been completed and this AEMR reports against operations.

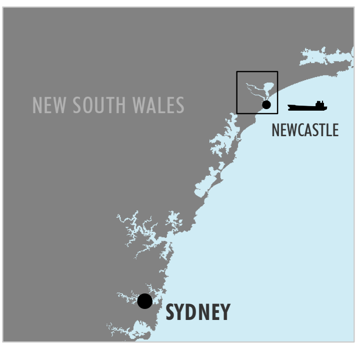
NCIG operates the Terminal and is a consortium of the following five companies:

- BHP
- Yancoal Australia
- Whitehaven Coal
- Peabody Energy Corporation
- Banpu Public Company Limited

The Terminal general arrangement is shown on **Figure 1-2.** Figures 1-1 and 1-2 have been sourced from the NCIG Coal Export Terminal Optimisation Statement of Environmental Effects (2020).

In April 2020 (during the reporting period), an application to Department of Planning, Industry and Environment (DPIE) was made to increase the operational capacity of the Terminal from 66 Mtpa to 79 Mtpa. The additional throughput capacity was approved in August 2020 and will be reported in the next AEMR reporting period.





LEGEND
- Railway
- National Park/Conservation Area
- Hunter Estuary Wetlands Ramsar Site
- Local Government Area Boundary
- Approximate Extent of Approved NCIG CET

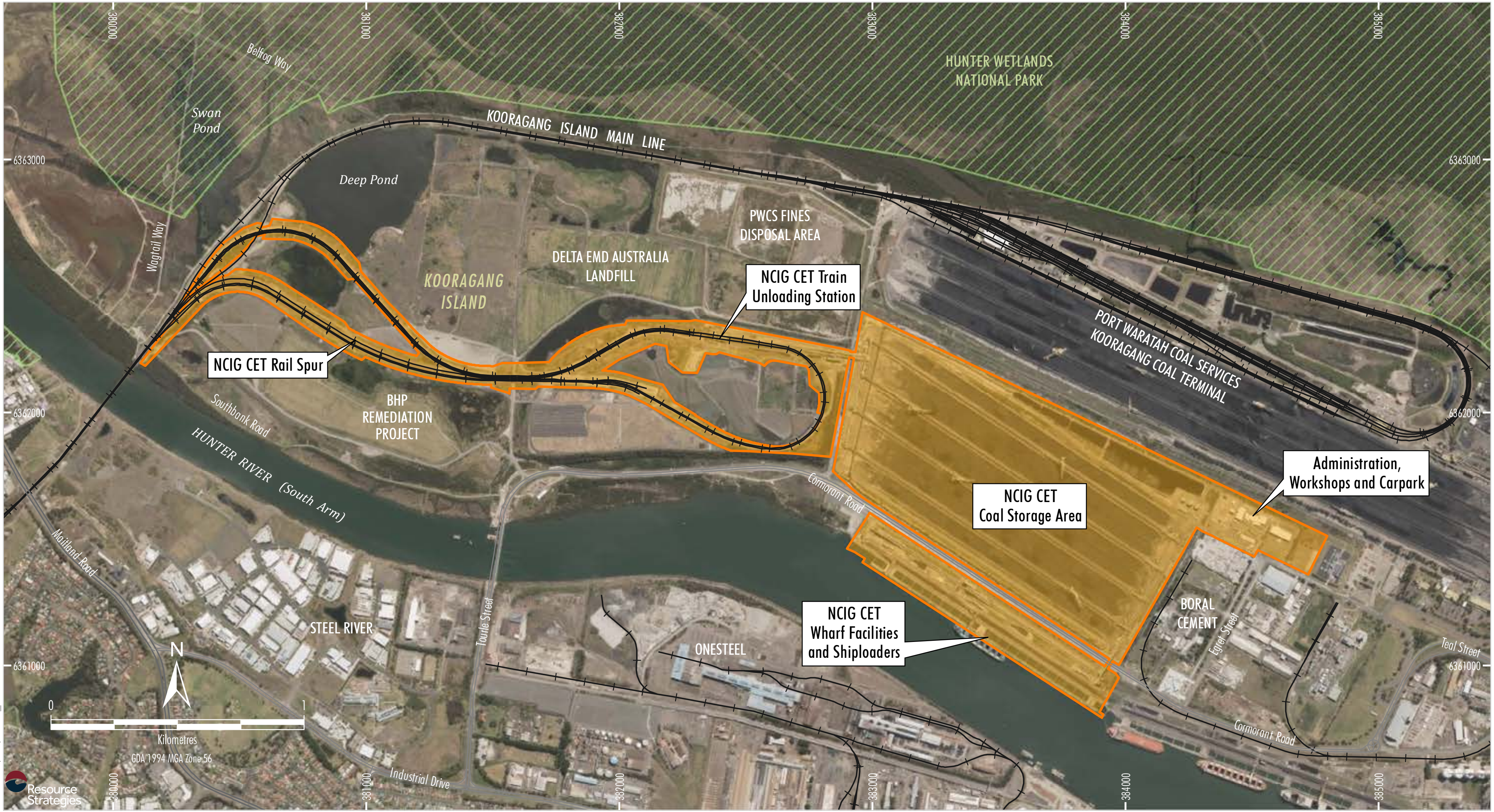
Source: NSW Spatial Services (2019)

Newcastle Coal Infrastructure Group

MODIFICATION REPORT

Regional Location

Figure 1-1



LEGEND
- Railway
- National Park/Consevation Area
- Approximate Extent of Approved NCIG CET

Source: NSW Spatial Services (2019)
Orthophoto: NSW Spatial Services (2019)

Newcastle Coal Infrastructure Group

MODIFICATION REPORT

Approved General Arrangement of the NCIG CET

Figure 1-2

2. OVERVIEW OF ACTIVITIES

2.1 OPERATION

The June 2019 to June 2020 reporting period included a continuation of terminal operations. All mechanical equipment was operational during the period, namely Dump Stations 1 and 2, Stacker/Reclaimers 1, 2, 3 and 4 and Ship loaders 1 and 2, along with associated inbound and outbound conveyor systems. Milestones achieved in this reporting period include:

- 10 years of operation achieved in February 2020
- Provided 66 million tonnes of capacity to NCIG customers
- Loaded 54.5 million tonnes of coal onto vessels for export

Operational activities are shown in **Photo 2-1** to **Photo 2-4**.

Photo 2-1: NCIG Site Overview Facing East

Photo 2-2: NCIG Site Overview Facing North

Photo 2-3: Stockyard with Stacker Reclaimers in Operation

Photo 2-4: Aerial Photograph of NCIG Terminal (October 2019)

3. SUSTAINABLE DEVELOPMENT POLICY

NCIG's approach to environmental management is guided by its Sustainable Development Policy, which is included in **Figure 3-1**.

Newcastle Coal
INFRASTRUCTURE GROUP

Sustainable Development Policy

Creating A Sustainable Business

The Newcastle Coal Infrastructure Group (NCIG) plays an important role in the coal export industry of the Hunter Valley. In fulfilling this role, NCIG acknowledges that it is of vital importance to balance the needs of all stakeholders in our business. Through the consideration of shareholders, employees, contractors, suppliers, the community and the environment, NCIG aims to make a significant contribution to the region, ensuring a sustainable business model.

- Critical to the achievement of sustainability is our objective to maintain an environment in which we:
- **Commit** to zero harm to safety, health and the environment;
- **Identify, evaluate** and **manage** risks to employees, contractors, visitors, the environment and our local community that may arise from our activities;
- Meet all legislative requirements and seek to continuously improve safety and environmental systems on our site to meet or exceed industry and internationally recognised standards;
- **Promote** and **improve** the health of our workplace, positively contribute to the community and protect the environment in which we operate, particularly through the prevention of pollution;
- Achieve our stated vision and mission by upholding our values;
- Promote a positive, high performance culture, through the support of a work environment where all people are treated fairly and with respect and encouraged to reach their full potential;
- Respect the indigenous and non-indigenous cultural and heritage value of the people, the terminal site and its surrounds;
- Regularly review our performance, set and achieve targets that promote the achievement of our stated goals;
- Engage regularly, openly and honestly with all stakeholders and consider any views and concerns raised in decision making; and
- Develop relationships that foster the sustainable development of our local communities.

In implementing this Policy, NCIG will engage with and support our shareholders, employees, contractors, suppliers, customers, business partners and local communities in sharing responsibility for meeting our stated requirements. We will be successful when our stakeholders determine that our contribution is valued.

Philip Garling
Chairman
Revision: D | June 2018

Figure 3-1: NCIG Sustainable Development Policy

4. ENVIRONMENTAL MANAGEMENT AND PERFORMANCE

Environmental monitoring is undertaken at NCIG for meteorology, dust, surface water, groundwater, noise, ecology and also waste and resource use. The results of monitoring for the reporting period are presented and discussed in the following sections.

4.1 ENVIRONMENTAL MONITORING PROGRAM

The Environmental Monitoring Program was implemented during the reporting period to monitor the environmental performance of the Terminal operations in accordance with the PA 06_0009, environmental licences and other statutory conditions. The NCIG Environmental Representative was responsible for the implementation of the Environmental Monitoring Program and is responsible for ensuring that adequate environmental monitoring is maintained.

The details of the monitoring undertaken are provided in the following sections, however an overview of the program is provided in **Table 4-1**. The environmental monitoring sites are shown in **Figure 4-1.**

Table 4-1: Operations Environmental Monitoring Program

MONITORING FOCUS	MONITORING SITES	FREQUENCY	CRITERIA
METEOROLOGY			
Temperature, relative humidity, net solar radiation rainfall, wind speed and direction and sigma theta (rate of change of wind direction)	Project automated meteorological station	Continuously monitored and the data averaged over 15-minute periods	N/A
EROSION AND SEDIMENT CONTROL			
Structural stability and effectiveness in controlling sediment migration	Drainage, erosion and sediment control infrastructure	Following significant rainfall events (i.e. greater than 20 millimetres (mm) in 24 hours) and during routine site inspections.	N/A
NOISE			
Attended noise monitoring	Fern Bay, Stockton, Mayfield, Carrington per Section 3.2 of the ONMP	6-monthly	See **Section 4.6.2**
Attended noise monitoring in case of complaint	Reference locations proximal to the Terminal	During operations after a complaint is received.	
AIR QUALITY			
Dust monitoring	DG1, DG2, DG3, DG4, DG5, DG6	Monthly	See **Section 4.3.2**
	HVAS1, HVAS2, HVAS3, HVAS4[2]	Every 6 days	
	BAM1, BAM2, BAM3, BAM4	Continuous	
	Additional Port Waratah Coal Services (PWCS) monitoring sites	Through regular consultation	
SURFACE WATER			
pH, electrical conductivity (EC), total dissolved solids (TDS), Turbidity, Dissolved Oxygen (DO), Temperature, Redox and total suspended solids (TSS)	Surface water monitoring sites	Monthly	See **Section 4.4.2**
Water level	Primary and secondary settling ponds	Following heavy rainfall (i.e. more than 20 mm of rainfall in a 24-hour period)	
pH, Electrical Conductivity (EC), Turbidity, Dissolved Oxygen (DO), Aluminium, Arsenic (III), Boron, Cadmium, Chromium (III), Cobalt, Copper, Iron, Lead,	Surface water sampling sites	6-monthly	

MONITORING FOCUS	MONITORING SITES	FREQUENCY	CRITERIA
Manganese, Mercury, Molybdenum, Nickel, Selenium, Zinc, Total Recoverable Hydrocarbons C6-C9, Total Recoverable Hydrocarbons C10-C14, Total Recoverable Hydrocarbons C15-C28, Total Recoverable Hydrocarbons C29-C36, Anthracene, Benzo (a) pyrene, Fluoranthene, Naphthalene, Phenanthrene, Ammonia, Nitrate, Total Kjeldahl nitrogen, Total phosphorus, Chloride			
GROUNDWATER			
Aluminium, Arsenic, Bromine, Cadmium, Conductivity, Copper, Cyanide, Iron, Manganese, Nickel, pH. Total PAHs, TPH C6-9, TPH C10-14, TPH C15-28, TPH C29-36, Zinc.	Groundwater sampling sites	6-monthly	See **Section 4.5.2**
Groundwater level		6-monthly	
ECOLOGY			
Green and Golden Bell Frog Population	Water bodies around the NCIG rail site	Minimum of 3 times during the breeding season	See **Section 4.7.2**
Water birds, including migratory shore birds	Water bodies around the NCIG site	Monthly	
WASTE			
Waste and recycling volumes	All operational waste streams	Monthly	See **Section 4.8.2**
RESOURCES			
Water usage	Potable water use and captured water use	Weekly	Reported within the 2020 Sustainability Report
Electricity usage	Terminal site	Monthly	
Fuel and vehicle usage	Terminal site (includes NCIG and Contractor vehicles, other plant and equipment)	Monthly	

[1]Dust deposition is analysed in accordance with AS/NZS 3580.10.1-2003 Methods for Sampling and Analysis of Ambient Air- Determination of Particulate Matter – Deposited Matter – Gravimetric Method.

[2]PM_{10} is monitored in accordance with the Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales (EPA,2001).

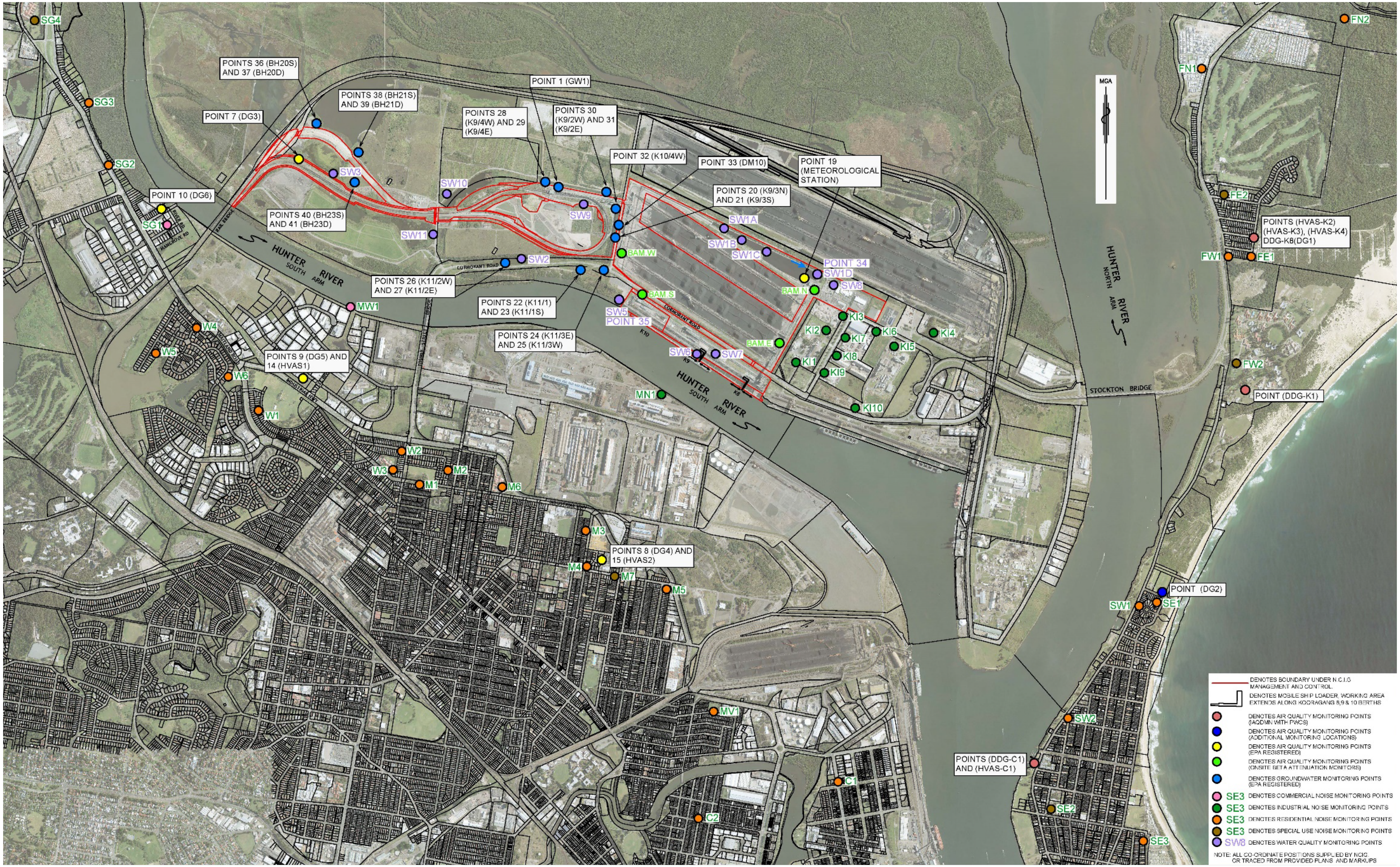


Figure 4-1: Environmental Monitoring Sites

4.2 METEOROLOGY

4.2.1 Environmental Management

In accordance with Condition 2.8, Schedule 2 of PA 06_0009, an onsite automated meteorological monitoring station was operated during the reporting period to monitor weather conditions representative of the site.

The automated meteorological monitoring station allows parameters such as wind direction to be used in the control of stockyard sprays. This includes activation of sprays based on evaporation of surface moisture from the coal stockpiles and deactivation of sprays under wind conditions where sprays would otherwise be ineffective in reaching coal stockpiles. NCIG also receives additional forecast data for rainfall, with forecast data provided seven days in advance. This information is used to assist with surface water management.

4.2.2 Environmental Performance

Table 4-2 describes the meteorological parameters recorded and frequency of monitoring for the Terminal operations in accordance with the OEMP. The location of the monitoring site in shown on **Figure 4-1.**

Table 4-2: Summary of Meteorological Monitoring Program

Monitoring Parameter	Monitoring Sites	Frequency	Criteria
• Temperature • Relative humidity • Net solar radiation • Rainfall • Wind speed and direction • Sigma theta[1]	Project automated meteorological station	Continuously monitored and the data averaged over 15-minute periods.	N/A

1 Sigma theta is the standard deviation of wind direction. The variability of wind direction can be used as an indicator or turbulence and mixing of the air.

4.2.3 Monitoring summary

Monthly statistical information for rainfall is detailed in **Table 4-3.** A total of 812.6 mm of rain was received on the site during the reporting period with the highest rainfall recorded in February 2020. The lowest rainfall was recorded in December 2019 with less than one millimetre recorded.

Table 4-3: Rainfall Statistics by Month

Month	Total rainfall (mm)*	Daily average (mm)	Daily maximum (mm)
July 2019	22.2 (72.6)	0.7	5.2
August 2019	109.6 (72.8)	3.5	63.4
September 2019	47.8 (60.1)	1.6	27.4
October 2019	29.2 (73.5)	0.9	14.8
November 2019	41.6 (81.9)	1.4	16.2
December 2019	0.4 (77.5)	0.01	0.4
January 2020	47.8 (98.3)	1.5	16.2
February 2020	182.6 (117.8)	6.3	85.0
March 2020	135.0 (120.7)	4.4	48.6
April 2020	45.4 (109.8)	1.5	21.0
May 2020	74.0 (108.6)	2.4	23.8
June 2020	77.0 (124.6)	2.6	19.8
Annual	**812.6 (1118.2)**	**2.2**	**85.0**

*Data shown in brackets refers to the mean monthly rainfall Williamtown data (1942 – 2019) – sourced from the Bureau of Meteorology (BOM). The Williamtown BOM station (station number 061078) is the closest BOM weather station and is located less than 11 km to the north east of the Terminal.

Figure 4-2 illustrates prevailing wind conditions throughout the reporting period, where the length of each spoke represents the frequency of winds from that direction. Wind speed and direction inform the scale of dust management measures implemented at the site. Winds prevail from the northwest during spring, autumn and winter.

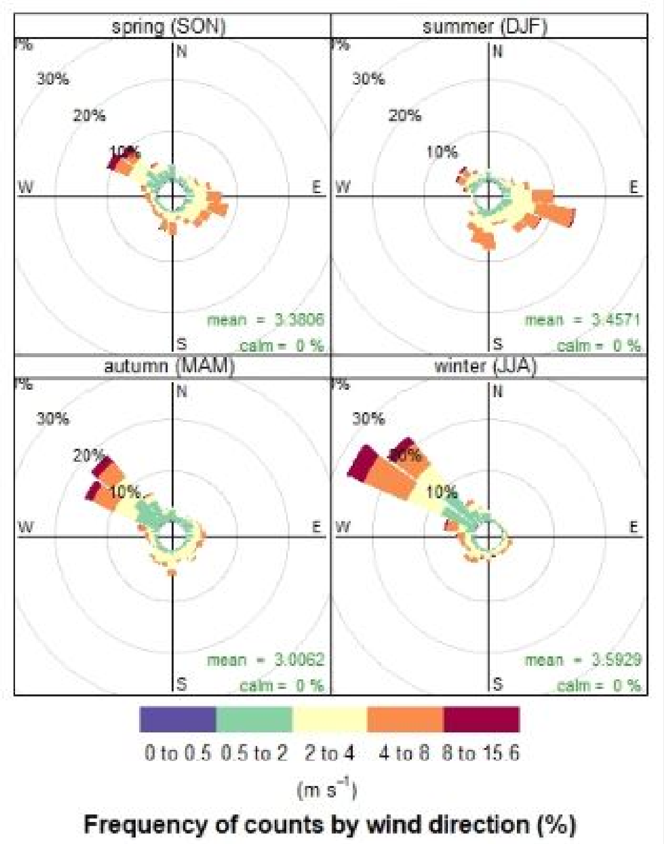


Figure 4-2: Seasonal Wind Conditions

The monthly statistical information for each of the remaining meteorological monitoring parameters is detailed in **Appendix 1**.

It is worth noting that during the reporting period, NSW experienced an unprecedented bushfire season during the months of November 2019 through to March 2020. High temperatures, dry conditions and strong westerly winds were identified as contributing factors to the bushfires (DPIE, 2020).

4.2.4 Reportable incidents

No environmental incidents relating to meteorological conditions occurred during the reporting period.

4.2.5 Further Improvements

No further improvements to the meteorological monitoring system are currently proposed.

4.3 AIR QUALITY

4.3.1 Environmental Management

Onsite dust management is conducted consistent with the ODAQMP to achieve the following key conditions.

- In accordance with Conditions 2.2 and 2.4, Schedule 2 of PA 06_0009 NCIG designed and constructed the Project in a manner that minimises or prevents the emission of visible dust beyond the boundary of the site (including windblown and traffic generated dust).
- In accordance with Condition 2.5, Schedule 2 of PA 06_0009 dust emissions are being controlled on all internal roads, trafficable areas and manoeuvring areas by sealing, or otherwise treating surfaces to minimise the potential for dust generation.
- In accordance with Condition 2.1, Schedule 2 of the PA 06_0009 NCIG did not permit any offensive odour, as defined under section 129 of the *Protection of the Environment Operations Act, 1997*, to be emitted beyond the boundary of the Project site.
- In accordance with Condition 3.2 e) of PA 06_0009, NCIG utilises real-time monitoring data to inform environmental management decisions during operations. This is done through interaction with real-time Beta Attenuation Monitors (BAMs), which measure Total Suspended Particles (TSP). These are located at the boundaries of the stockyard and used to assist the management of operations.

NCIG regularly reviews results from the Newcastle Air Quality Monitoring Network monitoring network, which provides real-time air quality measurements of PM_{10}, $PM_{2.5}$ and other industrial air pollutants, at Mayfield, Stockton, Carrington and Newcastle.

4.3.2 Environmental Performance

Table 4-4 outlines the monitoring locations, air quality parameters recorded, frequency of monitoring and air quality criteria for the operation of the Terminal in accordance with the OEMP. Depositional dust monitoring results are provided in **Appendix 2**.

Table 4-4: Summary of the Air Quality Monitoring Program

MONITORING PARAMETER	UNITS	FREQUENCY	LOCATION	METHODOLOGY
DEPOSITIONAL DUST MONITORING				
Depositional Dust	g/m^2/ month	Monthly	Stockton – NCIG Kooragang – DG3 Mayfield – DG4 Steel River – DG5 Sandgate – DG6	AS/NZS 3580.10.1[1]
Depositional Dust (Integrated Air Quality Monitoring Network (AQMN) with PWCS)			Fern Bay – DDG-K8 (DG1) Stockton Prawners Club - DDG-C1 Stockton Hospital – DDG-K1	
HIGH VOLUME AIR SAMPLING				
TSP	$\mu g/m^3$	6-daily	Steel River – HVAS1 Mayfield – HVAS2	NSW Approved Methods[2]
Particulate Matter <10 µm (PM_{10})				
TSP (Integrated AQMN with PWCS)			Stockton Prawners Club – HVAS-C1 Fern Bay – HVAS-K2 (TSP), HVAS-K3 (PM10), HVAS-K4 (Directional TSP)	
PM_{10} (Integrated AQMN with PWCS)				
NEWCASTLE LOCAL AIR QUALITY MONITORING NETWORK (ADMINISTERED BY THE EPA, OPERATED BY BCD[4], FUNDED BY INDUSTRY)				
PM_{10}	$\mu g/m^3$	Hourly (average daily values reported)	Stockton Carrington Mayfield Newcastle Wallsend Beresfield	NSW Approved Methods[2]
Particulate Matter <2.5 µm ($PM_{2.5}$)				
Wind Speed	ms^{-1}			AS 3580.1.1[3]
Wind Direction	Degrees			AS 3580.1.1[3]

MONITORING PARAMETER	UNITS	FREQUENCY	LOCATION	METHODOLOGY
ONSITE BETA ATTENUATION MONITORING (BAM)				
TSP	$\mu g/m^3$	Continuous	BAM E BAM N BAM S BAM W	DEC Approved Methods[2]

[1]Dust deposition is analysed in accordance with Australian standard AS/NZS 3580.10.1-2016 Methods for Sampling and Analysis of Ambient Air – Determination of Particulate Matter – Depositional Matter – Gravimetric Method (Standards Association of Australia 2016).

[2]PM_{10} is monitored in accordance with the methods specified in Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/air/07001amsaap.pdf

[3] AS 3580.1.1:2016 Methods for the sampling and analysis of ambient air. Part 1.1: Guide to siting air monitoring equipment., formerly (now superseded) AS 2292-1987 Ambient Air – Guide for the siting of sampling units.

[4] NSW Biodiversity Conservation Division

The depositional dust monitoring (insoluble solids) results for the reporting period are displayed in **Figure 4-3** and **Figure 4-4**.

Figure 4-3 shows that the highest deposited dust was measured during November 2019 and January 2020, with December 2020 also elevated. This coincided with the intense bushfire season of 2019-20. When compared against the annual average depositional dust criteria (refer to **Figure 4-4**), the criteria was not exceeded at any site.

Air quality monitoring results from the High Volume Air Samplers (HVAS) for total suspended particulates (TSP) and particulate matter with an equivalent aerodynamic diameter less than 10 Microns (PM_{10}), are displayed in **Appendix 2.** There were a number of measured exceedances of the 24-hour PM_{10} *National Environment Protection (Ambient Air Quality) Measure* (NEPM) criteria of 50 $\mu g/m^3$ throughout the reporting year. The majority of these occurred in late November and early December, coinciding with the regional bushfire events.

The annual average TSP concentrations for the five monitoring locations were below the DEC Annual Average Limit of 90 $\mu g/m^3$, as shown in **Appendix 2.** The results show elevated rolling annual average for PM_{10} from December 2019, coinciding with the bushfires. Mayfield remained elevated for the remainder of the reporting year, exceeding the annual PM_{10} criteria.

4.3.3 Reportable Incidents

No reportable environmental incidents relating to air quality occurred during the reporting period, however seven community complaints/enquiries relating to air quality were received by NCIG during the reporting period**.** Further information can be found in **Section 4.9.2**.

4.3.4 Further Improvements

During the reporting period a trial of the application of stockpile veneer was implemented. The application of veneer occurred on a weekly basis and in response to forecasted high wind events. NCIG undertook internal analysis of the effectiveness of the veneer application to determine the feasibility and effectiveness of the process as an ongoing control measure for dust mitigation during high wind events. NCIG will continue to investigate this control measure and alternative engineering controls to improve dust management at the site.

The Stockyard Rearrangement Project was conducted during the reporting period and included a major re-arrangement of the stockyard. Stockpiles of inherently dustier coal types were relocated away from downwind receivers, particularly those impacted by strong westerly winds. This project was undertaken with the cooperation of NCIG customers and close consultation with neighbours and internal stakeholders.

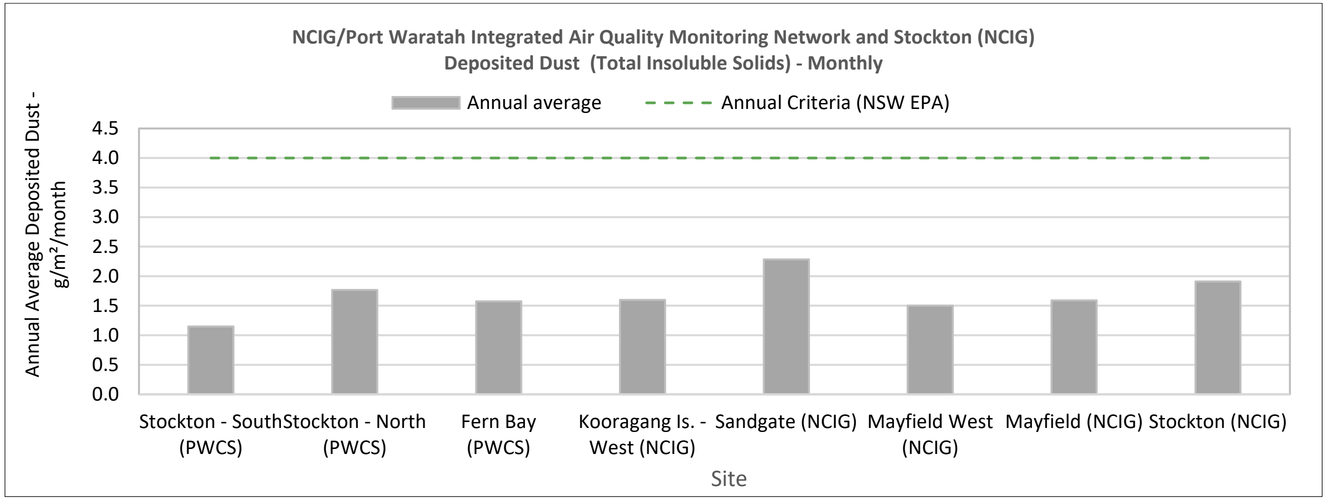


Figure 4-3: Monthly Dust Deposition

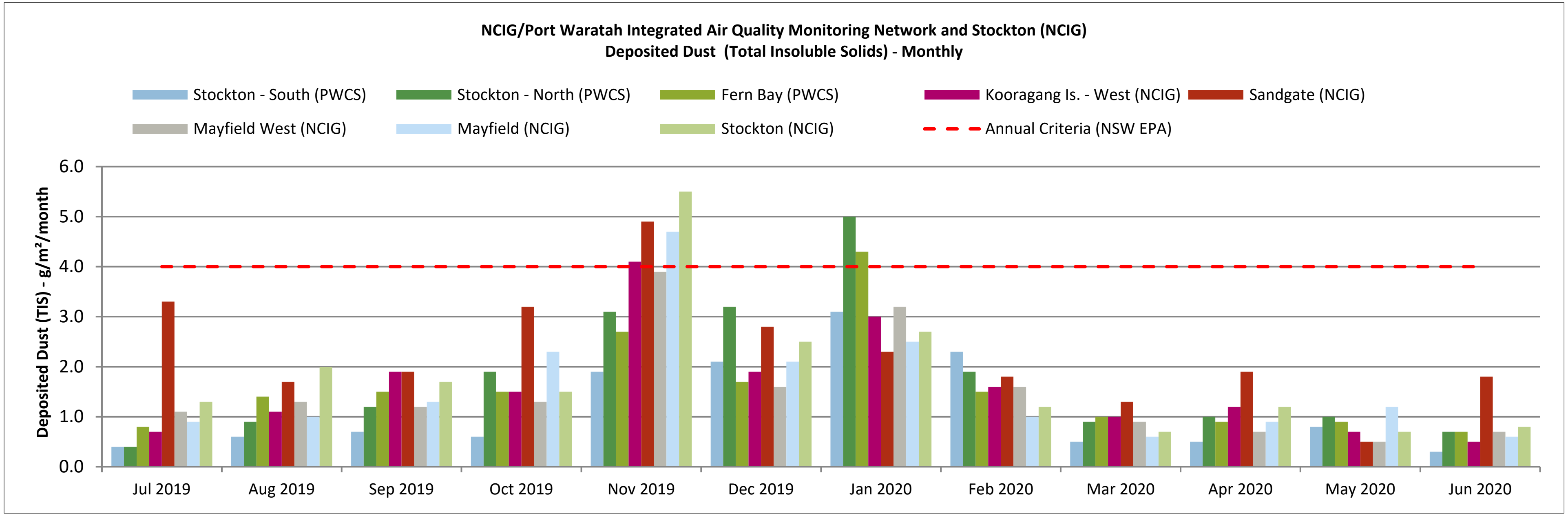


Figure 4-4: Annual Average Dust Deposition

4.4 SURFACE WATER

4.4.1 Environmental Management

In accordance with Condition 7.6 (c) Schedule 2 of PA 06_0009, an OWMP was developed which defines the surface water, stormwater and groundwater controls on the site during operation. The OWMP continues to be implemented across the site. In accordance with Condition 2.42, Schedule 2 of the PA 06_0009 NCIG has designed and constructed surface water and stormwater management infrastructure on the site to accommodate a 1 in 100 annual recurrence interval (ARI) rainfall event.

In accordance with Condition 2.49, Schedule 2 of PA 06_0009, all stormwater and surface water management infrastructure associated with the operation of the site is lined with a low-permeability material to minimise potential leakage. Stormwater is reused onsite for beneficial purposes such as the wetting of coal to reduce dust emissions from the site.

All grey wastewaters from the site are directed to sewer in accordance with a Trade Waste Licence, approved through Hunter Water Corporation, in accordance with Condition 2.51, Schedule 2 of PA 06_0009.

Erosion and sediment control measures and general surface water management measures for the Terminal are documented in the approved OWMP.

4.4.2 Environmental Performance

Table 4-5 outlines the monitoring locations, frequency of monitoring and monitoring parameters for the operation of the Terminal in accordance with the OEMP and OWMP. These monitoring elements form the Surface Water Monitoring Program for the Terminal.

Table 4-5: Surface Water Monitoring Program

MONITORING LOCATIONS	FREQUENCY	PARAMETER	UNITS	REQUIRED LIMIT OF REPORTING (LOR)
SW1-a, SW1-b, SW1-c, SW1-d (operational sites) SW2, SW3 (reference sites)	Monthly	pH	-	0.1
		EC	µS/cm-1	10
		TDS	mg/L	Not specified
		Turbidity	NTU	10
		Dissolved Oxygen (DO)	% and mg/L	1
		Temperature	°C	Not specified
		Reduction/ oxidation potential (Redox)	mV	Not specified
		TSS	Mg/L	Not specified
SW1-d, SW6, SW7, SW8, SW9 (operational sites) SW2, SW3, SW5, SW10, SW11 (background sites)	6-monthly	pH	-	0.1
		EC	µs/cm-1	10
		Turbidity	NTU	1
		DO	%	10
		Aluminium	mg/L	0.05
		Arsenic (III)	mg/L	0.05
		Boron	mg/L	0.05
		Cadmium	mg/L	0.0001
		Chromium (III)	mg/L	0.01
		Cobalt	mg/L	0.001
		Copper	mg/L	0.001
		Iron	mg/L	0.05
		Lead	mg/L	0.001
		Manganese	mg/L	0.5
		Mercury	mg/L	0.0001
		Molybdenum	mg/L	2
		Nickel	mg/L	0.01

MONITORING LOCATIONS	FREQUENCY	PARAMETER	UNITS	REQUIRED LIMIT OF REPORTING (LOR)
		Selenium	mg/L	0.001
		Zinc	mg/L	0.005
		Total Recoverable Hydrocarbons C6-C9	mg/L	0.02
		Total Recoverable Hydrocarbons C10-C14	mg/L	0.05
		Total Recoverable Hydrocarbons C15-C28	mg/L	0.1
		Total Recoverable Hydrocarbons C29-C36	mg/L	0.1
		Anthracene	µg/L	0.01
		Benzo(a)pyrene	µg/L	0.01
		Fluoroanthene	µg/L	0.01
		Naphthalene	µg/L	0.01
		Phenanthrene	µg/L	0.01
		Ammonia	mg/L	0.5
		Nitrate	mg/L	0.1
		Total Kjeldahl Nitrogen (TKN)	mg/L	0.5
		Total phosphorous (TP)	mg/L	0.01
		Chloride	mg/L	Not specified
SW1-d (discharge) EPL34, SW5 (Background) EPL35	Daily during discharge	pH	-	0.1
		Turbidity	NTU	10
		TSS	mg/L	Not specified
		Oil and Grease	mg/L	Not specified

[1]The location of monitoring sites is shown in **Figure 4-1.**

Sampling of surface water ponds was undertaken by RCA Australia in December 2019 and June 2020 during the reporting period in accordance with the OWMP. The location of the sampling undertaken is illustrated in **Figure 4-1** with the recorded water quality results detailed in **Appendix 3**. The monitoring is not a consent or licence requirement.

Ramboll (previously Environ), has undertaken five reviews of surface water data for NCIG (Environ 2013, Ramboll 2016, Ramboll 2017, Ramboll 2018 and Ramboll 2019). During each review the baseline environmental data were evaluated and Site-Specific Guideline Values (SSGVs) were developed and/or refined, where possible. Ramboll (2021) (2020 Surface Water Monitoring Data Review) undertook a review of the 6 monthly surface water quality monitoring data from December 2019 to mid-2020. The monitoring results were compared to trigger values that were either: site-specific trigger values (SSTVs); *Australian and New Zealand Fresh and Marine Water Quality Guidelines* (ANZG 2018) triggers for protection of 95% Aquatic Species; or *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000) triggers for physical parameters (EC, DO, pH and turbidity) in the absence of ANZG 2018 guidance.

The median concentrations of each parameter within the four operational locations were compared to the SSGVs derived from reference data from 2012-2020. Noting that the SSGVs are based on limited data and are therefore of low reliability. The freshwater SSGV was exceeded for turbidity at Wharf Sump (**Table 4-6**). All parameters were below the marine water SSGV at all operational locations (**Table 4-7**).

Table 4-6: Median NCIG Surface Water Quality Parameters at Freshwater Operational Locations compared to SSGV – Fresh

ANALYTE	WTP01	CLEARWATER POND	TRADEWATER POND	WHARF SUMP	SSGV - Fresh
pH Value	8.3	8.1	7.9	8.0	**9.0**
EC (µS/cm)	2205	1930	181	429	**2,750**
DO (%)	90	90	85	97	**109**
Turbidity (NTU)	53	48	18	**204.5**	**55**
TP (µg/L)	60	50	60	160	**410**
TKN (µg/L)	490	430	500	630	**2,800**
aluminium (µg/L)	290	280	160	625	**350**
copper (µg/L)	1.5	2	2.5	7	**50**
zinc (µg/L)	50	19	22	50	**70**

Bolded cells indicate median concentrations that exceed the SSGV.

Table 4-7: Median NCIG Surface Water Quality Parameters at Marine Operational Locations compared to SSGV – Marine

ANALYTE	HUNTER RIVER WHARF	SSGV - MARINE
EC (µS/cm)	50,000	**54,760**
Turbidity (NTU)	12	**59**
TP (µg/L)	70	**400**
TKN (µg/L)	300	**400**
Aluminium (µg/L)	415	**552**
Copper (µg/L)	10	**10**
Iron (µg/L)	395	**574**
Zinc (µg/L)	26	**52**

4.4.3 Reportable Incidents

During the reporting period two reportable incidents against NCIG's EPL (Condition O.71(a)) occurred with details provided below.

In July 2019, during wash down of a Shiploader it is estimated between 10 – 100 litres of water and coal fines mixture entered the harbour due to strong westerly winds during the washdown. On noticing the discharge, the washdown activity was immediately stopped and internal notification procedures enacted.

In November 2019, a Shiploader collided with a displaced checker plate ramp on the side of a maintenance bay causing the sump plugs to shear off three gearboxes resulting in a spill of approximately 20 – 30 litres of gearbox oil. The majority of the spill was contained within the checker plates located along the extent of the wharf however an estimated 10 litres of oil is assumed to have entered the harbour.

Relevant authorities were notified, including the EPA. It is noted that both incidents were assessed as minor and did not cause actual or potential significant off-site impacts on people or the biophysical environment (as outlined in Condition 8.1 of PA 06_0009), nor were the incidents considered to have resulted in 'material harm to the environment' as defined under the *Protection of the Environment Operations Act 1997*. NCIG received a Formal Warning from the EPA for the November incident. An internal investigation was undertaken for both incidents. Both incidents triggered a review of internal procedures, training and spill responses and the learnings and expectations were communicated with staff and contractors.

No discharge events occurred during the reporting period.

4.4.4 Further Improvements

The Discharge Water Management Project has been a work in progress over the last few years. The project aims to improve the water quality of NCIG's settling ponds, and potential discharge water during heavy rain events which exceed the design capacity of NCIG's system. Within this reporting period the planned upgrade to existing wharf infrastructure was successfully completed. Additionally, an engineering investigation and options review of the site-wide water management solution was completed. The review identified improvement opportunities in onsite operational and maintenance practices and considered major capital infrastructure works. The improvements remain as viable options for discharge water management should the need arise.

NCIG continued to explore the option of using imported recycled water for dust suppression and other process water uses. During the reporting period, discussions were held with a local recycled water provider to determine its viability. Further investigations into the feasibility and justification of the initiative will occur in FY21. NCIG are investigating this process water supply option to reduce its reliance on potable water use during prolonged periods of dry weather conditions at the site.

4.5 GROUNDWATER

4.5.1 Environmental Management

Groundwater management is regulated under EPL 12693 and NCIG's Operations Environmental Management Plan and Operations Water Management Plan. Specific groundwater quality trigger criteria have been developed for contaminants of concern, in particular; organic and inorganic contaminants associated with the former KIWEF, upon which parts of the NCIG Rail alignment is constructed. The trigger criteria for Points 20, 21 ,22, 23, 36, 37, 40 or 41 are:

- Trigger Condition 1 – Where monitoring of the parameters required under the licence demonstrates a sudden increase in concentration compared to historical data, or sudden decrease in pH is observed. A sudden increase or decrease is defined as a value that is greater than the mean plus twice the standard deviation for the historical data.
- Trigger Condition 2 – Where the trend analysis of the concentration of the parameters required under the licence against time shows an increasing concentration over the most recent four events. Trend analysis tools such as Mann-Kendall may be adopted.

4.5.2 Environmental Performance

Table 4-8 outlines the monitoring locations, groundwater monitoring parameters recorded, frequency of monitoring and groundwater criteria for the Project in accordance with Section M2.2 of EPL 12693.

Table 4-8: Summary of the Groundwater Monitoring Program (EPL)

MONITORING LOCATION[1]	FREQUENCY	PARAMETER	UNITS
GW1 (EPL 1) BH21S (EPL 38) BH21D (EPL 39)	6-monthly	pH	-
		EC	µS/cm
		Aluminium	mg/L
		Arsenic	mg/L
		Bromide	mg/L
		Cadmium	mg/L
		Copper	mg/L
		Cyanide (free)	µg/L
		Cyanide (total)	µg/L
		Iron	mg/L
		Manganese	mg/L
		Nickel	mg/L
		Zinc	mg/L
		Total Recoverable Hydrocarbons C6-C9	µg/L
		Total Recoverable Hydrocarbons C10-C14	µg/L
		Total Recoverable Hydrocarbons C15-C28	µg/L
		Total Recoverable Hydrocarbons C29-C36	µg/L
		Total PAHs	µg/L
K9/3N (EPL 20) K9/3S (EPL 21) K11/1 (EPL 22) K11/1S (EPL 23) BH20S (EPL 36) BH20D (EPL 37) BH23S (EPL 40)	6-monthly	pH	-
		EC	µS/cm
		Aluminium	mg/L
		Arsenic	mg/L
		Bromide	mg/L
		Cadmium	mg/L

MONITORING LOCATION[1]	FREQUENCY	PARAMETER	UNITS
BH23D (EPL 41)		Copper	mg/L
		Cyanide (free)	mg/L
		Cyanide (total)	mg/L
		Iron	mg/L
		Manganese	mg/L
		Nickel	mg/L
		Total PAHs	mg/L
		Total Recoverable Hydrocarbons C6-C9	µg/L
		Total Recoverable Hydrocarbons C10-C14	µg/L
		Total Recoverable Hydrocarbons C15-C28	µg/L
		Total Recoverable Hydrocarbons C29-C36	µg/L
		Zinc	mg/L
K11/3E (EPL 24) K11/3W (EPL 25) K11/2W (EPL 26) K11/2E (EPL 27) K9/4W (EPL 28) K9/4E (EPL 29) K9/2W (EPL 30) K9/2E (EPL 31) K10/4W (EPL 32) DM10 (EPL 33)	6-monthly if trigger conditions are exceeded at EPL 20, 21, 22, 23, 26, 37, 40 or 41	pH	-
		EC	µS/cm
		Aluminium	mg/L
		Arsenic	mg/L
		Bromide	mg/L
		Cadmium	mg/L
		Copper	mg/L
		Cyanide (free)	µg/L
		Cyanide (total)	µg/L
		Iron	mg/L
		Manganese	mg/L
		Nickel	mg/L
		Zinc	mg/L
		Total Recoverable Hydrocarbons C6-C9	µg/L
		Total Recoverable Hydrocarbons C10-C14	µg/L
		Total Recoverable Hydrocarbons C15-C28	µg/L
		Total Recoverable Hydrocarbons C29-C36	µg/L
		Total PAHs	µg/L

1 The location of monitoring sites is shown on **Figure 4-1**

A summary of the groundwater monitoring results recorded during the reporting period is provided in **Table 4-9** with full results provided in **Appendix 4**. Re-sampling events which were undertaken outside of the reporting period have been included to validate some results of sampling undertaken in December 2019 and June 2020.

Table 4-9: Summary of Groundwater Monitoring Results (EPL)

MONITORING SITES	DATES OF SAMPLING	EXCEEDANCE OF REQUIREMENTS?		COMMENTS
		EPL	OEMP/ OWMP	
GW1 (EPL 1)	12/12/19 15/06/20	N/A	N/A	
BH-21S (EPL 38)	11/12/19 15/06/20	N/A	N/A	
BH-21D (EPL39)	11/12/19 15/06/20	N/A	N/A	
K9/3N (EPL 20)	12/12/19 15/06/20	No	No	
K9/3S (EPL21)	12/12/19 15/06/20	Yes	Yes	Manganese concentrations exceeded Trigger Condition 2 in the December 2019 monitoring round (0.169 mg/L). The well was re-sampled in February 2020 forming 'Step 2' of the EPL contingency. Re-sampling reported the manganese concentration below the trigger condition. A review of the data confirmed the December 2019 result was within the range of historical concentrations. Bromide concentrations exceeded Trigger Condition 2 in the December 2019 monitoring round (4.52 mg/L). The well was re-sampled in February 2020 forming 'Step 2' of the EPL contingency. Re-sampling reported the bromide concentration below the trigger condition. A review of the data confirmed the December 2019 result was within the range of historical concentrations. Arsenic (V) concentrations exceeded Trigger Condition 1 in the June 2020 monitoring round (0.006mg/L). The well was re-sampled in August 2020 forming 'Step 2' of the EPL contingency. Re-sampling reported the arsenic concentration below the trigger condition and confirmed the June 2020 result to be anomalous.
K11/1 (EPL 22)	12/12/19 16/06/20	Yes	Yes	pH levels exceeded Trigger Condition 1 in the June 2020 monitoring round (7.64 pH units). The well was re-sampled in September 20 forming 'Step 2' of the EPL contingency. Re-sampling reported the pH below the trigger condition and confirmed the June 2020 result to be anomalous. Iron exceeded Trigger Condition 1 in the June 2020 monitoring round (0.87mg/L). The well was

MONITORING SITES	DATES OF SAMPLING	EXCEEDANCE OF REQUIREMENTS?		COMMENTS
		EPL	OEMP/ OWMP	
				not re-sampled immediately after and the EPA have been notified. The well was sampled in September 2020. The iron concentration was reported below the trigger condition. TPH C29-C36 and C10-C36 (total) exceeded Trigger Condition 1 in the June 2020 monitoring round (0.15mg/L and 0.22mg/L). The well was not re-sampled immediately after and the EPA have been notified. The well was sampled in September 2020. The TRH concentrations were below the trigger condition.
K11/1S (EPL 23)	12/12/19 16/06/20	No	No	
BH-20S (EPL 36)	11/12/19 15/06/20	No	No	
BH-20D (EPL 37)	11/12/19 15/06/20	Yes	Yes	pH levels exceeded Trigger Condition 2 in the June 2020 monitoring round (6.34 pH units). The well was re-sampled in August 2020 forming 'Step 2' of the EPL contingency. A pH of 6.59 was reported which was above the June 2020 result. The pH results are within the normal historical range and within Trigger Condition 1.
BH-23S (EPL 40)	11/12/19	No	No	BH23S was destroyed during HCCDC capping works and could not be sampled in June 2020. The well was re-instated in late 2020.
BH-23D (EPL 41)	11/12/19 03/07/20	Yes	Yes	Bromide concentrations exceeded Trigger Condition 1 in the June 2020 monitoring round (1,100 mg/L). The well was re-sampled in August 2020 forming 'Step 2' of the EPL contingency. Re-sampling reported the bromide concentration below the trigger condition. A review confirmed the June 2020 result to be anomalous.
K11/3E (EPL 24) K11/3W (EPL 25) K11/2W (EPL 26) K11/2E (EPL 27) K9/4W (EPL 28) K9/4E (EPL 29) K9/2W (EPL 30) K9/2E (EPL 31) K10/4W (EPL 32) DM10 (EPL 33)	March 2019 (EC only) January 2020 June 2020	No	No	Additional monitoring as outlined in Step 4 of the contingency response program was undertaken. Sampling was completed in March 2019 for EC and January and June 2020 for all parameters to assess for trends. The following wells were substituted for missing / lost wells: - BHe23S substituted for K11/2E - BHe23d substituted for K11/3W - BHe26S substituted for DM10 - BHe29D substituted for K10/4W A summary of the contingency wells results in relation to the trigger values listed above include: -The average manganese concentration for January 2019 was 0.6mg/L and the average

MONITORING SITES	DATES OF SAMPLING	EXCEEDANCE OF REQUIREMENTS?		COMMENTS
		EPL	OEMP/ OWMP	
				bromide concentration was 5.8mg/L. Both concentrations are higher than the concentration reported at K9/3S in December 2019, indicating that the concentrations reported are representative of the natural groundwater conditions. -The average arsenic concentration for June 2020 was 0.003mg/L, slightly below the concentration reported at K9/3S. Indicating the slightly elevated concentration is localised to K9/3S. Routine monitoring is recommended at the contingency wells to assess for trends and contaminant transport. -The average pH concentration for June 2020 was 7.5, slightly below the concentration reported at K11/1 but higher than BH20D, indicating the slightly elevated pH is localised to K11/1 and BH20D. The pH reported is within the ANZECC guidelines for marine waters. -The average iron concentration for June 2020 was 2.0mg/L, indicating that the concentrations reported are representative of the natural groundwater conditions. -The average TPH C29-C36 and C10-C36 (total) concentrations reported for June 2020 were 0.06 and 0.07mg/L respectively, slightly below the concentrations reported at K11/1. Indicating the slightly elevated TPH concentrations are localised to K11/1. Routine monitoring is recommended at the contingency wells to assess for trends and contaminant transport. -The average bromide concentration reported for June 2020 was 10.0mg/L, which is significantly lower than the concentration reported at BH23D. Bromide is routinely higher in this well indicating the elevated concentration is localised to BH23D.

4.5.3 Reportable Incidents

No environmental incidents or complaints relating to groundwater quality conditions were made during the reporting period.

4.5.4 Further Improvements

As mentioned above, additional monitoring as outlined in Step 4 of the contingency response program was undertaken in December 2019 and January 2020. A groundwater specialist will continue to review further monitoring to confirm the significance of these results.

4.6 NOISE

4.6.1 Environmental Management

In accordance with Condition 2.13, Schedule 2 of the PA 06_0009, Stage 1 of the NCIG Terminal has been designed, constructed, operated and maintained to ensure that the noise contributions from the plant do not exceed the maximum allowable noise contributions specified in **Table 4-11**, at the locations and the time periods indicated.

In accordance with Condition 2.14, Schedule 2 of PA 06_0009, the monitoring of noise contributions was:

- Measured at the most affected point on or within the Site boundary at the most sensitive receiver to determine compliance with $L_{Aeq(15\ minute)}$ night noise limits.
- Measured at one metre from the dwelling façade to determine compliance with $L_{A1(1\ minute)}$ noise limits.
- Subject to the modification factors provided in Section 4 of the NSW Industrial Noise Policy (EPA, 2000), where applicable.

In accordance with Condition 2.15, Schedule 2 of PA 06_0009, NCIG has taken steps to ensure that trains operated on the site meet established noise performance criteria. This included construction of dedicated noise abatement berms directly adjacent the NCIG rail line and design and construction of the rail alignment to reduce noise from locomotive and wagon wheels.

Operations noise management measures are further detailed in the ONMP.

4.6.2 Environmental Performance

Table 4-10 outlines the monitoring locations, noise monitoring parameters recorded, frequency of monitoring and noise and vibration criteria for the operation of the Terminal in accordance with the ONMP.

Table 4-10: Summary of the Noise Monitoring Program

MONITORING PARAMETER	MONITORING SITES	FREQUENCY	CRITERIA
Attended noise monitoring	Fern Bay West, Fern Bay East, Stockton West, Stockton East, Mayfield West, Mayfield, Carrington	6-monthly	See below
Attended noise monitoring	Static and mobile elements of terminal operations	6-monthly	See ONMP

1 The location of monitoring sites is shown on **Figure 4-1.**

Noise criteria for the site operations, as defined by the Project Approval and EPL 12693, are provided in **Table 4-11** and **Table 4-12.** Noise monitoring was undertaken by specialist acoustic consultants on a six-monthly basis during the reporting period.

Table 4-11: Residential Noise Criteria

Location	Day/Evening/Night At all times	Night 10:00pm to 7:00am Monday to Saturday 10:00pm to 8:00am on Sundays and Public Holidays	
	$L_{Aeq(15\ minute)}$	$L_{Aeq(night)}$	$L_{A1(1\ minute)}$
Fern Bay West	41	37	57
Fern Bay East	39	36	55
Stockton West	41	37	57
Stockton East	38	35	56
Mayfield West	45	40	55
Mayfield	44	39	62
Carrington	36	33	52

The maximum allowable noise conditions apply under:

a) wind speeds of up to 3 m/s at 10 m above ground level

b) temperature inversion conditions of up to 3 degrees Celsius (°C) per 10 m and 2 m/s at 10 m above ground level.

Table 4-12: Industrial Noise Criteria

NON-RESIDENTIAL LOCATION	LAND USE	INTRUSIVE $L_{AEQ(15 MINUTE)}$ DAY/EVENING/NIGHT	ACCEPTABLE AMENITY $L_{AEQ(PERIOD)}$[1]			MAXIMUM AMENITY $LA_{EQ(9 HOUR)}$
			Day	Evening	Night	Night
Mayfield West	Commercial Steel River	Intrusive noise not applicable	65	65	65	70
Kooragang Island	Industrial		70	70	70	75
Mayfield North			70	70	70	75
Any	School		External 45 when in use	50	-	-
Any	Hospital		External 50 when in use	55	-	-

1: Daytime 7:00am to 6:00pm, Evening 6:00pm to 10:00pm, Night-time 10:00pm to 7:00am.

The monitoring undertaken principally consisted of six-monthly attended noise monitoring. Operator attended noise surveys were conducted at each noise logger location to assist in defining noise sources and the character of noise in the area. All operator-attended noise measurements were conducted using a Bruel and Kjaer Type 2250L Type 1, integrating sound level meter (S/N 3004635) or Bruel and Kjaer Type 2270 Type 1, integrating sound level meter (S/N 2679354).

During the reporting period, offsite noise and onsite sound power monitoring was undertaken and reported biannually, with reports for the period ending December 2019 and June 2020. These reports concluded that offsite noise monitoring indicated compliance was achieved at both selected residential and industrial locations under prevailing conditions (SLR 2019 and SLR 2020). The respective noise reports are included in **Appendix 5**.

4.6.3 Reportable Incidents

No environmental incidents or complaints were reported relating to noise or vibration during the reporting period.

4.6.4 Further Improvements

No improvement to noise monitoring is required for the next period. Notwithstanding, NCIG implements a Continuous Noise Improvement Program. The program will continue to be implemented as part of ongoing NCIG operations.

4.7 ECOLOGY

4.7.1 Environmental Management

4.7.1.1 Kooragang Island Green and Golden Bell Frog Management

The Green and Golden Bell Frog (*Litoria aurea*) (GGBF) is listed as Endangered under the NSW *Biodiversity Conservation Act 2016* (BC Act) and Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Known and potential GGBF habitat is located across the Terminal site and surrounds and, as such, NCIG has various commitments to monitoring, management and offsetting of impacts to the GGBF.

A management plan for the relocation of GGBF individuals was prepared in accordance with Condition 2.16, Schedule 2 of PA 06_0009. The GGBFMP was developed in consultation with the Department of Environment and Climate Change (DECC) (now DoEE) and the Regional Land Management Corporation (now the Hunter and Central Coast Development Corporation (HCCDC)). This plan has now been incorporated into the site ELMP.

In June 2017, a Memorandum of Understanding (MOU) on the GGBF on Kooragang Island was executed between the former NSW Office of Environment and Heritage and NCIG, PWCS, HCCDC, BHP Billiton and University of Newcastle (UoN). The MOU was developed under the NSW Government's Saving our Species conservation program, which aims to maximise the number of threatened species that can survive in the wild in NSW for 100 years. Kooragang Island is one of seven management sites identified by NSW Biodiversity Conservation Division (BCD) for conservation activities to protect the GGBF. The MOU was developed to assist with data sharing from GGBF population and habitat monitoring programs completed by UoN for different stakeholders.

Monitoring and characterisation of the GGBF population on Kooragang Island, in and surrounding the industrial part of the island has been completed for the ninth year by the Conservation Biology Research Group, UoN. This work is being co-funded by NCIG, BHP, PWCS, PoN and HCCDC. Monitoring continued throughout the summer season and the annual report was finalised in December 2020, including population estimates for the island. A copy of the report is included in **Appendix 6**.

The objectives of the monitoring on Kooragang Island are to:

- Calculate a robust evaluation of total GGBF population size within Kooragang Island Management Zone.
- Determine the demographic composition of these populations, specifically the ratio of adults to sexually immature juveniles and the ratio of males to females.
- Define the spatial distribution of the GGBF population, including assessing where individuals are concentrated and evidence of movement between wetlands and across infrastructure barriers.

4.7.1.2 Compensatory Habitat and Ecological Monitoring Program

In accordance with Condition 2.20, Schedule 2 of PA 06_0009 NCIG developed and submitted for approval a CHEMP, which details how habitat and ecological values lost as a result of the project will be offset, and how ecological monitoring will be undertaken to inform ongoing ecological management. The CHEMP includes compensatory habitat for both the GGBF and migratory shorebirds. CHEMP monitoring reports are attached in **Appendix 7** for the reporting period. These include:

1. Kooragang Island GGBF Population monitoring, including the quarterly reporting undertaken by UoN (Conservation Biology Group): *Green and Golden Bell Frog Research and Monitoring Program on Ash Island*;
2. NCIG GGBF Compensatory habitat monitoring and management; and
3. NCIG Shorebird Compensatory habitat monitoring and management.

The objective of the shorebird compensatory habitat is to provide additional habitat for migratory shorebirds in accordance with PA 06_0009 and the subsequent Shorebird Compensatory Habitat Review of Environmental Factors (NCIG, 2014). NCIG is required to establish shorebird compensatory habitat for 4 ha of shorebird habitat clearance associated with the northern rail spur and rail flyover modification. NCIG has achieved this through mangrove removal and saltmarsh habitat restoration within an area on Kooragang Island known as Fish Fry Flats or Area E for reporting purposes (refer **Figure 4-9**).

4.7.2 Environmental Performance

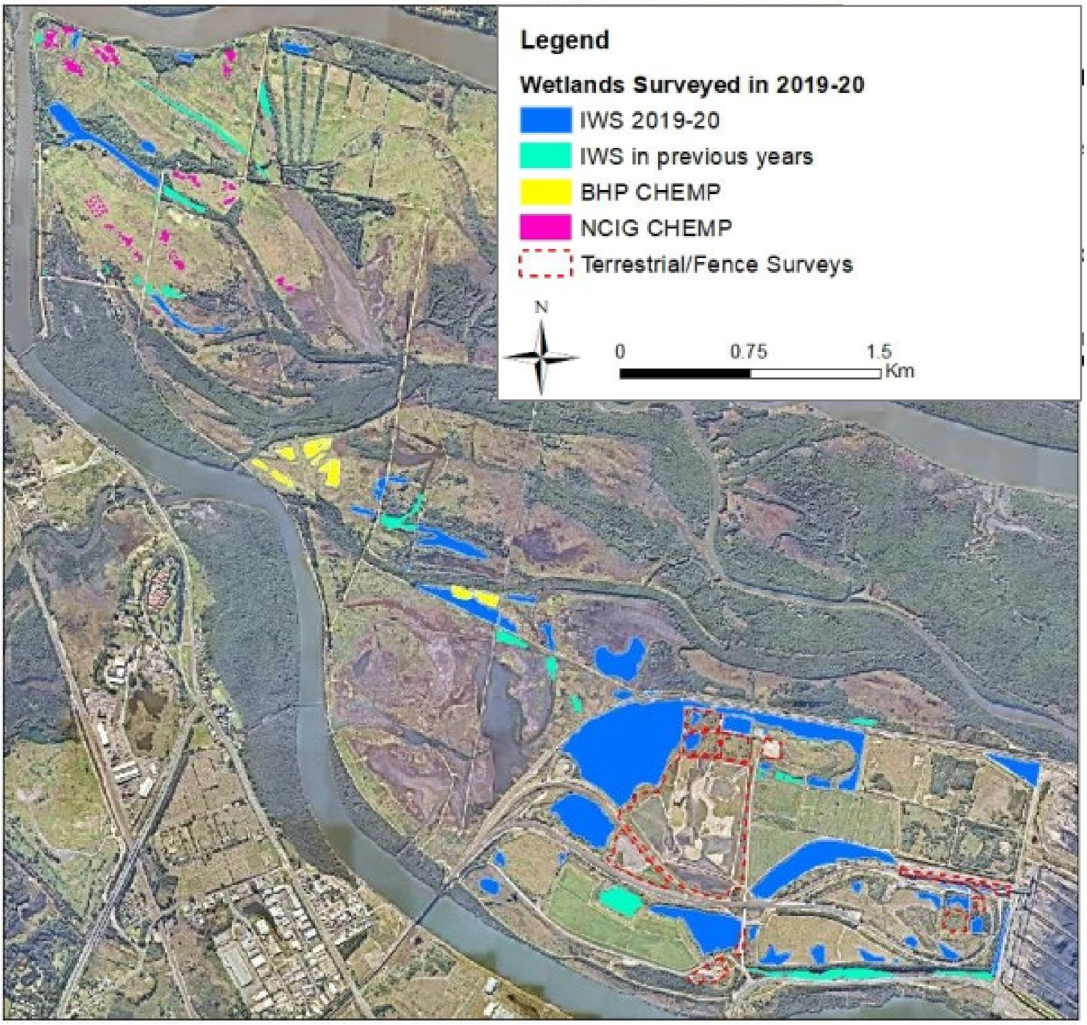
4.7.2.1 Kooragang Island Green and Golden Bell Frog UoN Research Program

Two methods were used to estimate the population per surveyed pond, namely Visual Encounter Surveys (VES) and Capture-Mark-Recapture Surveys (CMR). Both these methods utilise recording of morphometrics of individuals surveyed, location and environmental conditions where individual locations were found and micro-chipping using Passive Induction Transponder (PIT) tags. Both surveys were conducted at night using survey teams of two to six people. A full methodology is provided in **Appendix 6**.

A total of 60 wetlands were surveyed during the 2019/2020 breeding season, as shown in **Figure 4-5**. Four principal rounds of surveys were completed: Round 1 in September 2019; Round 2 in December 2019; Round 3 in February 2020; and Round 4 in March 2020.

Three additional rounds were completed: in early November 2019; after a large rainfall event occurred in February 2020; and following a GGBF dispersal event in March 2020. No GGBF were captured during the additional rounds.

A summary of the key results from the 2019/2020 surveys are summarised in **Table 4-13**.



Wetlands of Kooragang Island – showing 47 wetlands surveyed in each round of the 'island wide' surveys of 2019-2020. The positions of NCIG CHEMP and BHP CHEMP wetlands are also shown; 13 of these wetlands were surveyed in each round of the island-wide surveys in 2019-2020, making a total of 60 wetlands.

The location of wetlands that were surveyed in previous years is also shown.

Source: University of Newcastle, 2020

Figure 4-5: Green and Golden Bell Frog Island Wide Surveyed Areas

Table 4-13: Summary of Green and Golden Bell Frog Research Program Findings 2019/2020

Area	Characteristic	Summary of Findings
Population	Size	The population size is currently at approximately 3,000, similar to 2017-2018 season however smaller than 2018-2019 season which could indicate stabilisation of the population after a long term gradual upward trend since 2010-2011.
Demography	Age/sex class structure	Less than a third of the GGBF detected across the season were metamorphs or juveniles. One half to two thirds of the individual detected were male. These findings are broadly consistent with recent seasons.
	Recruitment	Sixteen wetlands within the Industrial Zone (defined in **Appendix 6**) held either tadpoles and/or metamorphs at some point during the 2019-2020 breeding season. It is thought that breeding occurred across all zones this season including one in the NCIG CHEMP wetlands. A large dispersal event occurred throughout April within the Industrial Zone. Hundreds of very small juveniles were detected indicating they were spawned in the February rainfall event (refer **Section 4.7.3**).
	Gravid females	Using 58 mm snout vent length as the threshold for onset of female maturity, 221 unique adult females (identified by tags) were captured during the season, being similar to data from the previous three years. This indicates the population size is sufficient for at least the immediate persistence of the population however concern for a lack of multiple breeding seasons is appearing.
Longitudinal Data	Persistence	Approximately 10% of the tagged GGBF that are recaptured are recaptured more than one year after their first capture, and 2% are recaptured after more than two years. This indicates a low rate of survival.
	Movement	Most movements were detected between wetlands within the Northern Industrial Zone and within the Southern Industrial Zone (areas defined in **Appendix 6**), with most movements this season being between wetlands less than 200m apart. Movements were made by nearly an equal number of adult males and females during the 2019-202 season.
Landscape Use	Distribution	The highest abundance of GGBF on Kooragang Island continues to be in the Industrial Zone, particularly in the northern region. An increase in abundance of adult GGBF was identified in the southern region of the Industrial Zone, likely linked to the construction of new wetlands in this area creating an effective habitat mosaic.
	Habitat	Over the last decade several phases of artificial wetlands have been constructed across Kooragang Island. Collectively these constructed wetlands appear to support nearly half of the Kooragang Island's GGBF population. This season indicated a marked increase in the abundance of GGBF in the NCIG CHEMP wetlands.
	Gambusia	The majority of breeding occurred in wetlands absent of *Gambusia* however breeding did occur in three wetlands with *Gambusia* present. This is an important finding as management strategies to control population density of *Gambusia,* as opposed to removal of *Gambusia* from waterbodies, could be effective.
	Chytrid	Infection by the pathogenic fungus *Batrachochytrium dendrobatidis* can result in the disease chytridiomycosis (commonly known as chytrid), which affects amphibians and has caused population declines and extinction worldwide. Average chytrid load across Kooragang can be assessed via swabbing of GGBF during late winter and early spring. 280 samples were collected in the 2019-2020 season. Forty percent of the viable samples taken were positive for chytrid.
	Habitat mosaic	A single large wetland, or an array of smaller very similar wetlands, is much less suitable than an array of different wetlands. This concept of multiple heterogeneous wetlands within a small area has been termed the 'habitat mosaic'**.** Three new cluster ponds were installed in 2019 to provide deep permanent refuge habitat in and around the rail loop. To ensure effectiveness of the habitat mosaic, larger permanent wetland in the Southern Industrial Zone would provide for both local persistence all year round and breeding opportunities.

Area	Characteristic	Summary of Findings
	Northern zone of island	This has long been the zone with the lowest abundance of GGBF, but numbers improved markedly in the 2019-2020 season, due mainly to increased occupancy at the NCIG CHEMP wetlands.
Specific Strategies Relevant to NCIG	Rail infrastructure mitigation strategy	Significant movements between northern and southern Industrial Zones were detected in the 2019-202 season. Movement was also detected which would require GGBF to go over or under rail lines. These findings indicate that rail does not constitute an impassable obstacle for GGBF and the rail infrastructure on Kooragang Island is not expected to lead to fragmentation of the population, especially where connectivity across the landscape is maintained or improved through well-designed constructed wetlands.
	Constructed wetland strategy	The NCIG CHEMP wetlands have not initially shown the success rates of the cluster ponds, HDC wetlands and BHP CHEMP wetlands. However, the 2018-2019 data showed an increase in occupancy and this was also reaffirmed with the 2019-2020 season. In addition, the detection of a juvenile within the NCIG CHEMP wetlands suggest that a breeding event occurred in the north.
Other Issues	Fire	The grass fire in the January 2019 was not fully extinguished until September 2019 along Bellfrog Way, restricting access to some areas until October 2019.
	Drought conditions	Drier than average conditions have been experienced on Kooragang Island over the past four seasons. The lower than average rainfall experienced in the 2019/2020 season resulted in many wetlands being void of water during the early to mid-Summer period, including many that have historically been characterised as 'permanent'. Late summer rainfall in February 2020 recharged the wetland system and sparked a large breeding event. Further investigation is required into the impact of extended dry periods on the GGBF population.

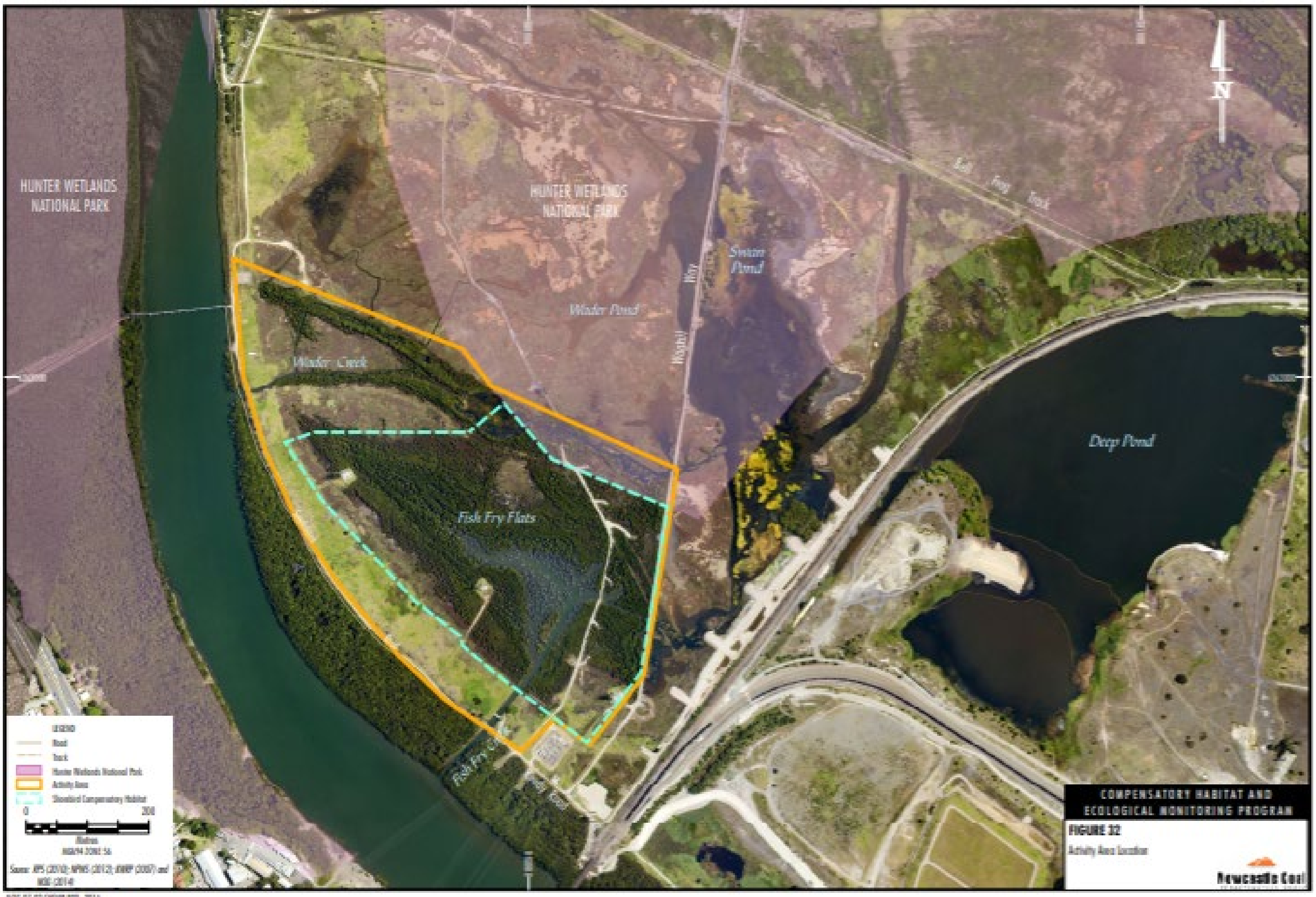
4.7.2.2 NCIG Green and Golden Bell Frog Compensatory Habitat Monitoring and Management

The Green and Golden Bell Frog Research and Monitoring Program on Ash Island was undertaken by the UoN (Conservation Biology Group) over the 2019/2020 season. Five rounds of surveys were conducted within the NCIG CHEMP constructed habitats during September 2019 and April 2020. A total of 99 GGBF were observed across 10 of 55 constructed ponds in the NCIG Compensatory Habitat during the survey period. One breeding event was confirmed within the CHEMP habitat. The small number of juveniles observed through the CHEMP system is evidence of continued low breeding activity across the NCIG CHEMP habitats (refer to **Appendix 7**). Within the previous reporting period physical macrophyte removal was undertaken to increase open water towards the 30 – 60% target under the CHEMP. Data analysis post macrophyte removal indicates the return of GGBF to the disturbed waterbodies however further investigation and research is required to develop an understanding of the benefits and/or impacts of adaptive management measures to optimise GGBF population density within the system.

4.7.2.3 NCIG Shorebird Compensatory Habitat Monitoring and Management

Area E Shorebird Monitoring

Monthly monitoring of migratory shorebirds and other waterbird species is conducted on the NCIG site and has been occurring since February 2017. This is completed primarily in the ponds around the NCIG rail facility, such as Deep Pond, Swan Pond and Wader Pond, refer to **Figure 4-6**. These surveys are conducted to monitor the effectiveness of the compensatory habitat program and to take appropriate management action to encourage colonisation on these species.



The blue dashed line signifies Fish Fry Flats (the area of habitat restoration) and the orange solid line an additional area of management and monitoring

Figure 4-6: Shorebird Compensatory Habitat Area and Surrounding Waterbodies

In accordance with the Shorebird Monitoring Evaluation Reporting and Improvement Plan (MERI), fortnightly surveys are undertaken in September-April (high tide, low tide and nocturnal roosting), and monthly in April-September (high tide and low tide). A summary of the results is presented in **Table 4-14**. In the 2019/2020 survey period a total of 32 shorebird species, including four migratory shorebird species, were recorded from all sites in Area E. Throughout the duration of the survey program, which commenced in 2017, a total of 49 shorebird species have been recorded for all sites within Area E. This includes a range of wetland and migratory shorebird species. A new shorebird species, the Banded Stilt, was recorded in December 2019.

Results to date identify a trend of stable shorebird richness within Fish Fry Flat with fluctuations throughout each year. The clearing of mangroves and habitat restoration has provided additional forage habitat for shorebirds and some migratory shorebird species. The area is primarily used for foraging rather than high tide roosting, however roosting did occur at Fish Fry Flat by Red-necked Stints and Sharp-tailed Sandpipers during the survey period. White-fronted Chats were observed on six occasions in 2019 in comparison to their first sighting in 2018 on three occasions.

Table 4-14: Migratory Shorebird Species Recorded in Area E 2017-2020

Species	All Sites Area E				Fish Fry Flats			
	2017	2018	2019	2020	2017	2018	2019	2020
Curlew, Eastern	p	p	p	p	p	p		p
Godwit, Bar-tailed	p	-	-	-	-	-		-
Greenshank, Common	p	-	-	p	p	-	p	-
Knot, Red	p	-	-	-	-	-		
Plover, Double-banded	p	p	p	p	p	-	p	p
Plover, Pacific Golden	p	p	-	-	p	p	-	-
Sandpiper, Curlew	p	p	-	-	-	p	-	-
Sandpiper, Marsh	-	p	-	-	-	-	-	-
Sandpiper, Sharp-tailed	p	p	p	p	p	p	p	p
Snipe, Lathams	-	p	-	-	-	p	-	-
Stint, Red-necked	p	p	p	p	p	p	p	p
Turnstone, Ruddy	-	-	-	p	-	-	-	-
Total Species	**9**	**8**	**4**	**6**	**6**	**6**	**4**	**4**

p = Present

Area E Wetland Hydrology Monitoring

UNSW Water Laboratories were commissioned to develop hydrological controls and annual SmartGate Trigger Levels to promote habitat restoration within Area E (Fish Fry Flats). Detailed investigations have been conducted since February 2017 to understand groundwater movement and interactions with surface water, as well as water quality, under different conditions including:

1. Wetland in natural tidal conditions;
2. Wetland flooded, with flushing restricted by the SmartGate; and
3. Wetland drained, with the gates preventing inundation.

To date, the project has been successful with the growth of saltmarsh and the return of shorebirds to the area due to the regulation of the site hydrological system. The project is considered one of the most significant habitat restoration projects for migratory shorebirds in Australia including being recognised internationally via a Working with Nature Certification from the World Association for Waterborne Transport Infrastructure. In addition, a scientific article based on the findings of this project has been published within the international Journal of Environmental Management (Sadat-Noori etal, 2019).

Success of the project can be seen in **Figure 4-7** sourced from the UNSW (2020) report which shows saltmarsh vegetation growth from February 2017 to December 2019. The images were taken by drone surveys conducted six monthly since February 2017.

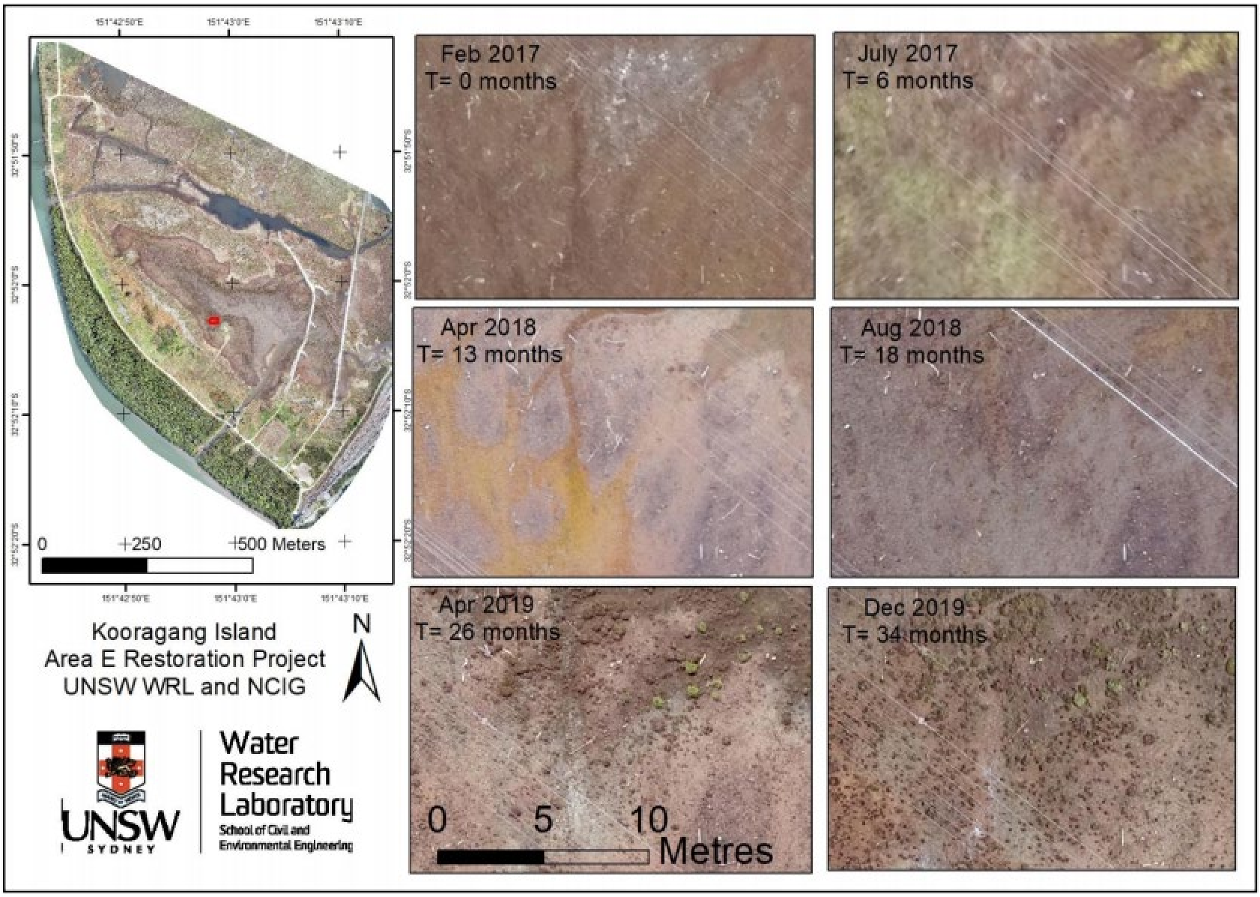


Figure 4-7: Saltmarsh vegetation growth from February 2017 to December 2019

4.7.2.4 Avifauna Monitoring Program

The Hunter Bird Observers Club (HBOC) undertook monthly surveys of Deep Pond North and Deep Pond South during the 2019 calendar year, refer to **Figure 4-6.** The aim of the monitoring program is to identify the pattern of usage of Deep Pond North and Deep Pond South by all birds over the annual cycle.

A summary of the results and of observations by Hunter Bird Observers Club is as follows:

- The count of migratory and resident shorebirds using Deep Pond in 2019 was high comparative to previous years, both in terms of the number of species and individual birds.
- Several species listed as under the BC Act or EPBC Act were observed utilising Deep Pond during 2019, including White-bellied Sea Eagles, Spotted Harrier, Black-tailed Godwit, and Eastern Curlew.
- Deep Pond (in particular Deep Pond North) remains an important site for migratory shorebirds (and waterfowl), especially when conditions elsewhere in the region may not be favourable.
- Given the diversity of avifauna using the site, Deep Pond remains a unique and important habitat entity in the Hunter Estuary.
- Seven migratory shorebird species were recorded at Deep Pond in 2019, compared to four in 2018.
- Five species of resident shorebird were recorded at Deep Pond during 2019 as was recorded in 2018, being Masked Lapwing, Black-fronted Dotterel, Black-winged Stilt, Red-capped Plover and Red-necked Avocet.

The detailed observations are provided in **Appendix 8**.

4.7.3 Reportable Incidents

No incidents or complaints were reported relating to flora and fauna management during the reporting period.

4.7.4 Further Improvements

Within the reporting period a review of the shorebird component of the CHEMP was undertaken. The intent of the review was to assess if the site management measures and monitoring program being implemented is meeting the aim and objectives of the CHEMP (in relation to the shorebird habitat) being:

- Reinstate saltmarsh/mudflat habitat for shorebirds through removing mangroves from a substantial area on Kooragang Island
- Provide additional habitat for migratory shorebirds in accordance with Condition 2.20 of PA 06_0009.

The review intended to identify any areas of deficiencies and recommend opportunities to improve the program to meet the aim and objectives of the CHEMP. Recommended actions resulting from the review will be implemented, as appropriate, within the next reporting period.

In addition to that stated above, works for 2020/2021 will include the following:

- Continued monitoring and analysis of the GGBF population and adaptive management measures within the NCIG construction habitat to encourage breeding activity within the system and increase population densities.
- Continued fox baiting program in collaboration with BHP including NCIG GGBF habitat, BHP GGBF habitat and NCIG shorebird habitat.
- Continued focus on removal of priority weeds through the CHEMP areas including Alligator Weed.

4.8 WASTE MANAGEMENT

4.8.1 Environmental Management

In accordance with Conditions 2.54 and 2.56, Schedule 2 of the PA 06_0009, waste materials removed from the site were directed to a waste management facility lawfully permitted to accept the materials (NCIG Waste Audit Report (Cross Connections Consulting Pty Ltd (2019) sighted by Ramboll).

A WMP has been developed and incorporated into the environmental management system for the operations of the Terminal. The WMP is reviewed and updated every two years. Waste volumes are tracked on a monthly basis, with the assistance of NCIG's waste management contractor.

A target was set for recycling of 65% of the total waste generated onsite. Waste streams at NCIG include: General waste, paper and cardboard, co-mingled, soft plastics, oily rags and oil absorbent material, oil filters, metal, used conveyor idlers, timber, oil and grease (including empty drums), oily water, effluent, E-waste, fluorescent tubes, batteries, aerosol cans, paint and hazardous chemicals, green waste.

In accordance with Condition 2.57, Schedule 2 of the PA 06_0009, waste was not received at the site during the reporting period.

4.8.2 Environmental Performance

The principles of waste management, being waste avoidance and reduction, material reuse and recycling have been adopted by NCIG and all contractors on the site during the reporting period. The focus of this process has been the avoidance of waste; however, the recycling of waste products was also actively pursued.

NCIG achieved their lowest volume of onsite generated waste in four years of operation during the reporting period. A total of 240 tonnes of waste was generated onsite, which is a 42% reduction on the previous reporting period. **Figure 4-8** shows the annual total waste generated and the breakdown of waste generated that ends up in landfill or is recycled. Just over 60% of waste generated in 2019-2020 was recycled. Additionally, 560 kg of soft plastics were recycled by NCIG staff and contractors as part of the Plastic Police Program initiative.

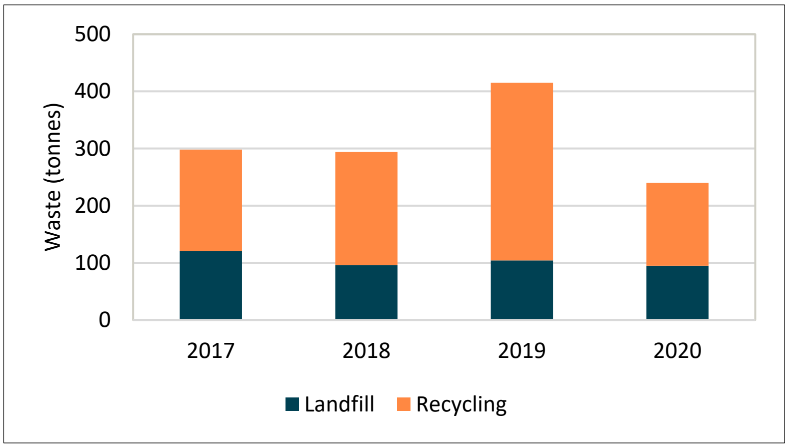


Figure 4-8: Annual Waste Generation and End Use Ratio

4.8.3 Reportable Incidents

No incidents or complaints were reported relating to waste management during the reporting period.

4.8.4 Further Improvements

Continue involvement in the Plastic Police Program to recycle soft plastics into reusable products alongside numerous government and community groups.

4.9 COMMUNITY RELATIONS

4.9.1 Environmental Management

The following complaints handling system was maintained during the reporting period:

- In accordance with Conditions 6.2, Schedule 2 of the PA 06_0009, NCIG operates a telephone number, postal address and email address for community complaints and enquiries. Current details are provided below:

  24-hour complaints telephone hotline: 1800 016 304
  Postal address for written complaints: Locked Bag 6003 HRMC NSW 2310
  Email address for electronic complaints: enquiries@ncig.com.au
- The community can access these details via the NCIG website (www.ncig.com.au), newsletters and signage at the NCIG site.
- In accordance with Conditions 6.3, Schedule 2 of PA 06_0009, NCIG recorded all complaints received in a Complaints Register.
- In accordance with Condition 6.4 of PA 06_0009, NCIG established and maintains a website for the provision of electronic information associated with the Terminal including all relevant Management Plans.

4.9.2 Environmental Performance

4.9.2.1 Complaints Management

Table 4-15 provides a summary of the complaints received during the reporting period. The outcome of the complaints handling process was recorded in the Complaints Register, including:

- Action taken by NCIG in relation to the complaint, including all follow-up contact with the complainant.
- Details of the finding of the investigation and the reason(s) why no action was taken.

NCIG's objective was to address the concerns of the complainant in a manner that resulted in a mutually acceptable outcome.

Table 4-15: Community Complaints Register Summary

COMPLAINT/ENQUIRY CATEGORY	NUMBER OF ENQUIRIES/COMPLAINTS	DESCRIPTION OF COMPLAINT/ENQUIRY
AIR QUALITY	7	• One of the complaints received regarding dust/air quality was not in relation to NCIG. • Five of the complaints/enquiries received regarding dust/air quality were received from neighbouring industrial businesses. Four of these were from one particular neighbouring industry who had concerns in relation to the dust potential of NCIG operational activities and were seeking assurance that NCIG were implementing systems to prevent any dust related impact on their workers' health and amenity. NCIG have held an open line of communication with the neighbouring industry and all communications are entered in the Complaints and Enquiries Register separately for tracking purposes. NCIG have held regular catchups with the business to provide updates and information on dust management controls. The neighbouring business has been satisfied with the response and have recently provided positive feedback in regard to dust management following the most recent wind season. • One of these enquiries is in relation to an information request received from the EPA in regard to preparedness and management of dust during a prolonged wind event – information was provided to the EPA in the requested time frame. • No further action is required for any of the above.
Water	0	N/A
Noise	0	N/A
Waste	0	N/A
Other	2	• One enquiry was received by the EPA in relation to a potential spill from a train on the NCIG rail network as reported by a rail haulage provider. NCIG was requested to assist in obtaining information as the EPA was unable to get in contact with the original caller. NCIG obtained information that the spill was contained within an internal catch tray on the train and no spillage occurred on the NCIG rail. NCIG provided the EPA with another contact to close the incident out with the rail haulage provider. • One enquiry was received by a community member in regard to a chipped wind screen whilst driving on Cormorant Road. An investigation was undertaken and found to be unlikely a result of NCIG operations. The community member was satisfied with the outcome of the investigation. • No further action is required for any of the above enquiries.

4.9.2.1 Community Engagement Group

NCIG continued the Community Engagement Group (CEG) established during the previous reporting period. The CEG aims to provide a forum to provide the local community with information about NCIG's operations and give a voice to the community in matters such as operational activities, environmental performance and community investment initiatives. Forums were held every four months in September 2019, January 2020 and May 2020. Minutes from each CEG Meeting are published on the NCIG website (https://www.ncig.com.au/community/community-engagement).

4.9.2.2 Community Investment Initiatives

NCIG has been providing community investment initiatives via two funding programs:

- The Community Support Program: catering for community organisations looking for funding assistance with an event, small projects/initiatives or purchases of equipment; and
- Community Partnership Program: a three-year program designed to develop a close partnership with an organisation or group who is seeking to implement a grassroots project of significance that benefits the wider community.

In particular, investments aim to meet one or more of the following objectives:

- Promote overall community involvement
- Implement community-generated programs to improve local amenity and the environment
- Promote physical or mental health through activity
- Promote and assist in education of our local community.

Historically the Community Support Program has had two application intakes, in March and September each year, from community groups seeking support for their endeavours. The September 2019 intake occurred as planned with NCIG providing financial support to sixteen community organisations. In response to COVID-19 the March 2020 intake was postponed. NCIG recognised the impacts and challenges COVID-19 was placing on the community and redirected the Community Support Program to support existing community partners who provide essential community services within the community. Through this COVID funding, NCIG donated a total of $145,000 to twelve community groups and organisations who provide social welfare programs such as mental health services and the supply of essential supplies to the vulnerable and disadvantaged were supported. A full list of recipients is provided in **Appendix 8.**

The Community Partnership Program accepts expressions of interests between September to November each year. NCIG established a partnership with HunterWiSE, Callaghan College and Newcastle High School for the 2019 Community Partnership Program. NCIG have committed $90,000 over three years to enable female STEM students from both schools to participate in specialised mentoring and enrichment programs.

NCIG additionally partnered with Mission to Seafarers (MTS) Newcastle, committing $15,000 per year for three years. MTS provides support to the vessel crew visiting the Port of Newcastle. Maintaining port-based operations were challenging during COVID-19 and new channels to continue support to the seafarers were developed. The health and wellbeing of the seafarers is of great importance to the operation of the port.

In total NCIG contributed $276,000 to support community initiatives and services over the 2019-2020 period. In 2020, NCIG celebrated 10 years of the Community Support Program and look forward to continuing to support the community.

4.9.2.3 Sustainability

NCIG prepared a Sustainability Report for the reporting period. The Sustainability Report highlights key achievements consistent with NCIG's Sustainability Development Policy in regard to people, critical infrastructure, the environment and contribution and engagement. The annual Sustainability Reports are maintained on the NCIG website at: https://www.ncig.com.au/business/corporate-sustainability

4.9.2.4 Community Engagement Summary

The chronology of community liaison held during the reporting period is outlined in **Table 4-16**.

Table 4-16: Community Liaison Summary

DATE	TYPE
2019	NCIG Newsletter Edition 1 2019
September 2019	Community Support Program – submissions called, 16 successful, CEG Meeting
2019	NCIG Newsletter Edition 2 2019
January 2020	CEG meeting
May 2020	Community Newsletter Edition 1 2020
March 2020	Community Support Program – 12 recipients
May 2020	CEG meeting
Autumn 2019	Community Newsletter Edition 2 2020

4.9.3 Reportable Incidents

No incidents were reported relating to community relations during the reporting period. Complaints received during the period are detailed in the section above.

4.9.4 Further Improvements

NCIG will prioritise projects or programs that fall under one of the NCIG community investment focus areas of community, environment, health and education – with applicants assessed on how well they align to these values and how they translate into a project that benefits the broader community.

NCIG will continue the Community Support Program and Community Partnership Program.

4.10 GENERAL OPERATIONAL MATTERS

4.10.1 Heritage

As the terminal is in operational mode and no further ground disturbance is required it is highly unlikely any Aboriginal heritage objects of significance would be present at the site (DEC, pers, comm, 15 February 2007). Induction training attended by all NCIG personnel continues to include information relating to Aboriginal heritage and the potential identification of items of archaeological significance.

5. COMPLIANCE AUDITS

Audits were undertaken in relation to NCIG activities which considered the compliance status of the Terminal operations for the reporting period. These reviews were conducted to meet the requirements of Condition 5.1 of development Approval 06_0009 (a):

> *5.1 The Proponent shall develop and implement a Compliance Tracking Program to track compliance with the requirements of this approval. The Program shall include, but not necessarily limited to:*
> *a) provisions for periodic review of the compliance status of the project against the requirements of this approval;*
> *c) a program for independent auditing at least annually, or as otherwise agreed by the Director-General, in accordance with ISO19011:2002, Guidelines for Quality and/or Environmental Management Systems Auditing.*

The details and outcomes of the audits conducted are illustrated below.

5.1 COMPLIANCE TRACKING PROGRAM UPDATED APRIL 2020

A Compliance Tracking Program was set up for the NCIG CET in accordance with Condition 5.1, Schedule 2 of PA 06_0009. The Compliance Tracking Program was updated in April 2020. The Compliance Tracking Program indicated that project compliance has been achieved for each condition of the Project Approval with the exception of one item as described in **Table 5-1.**

Table 5-1: Compliance Status Summary

REF	CONDITION	COMPLIANCE DETAILS	COMPLIANCE STATUS
2.41	Except as may be expressly provided under the provision of an Environment Protection Licence for the project, the Proponent shall comply with section 120 of the *Protection of the Environment Operations Act 1997* which prohibits the pollution of waters	As identified in Section 4.4.3, two incidents occurred during the reporting period which resulted in water pollution in the Hunter River. It is noted that both incidents were assessed as minor and did not cause actual or potential significant off-site impacts on people or the biophysical environment (as outlined in Condition 8.1 of PA 06_0009), nor were the incidents considered to have resulted in 'material harm to the environment' as defined under the *Protection of the Environment Operations Act 1997*. NCIG received a Formal Warning from the EPA in regard to the incident in November 2019.	As noted, both incidents were reported to the EPA and an internal investigation was undertaken. The resulting action of each incident is provided below: Incident occurring 10 July 2019 Key learning: meteorological conditions need to be considered before performing maintenance tasks A HSEC Alert was provided to the business, providing detail of the incident, corrective measures and the importance of recognising and managing impacts to the environment. Training/toolbox updates were provided to staff and contractors Incident occurring 21 November 2019 Key learning: additional focus is to be placed on wheel guards during monthly inspections and on daily walk arounds The damaged infrastructure was repaired, and the Shiploader hydrocarbon risk assessment was reviewed. A pollution response Drill included a harbour related spill scenario to test the preparedness of NCIG to response to a large pollution incident. There are no outstanding actions for the incidents or the non-compliance.

5.2 INDEPENDENT ENVIRONMENTAL AUDIT

An IEA will be conducted on a 3-yearly basis (as agreed by the Director-General's delegate in a letter dated 14 July 2016) in accordance with Conditions 5.1(c), Schedule 2 of PA 06_0009. The IEA will be conducted by a suitability qualified independent person and in accordance with *ISO 19001:2002 Guidelines for Quality and/or Environmental Management Systems Auditing*.

The first IEA was conducted within 12 months of the commencement of construction. This has been conducted annually until 2015, with the most recent IEA conducted in December 2018. All actions associated with the most recent IEA have been closed. The next IEA will be conducted in December 2021.

6. STANDARDS

NCIG achieved re-accreditation of the Environmental Management System (EMS) against the ISO 14001:2015 standard within the reporting period. Accreditation was first achieved in 2017. Re-accreditation resulted from an onsite audit conducted by SAI Global that occurred in June 2020. NCIG continues to effectively implement and improve the EMS and place a high priority on the environmental performance of the terminal. This accreditation is pursued voluntarily by NCIG.

7. ACTIVITIES PROPOSED IN NEXT AEMR PERIOD

The principal elements of activities proposed within the next reporting period are:

- Receive approval on the increased throughput of 79 Mtpa capacity CET.
- Continued implementation and improvement of the NCIG EMS.
- Ongoing incorporation of dust management technologies and controls to continue to improve the management practices for air quality. Consultation with neighbouring industries will continue to minimise impacts to receivers.
- NCIG will continue to investigate the feasibility and justification of using imported recycled water for dust suppression and process use to reduce the requirement for potable water during extended dry conditions.
- Continued fox baiting program in collaboration with BHP including NCIG GGBF habitat, BHP GGBF habitat and NCIG shorebird habitat.
- Continued weed management practices within the CHEMP areas with a focus on priority weeds and Alligator Weed.
- Implementation, as appropriate, of the recommendations identified in the CHEMP Shorebird Monitoring Program Review.
- Funding rounds will continue to open every six months in March and September, with funding of up to $10,000 available for applicants of the Community Support Project and up to $90,000 over the three-year period for the Community Partnership Program.

8. REFERENCES

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9. LIMITATIONS

Ramboll Australia Pty Ltd (Ramboll) prepared this report in accordance with the scope of work as outlined in our proposal to NCIG dated August 2019 and in accordance with our understanding and interpretation of current regulatory standards.

The conclusions presented in this report represent Ramboll's professional judgment based on information made available during the course of this assignment and are true and correct to the best of Ramboll's knowledge as at the date of the assessment.

Ramboll did not independently verify all of the written or oral information provided to Ramboll during the course of this investigation. While Ramboll has no reason to doubt the accuracy of the information provided to it, the report is complete and accurate only to the extent that the information provided to Ramboll was itself complete and accurate.

This report does not purport to give legal advice. This advice can only be given by qualified legal advisors.

9.1 USER RELIANCE

This report has been prepared exclusively for NCIG and may not be relied upon by any other person or entity without Ramboll Australia's express written permission.

APPENDIX 1

METEOROLOGICAL (OTHER THAN RAINFALL) SUMMARY

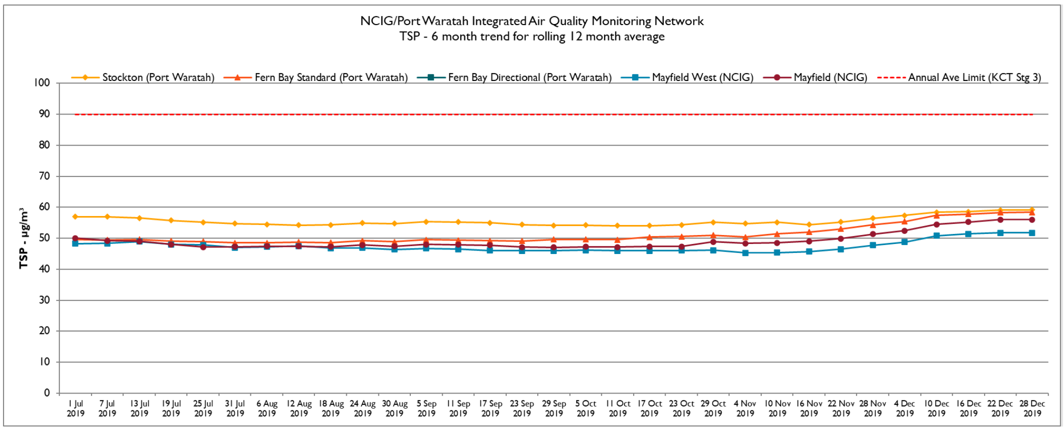
TABLE A1.1 METEOROLOGICAL STATISTICS BY MONTH									
MONTH	WIND SPEED			SIGMA THETA			SOLAR RADIATION		
	Monthly average m/s	Hourly min m/s	Hourly max m/s	Monthly average	Hourly min	Hourly max	Monthly average W/m²	Hourly min W/m²	Hourly max W/m²
July 2019	3.7	0.3	11.6	15.2	2.5	96.3	106.9	0.0	622.0
August 2019	3.9	0.3	14.7	15.0	3.0	89.5	133.9	0.0	765.0
September 2019	3.5	0.2	14.0	18.2	4.0	97.9	180.4	0.0	963.0
October 2019	3.0	0.2	14.8	22.5	4.9	99.0	232.5	0.0	1028.0
November 2019	3.7	0.6	12.8	18.3	2.3	87.8	267.8	0.0	1259.0
December 2019	3.8	0.3	10.7	16.8	3.3	92.3	198.2	0.0	993.0
January 2020	3.3	0.3	9.5	19.0	6.4	88.7	206.2	0.0	1004.0
February 2020	3.3	0.4	9.5	19.3	6.7	92.4	204.2	0.0	1116.0
March 2020	2.9	0.4	10.1	19.4	4.3	93.4	179.8	0.0	1159.0
April 2020	2.9	0.1	13.3	17.9	3.6	100.9	152.1	0.0	832.0
May 2020	3.2	0.3	15.6	18.2	3.4	94.3	112.9	0.0	822.0
June 2020	3.2	0.4	9.1	15.7	3.0	15.7	102.7	0.0	702.0

TABLE A1.2 METEOROLOGICAL STATISTICS BY MONTH								
MONTH	TEMPERATURE AT 2M ELEVATION (T2)			TEMPERATURE AT 10 M ELEVATION (T10)				
	Monthly average °C	Hourly min °C	Hourly max °C	Monthly average °C	Hourly min °C	Hourly max °C	Number of hours when T_{10}>T_2. Hours	% of month
July 2019	13.8	5.7	23.0	13.3	4.5	22.5	134	18%
August 2019	13.7	4.4	23.5	13.2	3.4	24.0	119	16%
September 2019	17.0	8.8	28.7	16.2	7.8	29.3	85	12%
October 2019	19.3	10.9	33.6	18.5	9.4	33.8	96	13%
November 2019	21.6	12.3	36.0	20.8	10.3	35.7	81	11%
December 2019	23.4	13.5	40.2	22.5	13.3	40.0	67	9%
January 2020	25.3	20.3	43.3	24.4	18.7	43.1	34	5%
February 2020	23.9	17.5	40.9	23.0	16.0	41.8	49	7%
March 2020	21.8	14.5	36.5	21.0	13.3	36.1	49	7%
April 2020	19.8	10.2	28.4	19.0	9.0	27.8	67	9%
May 20	15.2	7.1	26.4	14.5	5.6	25.6	90	12%
June 2020	13.9	6.8	22.2	13.3	6.0	22.4	89	12%

APPENDIX 2

AIR QUALITY MONITORING RESULTS AND TRENDS

TABLE A2.1 DUST DEPOSITION BY MONTH								
Month	Limit	DDG-CI (Stockton)	DDG-KI (Stockton)	DDG K8 (Fern Bay)	DG3 (KI)	DG4 (Mayfield)	DG5 (Mayfield)	DG6 (Sandgate)
July 2019	4	0.4	0.4	0.8	0.7	1.1	0.9	3.3
August 2019	4	0.6	0.9	1.4	1.1	1.3	1.0	1.7
September 2019	4	0.7	1.2	1.5	1.9	1.2	1.3	1.9
October 2019	4	0.6	1.9	1.5	1.5	1.3	2.3	3.2
November 2019	4	1.9	3.1	2.7	4.1	3.9	4.7	4.9
December 2019	4	2.1	3.2	1.7	1.9	1.6	2.1	2.8
January 2020	4	3.1	5.0	4.3	3.0	3.2	2.5	2.3
February 2020	4	2.3	1.9	1.5	1.6	1.6	1.0	1.8
March 2020	4	0.5	0.9	1.0	1.0	0.9	0.6	1.3
April 2020	4	0.5	1.0	0.9	1.2	0.7	0.9	1.9
May 2020	4	0.8	1.0	0.9	0.7	0.5	1.2	0.5
June 2020	4	0.3	0.7	0.7	0.5	0.7	0.6	1.8



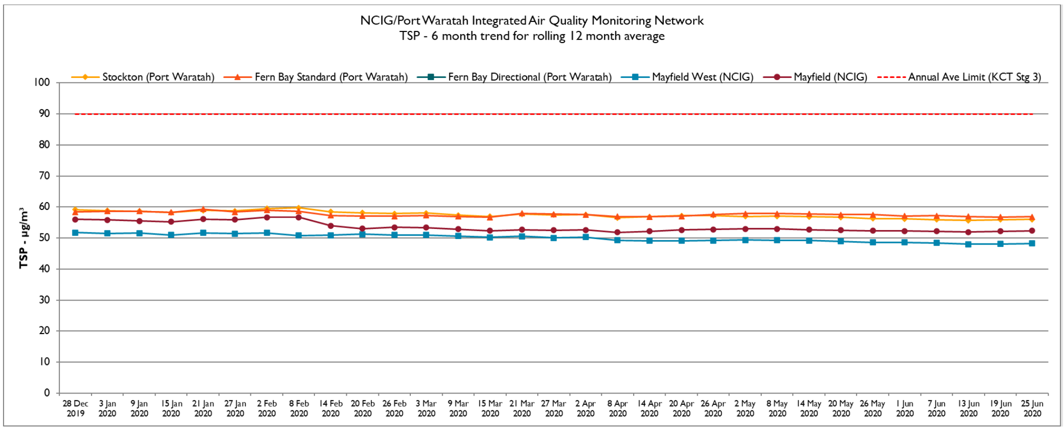


Figure A2.1: Rolling Annual Average Total Suspended Particulates (TSP)

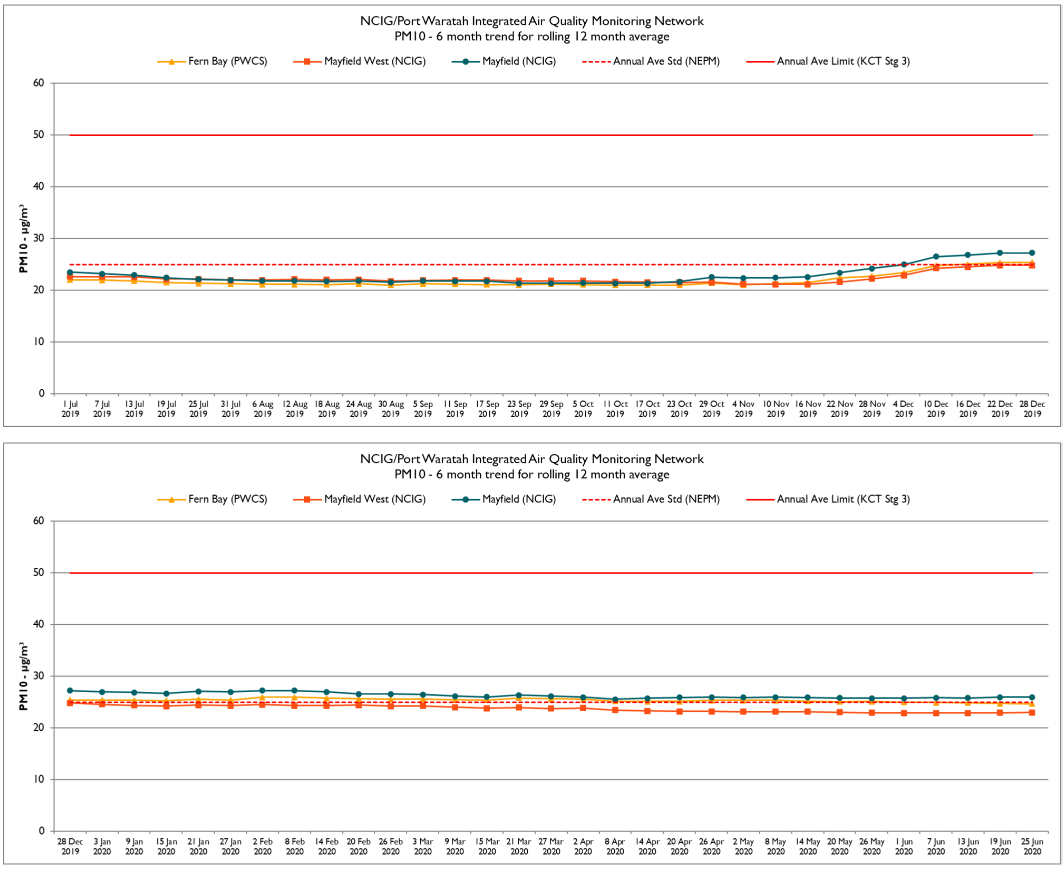


Figure A2.2: Rolling Annual Average Particulate Matter <10 µm (PM_{10})

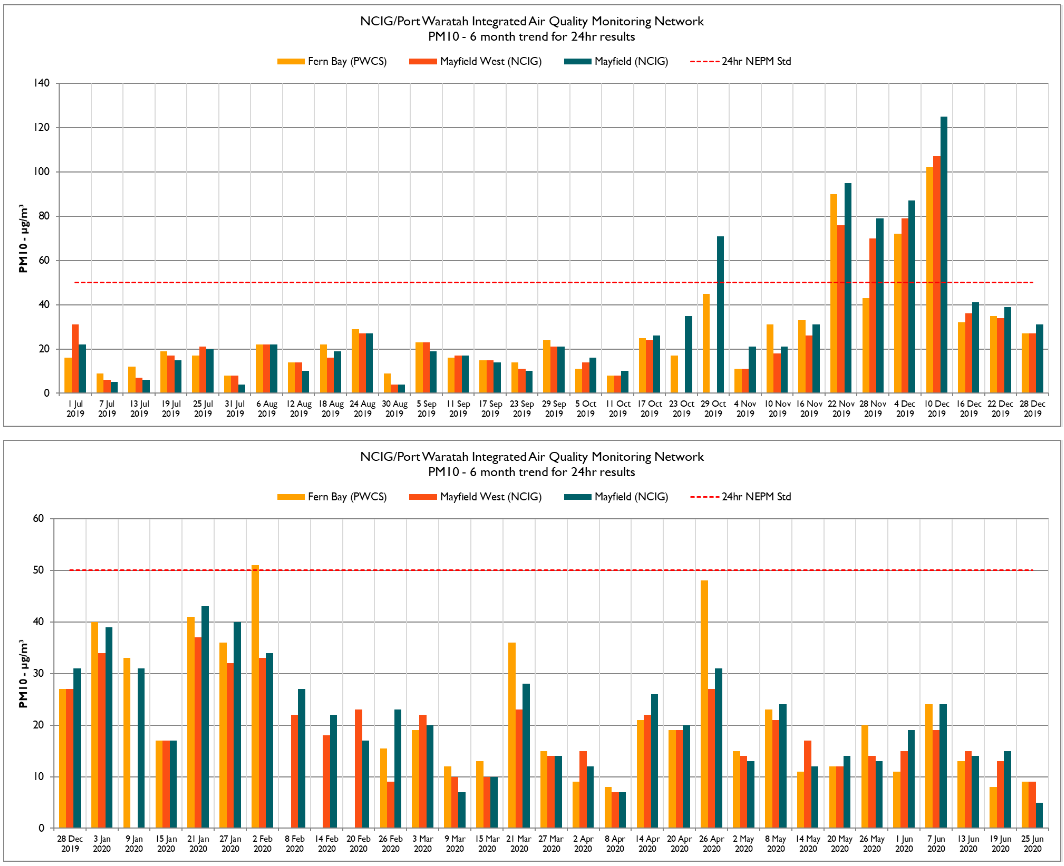


Figure A2.3: 24-hour Average Particulate Matter <10 µm (PM_{10})

APPENDIX 3

SURFACE WATER MONITORING RESULTS

MONTHLY SURFACE WATER MONITORING RESULTS

Analysis	Units	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20
SW1-A Pond												
Sample Number	-	012010481a001	022010481a008	032010481a029	042010481a003	052010481a003	062010481a001	072010481a001	082010481a028	092010481a003	102010481a003	112010481a003
Date Sampled	-	1/10/2020	2/7/2020	3/9/2020	4/6/2020	5/4/2020	6/5/2020	7/6/2020	8/5/2020	9/8/2020	10/9/2020	11/9/2020
Sampled By		LS/SK	LS	LS/SK	SK	SK	SK	SK	LS	SK	SK	SK
Time		12:13	11:13	8:09	8:38	6:00	11.09	11:40	12:18	10:16	7:23	10.07
pH	pH	8.38	8.05	7.97	8.12	8.01	8.21	7.99	8.12	8.4	7.59	8.2
Conductivity	µS/cm	828	454	1040	1010	1200	1280	1080	1360	1430	1260	1210
Turbidity	NTU	154	847	176	130	258	136	157	85	104	114	68
Total Dissolved Solids	mg/L	566	280	669	630	755	764	620	881	850	707	794
Total Suspended Solids	mg/L	108	205	155	31	54	29	<5	32	26	26	21
Redox**	mV	24	149	134	165	200	159	20	71	157	96	142
Dissolved Oxygen	%	63	66	52	53	65	74	72	57	59	98	40
Dissolved Oxygen	mg/L	5	6	4.5	5	6	7	7	5	5	9	3.6
Temperature	°C	28.0	23.0	23.0	18.0	15.0	15.0	15.0	14.0	19.0	21.0	22.0
SW1-B Pond												
Sample Number	-	012010481a004	022010481a009	032010481a030	042010481a004	052010481a004	062010481a002	072010481a002	082010481a029	092010481a004	102010481a004	112010481a004
Date Sampled	-	1/10/2020	2/7/2020	3/9/2020	4/6/2020	5/4/2020	6/5/2020	7/6/2020	8/5/2020	9/8/2020	10/9/2020	11/9/2020
Sampled By		LS/SK	LS	LS/SK	SK	SK	SK	SK	LS	SK	SK	SK
Time		12:26	11:08	8:52	7.31	10.22	11.07	11:37	12:22	10:13	7:26	10.05
pH	pH	8.31	8.15	7.98	8.18	8.17	8.24	8.23	8.21	8.59	8.13	8.2
Conductivity	µS/cm	760	696	624	876	948	1080	1110	1200	1400	1330	953
Turbidity	NTU	<1	153	120	52	167	74	66	33	14	44	41
Total Dissolved Solids	mg/L	532	438	414	555	622	662	621	748	788	784	570
Total Suspended Solids	mg/L	12	70	38	10	31	13	17	7	5	16	14
Redox**	mV	32	131	176	188	193	180	49	114	162	113	164
Dissolved Oxygen	%	57	63	58	60	66	41	74	61	63	84	95
Dissolved Oxygen	mg/L	5	5	5.1	5	6	4	7	6	6	8	8.5
Temperature	°C	28.0	23.0	23.0	19.0	15.0	14.0	15.0	14.0	19.0	21.0	21.0
SW1-C Pond												
Sample Number	-	012010481a003	022010481a010	032010481a031	042010481a005	052010481a005	062010481a003	072010481a003	082010481a030	092010481a005	102010481a005	112010481a005
Date Sampled	-	1/10/2020	2/7/2020	3/9/2020	4/6/2020	5/4/2020	6/5/2020	7/6/2020	8/5/2020	9/8/2020	10/9/2020	11/9/2020

Analysis	Units	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20
Sampled By		LS/SK	LS	LS/SK	SK	SK	SK	SK	LS	SK	SK	SK
Time		12:18	11:04	9:36	7.29	10.18	11.05	11:34	12:25	10:09	7:03	9.58
pH	pH	8.37	8.15	7.99	8.23	8.22	8.13	8.33	8.26	8.58	8.27	8.12
Conductivity	µS/cm	1330	735	526	774	914	794	990	994	1280	1420	931
Turbidity	NTU	<1	58	162	72	96	79	22	38	14	70	49
Total Dissolved Solids	mg/L	874	464	330	479	610	491	569	599	756	829	562
Total Suspended Solids	mg/L	48	32	45	16	22	14	11	17	5	19	14
Redox**	mV	36	131	188	186	187	180	74	123	170	123	169
Dissolved Oxygen	%	49	66	60	56	62	67	73	58	65	97	51
Dissolved Oxygen	mg/L	4	6	5.2	5	6	6	7	6	6	9	4.6
Temperature	°C	30.0	23.0	23.0	19.0	15.0	14.0	16.0	14.0	19.0	20.0	21.0
SW1-D Pond												
Sample Number	-	Dry	022010481a011	032010481a032	042010481a006	052010481a006	062010481a004	072010481a004	082010481a031	092010481a006	102010481a006	112010481a006
Date Sampled	-		2/7/2020	3/9/2020	4/6/2020	5/4/2020	6/5/2020	7/6/2020	8/5/2020	9/8/2020	10/9/2020	11/9/2020
Sampled By			LS	LS/SK	SK	SK	SK	SK	LS	SK	SK	SK
Time			10:52	11.59	7.26	10.15	11.01	11:31	12:30	10:05	7:34	9.55
pH	pH		7.69	8.03	8.21	8.26	8.3	8.04	8.03	8.25	8.18	7.81
Conductivity	µS/cm		2460	631	660	1110	922	1160	482	1100	2890	606
Turbidity	NTU		15	61	38	169	34	43	145	147	100	62
Total Dissolved Solids	mg/L		1450	393	472	737	548	664	299	633	1815	357
Total Suspended Solids	mg/L		22	21	11	31	5	12	40	41	37	18
Redox**	mV		143	192	193	196	175	51	140	179	132	181
Dissolved Oxygen	%		59	100	99	66	53	74	94	62	97	55
Dissolved Oxygen	mg/L		5	8.7	9	6	5	7	9	5	9	4.9
Temperature	°C		22.0	23.0	19.0	14.0	14.0	16.0	14.0	19.0	17.0	22.0
SW2 Pond												
Sample Number	-	Dry		032010481a033	042010481a007	052010481a007	062010481a005	072010481a005	082010481a0032	092010481a007	102010481a007	112010481a007
Date Sampled	-			2/7/2020	4/6/2020	5/4/2020	6/5/2020	7/6/2020	8/5/2020	9/8/2020	10/9/2020	11/9/2020
Sampled By				LS/SK	SK	SK	SK	SK	LS	SK	SK	SK
Time				12.29	6.59	9.45	10.06	10:23	10:48	9:36	6:55	9.25
pH	pH			8.94	7.18	7.73	7.75	7.55	7.23	7.47	7.81	7.34
Conductivity	µS/cm			1470	968	872	1380	1100	1240	2990	2080	1120
Turbidity	NTU			1	41	7	3	7	12	101	52	26

Analysis	Units	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20
Total Dissolved Solids	mg/L			1033	409	576	771	614	753	1715	1207	601
Total Suspended Solids	mg/L			<5	<5	35	23	15	<5	87	32	36
Redox**	mV			164	12	208	189	78	166	65	105	195
Dissolved Oxygen	%			102	94	29	24	38	22	8	38	49
Dissolved Oxygen	mg/L			8.8	8	3	2	4	2	<1	3	4.4
Temperature	°C			23.0	17.0	14.0	14.0	15.0	14.0	19.0	19.0	19.0
SW3 Pond												
Sample Number	-	Dry		032010481a034	042010481a008	052010481a008	062010481a006	072010481a006	082010481a0033	092010481a008	102010481a008	112010481a008
Date Sampled	-			2/7/2020	4/6/2020	5/4/2020	6/5/2020	7/6/2020	8/5/2020	9/8/2020	10/9/2020	11/9/2020
Sampled By				LS/SK	SK	SK	SK	SK	LS	SK	SK	SK
Time				12.24	7.48	11.02	11.27	11:17	12:09	10:38	7:12	9.13
pH	pH			7.83	7.25	8.89	8.36	7.19	6.93	7.32	7.47	7.44
Conductivity	µS/cm			12900	1410	12100	8720	5910	3250	3230	3500	2410
Turbidity	NTU			15	86	158	102	15	19	24	85	8
Total Dissolved Solids	mg/L			9109	584	8435	774	3856	2017	1976	2122	1400
Total Suspended Solids	mg/L			45	<5	409	146	58	7	29	80	12
Redox**	mV			211	3	158	181	112	61	124	-104	196
Dissolved Oxygen	%			64	97	58	73	44	24	31	3	102
Dissolved Oxygen	mg/L			5.4	9	5	7	4	2	3	<1	9.1
Temperature	°C			23.0	19.0	19.0	18.0	16.0	14.0	20.0	16.0	20.0

SIX-MONTHLY SURFACE WATER MONITORING RESULTS

ANALYSIS	UNITS	LOR	Hunter River		Black Swan Pond		Hunter River Wharf		Wharf Sump		Trade Waste Pond	
			Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	Jun-20
Sample Number	-	-	121910481a003		121910481a004		121910481a005				121910481a007	
Date Sampled	-	-	12/9/2019	6/19/2020	12/9/2019	6/19/2020	12/9/2019	6/19/2020	No water - dry	Inaccessible - dry	12/9/2019	6/19/2020
Sampled By	-	-	LS/SK	SK	LS/SK	SK	LS/SK	SK			LS/SK	SK
pH Value	pH unit	-	7.97	7.85	8.33	7.69	7.85	8.21			8.09	7.24
Conductivity	µS/cm	1	50300	46500	1810	1210	49400	3870			294	73
Dissolved Oxygen	%	2	45	3	103	<1	106	45			106	<1
Turbidity	NTU	1	26	59	38	33	9	77			3	56
Chloride	mg/L		21600	18600	383	98	19600	785			34	14
TRH C6-C9	µg/L	40	<20	<20	<20	<20	<20	<20			<20	<20
TRH C10-C14	µg/L	50	<50	<50	<50	<50	<50	<50			<50	<50
TRH C15-C28	µg/L	200	<100	<100	<100	<100	<100	<100			<100	<100
TRH C29-C36	µg/L	200	<50	<50	<50	<50	<50	<50			<50	<50
TRH C10-C36	µg/L	450	<50	<50	<50	<50	<50	<50			<50	<50
Naphthalene	µg/L	0.02	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0			<1.0	<1.0
Phenanthrene	µg/L	0.01	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0			<1.0	<1.0
Anthracene	µg/L	0.01	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0			<1.0	<1.0
Fluoranthene	µg/L	0.01	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0			<1.0	<1.0
Benzo(a)pyrene	µg/L	0.01	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	<0.5
Total PAH	µg/L	0.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	<0.5
Nitrate	mg/L	0.005	<0.05	0.11	<0.05	<0.05	0.06	0.23			<0.05	<0.05
Nitrite	mg/L	0.005	<0.05	<0.05	<0.05	<0.05	0.06	0.13			<0.05	<0.05
Total Kjeldahl Nitrogen	mg/L	0.05	0.4	0.2	6.3	0.8	0.3	2.4			0.5	0.1
Ammonia	mg/L	0.01	0.07	0.06	0.11	<0.05	0.13	0.97			<0.05	<0.05
Total Phosphorus	mg/L	0.05	0.1	0.06	0.39	0.07	<0.05	0.51			<0.05	<0.05
Total Arsenic (III)	mg/L	0.0005	0.0016	<0.005	0.0014	0.0006	<0.001	<0.0005			<0.0005	<0.0005
Trivalent Chromium (III)	mg/L	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	<0.01
Total Aluminium	mg/L	0.005	0.92	0.25	0.42	<0.01	0.25	0.62			0.07	0.04
Total Boron	mg/L	0.005	4.23	4.37	0.92	0.48	4.41	0.56			0.09	<0.05
Total Cadmium	mg/L	0.0001	<0.0010	<0.0010	<0.0001	<0.0001	<0.0010	0.0001			<0.0001	<0.0001
Total Cobalt	mg/L	0.001	<0.010	<0.010	<0.001	<0.001	<0.010	<0.001			<0.001	<0.001
Total Copper	mg/L	0.001	<0.010	<0.010	0.005	<0.001	<0.010	0.002			0.003	<0.001

ANALYSIS	UNITS	LOR	Hunter River		Black Swan Pond		Hunter River Wharf		Wharf Sump		Trade Waste Pond	
			Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	Jun-20
Total Lead	mg/L	0.001	<0.010	<0.010	0.004	<0.001	<0.010	0.002			<0.001	<0.001
Total Iron	mg/L	0.005	0.99	0.16	1.67	0.24	0.4	1.29			0.83	0.15
Total Manganese	mg/L	0.001	0.03	0.019	0.635	0.098	0.059	0.441			0.091	0.021
Total Molybdenum	mg/L	0.001	0.01	<0.010	0.051	0.006	0.012	0.006			<0.001	<0.001
Total Nickel	mg/L	0.001	<0.010	<0.010	0.003	<0.001	<0.010	0.003			0.001	<0.001
Total Selenium	mg/L	0.001	<0.10	<0.10	<0.01	<0.01	<0.10	<0.01			<0.01	<0.01
Total Zinc	mg/L	0.005	<0.052	<0.052	0.02	<0.005	<0.052	0.023			0.01	0.012
Total Mercury	mg/L	0.0001	<0.0001	<0.0001	0.0002	<0.0001	0.0001	<0.0001			<0.0001	<0.0001

ANALYSIS	UNITS	LOR	Clear Water Pond		WTP01		Delta Pond		Deep Pond		Pond 1	
			Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	Jun-20
Sample Number	-	-	121910481a008		Inaccessible	44001	Dry		Dry		Dry - water inaccessible	
Date Sampled	-	-	12/9/2019	6/19/2020				6/19/2020		6/19/2020		6/19/2020
Sampled By	-	-	LS/SK	SK		SK		SK		SK		SK
pH Value	pH unit	-	7.72	8.08		7.67		8.98		6.89		7.56
Conductivity	µS/cm	1	1970	722		843		1840		4810		483
Dissolved Oxygen	%	2	43	31		7		44		15		10
Turbidity	NTU	1	48	56		49		58		30		46
Chloride	mg/L		192	90		195		270		520		80
TRH C6-C9	µg/L	40	<20	<20		<20		<20		<20		<20
TRH C10-C14	µg/L	50	<50	<50		<50		<50		<50		<50
TRH C15-C28	µg/L	200	<100	<100		<100		<100		<100		<100
TRH C29-C36	µg/L	200	<50	<50		<50		<50		<50		<50
TRH C10-C36	µg/L	450	<50	<50		<50		<50		<50		<50
Naphthalene	µg/L	0.02	<1.0	<1.0		<1.0		<1.0		<1.0		<1.0
Phenanthrene	µg/L	0.01	<1.0	<1.0		<1.0		<1.0		<1.0		<1.0
Anthracene	µg/L	0.01	<1.0	<1.0		<1.0		<1.0		<1.0		<1.0
Fluoranthene	µg/L	0.01	<1.0	<1.0		<1.0		<1.0		<1.0		<1.0
Benzo(a)pyrene	µg/L	0.01	<0.5	<0.5		<0.5		<0.5		<0.5		<0.5
Total PAH	µg/L	0.1	<0.5	<0.5		<0.5		<0.5		<0.5		<0.5
Nitrate	mg/L	0.005	0.07	0.07		<0.05		<0.05		<0.05		<0.05
Nitrite	mg/L	0.005	0.07	<0.05		<0.05		<0.05		<0.05		<0.05
Total Kjeldahl Nitrogen	mg/L	0.05	2.8	<0.1		0.2		0.6		3.2		0.7

ANALYSIS	UNITS	LOR	Clear Water Pond		WTP01		Delta Pond		Deep Pond		Pond 1	
			Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	Jun-20
Ammonia	mg/L	0.01	0.5	<0.05		0.05		0.09		0.74		0.06
Total Phosphorus	mg/L	0.05	1.14	<0.05		<0.05		<0.05		0.7		0.07
Total Arsenic (III)	mg/L	0.0005	0.0006	<0.0005		<0.0005		<0.0005		<0.0005		<0.0005
Trivalent Chromium (III)	mg/L	0.05	<0.01	<0.01		<0.01		<0.01		<0.01		<0.01
Total Aluminium	mg/L	0.005	3.17	0.15		0.06		0.1		0.15		0.05
Total Boron	mg/L	0.005	0.28	0.09		0.35		0.95		0.79		0.13
Total Cadmium	mg/L	0.0001	0.001	<0.0001		<0.0001		<0.0001		0.0004		<0.0001
Total Cobalt	mg/L	0.001	0.002	<0.001		<0.001		<0.001		0.001		<0.001
Total Copper	mg/L	0.001	0.01	<0.001		<0.001		0.002		0.004		0.013
Total Lead	mg/L	0.001	0.01	<0.001		<0.001		0.005		<0.001		<0.001
Total Iron	mg/L	0.005	4.54	<0.05		0.08		0.12		0.63		0.48
Total Manganese	mg/L	0.001	0.665	0.007		0.015		0.106		1.74		0.076
Total Molybdenum	mg/L	0.001	0.011	0.005		0.008		0.105		0.069		0.008
Total Nickel	mg/L	0.001	0.008	<0.001		0.001		0.002		0.003		0.002
Total Selenium	mg/L	0.001	<0.01	<0.01		<0.01		<0.01		<0.01		<0.01
Total Zinc	mg/L	0.005	0.114	0.006		0.013		0.016		0.095		0.012
Total Mercury	mg/L	0.0001	0.0003	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001

APPENDIX 4

GROUNDWATER MONITORING RESULTS

ANALYSIS	UNITS	LOR	GW1		K9/3N		K9/3S				K11/1			K11/1S		BH20S	
			Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	**Feb-20**	Jun-20	**Aug-20**	Dec-19	Jun-20	**Sept-20**				
Sample Number			121910481a 019		121910481a 020		121910481a 021				121910481a 022			121910481a 023		121910481a 024	
Date Sampled			12/12/2019	6/15/2020	12/12/2019	6/15/2020	12/12/2019		6/15/2020		12/12/2019	6/16/2020		12/12/2019	6/16/2020	12/11/2019	6/15/2020
Sampled By			CR	RL	CR	RL	CR		RL		CR	CR		CR	CR	SK/CR	RL
Time Sampled			11:05	13:05	13:33	13:46	12:37		13:59		16:04	12:30		15:41	11:58	13:04	10:22
pH Value	pH unit		7.45	8.08	7.03	7.43	7.93		8.02		7.61	7.64	7.46	7.74	7.91	6.96	6.74
Conductivity	µS/cm		12200	8350	23500	2080	5100		3500		992	1870		9340	9920	3100	2780
Temperature	°C		20.7	20	22.9	21	22.6		19		20.8	19		23.6	20	20	20
Bromide	mg/L	0.01	10.8	7.37	23.5	17	4.52	2.58	2.31		0.018	0.982		8.93	7.09	0.175	0.573
Dissolved Metals																	
Aluminium	mg/L	0.01	<0.01	0.01	<0.01	<0.01	0.01		0.01		<0.01	<0.01		<0.01	<0.01	<0.01	0.03
Arsenic	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	0.002		0.006	0.004	<0.001	<0.001		<0.001	<0.001	0.006	0.007
Cadmium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001		<0.0001	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001
Copper	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.224	0.125	1.2	0.608	0.169	0.117	0.087		0.365	1.03		0.109	0.09	5.15	4.96
Nickel	mg/L	0.001	<0.001	0.002	0.001	0.002	0.001		<0.001		0.001	<0.001		0.002	<0.001	0.005	0.003
Zinc	mg/L	0.005	<0.005	0.013	<0.005	<0.005	<0.005		<0.005		<0.005	<0.005		<0.005	<0.005	0.013	0.009
Iron	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	0.22		<0.05		0.2	0.87		0.05	<0.05	3.98	7.5
Cyanide																	
Free Cyanide	mg/L	0.004	<0.004	<0.004	<0.004	<0.004	<0.004		<0.004		<0.004	<0.004		<0.004	<0.004	<0.004	<0.004
Total Cyanide	mg/L	0.004	<0.004	<0.004	<0.004	<0.004	<0.004		<0.004		<0.004	<0.004		<0.004	<0.004	<0.004	<0.004
Polynuclear Aromatic Hydrocarbons																	
Naphthalene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Acenaphthylene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Acenaphthene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Fluorene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Phenanthrene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Anthracene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Fluoranthene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Pyrene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0

ANALYSIS	UNITS	LOR	GW1		K9/3N		K9/3S				K11/1			K11/1S		BH20S	
			Dec-19	Jun-20	Dec-19	Jun-20	Dec-19	**Feb-20**	Jun-20	**Aug-20**	Dec-19	Jun-20	**Sept-20**				
Chrysene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	µg/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5		<0.5	<0.5		<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
Sum of PAHs	µg/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5		<0.5	<0.5		<0.5	<0.5	<0.5	<0.5
Total Petroleum Hydrocarbons																	
C6 - C9 Fraction	µg/L	20	<20	<20	<20	<20	<20		<20		<20	<20		<20	<20	<20	<20
C10 - C14 Fraction	µg/L	50	<50	<50	<50	<50	<50		<50		<50	70		<50	<50	<50	<50
C15 - C28 Fraction	µg/L	100	<100	<100	<100	<100	<100		<100		<100	<100		<100	<100	<100	<100
C29 - C36 Fraction	µg/L	50	<50	<50	<50	<50	<50		<50		<50	150		<50	<50	<50	<50
C10 - C36 Fraction (sum)	µg/L	50	<50	<50	<50	<50	<50		<50		<50	220		<50	<50	<50	<50
BTEX																	
Benzene	µg/L	1	<1	<1	<1	<1	<1		<1		<1	<1		<1	<1	<1	<1
Toluene	µg/L	2	<2	<2	<2	<2	<2		<2		<2	<2		<2	<2	<2	<2
Ethylbenzene	µg/L	2	<2	<2	<2	<2	<2		<2		<2	<2		<2	<2	<2	<2
meta- & para-Xylene	µg/L	2	<2	<2	<2	<2	<2		<2		<2	<2		<2	<2	<2	<2
ortho-Xylene	µg/L	2	<2	<2	<2	<2	<2		<2		<2	<2		<2	<2	<2	<2
Total Xylenes	µg/L	2	<2	<2	<2	<2	<2		<2		<2	<2		<2	<2	<2	<2
Sum of BTEX	µg/L	1	<1	<1	<1	<1	<1		<1		<1	<1		<1	<1	<1	<1

ANALYSIS	UNITS	LOR	BH20D		BH21s		BH21D				BH23S			BH23D
			Dec-19	Jun-20	Aug-20	Dec-19	Jun-20	Dec-19	Jun-20	**Aug-20**	Dec-19	Jun-20	Dec-19	Jun-20	**Aug-20**
Sample Number			121910481a025			121910481a026		121910481a027			121910481a028		121910481a029		
Date Sampled			12/11/2019	6/15/2020		12/11/2019	6/15/2020	12/11/2019	6/15/2020		12/11/2019	N/A bore damaged, unable to be sampled	12/11/2019	7/3/2020	
Sampled By			SK/CR	RL		SK/CR	RL	SK/CR	RL		SK/CR		SK/CR	RL/ZL	
Time Sampled			12:45	10:00		10:54	8:36	13:00	9:20		14:20		13:50	10:30	
pH Value	pH unit		6.25	6.34	6.59	11.13	11.27	7.8	9.46		7.57		6.89	7.00	
Conductivity	µS/cm		42100	454		1000	1170	8370	3140		623		17000	17000	
Temperature	°C		20.8	20		21	21	20.9	20		19.7		20.5	19	
Bromide	mg/L	0.01	53.1	41		0.868	0.71	8.98	1.53		0.321		26	1100	20.2
Dissolved Metals															
Aluminium	mg/L	0.01	<0.01	<0.10		0.59	0.5	0.07	0.12		0.1		<0.01	<0.01	
Arsenic	mg/L	0.001	0.007	<0.010		0.003	0.002	0.002	0.003		0.004		<0.001	<0.001	
Cadmium	mg/L	0.0001	<0.0001	<0.0010		0.0002	<0.0001	<0.0001	0.0001		<0.0001		<0.0001	<0.0001	
Copper	mg/L	0.001	<0.001	<0.010		<0.001	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001	
Manganese	mg/L	0.001	9.34	9.72		0.003	0.001	0.255	0.018		0.48		0.93	0.776	
Nickel	mg/L	0.001	0.016	<0.010		0.005	0.002	0.003	0.004		0.002		0.002	<0.001	
Zinc	mg/L	0.005	0.042	<0.050		<0.005	<0.005	<0.005	<0.005		<0.005		0.01	0.008	
Iron	mg/L	0.05	38.7	41.7		0.08	<0.05	1.21	0.07		2.69		11.6	11	
Cyanide															
Free Cyanide	mg/L	0.004	<0.004	<0.004		<0.004	<0.004	<0.004	<0.004		<0.004		<0.004	<0.004	
Total Cyanide	mg/L	0.004	<0.004	<0.004		0.241	0.25	0.232	0.345		0.075		0.012	0.014	
Polynuclear Aromatic Hydrocarbons															
Naphthalene	µg/L	1	<1.0	<1.0		158	171	111	160		<1.0		<1.0	<1.0	
Acenaphthylene	µg/L	1	<1.0	<1.0		3.2	2.3	<1.0	1.1		<1.0		<1.0	<1.0	
Acenaphthene	µg/L	1	<1.0	<1.0		2.8	2.3	<1.0	1.1		<1.0		<1.0	<1.0	
Fluorene	µg/L	1	<1.0	<1.0		4	2.8	<1.0	<1.0		<1.0		<1.0	<1.0	
Phenanthrene	µg/L	1	<1.0	<1.0		13.6	11	1.5	2.6		<1.0		<1.0	<1.0	
Anthracene	µg/L	1	<1.0	<1.0		3.1	1.7	<1.0	<1.0		<1.0		<1.0	<1.0	

ANALYSIS	UNITS	LOR	BH20D			BH21s	BH21D				BH23S				BH23D
			Dec-19	Jun-20	Aug-20	Dec-19	Jun-20	Dec-19	Jun-20	**Aug-20**	Dec-19	Jun-20	Dec-19	Jun-20	**Aug-20**
Fluoranthene	µg/L	1	<1.0	<1.0		10.2	5.2	<1.0	<1.0		<1.0		<1.0	<1.0	
Pyrene	µg/L	1	<1.0	<1.0		7.5	3.9	<1.0	<1.0		<1.0		<1.0	<1.0	
Benz(a)anthracene	µg/L	1	<1.0	<1.0		2.9	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0	
Chrysene	µg/L	1	<1.0	<1.0		2.5	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0	
Benzo(b+j)fluoranthene	µg/L	1	<1.0	<1.0		3	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0	
Benzo(k)fluoranthene	µg/L	1	<1.0	<1.0		1.5	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0	
Benzo(a)pyrene	µg/L	0.5	<0.5	<0.5		2.3	<0.5	<0.5	<0.5		<0.5		<0.5	<0.5	
Indeno(1.2.3.cd)pyrene	µg/L	1	<1.0	<1.0		1.3	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0	
Dibenz(a.h)anthracene	µg/L	1	<1.0	<1.0		<1.0	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0	
Benzo(g.h.i)perylene	µg/L	1	<1.0	<1.0		1.8	<1.0	<1.0	<1.0		<1.0		<1.0	<1.0	
Sum of PAHs	µg/L	0.5	<0.5	<0.5		218	200	112	165		<0.5		<0.5	<0.5	
Total Petroleum Hydrocarbons															
C6 - C9 Fraction	µg/L	20	<20	<20		20	<20	<20	<20		<20		<20	<20	
C10 - C14 Fraction	µg/L	50	<50	<50		240	260	160	260		<50		<50	<50	
C15 - C28 Fraction	µg/L	100	<100	<100		280	160	<100	120		<100		<100	<100	
C29 - C36 Fraction	µg/L	50	<50	<50		150	<50	<50	<50		<50		<50	<50	
C10 - C36 Fraction (sum)	µg/L	50	<50	<50		670	420	160	380		<50		<50	<50	
BTEX															
Benzene	µg/L	1	<1	<1		2	3	2	2		<1		<1	<1	
Toluene	µg/L	2	<2	<2		<2	<2	<2	<2		<2		<2	<2	
Ethylbenzene	µg/L	2	<2	<2		<2	<2	<2	<2		<2		<2	<2	
meta- & para-Xylene	µg/L	2	<2	<2		2	3	<2	2		<2		<2	<2	
ortho-Xylene	µg/L	2	<2	<2		3	4	2	3		<2		<2	<2	
Total Xylenes	µg/L	2	<2	<2		5	7	2	5		<2		<2	<2	
Sum of BTEX	µg/L	1	<1	<1		7	10	4	7		<1		<1	<1	

APPENDIX 5
NOISE MONITORING REPORTS

NEWCASTLE COAL EXPORT TERMINAL

Biannual Off-Site Noise and On-Site Sound Power Monitoring
July 2019 to December 2019

Prepared for:

Newcastle Coal Infrastructure Group
Locked Bag 6003
Hunter Regional Mail Centre NSW 2310

SLR Ref: 610.04515-R38
Version No: -v1.0
May 2020

SLR

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Newcastle Coal Infrastructure Group (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
610.04515-R38-v1.0	18 May 2020	Martin Davenport	Shannon Harvey	Martin Davenport

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DOCUMENT REFERENCES

TABLES

APPENDICES

1 Introduction

The Newcastle Coal Infrastructure Group Ltd (NCIG) obtained approval to construct and operate the Newcastle Coal Export Terminal (NCET) on Kooragang Island, NSW with a capacity of 66 million tonnes per annum (Mtpa), as per the Project Approval (PA 06_0009) dated 13 April 2007 (referred to as the NCET 66 Mtpa PA).

The NCET infrastructure was constructed in three stages, with the first stage (Stage 1) commissioned on the 3 May 2010 and designed to operate with a nominal capacity of 30 Mtpa and with the second stage (Stage 2AA) commissioned on 24 July 2012 and designed to increase the overall nominal capacity of the NCET to 53 Mtpa. The final stage (Stage 2F) was commissioned on 1 July 2013 and is designed to achieve the ultimate capacity of the NCET of 66 Mtpa.

NCIG has commissioned SLR Consulting Australia Pty Ltd (SLR) to conduct biannual off-site and on-site noise monitoring at the NCET in accordance with the NCET Operation Noise Management Plan (ONMP). The ONMP includes detailed descriptions of the following requirements:

- Monitoring objectives and NCIG roles and responsibilities.
- Receiver areas and noise criteria.
- Project activities and noise sources.
- Project noise impacts.
- Management procedures and noise control.
- Procurement process and equipment levels.
- Community concerns and noise enquires.
- Noise monitoring and reporting procedures.
- Noise audits and performance review.

Consistent with the requirements of the ONMP (Section 4), this report presents the results (only) of the off-site and on-site noise monitoring including:

Off-site Operator-attended Noise Measurement Results

- Residential property noise level measurement results.
- Industrial/commercial premise noise level measurement results.
- Quantitative and qualitative assessment of prevailing meteorological conditions.
- NCET plant and equipment operating log corresponding to the survey period.

On-site Operator-attended Plant and Equipment Noise Audits

- The measured plant and equipment sound power levels.

Environmental Noise Modelling Results

- Selected residential property calculated noise levels.

Compliance Assessment

- Assessment of noise impacts in accordance with NCET 66 Mtpa PA noise limits.
- Statement of Compliance.
- Recommendations for remedial or other action, as required.

2 Noise Criteria

The NCET 66 Mtpa PA residential noise limits and meteorological constraints are summarised and presented in **Table 1**.

Table 1 NCET 66 Mtpa PA – Noise Limits & Meteorological Constraints (dBA re 20 µPa)

<table>
<tr><th rowspan="2">Residential Location</th><th rowspan="2">Construction Noise</th><th colspan="3">Operational Noise</th></tr>
<tr><th>LAeq(15minute) Operation[1] Daytime, Evening, Night[2]</th><th>LAeq(night) Operation[1] Night[2]</th><th>LA1(1minute) Operation[1] Night[2]</th></tr>
<tr><td>Fem Bay West</td><td rowspan="7">The Proponent shall only undertake construction activities associated with the project that would generate an audible noise at any residential premises between 7:00 am and 6:00 pm, seven days a week. Audible noise is defined as "noise that can be heard at the receiver".</td><td>41</td><td>37</td><td>57</td></tr>
<tr><td>Fern Bay East</td><td>39</td><td>36</td><td>55</td></tr>
<tr><td>Stockton West</td><td>41</td><td>37</td><td>57</td></tr>
<tr><td>Stockton East</td><td>38</td><td>35</td><td>56</td></tr>
<tr><td>Mayfield West</td><td>45</td><td>40</td><td>55</td></tr>
<tr><td>Mayfield</td><td>44</td><td>39</td><td>62</td></tr>
<tr><td>Carrington</td><td>36</td><td>33</td><td>52</td></tr>
<tr><td>Notes</td><td colspan="4">The maximum allowable noise contributions apply under:
a) Meteorological conditions of: wind speeds up to 3 ms-1 at 10 metres above ground level; or
b) Temperature inversion conditions up to 3°C per 100 metres and wind speeds up to 2ms-1 at 10 metres above the ground.
For the purpose of assessment of noise from the project shall be:
c) Measured at the most affected point on or within the Site boundary at the most sensitive receiver to determine compliance with LAeq(15 minute) night noise limits;
d) Measured at one metre from the dwelling facade to determine compliance with LA1(1minute) noise limits; and
e) Subject to the modification factors provided in Section 4 of the NSW INP, where applicable.</td></tr>
</table>

Note 1: 7 days per week, 24 hours a day.

Note 2: Monday to Saturday 2200 hours to 0700 hours; Sundays and Public Holidays 2200 hours to 0600 hours.

Similarly, the NCET Environmental Assessment (EA) non-residential noise criteria are summarised and presented in **Table 2**.

Table 2 Environmental Assessment – Non- residential Noise Criteria

Non-residential Location	Land Use	Intrusive $L_{Aeq(15minute)}$			Acceptable Amenity $L_{Aeq(period)}$[1]			Maximum Amenity $L_{Aeq(9hour)}$
		Day	Evening	Night	Day	Evening	Night	Night
Mayfield West	Commercial Steel River	Intrusive noise not applicable			65	65	65	70
Kooragang Island	Industrial	Intrusive noise not applicable			70	70	70	75
Mayfield North		Intrusive noise not applicable			70	70	70	75
Any	School	Intrusive noise not applicable			External 45 when in use			50
Any	Hospital	Intrusive noise not applicable			External 50 when in use			55

Note 1: Daytime 0700 hours to 1800 hours, Evening 1800 hours to 2200 hours, Night-time 2200 hours to 0700 hours.

3 Noise Monitoring Equipment

All instrumentation used during noise measurements complied with the requirements of AS IEC 61672.1-2004 *"Electroacoustics – Sound Level Meters – Specifications"* and carried current NATA or manufacturer calibration certificates. Instrument calibration was checked before and after each measurement survey, with the variation in calibrated levels not exceeding ±0.5 dBA.

The noise measurement procedures employed throughout the monitoring program were guided by the requirements of AS 1055-1997 "*Acoustics - Description and Measurement of Environmental Noise*" and the *NSW Industrial Noise Policy* (INP).

All operator-attended noise measurements were conducted using a Bruel and Kjaer Type 2250L Type 1, integrating sound level meter (S/N 3003389) and Bruel and Kjaer Type 2270 Type 1, integrating sound level meter (S/N 2679354)

4 Off-Site Operator Attended Noise Monitoring – Residential Receivers

4.1 Noise Monitoring Results

Operator-attended noise measurements were conducted at the selected residential locations presented in **Table 3**.

Table 3 Residential Property Noise Monitoring Locations

Receiver Area	ID and Location		INP Noise Amenity Zone	LEP Zone
Fern Bay North	FN12	Bayway Village, Nelson Bay Road	Suburban	Residential
Fern Bay West	FW1	1 Fullerton Lane	Suburban	Residential
Fern Bay East	FE1	21 Braid Road		
Stockton West	SW1	284 Fullerton Street	Suburban	Residential
Stockton East	SE1	40 Eames Avenue		
	SE3	4 Pitt Street		
Mayfield West	W1	47 Stevenson Avenue	Urban	Residential
Mayfield	M1	68 Bull Street	Urban	Residential
	M4	52 Arthur Street		
Carrington / Maryville	C1	Cnr Hargrave and Young Streets	Urban	City Centre

The operator-attended night-time noise measurements were conducted on 18 December 2019 to 19 December 2019. The weather conditions during the monitoring period varied throughout the monitoring period consisting of temperatures ranging from 20°C-22°C, and light N-NE winds with wind speeds of 1 m/s to 3 m/s.

The operator-attended night-time noise measurements results are presented in **Table 4**, including an estimate of NCET intrusive $L_{Aeq(15minute)}$ noise levels as well as estimates of other contributing ambient noise sources (i.e. traffic, insects, animals, other industrial operations etc).

Table 4 Residential Property Noise Measurement Results

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Date/Start Time</th><th colspan="5">Primary Noise Descriptor (dBA re 20 µPa)</th><th rowspan="2">Comments and Description of Noise Emissions</th></tr>
<tr><th>LAmax</th><th>LA1</th><th>LA10</th><th>LA90</th><th>LAeq</th></tr>
<tr><td rowspan="2">FN1 - Bayway Village</td><td rowspan="2">18/12/2019 22:00</td><td>84</td><td>77</td><td>74</td><td>47</td><td>69</td><td>Road traffic, insects,</td></tr>
<tr><td colspan="5">Estimated NCET LAeq(15min) contribution <37 dBA.
Estimated NCET LA1(1min) <39 dBA</td><td>NCET not discernible</td></tr>
<tr><td rowspan="2">FW1 - Fullerton Lane</td><td rowspan="2">18/12/19 22:40</td><td>76</td><td>71</td><td>66</td><td>41</td><td>61</td><td>Road traffic, insects</td></tr>
<tr><td colspan="5">Estimated NCET LAeq(15min) contribution <41 dBA.
Estimated NCET LA1(1min) <43 dBA</td><td>NCET not discernible</td></tr>
<tr><td rowspan="2">FE1 - Braid Road</td><td rowspan="2">18/12/2019 22:21</td><td>50</td><td>43</td><td>41</td><td>39</td><td>40</td><td>Insect, other industry, road traffic</td></tr>
<tr><td colspan="5">Estimated NCET LAeq(15min) contribution <30 dBA.
Estimated NCET LA1(1min) <31 dBA</td><td>NCET not discernible</td></tr>
<tr><td rowspan="2">SW1 - Fullerton Street</td><td rowspan="2">18/12/2019 23:38</td><td>57</td><td>55</td><td>54</td><td>50</td><td>52</td><td>Surf, other industry, road traffic</td></tr>
<tr><td colspan="5">Estimated NCET LAeq(15min) contribution <40 dBA.
Estimated NCET LA1(1min) <42 dBA</td><td>NCET not discernible</td></tr>
<tr><td rowspan="2">SE1 - Eames Road</td><td rowspan="2">18/12/2019 23:20</td><td>60</td><td>57</td><td>55</td><td>50</td><td>53</td><td>Road traffic, industry</td></tr>
<tr><td colspan="5">Estimated NCET LAeq(15min) contribution <40 dBA.
Estimated NCET LA1(1min) <42 dBA</td><td>NCET not discernible</td></tr>
<tr><td rowspan="2">W1 - Stevenson Avenue</td><td rowspan="2">19/12/2019 00:10</td><td>58</td><td>53</td><td>50</td><td>44</td><td>47</td><td>Road traffic, other industry</td></tr>
<tr><td colspan="5">Estimated NCET LAeq(15min) contribution <34 dBA
Estimated NCET LA1(1min) <36 dBA</td><td>NCET not discernible</td></tr>
<tr><td rowspan="2">M1 - Bull Street</td><td rowspan="2">19/12/2019 00:31</td><td>62</td><td>57</td><td>52</td><td>48</td><td>51</td><td>Road traffic, insects, other industry</td></tr>
<tr><td colspan="5">Estimated NCET LAeq(15min) contribution <38 dBA.
Estimated NCET LA1(1min) <40 dBA</td><td>NCET not discernible</td></tr>
<tr><td rowspan="2">M4 - Arthur Street</td><td rowspan="2">19/12/2019 00:58</td><td>73</td><td>70</td><td>61</td><td>46</td><td>58</td><td>Traffic, other industry</td></tr>
<tr><td colspan="5">Estimated NCET LAeq(15min) contribution <36 dBA.
Estimated NCET LA1(1min) <38 dBA</td><td>NCET not discernible</td></tr>
<tr><td rowspan="2">C1 - Cnr Hargrave and Young Streets</td><td rowspan="2">19/12/2019 02:17</td><td>70</td><td>64</td><td>50</td><td>45</td><td>51</td><td>Road traffic, residential noise, other industry</td></tr>
<tr><td colspan="5">Estimated NCET LAeq(15min) contribution <35 dBA.
Estimated NCET LA1(1min) <37 dBA</td><td>NCET not discernible</td></tr>
</table>

4.2 Compliance Assessment

The following observations were made during the night-time survey period:

- NCET noise emissions were not identifiable from the overall industrial noise at all locations. Industrial noise emissions were audible from the direction of the Mayfield North Industrial Area and Kooragang Island. NCET noise emissions are expected to have remained below the intrusive noise limits.

Measured noise levels presented in **Table 4** indicate that compliance with the sleep disturbance $L_{A1(1minute)}$ noise criteria were achieved at all locations during the night-time noise surveys.

5 Off-Site Attended Noise Monitoring – Industrial Premises

5.1 Noise Measurement Results

Operator-attended noise measurements were conducted at the selected nearby industrial premises shown in **Table 5**.

Table 5 Industrial/Commercial Premise Noise Monitoring Locations

Receiver Area	ID and Location		INP Noise Amenity Zone	LEP Zone
Kooragang Island	KI1	Blue Circle Southern Cement	Industrial	Port and Industry
	KI5	Cargill		
	KI10	Sims Metal		

The operator-attended noise measurements were conducted on Friday 20 December 2019, generally coinciding with typical NCET operations. The prevailing weather conditions consisted of light to moderate south to south westerly winds of 3 m/s to 5 m/s with temperatures of 20 to 21°C

The operator-attended noise measurement results are presented in **Table 6**, including an estimate of NCET's intrusive $L_{Aeq(period)}$ noise level.

Table 6 Industrial/Commercial Premise Noise Monitoring Results

Location	Date/Start Time	Primary Noise Descriptor (dBA re 20 µPa)					Comments and Description of Noise Emission
		L_{Amax}	L_{A1}	L_{A10}	L_{A90}	L_{Aeq}	
KI1 Blue Circle Southern Cement	20/12/2019 09:14	70	65	62	59	60	Road traffic
		Estimated NCET $L_{Aeq(period)}$ contribution <49 dBA					NCET not discernible.
KI5 Cargill Australia	20/12/2019 08:13	90	76	66	54	65	Birdsong, road traffic, other Industry
		Estimated NCET $L_{Aeq(period)}$ contribution <44 dBA					NCET not discernible.
KI10 Sims Metal	20/12/2019 08:34	89	83	77	64	76	Road traffic, insects, other industry
		Estimated NCET $L_{Aeq(period)}$ contribution <54 dBA					NCET not discernible.

5.2 Compliance Assessment

NCET noise emissions at the selected nearby industrial premises monitoring locations were below the $L_{Aeq(period)}$ limit of 70 dBA.

6 On-Site Operations

On-site operator-attended noise monitoring was conducted of selected items of NCET plant and equipment to quantify the operating sound power levels (SWLs). The measured SWLs have been used to update the NCET Stage 1, Stage 2AA and Stage 2F Plant and Equipment SWL Database as presented in **Appendix A** with a maximum total SWL of 128 dBA.

7 Environmental Noise Modelling Results

7.1 Noise Prediction Procedures

Based on the measured sound power levels (refer **Section 6**), the NCET computer noise model has been updated, further validated and used to predict the operating noise for comparison with the NCET 66 Mtpa PA noise limits.

The computer model developed for the NCET EA incorporates the significant noise sources associated with the NCET site and rail loop, surrounding terrain, aspects of the built environment and nearby receiver areas. The noise model has been modified to include key components of the installed Stage 1, Stage 2AA and Stage 2F infrastructure as guided by NCIG/Aurecon in various information updates.

The field measured SWLs were incorporated into the model to predict the contributed noise level from each source to the receiver localities.

7.2 Noise Prediction Results

The predicted $L_{Aeq(15minute)}$ intrusive noise levels from the Stage 1, Stage 2AA and Stage 2F operations at the nearest receiver areas are presented in **Table 7**.

The predicted $L_{Aeq(period)}$ amenity noise levels from the Stage 1, Stage 2AA and Stage 2F operations at the nearest receiver areas are presented in **Table 8**.

Table 7 Stage 1, Stage 2AA and Stage 2F Predicted Intrusive Noise Levels (dBA re 20 µPa)

Receiver Area	ID/Location		Day	Evening	Night	Intrusive Noise Criteria $L_{Aeq(15minute)}$
Fern Bay West	FW1	1 Fullerton Lane	25	20	38	41
Fern Bay East	FE1	21 Braid Road	23	18	37	39
Stockton West	SW1	284 Fullerton Street	24	22	39	41
	SW2	Cnr Pembroke and Fullerton Streets	24	23	37	
Stockton East	SE1	40 Eames Avenue	24	21	38	38
Warabrook/Mayfield West	W1	47 Stevenson Avenue	30	40	33	45
	W2	4 Groongal Street	32	42	37	
Mayfield	M1	68 Bull Street	33	43	37	44
	M2	45 Simpson Crescent	33	43	38	
	M3	1 Arthur Street	30	43	39	
	M4	52 Arthur Street	32	42	40	
	M5	21 Crebert Street	32	41	41	
Carrington	C1	Cnr Hargrave and Young Sts	24	30	35	36

Meteorological conditions in accordance with the NCET EA 2006.

The NCET predicted intrusive noise levels were at or below the relevant noise criteria at the key residential locations during the July to December 2019 period.

Table 8 Stage 1, Stage 2AA and Stage 2F Predicted Amenity Noise Levels (dBA re 20 µPa)

Receiver Area	ID	Location	Night-time Amenity[1]	Night-time Noise Criteria
Fern Bay West	FW1	1 Fullerton Lane	34	37
	FW2	Stockton Hospital	34	
Fern Bay East	FE1	21 Braid Road	33	36
	FE2	Fern Bay Primary	33	
Stockton West	SW1	284 Fullerton Street	35	37
	SW2	Cnr Pembroke and Fullerton Streets	33	
Stockton East	SE1	40 Eames Avenue	34	35
	SE2	Stockton Primary	31	
Warabrook/ Mayfield West	W1	47 Stevenson Avenue	29	40
	W2	4 Groongal Street	33	
	W3	Mayfield West Primary	34	
Mayfield	M1	68 Bull Street	33	39
	M2	45 Simpson Crescent	34	
	M3	1 Arthur Street	35	
	M4	52 Arthur Street	36	
	M5	21 Crebert Street	37	
	M6	Hunter Christian School	33	
	M7	Mayfield East Primary	36	
Carrington	C1	Cnr Hargrave and Young Streets	31	33
Sandgate	SG1	4 Mangrove Road	28	65
Mayfield West	MW1	Steel River	35	
Kooragang Island	KI1	Blue Circle Southern	55	70
	KI2	Origin Energy	53	
	KI3	Boral Country Concrete	51	
	KI4	Port Waratah Coal Services	45	
	KI5	Cargill Australia	47	
	KI6	ERS Australia	49	
	KI7	Cleanaway	50	
	KI8	Port Hunter Commodities	50	
	KI9	BOC Gas	52	
	KI10	Sims Metal	49	
Mayfield North	MN1	OneSteel	48	70

Note 1: Night-time meteorological conditions in accordance with the NCET EA 2006.

The NCET predicted night-time noise amenity levels were below the relevant amenity noise criteria at the key residential, commercial and industrial locations during the July to December 2019 period.

8 Further Action and Conclusion

SLR has conducted off-site noise and on-site sound power level monitoring at the NCET for the July to December 2019 period in accordance with the NCET ONMP.

Off-site noise monitoring has indicated that compliance is achieved at all residential locations under prevailing conditions during the July to December 2019 period. Similarly, off-site noise monitoring has indicated that compliance is achieved at selected nearby industrial locations.

Predicted noise levels demonstrate that the NCET noise emissions were at or below the relevant noise criteria during the July to December 2019 period under prevailing meteorological conditions.

At this stage no specific further action is recommended. Notwithstanding, NCIG implements a Continuous Noise Improvement Program (the Program). The Program will continue to be implemented as part of the ongoing NCET operations.

APPENDIX A

NCET Plant and Equipment SWL Database

ENM Source No	Component	ID	Description	Capacity	Conveyor Length (m)	Overall SWL (dBA)	Conveyor Drive P1 (dBA)	Conveyor Drive P2 (dBA)
Stage 1								
	Rail-Loop	Train 1	PN 8200 Series (per 3 Loco set)	Locomotive idle		109		
	Rail-Loop	Train 2	PN 8200 Series (per 3 Loco set)/QR 5000 Series (per 2 Loco set)	Locomotive Moving - Approaching Dump Station		109		
	Rail-Loop	Train 2	PN 8200 Series (all wagons - 1600m excluding locos)	All Noise including squeal, coupling		111		
100	Rail-receival	DS01	Dump Station	8500tph		106		
	Rail-receival	TBA	Dust extraction fan	300kW fan				
103	Rail-receival	FE01	Belt Feeder	8500tph		100		
108	Rail-receival	CV01	Belt Conveyor	8500tph	582	111		
109	Rail-receival	CV01	Conveyor Drive P1, P2	2 x 1000kW		106	106	98
110	Rail-receival	TR01	Fixed Tripper for inbound sample	-		90		
111	Rail-receival	SA01	Sample Station	80tph		99		
112	Rail-receival	TH01	Transfer House (8 Chutes, only 2 see coal at any one time)	-		105		
200	Stacking	CV04	Belt Conveyor	8500tph	349	111		
201	Stacking	CV04	Conveyor Drive P1	As built 1000kW (2 x 630kW)		98	98	
202	Stacking	TT02	Transfer Point	-		<96		
203	Stacking	CV05	Belt Conveyor	8500tph	207	107		
204	Stacking	CV05	Conveyor Drive P1	630kW		99	99	
205	Stacking	03TT03	Transfer Point	-		<96		
300	Stockyard	CV08	Belt Conveyor	10500tph	1334	115		
301	Stockyard	CV08	Conveyor Drive P1, P2	2 x 1250kW		104	102	100
302	Stockyard	SR01	Stacker/Reclaimer	10500tph		108		
303	Stockyard	TR04	Fixed Tripper for magnet & dewatering	-		100		
304	Stockyard	TH06	Transfer Point	10500tph		<96		
305	Stockyard	CV09	Belt Conveyor	10500tph	1374	115		
306	Stockyard	CV09	Conveyor Drive P1, P2	2 x 1250kW		104	101	102
307	Stockyard	SR02	Stacker/Reclaimer	10500tph		113		
308	Stockyard	TR05	Fixed Tripper for magnet & dewatering	-		90		
309	Stockyard	TH07	Transfer Point	10500tph		<96		
400	Reclaiming	CV12	Belt Conveyor	10500tph	611	109		
401	Reclaiming	CV12	Conveyor Drive P1	1250kW		103	100	100
402	Reclaiming	BN01	Buffer Bin	2000t bin		100		
403	Reclaiming	FE04	Belt Feeder	6250tph, Hydraulic 500kW		99		
404	Reclaiming	FE05	Belt Feeder	6250tph, Hydraulic 500kW		99		
405	Reclaiming	CV15	Belt Conveyor	11500tph	625	112		
406	Reclaiming	CV15	Conveyor Drive P1 & P2	2 x 1000kW		107	105	101
407	Reclaiming	SA04	Sample Station	80tph		105		

ENM Source No	Component	ID	Description	Capacity	Conveyor Length (m)	Overall SWL (dBA)	Conveyor Drive P1 (dBA)	Conveyor Drive P2 (dBA)
408	Reclaiming	TH10	Transfer Point (2 Chutes)	-		<96		
426	Reclaiming	CV19 - 30Mt	Belt Conveyor	11500tph	63	104		
427	Reclaiming	CV19 - 30Mt	Conveyor Drive P1	1000kW		99	99	
430	Reclaiming	TH12	Transfer Point (2 Chutes)	-		102		
502	Shiploading	SL01 - 30Mt	Ship Loader	12500tph		109		
506	Shiploading	CV21 - 30Mt	Belt Conveyor	11500tph	689	113		
700	Stockyard		Dozer	D11		118		
600	Clearwater Pond	1	Clearwater Pond Pump 1 (Lift Pump)	-		90		
601	Clearwater Pond	4	Main Dust Suppression and Fire Pump 1	-		90		
602	Clearwater Pond	5	Main Dust Suppression and Fire Pump 2	-		90		
603	Clearwater Pond	6	Main Dust Suppression and Fire Pump 3	-		90		
604	Clearwater Pond	7	Main Dust Suppression and Fire Pump 4	-		90		
605	Clearwater Pond	10	Pressure Maintaining Pump (Jacking Pump 1)	-		90		
606	Clearwater Pond	21	Transfer House TH03 Pump	-		90		
607	Clearwater Pond	26	Conveyor CV12 Mid Point Sump Pump	-		90		
608	Clearwater Pond	30	Administration Vehicle Spray Wash Supply Pump	-		90		
609	Clearwater Pond	49	Sewer Pump 4: 4000 L	-		90		
610	Clearwater Pond	51	Potable Water Pump no. 1	-		90		
				Total Stage 1 (excluding Trains)		**124**		
				Stage 1 Trains		**115**		
				Stage 1 Total (including Trains)		**125**		
Stage 2AA								
	Rail-Loop	Train 3	PN 8200 Seires (per 3 Loco set)/QR 5000 Seires (per 2 Loco set)	Locomotive Moving - Approaching DS		109		
	Rail-Loop	Train 3	PN 8200 Seires (all wagons - 1600m excluding locos)	All Noise including squeal, coupling		111		
	Rail-Loop	Train 4	QR 5000 Seires (per 3 Loco set)	Locomotive Moving - Approaching DS		109		
	Rail-Loop	Train 4	QR 5000 Seires	All Noise including squeal, coupling		111		

ENM Source No	Component	ID	Description	Capacity	Conveyor Length (m)	Overal l SWL (dBA)	Conveyor Drive P1 (dBA)	Conveyor Drive P2 (dBA)
104	rail-receival	DS02	Dump Station	8500tph		104		
113	rail-receival	CV02	Belt Conveyor	8500tph		112		
114	rail-receival	CV02	Conveyor Drive P1, P2	2 x 1000kW		107	104	104
115	rail-receival	TR02	Fixed Tripper for inbound sample	-		90		
180	rail-receival	SA02	Sample Station	80tph		99		
206	Stacking	CV06	Belt Conveyor	8500tph		100		
207	Stacking	CV06	Conveyor Drive P1	1000kW		98	98	
208	stacking	TH04	Transfer Point	-		97		
310	Stockyard	CV10	Belt Conveyor	10500tph		114		
311	Stockyard	CV10	Conveyor Drive P1, P2	2 x 1250kW		101	98	99
312	stockyard	SR03	Stacker/Reclaimer	10500tph		111		
314	stockyard	TH08	Transfer Point	10500tph		<96		
511	reclaiming	CV13	Belt Conveyor	10500tph		110		
512	reclaiming	CV13	Conveyor Drive P1, P2	2 x 1000kW		102	100	97
513	reclaiming	BN02	Buffer Bin/Belt Feeders	2000t bin		104		
514	reclaiming	FE06	Belt Feeder	6250tph, Hydraulic 500kW		99		
515	reclaiming	FE07	Belt Feeder	6250tph, Hydraulic 500kW		99		
516	reclaiming	CV16	Belt Conveyor	10500tph		109		
517	reclaiming	CV16	Conveyor Drive P1, P2	2 x 1000kW		102	98	100
518	reclaiming	SA05	Sample Station	80tph		<96		
528	reclaiming	CV20	Belt Conveyor	10500tph		105		
529	reclaiming	CV20	Conveyor Drive P1	1000kW		97	97	
603	shiploading	CV22	Belt Conveyor	10500tph		115		
604	shiploading	CV22	Conveyor Drive P1, P2	2 x 1000kW		102	99	99
605	shiploading	SL02	Ship Loader	12500tph		110		
				Total Stage 2AA (excluding Trains)		**122**		
				Stage 2 AA Trains		**116**		
				Stage 2AA Total (including Trains)		**123**		
Stage 2F								
209	stacking	CV7	Conveyor	8,500 t/hr	78	100		
210	stacking	CV7	Conveyor Drive P1	1000 kW		97	97	
211	stacking	TH05	Transfer Tower	10,500 t/hr		103		
315	stockyard	CV11	Conveyor	10,500 t/hr	1447	114		
316	stockyard	CV11	Conveyor Drive P1, P2	1250 kW		102	100	99
317	stockyard	SR04	Stacker/Reclaimer	10,500 t/hr		110		
319	stockyard	TH09	Transfer Tower	10,500 t/hr		105		
509	reclaiming	CV17	Conveyor	10,500 t/hr	229	107		

ENM Source No	Component	ID	Description	Capacity	Conveyor Length (m)	Overall SWL (dBA)	Conveyor Drive P1 (dBA)	Conveyor Drive P2 (dBA)
410	reclaiming	CV17	Conveyor Drive	1000 kW		100	100	
519	reclaiming	CV18	Conveyor	10,500 t/hr	363	113		
520	reclaiming	CV18	Conveyor Drive	1000 kW		98	98	
521	reclaiming	TH11	Transfer Tower	10,500 t/hr		103		
522	reclaiming	CV19	Conveyor	10,500 t/hr	63	102		
523	reclaiming	CV19	Conveyor Drive	1000 kW		98	98	
524	reclaiming	CV20	Conveyor	10,500 t/hr	62	105		
525	reclaiming	CV20	Conveyor Drive	1000 kW		98	98	
531	reclaiming	TH12	Transfer Tower	10,500 t/hr		102		
606	reclaiming	CV21 Ext	Conveyor	10,500 t/hr	362	112		
601	reclaiming	CV21	Conveyor Drive P1, P2	1000 kW		105	101	103
603	reclaiming	CV22 Ext	Conveyor	10,500 t/hr	362	113		
604	reclaiming	CV22	Conveyor Drive P1, P2	1000 kW		103	99	100
				Stage 2F Total		**121**		
				Stage 1 + 2AA + 2F Total (excluding Trains)		**127**		
				Stage 1 + 2AA + 2FTrains		**119**		
				Stage 1 + 2AA + 2F Total (including Trains)		**128**		

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NEWCASTLE COAL EXPORT TERMINAL

Biannual Off-Site Noise and On-Site Sound Power Monitoring
January 2020 to June 2020

Prepared for:

Newcastle Coal Infrastructure Group
Locked Bag 6003
Hunter Regional Mail Centre NSW 2310

SLR Ref: 610.04515-R39
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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Newcastle Coal Infrastructure Group (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
610.04515-R39-v1.0	4 September 2020	Martin Davenport	SH/JM	Martin Davenport

CONTENTS

DOCUMENT REFERENCES

TABLES

APPENDICES

1 Introduction

The Newcastle Coal Infrastructure Group Ltd (NCIG) obtained approval to construct and operate the Newcastle Coal Export Terminal (NCET) on Kooragang Island, NSW with a capacity of 66 million tonnes per annum (Mtpa), as per the Project Approval (PA 06_0009) dated 13 April 2007 (referred to as the NCET 66 Mtpa PA).

The NCET infrastructure was constructed in three stages, with the first stage (Stage 1) commissioned on the 3 May 2010 and designed to operate with a nominal capacity of 30 Mtpa and with the second stage (Stage 2AA) commissioned on 24 July 2012 and designed to increase the overall nominal capacity of the NCET to 53 Mtpa. The final stage (Stage 2F) was commissioned on 1 July 2013 and is designed to achieve the ultimate capacity of the NCET of 66 Mtpa.

NCIG has commissioned SLR Consulting Australia Pty Ltd (SLR) to conduct biannual off-site and on-site noise monitoring at the NCET in accordance with the NCET Operation Noise Management Plan (ONMP). The ONMP includes detailed descriptions of the following requirements:

- Monitoring objectives and NCIG roles and responsibilities.
- Receiver areas and noise criteria.
- Project activities and noise sources.
- Project noise impacts.
- Management procedures and noise control.
- Procurement process and equipment levels.
- Community concerns and noise enquires.
- Noise monitoring and reporting procedures.
- Noise audits and performance review.

Consistent with the requirements of the ONMP (Section 4), this report presents the results (only) of the off-site and on-site noise monitoring including:

Off-site Operator-attended Noise Measurement Results

- Residential property noise level measurement results.
- Industrial/commercial premise noise level measurement results.
- Quantitative and qualitative assessment of prevailing meteorological conditions.
- NCET plant and equipment operating log corresponding to the survey period.

On-site Operator-attended Plant and Equipment Noise Audits

- The measured plant and equipment sound power levels.

Environmental Noise Modelling Results

- Selected residential property calculated noise levels.

Compliance Assessment

- Assessment of noise impacts in accordance with NCET 66 Mtpa PA noise limits.
- Statement of Compliance.
- Recommendations for remedial or other action, as required.

2 Noise Criteria

The NCET 66 Mtpa PA residential noise limits and meteorological constraints are summarised and presented in **Table 1**.

Table 1 NCET 66 Mtpa PA – Noise Limits & Meteorological Constraints (dBA re 20 µPa)

<table>
<tr><th rowspan="2">Residential Location</th><th rowspan="2">Construction Noise</th><th colspan="3">Operational Noise</th></tr>
<tr><th>LAeq(15minute) Operation[1] Daytime, Evening, Night[2]</th><th>LAeq(night) Operation[1] Night[2]</th><th>LA1(1minute) Operation[1] Night[2]</th></tr>
<tr><td>Fem Bay West</td><td rowspan="7">The Proponent shall only undertake construction activities associated with the project that would generate an audible noise at any residential premises between 7:00 am and 6:00 pm, seven days a week. Audible noise is defined as "noise that can be heard at the receiver".</td><td>41</td><td>37</td><td>57</td></tr>
<tr><td>Fern Bay East</td><td>39</td><td>36</td><td>55</td></tr>
<tr><td>Stockton West</td><td>41</td><td>37</td><td>57</td></tr>
<tr><td>Stockton East</td><td>38</td><td>35</td><td>56</td></tr>
<tr><td>Mayfield West</td><td>45</td><td>40</td><td>55</td></tr>
<tr><td>Mayfield</td><td>44</td><td>39</td><td>62</td></tr>
<tr><td>Carrington</td><td>36</td><td>33</td><td>52</td></tr>
<tr><td>Notes</td><td colspan="4">The maximum allowable noise contributions apply under:
a) Meteorological conditions of: wind speeds up to 3 ms-1 at 10 metres above ground level; or
b) Temperature inversion conditions up to 3°C per 100 metres and wind speeds up to 2ms-1 at 10 metres above the ground.
For the purpose of assessment of noise from the project shall be:
c) Measured at the most affected point on or within the Site boundary at the most sensitive receiver to determine compliance with LAeq(15 minute) night noise limits;
d) Measured at one metre from the dwelling facade to determine compliance with LA1(1minute) noise limits; and
e) Subject to the modification factors provided in Section 4 of the NSW INP, where applicable.</td></tr>
</table>

Note 1: 7 days per week, 24 hours a day.

Note 2: Monday to Saturday 2200 hours to 0700 hours; Sundays and Public Holidays 2200 hours to 0600 hours.

Similarly, the NCET Environmental Assessment (EA) non-residential noise criteria are summarised and presented in **Table 2**.

Table 2 Environmental Assessment – Non- residential Noise Criteria

Non-residential Location	Land Use	Intrusive LAeq(15minute)			Acceptable Amenity LAeq(period)[1]			Maximum Amenity LAeq(9hour)
		Day	Evening	Night	Day	Evening	Night	Night
Mayfield West	Commercial Steel River	Intrusive noise not applicable			65	65	65	70
Kooragang Island	Industrial	Intrusive noise not applicable			70	70	70	75
Mayfield North		Intrusive noise not applicable			70	70	70	75
Any	School	Intrusive noise not applicable			External 45 when in use			50
Any	Hospital	Intrusive noise not applicable			External 50 when in use			55

Note 1: Daytime 0700 hours to 1800 hours, Evening 1800 hours to 2200 hours, Night-time 2200 hours to 0700 hours.

3 Noise Monitoring Equipment

All instrumentation used during noise measurements complied with the requirements of AS IEC 61672.1-2004 *"Electroacoustics – Sound Level Meters – Specifications"* and carried current NATA or manufacturer calibration certificates. Instrument calibration was checked before and after each measurement survey, with the variation in calibrated levels not exceeding ±0.5 dBA.

The noise measurement procedures employed throughout the monitoring program were guided by the requirements of AS 1055-1997 "*Acoustics - Description and Measurement of Environmental Noise*" and the *NSW Industrial Noise Policy* (INP).

All operator-attended noise measurements were conducted using a Bruel and Kjaer Type 2250L Type 1, integrating sound level meter (S/N 3003389) and Svantek 957 Type 1, integrating sound level meter (S/N 20665)

4 Off-Site Operator Attended Noise Monitoring – Residential Receivers

4.1 Noise Monitoring Results

Operator-attended noise measurements were conducted at the selected residential locations presented in **Table 3**.

Table 3 Residential Property Noise Monitoring Locations

Receiver Area	ID and Location		INP Noise Amenity Zone	LEP Zone
Fern Bay North	FN12	Bayway Village, Nelson Bay Road	Suburban	Residential
Fern Bay West	FW1	1 Fullerton Lane	Suburban	Residential
Fern Bay East	FE1	21 Braid Road		
Stockton West	SW1	284 Fullerton Street	Suburban	Residential
Stockton East	SE1	40 Eames Avenue		
	SE3	4 Pitt Street		
Mayfield West	W1	47 Stevenson Avenue	Urban	Residential
Mayfield	M1	68 Bull Street	Urban	Residential
	M4	52 Arthur Street		
Carrington / Maryville	C1	Cnr Hargrave and Young Streets	Urban	City Centre

The operator-attended night-time noise measurements were conducted on 7 May 2020 to 8 May 2020. The weather conditions during the monitoring period varied throughout the monitoring period consisting of temperatures ranging from 13°C-14°C, calm periods and periods of light N-NW winds.

The operator-attended night-time noise measurements results are presented in **Table 4**, including an estimate of NCET intrusive $L_{Aeq(15minute)}$ noise levels as well as estimates of other contributing ambient noise sources (i.e. traffic, insects, animals, other industrial operations etc).

Table 4 Residential Property Noise Measurement Results

Location	Date/Start Time	Primary Noise Descriptor (dBA re 20 µPa)					Comments and Description of Noise Emissions
		LAmax	LA1	LA10	LA90	LAeq	
FN1 - Bayway Village	07/05/2020 22:00	75	71	61	41	60	Road traffic, other industry
		Estimated NCET LAeq(15min) contribution <31 dBA. Estimated NCET LA1(1min) <33 dBA					NCET not discernible
FW1 - Fullerton Lane	07/05/2020 23:47	82	69	60	50	57	Road traffic, insects, other industry
		Estimated NCET LAeq(15min) contribution <40 dBA. Estimated NCET LA1(1min) <42 dBA					NCET not discernible
FE1 - Braid Road	07/05/2020 22:19	65	48	47	44	46	Road traffic, other industry
		Estimated NCET LAeq(15min) contribution <34 dBA. Estimated NCET LA1(1min) <36 dBA					NCET not discernible
SW1 - Fullerton Street	07/05/2020 23:25	72	56	51	47	50	Road traffic, other industry, insects, surf
		Estimated NCET LAeq(15min) contribution <37 dBA. Estimated NCET LA1(1min) <39 dBA					NCET not discernible
SE1 - Eames Road	07/05/2020 23:05	69	58	50	45	53	Road traffic, other industry, insects, surf
		Estimated NCET LAeq(15min) contribution <35 dBA. Estimated NCET LA1(1min) <37 dBA					NCET not discernible
W1 - Stevenson Avenue	08/05/2020 00:15	60	58	53	45	50	Road traffic, industrial noise
		Estimated NCET LAeq(15min) contribution <35 dBA Estimated NCET LA1(1min) <37 dBA					NCET not discernible
M1 - Bull Street	08/05/2020 00:39	63	56	53	48	51	Road traffic, insects, other industry
		Estimated NCET LAeq(15min) contribution <38 dBA. Estimated NCET LA1(1min) <40 dBA					NCET not discernible
M4 - Arthur Street	08/05/2020 01:05	76	70	61	50	58	Road traffic, other industry
		Estimated NCET LAeq(15min) contribution <40 dBA. Estimated NCET LA1(1min) <42 dBA					NCET not discernible
C1 - Cnr Hargrave and Young Streets	08/05.2020 02:28	69	54	50	48	50	Traffic, residents
		Estimated NCET LAeq(15min) contribution <38 dBA. Estimated NCET LA1(1min) <40 dBA					NCET not discernible

4.2 Compliance Assessment

The following observations were made during the night-time survey period:

- NCET noise emissions were not identifiable from the overall industrial noise at all locations. Industrial noise emissions were audible from the direction of the Mayfield North Industrial Area and Kooragang Island. NCET noise emissions are expected to have remained below the intrusive noise limits.

Measured noise levels presented in **Table 4** indicate that compliance with the sleep disturbance $L_{A1(1minute)}$ noise criteria were achieved at all locations during the night-time noise surveys.

5 Off-Site Attended Noise Monitoring – Industrial Premises

5.1 Noise Measurement Results

Operator-attended noise measurements were conducted at the selected nearby industrial premises shown in **Table 5**.

Table 5 Industrial/Commercial Premise Noise Monitoring Locations

Receiver Area	ID and Location	INP Noise Amenity Zone	LEP Zone
Kooragang Island	KI1 Blue Circle Southern Cement	Industrial	Port and Industry
	KI5 Cargill		
	KI10 Sims Metal		

The operator-attended noise measurements were conducted on Wednesday 15 April 2020, generally coinciding with typical NCET operations. The prevailing weather conditions consisted of light to moderate north east to north westerly winds of 1 m/s to 5 m/s with temperatures of 22 to 27°C

The operator-attended noise measurement results are presented in **Table 6**, including an estimate of NCET's intrusive $L_{Aeq(period)}$ noise level.

Table 6 Industrial/Commercial Premise Noise Monitoring Results

Location	Date/Start Time	Primary Noise Descriptor (dBA re 20 µPa)					Comments and Description of Noise Emission
		L_{Amax}	L_{A1}	L_{A10}	L_{A90}	L_{Aeq}	
KI1 Blue Circle Southern Cement	15/04/2020 10:17	87	79	72	61	70	Road traffic, other industry
		Estimated NCET $L_{Aeq(period)}$ contribution ~55 dBA					NCET ship loading streams
KI5 Cargill Australia	15/04/2020 12:14	69	61	57	53	55	Road traffic, birds and insects
		Estimated NCET $L_{Aeq(period)}$ contribution <43 dBA					NCET not discernible.
KI10 Sims Metal	15/04/2020 10:39	86	81	75	65	72	Road traffic, other industry
		Estimated NCET $L_{Aeq(period)}$ contribution <55 dBA					NCET not discernible.

5.2 Compliance Assessment

NCET noise emissions at the selected nearby industrial premises monitoring locations were below the $L_{Aeq(period)}$ limit of 70 dBA.

6 On-Site Operations

On-site operator-attended noise monitoring was conducted of selected items of NCET plant and equipment to quantify the operating sound power levels (SWLs). The measured SWLs have been used to update the NCET Stage 1, Stage 2AA and Stage 2F Plant and Equipment SWL Database as presented in **Appendix A** with a maximum total SWL of 128 dBA.

7 Environmental Noise Modelling Results

7.1 Noise Prediction Procedures

Based on the measured sound power levels (refer **Section 6**), the NCET computer noise model has been updated, further validated and used to predict the operating noise for comparison with the NCET 66 Mtpa PA noise limits.

The computer model developed for the NCET EA incorporates the significant noise sources associated with the NCET site and rail loop, surrounding terrain, aspects of the built environment and nearby receiver areas. The noise model has been modified to include key components of the installed Stage 1, Stage 2AA and Stage 2F infrastructure as guided by NCIG/Aurecon in various information updates.

The field measured SWLs were incorporated into the model to predict the contributed noise level from each source to the receiver localities.

7.2 Noise Prediction Results

The predicted $L_{Aeq(15minute)}$ intrusive noise levels from the Stage 1, Stage 2AA and Stage 2F operations at the nearest receiver areas are presented in **Table 7**.

The predicted $L_{Aeq(period)}$ amenity noise levels from the Stage 1, Stage 2AA and Stage 2F operations at the nearest receiver areas are presented in **Table 8**.

Table 7 Stage 1, Stage 2AA and Stage 2F Predicted Intrusive Noise Levels (dBA re 20 µPa)

Receiver Area	ID/Location		Day	Evening	Night	Intrusive Noise Criteria $L_{Aeq(15minute)}$
Fern Bay West	FW1	1 Fullerton Lane	25	20	38	41
Fern Bay East	FE1	21 Braid Road	23	18	37	39
Stockton West	SW1	284 Fullerton Street	24	22	39	41
	SW2	Cnr Pembroke and Fullerton Streets	24	23	37	
Stockton East	SE1	40 Eames Avenue	24	21	38	38
Warabrook/Mayfield West	W1	47 Stevenson Avenue	30	40	33	45
	W2	4 Groongal Street	32	42	37	
Mayfield	M1	68 Bull Street	33	43	37	44
	M2	45 Simpson Crescent	33	43	38	
	M3	1 Arthur Street	30	43	39	
	M4	52 Arthur Street	32	41	40	
	M5	21 Crebert Street	32	41	41	
Carrington	C1	Cnr Hargrave and Young Sts	25	30	35	36

Meteorological conditions in accordance with the NCET EA 2006.

The NCET predicted intrusive noise levels were at or below the relevant noise criteria at the key residential locations during the January to June 2020 period.

Table 8 Stage 1, Stage 2AA and Stage 2F Predicted Amenity Noise Levels (dBA re 20 µPa)

Receiver Area	ID	Location	Night-time Amenity[1]	Night-time Noise Criteria
Fern Bay West	FW1	1 Fullerton Lane	34	37
	FW2	Stockton Hospital	34	
Fern Bay East	FE1	21 Braid Road	33	36
	FE2	Fern Bay Primary	33	
Stockton West	SW1	284 Fullerton Street	35	37
	SW2	Cnr Pembroke and Fullerton Streets	33	
Stockton East	SE1	40 Eames Avenue	34	35
	SE2	Stockton Primary	31	
Warabrook/ Mayfield West	W1	47 Stevenson Avenue	29	40
	W2	4 Groongal Street	33	
	W3	Mayfield West Primary	34	
Mayfield	M1	68 Bull Street	33	39
	M2	45 Simpson Crescent	34	
	M3	1 Arthur Street	35	
	M4	52 Arthur Street	36	
	M5	21 Crebert Street	37	
	M6	Hunter Christian School	33	
	M7	Mayfield East Primary	36	
Carrington	C1	Cnr Hargrave and Young Streets	31	33
Sandgate	SG1	4 Mangrove Road	28	65
Mayfield West	MW1	Steel River	35	
Kooragang Island	KI1	Blue Circle Southern	55	70
	KI2	Origin Energy	53	
	KI3	Boral Country Concrete	51	
	KI4	Port Waratah Coal Services	45	
	KI5	Cargill Australia	47	
	KI6	ERS Australia	49	
	KI7	Cleanaway	51	
	KI8	Port Hunter Commodities	50	
	KI9	BOC Gas	52	
	KI10	Sims Metal	49	
Mayfield North	MN1	OneSteel	48	70

Note 1: Night-time meteorological conditions in accordance with the NCET EA 2006.

The NCET predicted night-time noise amenity levels were below the relevant amenity noise criteria at the key residential, commercial and industrial locations during the January to June 2020 period.

8 Further Action and Conclusion

SLR has conducted off-site noise and on-site sound power level monitoring at the NCET for the January to June 2020 period in accordance with the NCET ONMP.

Off-site noise monitoring has indicated that compliance is achieved at all residential locations under prevailing conditions during the January to June 2020 period. Similarly, off-site noise monitoring has indicated that compliance is achieved at selected nearby industrial locations.

Predicted noise levels demonstrate that the NCET noise emissions were at or below the relevant noise criteria during the January to June 2020 period under prevailing meteorological conditions.

At this stage no specific further action is recommended. Notwithstanding, NCIG implements a Continuous Noise Improvement Program (the Program). The Program will continue to be implemented as part of the ongoing NCET operations.

APPENDIX A

NCET Plant and Equipment SWL Database

ENM Source No	Component	ID	Description	Capacity	Conveyor Length (m)	Overall SWL (dBA)	Conveyor Drive P1 (dBA)	Conveyor Drive P2 (dBA)
Stage 1								
	Rail-Loop	Train 1	PN 8200 Series (per 3 Loco set)	Locomotive idle		109		
	Rail-Loop	Train 2	PN 8200 Series (per 3 Loco set)/QR 5000 Series (per 2 Loco set)	Locomotive Moving - Approaching Dump Station		109		
	Rail-Loop	Train 2	PN 8200 Series (all wagons - 1600m excluding locos)	All Noise including squeal, coupling		111		
100	Rail-receival	DS01	Dump Station	8500tph		106		
	Rail-receival	TBA	Dust extraction fan	300kW fan				
103	Rail-receival	FE01	Belt Feeder	8500tph		100		
108	Rail-receival	CV01	Belt Conveyor	8500tph	582	111		
109	Rail-receival	CV01	Conveyor Drive P1, P2	2 x 1000kW		106	98	105
110	Rail-receival	TR01	Fixed Tripper for inbound sample	-		90		
111	Rail-receival	SA01	Sample Station	80tph		99		
112	Rail-receival	TH01	Transfer House (8 Chutes, only 2 see coal at any one time)	-		105		
200	Stacking	CV04	Belt Conveyor	8500tph	349	111		
201	Stacking	CV04	Conveyor Drive P1	As built 1000kW (2 x 630kW)		98	98	
202	Stacking	TT02	Transfer Point	-		<96		
203	Stacking	CV05	Belt Conveyor	8500tph	207	107		
204	Stacking	CV05	Conveyor Drive P1	630kW		99	99	
205	Stacking	03TT03	Transfer Point	-		<96		
300	Stockyard	CV08	Belt Conveyor	10500tph	1334	115		
301	Stockyard	CV08	Conveyor Drive P1, P2	2 x 1250kW		104	102	100
302	Stockyard	SR01	Stacker/Reclaimer	10500tph		108		
303	Stockyard	TR04	Fixed Tripper for magnet & dewatering	-		100		
304	Stockyard	TH06	Transfer Point	10500tph		<96		
305	Stockyard	CV09	Belt Conveyor	10500tph	1374	115		
306	Stockyard	CV09	Conveyor Drive P1, P2	2 x 1250kW		104	101	102
307	Stockyard	SR02	Stacker/Reclaimer	10500tph		113		
308	Stockyard	TR05	Fixed Tripper for magnet & dewatering	-		90		
309	Stockyard	TH07	Transfer Point	10500tph		<96		
400	Reclaiming	CV12	Belt Conveyor	10500tph	611	112		
401	Reclaiming	CV12	Conveyor Drive P1	1250kW		103	101	100
402	Reclaiming	BN01	Buffer Bin	2000t bin		100		
403	Reclaiming	FE04	Belt Feeder	6250tph, Hydraulic 500kW		99		
404	Reclaiming	FE05	Belt Feeder	6250tph, Hydraulic 500kW		99		
405	Reclaiming	CV15	Belt Conveyor	11500tph	625	112		
406	Reclaiming	CV15	Conveyor Drive P1 & P2	2 x 1000kW		107	105	101
407	Reclaiming	SA04	Sample Station	80tph		105		

ENM Source No	Component	ID	Description	Capacity	Conveyor Length (m)	Overall SWL (dBA)	Conveyor Drive P1 (dBA)	Conveyor Drive P2 (dBA)
408	Reclaiming	TH10	Transfer Point (2 Chutes)	-		<96		
426	Reclaiming	CV19 - 30Mt	Belt Conveyor	11500tph	63	104		
427	Reclaiming	CV19 - 30Mt	Conveyor Drive P1	1000kW		99	99	
430	Reclaiming	TH12	Transfer Point (2 Chutes)	-		102		
502	Shiploading	SL01 - 30Mt	Ship Loader	12500tph		109		
506	Shiploading	CV21 - 30Mt	Belt Conveyor	11500tph	689	113		
700	Stockyard		Dozer	D11		118		
600	Clearwater Pond	1	Clearwater Pond Pump 1 (Lift Pump)	-		90		
601	Clearwater Pond	4	Main Dust Suppression and Fire Pump 1	-		90		
602	Clearwater Pond	5	Main Dust Suppression and Fire Pump 2	-		90		
603	Clearwater Pond	6	Main Dust Suppression and Fire Pump 3	-		90		
604	Clearwater Pond	7	Main Dust Suppression and Fire Pump 4	-		90		
605	Clearwater Pond	10	Pressure Maintaining Pump (Jacking Pump 1)	-		90		
606	Clearwater Pond	21	Transfer House TH03 Pump	-		90		
607	Clearwater Pond	26	Conveyor CV12 Mid Point Sump Pump	-		90		
608	Clearwater Pond	30	Administration Vehicle Spray Wash Supply Pump	-		90		
609	Clearwater Pond	49	Sewer Pump 4: 4000 L	-		90		
610	Clearwater Pond	51	Potable Water Pump no. 1	-		90		
				Total Stage 1 (excluding Trains)		**125**		
				Stage 1 Trains		**115**		
				Stage 1 Total (including Trains)		**125**		
Stage 2AA								
	Rail-Loop	Train 3	PN 8200 Seires (per 3 Loco set)/QR 5000 Seires (per 2 Loco set)	Locomotive Moving - Approaching DS		109		
	Rail-Loop	Train 3	PN 8200 Seires (all wagons - 1600m excluding locos)	All Noise including squeal, coupling		111		
	Rail-Loop	Train 4	QR 5000 Seires (per 3 Loco set)	Locomotive Moving - Approaching DS		109		
	Rail-Loop	Train 4	QR 5000 Seires	All Noise including squeal, coupling		111		

ENM Source No	Component	ID	Description	Capacity	Conveyor Length (m)	Overall SWL (dBA)	Conveyor Drive P1 (dBA)	Conveyor Drive P2 (dBA)
104	rail-receival	DS02	Dump Station	8500tph		104		
113	rail-receival	CV02	Belt Conveyor	8500tph		112		
114	rail-receival	CV02	Conveyor Drive P1, P2	2 x 1000kW		106	105	103
115	rail-receival	TR02	Fixed Tripper for inbound sample	-		90		
180	rail-receival	SA02	Sample Station	80tph		99		
206	Stacking	CV06	Belt Conveyor	8500tph		100		
207	Stacking	CV06	Conveyor Drive P1	1000kW		98	98	
208	stacking	TH04	Transfer Point	-		97		
310	Stockyard	CV10	Belt Conveyor	10500tph		116		
311	Stockyard	CV10	Conveyor Drive P1, P2	2 x 1250kW		101	99	98
312	stockyard	SR03	Stacker/Reclaimer	10500tph		111		
314	stockyard	TH08	Transfer Point	10500tph		<96		
511	reclaiming	CV13	Belt Conveyor	10500tph		112		
512	reclaiming	CV13	Conveyor Drive P1, P2	2 x 1000kW		103	102	99
513	reclaiming	BN02	Buffer Bin/Belt Feeders	2000t bin		104		
514	reclaiming	FE06	Belt Feeder	6250tph, Hydraulic 500kW		99		
515	reclaiming	FE07	Belt Feeder	6250tph, Hydraulic 500kW		99		
516	reclaiming	CV16	Belt Conveyor	10500tph		112		
517	reclaiming	CV16	Conveyor Drive P1, P2	2 x 1000kW		102	98	100
518	reclaiming	SA05	Sample Station	80tph		<96		
528	reclaiming	CV20	Belt Conveyor	10500tph		105		
529	reclaiming	CV20	Conveyor Drive P1	1000kW		97	97	
603	shiploading	CV22	Belt Conveyor	10500tph		113		
604	shiploading	CV22	Conveyor Drive P1, P2	2 x 1000kW		104	101	101
605	shiploading	SL02	Ship Loader	12500tph		110		
				Total Stage 2AA (excluding Trains)		**122**		
				Stage 2 AA Trains		**116**		
				Stage 2AA Total (including Trains)		**123**		
Stage 2F								
209	stacking	CV7	Conveyor	8,500 t/hr	78	100		
210	stacking	CV7	Conveyor Drive P1	1000 kW		97	97	
211	stacking	TH05	Transfer Tower	10,500 t/hr		103		
315	stockyard	CV11	Conveyor	10,500 t/hr	1447	116		
316	stockyard	CV11	Conveyor Drive P1, P2	1250 kW		102	99	98
317	stockyard	SR04	Stacker/Reclaimer	10,500 t/hr		109		
319	stockyard	TH09	Transfer Tower	10,500 t/hr		105		
509	reclaiming	CV17	Conveyor	10,500 t/hr	229	107		

ENM Source No	Component	ID	Description	Capacity	Conveyor Length (m)	Overall SWL (dBA)	Conveyor Drive P1 (dBA)	Conveyor Drive P2 (dBA)
410	reclaiming	CV17	Conveyor Drive	1000 kW		100	100	
519	reclaiming	CV18	Conveyor	10,500 t/hr	363	113		
520	reclaiming	CV18	Conveyor Drive	1000 kW		98	98	
521	reclaiming	TH11	Transfer Tower	10,500 t/hr		103		
522	reclaiming	CV19	Conveyor	10,500 t/hr	63	102		
523	reclaiming	CV19	Conveyor Drive	1000 kW		98	98	
524	reclaiming	CV20	Conveyor	10,500 t/hr	62	105		
525	reclaiming	CV20	Conveyor Drive	1000 kW		98	98	
531	reclaiming	TH12	Transfer Tower	10,500 t/hr		102		
606	reclaiming	CV21 Ext	Conveyor	10,500 t/hr	362	112		
601	reclaiming	CV21	Conveyor Drive P1, P2	1000 kW		104	102	101
603	reclaiming	CV22 Ext	Conveyor	10,500 t/hr	362	110		
604	reclaiming	CV22	Conveyor Drive P1, P2	1000 kW		104	101	101
				Stage 2F Total		**121**		
				Stage 1 + 2AA + 2F Total (excluding Trains)		**128**		
				Stage 1 + 2AA + 2FTrains		**119**		
				Stage 1 + 2AA + 2F Total (including Trains)		**128**		

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APPENDIX 6

ANNUAL REPORT (2019/20) RESEARCH PROGRAM ON THE GREEN AND GOLDEN BELL FROG ON KOORAGANG ISLAND

Green and Golden Bell Frog (*Litoria aurea*) Research Program on Kooragang Island: Annual Report (2019-2020)

Conducted by the Amphibian Research Group, University of Newcastle.

Draft Report prepared by John Gould, Cassie Maynard, Finn McHenry, Alex Callen, Colin McHenry.

Prepared for Port Waratah Coal Services, Newcastle Coal Infrastructure Group and Hunter and Central Coast Development Corporation, and *Port of Newcastle*.

Draft prepared – August 2020.   Report finalised – December 2020

cbrg conservation biology research group

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Executive Summary

***Note**: An extended discussion of this summary is provided in the Discussion (Section 4), using the structure below for subheadings etc.*

<u>Conservation biology of *Litoria aurea* on Kooragang Island</u>

1. **<u>Population size</u>**: Averaging model estimates from capture-mark-recapture data over the previous three breeding seasons indicates that approximately six *L. aurea* individuals with SVL ≥ 40 mm are generally present for every one individual detected during VES. Based on this ratio, and the number of VES detections obtained during island-wide surveys of 60 wetlands this year, the *L. aurea* population of Kooragang Island is currently standing at approximately 3,000. This is similar to the calculations obtained for the 2017-18 season, and could suggest that the population is starting to stabilise after a long term but gradual upward trend since 2010-11.

2. **<u>Demography</u>**
   a. <u>Age/sex class structure:</u> Less than a third of individuals detected were metamorphs or juveniles, while approximately one half to two-thirds of adults were male (Figure 3.4.1). This is similar to results obtained in previous years. Demographic analysis identified at least three distinct cohorts of juveniles; one set spawned in the latter half of the previous breeding season, one early in the current season and a large spawning event in the latter half of the current season after heavy rainfall in February (Figure 3.4.5).

   b. <u>Recruitment</u>: 16 wetlands within the Industrial Zone held either tadpoles and/or metamorphs at some point during the 2019-20 breeding season. The largest numbers were recorded at K111 and K121 in the latter half of the season, both of which are in the southern Industrial Zone. These animals were recruited following a large rainfall event in February, and in autumn very large numbers of very small juvenile *L. aurea* were detected in Area 2 and close to the Rail Loop, indicating prolific breeding in K111-114, K121-123, and K105AS-K105B. Breeding events were also recorded at one of the BHP-CHEMP wetlands and three other wetlands within the Central Zone. One small juvenile was also detected in the Northern Zone, suggesting that breeding occurred across all zones this season. Few offspring were detected until the latter half of the season after heavy rainfall triggered the mass breeding event. Offspring where primarily detected in wetlands classified as permanent, demonstrating that *L. aurea* are not necessarily limited to ephemeral wetlands for breeding. The lack of breeding at temporary sites may be due to the dry conditions breeding adults were exposed to throughout much of the season as a result of lower than average rainfall.

   c. <u>Gravid females</u>: Using 58 mm as the threshold for the onset of female maturity, 221 unique adult females (identified by PIT tags) were captured during the 2019-20 season. This number is similar to data from the three previous seasons and indicates that the effective population size of *L. aurea* on Kooragang Island is sufficient for at least the immediate persistence of the population. However, the low percentage of recapture events between years suggests that few individuals are making it to multiple breeding periods. This is cause for concern as females generally take longer to reach sexual maturity than males, and consecutive seasons of poor recruitment will likely result in severe population decline.

3. **Survey rounds and weather**

   Movement and widespread calling indicate that a breeding event likely took place in this early part of the season following a rainfall event in September. This is supported by the detection of small numbers of metamorphs and juveniles in Round 2. Fewer captures occurred in Round 2, which is to be expected given that conditions in summer were dry, with lower than average rainfall. Many of the wetlands dried completely during the early to mid-summer period, including many that have historically been characterised as ‘permanent’. Round 3 occurred during a period of late summer rainfall in February that re-charged wetlands and sparked a large breeding event. Evidence for this come from the large number of adult females detected during this round, as well as the large number of metamorphs and juveniles detected later in Rounds 4 and 4.1. Near the end of the season in April (Round 4.1), a large juvenile dispersal event was detected away from water. This highlights a possibly important aspect of this species’ life history, which is the movement of vulnerable juveniles away from their natal waterbodies when weather conditions are suitable for dispersal across terrestrial habitat.

While drier than average conditions have been a common hallmark of the *L. aurea* breeding season on Kooragang Island for the past four seasons, it is clear that an extended breeding period affords this species a greater chance of being exposed to optimal breeding conditions on at least a few occasions. As such, while adults were met with poor breeding conditions in the first half of the season, the large rainfall event/s in the latter half of the season were sufficient to trigger a large breeding event, which theoretically should allow for sufficient recruitment of individuals in the adult population in the next season for continued persistence on the island. What remains unclear is the impact of extended dry periods on adult survival, as well as juveniles that have dispersed from aquatic sites.

4. **Longitudinal data**

   a. Persistence: As with previous seasons, persistence is low with most marked animals never recaptured. Of those that are, most are recaptured within six months of first capture, and only 10% are recaptured more than 12 months from first capture (Table 3.5.2). This indicates a low rate of survivorship. Note that only individuals larger than 40 mm SVL are tagged, so this survivorship rate cannot be attributed to the high mortality of eggs, tadpoles, metamorphs and small juveniles typical of many frogs. In contrast, adult survivorship of *L. aurea* on Kooragang Island is low – much lower than the rates seen in populations not affected by chytrid. This feature of the population means that it remains vulnerable (see point 2c above)

   b. Movement: Most detected movements were between wetlands within the northern Industrial Zone and within the Southern Industrial Zone (Figures 3.5.1, 3.5.2). In particular, most movements occurred between wetlands surrounding K105A, highlighting the strong connectivity between wetlands within this habitat mosaic. Several of these movements were made by adult females out of K29 into another wetland in the mosaic, providing support for the suggestion that *L. aurea* will move from ‘refuges’ (e.g. K29) to habitats that provide suitable breeding conditions at a particular time.

   Most movements this season were between wetlands less than 200 metres apart (Tables 3.5.4, 3.5.5). Over the past 9 years, most detected movements have been less than 500 metres, indicating that wetlands need to be within this distance to improve their connectivity. This could also be critical for promoting movements between zones, to improve gene flow between mosaics/locations across the island. Movement between the mosaic centred around K105 (referred to as the Northern Ponds mosaic) and K22/23, albeit only a small distance apart, indicates a degree of connectivity between the Industrial and Central Zone wetlands. However, there was no detection of movement between the Central and Northern Zones in 2019-20. While this has been detected in previous seasons, is it a rare occurrence and suggests that additional habitat mosaics between the Central and Northern Zones will be required to improve connectivity between these areas of the island.

A small number of larger movements greater than 500m were detected both within the current breeding season and between the current and previous season, showing movement of animals between the northern and southern Industrial Zones. In particular, movement was detected out of K100A into K105A and K42, suggesting that K100A is an important refuge, especially during dry periods.

5. Landscape use

a. Distribution: The largest number of adult detections occurred in the Industrial Zone, which is consistent with previous years, showing that this area remains a stronghold for *L. aurea* occupation/persistence. Adult numbers across both regions of the Industrial Zone have declined since the previous breeding season, though overall numbers (adults and offspring) have increased, indicating that this area remains critical for breeding on the island. More adults were detected in the northern region of the Industrial Zone, while the apparent increase in abundance in the southern region is likely linked to the construction of new wetlands that has created an effective habitat mosaic.

   Adult numbers in the Central Zone are similar to those recorded in the previous breeding season but – with the exemption of the BHP-CHEMP wetlands – are low compared to observations from pre-2014, though overall numbers (adults and offspring) have shown a marked increased. However, reduction in search effort due to issues in gaining access to sites along Bellfrog Way complicates assessment of the situation.

   Both densities and absolute numbers remain comparatively low in the Northern Zone. However, they have increased markedly compared to previous seasons before 2018-19, likely due to the construction of the NCIG-CHEMP wetlands. Numbers in the Milliam's Pond subregion are reasonably high and this appears to be a consistent signal across recent seasons. The NCIG_CHEMP habitats at Stage 4, 5, and 7 have been primarily responsible for this increase. This trend, along with the detection of a small juvenile in this zone, provide evidence that a population persists here with the capacity for breeding.

b. Landscape factors affecting distribution, abundance, and recruitment:

   (1) ***Gambusia*****:** The majority of breeding occurred in wetlands where *Gambusia* was absent. Currently, it is unknown to what degree breeding adults are able to perceive the presence of the fish and avoid potential oviposition sites where they are present. The presence of breeding at a few sites where the fish is present may suggest that successful breeding and then offspring development can occur in the presence of the fish, although likely dependent on their density. This is an important finding, as management strategies to remove the fish (which may not be feasible for large waterbodies and expensive) may not be needed. Instead, strategies that maintain densities at low levels could be equally effective. In any case, the fact that adults are avoiding fish-present sites is an issue as it means these potentially optimal breeding sites are unusable, thereby disrupting the effectiveness of habitat mosaics.

   Gambusia are currently absent from a large number of wetlands, only being present at four wetlands in the Industrial Zone (Figures 3.2.8, 3.2.9). This is primarily due to a string of dry years that has caused many of the waterbodies to dry out completely, removing the fish. This is a clear benefit of dry conditions, on the caveat that subsequent rainfall at some point replenishes water levels for breeding to occur.

Specific management issues relevant to research partners

6. **Habitat corridor mitigation strategy**: Compared with the situation prior to 2015, the abundance of *L. aurea* in the southern habitat corridor (i.e. the southern region of Industrial Zone) has been markedly higher from 2016-20, especially in terms of adults (Table 3.9.4). The increased population in the southern corridor is linked to the increased extent and connectivity of habitat provided by the constructed wetlands in this region, which have improved the quality of the habitat mosaic for *L. aurea*. In particular, there is now a larger number of wetlands used for breeding in the southern corridor than the northern. However, the southern corridor still lacks large permanent wetlands that provide suitable refuge habitat for large numbers of adult *L. aurea.* Further, the recorded movement of adult frogs between the northern and southern Industrial Zones indicates some connectivity, which could be improved by the addition of wetlands less than 500 metres apart for individuals to use as refuge while migrating across the site.

7. **Rail infrastructure mitigation strategy**: Longitudinal data from marked *L. aurea* shows that they frequently cross railways and associated infrastructure. Movements between the northern and southern Industrial Zones were detected in the 2019-20 season between wetlands situated within (e.g. K115) or east of the rail loop (K100A) and K105A. Movement that required animals to go over or under rail lines was also detected in the northern zone between K105B to K105AS. Although it is not yet possible to say if railway infrastructure represents a partial hindrance to movement of *L. aurea* across the landscape, it is clear that it does not constitute an absolute barrier. As such, the rail infrastructure on Kooragang is not expected to lead to fragmentation of the population, especially where connectivity across the landscape is maintained or improved through well-designed constructed wetlands.

8. **Constructed wetland strategy**: Of the four phases of constructed wetland design deployed on Kooragang Island over the last decade, three have been highly successful in providing habitat that is occupied by *L. aurea*: the 'cluster ponds', the 'HDC' wetlands, and the BHP CHEMP wetlands. These continued to be successful in 2019-20, with high levels of *L. aurea* abundance at the BHP CHEMP wetlands, and widespread breeding behaviour at both the HDC and the BHP CHEMP wetlands. The improvement in extent, connectivity, and heterogeneity of wetland provided by both the HDC and BHP CHEMP designs is understood to have markedly improved the quality of the habitat mosaic and is directly linked to the increased abundance of *L. aurea* in those respective subregions (Table 3.9.4). Altogether these constructed wetlands appear to support nearly half of the island's *L. aurea* population.

   Although the NCIG CHEMP wetland design has not been as initially successful as the others, there was indication in the 2018-19 data that occupancy here was starting to increase. This has been reaffirmed in the 2019-20 season by a further increase in *L. aurea* abundance, along with the detection of a juvenile that suggest breeding has occurred in the north. Of course, there is opportunity to improve the performance of these wetlands with the addition of more sites of varying hydroperiods, to create habitat mosaics similar to those found in the Industrial Zone.

9. Other issues

a. **Bellfrog Way surveys**: There was a reduction in search effort at this location for several reasons: i) ground fires that were ignited in January 2019 were not fully extinguished until September 2019, with access restricted until October, ii) increased safety and induction requirements by PoN prevented access further still to mid-November, and iii) we were able to survey K22-23 in early December but there was not enough suitable days at this time to complete the transect surveys as well.

b. **Recaptures over the season:-** What is interesting (and potentially concerning) is that few animals caught in earlier rounds were re-caught in Round 3 when conditions were presumably the most optimal across the season for breeding.

Acknowledgements

As with previous years, island wide monitoring of *L. aurea* on Kooragang Island in 2019-20 was an extensive and complex task spanning many land tenures and requiring significant human resource. We are grateful to the land managers who support the program and facilitate access to sites on the island, including Hunter Central Coast Development Corporation (Mike Bardsley, Grant Moylan and Suzana Georgeff), Newcastle Coal Infrastructure Group (Hayley Ardagh), Port Waratah Coal Services (Ben Lowder) and Port of Newcastle (Jackie Spiteri). We also recognise the support of the NSW Government (Enhua Lee – Department of Planning, Industry and Environment) for continuing to include part of the dataset in their Save Our Species (SOS) monitoring program for *L. aurea*, including Geoff Heart and Matt West for analysis under the SOS.

We especially thank the field survey team who put in hundreds of hours in the field on evenings reminiscent of GANGgajang's *Sounds of Then*; Jess McGregor, Gregory Knibbs, Lucy Gill, Cassandra Bugir, Rose Upton, Robert Scanlon, Chad Beranek, Dean Lenga, Samantha Sanders, Rebecca Seeto, Aaron Turner and Eli Turner.

Cover photo: Juveniles were the flavour of the last part of the 2019-2020 monitoring season, owing to mass breeding once the drought broke in late February 2020. Sources: S. MaHony, M. Bardsley.

Contents

1. Introduction

1.1 Background to the study: Historical context and research objectives.

The Conservation Biology Research Group (formerly the Amphibian Research Group) at the University of Newcastle (UoN) has been conducting annual surveys of the green and golden bell frog (*Litoria aurea*) on Kooragang Island since 2010. The research aims to provide insight into the biology and ecology of this endangered species, in order to inform effective habitat management and creation by the partner organisations. Those partner organisations – Port Waratah Coal Services (PWCS), Newcastle Coal Infrastructure Group (NCIG), the Hunter and Central Coast Development Corporation (HCCDC; formally HDC), and more recently Port of Newcastle (PoN)– are involved with 'on ground' management and landscape works across Kooragang Island. By providing high quality data from population monitoring, this project aims to inform those activities to ensure long-term persistence of *L. aurea* on the island.

Over the course of these surveys more than four thousand *L. aurea* have been captured (with another five thousand animals captured as part of different PhD projects at UoN), with this extensive data set representing one of the most comprehensive investigations of this threatened species to date. Continuous monitoring of this scale, especially of amphibian species, remains rare in an Australian context, and yet is essential given that amphibian populations exhibit classic boom and bust population growth linked closely to climate and weather patterns. Only long term datasets such as these allow scientists to determine whether changes to the conservation status of threatened species is associated with weather fluctuations or is influenced by acute human actions (eg habitat clearing and fragmentation). This is critically important for *L. aurea* as it is now found in less than 10% of its former range, confined largely to coastal environments that are also in high demand for human landuse.

The original wetlands surveyed over the past decade have remained consistent, however, some additional wetlands have been constructed and others have been altered. The absolute number of wetlands surveyed has thus increased, and the focus of each seasons' survey has shifted when necessary to track significant changes in population demographics. Nevertheless, the primary aims and methodology of consecutive surveys has remained consistent between years, and the original project aims continue to be prioritized. With respect to population monitoring, these are:

1. Gaining general insights into the biology and ecology of *L. aurea*.
2. Meeting population monitoring requirements for operation on Kooragang Island by:
    a. Providing a population size estimate for *L. aurea* on the island;
    b. Describing the demographic composition of the island population of *L. aurea*; specifically, the ratio of adults to juveniles and the ratio of males to females.
    c. Defining the spatial distribution of *L. aurea* across the island, considering movement patterns and aggregations.
3. Informing 'on the ground' management plans of partner organisations to balance business with the protection of the existing population of *L. aurea* on Kooragang Island.

1.2 Context of the green and golden bell frog decline; bell frogs in SE Australia

The general background to the decline of *Litoria aurea* – a once common and widespread species along Australia's East Coast and inland tablelands from northern New South Wales to southern Victoria – has been described in detail in our previous annual reports (see, for example, McHenry et al. 2019) and various published papers (Mahony et al., 2013, Pyke and White, 1996, Pyke et al., 2002). The current population is understood to be much smaller than it was 50 years ago and persists in less than 10% of its historical range, occupying fewer than forty sites in a highly fragmented set of small refuge habitats (White and Pyke, 1996, Mahony et al., 2013). While there has been some argument about the causes of decline in this species, attention has focused upon three primary threats; (i) habitat loss/degradation, (ii) the invasive fish species *Gambusia holbrooki*, and (iii) the fungal disease known as 'chytrid'.

<u>Habitat changes</u>: The former range of *L. aurea* largely encompasses regions that have been highly modified for agriculture, urban development, and industry since European occupation. In NSW, the frog was distributed across the Eastern coastal plains and slopes, the coastal hinterland highlands on the east side of the Great Dividing Range, the tablelands that make up the upper parts of the Murray-Darling catchment on the west side of the Great Dividing Range, and the slopes and plains of the Murray river catchment. Most of these areas have been profoundly altered in the last 200 years, and hence the loss and degradation of habitat is a clear potential factor in the decline of this species in the last 50 years (Mahony 1999, Clemann & Gillespie 2012, Mahony et al. 2013). In particular, removal of riparian vegetation and river access by sheep and cattle has caused severe bank erosion and sedimentary infill of deeper holes in riverbeds, resulting in the loss of basking, foraging, and refuge microhabitats for frogs such as *L. aurea* that require access to standing water all year around (David Hunter, pers. comm.). Regulation of rivers by large dams has also altered the timing and extent of flooding events, which has likely had negative consequences for *L. aurea* breeding habitat.

<u>The eastern plague minnow, *Gambusia holbrooki*</u>: This invasive species was introduced to many countries including Australia through the 20th Century as a putative control measure against mosquitos. It has been described as a voracious predator and possesses a combination of life-history traits that make it a highly successful invader of aquatic ecosystems. It has been demonstrated to significantly reduce survivorship of *L. aurea* tadpoles in laboratory experiments (Morgan & Buttemer 1996, Pyke and White 2000). *Litoria aurea* tadpoles also do not show any avoidance or refuge seeking behaviours when introduced to *Gambusia*, further increasing their susceptibility (Hamer et al., 2002b). Its current range in NSW and Victoria has strong overlap with the locations from which bell frogs have declined; as a result, ecologists seeking to understand the decline of bell frogs in the 1990s drew attention to the potential impact of *Gambusia* (Gillespie 1996, Mahony 1999).

<u>Chytrid</u>: Over the course of the 1990s, ecologists suspected that the pattern of amphibian declines and extinctions closely fitted that of a disease epidemic, rather than the effects of habitat degradation or predation by an invasive species. Support for this was found in 1996 with the description of chytrid; more correctly known as chytridiomycosis, this is a disease caused by the pathogenic fungus *Batrachochytrium*

dendrobatidis which can be fatal to a range of amphibian species (see summaries in Berger et al. 2007, Skerratt et al. 2018, Scheele et al. 2019).

Some aspects of the decline of *L. aurea* match the general pattern of chytrid-mediated decline of frog species. *Batrachochytrium dendrobatidis* is more active in cooler temperatures, and its greatest impacts have been upon frogs living at higher altitudes (Puschendorf et al. 2009, Puschendorf et al. 2013, Geoff Heard pers. comm.). This species has largely disappeared from the high altitude parts of its former range, and persists mainly in warmer coastal zones. More recently, *B. dendrobatidis* has been shown to have a low tolerance to saline environments, again consistent with the coastal distribution of surviving populations of *L. aurea*.

Combined effects: As much as chytrid appears to be the smoking gun behind *L. aurea* declines, there are some aspects that suggest that chytrid on its own may not be the whole story and that it is the interaction between these potential threatening processes that have contributed to declines. For example, at higher altitudes (coastal highlands of NSW and inland tablelands), *L. aurea* has experienced severe declines even with moderate or low habitat degradation and despite the absence of *Gambusia*. However, at lower altitudes and in more coastal areas, the situation becomes more complex. When *Gambusia* is present in high densities, the species persists only in saline environments, irrespective of the level of habitat degradation (coastal plains of NSW). When *Gambusia* is present at lower densities and habitat modification is not extreme, it may also persist (Mahony 1999, Gillespie & Clemann 2012). Similarly, where coastal plains have lower levels of both degradation and *Gambusia*, it persists (Heard et al. 2013, Gillespie and Clemann 2012), and where habitat modification is minimal and *Gambusia* is completely absent, the frog shows little evidence of decline (e.g. East Gippsland region of Victoria; Graeme Gillespie, pers. comm.). This pattern suggests that, whilst chytrid alone has likely extirpated *L. aurea* from the higher parts of its former range, the disease alone does not account for the pattern of decline in the lower-lying coastal and inland regions. The complexities of habitat degradation can be difficult to understand, but there appears to be a very clear signal with respect to the interaction between chytrid and *Gambusia.*

1.3 Threats interacting at a small scale: *Litoria aurea* on Kooragang Island

In laboratory challenge experiments *L. aurea* is particularly susceptible to the chytrid fungus, (Stockwell et al., 2010), and whilst it is unlikely the disease kills all infected wild individuals, the fungus clearly poses substantial threat to the persistence of wild populations. Survival estimates of the Kooragang Island population demonstrate significantly lower over-winter survival rates in infected individuals when compared with non-infected individuals (Stockwell et al, 2011). The population level effects of this mortality are significant: infected populations are predicted to decline at twice the rate of healthy ones (Stockwell et al, 2011).

The majority of extant *L. aurea* populations are found in coastal environments, consistent with the suggestion that the sensitivity of the chytrid fungus to salt may explain the persistence of *L. aurea* in weakly saline environments (White, 2006; Stockwell et al., 2012). Significant negative correlations have been experimentally confirmed between infection load in captive *L. aurea* and the salinity of the water bodies they are kept in (Stockwell, 2011). Wild populations of *L. aurea* inhabiting water bodies with up to 3.5 ppt salt were also found to have lower infection loads than those frogs not exposed to saline conditions (Stockwell et al. 2012, Clulow et al. 2018). Indeed, salt concentrations above 2 ppt but not exceeding 5ppt were found to be beneficial (Stockwell et al., 2015b, Stockwell et al., 2015a). The potential for using salt as part of a management tool for *L. aurea* on Kooragang was investigated by Callen (2018), who found that an array of wetland habitats which provided wild *L. aurea* with access to at least some saline wetlands did result in improved survivorship.

Callen (2018) also found that variation in hydroperiod was also important for the persistence of the subpopulation that was the focus of the study. This variation in wetland characteristics between neighbouring wetlands has been dubbed the 'habitat mosaic' and is emerging as an important concept in the conservation management of *L. aurea*. Connectivity (proximity of an array of wetlands to each other, with suitable interconnecting habitat) is a key attribute of an effective mosaic (Hamer et al. 2008, Wassens et al. 2008, Heard et al. 2015), but variation in hydroperiod among wetlands is just as important (Klop-Toker 2016, Callen 2018). In the context of *L. aurea* on Kooragang Island, an effective habitat mosaic should have variation in microhabitat sufficient to provide environmental protection against chytrid via access to increased salinity and temperatures (Heard et al. 2014, Heard et al. 2018). Variation in hydroperiod can also provide protection against *Gambusia*, which have a significant impact on *L. aurea* recruitment on the island (Klop-Toker 2016).

Whilst the relationship between *L. aurea* declines and the expansion of *Gambusia* into NSW has been debated, numerous sites exist where *L. aurea* declined despite local water bodies being free of the predatory fish (Mahony et al. 2013). While several studies have noted the co-occurrence of *L. aurea* tadpoles and *Gambusia* in the same water body (Sanders et al., 2015, Hamer et al., 2002a), the pattern seen from field studies on Kooragang leaves little doubt that *L. aurea* recruitment is heavily affected by the presence of *Gambusia* (Klop-Toker 2016, McHenry et al. 2017, 2019, this annual report). *Gambusia* do not affect adult *L. aurea* (Klop-Toker 2016), but their impact on tadpoles means that *L. aurea* populations subject to chytrid and coexisting with *Gambusia* will be subject to both increased adult morality and reduced recruitment. Bell frogs appear to have bred in permanent water bodies more frequently in the past than they do now and this may be because ephemeral water bodies that dry frequently do not sustain populations of the fish (Pyke and White 1996; Hamer et al. 2002; Pyke, White et al. 2002), highlighting the importance of designing wetland infrastructure to control for *Gambusia* infestation.

1.4 Research Objectives

Research objectives for the 2019-20 season are largely consistent with previous years, and target areas of *L. aurea* biology and ecology that are relevant for management of this species and its habitat on Kooragang Island:

1. What is the estimated population size on the island?
2. What is the demographic composition on the island?
    - What are the proportions of juveniles, adult males, and adult females?
    - How much recruitment is known, and where is it occurring on the island?
3. How do *L. aurea* utilise the island landscape?
    - What is the distribution?
    - What factors affect distribution, abundance, and recruitment?
4. What information can be gained from longitudinal data?
    - What are the growth patterns of *L. aurea* on the island?
    - How long do individual *L. aurea* persist?
    - What are the movements of *L. aurea* across the island?

In addition, there are several objectives that relate to specific management issues faced by partner organisations:

5. **Habitat corridor mitigation strategy (PWCS)**: A long-term aim is to decrease the proportion of *L. aurea* occupancy of wetlands in the north of the precinct (previously earmarked for development - see Section 2.1: Site Context), and to increase occupancy of wetlands in the southern part of that site. This requires detailed understanding of population numbers, distribution and movement in the northern and the southern parts of the Industrial Zone.

6. **Rail infrastructure mitigation strategy (NCIG)**: The construction of the NCIG 'rail loop' enclosed several wetlands that were important habitat for *L. aurea* with a high traffic rail line. It is important for NCIG to understand if the rail loop has effectively isolated the populations in those wetlands from the Kooragang Island metapopulation. This requires detailed understanding of population numbers, distribution, and movement within the rail loop and adjacent wetlands.

7. **Constructed wetlands strategy (HCCDC)**: As part of capping within the rail loop in 2015, HCCDC constructed sedimentation ponds that were designed to provide suitable habitat for *L. aurea*. The efficacy of that design, and the location of these artificial wetlands within the landscape, is an important question for HCCDC as further capping works are implemented. This requires detailed understanding of population numbers, distribution, and movement at the HCCDC constructed and adjacent wetlands.

2. Methods

2.1 Site context

Kooragang Island lies at the northern boundary of the Newcastle Local Government Area, on the NSW Central Coast (Figure 2.1.1). The island itself is estuarine in nature, and is bounded to the north and south by channels of the Hunter River. Soils are composed of deposited sand, silt and clay sediments. Several tidal channels extend onto the island, which historically once separated the current landmass into smaller islands prior to human development. The natural hydrology of the island has been considerably altered, with agricultural development (e.g. draining of land for pastures) and industrial activity (e.g. road construction and land reclamation). Its deltaic nature, which includes low elevation, supports a diversity of wetlands ranging from saltmarsh and tidal flats to freshwater swales and large permanent freshwater wetlands.

Sixty wetlands have been the focus of the island-wide surveys, and these were all surveyed again in the 2019-20 breeding season. Additional surveys of other wetlands were added to the dataset Figure 2.1.2). This approach gives a largely consistent list of wetlands surveyed each year, with some variation between each season (see Table 2.2.1). Figures 2.1.3 and 2.1.4 show the nomenclature used by UoN to identify specific wetlands.

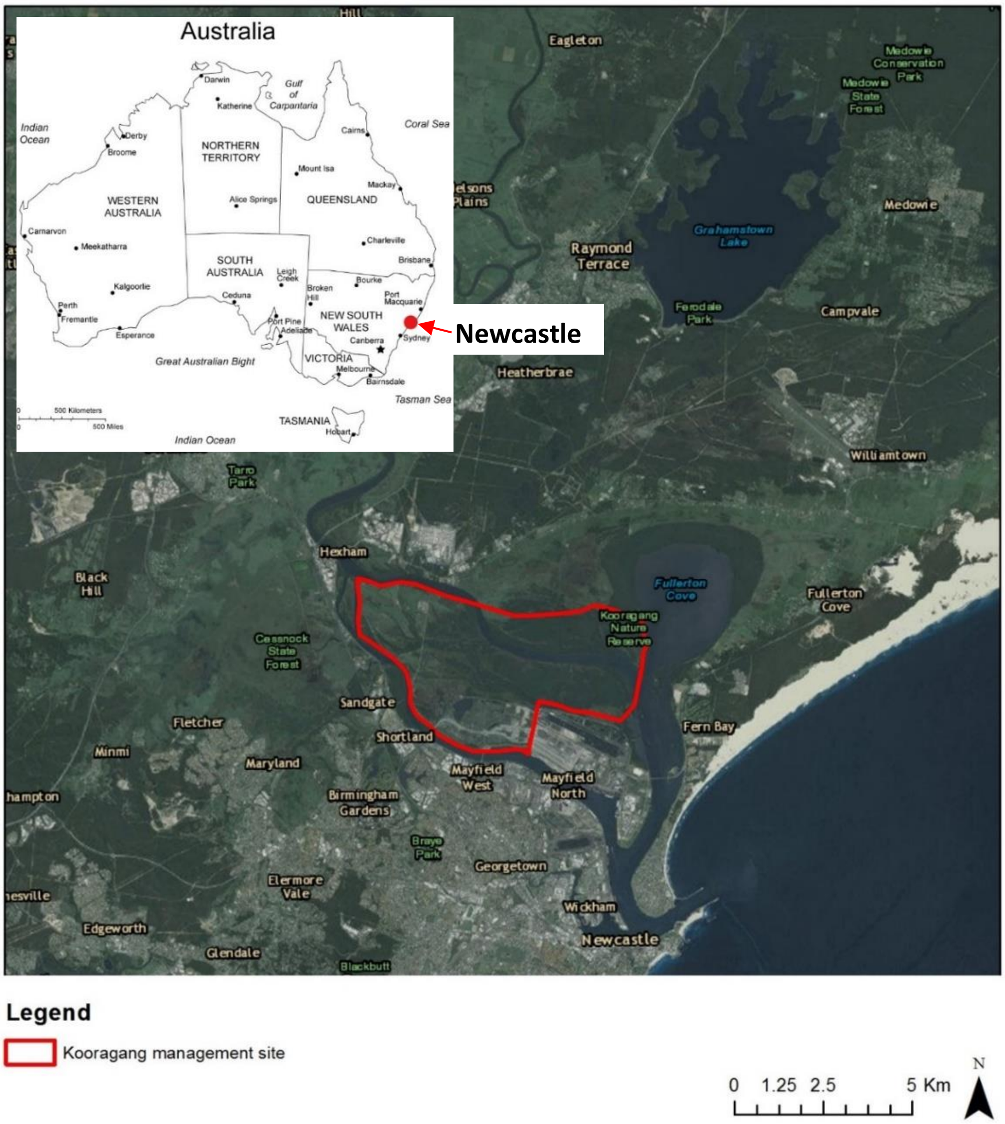


Figure 2.1.1: Contextual map depicting the location of Kooragang Island, near Newcastle, NSW.

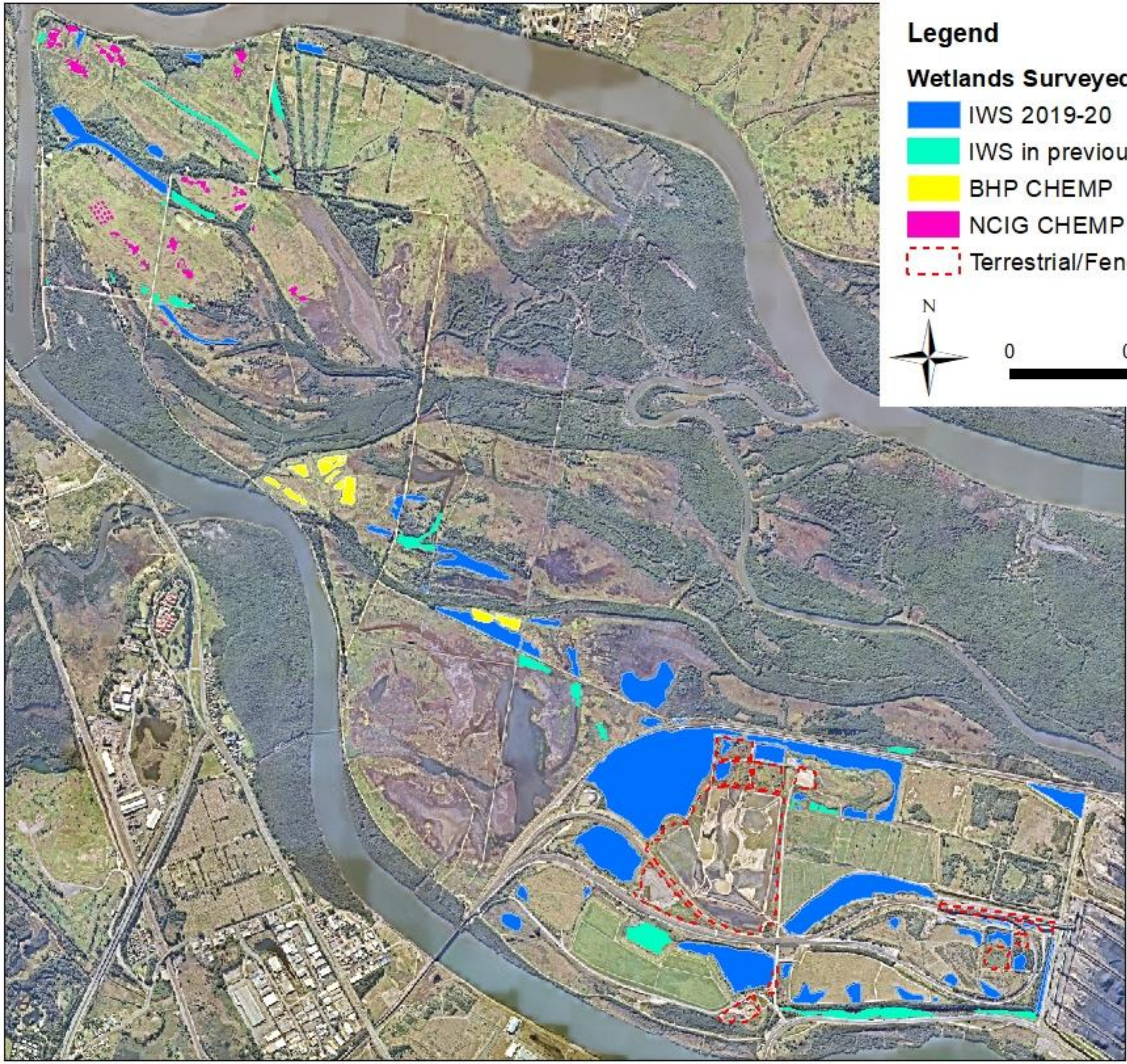


Figure 2.1.2: Wetlands of Kooragang Island - showing wetlands surveyed in each round of the 'island-wide' surveys of 2019-20. The position of NCIG and BHP CHEMP wetlands are also shown; 13 of these wetlands were surveyed in each round of the island-wide surveys in 2019-20, making a total of 60 wetlands which make up the core of the data presented in this report.

The location of wetlands that were surveyed in previous years is also shown. Most of these were not surveyed at all this year, but some were surveyed during one or two rounds; results from those surveys have been included into the data summaries in Section 3.4 and 3.9.

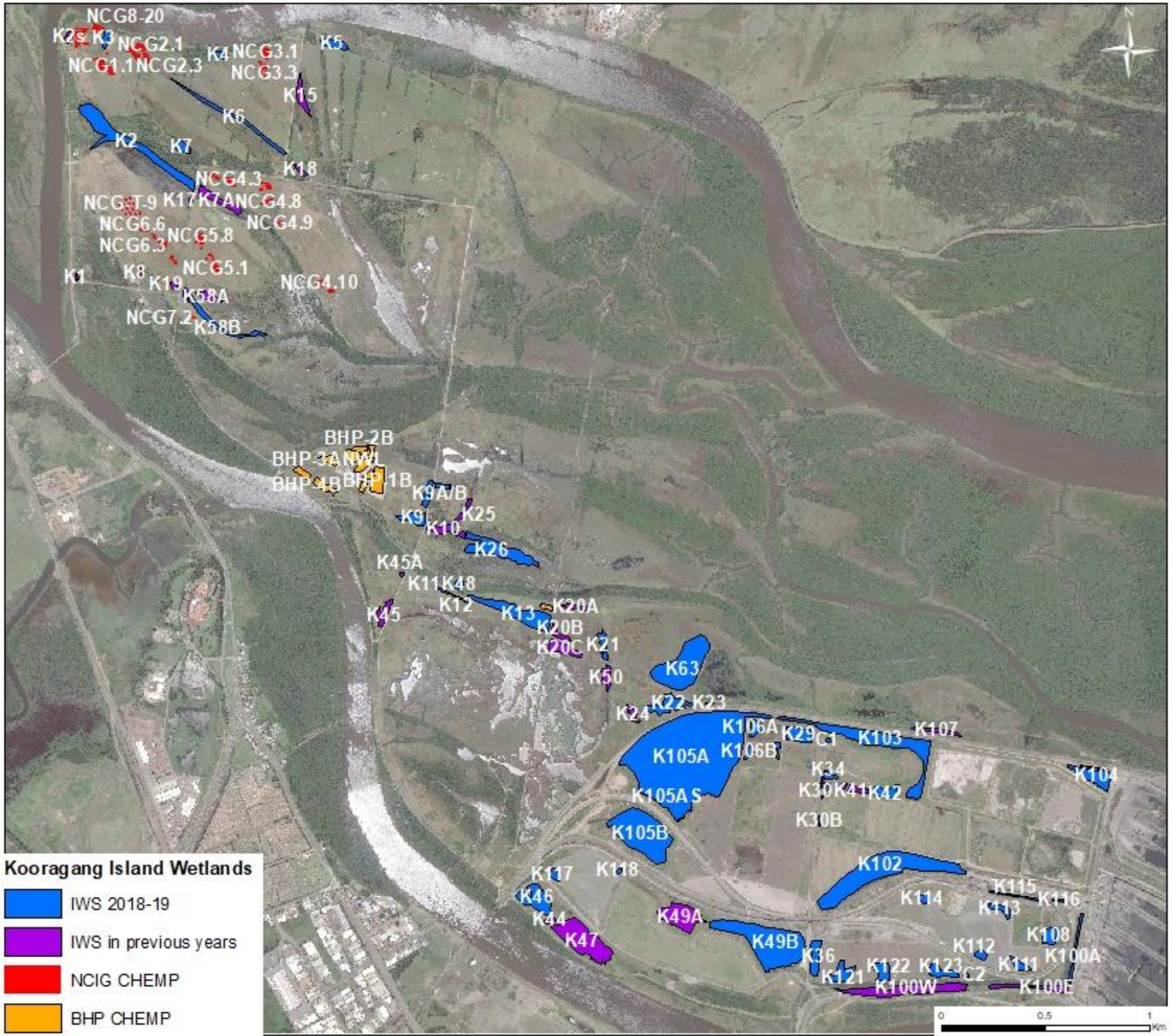


Figure 2.1.3: UoN reference labels for the wetlands shown in Figure 2.1.2.

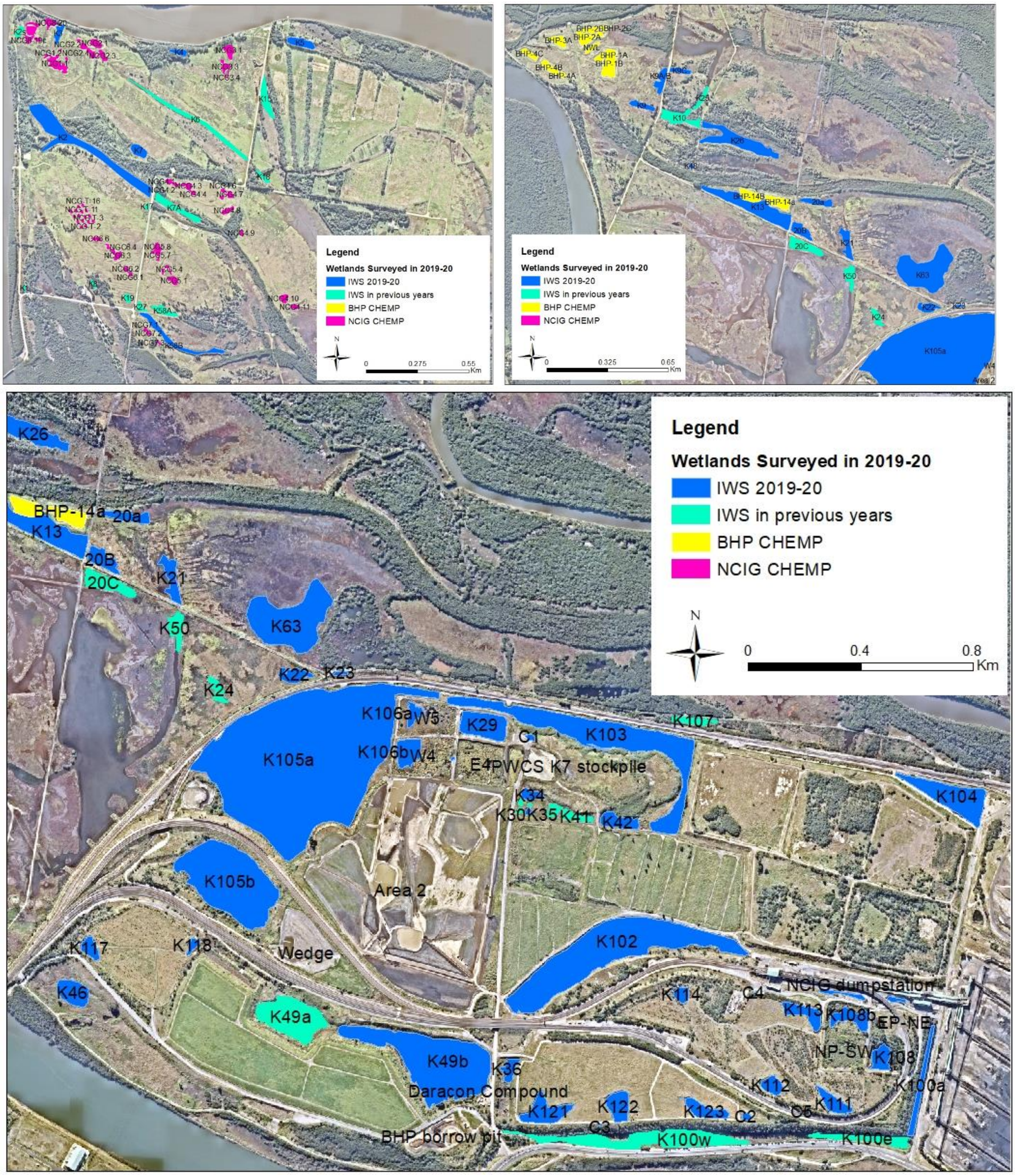


Figure 2.1.4: Close-up of wetlands (with UoN labels) in each of the three zones: Northern Zone (top-left), Central Zone, (top right), and Industrial Zone (bottom) – see Section 2.2. Note that the Industrial Zone lies in the southern portion of Kooragang Island.

2.2 Groupings of wetlands: Zones, Regions, Subregions, and Jurisdictions

To assist survey logistics and analysis of spatial patterns of *L. aurea* distribution, the surveyed wetlands on Kooragang Island are organised into areas as follows:

A. **Zones**: wetlands are grouped into three geographical zones - the Northern, Central and Industrial zones.

1. Northern Zone: this zone includes the Hunter Wetlands National Park from the Sandgate bridge in the south to Scott's Point in the north, and has an area of 377 ha. Within this zone there are 14 wetlands sampled as part of the program this year. Overall the zone has experienced a range of disturbance histories, including, grazing, clearing, draining, impounding, flood-gating and other types of human development.
2. Central Zone: this zone also includes part of the National Park Estate. It ranges from the south from the PWCS rail line, where wetland sample sites are found adjacent to Bell Frog Track, to north at Milam Rd and terminating at the north arm of the Hunter River. Overall, this zone has an area of 293 ha, of which 90% is mangrove forest community. Within this zone there are 15 wetlands sampled as part of this program this year. Compared to the Northern zone, this area has been less impacted by human activity. Nonetheless, there is evidence of historic disturbance, including clearing, draining, impounding, road construction, utility easements, and flood-gating.
3. Industrial Zone: Wetlands in this zone are located in the south-eastern part of the island, on industrial and commercial lands leased or owned by organisations undertaking a range of business activities on the site. The Industrial Zone is dominated by the Kooragang Island Waste Emplacement Facility (KIWEF), a series of constructed ‘cells’ on top of the estuarine wetland floor that were filled with industrial waste from the Newcastle steelworks and other heavy industry through the 20th Century. Some of the unfilled cells now provide wetland habitat, whilst closure works on filled cells have required the construction of sediment control ponds that have now also provided suitable habitat for *L. aurea*. Within this zone there are 31 wetlands sampled as part of this program this year, with a wide variety of types and sizes represented in the overall area of 346 ha. The northern part of the Industrial Zone was the approved site for the development of a fourth coal terminal (‘T4’), but progress on that development was halted in 2019 and is not expected to proceed. Industry dominates this zone and it has been both historically modified and continues to be a modified and disturbed part of the site. Nonetheless, the wetlands within this zone are easily delineated and in numerous cases protected from the chronic impacts of industrial activities. Compared to the rest of the site, this area has undergone the greatest level of historical disturbance and continues to be impacted by human activity, yet supports the largest numbers of *L. aurea* on Kooragang Island.

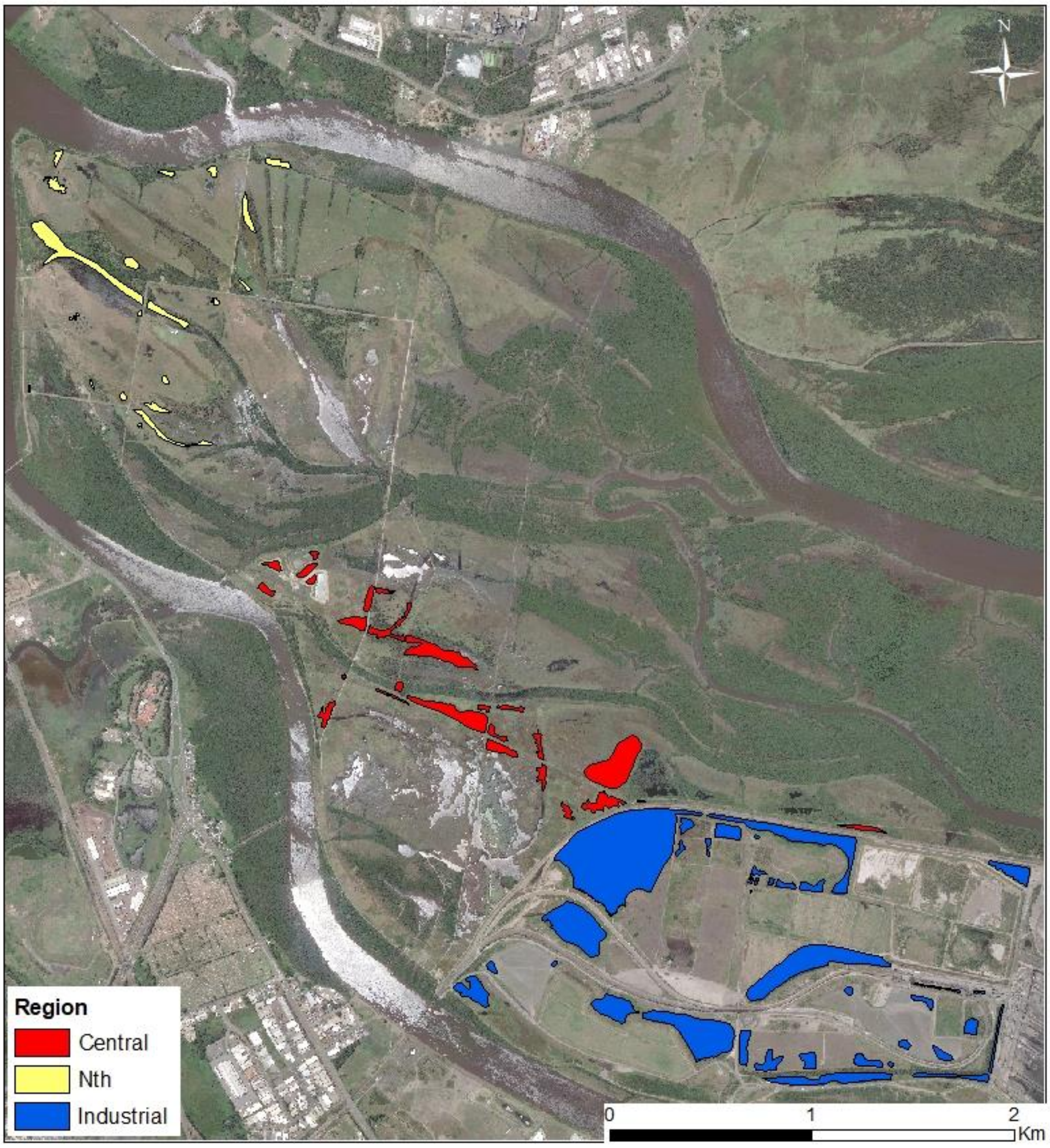


Figure 2.2.1: Location of surveyed wetlands on Kooragang Island within Zones; see text and Table 2.2.1 for explanation.

B. **Regions**: each zone is subdivided into two regions. This grouping of wetlands into regions allows (1) the habitat corridor mitigation strategy to be assessed (as this involves comparison of the northern vs southern parts of the Industrial Zone), and (2) equivalent subdivisions of the other two zones for the purposes of multi-year occupancy analysis (**Section 3.9**).

- Northern Zone:
  - i. Hunter River North
  - ii. School House
- Central Zone
  - iii. Cobban's Creek
  - iv. Bellfrog Way
- Industrial Zone
  - v. Industrial Zone North
  - vi. Industrial Zone South

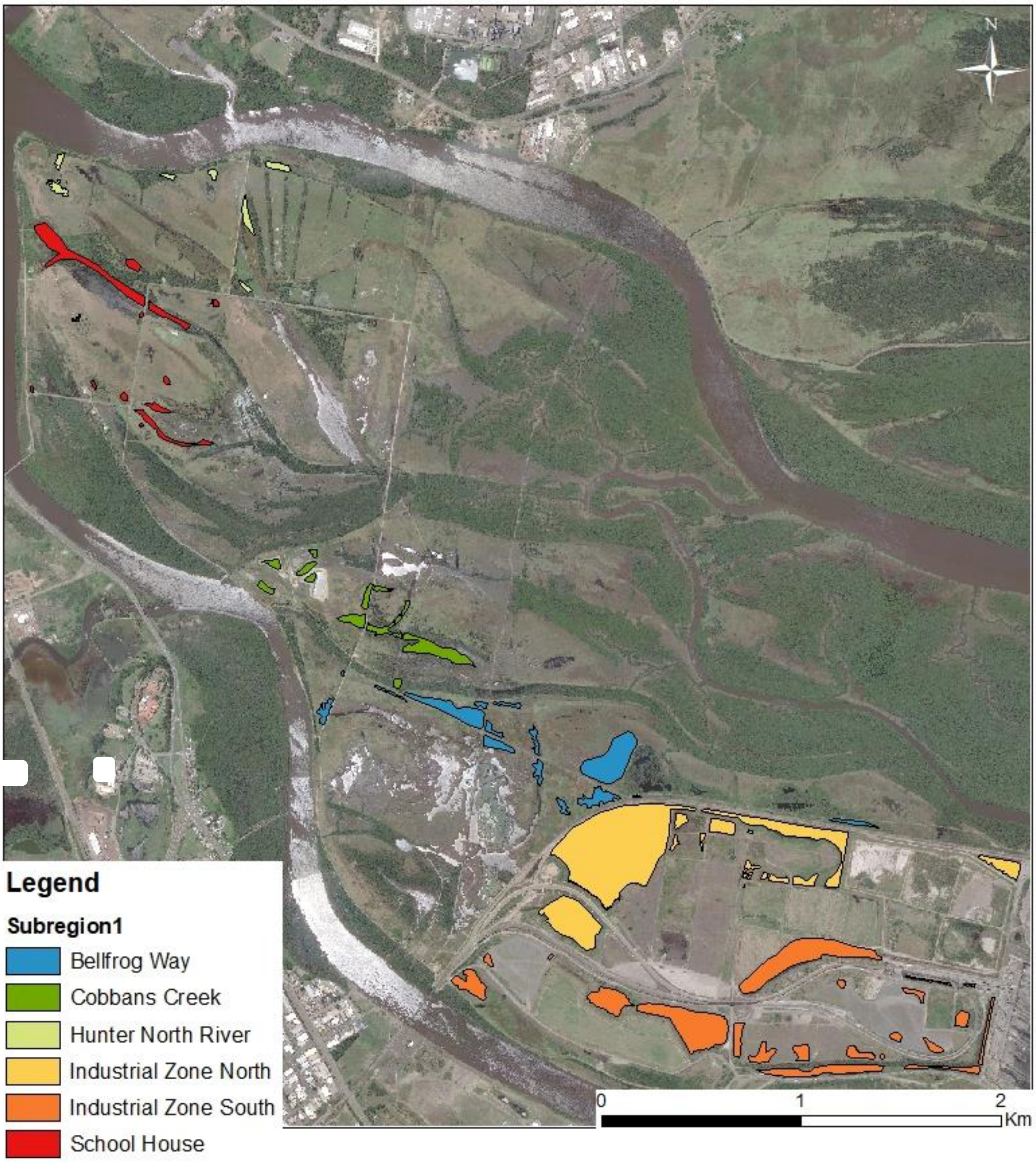


Figure 2.2.2: Allocation of surveyed wetlands to Regions. See text and **Table 2.2.1** for explanation.

Subregions: the regions are subdivided into a number of subregions, each at a consistent spatial scale (<1 km across) and determined by natural and artificial boundaries such as creeks, roads, and rail-lines. Grouping of wetlands at this scale is required for assessment of the rail infrastructure mitigation strategy and the constructed wetlands strategy:

- Hunter River North
  a. Scott's Point
  b. Riverside Park
- School House
  c. Wet meadow
  d. Millam's Pond
- Cobban's Creek
  e. Ramsar Road West
  f. Ramsar Road East
- Bellfrog Way
  g. Bellfrog Way West
  h. Bellfrog Way NE
  i. Bellfrog Way SE
- Industrial Zone North
  j. Delta Ponds
  k. KIWEF *K7*
  l. Deep Pond
- Industrial Zone South
  j. NCIG rail central & east
  k. Rail loop (*K10 North*)
  l. Cormorant Road
  m. Rail loop SW (*K10 South*)
  n. KIWEF *K2*

A total of 60 wetlands were surveyed in the 2019-20 in each of the survey rounds. A further 30 wetlands were surveyed opportunistically in one or two of the rounds. A full list of the wetlands included in each zone, region, and subregion is included in Table 2.2.1. Note that 'K' numbers relating to the KIWEF nomenclature of areas within the industrial zone are shown in *blue italic* font, and should not be confused with the 'K' numbers used in the UoN nomenclature for surveyed wetlands (the latter are shown in normal font).

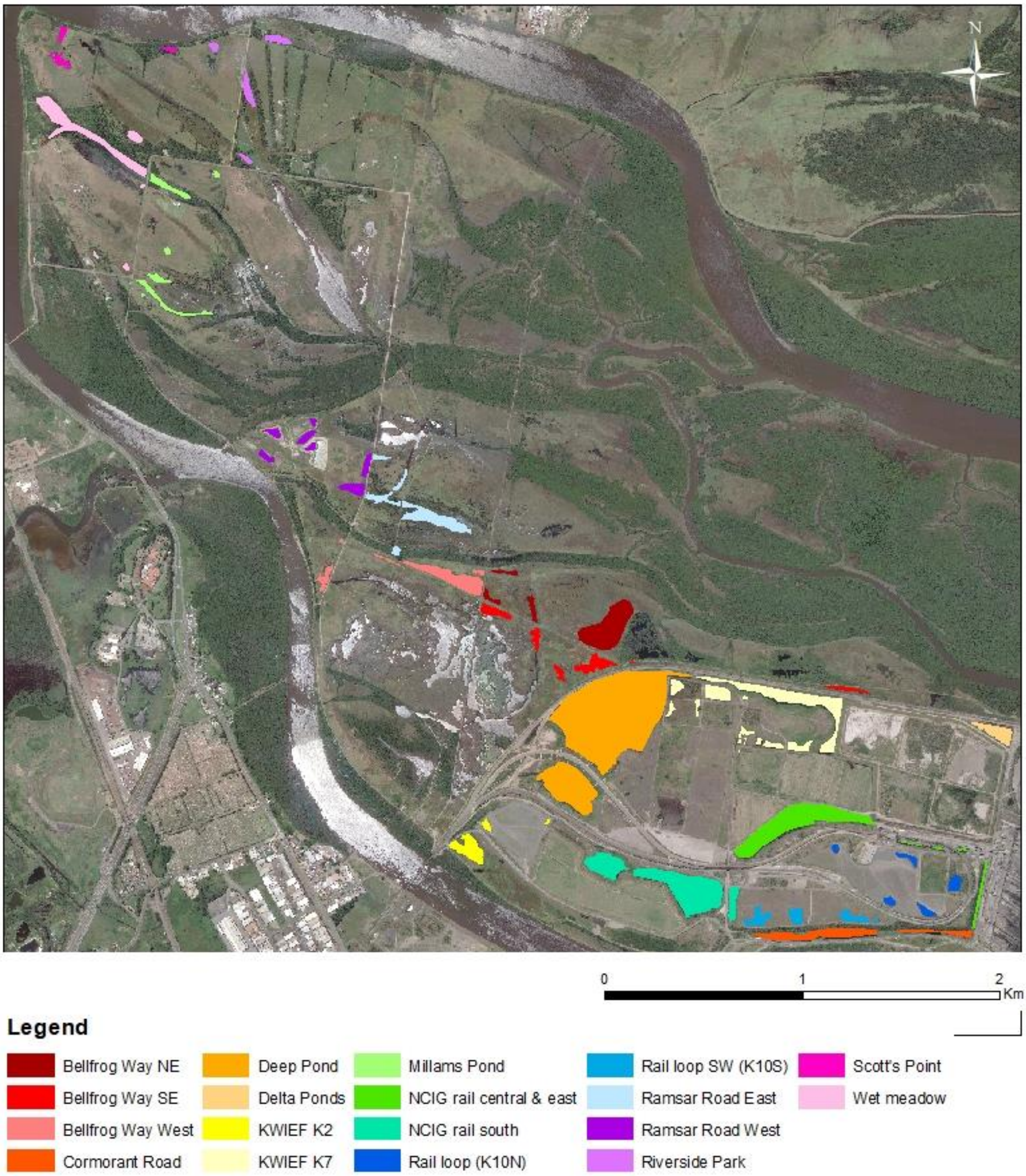


Figure 2.2.3: Allocation of surveyed wetlands to Subregions. See text and Table 2.2.1 for explanation.

Zone	Region	Subregions	Wetlands included
Nth	Hunter River North	Scott's Point	K2S, K3, K4, NCIG-1
		Riverside Park	K15, K16, K18, K5, K6, NCIG-3.1
	School House	Wet meadow	*K1*, K17, K19, K2, K7, K8, NCIG-T13, NCIG-T14, NCIG-T15
		Millam's Pond	K27, K58A, K58B, K7A, NCIG-4, NCIG-5, NCIG-6, NCIG-7
Central	Cobban's Creek	Ramsar Rd West	BHP-1, BHP-2, BHP-3, BHP-4, K9, K9A/B, NWL
		Ramsar Rd East	K10, K25, K26, K48, K9C
	Bellfrog Way	Bellfrog Way West	BHP-14, K11, K12, K13, K45, K45A
		Bellfrog Way NE	*K20A*, *K20B*, K21, K63
		Bellfrog Way SE	K107, K20C, K22, K23, K24, K50
Industrial	Industrial Zone North	Delta Ponds	K104
		KIWEF K7	C1, *Delta road*, *E4*, K103, K106A, K106B, K106C, K29, K30, K30A, K30B, K31, K32, K33, K34, K35, K41, K42, *PWCS K7 stockpile*, S7, *W4, W5*
		Deep Pond	K105A, K105AS, K105B
	Industrial Zone South	NCIG rail central & east	K100A, K102, K115, K116, K119, *NCIG dumpstation*
		Rail loop (*K10 North*)	*C4, C5, EP-NE*, EP-SW, K108, *K108B*, K111, K112, K113, K114, K120
		Rail loop SW (*K10 South*)	C2, *C3*, K121, K122, K123
		NCIG rail south	*BHP Borrow Pit, Daracon compound*, K36, K49A, K49B, *Wedge*
		KIWEF *K2*	K117, K118, K44, K46, K47
		Cormorant Road	K100E, K100W

Table 2.2.1: Categorisation of surveyed wetlands into Zones, Regions, and Subregions (see text for explanation; see also Figures 2.2.1 to 2.2.3). Wetlands shown in light font have been surveyed in previous years but were not surveyed in 2019-20; wetlands shown in *italics* were surveyed in one or two rounds only (i.e. opportunistically); Underlined wetlands are those that are also surveyed in the SoS project.

Jurisdiction

Wetlands surveyed for the Whole Island Monitoring Program fall under the following seven jurisdictional categories (see Figure 2.2.4).

- National Parks and Wildlife (NPWS): 14 wetlands (North and Central zones)
- CHEMP (NCIG and BHP): 13 wetlands in the North and Central zones of the National Park.
- Port of Newcastle (PoN): 2 wetlands (Central zone)
- Port Waratah Coal Services (PWCS): 1 wetland (Industrial Zone)
- Newcastle Coal Infrastructure Group (NCIG): 2 wetlands (Industrial Zone).
- Hunter Development Corporation (HDC): 28 wetlands (Industrial Zone)

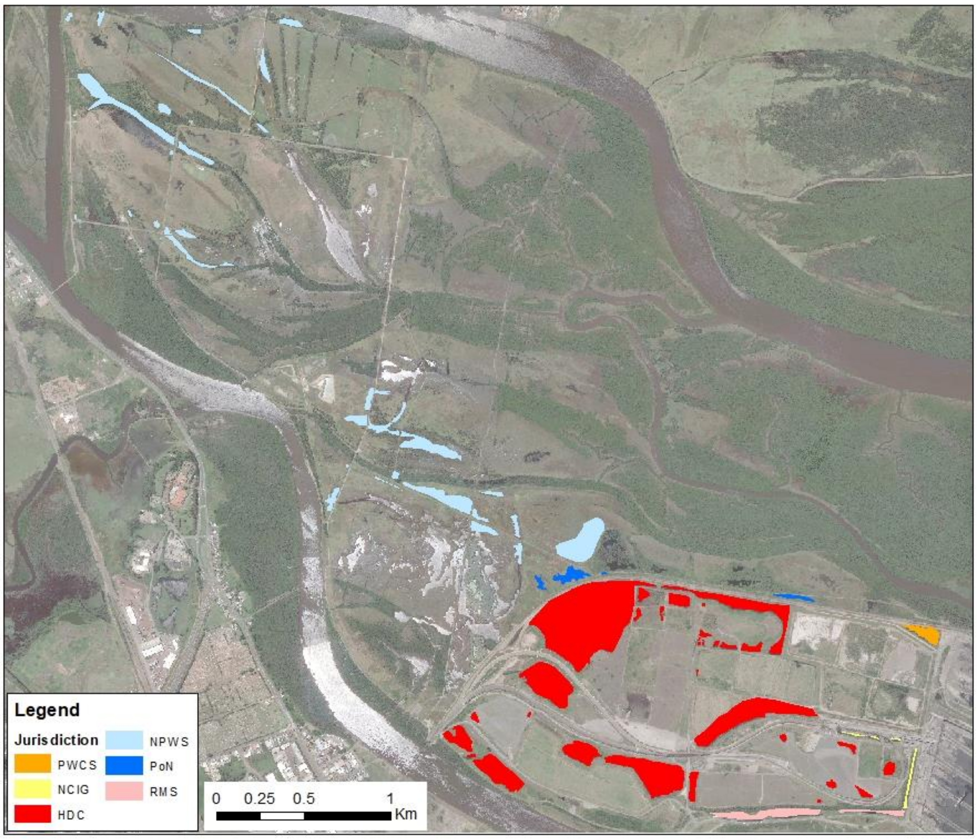


Figure 2.2.4: Named wetlands on Kooragang Island, summarized by jurisdiction. Note that not all of these were surveyed in the 2019-20 season (see text and Table 2.2.1)

2.3 Long-term monitoring approach

The whole island monitoring program has followed a standard method for eight years and was established to enable tracking of *L. aurea* distribution and abundance against time. In the past three years significant habitat creation projects and other landscape works have occurred on the site that materially should affect the distribution and abundance of the *L. aurea* population. These new wetlands must be included to enable assessment of the effectiveness of mitigation strategies in increasing distribution and abundance of the *L. aurea* population. Therefore, whilst consistency is important and we aim to monitor within a predefined set of wetlands, we must also be responsive to landscape changes (see Appendix A). Finally, several newly constructed wetlands created by HDC following capping works across the southern part of the Industrial Zone were included in surveys.

2.4 Survey techniques

There were two types of survey used:

i. Visual Encounter Survey (VES) of wetlands
ii. Fence surveys (FS) to detect juvenile dispersal

Both survey types involved systematic night-time surveying by between 2-6 people, using >150 lumen LED head torches. Surveys began by listening for calling activity, before using call playback to try and elicit a response. The survey itself involves walking slowly through the wetland and surrounding terrestrial habitat, paying careful attention to vegetation, which *L. aurea* tend to associate with (mainly emergent reeds). Where wetlands were too deep for wading, we used small personal watercraft (e.g. canoes).

Recording of Climatic conditions

Climatic variables were recorded at regular intervals during each night of surveying. We recorded: temperature, dew point, wet bulb temperature, barometric pressure, wind speed (average and maximum), and relative humidity, using a multi-probe instrument (Kestrel).

Methodology - Adult Frogs

For each survey, each surveyor recorded

i. Start and end times of survey,
ii. Any frogs (*L. aurea* or other species) heard calling
iii. Water depth (qualitative)
iv. Presence/absence of *Gambusia*
v. Other non-target species of frog seen
vi. For each *L. aurea* encountered:
    - Time
    - Habitat structure (tree, reed, grass, rock, ground, aquatic)
    - Height from ground/water surface
    - Distance from water's edge (where in the terrestrial habitat)
    - Size class (adult/juvenile)
    - Was the animal observed calling?
    - Other relevant observations

In general, we attempted to capture all *L. aurea* observed. This was done using a thin plastic bag (sandwich bags). Captured frogs were labelled with a capture code, and tied in the bag with sufficient air. If the frog was touched during capture, we washed hands with disinfectant gel (NSW NPWS Hygiene Protocol). The capture site was marked with flagging tape or on a sketch map of the wetland.

Captured frogs were processed as follows:

i. Scanned using a Passive Induction Transponder reader to see if the frog had been previously captured and tagged.
ii. If the frog had a passive induction transponder (PIT) tag, the number was recorded.
iii. Visual inspection of frog for injuries, as well as nuptial pads (to identify males from females) and candle lit (to identify gravid females).
iv. Snout-vent-length (SVL) and tibia length (TL) were measured using callipers.
v. Body weight was measured using a 10g, 60g or 100g spring balance (Pesola).
vi. The frog was swabbed for chytrid fungus by the standard protocol used by the UoN Amphibian Research Lab (two strokes on each side of the animal for each of: flank, inguinal region, posterior thigh, palms of hands, soles of feet).
vii. If the animal had not been previously tagged:
    - A small tissue sample (piece of webbing from a foot) was taken using a biopsy punch and stored in 70% ethanol.
    - A PIT tag was injected subcutaneously into the lower back and manipulated into the inguinal region.

Tadpoles and metamorphs

Where possible, tadpoles were collected in the field and identified in the lab, using the key in Anstis (2002). Metamorphs were identified and classified on the basis of the presence of a tail stub combined with adult colouration.

Data collection

Tissue samples and swabs were marked using the bar code from the PIT label. Processing took approximately 10 person-minutes per frog. Not every frog captured is weighed (the project already has hundreds of data points for length-weight relationship from this population, and taking weight measurements adds to the per-frog processing time). Swabs for chytrid are not collected in the summer, while tissue samples for genetic analysis are collected from a subsample of captured frogs only. Frogs were returned to their point of capture after completion of the survey.

A single **primary** VES was performed at each wetland during each survey round; three survey rounds were performed between September 2019 and March 2020. In Visual Encounter Surveys, the entirety of each wetland was surveyed for a maximum of 30 minutes. Care was taken not to overlap surveys by each person, or to search the same area more than once. We attempted to keep a uniform survey speed at each wetland, although that did vary between and within wetlands depending on vegetation density. Any frogs captured were processed at the end of the survey, and frogs were then released at their point of capture.

2.5 Search effort

VES summary (primary VES)	2014-15	2015-16	2016-17	2017-18	2018-19	**2019-20**
Wetlands surveyed	55	75	71	60	63	**96**
Total wetland surveys	118	150	195	245	207	**333**
Nights of field surveys	38	37	41	48	48	**50**
Total search effort VES (person.minutes)	7,979	8,899	8,861	11,201	13,375	**15,737**

Table2.5.1: Survey statistics and search effort for visual encounter surveys for *L. aurea* undertaken under the island-wide surveys across the four most recent seasons.

In addition to the three principal survey rounds, we undertook three additional rounds in early November 2019 (Round 1.9), after a large rainfall event in February (Round 4) and a month later during a *L. aurea* dispersal event (Round 4.1). No animals were captured during these additional rounds (Table 2.2.1, Figure 2.5.1).

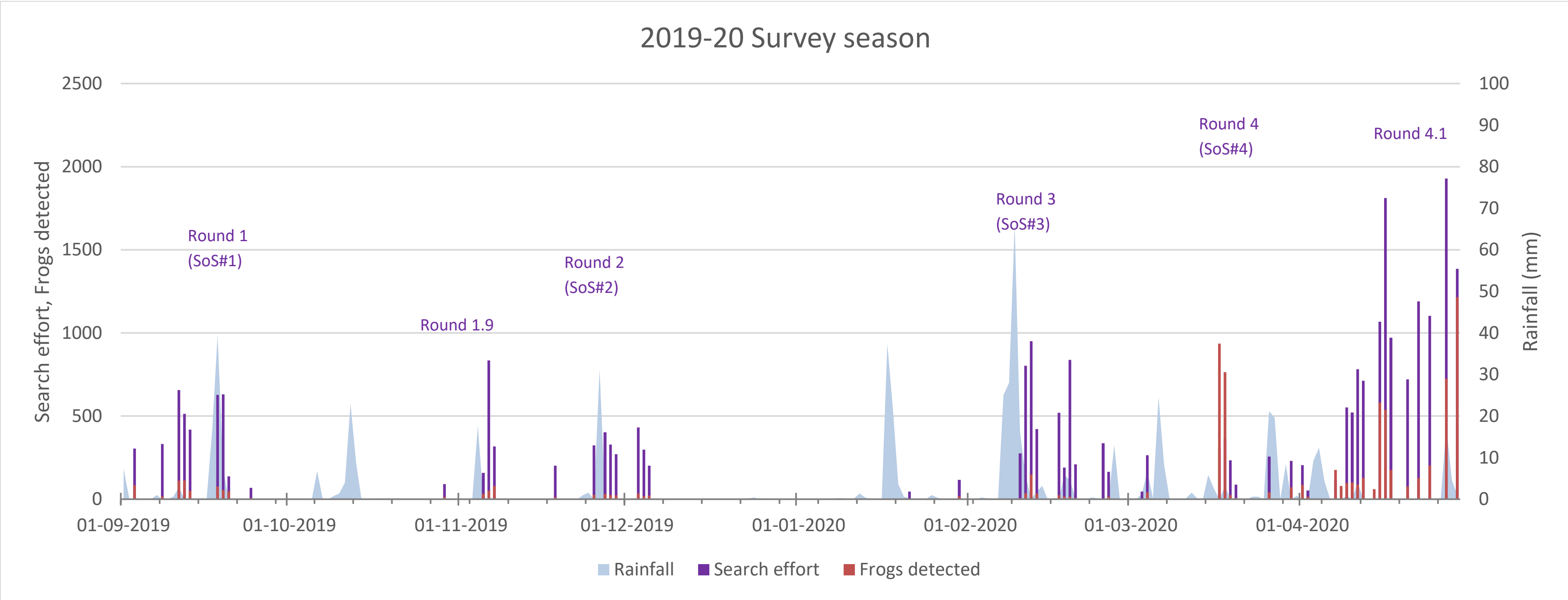


Figure 2.5.1: Search effort and *L. aurea* detections across the 2019-2020 survey period, shown alongside rainfall.

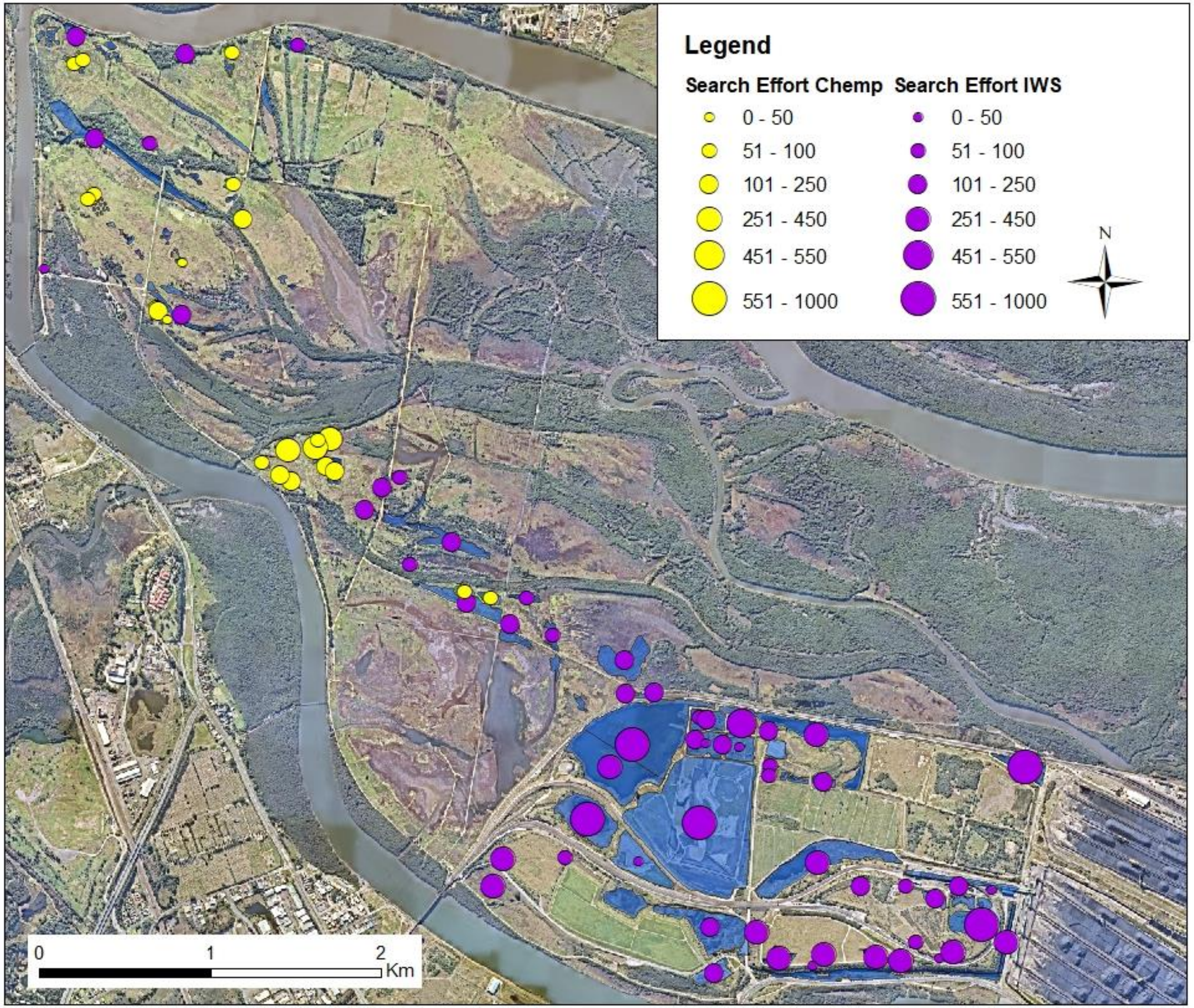


Figure 2.5.2: Search effort (person.minutes) across the 60 wetlands surveyed as part of Island-wide monitoring in 2019-20.

Data is for **primary** VES surveys only.

Note that the CHEMP wetlands shown here are only those included in the Save Our Species (SOS) and Island-wide 2019-20 surveys; they do not include all CHEMP wetlands

2.6 Methodological approaches used to address objectives

Estimating population size

Over past breeding seasons, population estimates have been obtained for three specific wetlands (K22-23, K29 'the cell' and K104) based on data from Capture-Mark-Recapture (CMR) surveys. Repeated CMR surveys at a wetland provide data on the ratio of captured to uncaptured animals in a population, allowing an estimate of total population size (Figure 2.6.1). This CMR survey data can be used to extrapolate island-wide population estimates using VES survey data obtained from each wetland. In this season, CMR modelling estimates obtained for the past three seasons (2016-17 to 2018-19) were applied to VES survey data obtained this year in order to estimate population size across all wetlands surveyed. It is important to note that this approach to estimate population size relies upon a consistent survey method across all wetlands.

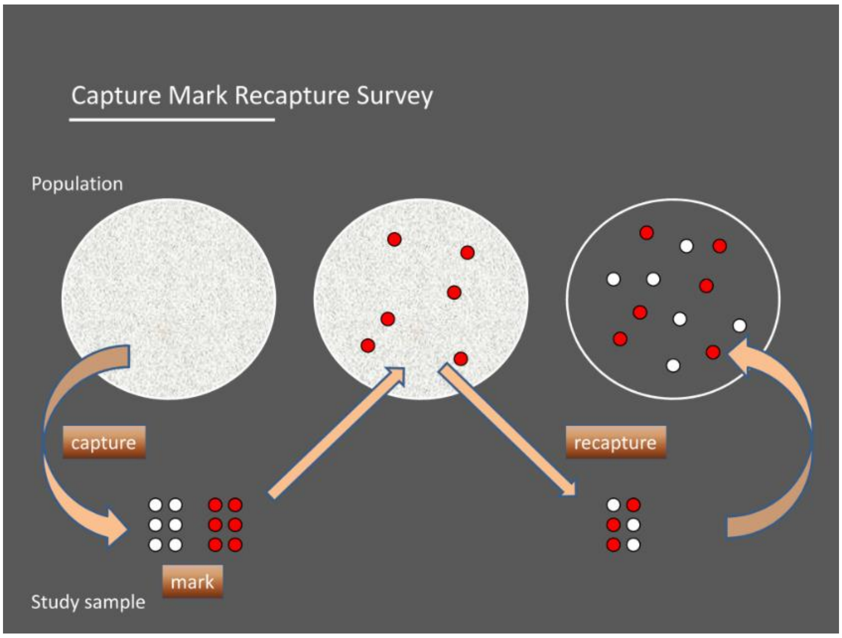


Figure 2.6.1. A simple illustration of capture-mark-recapture survey (based on two capture events only). Left circle: nothing is known about the population size, during the first capture event animals are caught, marked and released. Middle circle: the number of marked animals within the population is known. During the second capture event marked and unmarked individuals are caught. Right circle: the population size can be estimated based on the proportion of marked individuals caught during the second capture event.

Assumptions applied to survey effort and population modelling

For analytical purposes, we assume that survey efforts were consistent across the entire monitoring season. In reality, there are several important sources of variation:

Within and between individual observers: survey effectiveness can vary among observers, particularly given that *L. aurea* are generally cryptic and difficult to see. To overcome detection bias we used a core of experienced observers within the survey teams but this remains an important methodological limitation.

<u>*Within and between sites*</u>: Along with being cryptic and difficult to see, *L. aurea* are well camouflaged in a variety of vegetation types. They are particularly difficult to spot in dense vegetation, and so wetlands with dense reeds (many of the wetlands on the northwest part of Kooragang, such as K7, K5, K4; also K13, K21, K108) are expected to have low detection rates for a given abundance of frogs. The highest probability of detection seems to be in wetlands that have a narrow band of *Juncus acutus* surrounding open water that is > 3 metres across and > 1 metre deep (e.g. K23; southern side of K104); during summer, the frogs sit on the edge of the vegetation. The constructed HDC wetlands can also contain high numbers of frogs (e.g. K111, K114), and the lack of mature vegetation at these sites, combined with their size, makes detection rates high. Conversely, parts of a wetland with dense *Typha* and especially *Phragmites* may hold large numbers of *L. aurea*, but have low detection rates. Weather conditions also influence detection probability; warmer nights with low wind speeds seem to be better for detecting *L. aurea* (although this is difficult to demonstrate quantitatively). Temporal variation in frog detectability can occur across one evening (frogs seem to be more detectable past 1 hour after sunset), across consecutive nights (with weather), and across the season; the evidence is that some wetlands (e.g. K23, K29, K108) are over-wintering sites, from which frogs disperse to ephemeral wetlands during the mid-summer and then return to towards autumn.

So that we could account for the inherent bias produced by habitat complexity all surveys were timed, and the survey effort calculated as part of the detection probability. We also calculated wetland size and perimeter length so that we could assess frog density. Limiting bias created by different weather patterns and seasonal conditions is more difficult to account for in analysis. To limit the effect of different weather patterns we aimed to accomplish a complete survey of all wetlands in a two to three-week period, thus limiting the impact of short term climate variations. To overcome seasonal effects, the surveys were replicated thrice, one in late spring, one in mid-summer, and a final survey round in late summer/early autumn. Despite this design, the 2019-20 season was punctuated with several large rainfall events that occurred in the middle of and before surveys. Such events do effect frog detection and occupancy at wetlands. Detection of bell frogs is increased when males are actively calling, and during these times they are more active around the edge of wetlands and on the water surface, making visual encounter easier. Associated with large rain events, bell frogs disperse from permanent wetlands and move to ephemeral wetlands. In some situations, this may only be a matter of metres and in others it may involve distances of tens of metres.

Demographic composition and effective population size

To construct the age-class structure of the *L. aurea* population we determined the age of individual frogs collected based upon a growth curve developed for this species on Kooragang Island (see Hamer et. al., 2008 for a description of the method used to construct and verify the growth curve). This approach relies on knowing the relationship between body length, measured as snout to vent length (SVL), and the age of the frog. Since bell frogs have seasonal reproduction (the summer season when reproduction occurs and tadpoles usually metamorphose) most individuals can be placed in a yearly cohort, although tadpoles may overwinter and metamorphose early in a subsequent breeding year, adding a level of complexity to identifying cohorts. Thus, it is possible to assign all individuals to size-classes and express the population demography in age cohorts.

Designation of adult males, adult females, and sub-adult females.

In previous years, we categorised animals into age classes by using SVL data, based on the analysis of Hamer et al. (2008). Adulthood is defined as the capacity to reproduce. In 2015-16, this was designated as SVL >49 mm for males, and SVL > 68 mm for females. This difference between the sexes is due to the fact that *L. aurea* adults are sexually dimorphic; females reach a large body size and mass than the equivalent aged males. Based on this criteria, the categories used in earlier years of the project were:

Age-class determination:

- Nuptial pads apparent → adult male (typically > 44 mm SVL)
- Body length < 44 mm and nuptial pads not apparent → Juvenile (sex unknown)
- Body length > 44 mm, nuptial pads not apparent → juvenile females
- Body length > 68 mm, nuptial pads not apparent → adult female.

The very large number of captures in 2016-17 (see Section 3) provided the opportunity to test these categories quantitatively. Males were determined on the basis of nuptial pads. Since females are identified on the basis of the absence of these pads, there is some uncertainty as to what point a small individual can be considered a juvenile female as opposed to a juvenile.

Plotting the percentage of males captured against SVL (Figure 2.6.2) indicates that, between 50 mm and 60 mm SVL, adult males are consistently 60% of the population. At 48 mm, about 35% of captured animals display nuptial pads, but above 49 mm 60% do. An animal above 49 mm without nuptial pads is therefore a sub-adult female (until large enough to be considered an adult female).

Gravid females can be detected by 'candle-lighting' (= 'candling'), i.e. placing a bright light such as a head-torch against their back, and looking at the silhouetted visceral organs from the ventral surface for the presence of eggs (Figure 2.6.3). Large females were checked for gravidity ad hoc. The smallest females to be found gravid were 58 mm SVL, and by 68 mm 100% of inspected females were gravid. The onset of adulthood for females is therefore less than 68 mm (used in 2015-16); we used a length of 58 mm in this analysis. Note that this is similar to the analysis conducted last year, but quite different to the categories used to analyse demography in previous years.

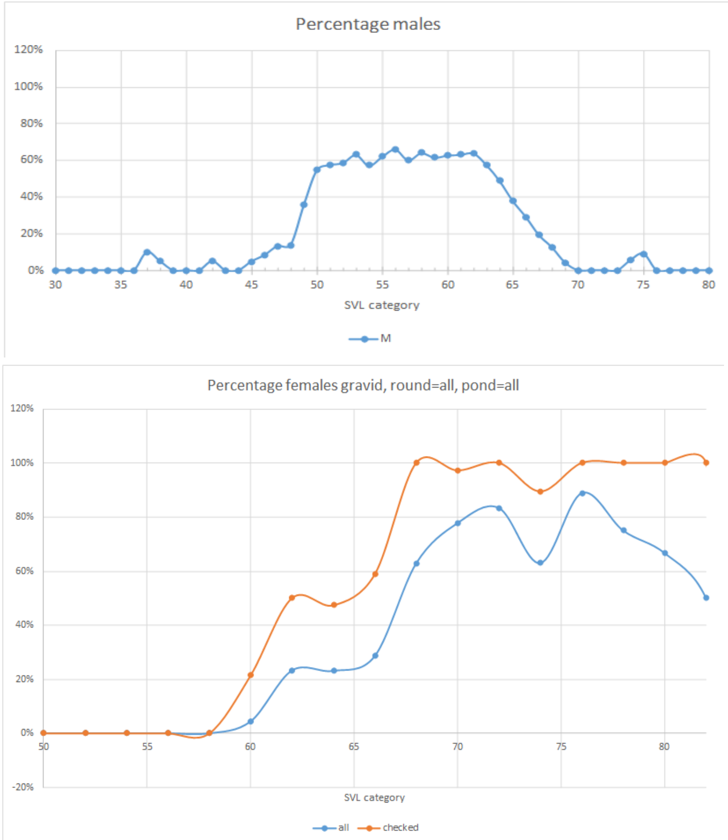


Figure 2.6.2: Proportion of animals that can be confirmed as reproductively mature (i.e. adult), plotted against SVL. Top, males; Bottom, females. In the lower chart, the red line represents the number of females found to be gravid, as a proportion of the animals inspected for gravidity, whilst the blue line shows that number as a proportion of all animals captured. Data from 2016-17 surveys.

Figure 2.6.3: Illustration of the 'candle-light' method of checking for gravidity in females. A large, bilateral mass in the mid to upper trunk region indicates enlarged ovaries and thus gravidity.

The categories used this year are thus:

- Nuptial pads apparent → adult male (typically > 44-58 mm SVL)
- Body length < 49 mm and nuptial pads not apparent → Juvenile (sex unknown)
- Body length > 49 mm, nuptial pads not apparent → juvenile female

Body length > 58 mm, nuptial pads not apparent → adult female

3. Results

3.1. Summary of survey counts

	Round 1	Round 2	Round 3	Round 4
	Total	Total	Total	Total
Search effort	3629	3192	4758	2350
VES Detections	458	227	217	2298
All Detections	566	310	295	2545
Captures	373	220	124	103
Unique	359	206	149	7

Round 1.9	Round 4.1
Total	Total
602	1196
60	141
60	3931
8	50
7	5

Table 3.1.1: Summary data from all surveys in 2019-20 season. 'Detections' refers to total encounters (i.e. captures and non-capture observations). Because some individuals are encountered and captured multiple times, 'Detections', and 'Captures' provide overestimates of the number of unique individual frogs actually encountered ('Unique'). Note that Rounds 1.9 and 4.1 are partial surveys some wetlands only. (see Section 2.5)

The highest number of detections were in the Round 1 (September) (Table 3.1.1), declining steadily in Round 2 and 3 despite equal or increased survey effort. It is possible that low numbers in Round 2 and 3 were the result of dry conditions during the summer period. Most detections in Round 1, 1.9, 2 and 3 were adults, while large numbers of juveniles and metamorphs were detected in Round 4 and 4.1 after a large breeding event in February 2020.

Zones (detections)	Search effort (VES)	VES	Total	Search Sensitivity
Northern	1,654	47	88	0.03
Central	3,661	629	671	0.17
Industrial	10,422	2,725	6,948	0.26

Jurisdiction (detections)	Search effort (VES)	VES	Total	Search Sensitivity
NPWS	1,851	72	77	0.04
NPWS (NCIG-CHEMP)	953	41	81	0.04
NPWS (BHP-CHEMP)	2,153	493	525	0.23
PoN	358	70	76	0.20
PWCS	999	115	135	0.12
NCIG	128	10	422	0.08
HDC	9,295	2,600	6,391	0.28

Table 3.1.2: Location (summarised by Zone and Jurisdiction) of *L. aurea* detected.

As with previous survey seasons, the highest number of detections were in the Industrial Zone (Table 3.1.2). Compared with the previous breeding season, numbers have increase in the Industrial and Central zones, but have slightly decreased in the northern zone, while search sensitivity across each zone has remained relatively unchanged. The number of frogs detected in the CHEMP wetlands is consistent with the previous season.

The total number of frogs detected was higher than in previous years, more than double that of the 2018-19 season (Table 3.1.3), while total number captured was much less. Both of these results are likely a consequence of the significant breeding events that occurred late in the season after heavy rainfall in February, when few animals were captured. The total number of unique individuals encountered during the main survey rounds was less than in the previous season (see Figure 3.4.3B).

	Primary VES	Total
Detections	3,401	7,707
Captures	600	878

	Captures	Unique
PIT tagged frogs	781	698

	Captured		PIT Taggable		Unique		Recapture
Demographic summary	**number**	**%**	**number**	**%**	**number**	**%**	**index**
juveniles (SVL < 49.5 mm)	129	15%	53	7%	52	8%	1.02
subadult females (49.5mm<SVL<58mm, no nups)	81	9%	81	10%	79	11%	1.03
adult males (>49.5, nups)	425	50%	425	54%	386	56%	1.10
adult females (>58mm SVL, no nups)	221	26%	221	28%	174	25%	1.27
Metamorphs	15		-		-		
unknown animals (not tagged)	7		7		7		
	878		**787**		**698**		

Table 3.1.3: Summary of demographic data. Recapture index shows the ratio of captures per unique individuals (i.e. higher values indicate a higher probability of recapture).

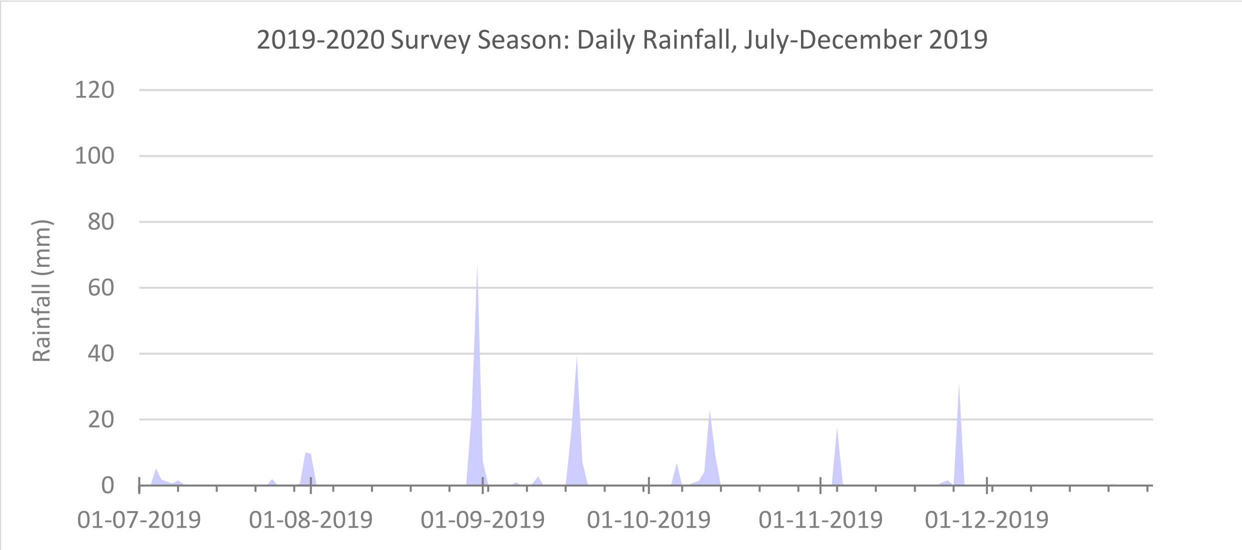
For unique animals, the proportion of adult females was similar to the previous year at 25%. Note that this figure is dependent on accurate categorisation of females of SVL ≥ 58 mm as reproductively mature adults (see Section 2.6 above and 3.6 below for discussion of this key issue); this categorisation is based upon candling but more reliable data (such as hormonal analysis) is needed to have full confidence in this size threshold. The recapture index for adult females was again high (1.27); this means that the probability of recapturing an adult female was greater than for any other demographic.

As only frogs above 40 mm SVL are tagged, and smaller individuals are counted but not tagged, the actual proportion of juveniles in the population is much greater than the 7% indicated by PIT tagged animals. The proportion of captured *L. aurea* that were juveniles (15%) is low compared to the previous season (37%), likely due to the low number of juveniles detected in the three primary survey rounds when captures occurred despite the large number detected in later, non-capture rounds.

3.2. Seasonal context: environmental factors

Overview

Drier than normal conditions over the 2019 winter reduced runoff that typically feeds waterbodies into spring, resulting in many wetlands being dry at the start of the *L. aurea* breeding season (September). Low levels of rainfall subsequently occurred during the summer period, following a similar pattern of rainfall recorded in the previous breeding season. In particular, less than 1 mm of rainfall was recorded in December 2019, compared with a long term average monthly rainfall above 75 mm. Low summer rainfall lead to almost all wetlands, including several characterised as 'permanent', being dry at the start of January 2020. Much higher rainfall occurred in the latter half of the breeding season, with above long-term average monthly rainfall recorded in February that partially recharged most systems. This rainfall was sufficient to stimulate a late season breeding event across several wetlands.



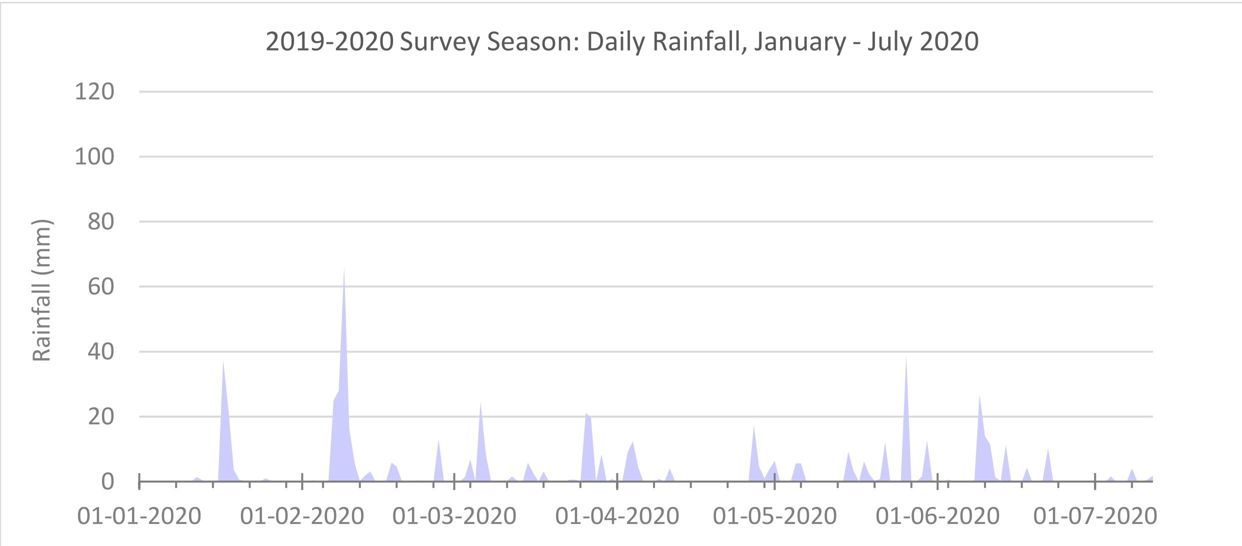


Figure 3.2.1: Weekly rainfall before, during, and after the 2019-20 survey season (October to April) on Kooragang Island. Measurements obtained from BoM records for Williamtown airport.

Table 3.2.1: Summary of water presence at each wetland per round, along with presence of *Gambusia* and observed breeding.

Pond	Hydrology Spring	Early Summer	Late Summer	***Gambusia***	**Breeding**
K2	1	1	1	-2	
K3	1	1	1	-2	
K4	no data	0	1	-2	
K5	1	1	1	-2	
K7	1	0	1	-2	
K58B	1	1	1	-2	
NCIG-1.1	1	1	1	2	
NCIG-1.3	1	1	1	-2	
NCIG-3.1	1	1	1	-2	
NCIG-4.7	1	1	1	2	
NCIG-4.9	1	1	1	-2	
NCIG-5.1	1	1	1	-2	
NCIG-7.1	1	1	1	2	
NCIG-7.2	1	1	1	-2	
NCIG-T13	1	1	1	-2	
NCIG-T14	1	1	1	-2	
NCIG-T15	1	1	1	-2	
BHP-1A	1	1	1	-2	
BHP-2C	1	1	1	-2	
BHP-3A	1	1	1	-2	
BHP-4B	1	1	1	-2	
BHP-14A	1	1	1	-1	
K9A/B	0	1	1	-2	mets
K9C	0	1	1	-2	
K9	1	1	1	-2	mets
K26	1	1	1	-1	
K48	1	1	1	-2	
K13	0	1	1	-2	mets
K20A	0	1	1	-2	
K21	0	1	1	-2	
K63	0	1	1	-2	
K22	0	0	1	-2	
K23	0	0	1	-2	
K104	1	1	1	2	tads mets
K103	1	1	1	2	mets
K105A	0	1	no data	-2	
K105AS	0	no data	1	-2	
K105B	no data	1	1	-2	tads
K106A	0	1	no data	-2	
K106B	0	1	1	-2	
K106C	1	no data	no data	-2	

Pond	Hydrology			Gambusia	Breeding
	Spring	Early Summer	Late Summer		
K29	1	no data	1	-2	tads
C1	1	1	no data	-2	
K31	1	1	no data	-2	tads
K34	1	1	1	-2	
K42	1	1	no data	0	
K102	1	1	1	2	mets
K36	1	1	1	-2	mets
C2	1	1	1	-2	
K115	1	1	no data	-2	
K116	1	1	no data	-2	
K100A	1	1	1	2	
K108	0	1	0	-2	
K111	1	1	1	-2	tads mets
K112	0	1	1	-2	tads mets
K113	0	1	1	-2	tads mets
K114	1	1	1	-2	tads
K121	1	1	1	-2	tads mets
K122	1	1	1	-2	tads mets
K123	1	1	1	-2	tads mets
K46	1	1	1	-2	
K49B	1	1	1	-2	tads
K117	1	1	no data	-2	
K118	1	1	1	-2	tads mets

Tads	tadpoles	0	dry	2	*Gambusia* present
Mets	metamorphs	0.3	low	1	*Gambusia* (re)appeared
		0.5	intermediate	0	unknown status
		1	good	-1	*Gambusia* disappeared
				-2	*Gambusia* absent

Repeated years of dry summers have continued to exclude *Gambusia* from a large number of surveyed wetlands. This year, the fish was no longer present by the end of the season at three wetlands (BHP-14A, K3 and K105AS) in which it was detected in the previous breeding season. However, the fish has re-appeared in one site since last year (BHP-14B). Local extirpation events within season were also recorded at two sites (K26 and BPP-14A), likely a direct result of their drying in summer. As of March 2020, only seven wetlands are believed to contain *Gambusia*, compared with 13 in March 2019, 16 in March 20018, and 24 in February 2017. These wetlands are located in the Industrial Zone and NCIG CHEMP wetlands.

Breeding was detected in 19 primary wetlands, along with one additional wetland (BHP-2A) that was surveyed opportunistically, as noted by the presence of *L. aurea* tadpoles and/or metamorphlings. This is slightly more than in the previous breeding season (17 wetlands) and the largest number recorded over the last six seasons. A majority of metamorphs were detected in Round 4 after large rainfall in February resulted in a large breeding event late in the season. Breeding events were primarily detected in wetlands where *Gambusia* was absent, except for three nearby wetlands in the Industrial Zone (K102, K103 and K104) in which *L. aurea* metamorphlings were recorded.

Hydrology

Figures 3.2.2 to 3.2.4 show the changing hydrology of the wetlands across the 2019-20 breeding season. A number of surveyed wetlands were dry in Round 1 (24%), due to low levels of prior rainfall in later winter (Figure 3.2.1, 3.2.2, 3.2.3). Early sping rainfall recharged many of the wetlands

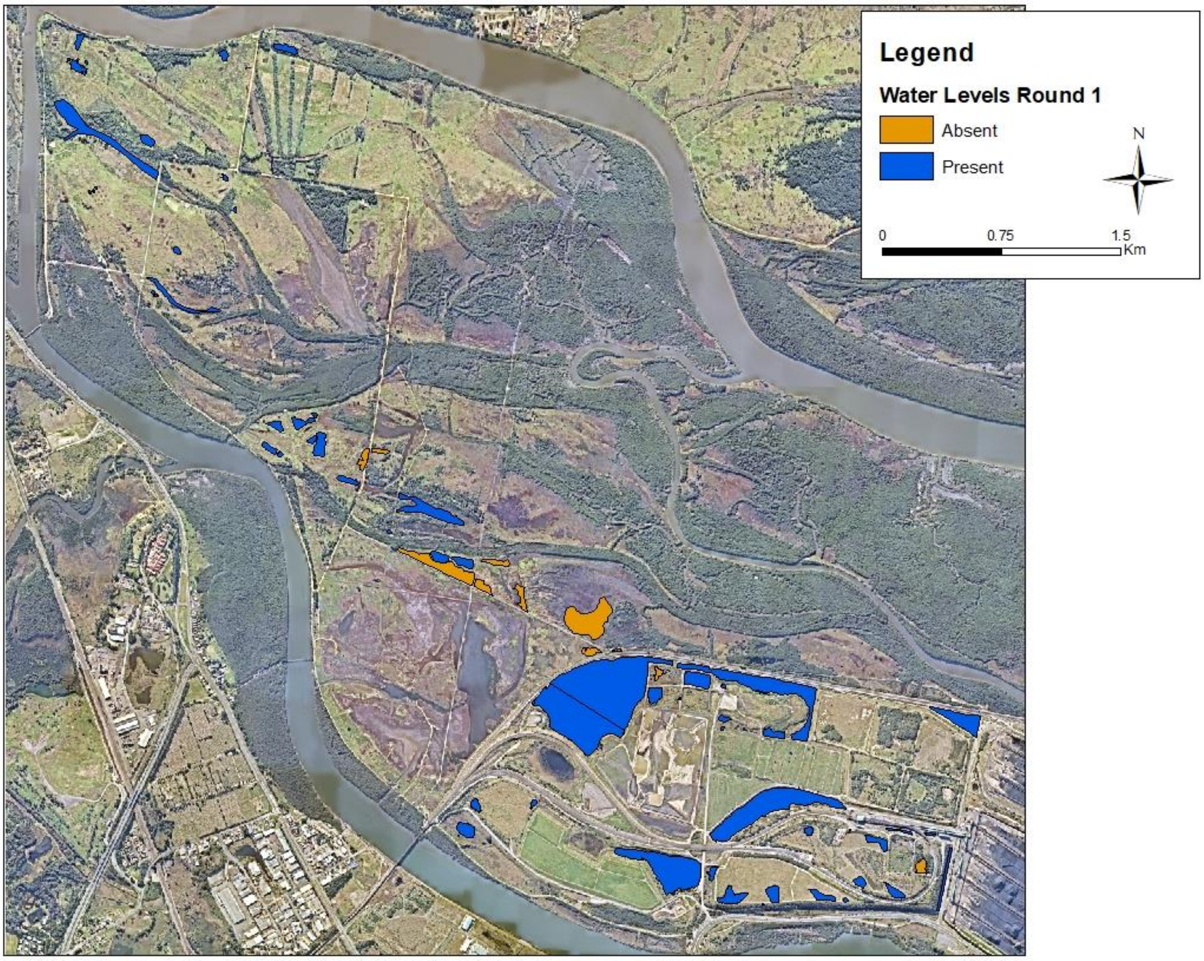


Figure 3.2.2: Water presence/absence across southern Kooragang Island wetlands in September 2019 (Round 1)

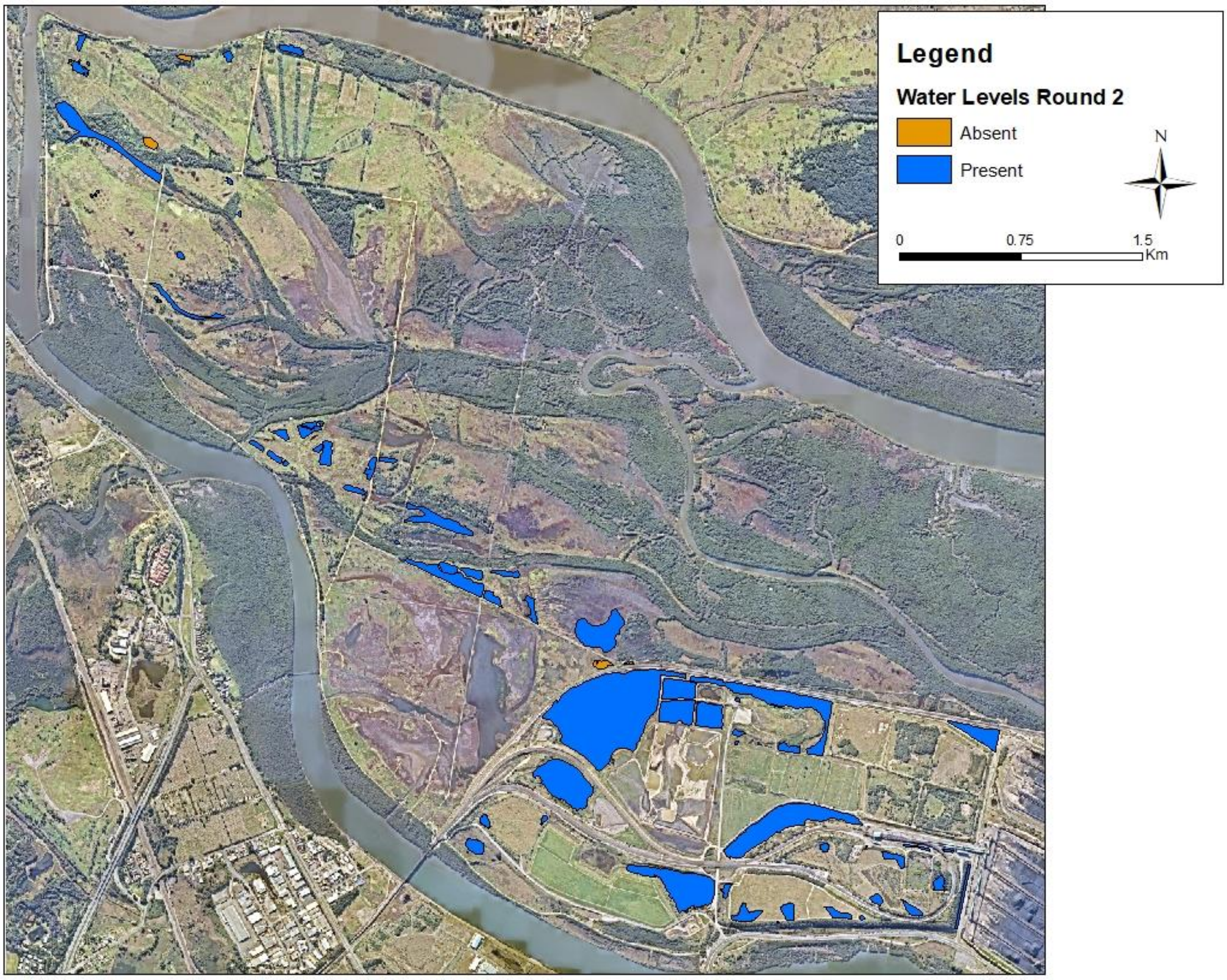


Figure 3.2.3: Water presence/absence across surveyed wetlands in mid-November to early December 2019 (Round 2).

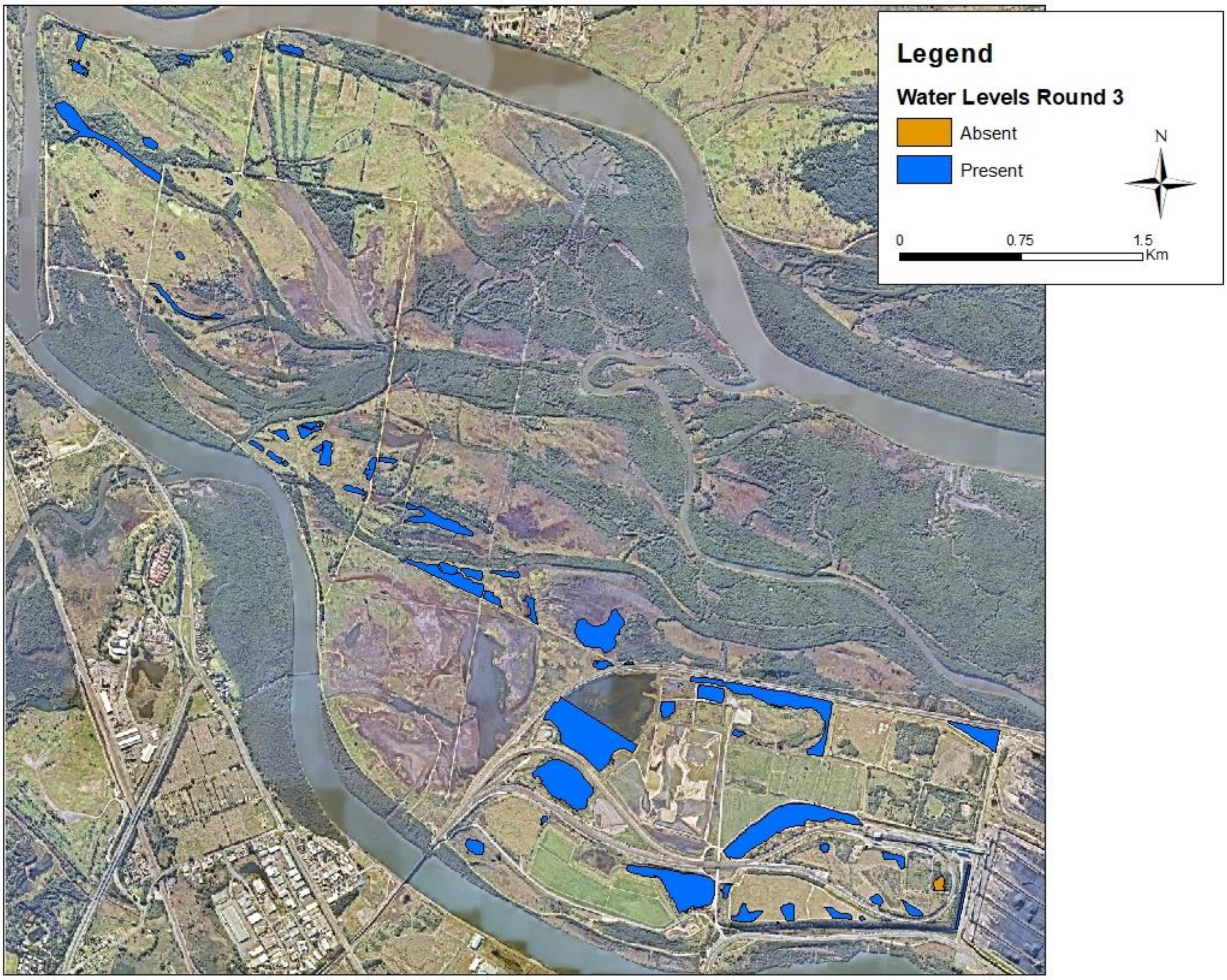


Figure 3.2.4: Water presence/absence across Kooragang Island in mid-February to early March 2020 (Round 3).

By round 2, few wetlands were dry (7%), with the island system recharged by rainfall in spring. Between Round 2 and 3, a majority of wetlands dried, due to lower than average rainfall in the summer period. However, few were dry by Round 3 (2%), being recharged by strong rainfall in February 2020.

Salinity

The maximum salinity levels recorded across the breeding season are shown in Figure 3.2.5. A majority of surveyed wetlands (64%) recorded salinity values less than 2 ppt, well below the known tolerance levels observed for successful development in *L. aurea* tadpoles (up to 5 ppt in the field). A further 17% of wetlands had salinity values ranging between 2 and 5 ppt, while 19% of wetlands had salinity values above 5 ppt. As with the previous season, the highest salinity levels were seen at wetlands immediately north of Bellfrog Way, including BHP-14A (27 ppt) and K9C (20 ppt), indicating connectivity with estuarine water, especially during dry conditions when they can be inundated by estuarine water during king tides. Generally, salinity was lower in constructed compared to natural wetlands.

Breeding occurred at four waterbodies where maximum salinity values were at or above the known tolerance levels for *L. aurea* tadpoles (K9A/B, K103, K104 and K105B) – although these maximum levels were not necessarily recorded at the same time that breeding was observed. No breeding occurred at wetlands with salinity above 10 ppt.

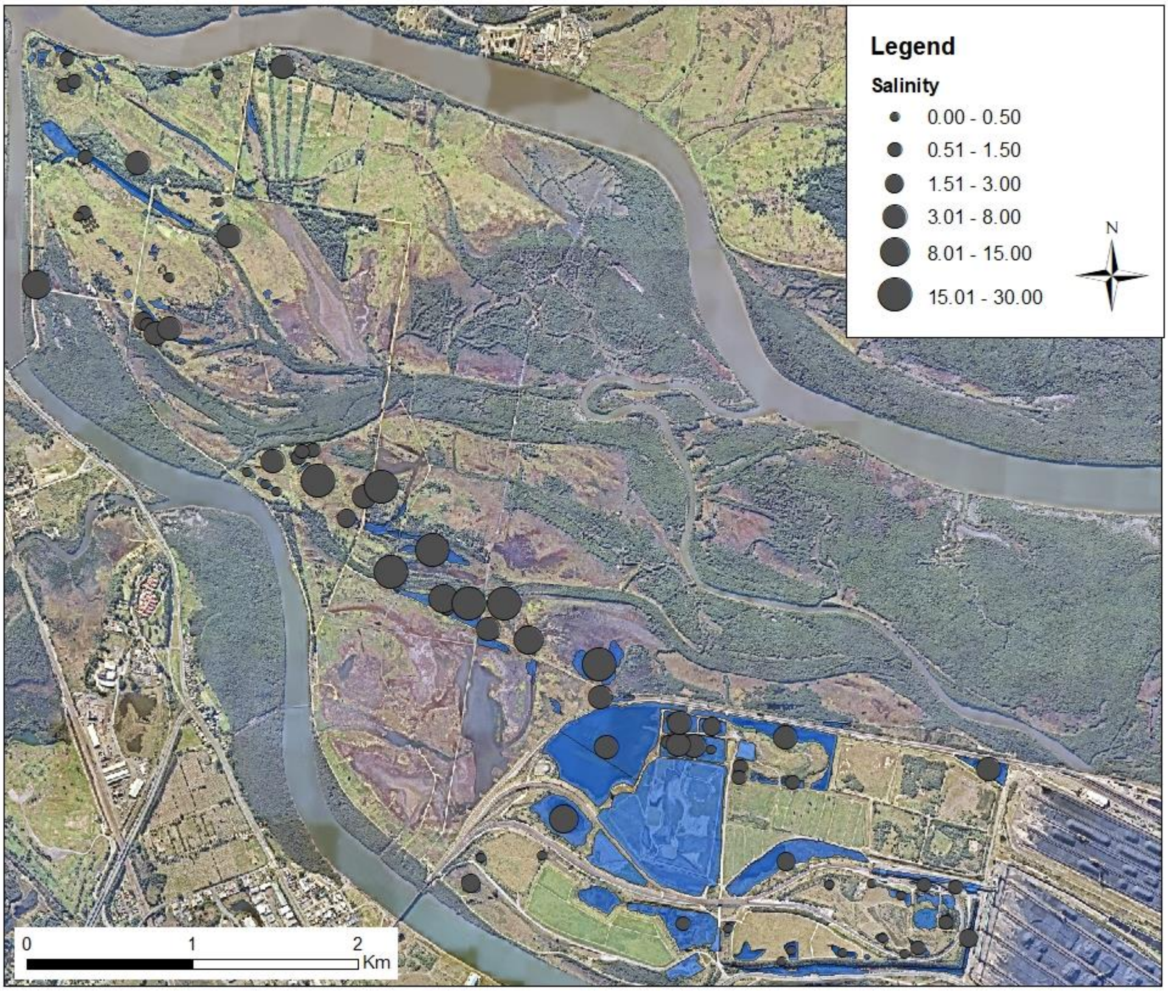


Figure 3.2.5: Maximum salinity levels (ppt) recorded across the 2019-20 survey season.

Hydroperiod

It has become increasingly apparent that a mosaic of interconnected wetland habitats is required to maintain a healthy *L. aurea* population on Kooragang Island. Wetland hydroperiod is a key attribute of such mosaics, with clear evidence to suggest that frogs transition between sites due to spatio-temporal differences in resource availability. In particular, ephemeral sites are often used for breeding when they are recharged by rainfall, while more permanent sites are used as refuge when conditions become dry.

In this report, wetland hydroperiod has been categorised at a 'fine-grain' to capture the complexities of habitat that we perceive in the course of fieldwork and to ensure that it is relevant to understanding *L. aurea* ecology (Table 3.2.2). The 'finer-grained' categorisation used here has several advantages:

- It helps explain current *Gambusia* distribution; i.e. by distinguishing between wetlands that did not dry out in a drought year (deep permanent), and those that did dry out, the categorisation system accounts for the distribution and density of *Gambusia* immediately following a drought.
- It better shows the range of wetland hydroperiods in locations with good *L. aurea* numbers (e.g. around K29). This subtle variation in wetland hydroperiod within a relatively small area may be an important factor in determining habitat mosaics that support *L. aurea*.

Wetlands were allocated to one of these categories, based upon hydrology data from 2015-16 (a wet year) and 2016-17 (a dry year), as well as 2017-18 and 2018-19 (drought years) (Table 3.2.3, Figure 3.2.6, Figure 3.2.7).

Table 3.2.2: Categories of wetland hydroperiod used in the present analysis of *L. aurea* habitat on Kooragang Island

Category	Notes	Score
Managed (effectively permanent)	Artificial/operational ponds whose water levels can be regulated by deliberate removal or addition of water. (e.g. cluster ponds, NCIG conveyor ponds)	9
Saline (irregular)	Wetlands that can be influenced by large tides when their own levels of fresh water are low (i.e. a king tide during a drought). Lack of tidal flushing can produce hypersaline conditions (e.g. K26)	8
Saline (regular)	Wetlands that are close to estuarine waters and which are influenced by regular tidal cycles (e.g. K5)	7
Deep Permanent	Deep wetlands that always hold water	5
Nearly permanent	Hold water year around, except in drought (e.g. 2017-18)	4
Semi-permanent	Hold water year around in normal years but not in dry years (e.g. 2016-17)	3
Seasonal (long-term ephemeral)	Hold water for long periods after rain	2
Temporary (short-term ephemeral)	Hold water for short periods after rain (e.g. K106A, K106B), sufficient to allow breeding by *L. aurea*	1
Non-breeding ephemeral	Wetlands that even after significant rainfall only hold water for a period too short for successful breeding by *L. aurea* (e.g. K7)	0

Wetland	Score	Description
K2	2	Seasonal
K3	3	Semi-permanent
K4	2	Seasonal
K5	7	Saline (regular tidal)
K7	1	Temporary
K58B	8	Saline (irregular)
NCIG_1.1	5	Deep permanent
NCIG_3.1	2	Seasonal
NCIG_4.7	5	Deep permanent
NCIG_5.1	3	Semi-permanent
NCIG_7.1	5	Deep permanent
NCIG_T13	5	Deep permanent
NCIG_T14	2	Seasonal
NCIG_T15	5	Deep permanent
BHP-1A	5	Deep permanent
BHP-2C	5	Deep permanent
BHP-3A	5	Deep permanent
BHP-4B	3	Semi-permanent
BHP-14A	8	Saline (irregular)
K9A/B	8	Saline (irregular)
K9C	8	Saline (irregular)
K9	3	Semi-permanent
K26	8	Saline (irregular)
K48	8	Saline (irregular)
K13	2	Seasonal
K21	8	Saline (irregular)
K63	8	Saline (irregular)
K22	2	Seasonal
K23	4	Nearly permanent
K104	5	Deep permanent
K103	5	Deep permanent
K105A	5	Deep permanent
K105AS	5	Deep permanent
K105B	3	Semi-permanent
K106A	1	Temporary
K106B	1	Temporary
K106C	4	Nearly permanent
K29	4	Nearly permanent
C1	9	Managed
K31	3	Semi-permanent
K34	3	Semi-permanent
K42	4	Nearly permanent
K102	5	Deep permanent
K36	5	Deep permanent
C2	9	Managed
K115	9	Managed
K116	9	Managed
K100A	5	Deep permanent
K108	1	Temporary
K111	3	Semi-permanent
K112	2	Seasonal
K113	2	Seasonal
K114	3	Semi-permanent
K121	3	Semi-permanent
K122	3	Semi-permanent
K123	3	Semi-permanent
K46	3	Semi-permanent
K49B	4	Nearly permanent
K117	5	Deep permanent
K118	4	Nearly permanent

Table 3.2.3: Categorisation of hydroperiod for the primary 60 wetlands surveyed in the 2019-20 season.

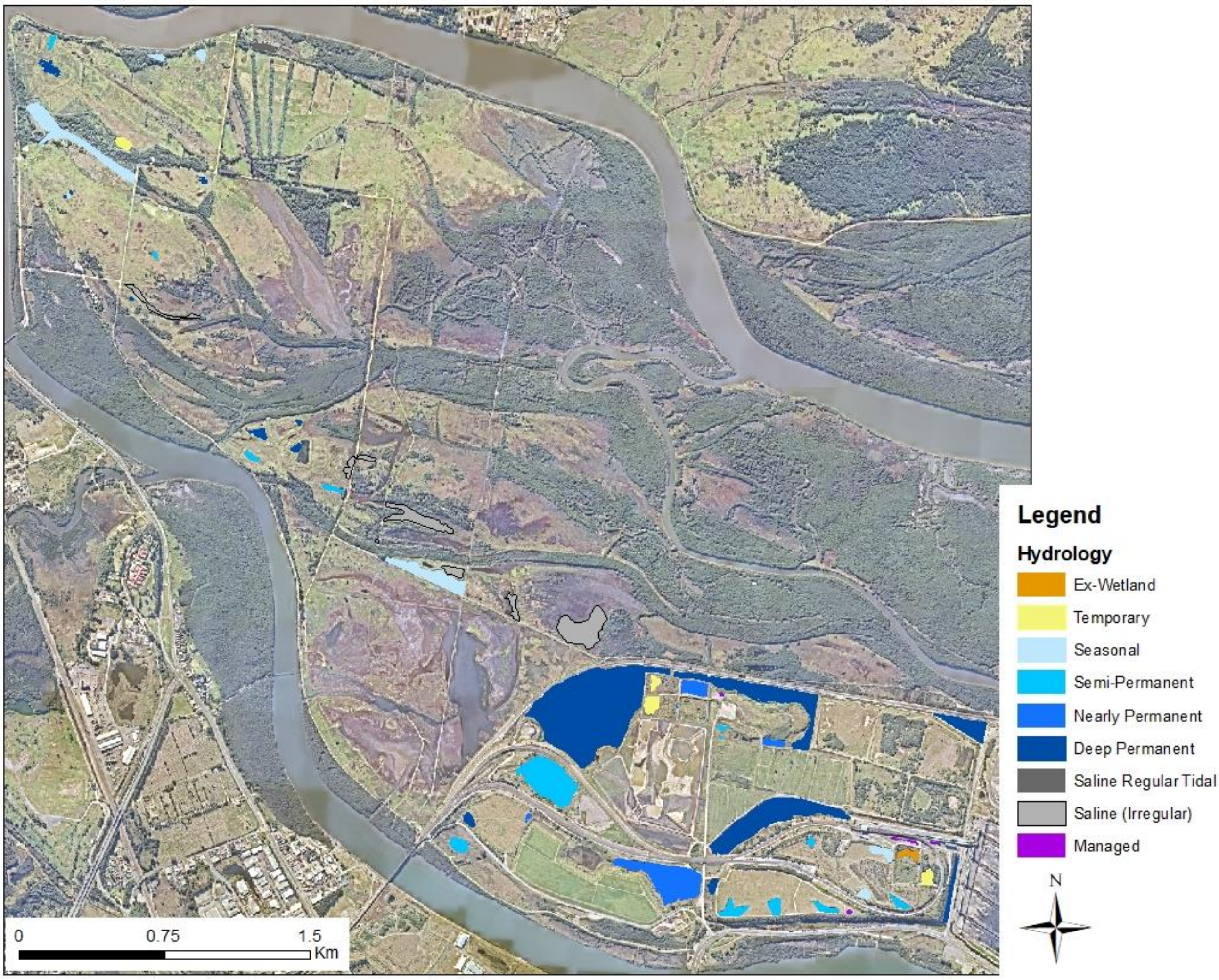


Figure 3.2.6: Hydroperiod scores for wetlands across the Northern, Central and Industrial Zones of Kooragang Island, updated using information from the 2018-19 survey season. See text for explanation of categories

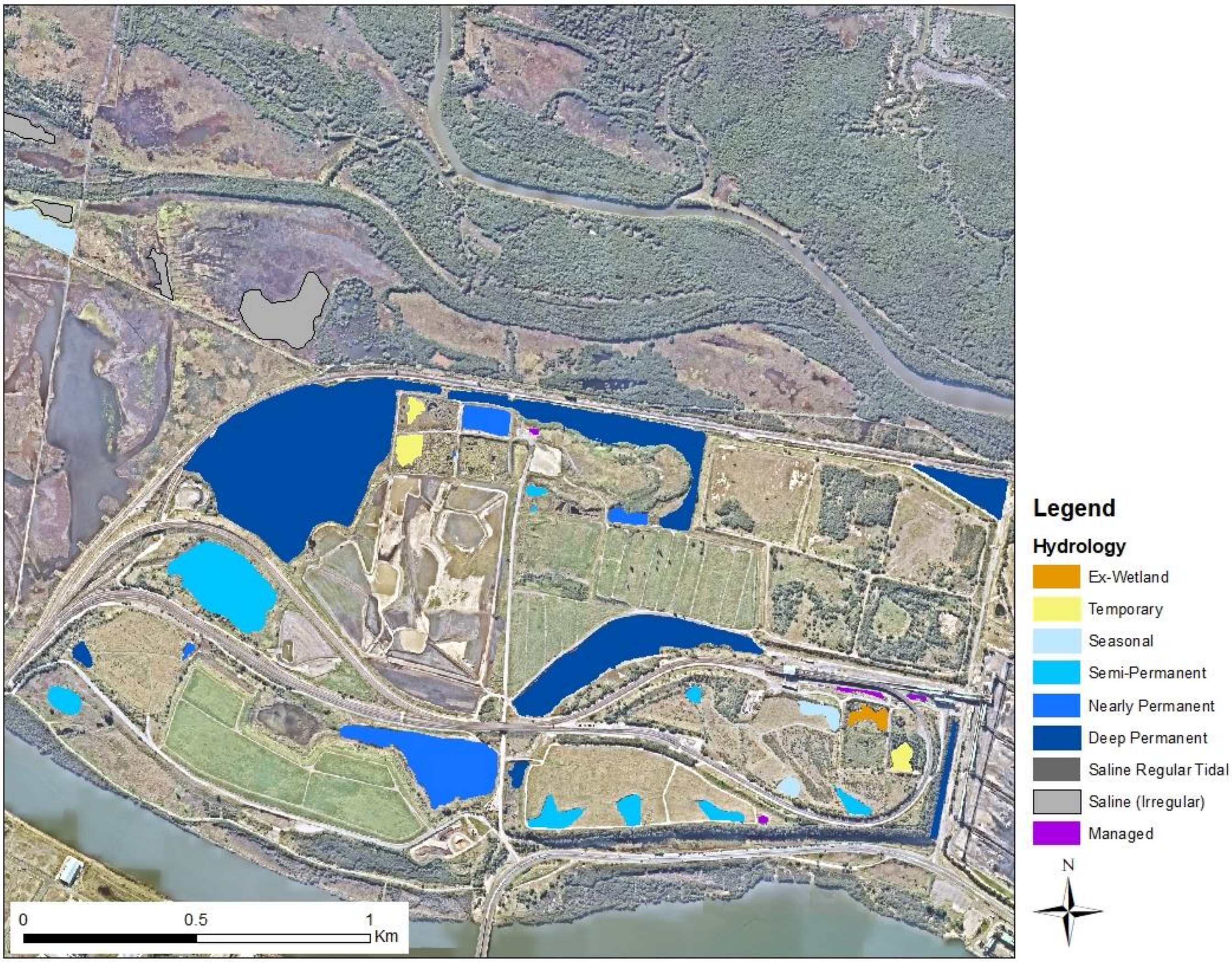
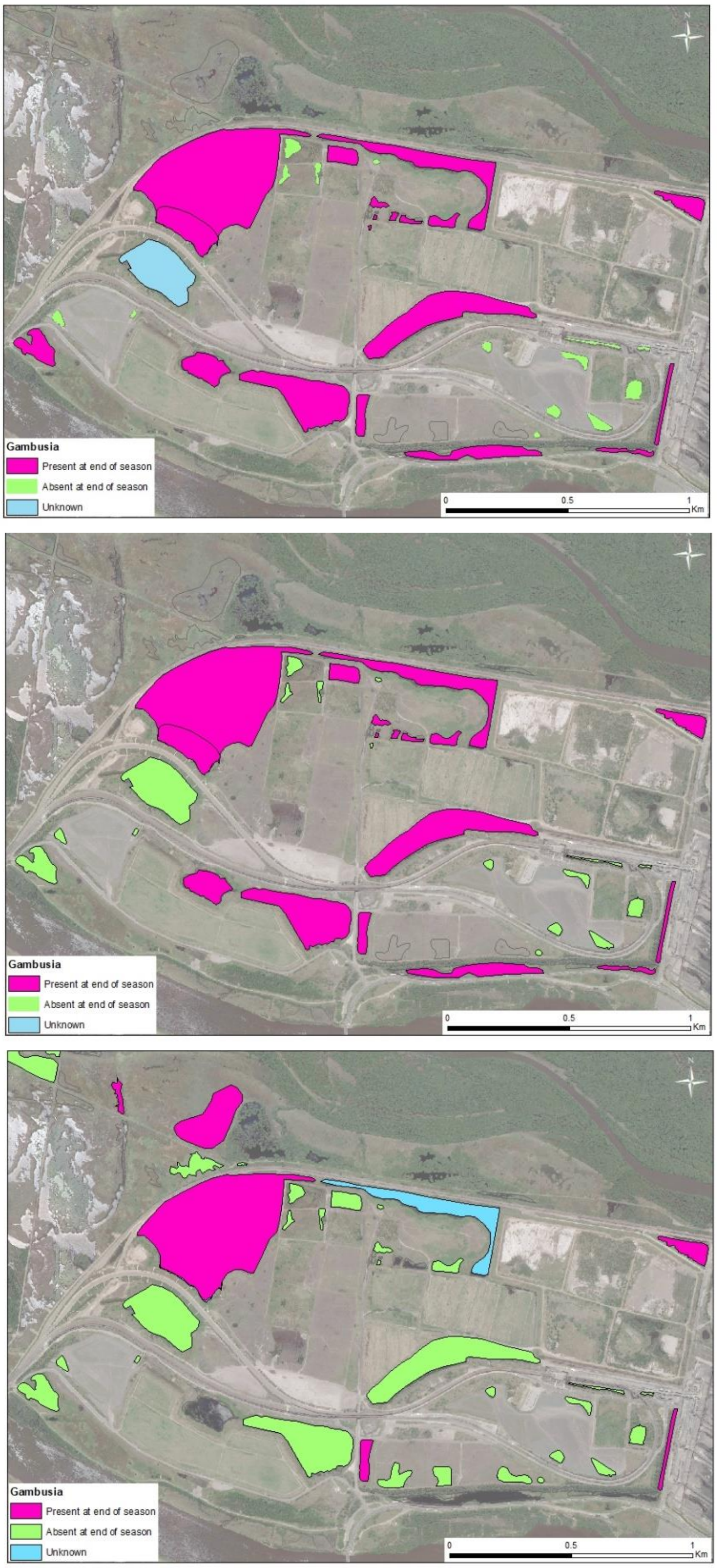


Figure 3.2.7: Close-up of wetland hydroperiod in the Industrial Zone of Kooragang Island. See text for explanation of categories. Note the diversity of hydroperiod categories for wetlands around K29 and the Rail-loop (c.f. habitat mosaic)

Gambusia



The 2019-20 season was the fourth year of lower than average summer rainfall. The repeated and incremental cycles of drying and recharging of wetlands has gradually removed *Gambusia* from much of the system. Across Kooragang Island, the number of wetlands with *Gambusia* present has declined from 65 in March 2016 to seven in March 2020 (Table 3.2.1). Within the Industrial Zone, only 13 wetlands were free of *Gambusia* in March 2016; by March 2020 that number had increased to 27 and *Gambusia* was detected in only four wetlands within that zone (K100A, K102, K103 and K104).

Note that *Gambusia* have always been absent from the constructed HDC wetlands and the cluster ponds.

Figure 3.2.8: Distribution of *Gambusia* across the **Southern** part of Kooragang Island, late summer of 2016 (top), 2017 (middle), and 2018 (bottom). After extensive infestation in 2015 following heavy summer rains, two consecutive dry summers eliminated *Gambusia* from most wetlands.

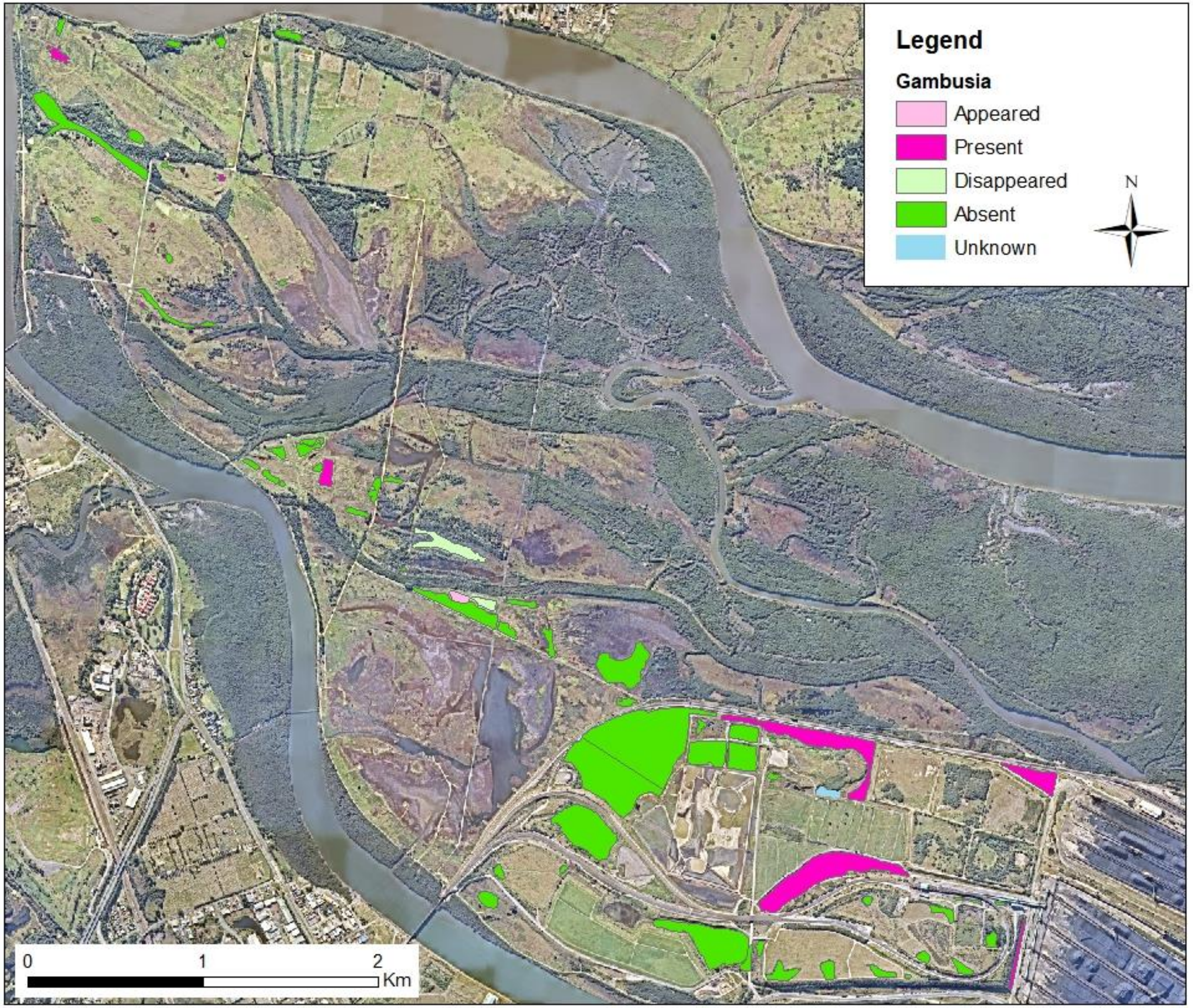


Figure 3.2.9: *Gambusia* distribution across the southern wetlands at the end of the 2019-20 season. Wetland scored as 'disappeared' are mostly those that dried during the season.

Note that the data for K105A shows very low densities of *Gambusia* in the southern part; *Gambusia* was not detected in the northern part but these parts are connected and *Gambusia* must have been present at very low densities across all of K105A in the early part of the season. K105A dried out during May 2019 so *Gambusia* may have been completely eliminated from that wetland.

For those wetlands that could not be surveyed in Round 3 (due to the Industrial Zone ground fire), *Gambusia* distribution is inferred based upon (1) status in Round 2, (2) persistence of water through the summer as ascertained through aerial photography, and (3) patterns from previous years.

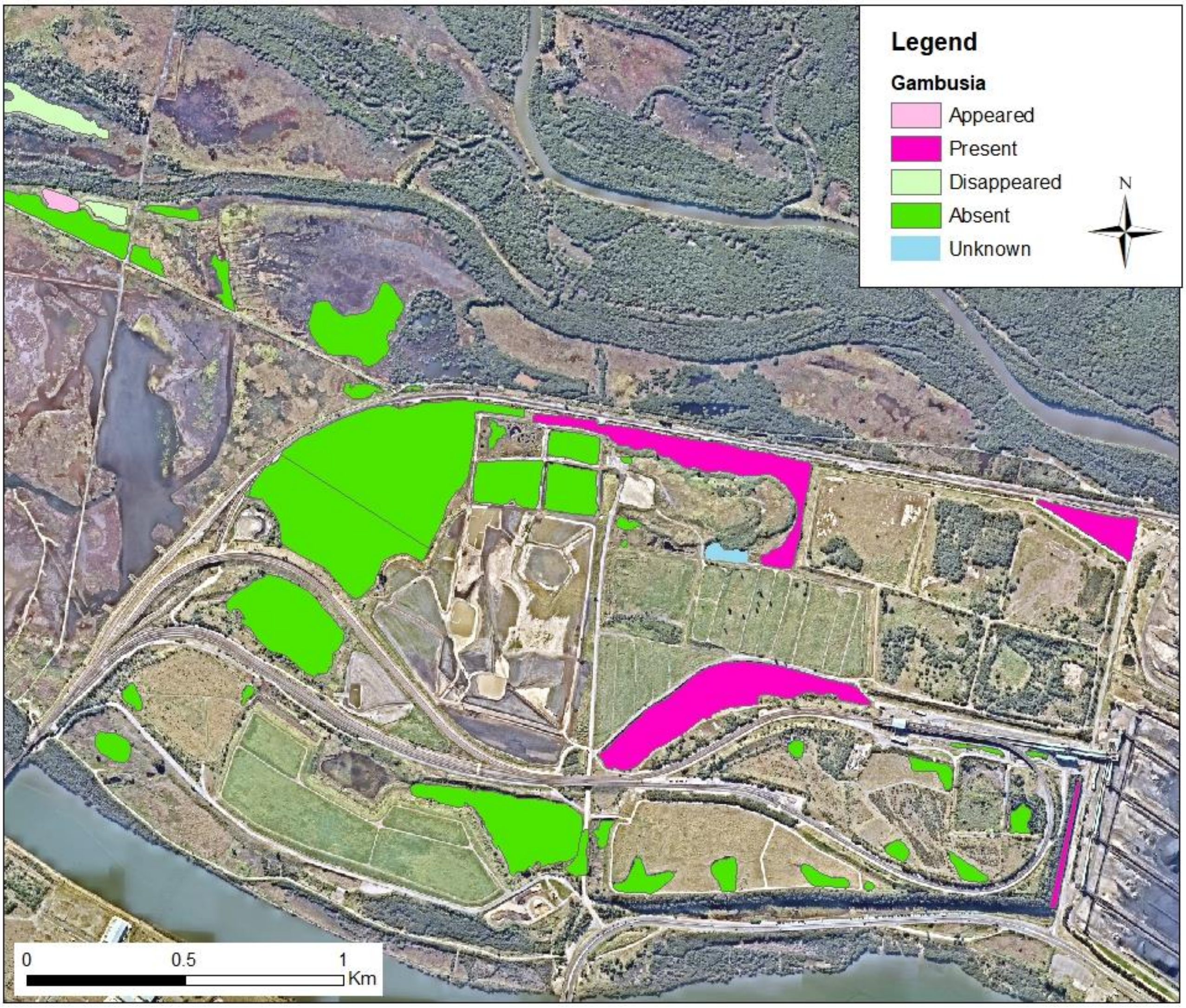


Figure 3.2.10: Gambusia distribution for the wetlands around the Industrial Zone; see Figure 3.2.9 for explanation.

3.3. Distribution of *Litoria aurea* across Kooragang Island

The distribution of *L. aurea* across Kooragang Island is shown using:

i. Search Sensitivity plots showing the number of frogs detected per unit search effort – it is thus a proxy measure of density or relative abundance (although it is affected by detectability).
ii. Demographic plots showing absolute numbers detected during standardised visual encounter surveys (VES).
iii. Demographic plots differ from search sensitivity plots in that they indicate the actual number of *L. aurea* detected during primary VES. They also show a demographic breakdown of those survey numbers. While VES surveys are standardised and timed for each wetland, many *L. aurea* are detected outside of the primary VES, such as in a secondary VES (which are undertaken for a variety of reasons, such as surveying for breeding behaviour following rain), and those detections are also shown in these figures.

Figure 3.3.1/2 shows Search Sensitivity calculated for primary VES for the three completed principal survey rounds (i.e. Rounds 1, 2 and 3), along with the non-capture Round 4 that occurred later in the season. Figure 3.3.3 shows the metric pooled across the whole season. Frogs were widely distributed across southern Kooragang, particularly across wetlands within the Industrial Zone (as with last year). Low densities were detected across the northern island, while densities in the Central Zone were high at the BHP CHEMP wetlands.

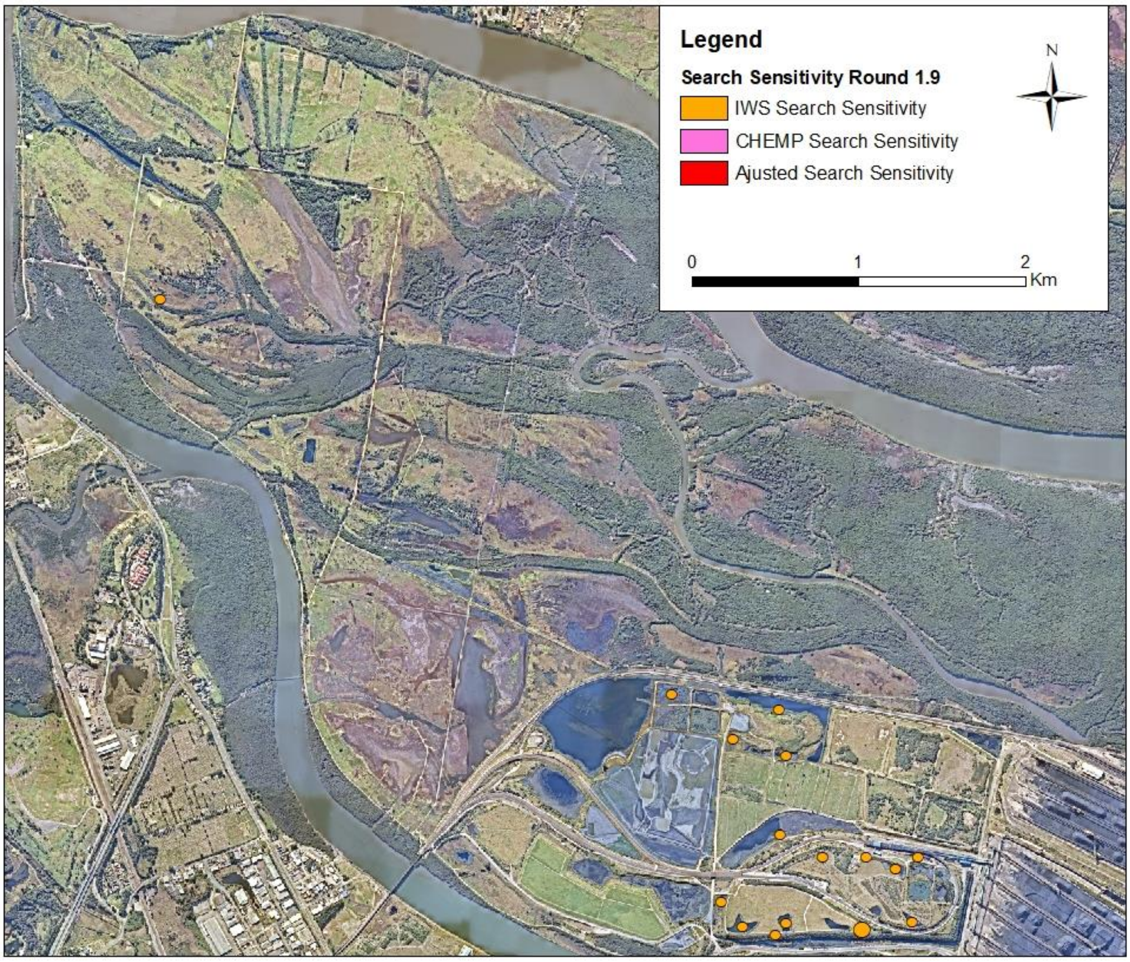
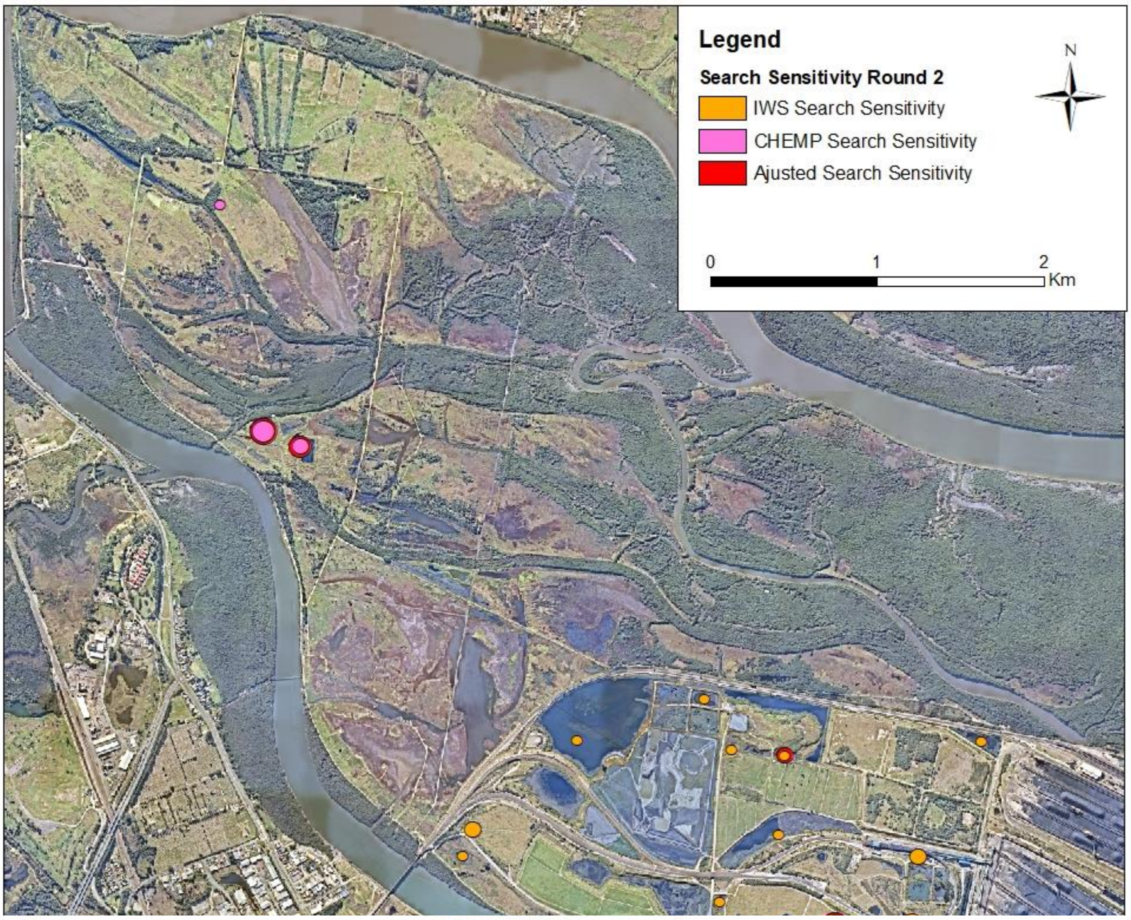


Figure 3.3.1: Search sensitivity (frogs detected per person.minute) across the 60 wetlands surveyed as part of 'whole island' monitoring in 2019-20, for Round 1 (September 2019) and Round 1.9 (early November 2019).


Legend
Search Sensitivity Round 2
IWS Search Sensitivity
CHEMP Search Sensitivity
Ajusted Search Sensitivity
N
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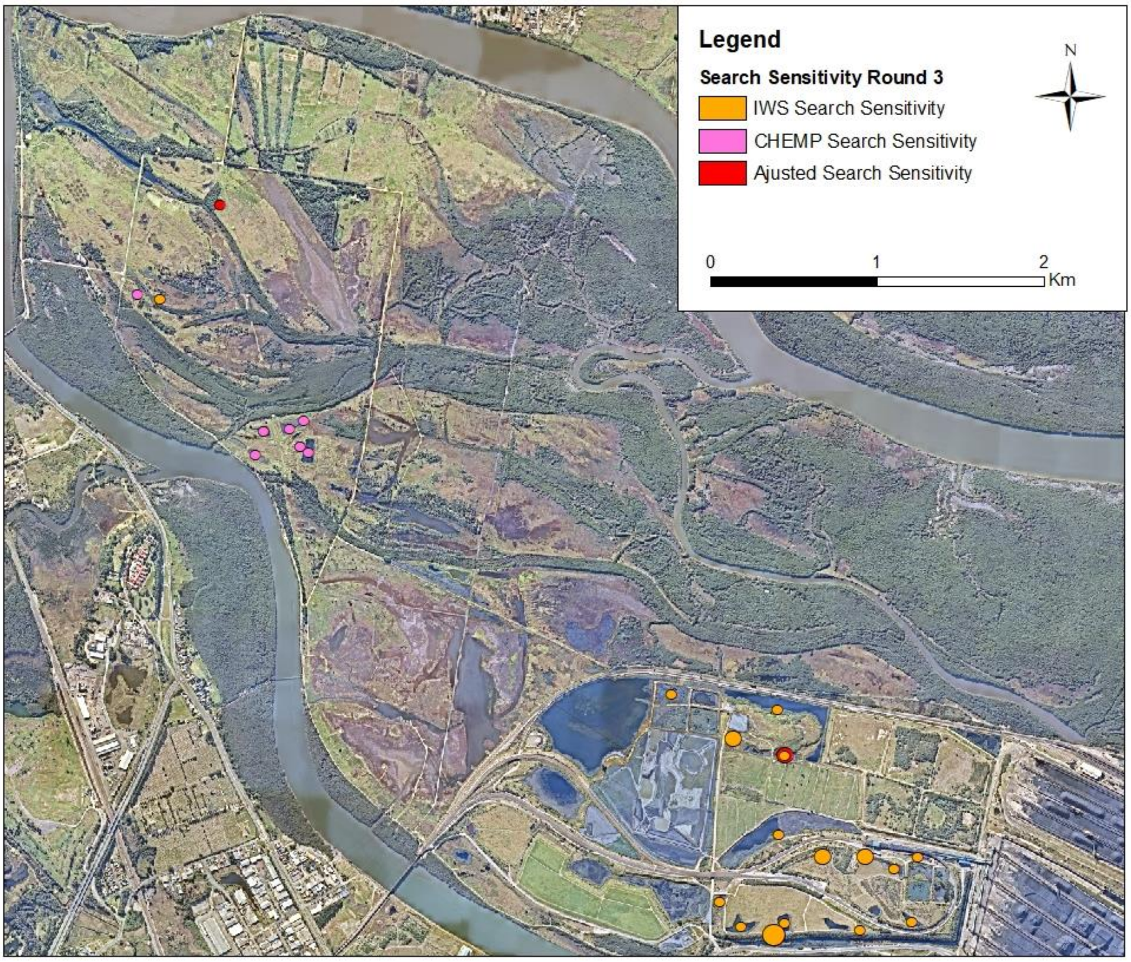
Legend
Search Sensitivity Round 3
IWS Search Sensitivity
CHEMP Search Sensitivity
Ajusted Search Sensitivity
N
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1
2
Km

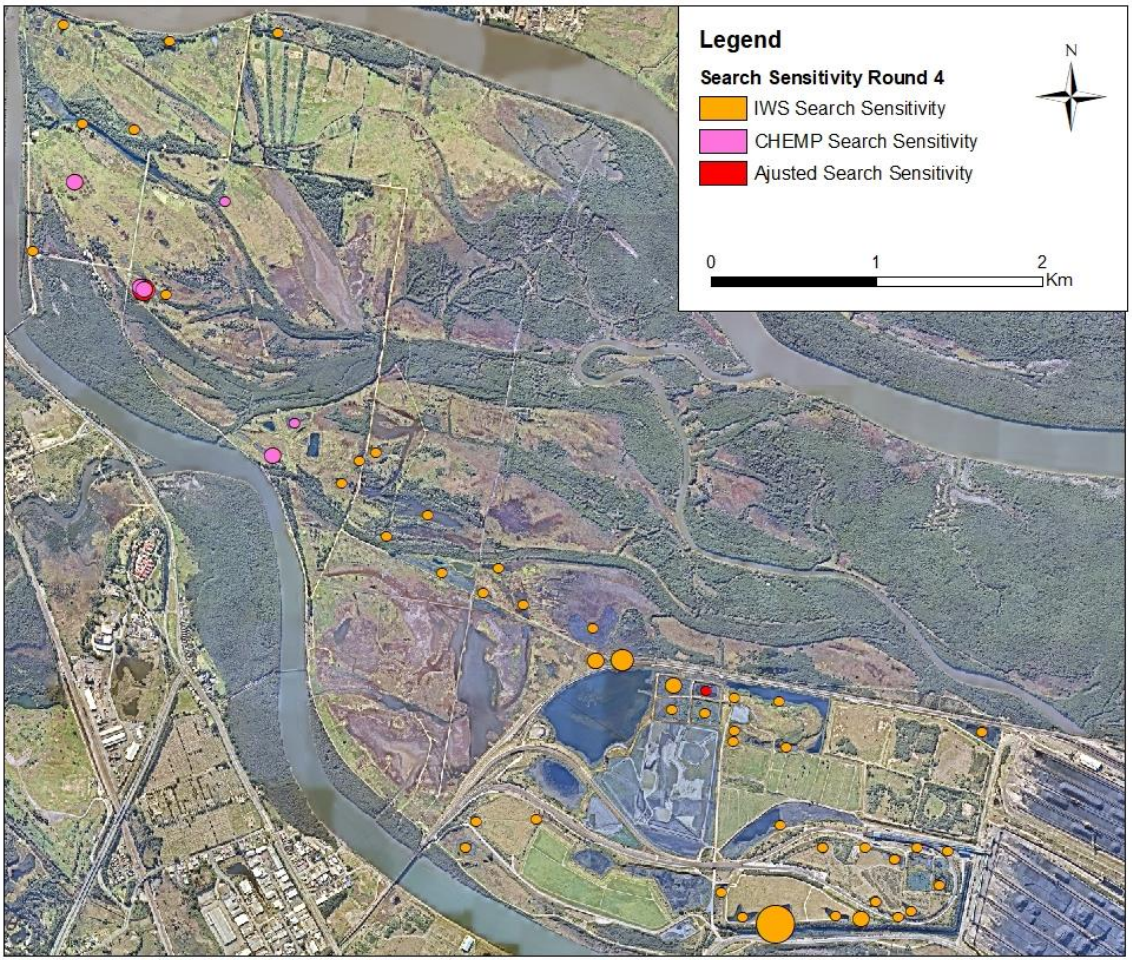


Figure 3.3.2: Search sensitivity (frogs detected per person.minute) across the 60 wetlands surveyed as part of 'whole island' monitoring in 2019-20, for Round 2 (November- December, 2019), Round 3 (Febuary2020), and Round 4 (March, 2020)

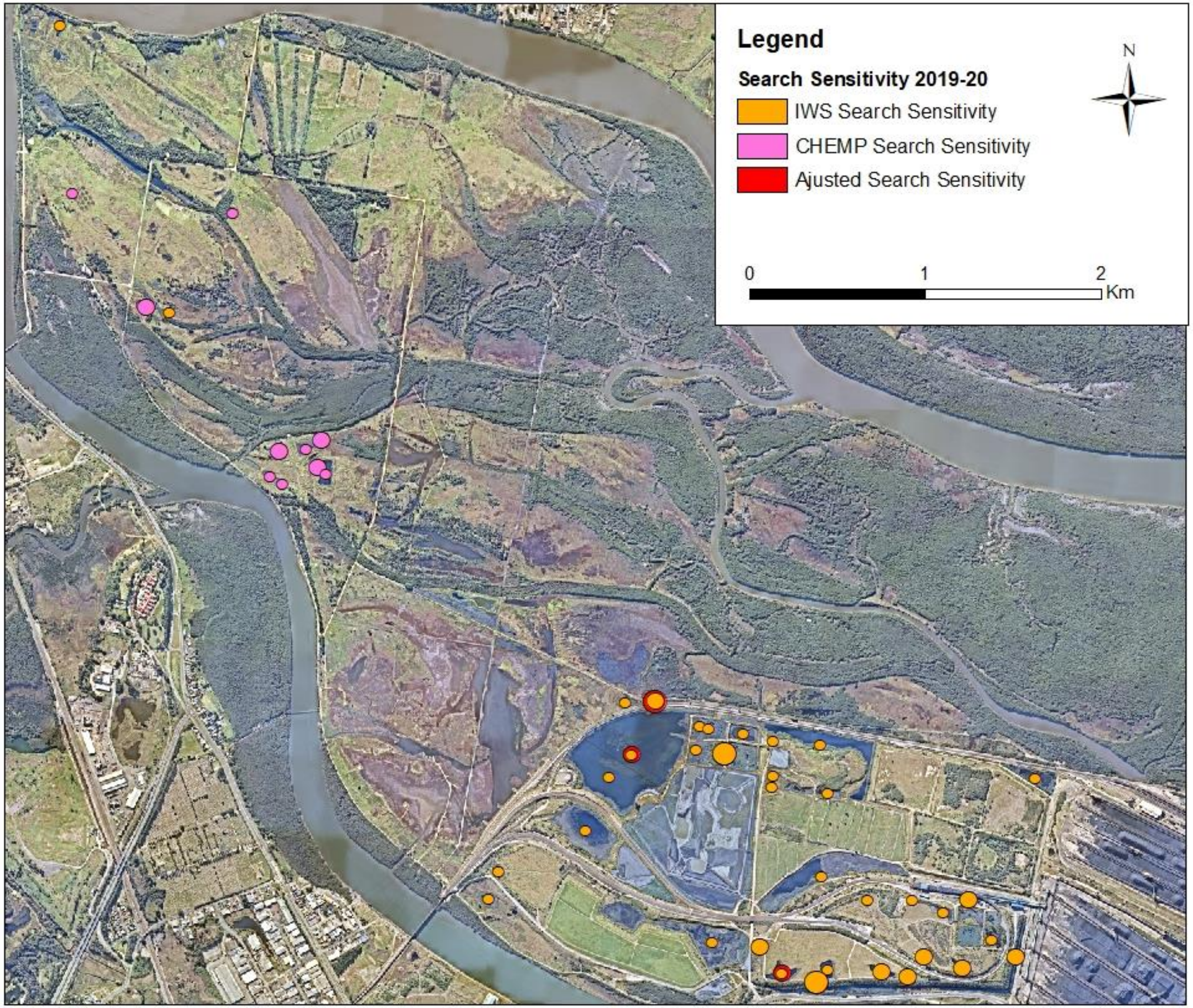


Figure 3.3.3: Search sensitivity (frogs detected per person.minute) across the 60 wetlands surveyed as part of 'whole island' monitoring in 2019-20, pooled across the principal survey rounds.

'Unadjusted' search sensitivity is simply <frogs detected in 1° VES> / <search effort at each wetland (in person.minutes)>. This is the same calculation as used in previous reports (and should be used when comparing data with those).

'Adjusted' search sensitivity deducts a fixed handling time (1 minute for each frog captured) from the total search effort for each wetland. This provides a better comparison between wetlands with high vs low numbers of frogs (within the same season).

Compare with the map of Search Effort (Fig. 2.5.2)

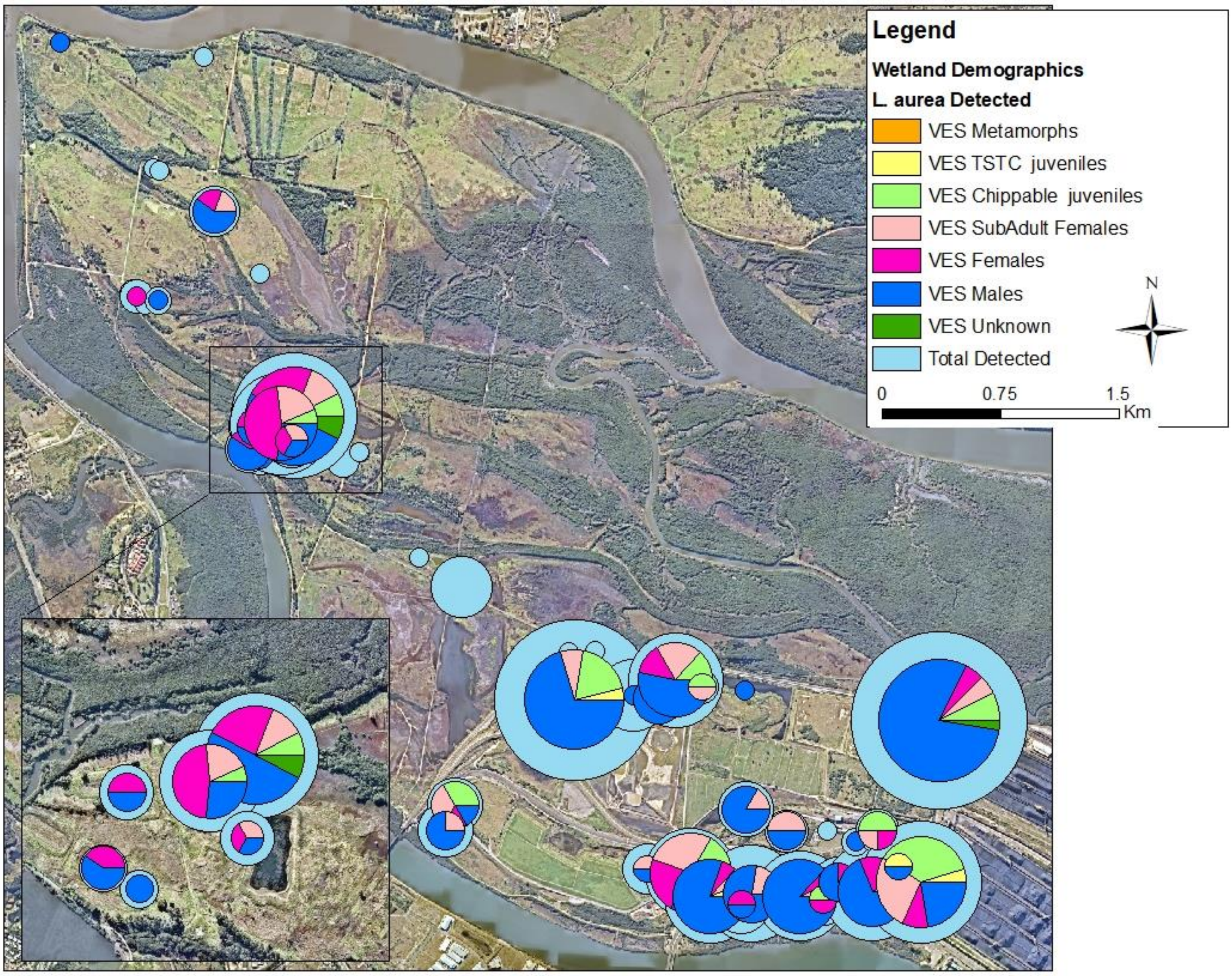


Figure 3.3.4: Demographic breakdown of frogs detected during Round 1 in September 2019. **Total Detected** denotes animals that were detected during VES surveys. Breakdown into demographic groups is based upon data taken from frogs captured during VES surveys only. TSTC = 'Too Small to Chip', i.e. juveniles <40 mm SVL; 'Chippable Juvs' are juveniles that are >= 40 mm SVL. 'VES unknown' are animals detected during VES but not captured or readily identifiable as juveniles/adults. See Figure 3.3.5 caption for explanation of demographic categories.

Round 1 (September). Immediately before the start of this round there was early spring rainfall (~96 mm in four days). Large numbers of adults were found in the Industrial Zone and BHP compensatory habitat, including K104, K105A, BHP-2A and BHP-2C. Adults were predominantly male, with widespread calling at multiple wetlands. Large numbers of females were also found at BHP-2A, BHP-2C and K36. Juveniles were found in 14 wetlands, especially K100A (Fig. 3.3.4). Presumably, these individuals were spawned during rain in autumn and overwintered as tadpoles.

Round 1.9 (Early November). This was a small survey round that occurred after a small rain event early in November (~18.0 in two days). Adults were detected at 10 wetlands in the Industrial Zone, including at four of the cluster pond locations. The majority of adults were male, with only a few females detected at C1 and C2. A small number of juveniles were also detected at two wetlands (K111 and K123).

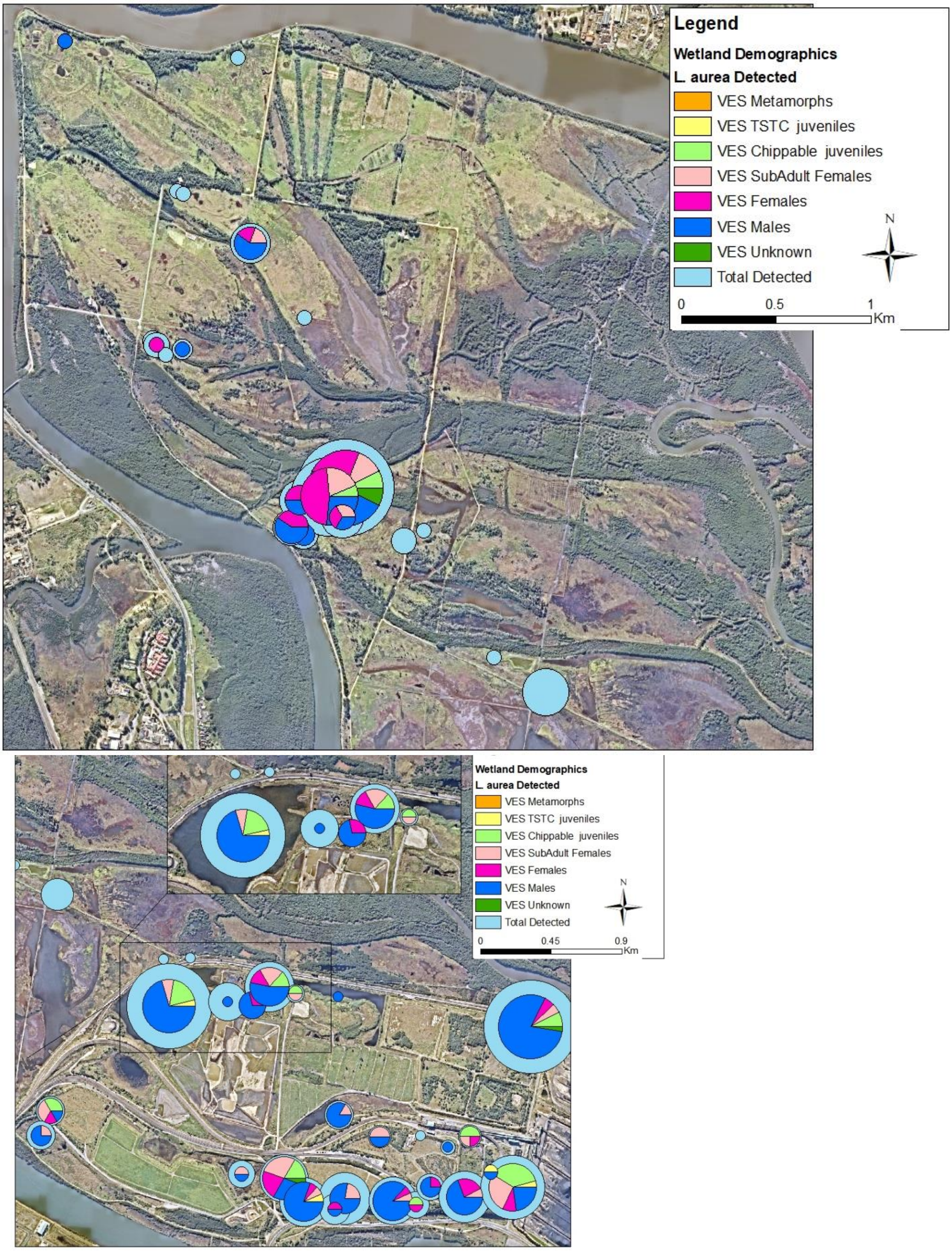


Figure 3.3.5: Demographic GIS plots for Round 2 (November). **Total detected** denotes animals that were detected during VES surveys. Breakdown into demographic groups is based upon data taken from frogs captured during VES surveys only. TSTC = 'Too Small to Chip', i.e. juveniles <40 mm SVL; 'Chippable Juvs' are juveniles that are >= 40 mm SVL. 'VES unknown' are animals detected during VES but not captured or readily identifiable as juveniles/adults. Upper map shows the Northern and Central Zones, while the lower shows the Industrial Zone.

Round 2 (November – early December 2019): commenced after earlier rainfall in November (~ 18 mm in two days), with little additional rain until the end of November. Relatively fewer adults were detected compared to round 1 and little calling, with the largest numbers of both males and females recorded at BHP-3A.

Juveniles were detected at seven wetlands (Fig. 3.3.5), all of which were in the Industrial Zone (K29, K100A, K104, K106C, K111, K123 and C2). These may have been spawned during rainfall earlier in September or may have overwintered as tadpoles. As juvenile *L. aurea* move readily cross the landscape (unpublished data), their presence does not necessarily indicate breeding at these wetlands but does provide evidence to suggest they contain suitable habitat for young animals. Metamorphs were detected in three wetlands (K111, K122 and K123), highlighting that at least some ponds with juveniles present were sites of *L. aurea* breeding. Indeed, K111 has consistently had breeding events over the previous four seasons, and it is likely that juveniles located in K100A and other nearby wetlands originated from here.

Round 3 (mid February - early March 2020): This round started during a large rainfall event (147 mm in 11 days) that recharged many of the systems that had dried up entirely. Adults were detected in 40 wetlands, with large numbers in five close by (K100A, K105A, K105B, K106A and K106B) (Fig. 3.3.6). Calling was also widespread across many wetlands. Much larger numbers of males were detected in the K105 ponds, while larger numbers of females were detected in K100A and K106A. This disparity between nearby wetlands may indicate different spatial use of breeding vs refuge wetlands immediately following rainfall, which has been recorded in previous breeding years.

Despite the large rainfall event at the start of this round, no metamorphs were detected in any of the wetlands. Small numbers of juveniles were detected across five wetlands (K105B, K121, C2, E4 and BHP-4B), suggesting breeding occurred earlier in the season.

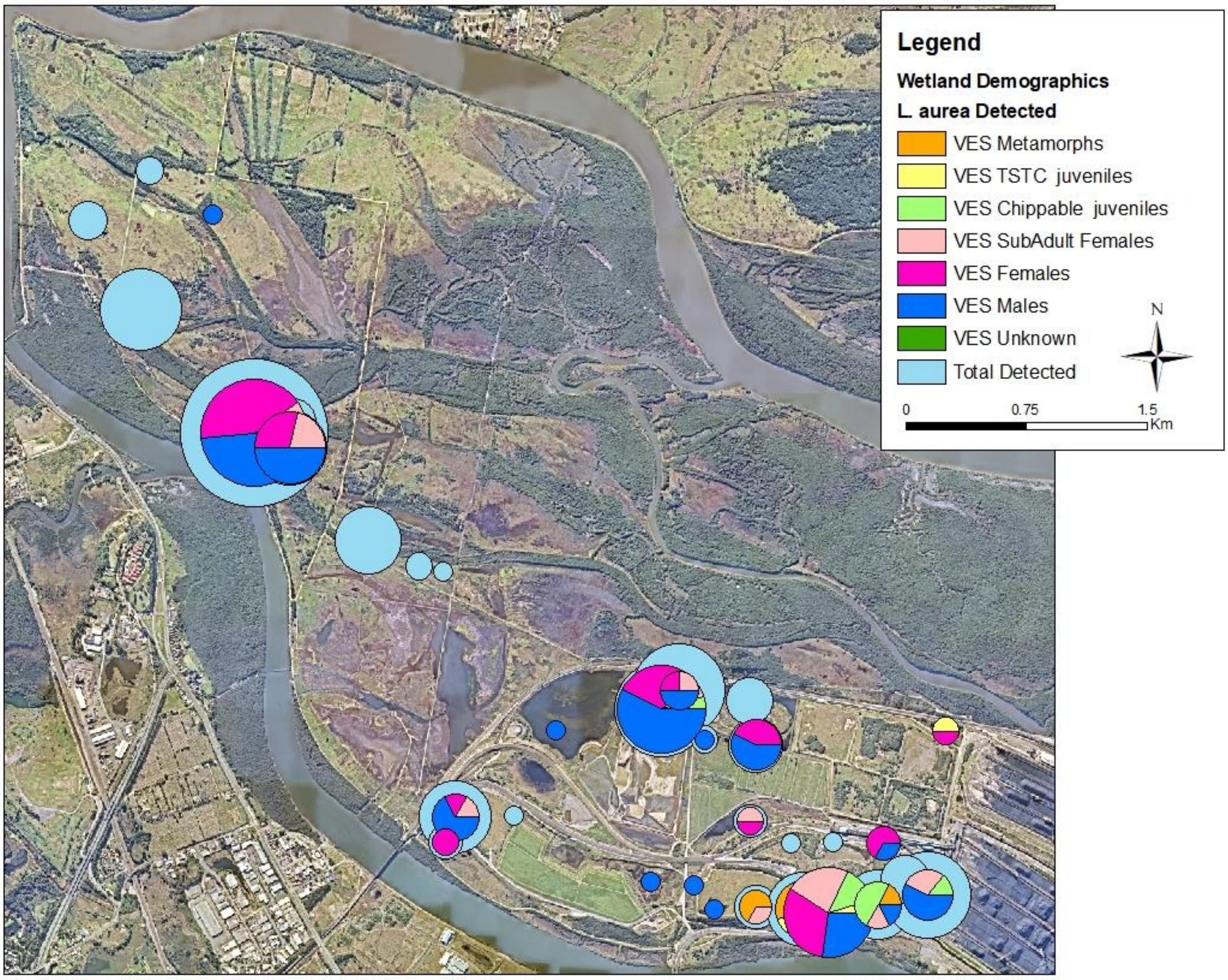
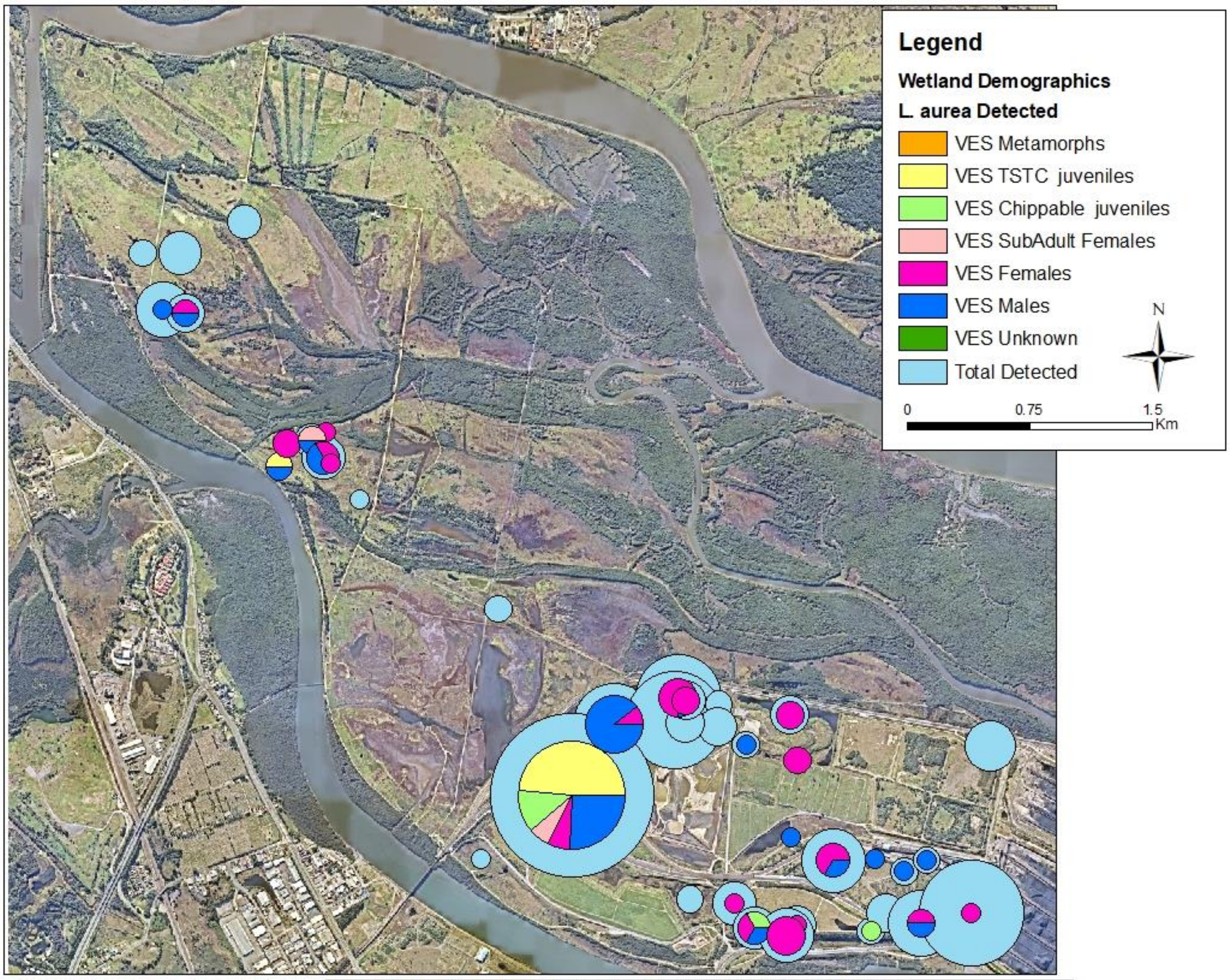


Figure 3.3.6: Demographic GIS plots for Round 3 (February). **Total detected** denotes animals that were detected during VES surveys. Breakdown into demographic groups is based upon data taken from frogs captured during VES surveys only. TSTC = 'Too Small to Chip', i.e. juveniles <40 mm SVL; 'Chippable Juvs' are juveniles that are >= 40 mm SVL. 'VES unknown' are animals detected during VES but not captured or readily identifiable as juveniles/adults.

Round 4 (mid March 2020): This was a non-capture survey period that was conducted as a breeding check across the Island. Several rainfall events occurred across March (106.2 mm over 17 days). Adults were detected in 29 wetlands, with the most occurring in K23 (Fig. 3.3.7). Juveniles were detected across 26 wetlands, with large numbers of more than 200 individuals recorded at K121 and BHP-3A. Metamorphs were detected in 15 wetlands, with large numbers of more than 100 individuals found at four nearby wetlands (K111, K121, K122 and K123). The presence of both metamorphs and juveniles in large numbers strongly suggests successful breeding at these wetlands. However, juveniles and metamorphs can move from their natal ponds to nearby wetlands and so smaller numbers found at some wetlands may indicate that breeding took place elsewhere. In the case of K111 and K121, there can be little doubt that a very large breeding event took place at both sites soon after the large rainfall event that occurred in February.



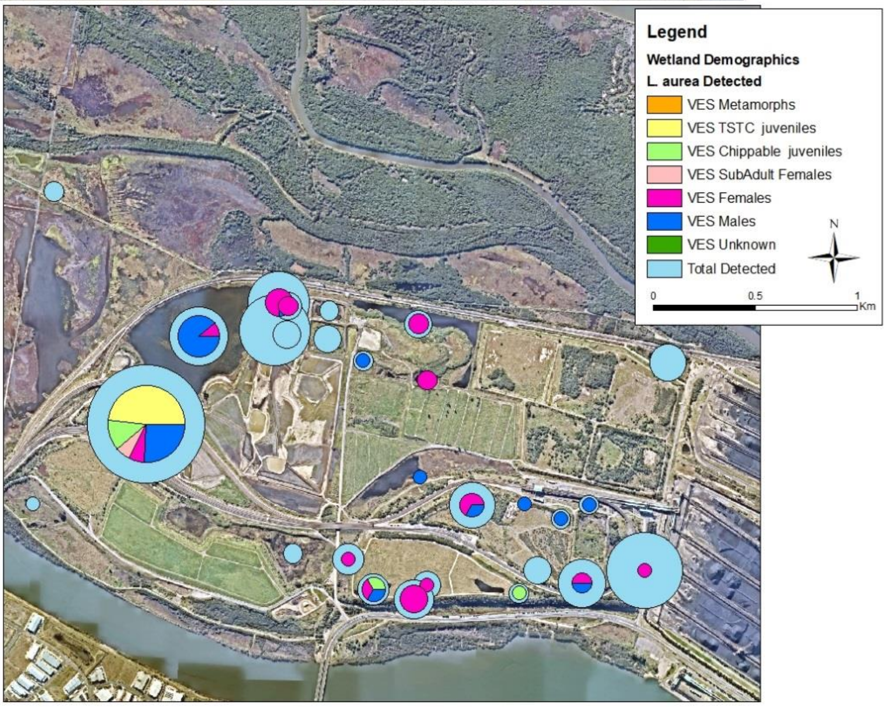


Figure 3.3.7: Demographic GIS plots for round 4 (March). Lower map shows close-up of the Industrial Zone. See Figure 3.2.4 for explanation of demographic categories.

Round 4.1 (April 2020): A final survey took place during a dispersal event of *L. aurea* juveniles across the island. Adults were detected at only two sites (K105AS and Area 2), suggesting that they were no longer reproductively active. Large numbers of juveniles ranging from 200 to more than 2000 were detected at four locations (K105AS, NCIG dump-station, The Wedge and Area 2), further highlighting the large breeding event that occurred late in the season following strong rainfall in February. However, no metamorphs were detected, indicating that breeding had likely stopped by this stage.

Total detected: Figure 3.3.8 shows all *L. aurea* detected, pooled across all surveys; another version of this is shown in Figure 4.4.1. It shows that large adult populations were recorded across the Industrial Zone (K23, K100A, K104, K105A and K105AS) and BHP compensatory habitat (BHP-2C and BHP-3A). Many of these ponds also showed high numbers of both juvenile and metamorphs, an indication of breeding events, particularly at K105AS and BHP-3A, along with others including K111, K113, K121, K122 and K123. Dispersal of juveniles away from aquatic sites was also apparent by the end of the season, with large numbers recorded at The Wedge and Area 2.

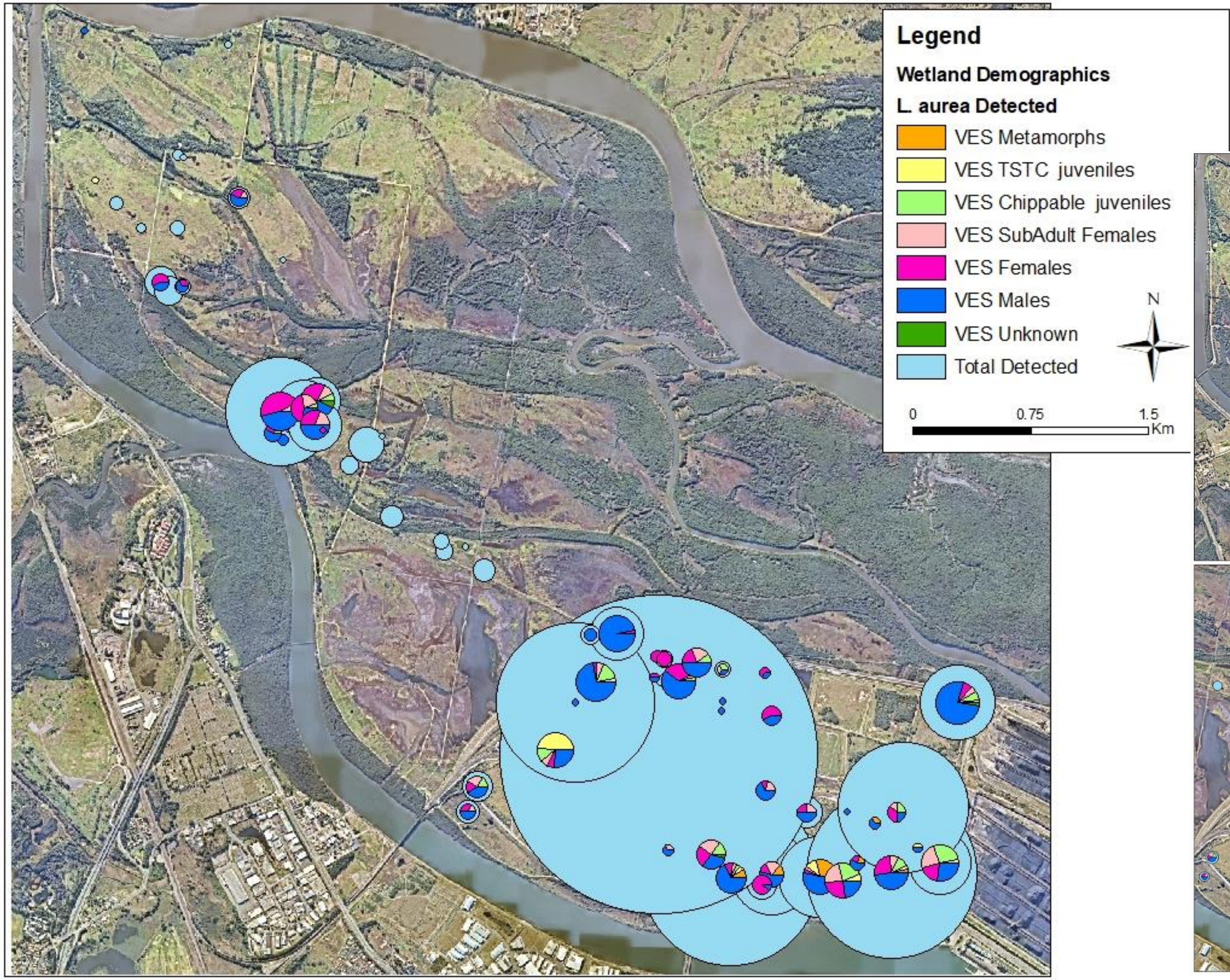
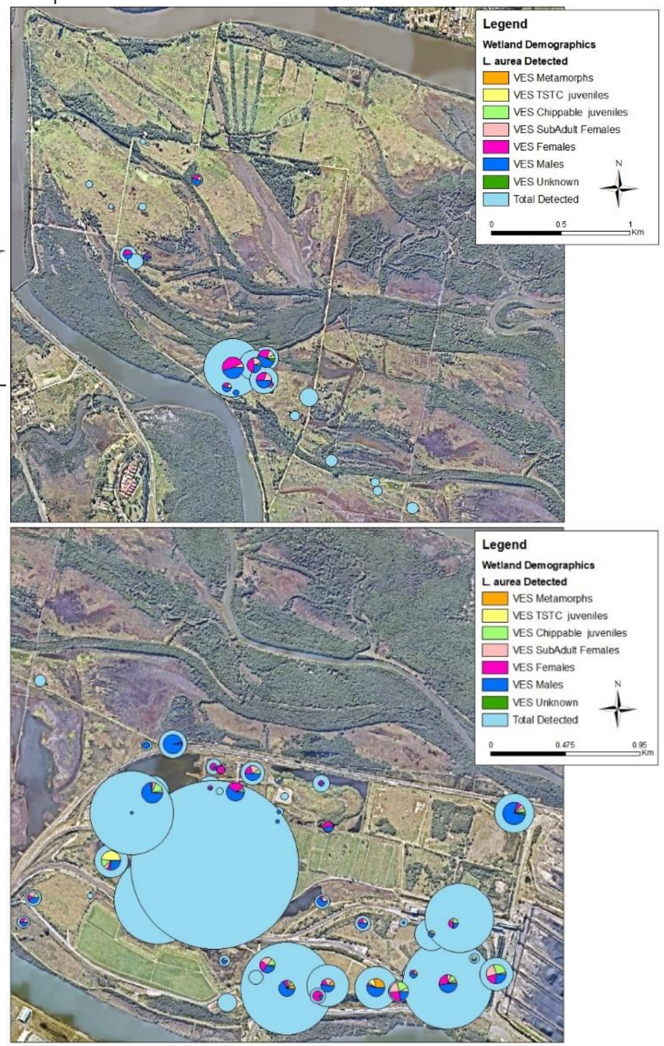


Figure 3.3.8: Demography of all detected frogs during the 2019-20 surveys, summed across all survey rounds. Close-ups on the right show Northern and Central Zones (upper) and Industrial Zone (lower).



3.4. Demographics

Proportions of juveniles, adult males, and adult females

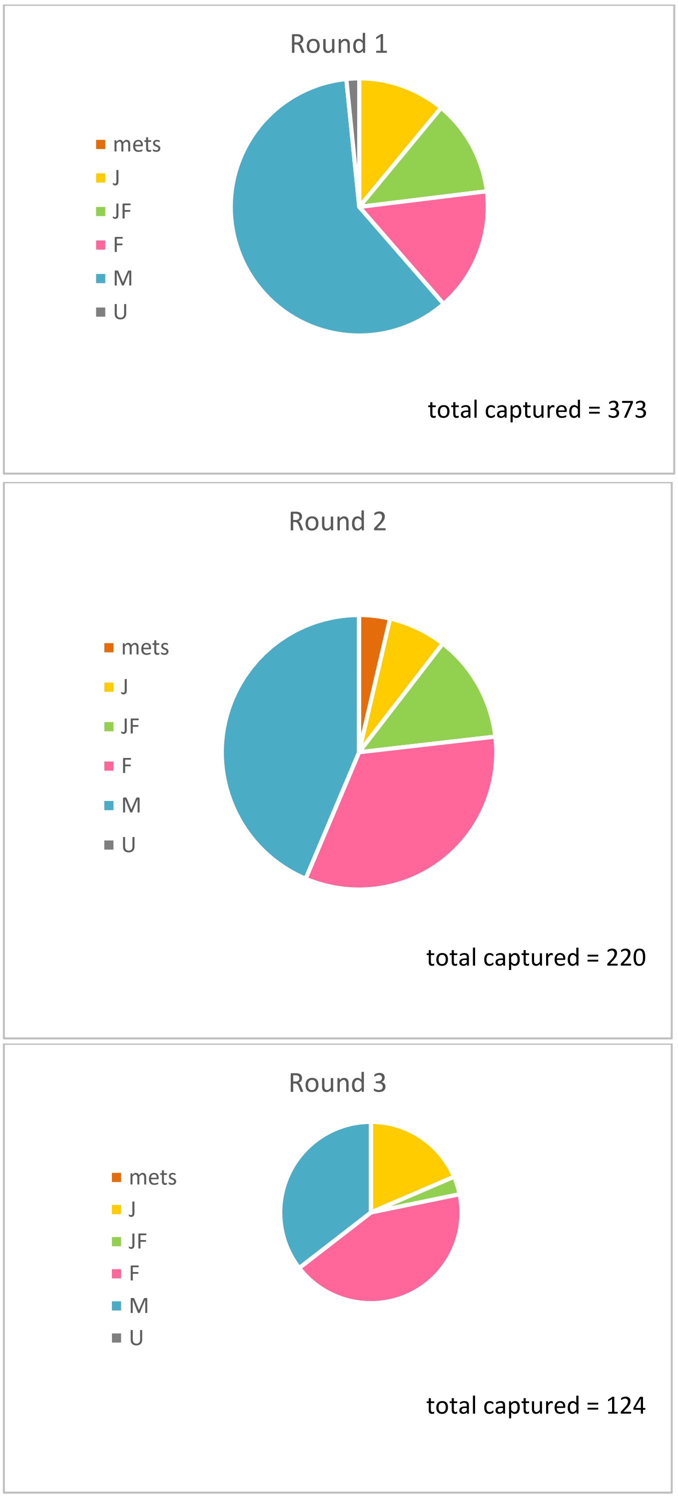
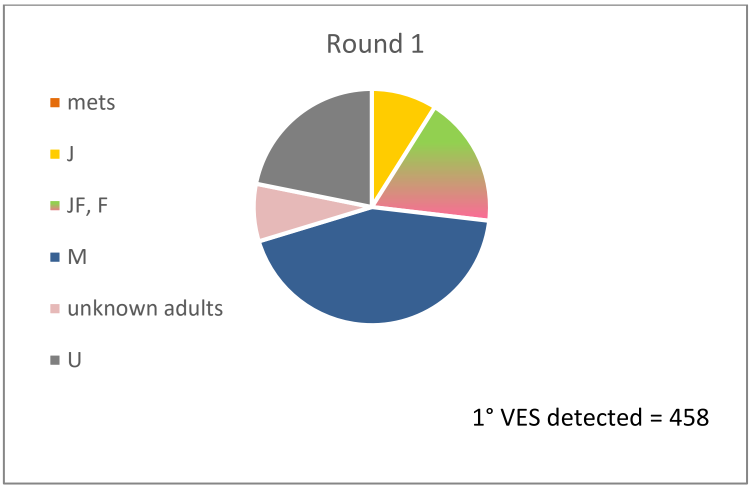
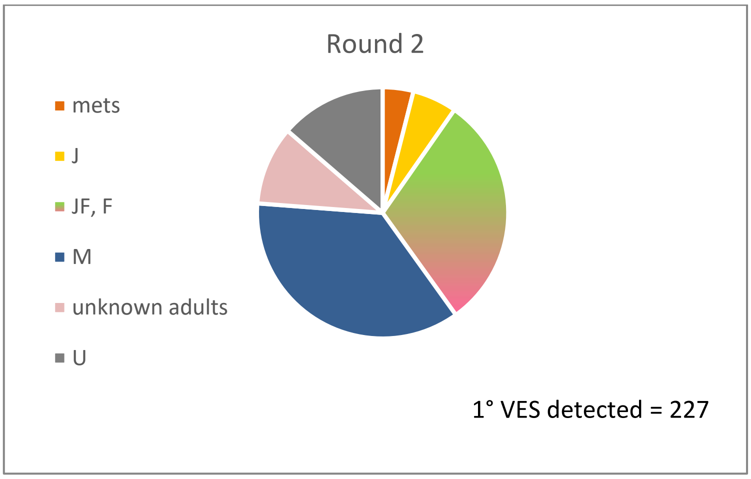


Figure 3.4.1: Summary demographics of all captured *L. aurea* (i.e. VES surveys, including recaptures and non-tagged individuals) for primary rounds only. Mets, metamorphs; M, adult males; J, juveniles; JF, subadult females; F, adult females; U, animals of unknown demography.

Figure 3.4.1 presents the demographic data in the preceding section, summarised for **captured** *L. aurea* across all wetlands, whilst Figure 3.4.2 shows the data for VES **detections**. Overall, the highest numbers of *L. aurea* were captured in round 1. Across all rounds, the majority of captures were adult males. A small proportion of juveniles were captured in round 1 and 2, suggesting that little breeding occurred in the first half of the season. In round 1, the small percentage of captured juveniles suggests that some offspring spawned in the previous season overwintered as tadpoles and continued development early this season. A larger proportion of juveniles were captured in round 3, though the largest breeding event occurred after summer rainfall in February 2020. In round 3, a large proportion of animals captured were also adult females; this likely occurred as females were responding to significant rainfall that occurred during this period in February, which subsequently triggered a large breeding event.

VES Demographics





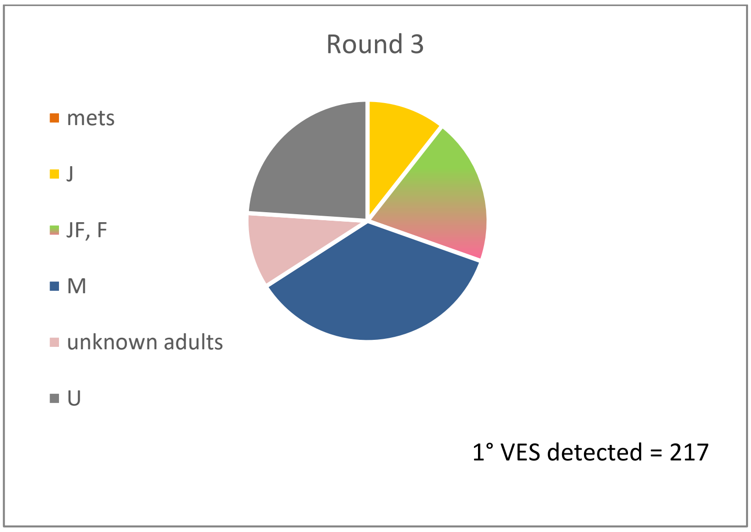


Figure 3.4.2: *L. aurea* detected during primary VES only, by round. M, adult males; F, adult females; JF, subadult females; J, juveniles; mets, metamorphs; unknown adults, *L. aurea* for whom demographic data was not collected (note that for these counts, subadult females and adult females are counted together).

Unique individuals

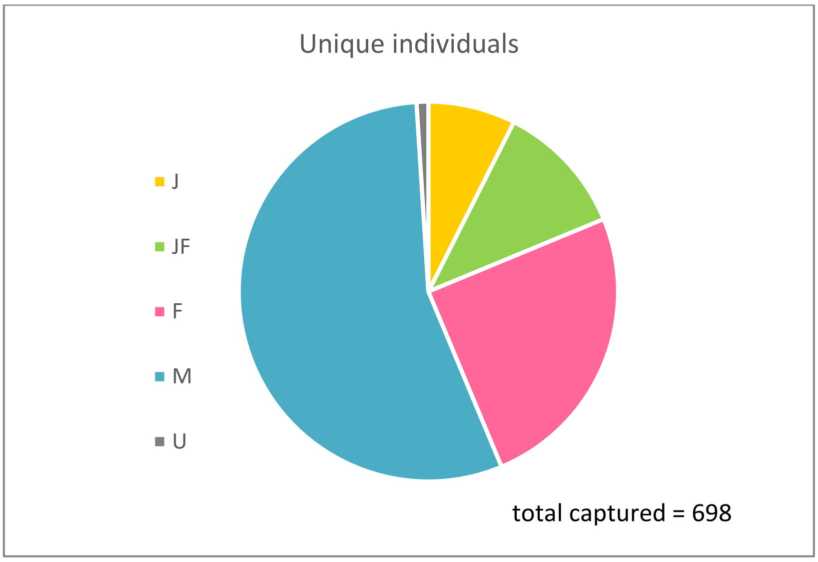


Figure 3.4.3A: Proportions and numbers of PIT-marked individuals captured during 2019-20 VES surveys. See Fig 3.4.1 for legend.

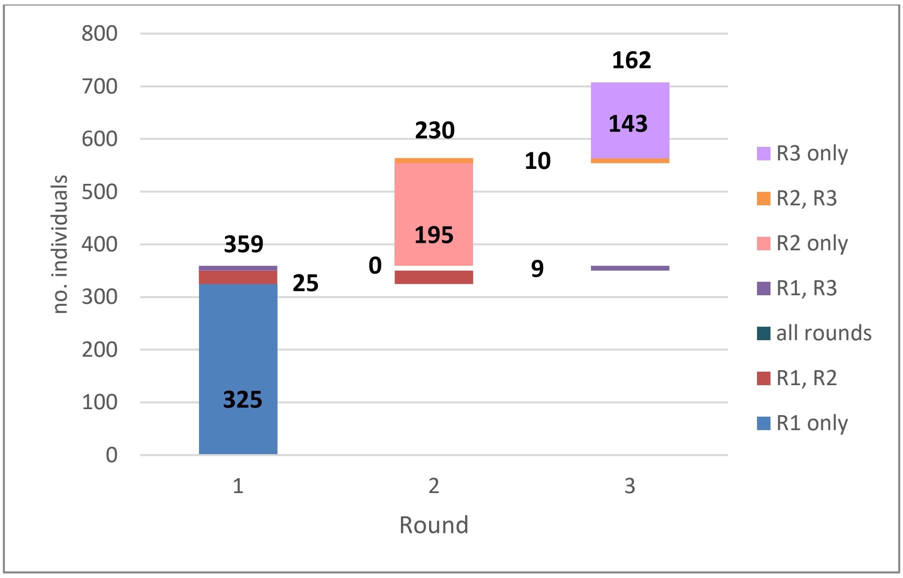
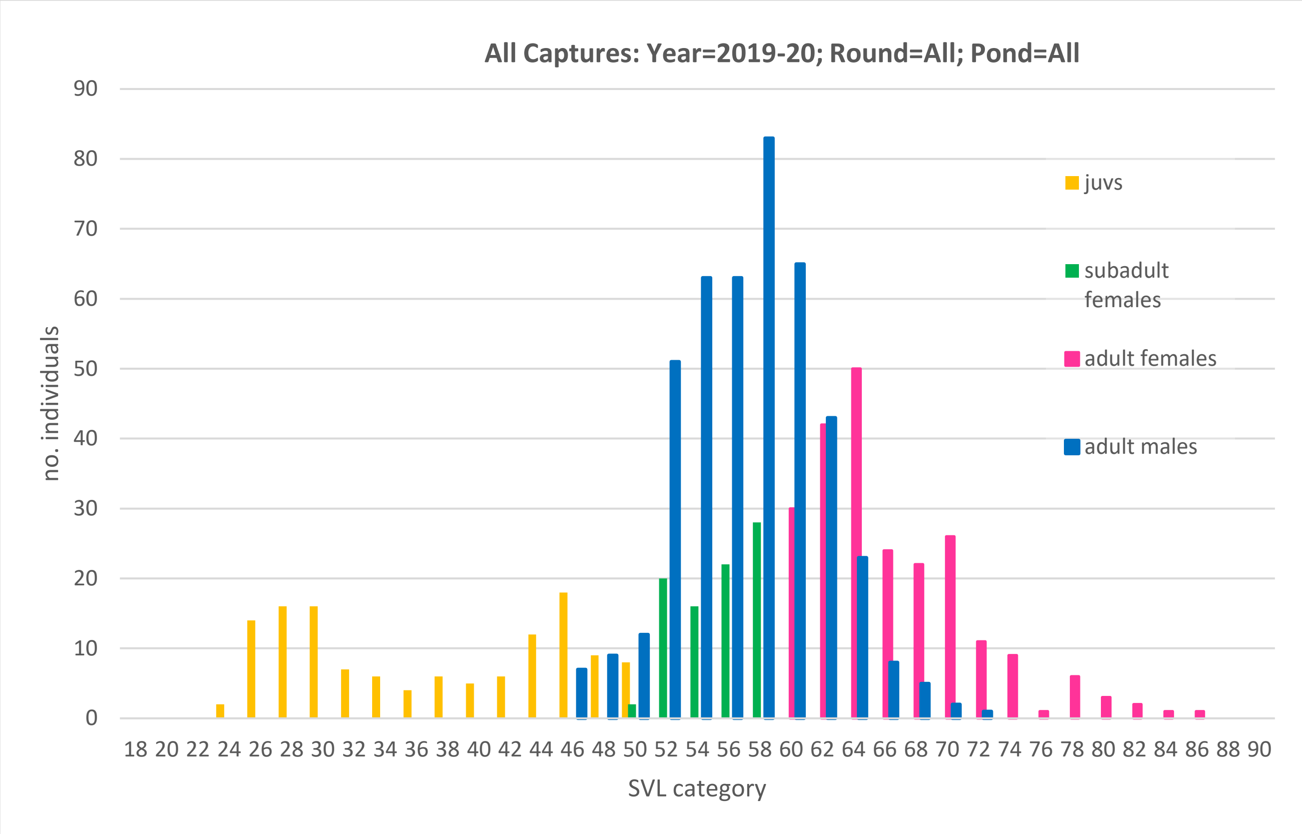


Figure 3.4.3B: Unique PIT-marked individuals captured in each of the three principal rounds, showing those animals caught in multiple rounds versus only one round.

Unique individuals are identified on the basis of PIT tags, and can only be ascertained from captured frogs. Figure 3.4.3A shows that, similar to the previous season, a large proportion of these were adult males, and that there were more adult females than sub-adult females. Only a small proportion of unique individuals were juveniles, despite the large number of juveniles recorded this season, which is primarily due to restrictions of tagging small frogs.

Figure 3.4.3B shows the pattern of capture of these individuals across the three complete rounds. More unique individuals were recorded in round 1 compared to any other round. A majority of individuals caught in each round were not caught again in the season, including 91% caught only in round 1, 85% caught only in round 2, and 88% caught only in round 3. Most recapture events occurred between successive rounds (e.g. between round 1 and 2, or between round 2 and 3), while a small number of individuals caught in round 1 were re-caught in round 3. No individual was captured in all three rounds.

Size classes and cohorts of captured frogs



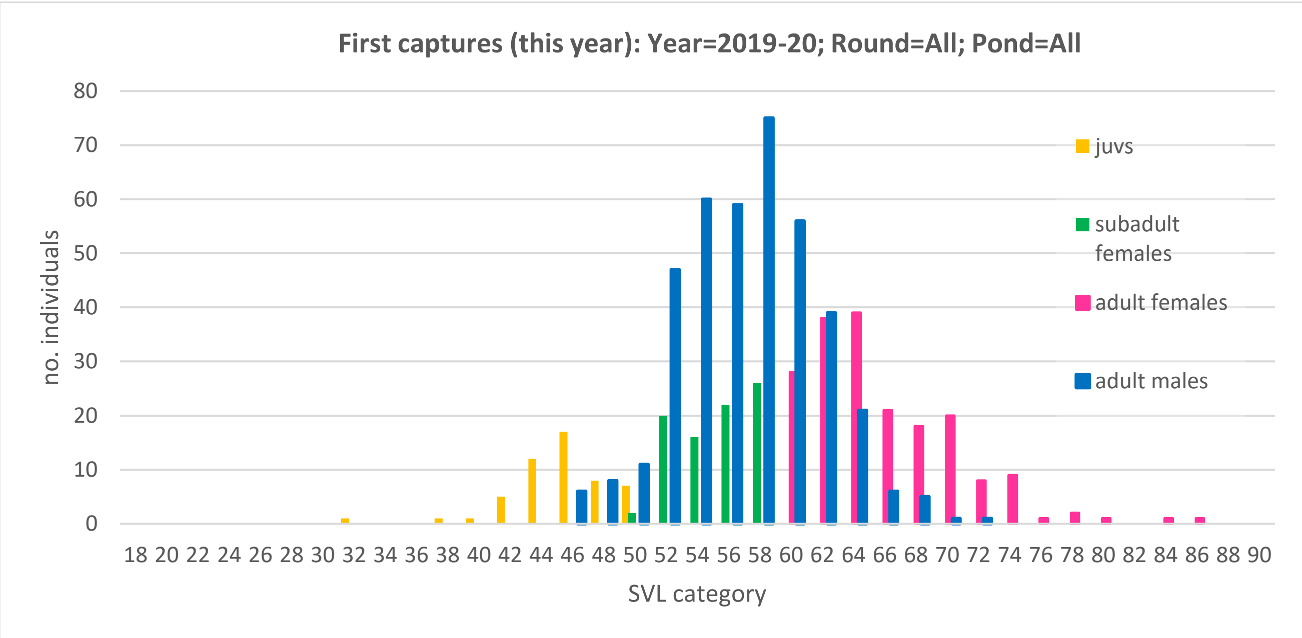


Figure 3.4.4: Frequency distribution of different sized animals captured during VES surveys. Size is measured by snout-vent length (SVL), and size categories are measurements 'binned' into 2 mm groups, i.e. the frequency of animals 56 mm > SVL >= 58 mm is shown in the column labelled '58'. **Top**; all captures where demographic data was recorded. **Below**: 'Frist captures' shows only unique PIT tagged individuals (generally, SVL > 40 mm), i.e. with recapture data removed.

Figure 3.4.4 shows the frequency distribution of SVL class (in 2 mm 'bins'). The difference between 'all

All captures, by round

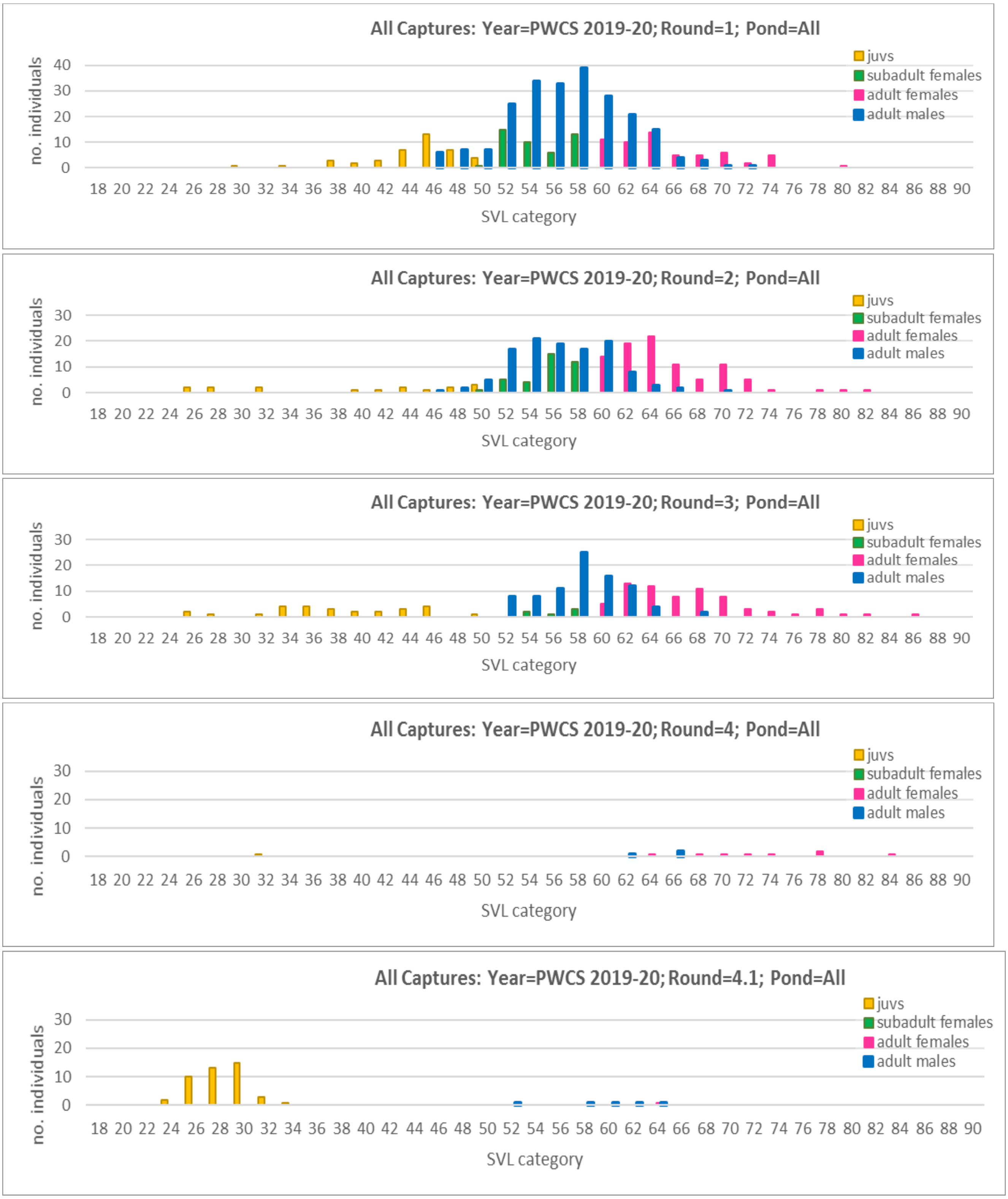


Figure 3.4.5: Frequency distribution of size classes, showing all captures for each survey round (VES). See Fig 3.4.1 for legend and Fig. 3.4.4. for explanation of size classes.

captures' and 'first captures' indicates (1) recaptured individuals (for SVL > 40 mm), and (2) the number of captured juveniles that were too small to mark with PIT tags. As with previous seasons, a large number of individuals captured were adult male, with most males being between 52 and 64 mm SVL. Relatively fewer adult and sub-adult females were captured. A large number of juveniles were captured, with sizes ranging between 24 and 50 mm SVL, though only a small proportion were above 40 mm SVL (the minimal size required for tagging).

Plots of size/frequency distribution over the different rounds (Figure 3.4.5) show a cohort of mid to large-sized juveniles in round 1 (mid-September); these have a modal SVL of ~46 mm and were likely spawned late in the previous season. By round 2 (November), this juvenile cohort had decreased in numbers, which suggests recruitment into the adult population. By this round, a new cohort of smaller juveniles had also emerged, potentially spawned early in this season, which had grown to become mid-large sized juveniles by round 3 (mid-February). Few juveniles were captured in round 4. However, a new cohort of juveniles with a modal SVL of 28-30 mm had emerged by round 4.1, most likely produced during the large rainfall event earlier in February.

In round 1, there was a greater number of adult males captured compared to adult females. However, there was an apparent decrease in adult males captured and an increase in adult females captured in round 2. Relatively fewer individuals were captured in round 3 in general, though a similar trend of greater adult male captures was again evident. Adults were still being recorded late in the season in Round 4 (March) and Round 4.1 (April), though breeding activity had likely ceased prior to this last round.

Captures by wetland

K29

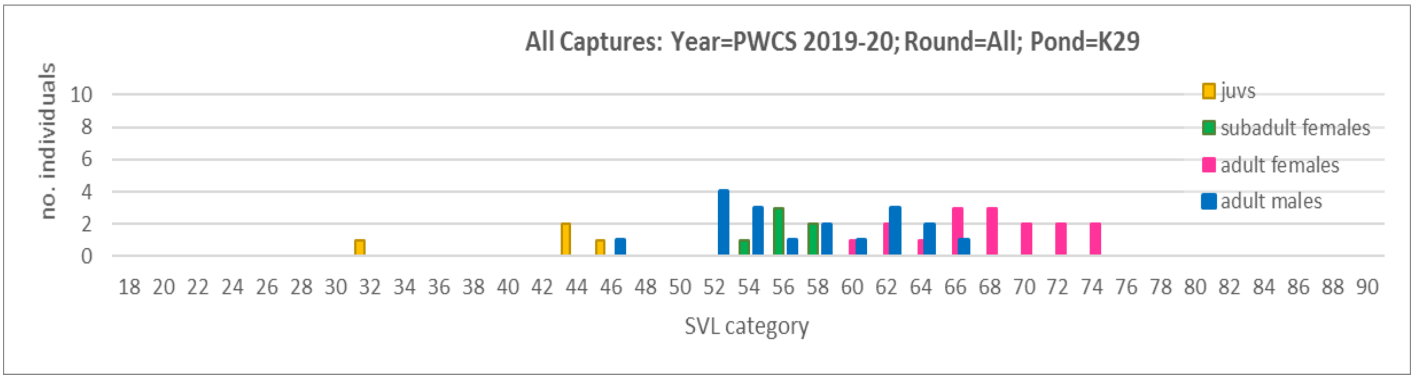


Figure 3.4.6: Frequency distribution of size classes at K29 for all captured animals, summed across all survey rounds. See Fig. 3.4.1 for legend and Fig. 3.4.4. for explanation of size classes.

The number of *L. aurea* detected at K29 was low compared to the previous three years, and the lowest since 2015-16. Among adult captures, a comparatively high proportion (~50%) were adult females (Figure 3.4.6). A very small number of mid to large sized juveniles were detected in round 1, suggesting that some individuals were spawned in the previous season and overwintered, though a small number of small juveniles were detected in round 2, suggesting that a breeding event may have also occurred early in the season. This is supported by the detection of both calling and *L. aurea* tadpoles at this wetland this season. However, as in previous years, it may also be possible that some juveniles were spawned in the nearby K105 wetlands and dispersed to K29 following metamorphosis.

K104

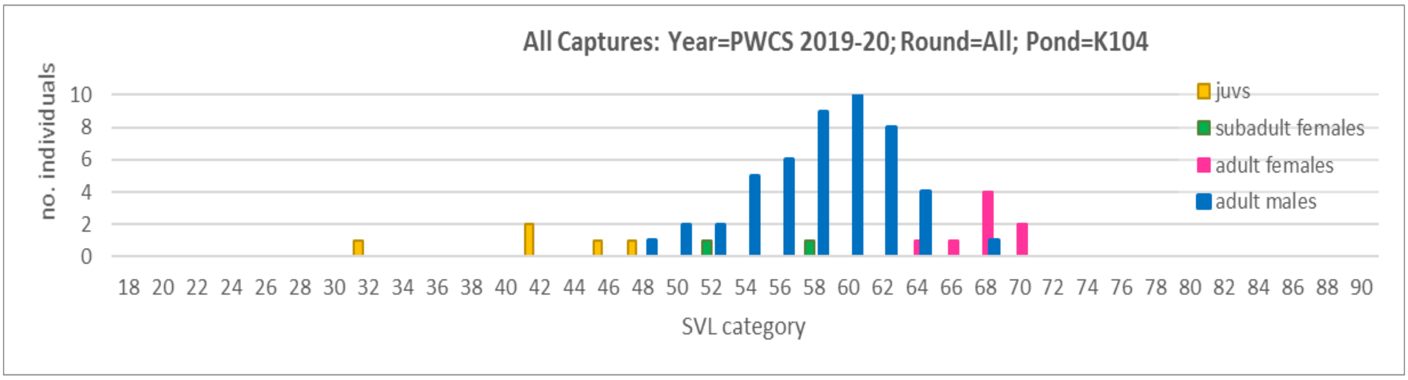


Figure 3.4.7: Frequency distributions for K104 wetland all captured animals, summed across all survey rounds. Refer to Fig. 3.4.6 for explanation of charts.

The number of adults captured at K104 was low compared to the previous season, with the majority of adults being male (84%). A small number of juveniles captured in round 1, suggesting that individuals were spawned in the previous season and overwintered. However, this wetland was the site of a large breeding event later in the season, as indicated by the large number of metamorphs detected in round 4, despite the presence of *Gambusia*. Both calling and *L. aurea* were detected at this wetland, further suggesting that breeding occurred here. Most adults were captured during round 1, with the lack of adults captured in round 2 and 3 likely due to the dry conditions that occurred throughout most of the middle of the season.

K22-23

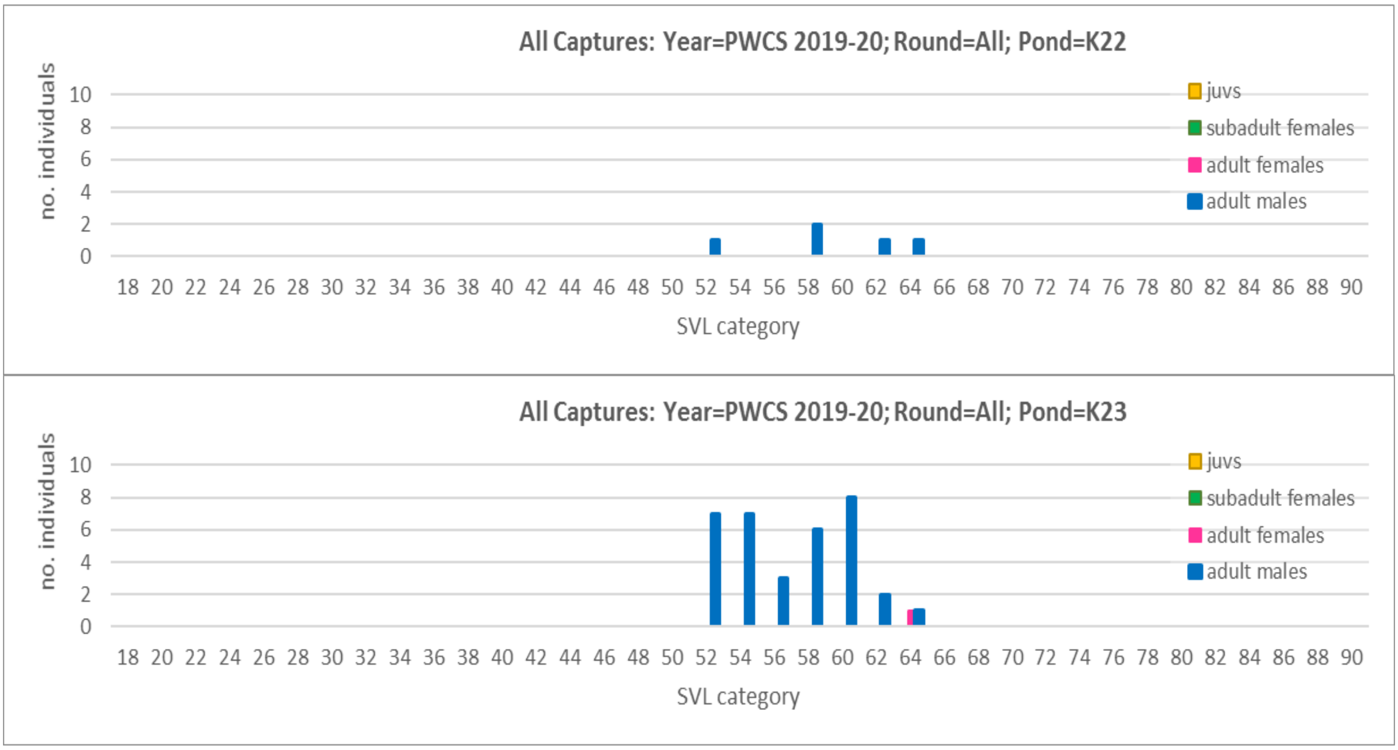


Figure 3.4.8: Top: frequency distributions for K22 and K23 wetlands all captured animals, summed across all survey rounds. Refer to Fig. 3.4.6 for explanation of charts.

K22 and K23 are a pair of wetlands in close proximity to each other, situated immediately north of the PWCS rail line and adjacent to the north shore of K105A. Historically, these wetlands have held large numbers *of L. aurea* and have been the focus of intensive CMR surveys; however, since 2016-17 numbers have been steadily less than in previous years (see discussion in Section 4.4, and data in Table 4.4.1). The total number of detected during the 2019-20 season was lower still for K22, though higher in K23 than in the previous year. The majority of adults were detected in round 4, with no adult females recorded at K22 and very few in K23 (2%). No tadpoles, metamorphs or juveniles were detected in either wetland across the season, though calling was recorded at both sites. It is possible that both these sites remain affected by grass fires that occurred in January 2019, when most aquatic and terrestrial vegetation were destroyed.

K105 wetlands

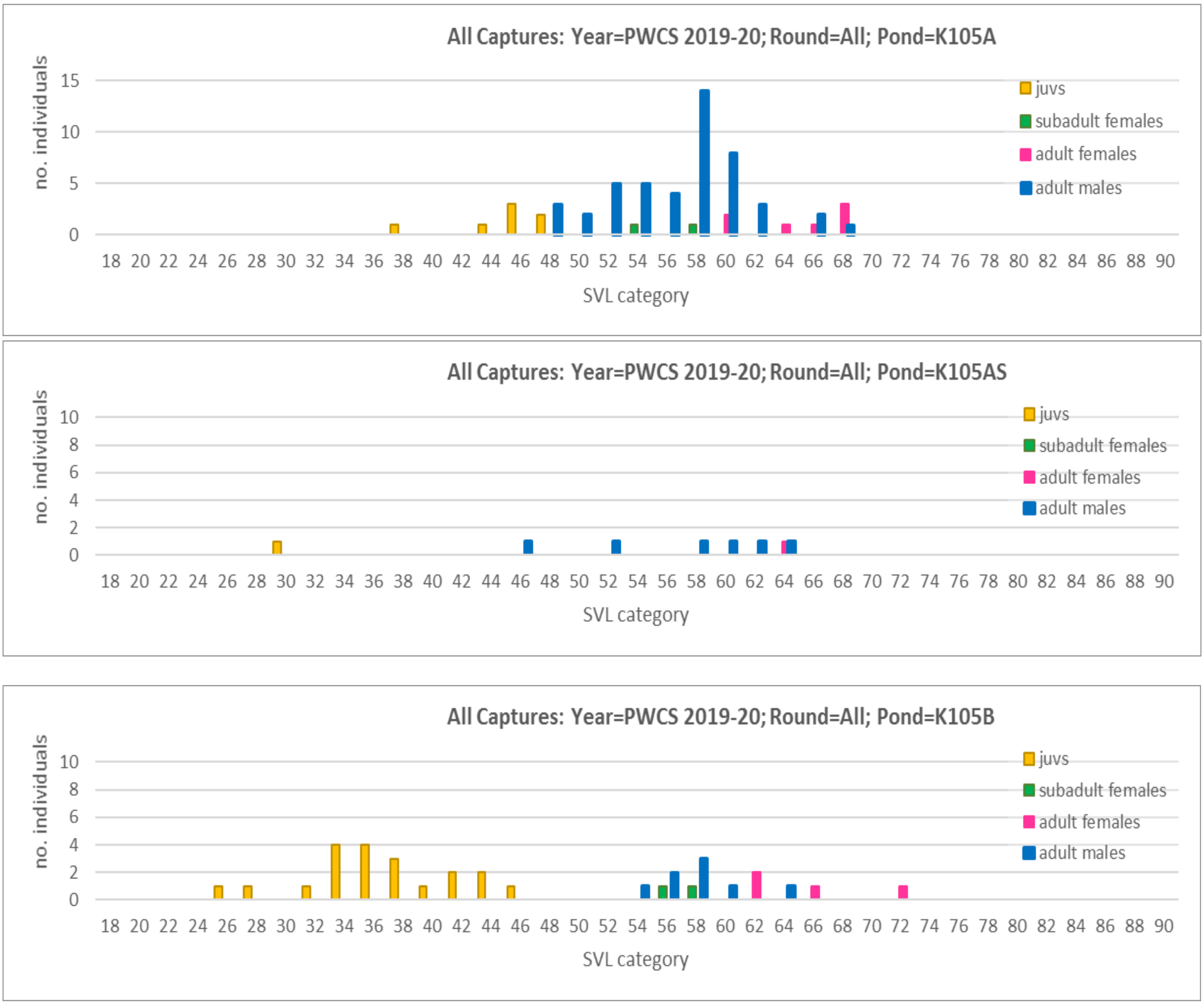
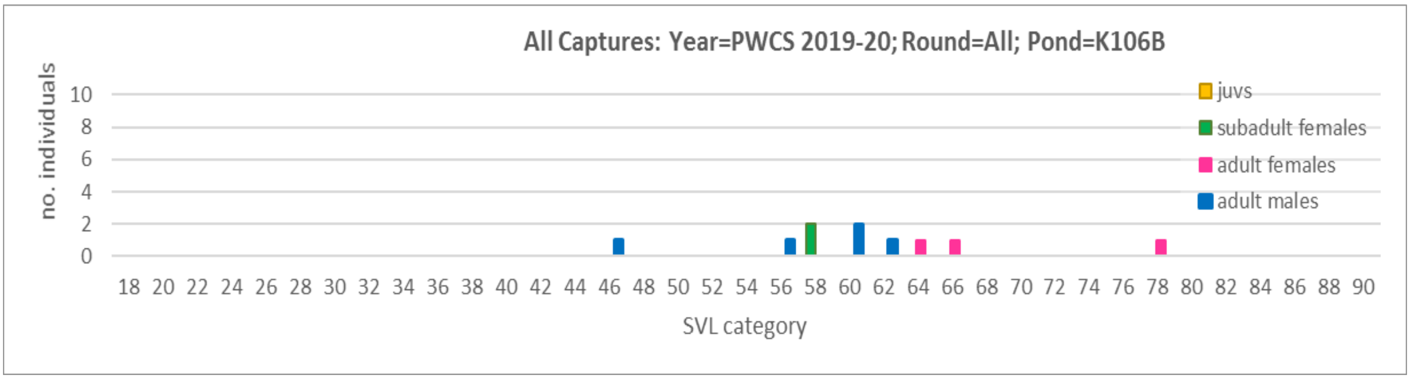


Figure 3.4.9: Frequency distributions for the large **K105** wetlands west of K29. Refer to Fig. 3.4.6 for explanation of charts.

'Deep pond' was originally a single very large wetland in the NW part of the Industrial Zone; it sits on the original substrate of the island (rather than on artificial substrate, as is the case with some other wetlands), and appears to be a remnant of the natural wetlands in this part of Kooragang that were present prior to substantial alteration by human activity. Following the completion of the NCIG infrastructure, this wetland was split into a larger northern part (**K105A)**, and a smaller southern part **(K105B)**. These are surveyed separately; furthermore, the southern part of K105A has been surveyed separately to the northern edges and is labelled **K105AS** in our analyses.

The largest number of adult captures occurred at K105A (50%), with comparatively less in K105B and K105AS. However, access to K105AS and K105B was impeded for the first half of the season by operational activities in these areas, with the result that search effort was substantially greater in Kk105A. In the previous season, K105A was the focus of a significant breeding event which resulted in large numbers of juveniles being present that year. This year, a small number of large juveniles were recorded in K105A in round 1, which are assumed to have overwintered. A well-defined cohort of juveniles was found at K105B in round 3 with a model SVL between 34 and 36 mm, which suggests that a breeding event occurred in the first half of the season. However, it was not until round 4 that large number of juveniles were detected; K105B and especially K105AS were apparently the location of a very large breeding event that followed the late summer rains in February. Interestingly, both calling and *L. aurea* tadpoles were only recorded at K105B (although this may also be at least partially a result of constrained survey effort). It is considered likely that dispersal of small juveniles between these three sites occurred in March and April following the large breeding event in late summer.

K106 wetlands



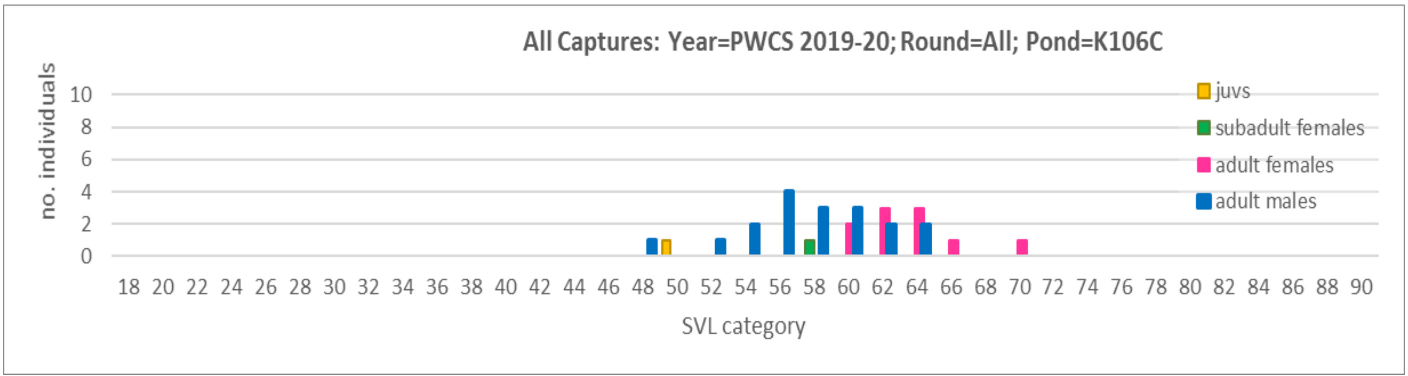


Figure 3.4.10: Frequency distributions for the K106B and K106C wetlands immediately west of K29. Refer to Fig. 3.4.6 for explanation of charts.

K106B is a temporary ephemeral wetland, and along with **K106A** has previously been a site of a very large breeding event (e.g. 2015-16). In this season, comparatively more adult females were detected at K106A than adult males, with the opposite being true for K106B. Despite calling being recorded at both wetlands, no juveniles were detected in any round.

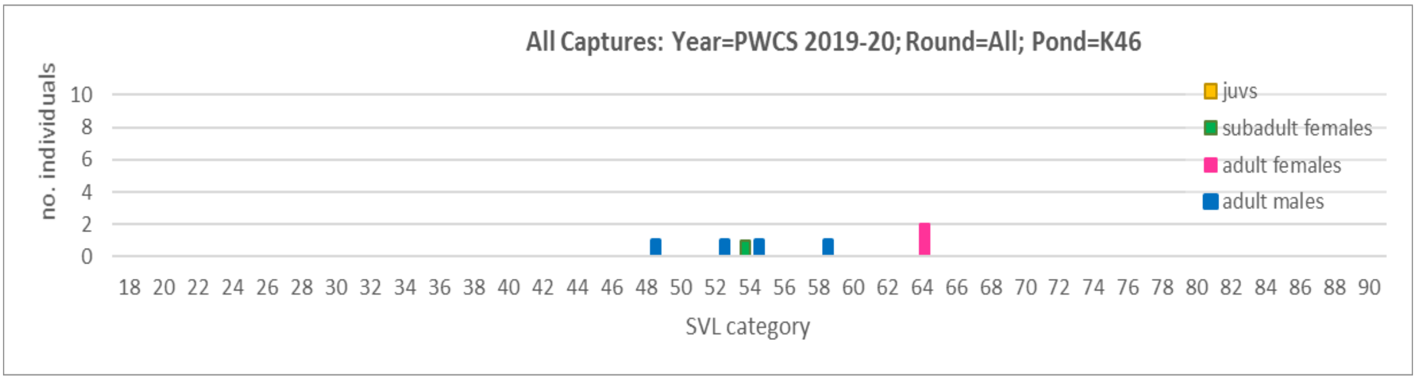
K106C is a small, deep wetland that is nearly permanent. It is well shaded and surrounded by emergent reeds, and has no *Gambusia*; in some ways, it might be considered a 'natural' version of the small refuge wetlands exemplified by the cluster ponds (C1 and C2). It usually contains a lot of adults, but this season had a small number (<30) (Figure 3.4.10). This was another wetland for which surveys were constrained following safety concerns relating to the nearby slag wall, and surveys were not conducted after round 2. One juvenile was detected in round 2, and since K106C is located close to the K105 wetlands, where breeding did apparently take place, it is possible that animals may have dispersed from K105A. (Figure 3.4.10). It must be noted that K106A, K106B, and K106C were all extensively damaged by the grass fire in January 2019, with most aquatic and terrestrial vegetation being burnt out. These wetlands were also partially affected by the ensuing ground fire for several months after January 2019. However, by May 2019 most of the aquatic vegetation had at least partially recovered.

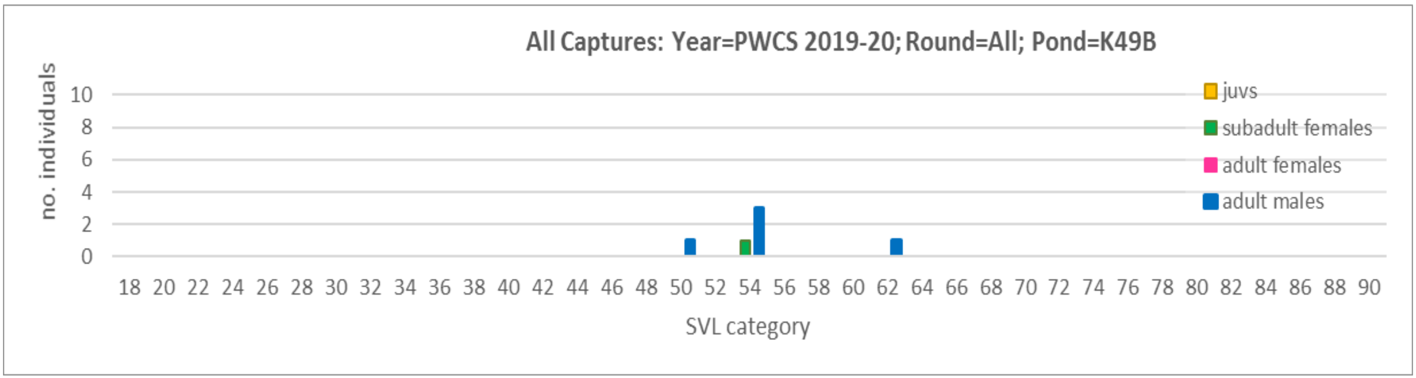
Southern Industrial Zone wetlands: A number of wetlands across the southern region of the Industrial Zone support important numbers of *L. aurea* (although the numbers are not as large as in the northern part of the Industrial Zone). Some of these are 'older' wetlands that have been established for many decades; they are shown in Figure 3.4.11.

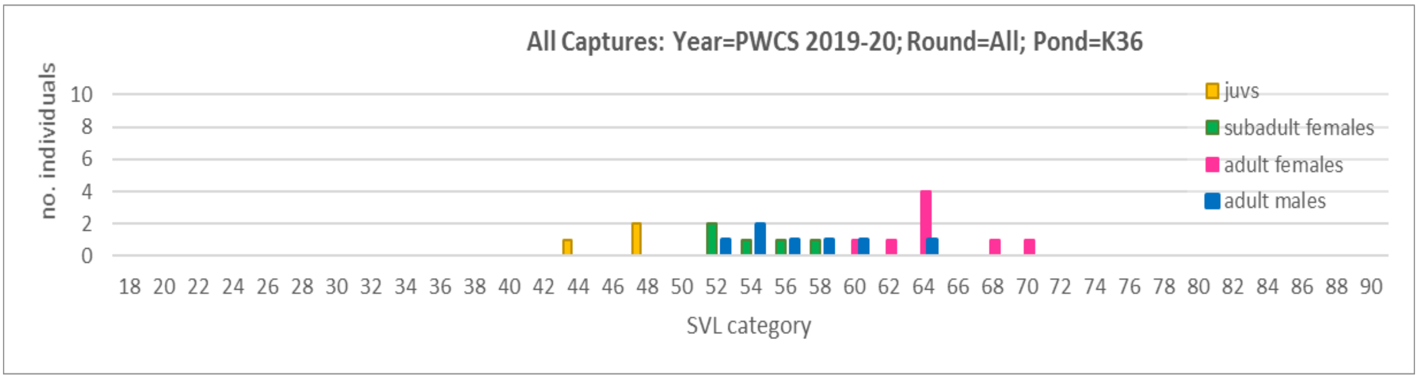
The number of adults present in K46 was low, similar to the previous year. While calling was recorded at this wetland, no juveniles were detected. Likewise, very few animals were detected at K49B, though *L. aurea* tadpoles were detected, suggesting breeding did occur at this wetland. A greater number of adults were detected at the adjacent K36. This site also contained mid to large sized juveniles, which were recorded in round 1, as well as some metamorphs detected in round 4. Each of these wetlands are classed as permanent wetlands and have retained water through the previous dry years; as such, they have consistently contained *Gambusia*. However, they have all appeared to have dried out prior to this year as no *Gambusia* could be detected.

K102 ('Boomerang' pond) is a very large wetland but generally has lower densities of *L. aurea* than the large wetlands (K29, K104 and K105A) in the northern region of the Industrial Zone. Metamorphs and juveniles were detected later in the season in round 4, indicating that breeding may have occurred following heavy rainfall in February, despite the presence of *Gambusia* at low densities.

Sothern Industrial Zone wetlands







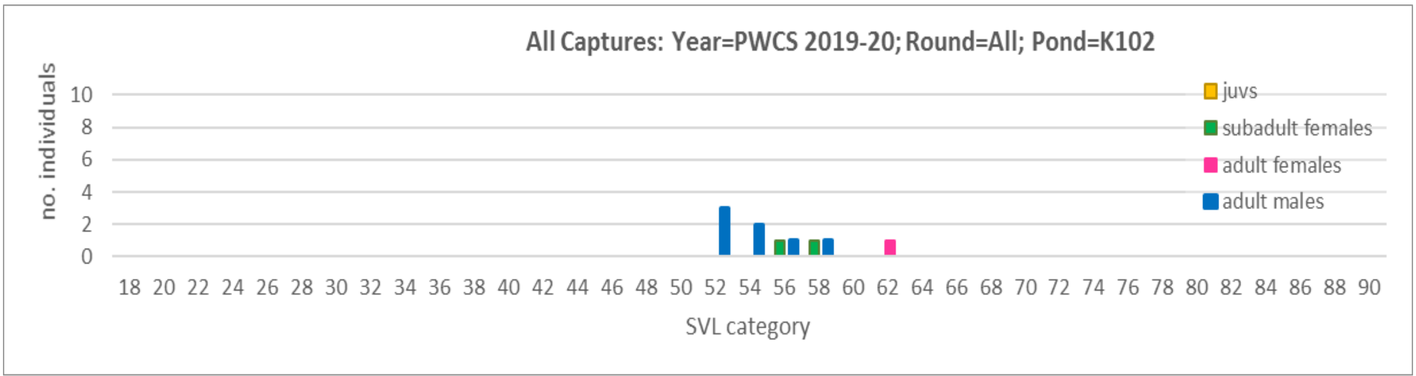


Figure 3.4.11: Frequency distributions for selected wetlands in the southern part of the Industrial Zone. Refer to Fig. 3.4.6 for explanation of charts.

Wetlands near NCIG Rail Loop

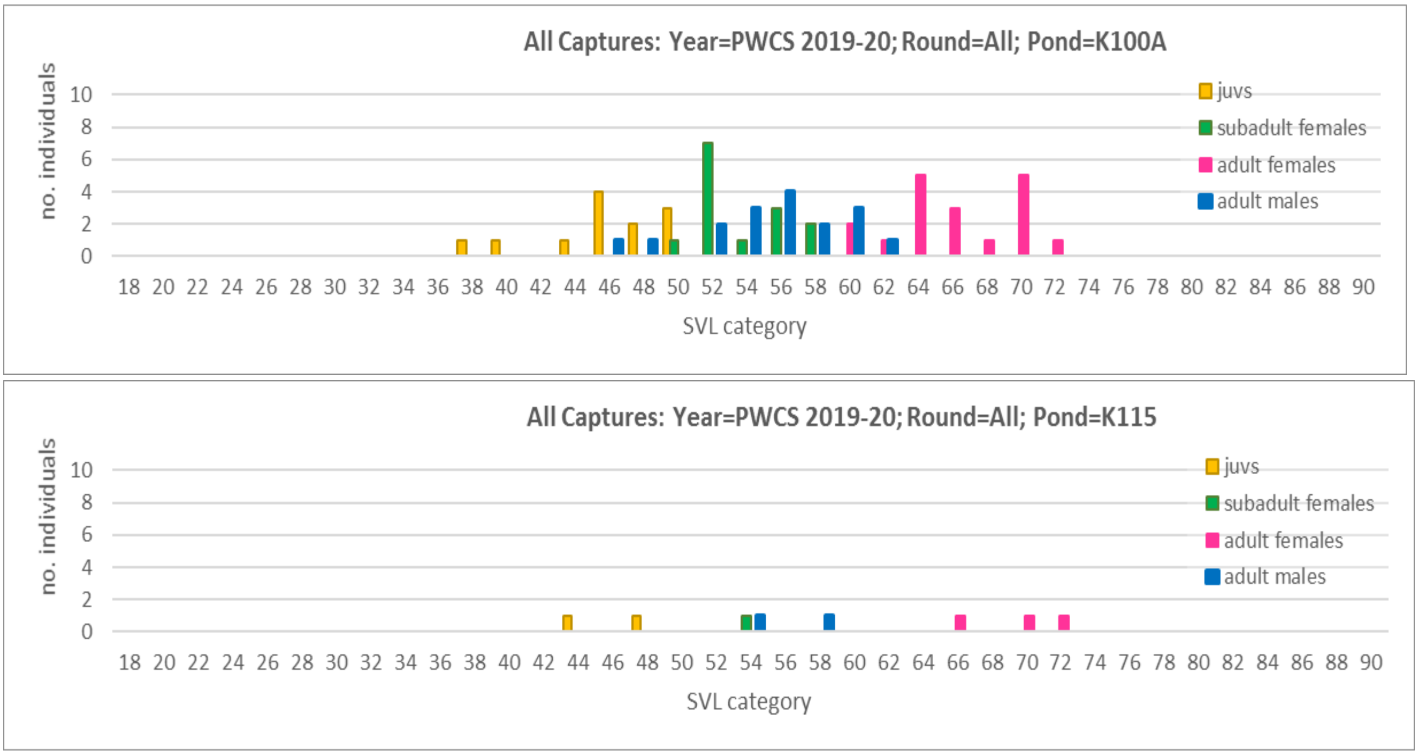


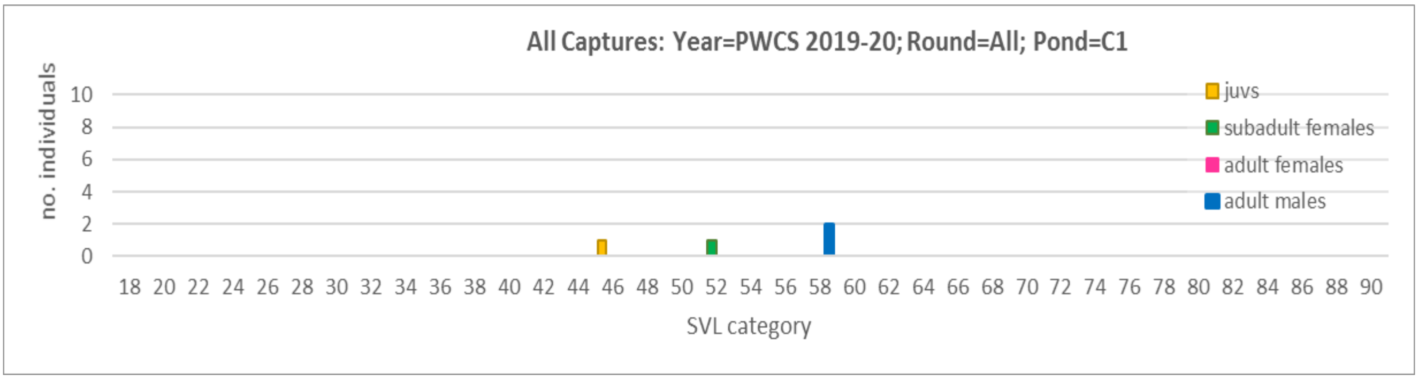
Figure 3.4.12: Frequency distributions for selected wetland immediately near the NCIG rail loop. Refer to Fig. 3.4.6 for explanation of charts.

K100A is a deep permanent wetland alongside Windmill Road, on the eastern edge of the Industrial Zone. It is surrounded by dense stands of *Casuarina* trees, and contains *Gambusia* in very high densities. It often has relatively large numbers of *L. aurea*, but does not appear to support breeding. Comparatively more adult and sub-adult females were captured than adult males at this wetland. A defined cohort of medium to large sized juveniles were also captured in round 1, though it is likely that these were spawned in the previous year in the nearby K111 wetland where breeding is known to regularly occur.

K115 is an artificial sump pond for the NCIG dump station. It is a managed wetland (water is pumped in and drained out according to the operational requirements of the dump station), and is mostly clear of aquatic vegetation except for a dense patch of *Typha* reeds at its western end. This year, it contained few adults and, in contrast to last year, few juveniles, which were detected in round 1. Breeding behaviours (such as calling, tadpoles, or metamorphs) have never been observed at K115, which was also apparent this year. However, it is close to K114 where breeding occurs consistently, and juveniles recorded at K115 may have been spawned here or in other HDC ponds close by.

Although the data is not shown here, during the 'dispersal event' in early autumn large numbers of very small juvenile *L. aurea* were found in the NCIG operational zone close to K115. It is believed that these animals were spawned in the nearby HDC ponds within the rail loop (K111-1114) and dispersed in large numbers following rain in early April. These animals were relocated to K102 and K36, consistent with NCIG operational protocols.

Cluster ponds



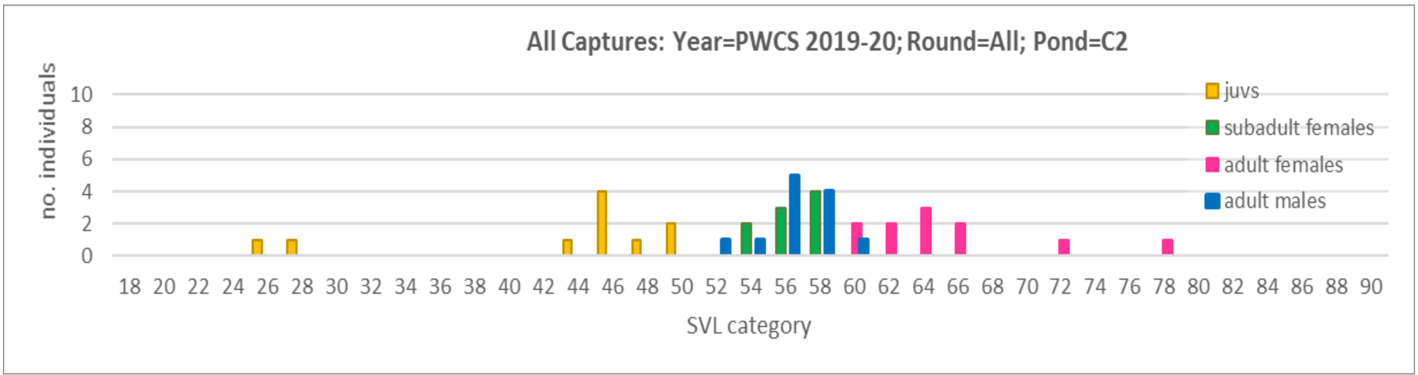


Figure 3.4.13: Frequency distributions for the PWCS 'Cluster Ponds'. Refer to Fig. 3.4.6 for explanation of charts.

The 'cluster ponds': these (**C1** and **C2**) are artificial wetlands installed by PWCS in the northern and southern regions of the Industrial Zone, respectively. Although they are small, they are deep permanent wetlands that can be managed to ensure they hold water during drought, and are free of *Gambusia*. C1 is part of the habitat mosaic close to K29, and has held relatively high densities of *L. aurea* for several seasons. When constructed, C2 was further away from other *L. aurea* habitat and until the construction of the HDC wetlands in 2015-17 contained no (or very few) *L. aurea*. With the construction of the HDC wetlands, C2 is now apparently part of a connected habitat mosaic, and supported *L. aurea* for the first time in the 2016-17 season.

In 2019-20, a small number of adults were detected at C1 in round 1 but were absent for the rest of the season (Figure 3.4.13). A small number of juveniles were captured in round 1. C1 is closely connected with K29 and K105A in terms of *L. aurea* movement, with many frogs moving between these sites. It is possible that juveniles dispersed to C1 from these nearby sites. It must be stated that C1 was extensively damaged by the grass fire that swept across the northern part of the Industrial Zone in early January 2019; the surrounding terrestrial vegetation was completely burnt, as was large parts of the aquatic vegetation. The tubs themselves were all partially melted and their capacity to hold water has been substantially decreased. Nonetheless, they still contained water and several *L. aurea* have been detected this year.

The number of *L. aurea* detected at the C2 cluster ponds has been steadily increasing since their first detection there in 2016-17. In 2019-20 more adult females were detected than adult males (Figure 3.4.13). A small number of juveniles were recorded in rounds 1, 2, 3 and 4, though no signs of breeding were apparent at this site (e.g. calling, tadpoles or metamorphs). The cluster ponds are the only well vegetated permanent wetlands in the *K10 South* and *K10 North* subregions. While they do not appear to provide breeding habitat themselves, they are close to several wetlands where high levels of breeding activity have been recorded in previous seasons (e.g. K121-123). It appears that the C2 clusters provide habitat for animals that have been spawned in those nearby wetlands, which could account for the relatively large number of sub-adult females, and could potentially be important refuges during extended dry periods.

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'New' cluster ponds

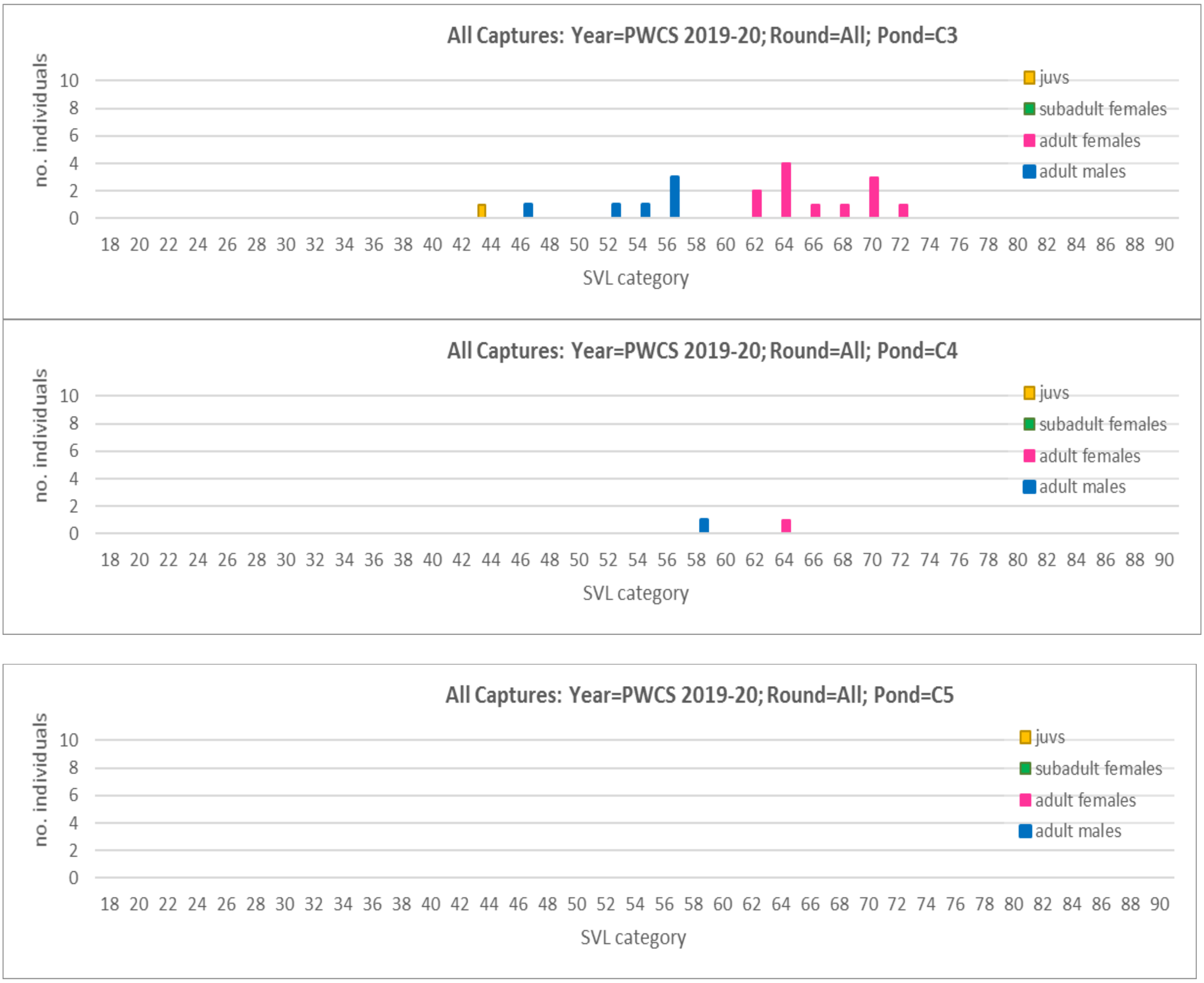
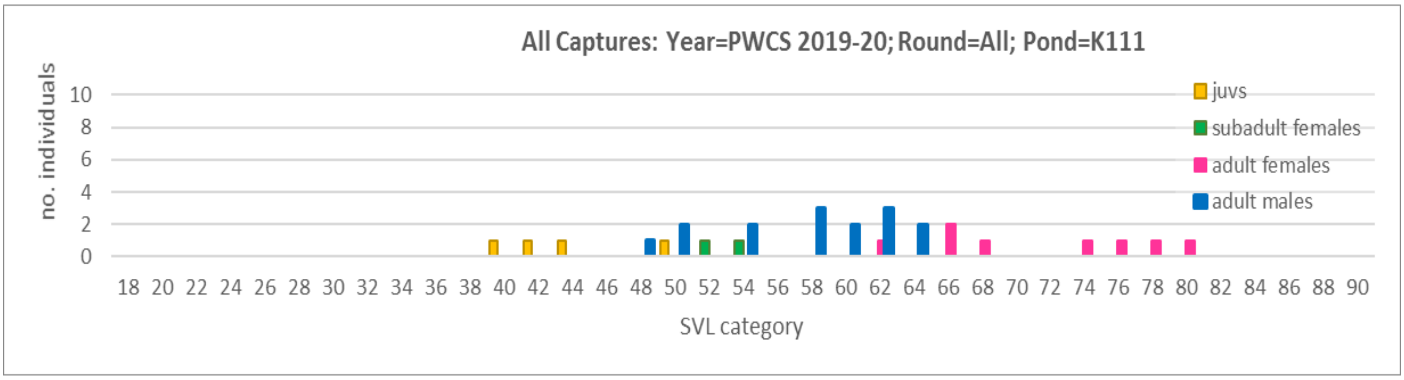
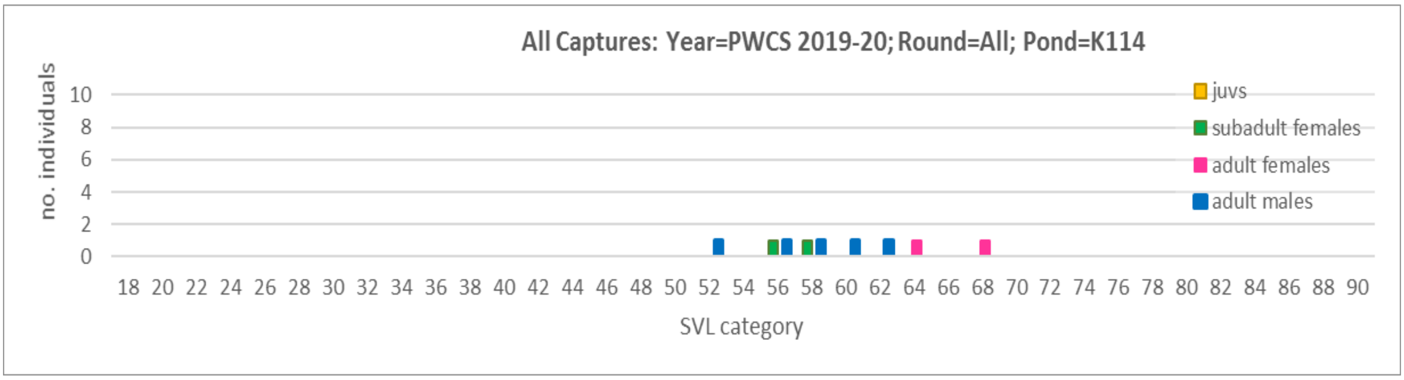


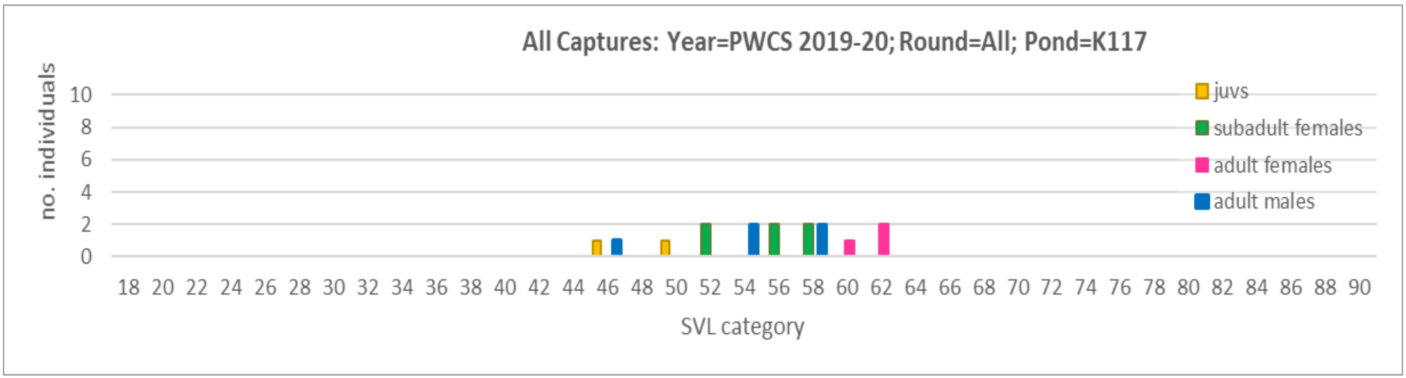
Figure 3.4.14: Frequency distributions for the 'new cluster ponds'. Refer to Fig. 3.4.6 for explanation of charts.

During the 2018-19 season, three new sets of smaller cluster ponds were installed in the *K10 South* and *K10 North* subregions. These new clusters each comprised two 4,500 litre tubs (comparable to the size of the tubs in each of the C1 and C2 clusters), and were located close to the HDC wetlands in those subregions. The intent was to provide additional wetlands that could function in the way that the C1 and C2 clusters appear to; i.e. providing small but permanent wetlands in their respective habitat mosaics. The C3 cluster was installed in *K10 South*, in between K121 and K122. The C4 and C5 clusters were located in *K10 North*; C4 in between K113 and K114, and C5 in between K111 and K112. Installation was November 2018. Last year, these new clusters were very quickly colonised by several species of frogs; *Litoria aurea*, *Litoria peronii*, *Limnodynastes peronii*, and *Limnodynastes tasmaniensis.* Across these three clusters, captures primarily occurred in C3 this year, with more than half of adult captures being female. A small number of juveniles were detected in C3 during round 1, though likely spawned in nearby wetlands.

HDC constructed wetlands







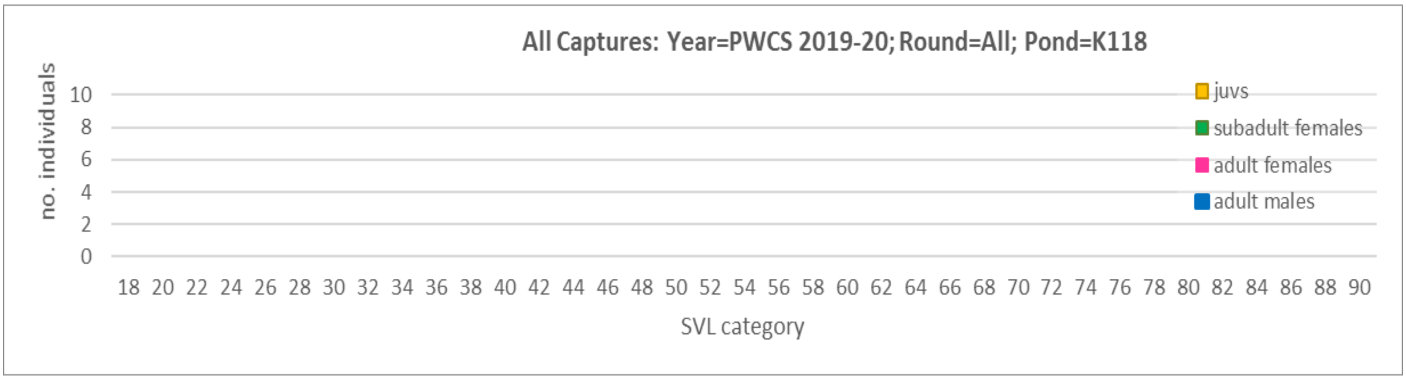


Figure 3.4.15: Frequency distributions for selected HDC constructed wetlands. Refer to Fig., 3.4.6 for explanation of charts.

In 2019-20 the number of adults detected was greater at K111 than K114, including some large adult females with SVL above 70 mm. In K111, a small number of metamorphs and juveniles were recorded in round 2, along with a large number of metamorphs and juveniles in round 4, indicating that a large breeding event took place here later in the season (confirmed by the presence of calling and *L. aurea* tadpoles). No juveniles were recorded at K114, though calling and *L. aurea* tadpoles were.

Few adult captures occurred at K117 while none occurred at K118. A small number of juveniles were recorded in K117 during round 1, though possibly linked to breeding events in nearby wetlands. However, breeding evidently took place in K118 this year, given the presence of *L. aurea* tadpoles.

K121-123

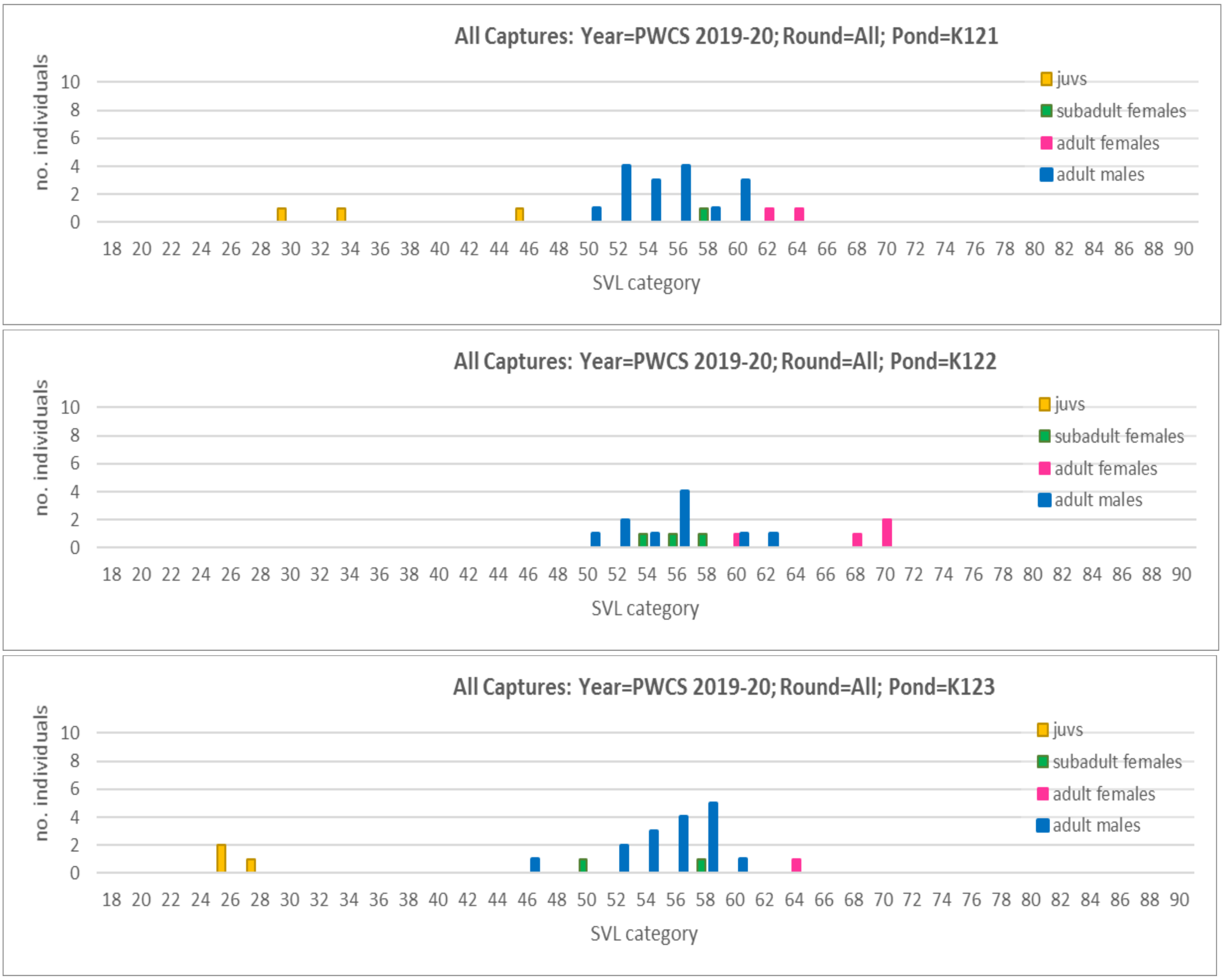


Figure 3.4.16: Frequency distributions for HDC constructed wetlands in the *K10 South* subregion. Refer to Fig., 3.4.6 for explanation of charts.

K121, **K122**, and **K123** were constructed in 2016-17 and are located in the *K10 South* subregion, adjacent to the rail loop. They lie between C2 and K36, and have greatly increased the amount of aquatic habitat in that area. Roughly equal numbers of adults were detected at each of these sites, the majority of which were males. A small number of metamorphs and/or juveniles were detected in K121 in round 1 and 3, and in K122 and K123 in round 2, suggesting that some breeding occurred in these wetlands earlier in the season. Very large numbers of juveniles were detected in K121 in round 4, along with large numbers of metamorphs across all three sites in this round. In addition, the presence of calling and *L. aurea* tadpoles across all three sites indicates that breeding events occurred at each. Together with C2 and K36, these findings indicate that the *K10 South* subregion now appears to provide a habitat mosaic capable of supporting both adult *L. aurea* and consistent breeding behaviour.

K108; the Eastern Ponds ('rail loop')

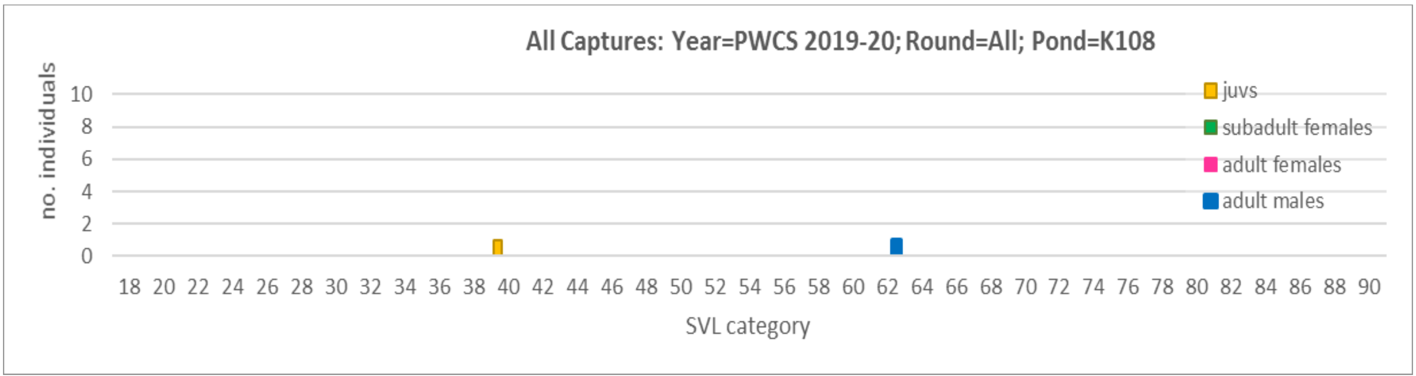


Figure 3.4.17: Frequency distributions for K108, the 'rail loop' wetland within the Eastern Ponds. Refer to Fig., 3.4.6 for explanation of charts.

The 'Eastern Ponds' are the only part of the *K10 North* subregion that are not recently constructed wetlands. **K108** – previously known as the 'rail loop' pond, is the largest wetland of these. Prior to the construction of the NCIG rail loop it was a large semi-permanent / permanent wetland that consistently held large numbers of *L. aurea*. However, in recent years the hydroperiod of this wetland has decreased from semi-permanent to seasonal to temporary, and has previously been dry for some entire seasons (e.g. 2016-17 and 2017-18). Only a small number of adults were detected at this site on 2019-20, all of which were males. One juvenile was recorded in round 1, though breeding is not thought to have occurred here, as neither tadpoles nor metamorphs were detected. It is likely that these juveniles were spawned in nearby wetlands such as K111. Note that K100A, which often contains large numbers of adults and appears to act as a refuge habitat, is very close to K108.

Area 2 Fences construction zone

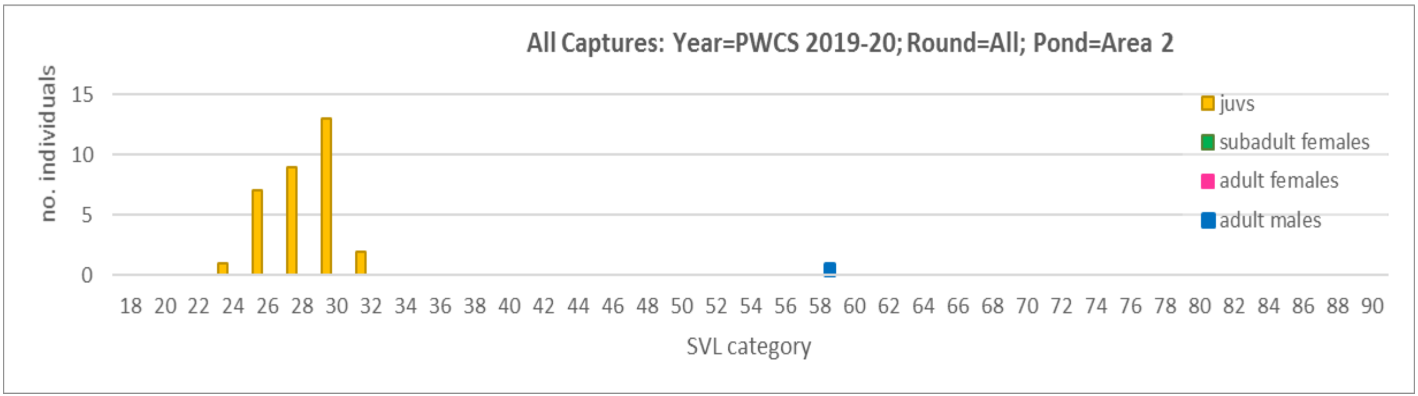


Figure 3.4.18: Frequency distributions for *L. aurea* captured in the Area 2 drift fence. Refer to Fig., 3.4.6 for explanation of charts.

In 2019-20, the fence successfully trapped appreciable numbers of small and very small *L. aurea* juveniles in round 4.1. Presumably, these juveniles were spawned during heavy rainfall in February 2019 in the nearby K105A and were using this terrestrial part of the Industrial Zone to disperse during additional rainfall at the end of the season.

NCIG CHEMP wetlands

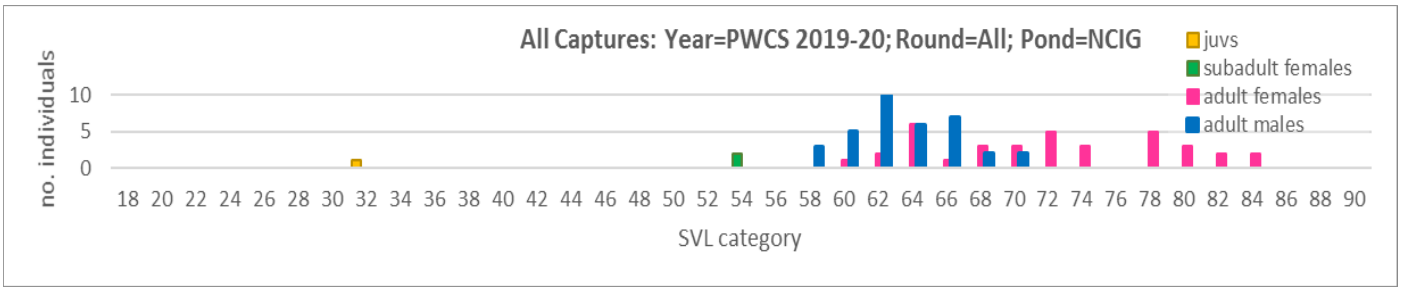


Figure 3.4.19: Frequency distributions for the NCIG CHEMP wetlands. Refer to Fig., 3.4.6 for explanation of charts.

The NCIG CHEMP wetlands were established in 2016 with the aim of providing suitable habitat for *L. aurea* in the northern region of Kooragang Island. At that time, the *L. aurea* population in the north of the island was very low (and had been for some 10 years previous; John Clulow, pers. comm.).

Not all of the NCIG CHEMP wetlands were surveyed as part of the island-wide surveys during the 2019-20 season; we surveyed eight of these wetlands in each survey round, and a further four were surveyed opportunistically in at least one round. In those surveys, most adult captures occurred at three ponds (NCIG-4.9, 7.2, and 7.3), including both adult males and females. No tadpoles, metamorphs or juveniles were detected across any of NCIG wetlands this season except for a small number of juveniles at NCIG-T13, while calling was detected at two ponds (NCIG-4.9 and 7.2). Currently, these wetlands appear to be providing important habitat in this region of the island, particularly considering the low number of *L. aurea* detected in the north in previous seasons, and this number appears to be increasing.

The BHP CHEMP are a focus of a separate research agreement and the demographics of those will be reported separately.

3.5. Longitudinal data: persistence and movement

The best measures of how animals move around the study site, and how long they live comes from repeated surveys at selected wetlands. This provides what is known as a longitudinal dataset, and is enabled by the use of PIT tags.

In order to maximise the power of analysis of persistence and movement, we combined several datasets from research programs focusing on *L. aurea* on Kooragang Island. Five of these were from the island-wide research program for the past five breeding seasons (i.e. 2014-15, 2015-16, 2016-17, 2017-18, and 2018-19), along with the current 2019-20 season. We also included datasets from other research and monitoring projects conducted at the UoN Amphibian Research Laboratory. Combined, these sources resulted in a single dataset with >10,000 individual records of *L. aurea* captures where the frog was marked with a PIT tag (Table 3.5.1).

Source data	Seasons spanned
Alex Callen (PhD study)	2013-17
IWS 2014-15 (James & Campbell)	2014-15
IWS 2015-16 (McHenry & Moses)	2015-16
SOS surveys (Beranek, King, McHenry)	2016-18
IWS 2016-17 (McHenry & King)	2016-17
IWS 2017-18 (McHenry & Maynard)	2017-18
SOS surveys (Beranek, Lenga, McHenry, Maynard	2017-18
IWS 2018-19 (McHenry & Maynard)	2018-19
SOS surveys (Beranek, Lenga, McHenry, Maynard	2018-19
IWS 2019-20 (McHenry, Maynard, Callen)	2019-20
SOS surveys (Beranek, Sanders, Lenga, McHenry, Maynard, Callen)	2019-20

Table 3.5.1: Individual study datasets used for the longitudinal analysis of persistence and movement in this section. Names shown for IWS (Island Wide Survey) studies are project officers for each season.

Persistence

As used here, persistence refers to the period between the first and most recent capture of frogs, of taggable size, that were caught on multiple occasions. It is related to concepts of age and longevity, but is not identical to them as the age when they were first tagged is usually unknown.

Table 3.5.2 summarises the persistence of *L. aurea* based on the extended dataset. It shows that 3,262 tagged frogs where recaptured at least once. Of these, a large majority (75%) had less than six months between their first and last capture. Only 825 frogs had more than six months between first and last capture; for most of these (15% of all recaptured frogs) the period was less than 12 months. Only 325 frogs were recaptured more than 12 months after first capture (10% of all recaptured frogs). The number of frogs that persisted more than 2 years was 53, while 12 of these lasted longer than 3 years. Four animals persisted for more than 4 years.

Calculation of survivorship rate should include data for animals that were tagged but never recaptured, which have not been analysed here. However, calculating the proportion of marked-and-recaptured animals in each time class gives a 'persistence rate' which might be expected to have a similar shape to a true survival rate (Table 3.5.2). Persistence of animals even one year beyond the time of first capture is low, and persistence beyond 2 years is very low.

It is important to note that persistence time categories are not age categories. For example, an individual may be a year old when it is first marked; if it survives more than 12 months after that, then it has reached its third year. As frogs are only marked when they are large juveniles (i.e. SVL > 40 mm), they are generally at least six months old and more often are older.

Time between first and most recent capture	*N*	persistence rate
x > 4 years	4	0.1%
3 < x < 4 years	8	0.4%
2 < x < 3 years	41	1.6%
1 < x < 2 years	272	10.0%
6 < x < 12 months	500	25.3%
x < 6 months	2437	
Total	3262	

Table 3.5.2: Persistence of *L. aurea* marked in multiple studies. See text for explanation.

Movement

		up to 2018-19	seen in 2019-20
Total animals tagged	9,552		
Total animals recaptured	3,274		
Total movements detected	593	514	79
Between K22-23	53	53	0
Within BHP_CHEMP (Ramsar Rd West)	346	326	20
Within NCIG_CHEMP stages	36	23	13
Other movements	160	112	46

Table 3.5.3: Movement detected from recaptures of *L. aurea* marked with PIT tags. Recaptures are taken to indicate a movement if they are located in a different wetland to the previous capture, i.e. they do not include movements within a wetland (which can be considerable). Data up to the 2018-19 season was detailed in the annual report for 2018-19 (McHenry et al. 2019) (middle column). Additional movements detected in the current 2019-20 season are summarised in the right-hand column. Most detected movements are between neighbouring CHEMP wetlands and between K22 and K23). The 'Other movements' involving movement detected in the current 2019-20 season are detailed in **Tables 3.5.4** and **3.5.5** and Figures 3.5.1 and **3.5.2**.

Approximately 18% of recaptures (593 out of 3,274) indicated *L. aurea* that moved between wetlands from one capture to the next (Table 3.5.3). Of those, most were relatively small movements, such as within the BHP

Animal ID (PIT #)	Sex	Initial date	Starting point	End date	Destination	Minimum distance (metres)
In/out of CHEMP (includes between NCIG stages)						
0007D3C8BE	M	27/03/2018	NCIG_4.9	19/09/2019	K3	1,218
0007A35266	M	15/01/2019	NCIG_7.2	24/09/2019	K58B	34
0007D1FA9F	F	05/02/2019	BHP-14B	12/09/2019	BHP-2A	1,022
In/out of K105A / K29 mosaic						
0007D20811	M	14/11/2017	K23	03/09/2019	K105A	52
0007D23B9B	M	10/12/2018	K105A	12/02/2020	K23	52
0007A10739	M	20/11/2017	K29	03/09/2019	K105A	201
0007D27201	M	12/12/2018	K29	03/09/2019	K105A	201
0007DDFABC	M	13/12/2018	K29	03/09/2019	K105A	201
0007DE3F1C	M	13/12/2018	K29	03/09/2019	K105A	201
0007DDFBCC	M	10/12/2018	K105A	28/11/2019	W4	162
000791EF0C	M	12/12/2018	K29	05/11/2019	C1	65
0007A0BABA	F	13/12/2018	K29	28/11/2019	W4	132
0007A0FD45	M	12/12/2018	K29	28/11/2019	K106C	61
Other movements						
0007DDFC40	M	18/02/2019	K100A	03/12/2019	K42	1,216
0007DE2861	F	12/09/2018	K100A	19/09/2019	K111	206
0007D245BA	M	29/10/2018	K100A	18/09/2019	K121	1,145
0007DDF9BC	M	28/01/2019	C2	18/09/2019	K123	51
0007DDF9C9	M	28/01/2019	C2	18/09/2019	K123	51

Table 3.5.4: Detected movement between study seasons, for data including 2019-20 season detections. Data sourced from multiple studies (see text). Coloured fonts show individuals where multiple movements were detected (compare with Table 3.5.5 and Figure 3.5.1, and with previous year's report).

CHEMP wetlands in the Ramsar Rd West subregion, between K22 and K23, or within stages in the NCIG CHEMP wetlands. Details of the 112 'other' movements detected from 2014 to 2019 are provided in the 2018-19 annual report (McHenry et al. 2019). A further 46 'other' movements were detected in the 2019-20 season and these are shown here; in Table 3.5.4 (for movements involving previous seasons) and Table 3.5.5 (for movements within the current season), and in Figures 3.5.1 and 3.5.2 respectively.

Most movements between the previous and current seasons occurred within Zones. This included the movement of adult males from K29 into wetlands that are understood to form a consistent habitat mosaic in the Industrial Zone (K29, Deep pond, C1, and K106), as well as movement from K100A and C2 into K121-K123. Movements between the northern and southern Industrial Zones was also detected between K100A and K42, while movement was also detected out of the NCIG-CHEMP wetlands (4.9 and 7.2) to K3 and K58B. Most animals moved between wetlands less than 200m apart, though four individuals (three males and one female) did make much larger movements of more than 1000m.

Animal ID (PIT #)	Sex	Year of first capture	Starting point	Year of recapture	Destination	Minimum distance (metres)
	In/out of CHEMP (includes between and within NCIG stages)					
00078A9A20	F	07/11/2019	NCIG-7.3	17/02/2020	K58B	26
00078A9A20	F	17/02/2020	K58B	20/03/2020	NCIG-7.2	24
In/out of K105A / K29 mosaic						
0007A09ABD	M	12/02/2020	K22	13/02/2020	K105A	103
0007DF2690	M	03/09/2019	K105A	12/02/2020	K23	52
0007DF3103	M	03/09/2019	K105A	12/02/2020	K23	52
0007DF2C7C	M	27/11/2019	K29	12/02/2020	K23	367
0007DF2520	F	27/11/2019	K29	19/03/2020	K105A	201
00079F5A81	M	03/09/2019	K105A	12/09/2019	K106C	170
0007D1893F	M	03/09/2019	K105A	12/09/2019	K29	201
0007DF24B8	M	03/09/2019	K105A	28/11/2019	K106C	170
0007E032EF	M	13/02/2020	K105A	19/03/2020	K106B	26
0007DF25CF	M	29/11/2019	K115	13/02/2020	K105A	1,357
0007E04B1D	F	30/01/2020	K100A	19/03/2020	K105A	1,885
0007DF2CBF	F	03/12/2019	K31	04/03/2020	K106A	410
0007DF23BB	F	27/11/2019	K29	04/03/2020	W5	65
0007DF2406	F	12/09/2019	K29	04/03/2020	K106A	173
0007DF25DD	F	27/11/2019	K29	04/03/2020	W5	65
0007DF2B7D	F	12/09/2019	K29	19/03/2020	K106B	186
0007DF24D5	F	28/11/2019	K106C	13/02/2020	K106A	154
0007DF25E1	M	12/09/2019	K106B	28/11/2019	W4	80
Other movements						
0007DDF590	M	11/09/2019	K104	12/02/2020	K23	1,759
0007DDF619	M	08/09/2019	K102	12/02/2020	K23	1,089
0007E0B2B7	F	12/02/2020	K105B	22/04/2020	K105AS	128
0007DF2D42	M	19/09/2019	K112	29/11/2019	K111	183
0007DF23D8	F	13/09/2019	K36	17/02/2020	C3	367
0007DF269D	M	13/09/2019	K36	25/11/2019	C2	737
0007DF2D78	F	25/11/2019	K122	04/12/2019	K46	1,615
0007E0B396	M	17/02/2020	K121	03/03/2020	C3	147

Table 3.5.5: Detected movement within the 2019-20 study season. Data sourced from multiple studies (see text). Coloured fonts show individuals where multiple movements were detected (compare with Table 3.5.4 and Figure 3.5.2)

Within the 2019-20 season (Table 3.5.5), movements were made by nearly an equal number of adult males and females. Most detected movements were between Deep pond, K29 and K106 that form a mosaic within the Industrial Zone. In particular, several of these movements were of adult females out of K29, providing support for the suggestion that *L. aurea* will move from 'refuge' habitats (e.g. K29) to habitats that provide suitable breeding habitat at a particular time. Movements were also detected out of this mosaic to K23, which is nearby. Movements between the northern and southern Industrial Zones was also detected, including movement out of K100A and K115 into K105A. Movements between wetlands in the Southern region of the Industrial Zone show connectivity in this area, although at a lesser extent that in the Northern region.

In the Northern Zone of the island, the movement by an adult female from a permanent wetland (NCIG-7.3) to a nearby ephemeral wetland (K58) following heavy rain in early February, and then back to a permanent wetland (NCIG-7.2) in early autumn involved only small movements but demonstrates one of the breeding strategies used by *L. aurea*. Most movements were between wetlands less than 200 m apart. Larger movements of more than 1000 m were also detected, though these movements occurred over several months:

I. K102 to K23 (1,089m)
II. K155 to K105A (1,357m)
III. K122 to K46 (1,615)
IV. K104 to K23 (1,759m)
V. K100A to K105A (1,885m)

The movement of individuals between K104 and K23 shows that, despite its distance from other surveyed wetlands, K104 is not completely isolated. This connectivity of K104 to other wetlands was also found in the previous season, where individuals were found moving between K104 and K29.

Most movements detected since 2013 have been less than 500 m distance (94%), with most being less than 100 m. However, 26 movements have been greater than 1,000m (Table 3.5.6).

minimum distance of movement (m)	count (*n*)
0-100	325
101-500	232
501-1000	10
>1000	26

Table 3.5.6: frequency of movement distance for movements detected since 2013.

Most (60%) movements detected since 2013 involve males, eight of which were first caught as juveniles (Table 3.5.7). Of the 164 females detected, 17 were first caught as juveniles.

Age/Sex class	n
J (J)	70
J (M)	8
J (F)	17
M	350
F	147

Table 3.5.7: Age/sex class summary of the 595 movements detected between 2012 and 2020. Brackets indicate sex at maturity for animals first captured as juveniles. See text for discussion.

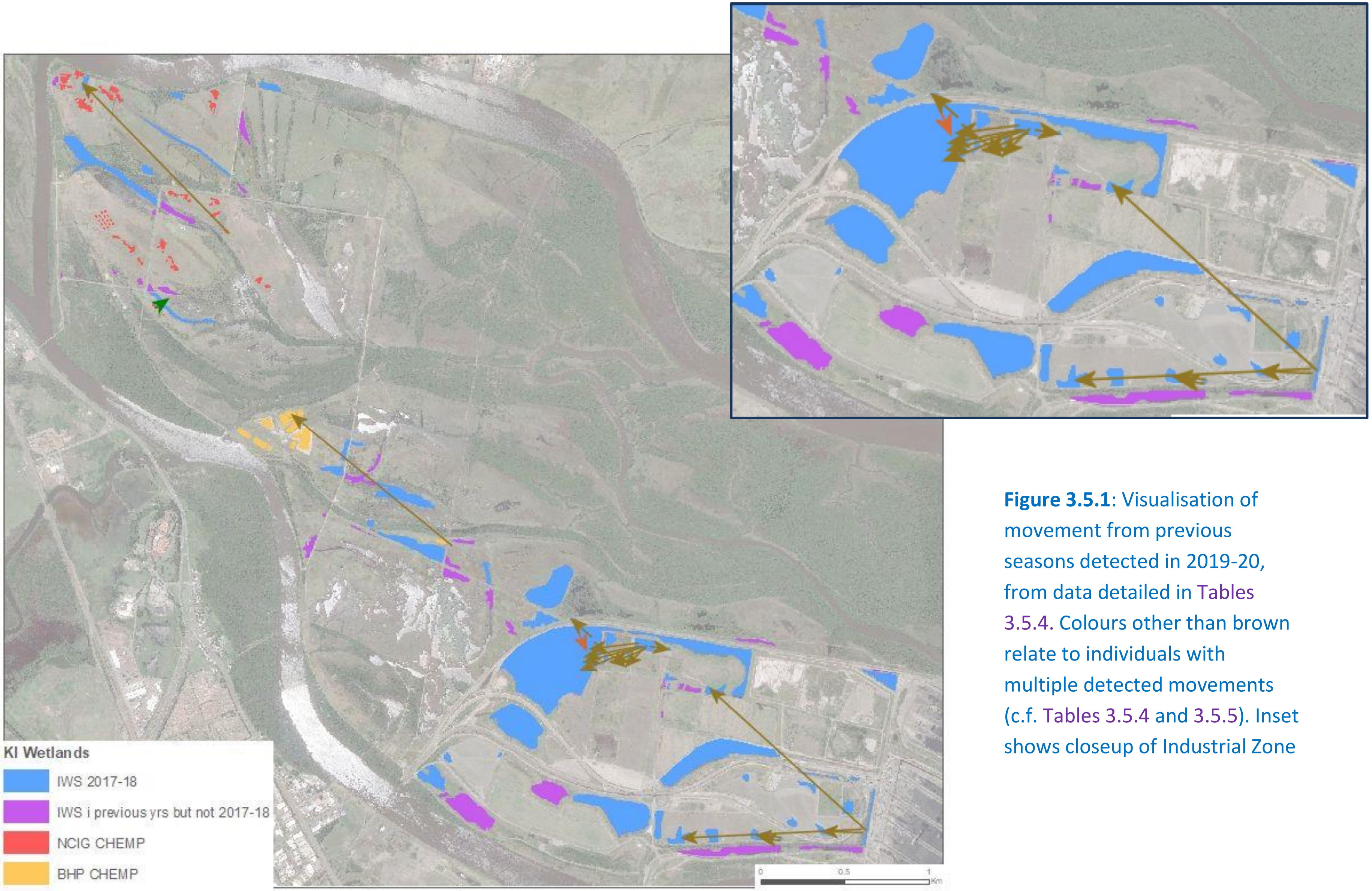


Figure 3.5.1: Visualisation of movement from previous seasons detected in 2019-20, from data detailed in Tables 3.5.4. Colours other than brown relate to individuals with multiple detected movements (c.f. Tables 3.5.4 and 3.5.5). Inset shows closeup of Industrial Zone

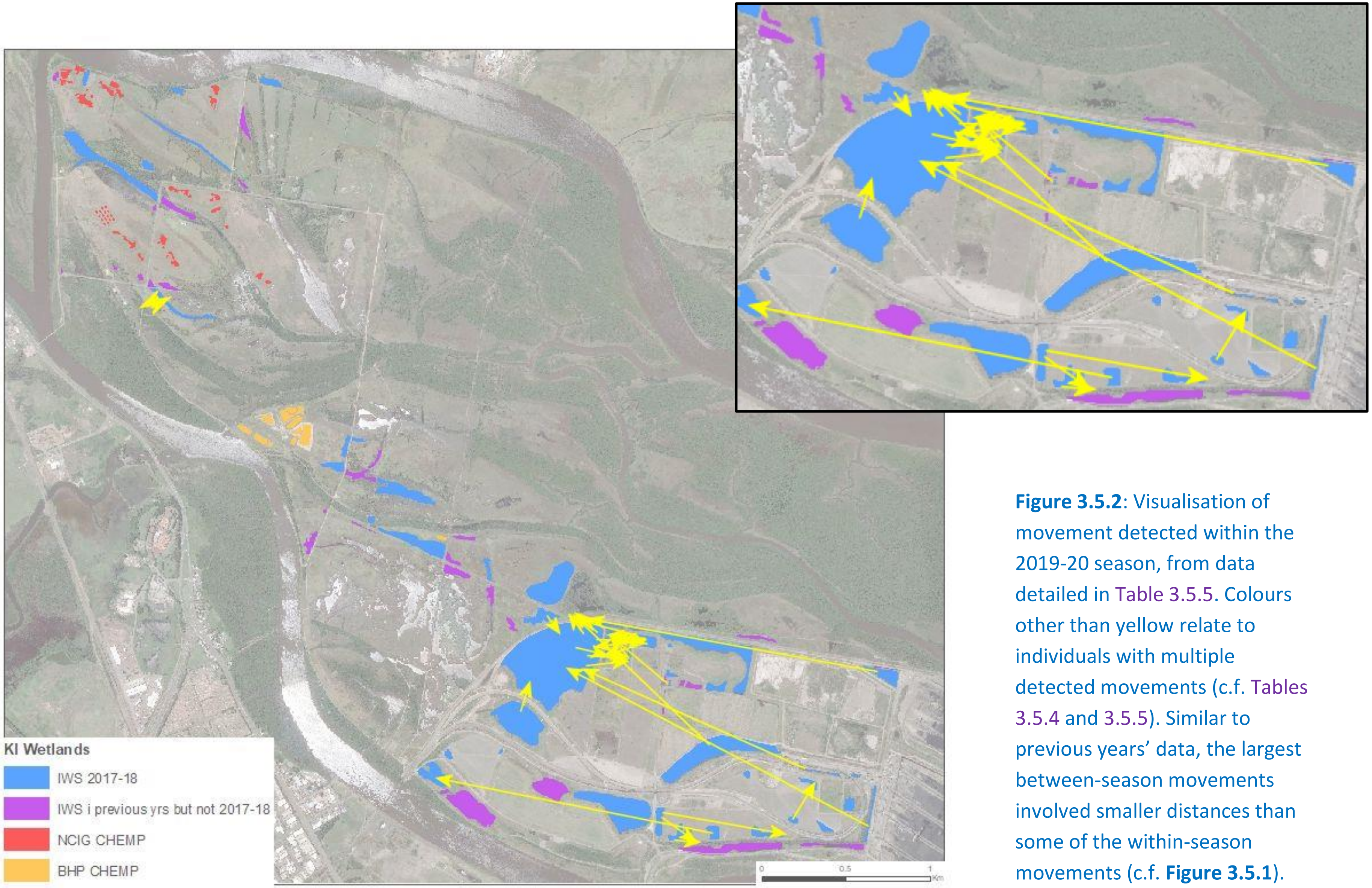


Figure 3.5.2: Visualisation of movement detected within the 2019-20 season, from data detailed in Table 3.5.5. Colours other than yellow relate to individuals with multiple detected movements (c.f. Tables 3.5.4 and 3.5.5). Similar to previous years' data, the largest between-season movements involved smaller distances than some of the within-season movements (c.f. **Figure 3.5.1**). Inset shows closeup of Industrial Zone.

Interaction between movement and persistence

A *prima facie* reading of the longitudinal data suggests that *L. aurea* on Kooragang Island show a high level of philopatry; the vast majority of individuals are re-caught in the same wetland of initial capture. Of the 3,262 recaptured animals, 2,437 were captured for the last time less than six months after their first capture. The probability of detecting movement in this time must inevitably be lower than for individuals with a greater time between first and last capture. Indeed, of the 2,437 frogs whose final capture was less than six months after their first, only 293 had moved (a proportion of 13%), although multiple movements were detected for some of these and the total number of movements for those 293 animals was 338. This increased to more than 30% all individuals when the time between capture events was more than a year, and nearly 70% when the time between captures was more than three years.

	maximum 'age' (non-cumulative)				'age' at movement (cumulative)			
	number of animals	oldest 'age' of animals that moved	number of movements detected		cumulative total of animals that made it to this age	animals that moved	most recent movement	% moved
x < 6 months	2437	292	336		3262	410	326	13%
6 < x < 12 months	500	100	132		825	191	157	23%
1 < x < 2 years	272	62	99		325	101	77	31%
2 < x < 3 years	41	8	25		53	15	13	28%
3 < x < 4 years	8	0	0		12	8	6	67%
4 < x < 5 years	4	0	1		4	3	3	75%

Table 3.5.8: Numbers of *L. aurea* in each persistence 'age' class (c.f. Table 3.5.2), numbers of movements detected, and proportions thereof. Columns to the left ('non-cumulative') organise data according to the time between first and last capture of each frog. Columns to the right ('cumulative') show data according to the time between first capture and the detection of movement. See text for discussion.

3.6 Breeding and recruitment

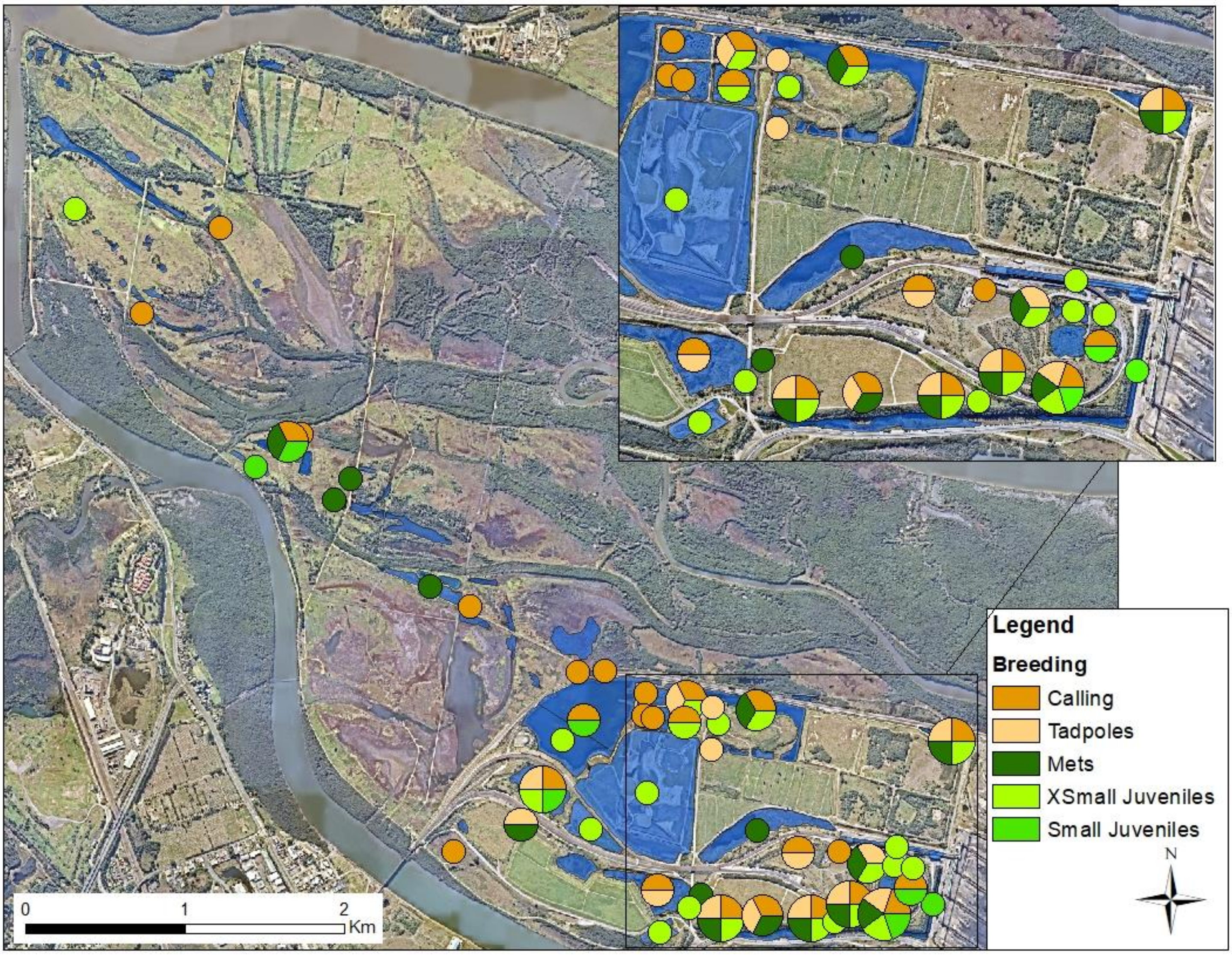


Figure 3.6.1: *L. aurea* breeding (i.e. calling, detection of tadpoles and/or metamorphs, small juveniles) during the 2019-20 survey season. 'Xsmall' juveniles have SVL < 35 mm; 'Small' juveniles have 35 < SVL < 40 mm. Note that the size of the segments within the pie charts denotes only presence of an age/six class or breeding behaviour; it does not indicate the quantity within each category. See Figure 3.6.2 for close up of Industrial Zone wetlands.

Across the season, calling was detected at 19 wetlands, though this does not necessarily indicate that breeding took place at these locations. Instead, the most direct evidence is the presence of *L. aurea* tadpoles. These were detected across a large number of wetlands across the Industrial Zone (Figure 3.6.2) and absent in other regions that were surveyed. Within the Industrial Zone, tadpoles were found at K29, K31, K104 and K105B in the northern region, and K49B, K111, K112, K113, K114, K118, K121, K122 and K123 in the southern region. Tadpoles were found during Round 1 (eight wetlands), Round 2 (three wetlands) and Round 4 (11 wetlands).

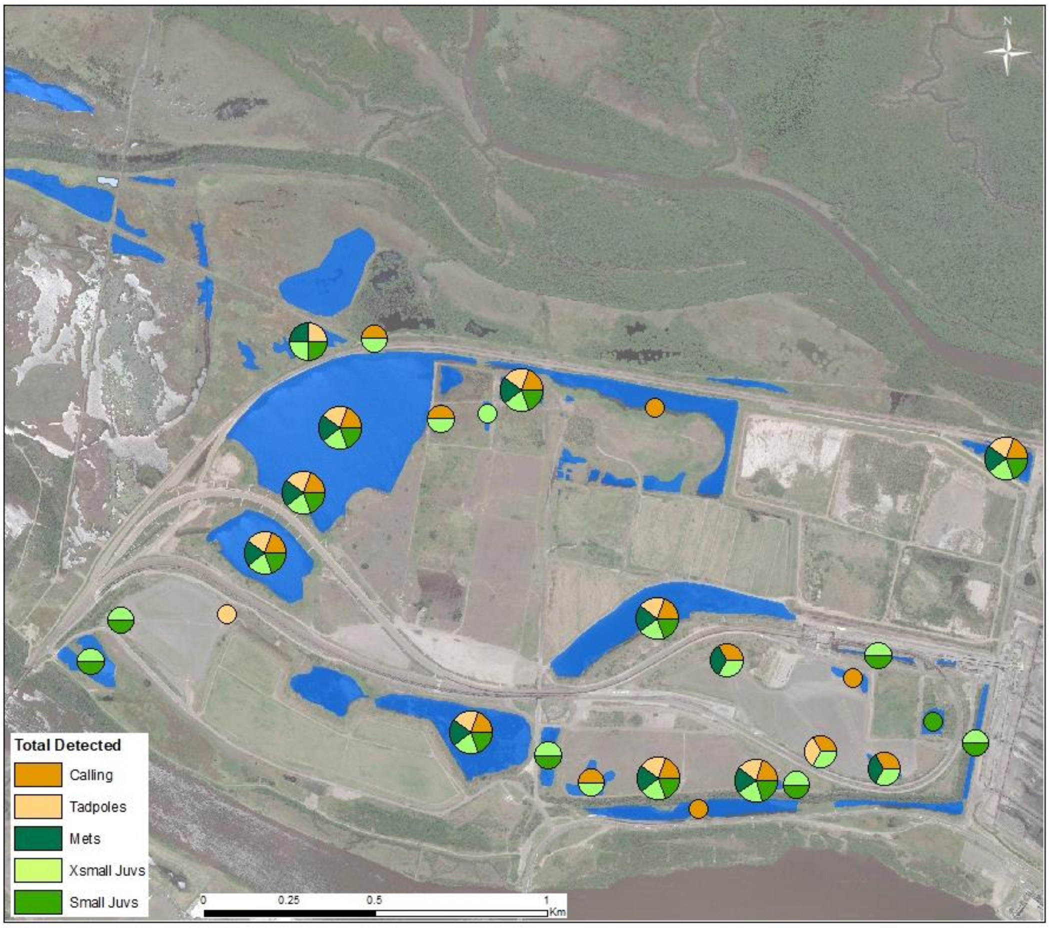


Figure 3.6.2: Evidence for *L. aurea* breeding in southern Kooragang Island. See Fig. 3.6.1 for explanation.

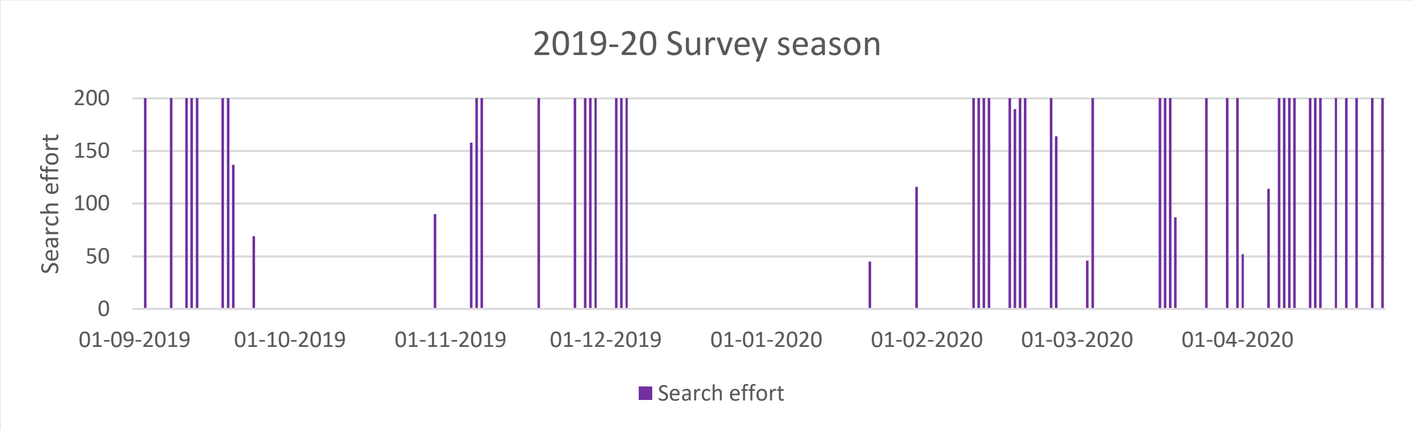
A difficulty with detecting *L. aurea* tadpoles is that positive identification in the field is difficult. In contrast, *L. aurea* metamorphs can be reliably identified in the field and usually (but not always) indicate breeding has occurred in the wetland where they were observed. Metamorphs are known to disperse over terrestrial habitat and so do not always indicate breeding at a specific wetland; but if present in large numbers then breeding can be confidently said to have occurred at the site of detection. Metamorphs were detected primarily at wetlands within the Industrial Zone (11 wetlands), as well as in the National Park (three wetlands) and BHP compensatory habitat (one wetland) further north. Note that Figures 3.6.1 shows only the presence/absence of tadpoles, metamorphs etc., not their abundance. The largest numbers of metamorphs were seen in four nearby wetlands in the southern region of the Industrial Zone (K111, K121, K123 and K123). Almost all metamorphs were detected in Round 4 (March/April 2020), though a small number were also detected earlier in Round 2 (November 2019) in K111, K122 and K123.

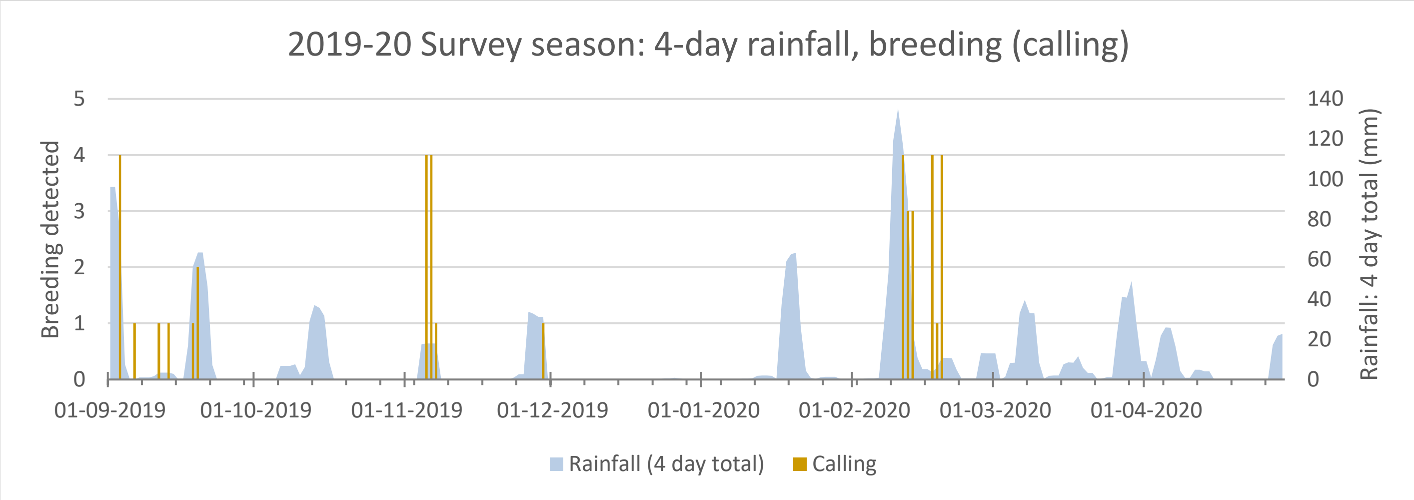
Juvenile frogs are, of course, mobile and do not provide a reliable indication that breeding as occurred in a specific wetland; however, large numbers of small juveniles (SVL < 30 mm) in a wetland are suggestive of a cohort of frogs that have spawned at that location. Large numbers (≥ 10) of very small juveniles were detected in K100A in Round 1, as well as K103, K112, K105B, K111, K113, NCIG dump-station, K121, K105AS, BHP-1A, BHP-2A and BHP-3A in Round 4 (March), and Daracon Compound, EP-NE, BHP Borrow Pit, NCIG dump-station, K105AS, The Wedge and Area 2 in Round 4.1 (April). The largest number of very small juveniles were captured in the Area 2 drift fence. This is a terrestrial habitat up to 300 metres away from the nearest wetland from which they might have originated, indicating a dispersal event at the end of the season.

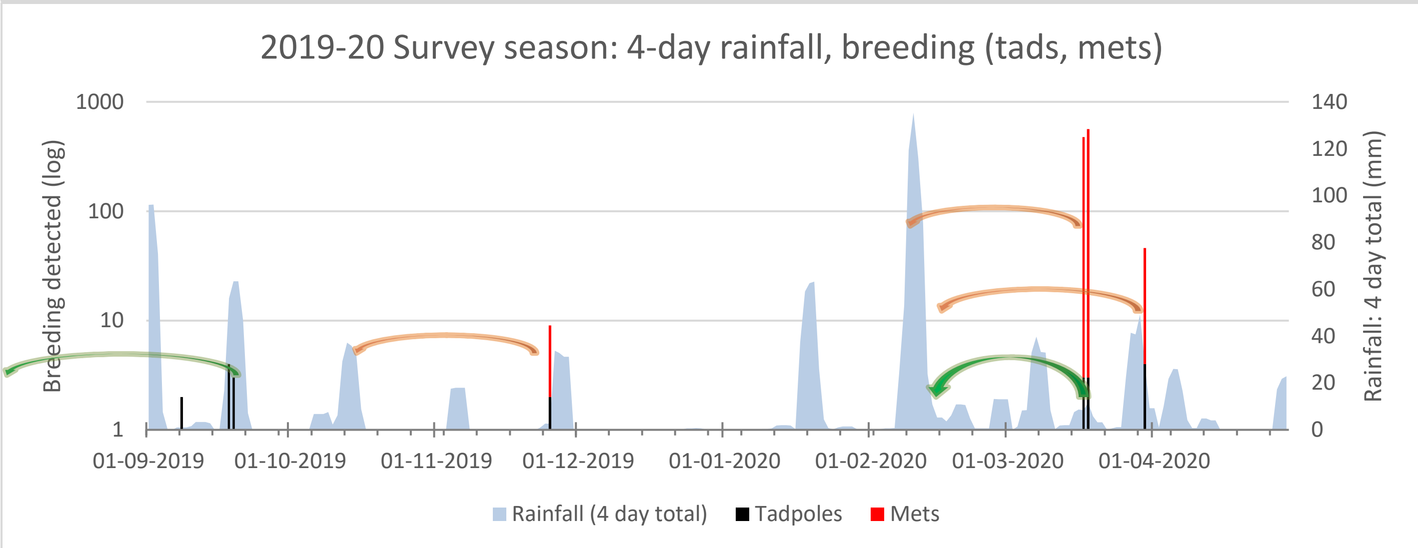
Tadpoles and metamorphs were detected mainly in wetlands classified as permanent (i.e. 'nearly permanent' or 'deep permanent' hydroperiod categories detailed in **Section 3.2**), except for K13, K112 and K113 which are seasonal and K9A/B which is saline irregular, demonstrating that *L. aurea* are not necessarily limited to ephemeral wetlands for breeding. The lack of breeding at temporary sites may be due to the dry conditions breeding adults were exposed to throughout much of the season as a result of lower than average rainfall, particularly in the first half of the season. The characteristic that all of these wetlands did have in common was that no *Gambusia* were present when tadpoles and/or metamorphs were detected, except for three nearby wetlands in the industrial site (K102, K103 and K104).

The presence of *L. aurea* offspring at various stages of development provides information on when spawning most probably occurred during the breeding season. Metamorphosis in *L. aurea* happens within a relatively short time frame and detection of metamorphs generally indicates spawning 4-5 weeks earlier (although this can extend to 6 weeks or more in spring or autumn, when temperatures are lower). The detection of tadpoles provides a less precise indication of spawning time but can still be correlated with rain events (Figure 3.6.3). The large numbers of very small ('Xsmall'; SVL < 35 mm) and small (35 < SVL < 40 mm) juveniles indicate cohorts resulting from periods of spawning earlier in the season. For young L. aurea detected in the 2019-20 breeding season, spawning likely occurred:

1. Frogs that were spawned in the previous season (2018-19) and overwintered as tadpoles.
2. Frogs that spawned during rainfall in early and mid-Spring 2019.
3. Frogs that were spawned in late summer 2020 following a large rainfall event in February


2019-20 Survey season
Search effort
200
150
100
50
0
01-09-2019
01-10-2019
01-11-2019
01-12-2019
01-01-2020
01-02-2020
01-03-2020
01-04-2020
Search effort


2019-20 Survey season: 4-day rainfall, breeding (calling)
Breeding detected
5
4
3
2
1
0
140
120
100
80
60
40
20
0
Rainfall: 4 day total (mm)
01-09-2019
01-10-2019
01-11-2019
01-12-2019
01-01-2020
01-02-2020
01-03-2020
01-04-2020
Rainfall (4 day total)
Calling


2019-20 Survey season: 4-day rainfall, breeding (tads, mets)
Breeding detected (log)
1000
100
10
1
140
120
100
80
60
40
20
0
Rainfall: 4 day total (mm)
01-09-2019
01-10-2019
01-11-2019
01-12-2019
01-01-2020
01-02-2020
01-03-2020
01-04-2020
Rainfall (4 day total)
Tadpoles
Mets

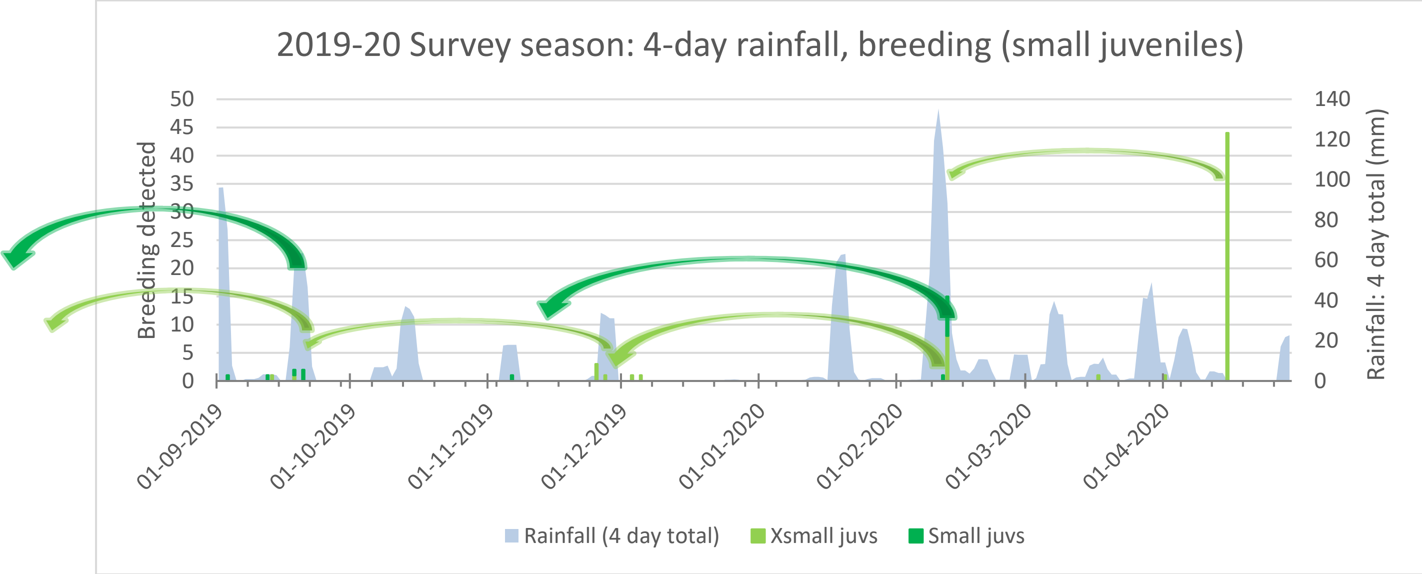
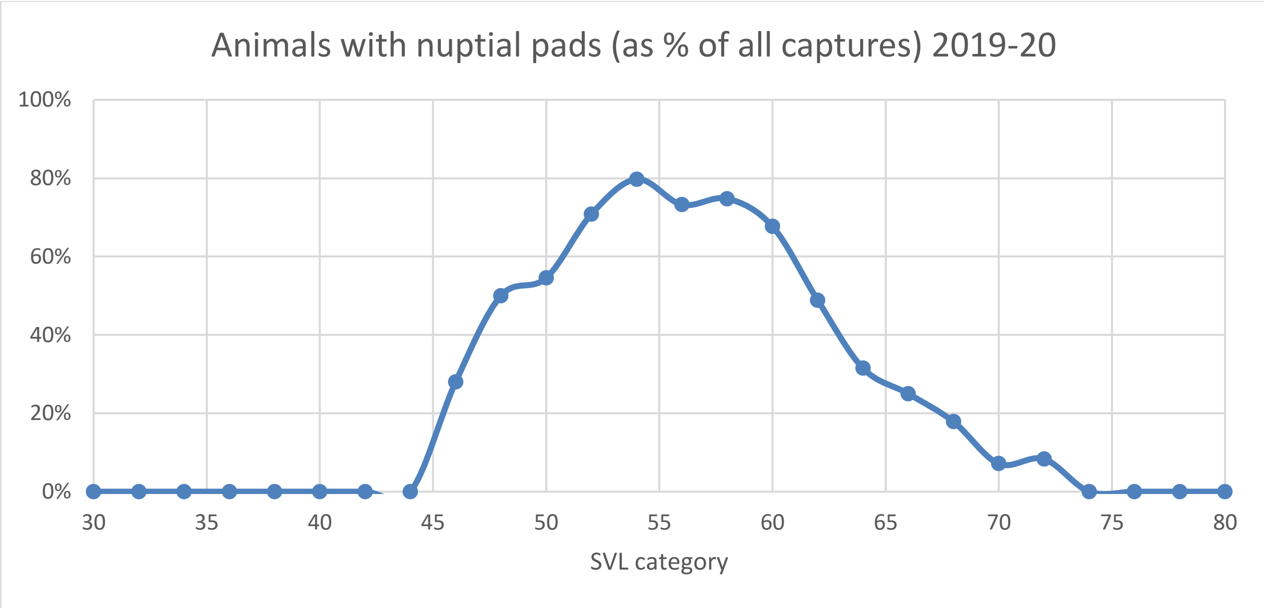


Figure 3.6.3: Survey nights (top), nights where calling was heard, detections of tadpoles and metamorphs, and detections of small juveniles (bottom), correlated with rainfall. Arrows indicate potential laying dates for animals detected as tadpoles (brown arrows), metamorphs (dark green), very small ('Xsmall'; SVL < 35 mm; light green) and small (35 < SVL < 40 mm; dark green in bottom chart) juveniles. Numbered arrows related to potential cohorts outlined in the text.

Size at sexual maturity



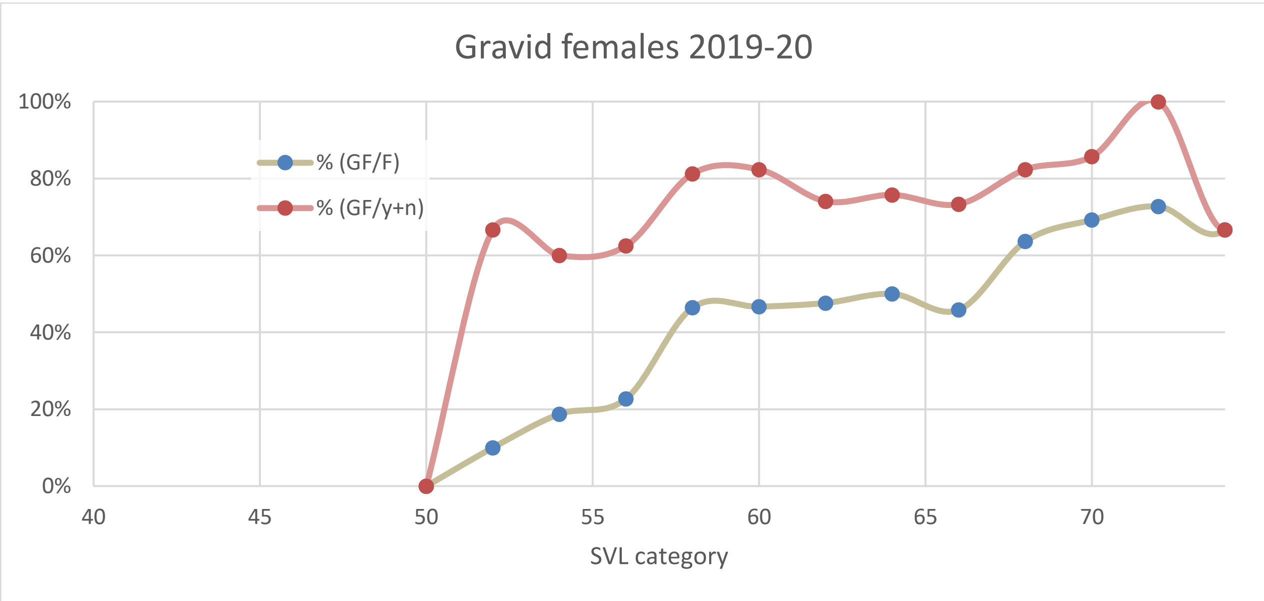


Figure 3.6.4: Proportions of animals with nuptial pads (top), and proportion of gravid animals (bottom). See text for discussion.

Data from the 2019-20 (Figure 3.6.4) is broadly consistent with the observation from the previous two seasons (Section 2.6, Figure 2.6.2) that *L. aurea* males reach sexual maturity at approximately 50 mm SVL. There were some slight differences; the proportion of *L. aurea* with nuptial pads plateaued at approximately 60% in 2016-17, but closer to 80% for both the 2017-18 and 2018-19 datasets. That latter percentage was the plateau point for the 2019-20 data as well (Figure 3.6.4). That ~80% plateau was achieved at approximately 53 mm SVL, compared to the 60% plateau being achieved at 50 mm SVL in the 2016-17 dataset.

The exact point of this plateau does not affect the counts of males (which are positively identified by the presence of nuptial pads), but does affect the counts of juvenile females (which are identified by the absence of nuptial pads but an SVL greater than 49.5 mm). The data from the current 2019-20 season indicates that that size threshold for identifying an animal as a juvenile female (as opposed to simply a juvenile of unknown gender) may be slightly too small. We have not adjusted that threshold in analysing the demographics, but highlight this issue here for future consideration.

If the onset of sexual maturity for *L. aurea* females is the production of eggs, and if egg masses can be reliably detected using candling (Section 2.6), then it indicates that some females achieved sexual maturity in the 2019-20 breeding season at 52 mm SVL (Figure 3.6.4). This is similar to the 52 mm size recorded in the 2017-18 data (McHenry et al. 2019), but slightly smaller than the size recorded in the 2018-19 season (54 mm SVL). There was a general increase in the percentage of females gravid with increases in size, and by 57 mm SVL more than 80% of the females candled were gravid.

The size threshold used to delineate between adult and juvenile females in 2016-17 was 58 mm SVL; we here cautiously retain that threshold. Confirmation of sexual maturity in *L. aurea* below a SVL of 58 mm awaits confirmation from hormone analysis.

Interactions between breeding and *Gambusia*

	Total wetlands with	Gambusia	no Gambusia
2015-16	tads/mets	3	4
	no tads/mets	56	15
2016-17	tads/mets	3	5
	no tads/mets	21	42
2017-18	tads/mets	1	9
	no tads/mets	15	35
2018-19	tads/mets	3	11
	no tads/mets	10	49
2019-20	tads/mets	3	18
	no tads/mets	7	60

Table 3.6.1: Interaction between presence of *Gambusia*, and breeding behaviour of *L. aurea* (as evidenced by the presence of tadpoles and/or metamorphs), for the current 2019-20 breeding season and previous four seasons.

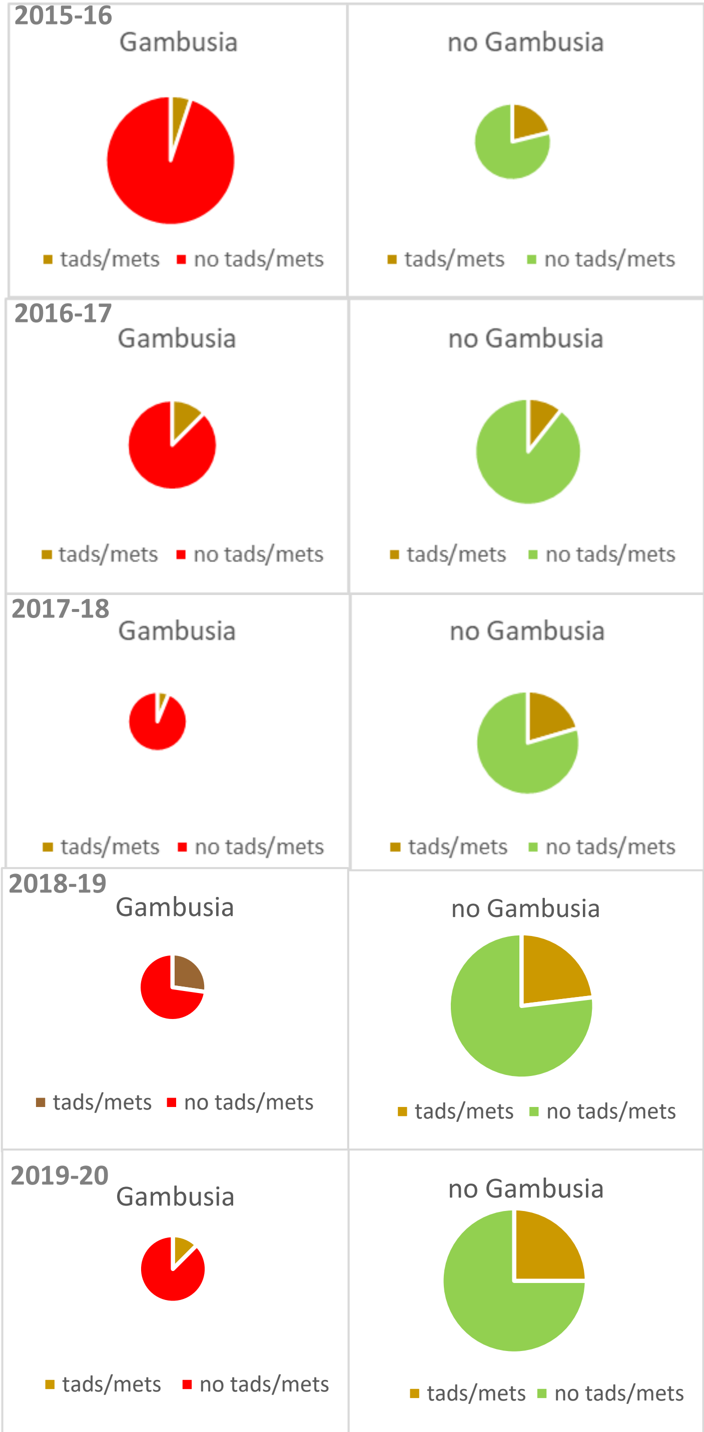


Figure 3.6.5 shows a strong interaction between the presence of *Gambusia* and breeding by *L. aurea in* 2015-16 and 2017-18. However, based only on binary presence-absence data, there appears to be no effect in some breeding years (e.g. 2016-17 and 2018-19 data). As noted previously (McHenry et al. 2019), looking simply at presence/absence of *Gambusia* may underestimate this effect. Breeding of *L. aurea* is likely to be related to density of *Gambusia*, not just presence. For instance, in K104 there was a significant breeding event in 2017-18; *Gambusia* was present, but at much lower densities than in 2015-16. Adjusting for the charts so that wetlands with low density and absence of *Gambusia* are grouped together again indicates that breeding across all years is seen more frequently when *Gambusia* is not abundant (Figure 3.6.5).

The differences in *Gambusia* presence/absence, as well as density are directly related to the hydrology of the wetland prior to the breeding season. Each of these almost completely dried out in the 2018-19 season; whilst *Gambusia* were not eradicated completely, their numbers at each wetland were evidently substantially reduced.

Figure 3.6.5: Graphical representation of the data presented in Table 3.6.1. The filled charts at the bottom show the 2019-20 adjusted to show counts with low and/or zero densities of *Gambusia*.

3.7 Microhabitat and Habitat

Vegetation (microhabitat)

Table 3.7.2: Detailed microhabitat of *L. aurea* captures, pooled across the whole 2019-2020 season.

Species	N (captures)	Species	N (captures)
Acacia	1	cable-tray	0
branch	1	Fence trap	0
Casuarina	13	metal	0
dead branch	8	post	0
fallen tree	0	pot	3
mangrove	0	rope	0
tree	6	sump wall	0
Baumea	0	tub	3
Bolboschoenus	62	Anagallis	0
Eleocharis	0	Aster	1
Juncus	7	daisy	0
Phragmites	48	dead grass	0
reed	8	Foeniculum	0
Schoenoplectus	27	grass	40
Typha	245	Hydrocotyle	1
algae	40	Lomandra	0
aquatic veg.	0	Ludwigia	0
duckweed	0	mangrove root	0
flooded grass	0	moss	0
water	171	nest	0
waterlily	0	Paspalum	3
bank	1	ragweed	0
burrow	0	shrub	0
concrete	0	Vicia	0
gravel	2	Chrysanthemoides	0
ground	43	Cortaderia	1
mud	11	Lantana	2
road	25	nightshade	0
rock	46	Persoonia	0
sand-bag	3	Ricinus	0
block	5	vine	0
cable tray	0	unknown	0

Structures	*n* (captures)
trees	29
emergent vegetation	397
water	211
ground	131
man-made structure	11
ground vegetation	45
shrubs	3

Table 3.7.1: Broad microhabitat categories of *L. aurea* captures, pooled across the 2019-20 season

Litoria aurea individuals were predominantly detected on emergent aquatic vegetation (Table 3.7.1); especially the reed plants *Bolboschenus*, *Phragmites*, *Schoenopelctus* and *Typha* (Table 3.7.2). Individuals were also frequently found in the water, most often floating at the surface in amongst algae, or on the ground, most often on exposed rocks. Individuals were occasionally found in trees such as *Casuarina*, and on shrubs such as *Lantana*.

Wetland Physiognomy

Score	5	4	3	2	1
Size	Very large	Large	Med	Small	Very small
Openness (tall reeds)	Open	Nearly open	Partially open	Nearly closed	Closed
Edge vegetation extent (tall reeds)	Totally surrounded by reeds	Lots	Approx. half	Small amount	Very little/none

Table 3.6.3: Qualitative scores used for preliminary analysis of the effects of wetland physiognomy upon *L. aurea* abundance; c.f. Fig. 3.6.1, Fig.3.6.2.

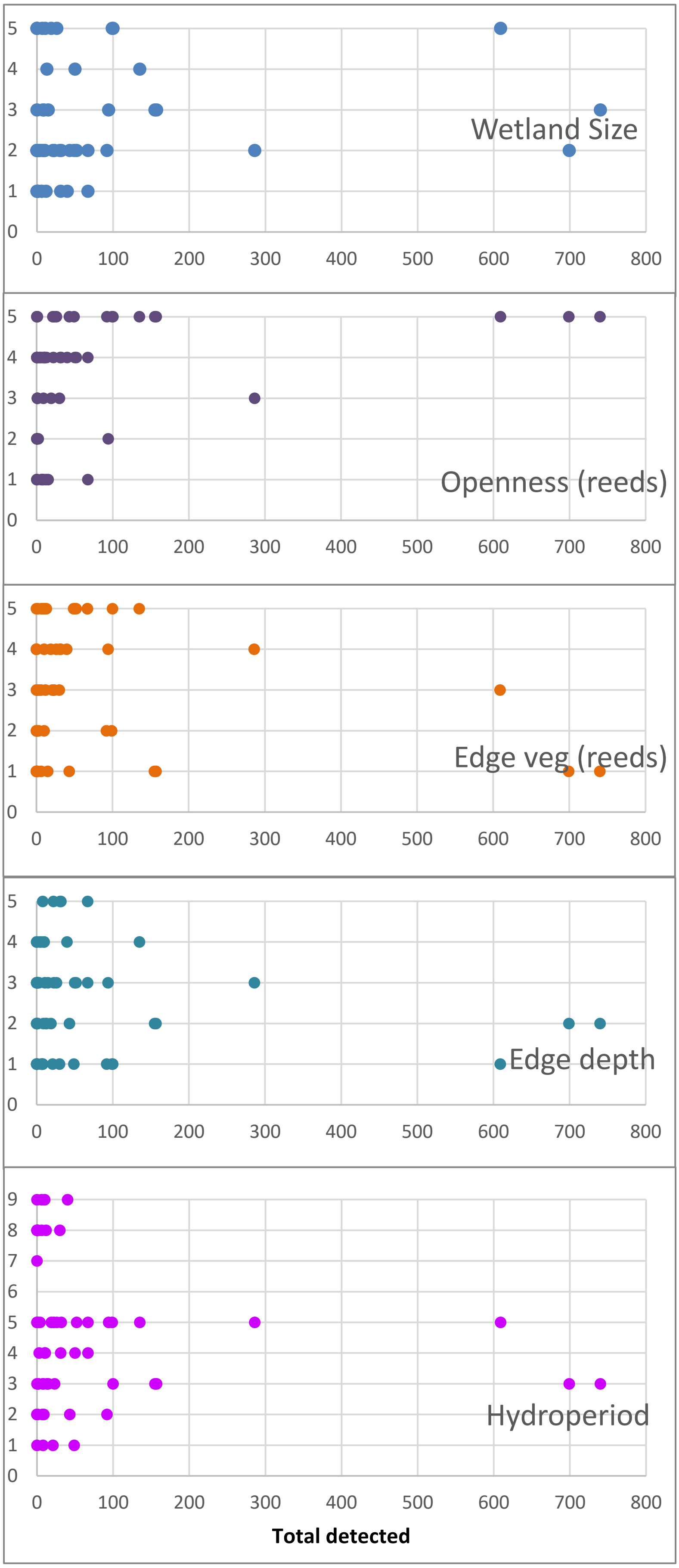


Figure 3.7.1: Scores for wetland size, openness, edge vegetation, edge depth, and hydroperiod, plotted against values of **Total Detected** bell frogs for each wetland surveyed in 2019-20.

An important question in understanding *L. aurea* ecology concerns the habitat requirements of this species. Figure 3.7.1 and Figure 3.7.2 show visualisations of potential links between *L. aurea* abundance and wetland physionomy.

Wetland physiognomy involves a subset of habitat parameters that incorporate ‘physical’ factors such as size, openness, and density of edge vegetation. Quantitative measurement of these factors for large numbers of wetlands is a logistically complex process. Here, we use qualitative scores to provide a visualisation of the relationships between these traits and *L. aurea* abundance in terms of total frogs detected and search sensitivity (a measure of frog density).

Each surveyed wetland was scored for these parameters (Table 3.7.3). The scores for hydroperiod (**Section 3.2**) were also used.

When plotted against the numbers of frogs detected there is a great deal of noise in the data (which is one of the challenges for quantitative analysis). However, qualitatively, high vales of Total Detected are strongly related to high scores for Openness, but low scores for Edge vegetation and Edge depth (Figure 3.7.1). The largest numbers were found in wetlands with a semi-permanent Hydroperiod. It also appears that Total detected is affected by medium scores for Wetland size. However, the large breeding event in late summer/autumn means that these data are skewed by breeding behaviours and may not indicate the physiognomy of ‘refuge’ wetlands.

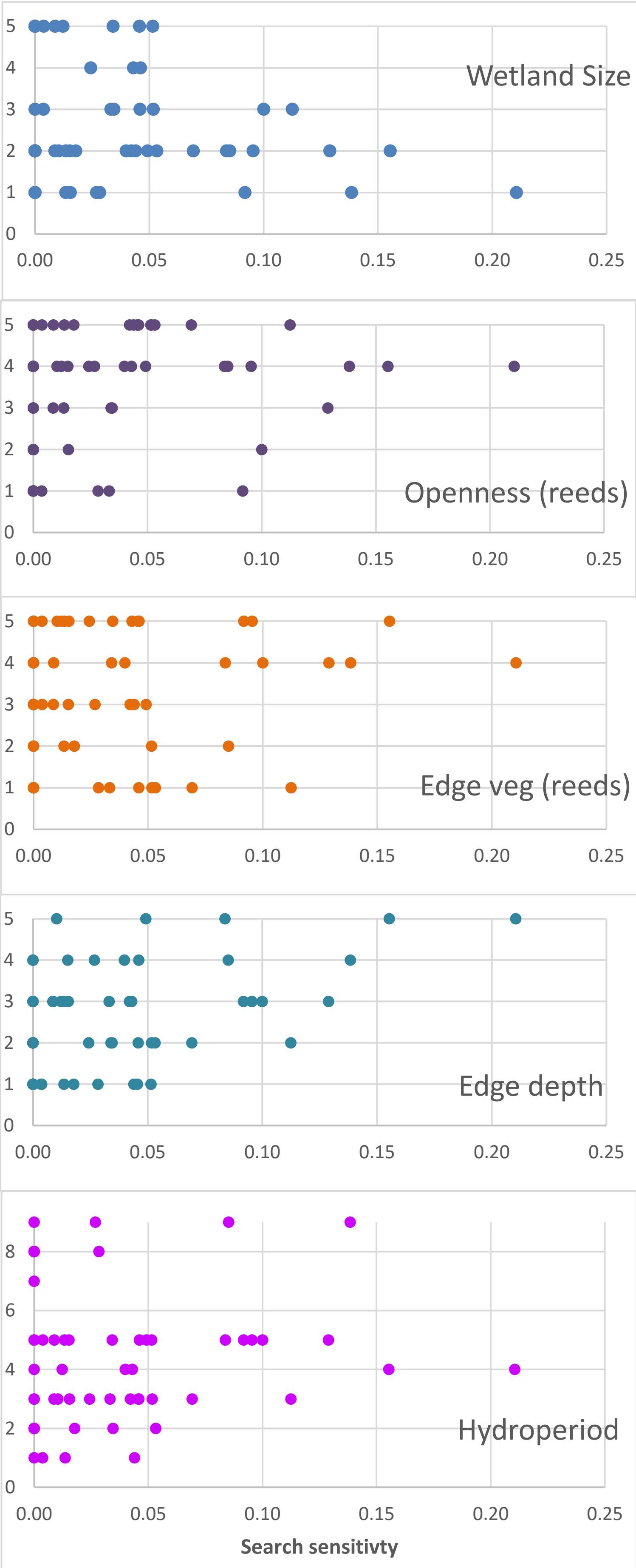


Figure 3.7.2: Scores for wetland size, openness, edge vegetation, edge depth, and hydroperiod, plotted against values of **Search Sensitivity** for each wetland surveyed in 2019-20.

Search sensitivity (Figure 3.7.2) was also strongly affected by high scores for Openness. In contrast to Total Detected, Search Sensitivity was also affected by high scores for Edge vegetation and Edge depth. It appears that search sensitivity is also affected by low scores of Wetland Size and Hydroperiod.

This data indicates that high numbers of *L. aurea* are found in medium sized wetlands that are i) comparatively open, ii) with sparsely vegetated (reeds) edges, iii) shallow edge depths and short hydroperiods. While high densities are also found in semi-permanent wetlands that are comparatively open, they are high in smaller wetlands that have i) densely vegetated edges, and ii) with deeper edge depths.

Interestingly, this result, although preliminary, suggests that *L. aurea* population sizes and densities differ between wetlands in a manner that is dependent on habitat structure, though an overall preference for open wetlands.

This initial analysis is constrained by low quality of the data for physiognomic parameters. Better quality data will inevitably allow more powerful analyses. The question of how wetland physiognomy affects breeding habitat quality is also important and should be explored further. However, we note that these patterns of occupancy connect strongly with the concept of the *L. aurea* 'habitat mosaic' outlined in **Section 3.2**.

3.8 Population size

Using VES data to estimate of *L. aurea* population on Kooragang Island

Usually, we aim to conduct Capture-Mark-Recapture (CMR) surveys at three focal wetlands each breeding season; K22/23, K29, and K104. (Table 3.8.1). The results of these surveys are subsequently analysed by Robust modelling to obtain estimates of *L. aurea* population size at these selected sites. The first step in producing a whole-island estimate of *L. aurea* numbers is to determine the proportion of frogs inhabiting a wetland that are detected during a Visual Encounter Survey. This is achieved by using the CMR survey results to calculate a conversion factor (1/<proportion detected in VES>) that can be used to estimate the total number of *L. aurea* at each surveyed wetland, based on the number of frogs detected in each VES (Table 3.8.5).

Various logistical issues can impede these surveys; in previous years, CMR surveys have been abandoned because of insufficient frogs at the wetland in that round, sometimes combined with obvious high levels of immigration/emigration from the wetland during the survey, or because drying wetlands contain deep mud that makes intensive surveying treacherous. In this season, CMR surveys were not conducted. Instead, we used the conversion factors (Table 3.8.5) obtained from pooled CMR survey results from the previous three breeding seasons to produce estimates of numbers across the entire island during each survey round. The pooled conversion factor for the past three seasons was 6.4; i.e., for every ≥ 40 mm SVL *L. aurea* detected during VES, we expect that a total of ≥ 40 mm SVL 6.4 frogs were actually present but that 5.4 remained undetected (the conversion factor is thus the inverse of the detection probability).

Wetland	**Conversion factor (VES detected - CMR pop. estimate)**				
	min-lower	mean-lower	mean-N-hat	mean-upper	max-upper
2018-19	2.16	4.49	5.32	6.71	24.82
2017-18	2.80	6.42	7.51	9.38	21.52
2016-17	3.00	5.23	6.37	8.43	14.13
Pool (all years)	2.65	5.38	6.40	8.17	20.16

Table 3.8.5: Conversion factors (calculated as <population estimate> / <number detected in VES>) calculated from CMR surveys conducted in 2016-17, 2017-18 and 2018-19. 'min', 'mean', and 'max' relate to the minimum, mean, and maximum values for that ratio respectively. 'lower', 'N-hat', and 'upper' relate to the range of population estimates calculated using robust modelling (see Table 3.3.4). Combining these two dimensions of variation produces a range of estimates for the conversion factor (see text for discussion).

Note that this number should consider only 'taggable' frogs, i.e. adults and juveniles with an SVL of at least 40 mm; since only taggable frogs can be used to calculate the n-hat in the robust modelling of the CMR data, the conversion factor should only consider 'taggable' frogs detected during the VES. For captured frogs, this can be determined with confidence, but for uncaptured juveniles it represents a potential source of error as there is no way to determine how many may have been smaller than 40 mm SVL.

Several conversion factors are considered when estimating population size. Min, mean, and max values for the conversion factor are obtained for each year based on the animal detected/population ratio found for each CMR wetland. We use five of these potential values:

1. **Min-lower**: the minimum value of the <detected/population> ratio, using the lower estimate of population size.
2. **Mean-lower**: the mean value of the <detected/population> ratio, using the lower estimate of population size.
3. **Mean-N-hat**: the mean value of the <detected/population> ration, using the preferred ('N-hat') estimate of population size.
4. **Mean-upper**: the mean value of the <detected/population> ratio, using the upper estimate of population size.
5. **Max-upper**: the maximum value of the <detected/population> ratio, using the upper estimate of population size.

These conversion factor values are then applied to the VES detection data in order to generate estimates of overall population size in each survey round. These min and max values, once applied to the VES data, provide min and max estimated population size boundaries which the true population size likely falls within. The final step in making the island-wide population estimate is to adjust for those wetlands that are too large to fully survey in a 30 minute VES. For these, the proportion of the wetland surveyed during VES was measured using GIS to calculate an area weighting. The estimates for total population size (*L. aurea* ≥ 40 mm SVL) for the VES surveyed wetlands are shown in Table 3.8.6.

Using VES data to convert CMR results into an island wide estimate of *L. aurea* population

	min-lower	mean-lower	mean-N-hat	mean-upper	max-upper
	Non CHEMP				
Round 1	1,171	2,184	2,598	3,317	8,185
Round 2	413	839	998	1,275	3,145
Round 3	549	1,114	1,325	1,691	4,173
	CHEMP				
Round 1	244	495	589	752	1,855
Round 2	215	436	518	662	1,633
Round 3	48	97	115	147	363
	Total				
Round 1	1,414	2,679	3,187	4,069	10,040
Round 2	628	1,275	1,517	1,936	4,778
Round 3	596	1,211	1,440	1,838	4,536

Table 3.8.6: Population estimates for 47 non-CHEMP and 13 CHEMP wetlands. Estimates are based on the pooled conversion factors from the past three breeding seasons (Table 3.8.5).

These estimates should be interpreted as follows:

- It is **highly likely** that the population of *L. aurea* at the 60 surveyed wetlands was between the 'min-lower' and 'max-upper' limits (i.e. between 1,497 and 8,712 in Round 1).
- It is **probable** that the population was between the 'mean-lower' and the 'mean-upper' figures (i.e. between 2,573 and 3,904 in Round 1)
- The model estimation for the **approximate** population is the 'mean-N-hat' figure, i.e. 3,063 in Round 1.

It is not correct to say that that the population was 3,063 in Round 1; rather, the population was **approximately** 3,063.

Note that these estimates include the CHEMP wetlands created in the Central and Northern Zones of Kooragang Island. Estimates from previous island-wide surveys have not included those wetlands. Comparing the estimate for the non-CHEMP wetlands with data from the previous three seasons provides some indication of the population dynamics for *L. aurea* on Kooragang Island since the island-wide surveys began in 2010 (Figure 3.8.1 to Figure 3.8.3)

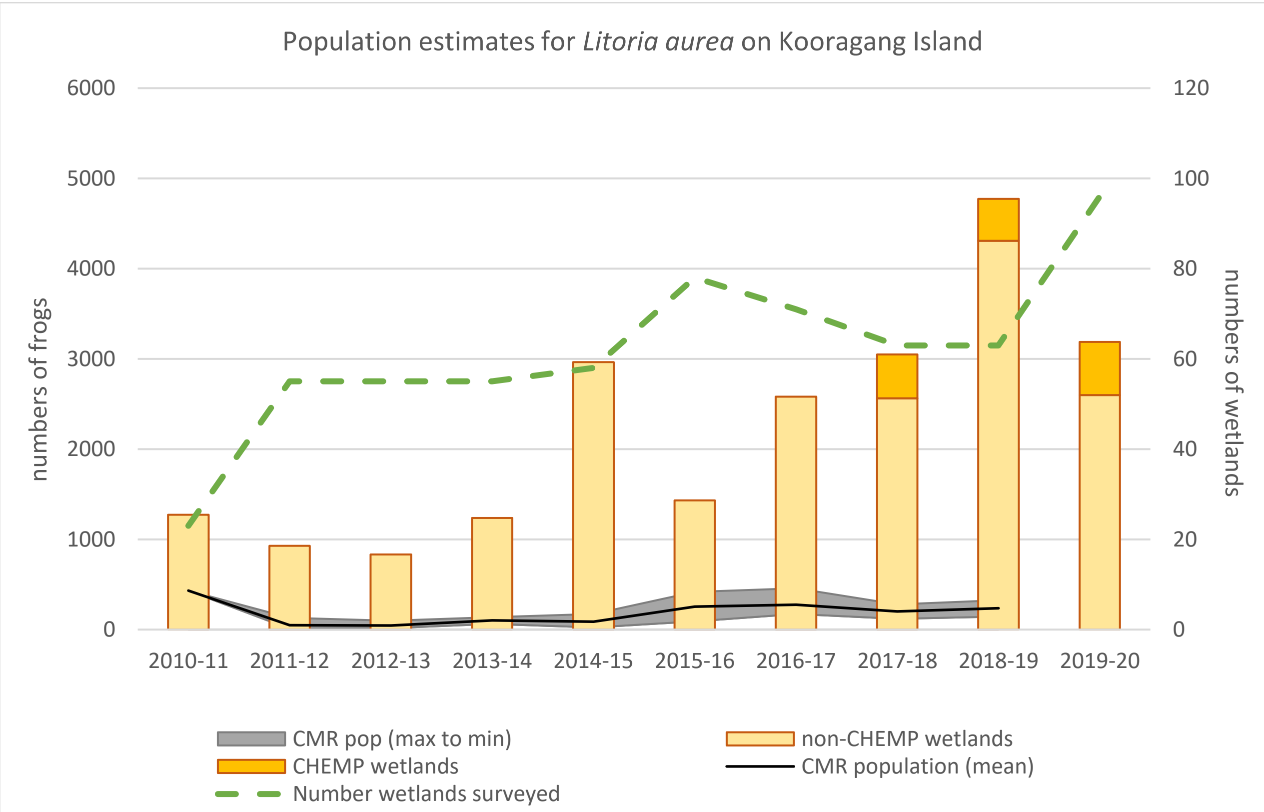


Figure 3.8.1: Population estimates for *L. aurea* on Kooragang Island. Data for 2010-2019 is from previous annual reports for the current project, while the 2019-20 data is from the current report. The light yellow columns show **maximal** population estimates derived from VES counts for the non-CHEMP wetlands only, while the darker orange columns show the maximum 2017-18, 2018-19 and 2019-20 estimates for all wetlands including the CHEMP wetlands (see data shown in Table 3.8.7). The black line shows the average (across all rounds in a given season) total N-hat for wetlands where CMR surveys were conducted, whilst the greyed area shows maximum and minimum N-hat values across all surveys for each season. The dashed green line shows the number of wetlands surveyed each season (Y2 axis).

This analysis indicates a standing population of 500-1000 individuals from 2010-2014, increasing to a larger population of 1,500-2,500 from 2014-2018. The apparent increase to approximately 4,000 in 2018-

19 may be real, but may be an inflated estimate caused by the presence of large numbers of juveniles following a large breeding event that occurred in that season. While the current 2019-20 season also saw a large breeding event, this occurred much later in the season after Round 3 and so the effects of this on the population estimates are not apparent. Instead, the standing population of approximately 3,000 is similar to that calculated for the 2017-18 season (Figure 3.8.1), further suggesting that the inflated numbers in 2018-19 was indeed a result of high detection probability caused by the presence of a large number of juveniles. Over the past three breeding seasons, more than a third to nearly one half of the island population has been located at constructed wetlands (Figure 3.8.3), indicating that these man-made aquatic sites are providing the necessary resources for *L. aurea* occupation and usage.

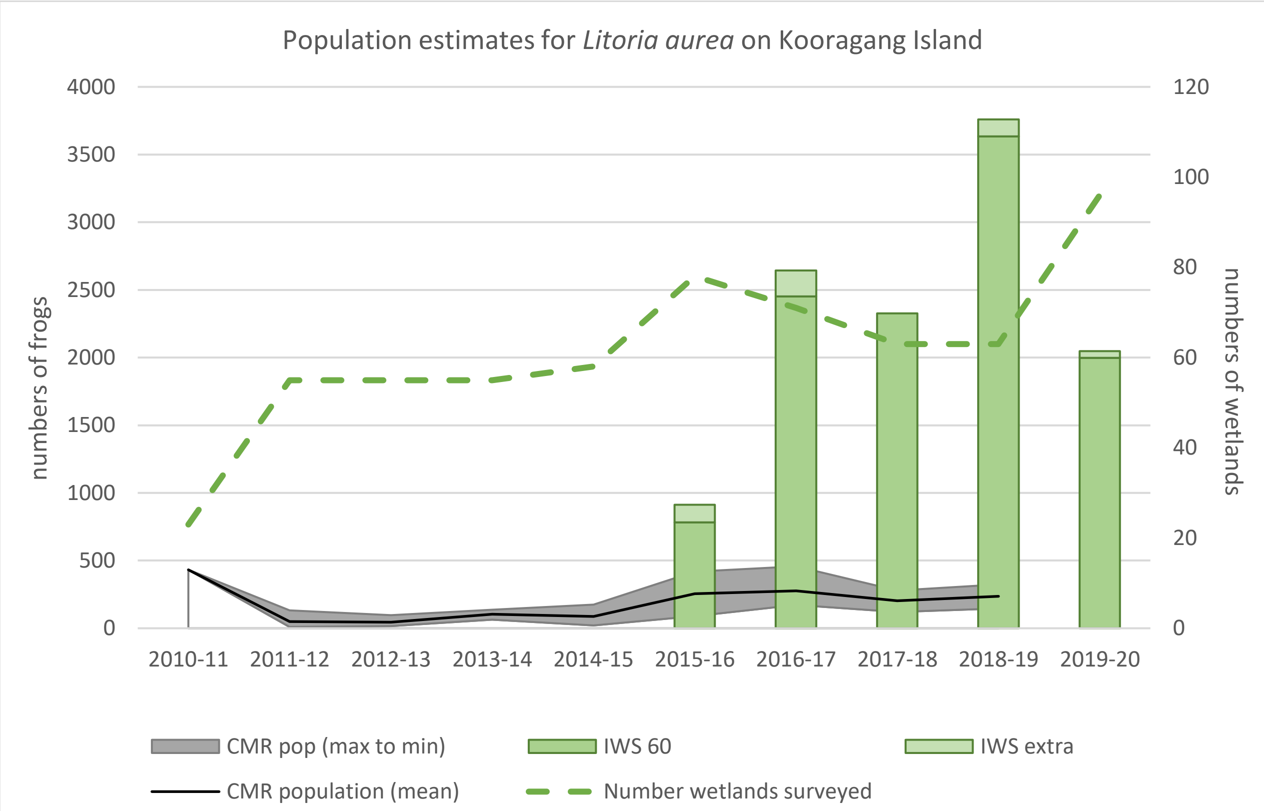


Figure 3.8.2: Population estimates for *L. aurea* on Kooragang Island. Data for 2010-2019 is from previous annual reports for the current project, while the 2019-20 data is from the current report. The dark green columns show **average** population estimates derived from VES counts for the primary 60 IWS wetlands surveyed in each round, while the lighter green columns show the average population estimates for wetlands that were surveyed opportunistically. The black line shows the average (across all rounds in a given season) total N-hat for wetlands where CMR surveys were conducted, whilst the greyed area shows maximum and minimum N-hat values across all surveys for each season. The dashed green line shows the number of wetlands surveyed each season (Y2 axis).

Note that the number of wetlands surveyed has remained relatively stable over the past three seasons. Surveys prior to 2013-14 targeted a smaller number of wetlands than did those in 2015-16 and 2016-17, but the changes in population estimate do not appear to be a simple product of sampling effort and unintended bias. Overall, the population seems to be at least stable, especially in the last five seasons, and there is no evidence for a sustained decline across the last eight seasons

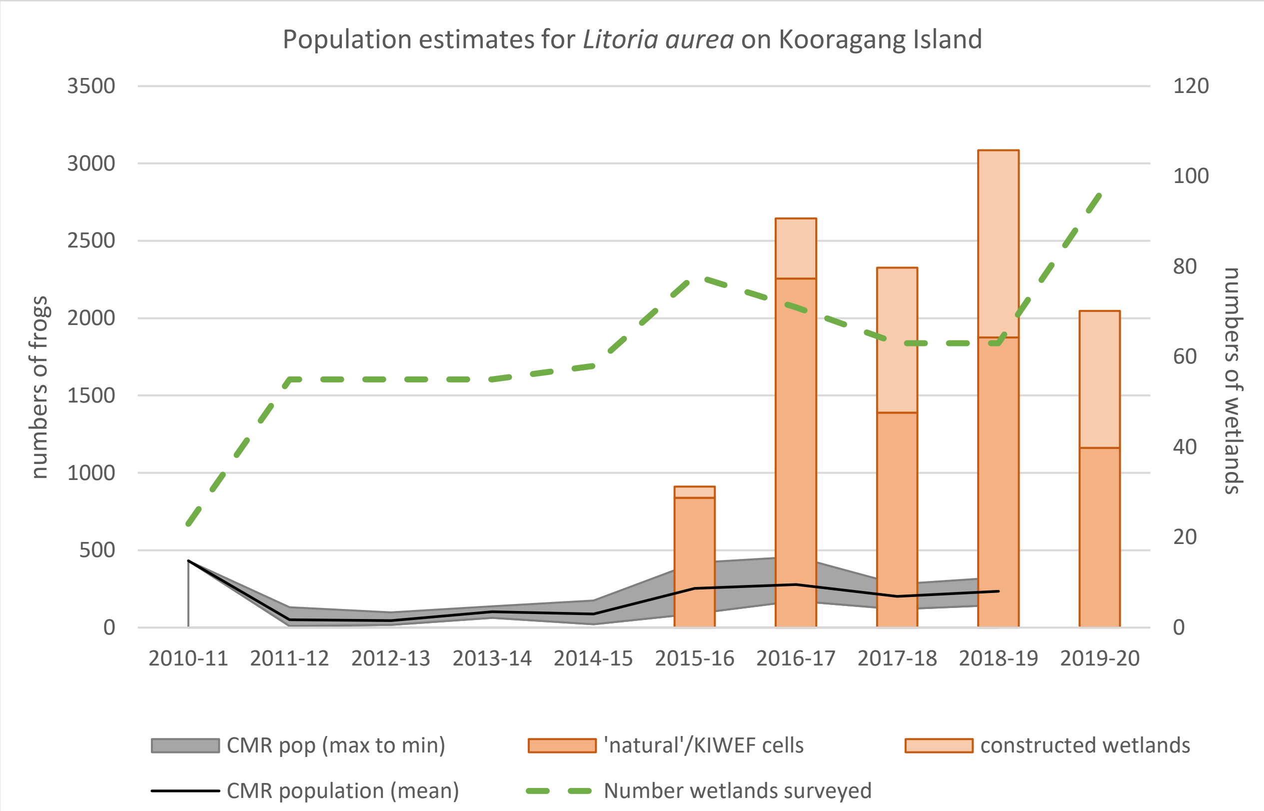


Figure 3.8.3: Population estimates for *L. aurea* on Kooragang Island. Data for 2010-2019 is from previous annual reports for the current project, while the 2019-20 data is from the current report. The dark pink columns show **average** population estimates derived from VES counts for the natural wetlands surveyed, while the lighter pink columns show the average population estimates for constructed wetlands (CHEMP wetlands, 'HDC' sedimentation ponds, and cluster ponds). The black line shows the average (across all rounds in a given season) total N-hat for wetlands where CMR surveys were conducted, whilst the greyed area shows maximum and minimum N-hat values across all surveys for each season. The dashed green line shows the number of wetlands surveyed each season (Y2 axis).

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3.9 Multi-year occupancy

To provide a spatio-temporal context for occupancy of Kooragang Island by *L. aurea*, data from 2014-20 (i.e. six complete seasons) was analysed with respect to the subdivisions outlined in **Section 2.2**:

1. **Jurisdiction**: i.e. the organisations responsible for / active on various parts of the island.
2. **Zone**: splitting the island into three large-scale regions.
3. **Region**: subdivisions of zones, bounded broad geographic distance, at a scale of ~2 km.
4. **Subregion**: bounded by rail-lines, roads, and creeks, at a scale of up to ~1 km.

The following charts show data from survey counts, broken down by these four criteria. Survey count data is summarised according to:

i. **VES detected** (number of *L. aurea* detected during primary VES surveys)
ii. **Total detected** (number of *L. aurea* detected during all surveys)
iii. **Search sensitivity** (a proxy for density; the number of animals detected in VES divided by search effort)

Raw survey counts are not subject to the various assumptions inherent in estimating populations from robust modelling, and can therefore provide an additional and useful perspective on spatio-temporal trends in occupancy. However, they are a product of both occupancy and search effort; thus, in interpreting the counts to understand occupancy, it is important to take into account search effort. The landscape of Kooragang Island is not constant, and search effort and detectability has changed from year to year as new wetland habitats are created, and some old ones go through vegetative and hydrological changes.

For the data presented here, no single table provides a complete picture of *L. aurea* occupancy. Rather, the data for **VES Detected**, **Total Detected**, and **Search Sensitivity** should be viewed together. Large wetlands may contain large numbers of frogs (high values of **VES Detected** and **Total Detected**) at low or medium densities (lower values of **Search Sensitivity**). Conversely, small wetlands may contain high densities of frogs but with low overall numbers.

The search effort (measured in person.minutes) of VES surveys across the last six seasons is shown in Table 3.9.1. Total search effort has increased steadily across this time. Compared to last year, search effort has again increased in the Central and Southern Zones, though the Northern Zone has seen a relative decline (c.f. Table 2.5.1). The HDC jurisdiction has seen a considerable increase in search effort in 2019-20 compared to all previous years. Each wetland takes a minimum of 90 person.minutes to survey over the season, and most take considerably more; as new wetlands have been constructed (HDC wetlands in the Industrial Zone, CHEMP wetlands in the Central and Northern Zones), the number of NPWS, PWCS, HDC (BHP) and RMS wetland surveys have been reduced slightly to keep survey logistics manageable. Search effort remains well distributed across the island as a whole (Figure 2.5.2).

	All animals (not including mets)					
	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Jurisdiction						
NPWS	2028	3693	2758	1460	1560	1851
NCIG_CHEMP	0	0	0	296	2228	953
BHP_CHEMP	30	279	0	1523	1483	2153
PoN	1475	697	1033	423	641	358
PWCS	2347	2224	3305	4563	4600	999
NCIG	104	348	319	574	680	128
HDC	393	720	848	1681	1677	9295
HDC (BHP)	1304	615	442	582	506	0
RMS	298	278	156	0	0	0
Zone						
Nth	1027	1617	1056	1040	3014	1654
Central	2423	3052	2735	2662	2898	3661
Southern	4446	4185	5070	7400	7463	10422
Region						
Hunter North River	611	657	395	414	1021	620
School House	469	960	661	626	1993	1034
Cobbans Creek	458	1132	651	1728	1805	2507
Bellfrog Way	1995	1920	2084	934	1093	1154
Industrial Zone North	2093	1783	2887	3924	3840	5452
Industrial Zone South	2353	2402	2183	3476	3623	4970
Subregion						
Scott's Point	174	264	201	259	726	437
Riverside park	437	393	194	155	295	183
Wet meadow	395	678	448	410	426	414
Millam's Pond	74	282	213	216	1567	620
Ramsar Road West	110	564	258	1601	1587	2251
Ramsar Road East	348	568	393	127	218	256
Bellfrog Way West	152	403	350	205	201	376
Bellfrog Way NE	270	588	465	306	251	420
Bellfrog Way SE	1573	929	1269	423	641	358
Delta Ponds	435	195	570	881	845	999
KIWEF K7	1436	1441	1823	2037	1007	2025
NCIG rail central & east	240	507	496	775	941	764
Rail loop (K10 Nth)	393	606	596	902	730	1568
Cormorant Road	298	278	156	0	0	0
Rail loop SW (K10 Sth)	27	110	112	725	906	1372
NCIG rail south	1345	555	474	405	529	657
KIWEF K2	50	346	349	669	517	609
Deep pond	222	147	494	1006	1988	1731
KIWEF K5 (Area 2)	-	-	-	-	0	697

Table 3.9.1: Search effort (in person.minutes) across the latest 2019-20 season along with the previous five seasons, tabulated by Jurisdiction, Zone, Region, and Subregion. Note that search effort is measured for visual encounter surveys (VES) only.

	All animals (not including mets)						Adults only					
	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Zone												
Nth	8	3	0	6	92	47	4	2	0	3	70	46
Central	85	83	120	456	358	592	50	41	72	225	177	242
Southern	348	115	1118	995	1397	1638	144	64	418	500	688	519
Region												
Hunter North River	0	0	0	1	2	3	0	0	0	1	2	3
School House	8	3	0	5	90	44	4	2	0	2	68	43
Cobbans Creek	13	31	3	404	301	498	13	20	2	180	141	154
Bellfrog Way	72	52	117	52	57	94	37	21	70	45	36	88
Industrial Zone North	322	86	546	649	837	578	127	52	278	347	463	245
Industrial Zone South	26	29	572	346	560	1060	17	12	140	153	225	274
Subregion												
Scott's Point	0	0	0	1	2	2	0	0	0	1	2	2
Riverside park	0	0	0	0	0	1	0	0	0	0	0	1
Wet meadow	8	2	0	1	8	1	4	2	0	1	4	0
Millam's Pond	0	1	0	4	82	43	0	0	0	1	64	43
Ramsar Road West	1	25	2	404	301	489	1	14	2	180	141	154
Ramsar Road East	12	6	1	0	0	9	12	6	0	0	0	0
Bellfrog Way West	3	2	0	2	4	12	2	2	0	1	2	6
Bellfrog Way NE	8	4	3	0	5	12	6	3	1	0	5	12
Bellfrog Way SE	61	46	114	50	48	70	29	16	69	44	29	70
Delta Ponds	204	62	101	153	162	84	33	36	57	65	96	50
KIWEF K7	116	19	358	276	87	134	92	13	182	215	70	96
NCIG rail central & east	0	11	98	95	154	86	0	3	72	54	77	42
Rail loop (K10 Nth)	15	16	383	82	66	301	10	9	28	16	46	83
Cormorant Road	0	0	6	-	-	-	0	0	3	-	-	-
Rail loop SW (K10 Sth)	0	0	16	51	236	605	0	0	10	19	63	105
NCIG rail south	9	2	58	42	69	36	5	0	20	19	23	26
KIWEF K2	2	0	11	76	35	32	2	0	7	45	16	18
Deep pond	2	5	87	220	588	257	2	3	39	67	297	99
KIWEF K5 (Area 2)	-	-	-	-	-	103	-	-	-	-	-	0

Table 3.9.2: VES Detected numbers for the latest 2019-20 season along with the previous five seasons, summed for Jurisdiction, Zone, Region, and Subregion. Comparing the values for 'All *L. aurea*' (left columns) and 'Adult *L. aurea*' (right columns) provides an indication of the number of juveniles.

Data for **VES Detected** (Table 3.9.2) shows that the 2019-20 season had the highest numbers of *L. aurea* detected. Most detections occurred in the south of the island, particularly in the Industrial Zone (North and South). Less than half of all detections in the Central and Industrial Zones were classified as adults, while nearly all detections in the Northern Zone were adults. The high numbers detected this year are likely a result of several factors; the large breeding event that occurred in late summer 2020; but also a growing population in the BHP CHEMP wetlands and the southern part of the Industrial Zone.

	All animals (not including mets)						Adults only					
	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Zone												
Nth	0.01	0.00	0.00	0.01	0.03	0.03	0.00	0.00	0.00	0.00	0.02	0.03
Central	0.04	0.03	0.04	0.17	0.12	0.16	0.02	0.01	0.03	0.08	0.06	0.07
Southern	0.08	0.03	0.22	0.13	0.19	0.16	0.03	0.02	0.08	0.07	0.09	0.05
Region												
Hunter North River	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
School House	0.02	0.00	0.00	0.01	0.05	0.04	0.01	0.00	0.00	0.00	0.03	0.04
Cobbans Creek	0.03	0.03	0.00	0.23	0.17	0.20	0.03	0.02	0.00	0.10	0.08	0.06
Bellfrog Way	0.04	0.03	0.06	0.06	0.05	0.08	0.02	0.01	0.03	0.05	0.03	0.08
Industrial Zone North	0.15	0.05	0.19	0.17	0.22	0.11	0.06	0.03	0.10	0.09	0.12	0.04
Industrial Zone South	0.01	0.01	0.26	0.10	0.15	0.21	0.01	0.00	0.06	0.04	0.06	0.06
Subregion												
Scott's Point	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Riverside park	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Wet meadow	0.02	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.01	0.00
Millam's Pond	0.00	0.00	0.00	0.02	0.05	0.07	0.00	0.00	0.00	0.00	0.04	0.07
Ramsar Road West	0.01	0.04	0.01	0.25	0.19	0.22	0.01	0.02	0.01	0.11	0.09	0.07
Ramsar Road East	0.03	0.01	0.00	0.00	0.00	0.04	0.03	0.01	0.00	0.00	0.00	0.00
Bellfrog Way West	0.02	0.00	0.00	0.01	0.02	0.03	0.01	0.00	0.00	0.00	0.01	0.02
Bellfrog Way NE	0.03	0.01	0.01	0.00	0.02	0.03	0.02	0.01	0.00	0.00	0.02	0.03
Bellfrog Way SE	0.04	0.05	0.09	0.12	0.07	0.20	0.02	0.02	0.05	0.10	0.05	0.20
Delta Ponds	0.47	0.32	0.18	0.17	0.19	0.08	0.08	0.18	0.10	0.07	0.11	0.05
KIWEF K7	0.08	0.01	0.20	0.14	0.09	0.07	0.06	0.01	0.10	0.11	0.07	0.05
NCIG rail central & east	0.00	0.02	0.20	0.12	0.16	0.11	0.00	0.01	0.15	0.07	0.08	0.05
Rail loop (K10 Nth)	0.04	0.03	0.64	0.09	0.09	0.19	0.03	0.01	0.05	0.02	0.06	0.05
Cormorant Road	0.00	0.00	0.04	-	-	-	0.00	0.00	0.02	-	-	-
Rail loop SW (K10 Sth)	0.00	0.00	0.14	0.07	0.26	0.44	0.00	0.00	0.09	0.03	0.07	0.08
NCIG rail south	0.01	0.00	0.12	0.10	0.13	0.05	0.00	0.00	0.04	0.05	0.04	0.04
KIWEF K2	0.04	0.00	0.03	0.11	0.07	0.05	0.04	0.00	0.02	0.07	0.03	0.03
Deep pond	0.01	0.03	0.18	0.22	0.30	0.15	0.01	0.02	0.08	0.07	0.15	0.06
KIWEF K5 (Area 2)	-	-	-	-	-	0.15	-	-	-	-	-	-

Table 3.9.3: Search sensitivity for the latest 2019-20 season along with the previous five seasons, summed for Jurisdiction, Zone, Region, and Subregion. The numbers indicate the number of frogs detected per person.minute of search effort, i.e. for a value of 0.25, one frog is detected every four person.minutes of search effort.

The overall trend continues to be an increase in the abundance of *L. aurea* over the six years from 2014-15 to 2019-20. This does not appear to be a simple result of the increase in search effort. **Search Sensitivity** (Table 3.9.3), which is defined as the number of animals detected during VES per unit of search effort, has also increased steadily over this time. However, while search sensitivity in 2019-20 compared to the previous year has increased in the Central Zone, it has remained the same in the Northern Zone

	All animals (not including mets)						Adults only					
	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Jurisdiction												
NPWS	44	29	27	13	17	42	35	20	14	4	15	22
NCIG_CHEMP	0	0	0	10	97	81	0	0	0	5	74	80
BHP_CHEMP	0	19	0	394	318	523	0	13	0	178	142	186
PoN	420	220	455	330	98	76	294	98	247	271	71	76
PWCS	534	922	2464	1918	2102	104	316	410	1389	1130	1156	69
NCIG	0	12	86	87	136	422	0	4	62	50	71	7
HDC	66	36	393	209	353	5335	45	26	34	52	133	678
HDC (BHP)	11	2	48	68	59	0	7	0	18	39	24	0
RMS	0	2	6	0	0	0	0	2	3	0	0	0
Zone												
Nth	10	4	0	11	102	88	6	3	0	6	79	87
Central	454	264	482	736	428	634	323	128	261	452	223	277
Southern	611	974	2997	2282	2650	5861	368	442	1506	1271	1384	754
Region												
Hunter North River	0	0	0	3	3	4	0	0	0	3	3	4
School House	10	4	0	8	99	84	6	3	0	3	76	83
Cobbans Creek	13	34	5	404	320	534	13	22	2	180	144	183
Bellfrog Way	441	230	477	332	108	100	310	106	259	272	79	94
Industrial Zone North	532	921	2420	1858	1962	3582	314	410	1362	1094	1101	416
Industrial Zone South	79	53	577	424	688	2279	54	32	144	177	283	338
Subregion												
Scott's Point	0	0	0	3	3	3	0	0	0	3	3	3
Riverside park	0	0	0	0	0	1	0	0	0	0	0	1
Wet meadow	10	3	0	1	8	1	6	3	0	1	4	0
Millam's Pond	0	1	0	7	91	83	0	0	0	2	72	83
Ramsar Road West	1	28	3	404	320	521	1	16	2	180	144	183
Ramsar Road East	12	6	2	0	0	13	12	6	0	0	0	0
Bellfrog Way West	4	2	7	2	5	12	3	2	2	1	3	6
Bellfrog Way NE	12	4	4	0	5	12	9	3	2	0	5	12
Bellfrog Way SE	425	224	466	330	98	76	298	101	255	271	71	76
Delta Ponds	209	859	718	559	720	104	38	364	372	236	428	69
KIWEF K7	321	57	1603	991	465	232	274	43	939	771	327	172
NCIG rail central & east	0	13	103	99	165	529	0	4	76	57	83	69
Rail loop (K10 Nth)	66	36	383	101	105	324	45	26	28	22	66	90
Cormorant Road	0	2	6	-	-	-	0	2	3	-	-	-
Rail loop SW (K10 Sth)	0	0	16	89	301	631	0	0	10	25	88	124
NCIG rail south	11	2	58	45	79	758	7	0	20	21	29	32
KIWEF K2	2	0	11	90	38	37	2	0	7	52	17	23
Deep pond	2	5	99	308	689	808	2	3	51	87	340	170
KIWEF K5 (Area 2)	-	-	-	-	-	2438	-	-	-	-	-	5

Table 3.9.4: Total Detected for the latest 2019-20 season along with the previous five seasons, summed for Jurisdiction, Zone, Region, and Subregion Areas with high values indicate the location of the CMR wetlands. Across most years, K22-23 in Bellfrog Way SE, and K29 in the KIWEF *K7* have been CMR locations. In 2014-15 K108 (in the Rail Loop *K10S*) was a CMR wetland, but was replaced by K104 (Delta Ponds) from 2015-16 onwards.

and decreased in the Southern Zone. Within the Industrial Zone, there has been an increase in overall search sensitivity in the south but a concomitant decease in the north. Likewise, search sensitivity for adults only has decreased in the north Industrial Zone but has remained the same in the south Industrial Zone compared to the previous year. The greatest jump in search sensitivity appears to be in subregions associated with the Rail loop. Likewise, the **Total Detected** (Table 3.9.4) number of *L. aurea* has also continued to increase each year from 2014-15 to 2019-20 across all regions except for the northern Industrial Zone, but with a peak in the 2016-17 season. The highest numbers of detections occurred at KIWEF K5 (Area 2), of which the overwhelming majority were not adults, highlighting the large breeding event that has occurred in the vicinity of this subregion this year.

Within these overall trends, the data also provides an overview of the recent occupancy by *L. aurea* in different parts of the island. In terms of jurisdiction, animal numbers in NPWS wetlands have increased from previous years to nearly the same level recorded in 2014-15, despite only a small increase in search effort. However, densities at these wetlands have remained relatively low and similar to previous years, and were the lowest recorded for any jurisdiction this year. Numbers have slightly decreased at the NCIG CHEMP wetlands from a peak recorded last year, despite a considerable drop in search effort. At the BHP CHEMP wetlands, numbers have generally shown a positive trend each year, with the highest recorded this year (the majority of which were not adults). However, search effort has also peaked this year and so densities values have remained relatively similar to the previous year, though still the highest recorded across all jurisdictions in 2019-20. A notable trend has been the decrease in numbers in the PoN wetlands; these include K22 and K23, which have historically been considered significant wetlands for the *L. aurea* populations of Kooragang Island. This trend has continued into this year, with all individuals detected being adults, though density has seen a significant increase over previous years.

Following changes in jurisdiction of many of the wetlands in the Industrial Zone, only one of the surveyed wetlands is counted as a PWCS wetland and, as such, the totals for PWCS are the low. There was a considerable increase in counts at both the NCIG and HDC wetlands, the majority of which have been non-adults; following the late summer breeding event. The HDC wetlands now include many of the wetlands formerly administered by PWCS, and consequently search effort in HDC wetlands was the highest across all jurisdictions in 2019-20. The NCIG wetlands continue to see a decline in density from a peak in 2016-17, though search effort was lower this year than most other years (note that the large numbers of juvenile frogs detected in NCIG areas during the April ‘dispersal event’ are not included in the calculations of density).

At the regional level, there appears to be a general trend of increasing detections each year at Cobbans Creek, as well as both Industrial Zones (north and south), with these regions showing the highest densities as well. The majority of detections for these regions this year were not adults. The increase counts and density in the Cobban’s Creek region has been driven by the Ramsar Rd West subregion (i.e. the BHP CHEMP wetlands). In contrast, there continues to be a decline in detections along Bellfrog way, with numbers this year the lowest they’ve been over the past six years and comprised only of adults (mostly located in the south-east subregion). In the Northern Zone, the counts and density in the School House region have increased markedly since 2018-19, driven by increases at the NCIG CHEMP wetlands, primarily in the Millam’s Pond subregion (which contains NCIG stage 4, 5, and 7), and have continued to remain high this year. Numbers in the Hunter River North region continue to remain very low.

4. Discussion

Conservation biology of *L. aurea* on Kooragang Island

1. **Population size**: Averaging model estimates from capture-mark-recapture data over the previous three breeding seasons indicates that a total of approximately six *L. aurea* individuals with SVL ≥ 40 mm are generally present for every one individual detected during VES. Based on this ratio, and the number of VES detections obtained during island-wide surveys of 60 wetlands this year, the *L. aurea* population of Kooragang Island is currently standing at approximately 3,000. This is similar to the calculations obtained for the 2017-18 season, though smaller than for calculations obtained for 2018-19, and could suggest that the population is starting to stabilise after a long term but gradual upward trend since 2010-11. This season, nearly half of the population was located at constructed wetlands, indicating that these man-made aquatic sites are providing the necessary resources for *L. aurea* occupation and usage.

   Raw counts of abundance and density also suggest that, from 2014, population levels have continued to increase but that they have possibly also started to stabilise. Only slight increases have been seen across the Northern, Central and southern Industrial Zones, while a decrease has been seen in the northern Industrial Zone.

   Applying pooled model estimates or consistent estimates to VES data each year may be an effective means of comparing population sizes between years and should be continued.

2. **Demography**
   a. Age/sex class structure: For those frogs where age/sex class was identified, less than a third of individuals detected in each round were metamorphs or juveniles. Of the individual adults captured and identified, approximately one half to two-thirds were male. These proportions are broadly consistent with the pattern from recent seasons.

      Several cohorts of younger *L. aurea* could be identified. Juveniles detected early in the season in Round 1 likely overwintered as tadpoles. A new cohort of juveniles was detected in Round 2, likely linked to rainfall events that occurred earlier in September and indicating that breeding occurred in the first half of the season. However, it was not until the end of the season, after heavy rainfall in February, that large numbers of both metamorphs and juveniles were detected. Few juveniles were captured and/or tagged despite the large numbers detected in Round 4 and 4.1. This is primarily due to detections occurring during non-capture rounds.

   d. Recruitment: 16 wetlands within the Industrial Zone held either tadpoles and/or metamorphs at some point during the 2019-20 breeding season. The largest numbers were recorded at K111 and K121 in the latter half of the season, both of which are in the southern Industrial Zone. This is in contrast to the previous season, where the largest breeding event took place in K105A within the northern Industrial Zone. Breeding events were also recorded at one of the BHP-CHEMP wetlands and three wetlands within the Central Zone. One small juvenile was also detected in one of the wetlands situated in the Northern Zone, suggesting that breeding took place here as well. If this is the case, then breeding occurred across all zones this season. Later in the season, large numbers of juveniles were detected at K121, and also K105AS. Throughout April, a large dispersal event was recorded in the *K10* and *K3-K5* areas of the Industrial Zone. This event involved the detection of many hundreds of very small juvenile *L. aurea* in operational and construction sites. From the size of the animals detected, they were spawned in the February rainfall event and had all recently metamorphosed and apparently dispersed away from their natal wetlands following rain in late March – early April, i.e. at the time of their metamorphosis. Based upon the location of their detection in aquatic and terrestrial habitats, the dispersal event indicates very high levels of breeding at K105B, K105AS, and the K111-K114 and K121-K123 wetlands of the *K10N* and *K10S* areas.

Tadpoles and metamorphs were detected mainly in wetlands classified as permanent (i.e. 'nearly permanent' or 'deep permanent'), except for K13, K112 and K113 which are seasonal and K9A/B which is saline irregular, demonstrating that *L. aurea* are not necessarily limited to ephemeral wetlands for breeding. The lack of breeding at temporary sites may be due to the dry conditions breeding adults were exposed to throughout much of the season as a result of lower than average rainfall, particularly in the first half of the season

e. Gravid females: Using 58 mm as the threshold for the onset of female reproductive maturity means about one quarter of individual adult *L. aurea* on Kooragang Island are female; 221 individual PIT tagged females were detected across the 2019-20 season. This number is similar to the corresponding data from the three previous seasons and indicates that the effective population size of *L. aurea* on Kooragang Island is sufficient for at least the immediate persistence of the population. However, the low percentage of recapture events between years suggest that few individuals are making it to multiple breeding periods. This is cause for concern for two reasons: i) females generally take longer to reach sexual maturity than males, and ii) just two consecutive years of poor recruitment is predicted to have a strong negative effect on population size.

3. Survey rounds and weather

The largest number of adult captures occurred in Round 1, which followed rain in early September. Movement and widespread calling indicate that a breeding event likely took place in this early part of the season following that rainfall event. This is supported by the detection of small numbers of metamorphs and juveniles in Round 2. Fewer captures occurred in Round 2, which is to be expected given that conditions in summer were dry, with lower than average rainfall. Many of the wetlands dried completely during the early to mid-summer period, including many that have historically been characterised as 'permanent'. Round 3 occurred during a period of late summer rainfall in February that re-charged wetlands and sparked a large breeding event. Evidence for this come from the large number of adult females detected during this round, as well as the large number of metamorphs and juveniles detected later in Rounds 4 and 4.1 (see below). Large numbers of metamorphs were detected in Round 4 in K111, K121, K122 and K123, indicating highly suitable conditions for offspring survival.

Near the end of the season in April (Round 4.1), a large dispersal event was detected, with high numbers of juveniles detected at fence lines established in terrestrial habitat away from water (these fences were part of operational activities on the site). These small juveniles were of the same cohort as those which were detected as tadpoles and metamorphs in Round 4. This highlights a possibly important aspect of this species' life history, which is the movement of vulnerable juveniles away from their natal waterbodies when weather conditions are suitable for dispersal across terrestrial habitat.

While drier than average conditions have been a common hallmark of the *L. aurea* breeding season on Kooragang Island for the past four seasons, it is clear that an extended breeding period affords this species a greater chance of being exposed to optimal breeding conditions on at least a few occasions. As such, while adults were met with poor breeding conditions in the first half of the season, the large rainfall event/s in the latter half of the season were sufficient to trigger a large breeding event, which theoretically should allow for sufficient recruitment of individuals in the adult population in the next season for continued persistence on the island. In fact, this year saw breeding in more wetlands than any other previous season. However, what remains unclear is the impact of extended dry periods on adult survival and whether these conditions affect the acquirement of sufficient energy for breeding to occur when conditions do become optimal. The lower numbers of adult *L. aurea* detected this season compared with 2018-19 may indicate that extremely dry summers cause significant levels of adult mortality. Alternatively, adult activity in very dry periods may change in a way that makes detection especially difficult. What also remains unknown is how extended dry periods affect juveniles that have dispersed from aquatic sites, given that they are more susceptible to desiccation and are less proficient at migrating to optimal microhabitat oases than adults.

4. Longitudinal data

b. Persistence: As with previous seasons, persistence is low with most marked animals never recaptured. Of those that are, most are recaptured within six months of first capture, and only 10% are recaptured more than 12 months from first capture.

c. Movement: Most detected movements were between wetlands within the northern Industrial Zone and within the Southern Industrial Zone. In particular, most movements occurred between wetlands surrounding K105A, highlighting the strong connectivity between wetlands within this habitat mosaic. Several of these movements were made by adult females out of K29 into another wetland in the mosaic, providing support for the suggestion that *L. aurea* will move from 'refuges' (e.g. K29) to habitats that provide suitable breeding conditions at a particular time.

Most movements this season were between wetlands less than 200 metres apart. Over the past 9 years, most detected movements have been less than 500 metres, indicating that wetlands need to be within this distance to improve their connectivity within habitat mosaics. This could also be critical for promoting movements between zones, to improve gene flow between mosaics/locations across the island. Movement between the mosaic centred around K105 (referred to as the Northern Ponds mosaic) and K22/23, albeit only a small distance apart, indicates a degree of connectivity between the Industrial and Central Zone wetlands. However, there was no detection of movement between the Central and Northern Zones in 2019-20. While this has been detected in previous seasons, is it a rare occurrence and suggests that additional habitat mosaics between the Central and Northern Zones will be required to improve connectivity between these areas of the island.

A small number of larger movements greater than 500m were detected both within the current breeding season and between the current and previous season, showing movement of animals between the northern and southern Industrial Zones. In particular, movement was detected out of K100A into K105A and K42, suggesting that K100A is an important refuge, especially during dry periods. Movement was also detected between K104 to K23, indicating that while K104 is a relatively isolated wetland within the Industrial Zone, that animals are able to successfully migrate out of this wetland to other sites. It is, however, likely that animals moving from K104 will be moving to nearby wetlands prior to making extended journeys to more distant wetlands.

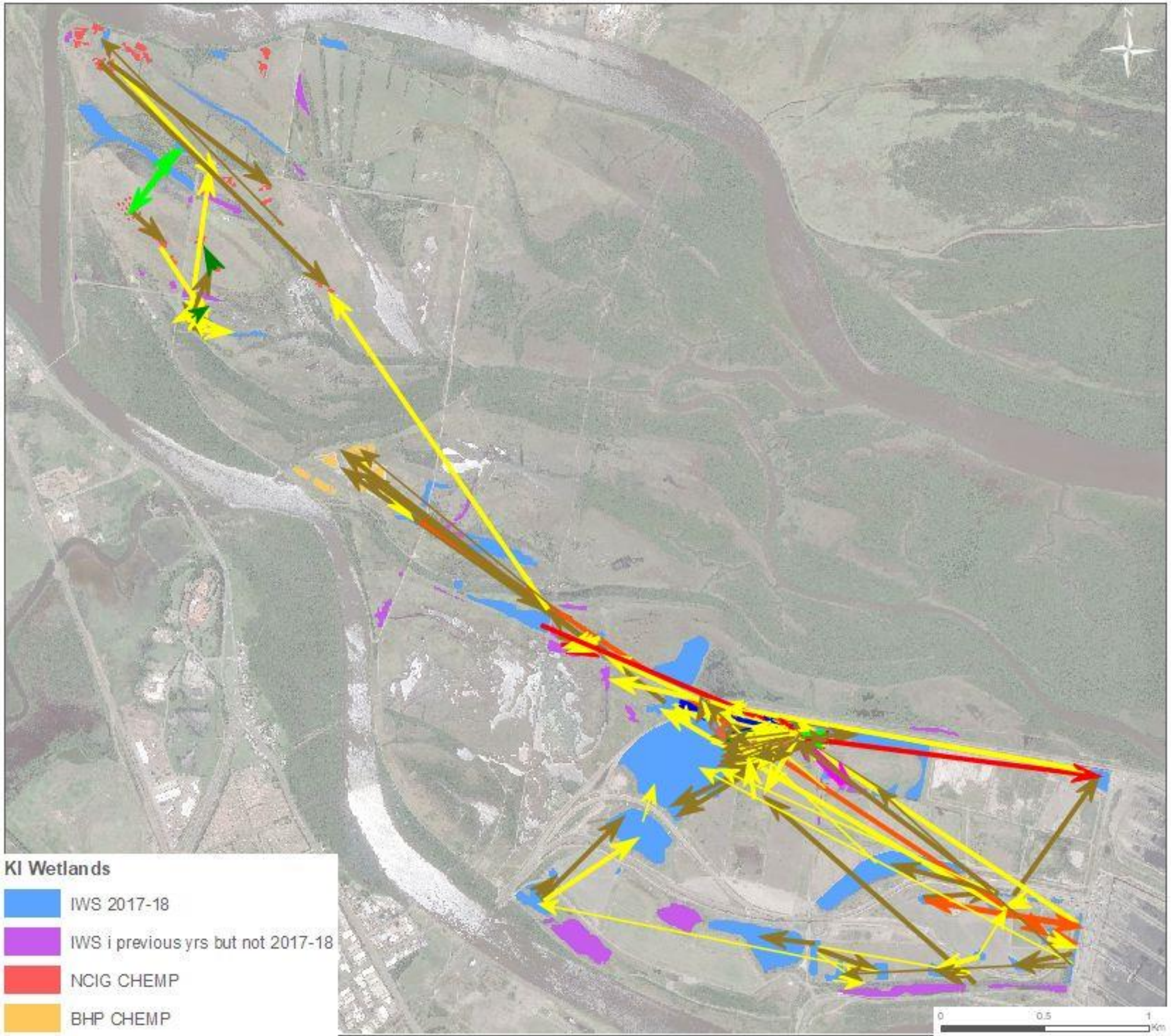

Figure 4.5.1: Detected movements of tagged *L. aurea* across Kooragang Island, 2011-20. Data combines detections from multiple datasets (see Section 3.5 for discussion).

5. Landscape use

a. Distribution: The largest number of adult detections occurred in the Industrial Zone, which is consistent with previous years, showing that this area remains a stronghold for *L. aurea* occupation/persistence. More adults were detected in the northern region of the Industrial Zone. Historically, *L. aurea* abundance has always been higher in the northern region, while the apparent increase in abundance in the southern region is likely linked to the construction of new wetlands in this area that has created an effective habitat mosaic. Adult numbers across both regions of the Industrial Zone have declined since the previous breeding season, though overall numbers (adults and offspring) have increased, indicating that this area remains critical for breeding on the island.

   Adult numbers in the Central Zone are similar to those recorded in the previous breeding season but – with the exemption of the BHP-CHEMP wetlands – are low compared to observations from pre-2014, though overall numbers (adults and offspring) have shown a marked increase. However, reduction in search effort due to issues in gaining access to sites along Bellfrog Way complicates assessment of the situation.

   Both densities and absolute numbers remain comparatively low in the Northern Zone. However, they have increased markedly compared to previous seasons before 2018-19, likely due to the construction of the NCIG-CHEMP wetlands. Numbers in the Milliam's Pond subregion are reasonably high and this appears to be a consistent signal across recent seasons. The NCIG CHEMP habitats at Stage 4, 5, and 7 have been primarily responsible for this increase. Milliam's Pond is further 'downstream' (in terms of drainage patterns across the island towards the Hunter River estuary) than the other subregions in the Northern Zone, and may experience different salinity profiles; however, the salinity profiles and any potential interaction with *L. aurea* abundance within the Northern Zone requires further investigation. In any case, the current trend of *L. aurea* occupancy in this subregion, along with the detection of a small juvenile in this zone, provide evidence that a population persists here with the capacity for breeding.

c. Landscape factors affecting distribution, abundance, and recruitment:

   b. **Gambusia:** The majority of breeding occurred in wetlands where *Gambusia* was absent. However, breeding did occur in three wetlands (K102, K103, K104) in the Industrial Zone where the fish was present, albeit not in high densities. Currently, it is unknown to what degree breeding adults are able to perceive the presence of the fish and avoid potential oviposition sites where they are present. The fact that most breeding occurs away from these sites would be indicative of this capacity. The presence of breeding at some sites where the fish is present may suggest that successful breeding and then offspring development can occur in the presence of the fish, although likely dependent on fish density. This is an important finding, as management strategies to remove the fish (which may not be feasible for large waterbodies and expensive) may not be needed. Instead, strategies that maintain densities at low levels could be equally effective. In any case, the fact that adults are avoiding fish-present sites is an issue as it means these potentially optimal breeding site are unusable, thereby disrupting the effectiveness of habitat mosaics.

      Gambusia are currently absent from a large number of wetlands, only present at four wetlands in the Industrial Zone. This is primarily due to a string of dry years that has caused many of the waterbodies to dry out completely, removing the fish. There is also evidence of the fish being extirpated from wetlands during the season, opening up sites that are originally unusable at the start of the season later on. This is a clear benefit of dry conditions, on the caveat that subsequent rainfall at some point replenishes water levels for breeding to occur. Strategies to manage *Gambusia* on the island should take advantage of this situation, ensuring that the fish does not re-invade sites where they are now absent.

Chytrid: In the early spring (2019) survey round we swabbed 208 captured *L. aurea*, with the objective of measuring Bd prevalence at that time. Bd (*Batrachochytrium dendrobatidis*) is the fungal pathogen that causes the disease chytridiomycosis (chytrid), responsible for more than 40% of global amphibian declines over the last three decades. This is the most effective time within the IWS sampling season to detect Bd as it is a winter-active pathogen that exists in water and moist soil during the cooler months on the east coast of Australia. The mean infection load across the total number of individuals swabbed was 25 zoospore equivalents (SE±1.3), however the results of 66 samples either had very low Bd levels of non-specific amplication and are thus unreliable. When excluding these data, almost 40% of individuals swabbed were infected with Bd with a mean infection load of 35 zoospore equivalents (SE± 0.29), suggesting infection loads were similar across all individuals where swabs were not inihibited (able to be confidently analysed using the quantitative polymerase chain reaction analysis). The disease-inducing threshold of Bd infection for *L. aurea* has not been consistently confirmed for both adults and juveniles of the species under laboratory and field conditions and infection load is likely to be influenced by a complex combination of individual fitness and environmental conditions.

Chytrid is known to be strongly affected by temperature and salinity, with temperatures above 22°C and salinity levels greater than 3 ppt substantially reducing infection load (Heard et al. 2015; Stockwell et al. 2012). Within its former range, *L. aurea* is understood to persist only in locations where environmental conditions lead to reduced chytrid load via temperature and salinity effects.

For wetlands on Kooragang Island, salinity is affected by wetland connections with estuarine groundwater and/or sediments with concentrations of salts. Based on work by Heard and colleagues on microhabitat factors in wetland in central Victoria, temperature is affected by wetland size (larger wetlands are warmer) and the amount of tall vegetation shading the water surface (Heard et al. 2015). Both of these factors are known to vary across Kooragang, and it is therefore likely that a number of wetlands on the island have environmental conditions that reduce chytrid load and thus provide some protection to *L. aurea*.

Discerning these relationships in the field is difficult, however, Callen (2018) noted that, whilst the presence of saline wetlands in the landscape is likely an important factor in the local survival of *L. aurea*, a straightforward connection between salt levels and *L. aurea* survival at specific wetlands cannot be demonstrated in the field – despite the fact that such a relationship can be clearly demonstrated in laboratory experiments (Stockwell et al. 2012). Rather than establishing a straightforward connection between salinity and *L. aurea* survival at specific wetlands, Callen emphasises that *L. aurea* survival is likely increased if they have access to saline wetlands somewhere within their local landscapes. A similar pattern may apply for temperature, and this logic is a key component of the concept of the habitat mosaic**.** It would be useful to have a 'wetland-by-wetland' or 'region-by-region' insight into how chytrid load varies across the island, but this requires very high levels of sampling and has thus far not been attempted.

Specific management issues relevant to research partners

6. **Habitat corridor mitigation strategy**: The extent of wetland habitat, connectivity, and variation in wetland hydroperiod across the southern Industrial Zone has increased markedly in recent years, primarily as a result of the construction of nine wetlands by HCCDC since 2015. The density and abundance of *L. aurea* in this region has increased markedly over the last four seasons (**Section 3.9**), and breeding now occurs frequently (**Section 3.6**). As such, the strategy to improve *L. aurea* populations in the 'southern corridor' has been somewhat successful. Further, the recorded movement of adult frogs between the northern and southern Industrial Zones indicates sufficient connectivity, which could be improved by the addition of wetlands less than 500 metres apart for individuals to use as refuge while migrating across the site.

   While the southern Industrial Zone has become key habitat for the persistence of *L. aurea* on Kooragang Island, it is currently lacking in large, permanent wetlands that may be critical refuge during particularly dry periods throughout the year. Historically, this role was filled by K108, which has now declined in terms of hydroperiod and extent of open water as a result of industrial landscape changes in the vicinity. In 2019, three new cluster ponds were installed in K10 South, in between K121 and K122 to produce additional deep permanent refuge habitat in and around the rail loop. However, further efforts should be made to provide larger permanent wetlands in the southern Industrial Zone as well, to ensure that this habitat mosaic is able to adequately provide all necessary resources for both local persistence all year round and breeding.

7. **Rail infrastructure mitigation strategy**: At the time that the NCIG rail infrastructure was constructed, there was (reasonable) concern that this infrastructure would reduce the extent and connectivity of wetland habitat across the southern part of the Industrial Zone. Direct impacts upon the existing wetland habitat were contained to a stretch of wetland at the east edge of K102 where the dump station is now located, and the southern part of Deep Pond that now divides K105A and K105B (Figure 4.6.1). Indirect impacts may include the change in wetland hydroperiod of the Eastern Ponds (K108). What is unequivocal is the separation of large parts of the southern Industrial Zone from the northern region by rail tracks and associated infrastructure.

   Although the potential for railways to impede movement of animals across the landscape is real, there is evidence to indicate that adults do not avoid traversing them. In particular, significant movements between the northern and southern Industrial Zones were detected in the 2019-20 season between wetlands situated within (e.g. K115) or east of the rail loop (K100A) and K105A. Movement that required animals to go over or under rail lines was also detected in the northern zone between K105B to K105AS. Although it is not yet possible to say if railway infrastructure represents a partial hindrance to movement of *L. aurea* across the landscape, it is clear that it does not constitute an absolute barrier, though further research is required to determine whether assistance in movement across the rail line is needed into the future.

8. **Constructed wetland strategy**: Over the last decade, there have been several phases of artificial wetland construction across the island:
   i. The 'cluster ponds' installed by PWCS; in both the northern and southern regions of the Industrial Zone.
   ii. The HDC wetlands constructed as part of closure works in the southern region of the Industrial Zone,
   iii. The NCIG CHEMP wetlands in the Northern Zone of the island, and
   iv. The BHP CHEMP wetlands in the Central Zone of the island.

   Each of these phases are now occupied by *L. aurea* at some level. Altogether these constructed wetlands appear to support nearly half of the island's *L. aurea* population.

Cluster ponds – While the grass fire of early January 2019 caused extensive damage to the C1 cluster ponds and the surrounding area, they still contained water this season and vegetation has recovered. A small number of *L. aurea* adults were detected using this pond set, indicating that they continue to provide some level of suitable habitat for animals in this region. Note that the C1 cluster ponds were repaired through the addition of additional tanks in May 2020, after the 2019-20 breeding season but potentially providing some level of habitat improved for the following seasons.

The number of *L. aurea* detected at the C2 cluster ponds has been steadily increasing since their first detection there in 2016-17. While juveniles were found in these ponds throughout the 2019-20 season, they do not appear to provide breeding habitat themselves. Instead, it appears that the C2 cluster provides habitat for animals that have been spawned in nearby wetlands, including K121-123, and is likely important refuges of permanent water during extended dry periods.

During the 2018-19 a fifth set of artificial wetlands based on the **cluster pond** design were installed in the Southern Industrial Zone by HDC and UoN (see Figure 3.4.14 and accompanying text for details). The purpose of these was to produce additional deep permanent, small refuge habitat in and around the rail loop, as that wetland type is currently not present in the habitat mosaic. While C3, C4 and C5 were quickly colonised by several frog species, including *L. aurea*, it appears that the C3 cluster in *K10 South* is being utilised more than C4 and C5 in *K10 North*.

HCCDC - All of the nine HDC wetlands (K111-114, K117-118, K121-123) continue to be occupied by *L. aurea*. This includes the detection of large numbers of metamorphs and/or juveniles at six of these wetlands this breeding season, along with tadpoles in all but one wetland, suggesting that they have the capacity to be critical breeding sites for *L. aurea* on the island. Overall, the HDC wetlands continue to underlie the increased abundance of adult *L. aurea,* extent of breeding habitat, and wetland connectivity in the southern region of the Industrial Zone. Their success supports the findings of previous studies on bell frogs (e.g. Heard et al., 2018) that show the addition of new, well-designed constructed wetlands is more effective at increasing survival compared to attempts to improve existing habitat.

NCIG and BHP CHEMP - While abundance at the NCIG CHEMP wetlands has historically been low, it has increased markedly since the 2018-19 season. In 2019-20 it was higher still (Figures 3.8.2, 3.8.3, 3.8.4), although it remains lower than the other zones. Both the NCIG and the BHP CHEMP are the focus of current research projects and detailed information is reported separately.

9. Other issues

c. **Bellfrog Way surveys**: A reduction in search effort at this location given difficulties in completing surveys occurred for several reasons: i) ground fires that were ignited in January 2019 were not fully extinguished until September 2019, with access restricted until October, ii) increased safety and induction requirements by PoN prevented access further still to mid-November, and iii) we were able to survey K22-23 in early December but there was not enough suitable days at this time to complete the transect surveys as well.

d. **Recaptures over the season:-** What is interesting (and potentially concerning) is that few animals caught in earlier rounds were re-caught in Round 3 when conditions were presumably the most optimal across the season for breeding.

Closing Statement

Litoria aurea was once both a common species and widespread in its distribution in NSW. This suggests an historical ability to occupy wide ranging habitats with frequent seasonal breeding or large breeding events. The seasonal surveys conducted across Kooragang Island over the last decade are testament to this ecology and biology, with individuals detected in almost all wetlands at one time or another provided they contain water, irrespective of the presence of the predatory *Gambusia* fish. The coastal climatic influences on Kooragang Island lead to dynamic environmental conditions and *Litoria aurea* matches their movement and breeding in response to a complex relationship of seasonal rainfall patterns, wetland physiognomy and density of *Gambusia*. The mosaic of natural and created wetlands across Kooragang Island is likely playing a significant role in securing the persistence of this population in the presence of both invasive predators and disease, as well as buffering the impacts of shifting climate patterns such as increased frequency of extended dry periods by ensuring permanent wetlands exist as refuge sites.

5 References

(* indicates previous reports for the island-wide monitoring programme)

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Appendix A

Wetland sample sites: Wetlands are included within the Whole Island Monitoring Program if:

1. They have been surveyed since the establishment of early monitoring programs on the Island (i.e. a Hamer study site (Hamer 1998)), or
2. they have since been identified as providing habitat for *L. aurea*, or
3. are newly created within key areas (e.g. HDC constructed wetlands within the Terminal 4 industrial zone.

From the program's commencement (2010/2011) more than 50 additional wetlands had been added by the 2015-16 surveys, making a total of 76 wetlands surveyed in that season. The survey effort required for this number of wetlands was high and contributed (along with other logistical issues) to only two full surveys rounds being completed in the 2015-16 season. In 2016-17 we did not survey several of the wetlands that had been surveyed in the previous years (K6, K27, K30B, K44, K47, and K119; these had consistently had very low numbers of *L. aurea*). As the NWL wetland was now included in the BHP CHEMP, it was no longer on the island-wide survey schedule; the addition of K105B meant that a total of 71 wetlands were surveyed in 2016-17 (Figure 2.1.1).

With the completion of three new wetlands by HDC in mid 2017 (designated K121, K122, and K123) and an increasing focus on the changing habitat mosaic of the southern industrial zone, and the addition of K105B to the survey schedule (as part of the need to understand any effects of the NCIG rail infrastructure; see Aim #6 in Section 1.5 above), the logistics of survey effort were managed by removing a number of wetlands from the survey schedule. Some of these (K1, K2S, K7A, K8, K15, K16, K17, K18, K19, K58A) were (i) becoming 'choked' with vegetation and held very little water, with very few detections of GGBF in recent years, (ii) are located close to the new NCIG CHEMP habitats in the Northern Zone. Since significant search effort was being focused on the new habitats, we decided that we could remove those older wetlands from the survey schedule and whilst maintaining equivalent search effort in the Northern zone of the island. Similarly, construction of the BHP CHEMP habitats in the Central Zone meant that K10, K11, K12, K20, K24, K25, K45, K45A, and K107 could be removed from the survey schedule whilst maintaining levels of search effort in the Central Zone consistent with previous years. Within the Industrial Zone, several wetlands in the 'K30' area were removed from the survey schedule as survey effort was very high in these; K30, K30A, K32, K33, K35, and K41 were not surveyed this year, leaving K34, K31, and K42 from this part of the Industrial Zone in the survey schedule. K49A, K100E, and K100W were also removed from the schedule; these wetlands present considerably difficulties to survey and omitting them provided significant benefits for the management of survey logistics. In each case, nearby wetlands continued to be surveyed.

The removal of these 28 wetlands from the schedule was countered by the addition of three wetlands within the Industrial Zone, five wetlands from the BHP CHEMP, and eight wetlands from the NCIG CHEMP, as well as splitting surveys in the large Deep Pond wetland between the northern section (K105A) and southern edge (K105AS), leaving a total of 60 wetlands surveyed in the 2017-18 research program.

To maintain consistency, identification and sample site nomenclature follows Hamer's numbering scheme and has been extended to the additional wetlands; refer to Figure 2.1.2 and Figure 2.1.3 for details of and numbering.

APPENDIX 7

CHEMP MONITORING UPDATE REPORTS

Green and Golden Bell Frog Research and Monitoring Program on Ash Island, Hunter Estuary [NCIG CHEMP Habitat].

Report for September 2019 - April 2020 (2019/20 Breading Season)

Prepared for *Newcastle Coal Infrastructure Group*

Prepared: Dean Lenga, Assoc Prof. John Clulow (Univ of Newcastle)

Reviewed: Prof. Michael Mahony (Univ of Newcastle), Dr Simon Clulow (Macquarie University).

September, 2020

Executive Summary / Key Findings

- Five rounds of surveys for Green and Golden Bell Frogs (*Litoria aurea*) were conducted during Sept 2019 – April 2020 across the NCIG CHEMP wetlands.
- GGBF were recorded in 19 of the 55 (35%) waterbodies within constructed wetlands in the period from September 2019 to April 2020. There were 86 GGBF recorded across the NCIG compensatory habitat during the Sept 2019 - April 2020 surveys.
- Highest numbers of records across the system were in Stages 4, 5, 6 and 7. The predominance of records in these Stages indicates these were functioning as the most active habitats for GGBF in the system during 2019/20
- 78 of these observations resulted in captures with gender and morphometric data recorded (data not shown).
- Breeding was confirmed in one Stage in the habitats (Stage 6.6) through the detection of metamorphs. A small number of juvenile frogs (suggesting breeding in other waterbodies, or movement after breeding between waterbodies) were found in Stages 4 and 7. Breeding activity was concluded to be relatively low.
- Low breeding activity is not solely explained by climate (low rainfall effects), as higher breeding activity is detected in other areas of the Ash Island-Kooragang Wetland System.
- A management action of vegetation clearance (physical macrophyte removal) to reduce vegetation density and increase open water in waterbodies was undertaken by NCIG under the NCIG GGBF CHEMP Management Action Plan during 2019. Ongoing monitoring indicated reoccupation of disturbed ponds, with some evidence of site fidelity by GGBF to disturbed ponds. There was no response as measured by increased occupancy of waterbodies or additional breeding events in response to disturbance (compared to pre-disturbance conditions or non-disturbed sites).
- Ongoing research and monitoring is required to understand population trends in the system, identify and investigate adaptive management actions to increase occupancy and breeding in constructed waterbodies, and improve long-term prospects for population persistence.

1.0 Introduction

This report provides a summary of data and results of surveys for the presence, abundance and breeding of green and golden bell frogs (*Litoria aurea*) (GGBF) within the NCIG Compensatory Habitat Wetlands (Stages 1-7), Ash Island, undertaken between September 2019 and April 2020. The surveys were undertaken by members of the University of Newcastle (Conservation Biology Research Group) as a part of the Compensatory Habitat and Ecological Management Program (CHEMP) of NCIG on Ash Island.

The report also recapitulates data from periods prior to the current survey period (2018-2020) to assist interpretation of survey data (Appendix 2).

The results summarise data for bell frogs encountered during surveys using visual encounter surveys (VES) and capture-mark-recapture (CMR) methods, tadpole surveys by fyke netting, water chemistry data, and summarises results of a pond disturbance (vegetation removal) program undertaken in March 2019.

2.0 Survey Periods and Techniques

Five rounds of surveys (Table 3) were undertaken involving most of the waterbodies (ponds) in Stages 1-7 of the NCIG CHEMP constructed habitats in each round during September 2019 to April, 2020: Round 1 (September 2019), Round 2 (October/November 2019), round 3 (January 2020), round 4 (February 2020) & round 5 (March/April 2020). Surveys were undertaken for the presence of GGBF tadpoles and metamorphosing froglets and juvenile and adult GGBF's, as well as the presence of the invasive fish species, *Gambusia holbrooki*.

Wetlands were surveyed using standard methods for surveys of Green and Golden Bell frogs on Ash/Kooragang Islands over multiple seasons. Techniques are described below:

- Visual Encounter Surveys (VES): timed counts, adjusted for observer number, of GGBF in and around wetland habitats used to generate estimates of relative population densities.
- Capture Mark Release Surveys in GGBF occupied waterbodies:
  - Recording gender, reproductive status, weight, snout-vent length.
  - Individual adult frogs are marked with microchips.
  - Estimating population sizes at individual wetlands & across the whole landscape using mark-release-recapture data, monitoring development and growth of individuals, and the movement of individuals between wetlands.
- Fyke netting of waterbodies:
  - This allows monitoring of the presence of tadpoles, fish and invertebrates in each wetland.
  - Data on GGBF tadpole presence will be used as evidence of breeding events, and as an indicator of habitat suitability.
  - Determination of the occurrence and population density of *Gambusia* is also used as an indicator of predatory pressure and impacts on GGBF in the studies wetlands.
- Habitat data collection:
  - Regular surveys are conducted of the state of the habitat in each of the monitored wetlands including: vegetation composition and percentage cover, water quality, water body size and water depth.
- Classification of developmental stages and sex of frogs:

Frogs less than 45 mm (snout-vent length) were classified as a juvenile (unsexed); > 45mm SLV but without nuptial pads during breeding season were classified as juvenile female; any frogs with nuptial pads were recognised as adult males; frogs > 60 mm (or clearly gravid) without nuptial pads were classed as adult females.

Weather data were accessed from Bureau of Meteorology, Williamstown Weather Station, for period September 2019 to April 2020.

3.0 Results (Sept 2019 – April 2020)

3.1 Temperature, rainfall, pond volume (hydration) and water quality (September 2019 – April 2020)

Temperature (Fig. 1) and rainfall (Fig. 2; Table 1) data reflected the drought conditions persisting on Ash Island through 2019/2020 until extensive, above average rainfall fell during February 2020. This rainfall effectively broke drought conditions and recharged the aquifer and waterbodies from February, 2020. Above average air temperatures coincided with the absence of rainfall until Feb, 2020, a factor that would have exacerbated the drying of wetlands throughout the system, and probably contributed to the extremely low levels of GGBF breeding activity in the system before February, although low rainfall does not readily explain the absence of breeding after February.

Average air temperatures were higher than long-term (78 year) averages every month from Sept 2019 to Jan 2020, and were particularly elevated during November to January, coinciding with the low rainfalls during those months (Fig. 1). These elevated temperatures followed on from above average temperatures in the early summer period at the end of 2018 (Lenga and Clulow, 2019).

Rainfall was above average in Sept 2019, but well below long-term averages during October 2019 to Jan 2020 (Table 1, Fig. 1). Of particular note, and coinciding with above average temperatures, the total rainfall for Dec 2019 was only 0.8 mm. The substantially lower rainfall up to Feb 2020 resulted in many of the ephemeral and semi-ephemeral waterbodies drying over the first half of the summer period, and in turn these conditions were associated with low rates of GGBF observations during surveys during the summer, even after rainfall increased from Feb 2020 (see Tables 3, 4, A2.1, A2.2). The large rain event that occurred in the early part of February 2020 saw an influx of 141mm into the habitats over 5 days, and a total of 331mm from Feb to April 2020. This caused the majority of the wetlands to recharge as well as an increase of frog activity in the habitats, although total numbers recorded in surveys did not rise substantially (Table 3), indicating relatively low numbers across the landscape.

Despite the drought conditions resulting in many waterbodies drying substantially or completely, the resultant water quality indicators mostly remained within acceptable parameters for frog and tadpole hydration and survival (salinity most ponds low, ≤ 1 ppt, with a relatively small proportion 1 – 4 ppt, and pH ≥ 6.00; Table 2) and would have been capable of supporting tadpole development through to metamorphosis. Two ponds had high salinity (K58B, 7.07 ppt; Pond 4.11, 10.4 ppt; Table 2) measurements on one occasion (readings not replicated on more than one occasion), values too high to support tadpole development. Maximum and minimum water depths in ponds varied substantially (Table 2) due to the dry conditions prior to February, 2020, and the recharge of the system from February onwards.

3.2 GGBF records during surveys (Rounds 1 to 5) – September 2019 to April, 2020.

GGBF were recorded in 19 of the 55 (35%) waterbodies within constructed wetlands in the period from September 2019 to April 2020 (Table 3; also Tables A2.1, A2.2, A2.3). Nevertheless, counts were not high across the system. There were only 86 GGBF recorded across the NCIG compensatory habitat during the

Sept 2019 - April 2020 surveys. 78 of these observations resulted in captures with gender and morphometric data recorded (data not shown):

- Female: 32
- Male: 35
- Juvenile Female: 4
- Juvenile: 7

Highest numbers of records across the system were in Stages 4, 5, 6 and 7; specifically, the five highest counts were recorded in ponds 4.9 (10 records), 5.4 (6 records), 6.6 (9 records), 7.2 (17 records), 7.3 (17 records). The predominance of records in Stages 4, 5, 6 and 7 indicates these were functioning as the most active habitats for GGBF in the system during 2019/20 (see Appendix A1 for locations of Stages and waterbodies within stages).

All GGBF records for the spring/summer surveys of 2019/2020 are presented in Table 3. There were records of juveniles in ponds 4.9, 4.10, 7.2, 7.3 and T13 (former Trial site ponds) however, breeding was not confirmed in any of these stages, although it may be inferred. Breeding was only confirmed at one Stage, in pond 6.6, through the detection of metamorphs (see Table A2.3) during 2091/2020. Presence of juveniles does not indicate in which Stage breeding occurred. It is likely that the observation of one juvenile in T13, for example, may represent GGBF juvenile movement from Stage 6 breeding (these waterbodies are in close proximity).

Taken together, the data indicate an absence of breeding activity, in Stages 1, 2, 3 and 5, possible breeding activity in Stages 4 and 7, and confirmed breeding in Stage 6 during 2019/20. It is worth noting the spatial location of these stages relative to each other i.e. the stages with absence of breeding are in the north-west of the CHEMP system (towards Scotts Point), while the stages with inferred or confirmed breeding are in the south-east of the system, closer to BHP habitats (where large breeding events occurred in 2019/2020) and the Industrial zone of the Ash Island-Kooragang system (also large breeding events).

3.3 Macrophyte clearance (successional disturbance) of water bodies: GGBF response after one year.

Macrophyte reduction took place in a range of waterbodies in the NCIG CHEMP system in March, 2019 in compliance with the Hunter Wetlands NP/NCIG CHEMP constructed habitats Management Plan. Further information on that clearance event and the ponds in which macrophyte cover was reduced is presented in Lenga & Clulow (2019). By way of clarification, 13 waterbodies were involved in the design of that study, but only 9 were directly cleared (four were retained as uncleared “controls”). About 70-80% of vegetation was removed from disturbed ponds to restore the ratio of open water to emergent vegetation to a level considered favourable for GGBF occupation and breeding in ponds.

Return to waterbodies post-disturbance As noted in Lenga & Clulow (2019), there was evidence of rapid re-occupation of disturbed ponds within a short period after the disturbance (GGBF removed in pre-clearance surveys were relocated to the nearest undisturbed waterbody). Evidence for this is presented in Tables 4, 5 and Figure 3. Most relocated frogs were moved from stage 7.3 to 7.1 and about 50% of these rapidly moved back to stage 7.3. Fewer frogs were relocated from other disturbed ponds, so data from those relocations is restricted by the smaller sample sizes.

GGBF occupation of waterbodies post-disturbance Comparison of pre- and post-disturbance GGBF survey data is presented in Table 4. This shows a variable response across disturbed ponds with some stages (especially stages 4 and 7; waterbodies 4.9, 7.2, 7.3) returning to high elevated counts post-disturbance, while others showed no response or decline (Stages 3 and 5). There was no confirmed breeding event in any of the disturbed waterbodies, even after the return of rains from Feb, 2020, although a juvenile (Table 3) was located at 7.2 during March/April 2020. This single individual may have been produced by breeding in these ponds (no tadpoles or metamorphs were detected), but is more likely to have moved from the confirmed breeding at waterbody Stage 6.6 (see *Results 3.2*). In summary, although the disturbed waterbodies were re-occupied after vegetation reduction, there was no evidence of a large movement into those waterbodies, or an induced breeding event in response to the disturbance events.

4.0 Discussion

4.1 2019/2020 Season: Low rainfall, elevated temperatures and low breeding activity

The first half of the 2019/2020 season was characterised by low rainfall, elevated temperatures and an absence of breeding activity as in the Jan-April 2019 (Lenga & Clulow, 2019). Periods of above average rainfall, and recharge of the wetlands system only occurred from Feb, 2020. Nevertheless, the recharging of the NCIG constructed habitats was not associated with major increases in GGBF detection rates (suggesting relatively low numbers across the whole system), and there was no evidence of major or explosive breeding events in response to post-January rainfall. One breeding event in Stage 6.6 was confirmed (presence of metamorphs); there are inferred (possible) breeding events at other stages of the system from the observation of a few juveniles in Stages 4 and 7, but the origin of those juveniles does not confirm breeding at those Stages. Extensive tadpole trapping did not find tadpoles in those waterbodies during 2019/2020, and the small numbers of juveniles observed through the whole system is evidence of continued low breeding activity across the CHEMP habitats. This contrasted with reports of explosive/large scale breeding events in other sections (BHP modified habitats; Industrial areas) of the Kooragang/Ash Island system (McHenry et al, 2020).

4.2 Vegetation Clearance: Management Action (assessment to date)

The vegetation clearance undertaken with the physical removal of macrophytes in March 2019 was the first such activity undertaken to reduce macrophyte cover and increase open water towards the 30 – 60 % target under the CHEMP Management Plan (Section 13.1; CHEMP Management Plan, 2018). Resources from the Research and Monitoring program were committed to monitoring the pre-clearance removal of GGBF from the affected waterbodies, and to post-clearance monitoring at the same waterbodies (see Lenga & Clulow, 2019), and this continued into 2019/20 until April 2020. There is now one year of data available on the post-disturbance response of GGBF in the system.

Data analysis is ongoing (future analysis of the data sets will include appropriate statistics and modelling based on occupancy and general linear modelling (GLM) approaches, but broad conclusions can be drawn on the response of the system:

(i) It is clear that a proportion of relocated GGBF returned to disturbed, successional habitats suggesting some form of site fidelity behaviour
(ii) Disturbed waterbodies were re-occupied by GGBF but the response was variable, and the results to date do not provide evidence of an immediate, rapid response of GGBF across the system in response to the physical disturbance events in a proportion of the system, including
(iii) No rapid or explosive breeding event in response to the disturbance event.

Nevertheless, this one disturbance event (vegetation reduction), undertaken in March, 2019, may not be a fair or complete test of a disturbance-response hypothesis of GGBF movement and breeding in this or other coastal ecosystems. This is because the vegetation removal was undertaken during a period of low rainfall and low water levels in the wetland system to take the opportunity of facilitating on-ground work in the landscape. It is possible that a major disturbance, closer to the timing of a major rainfall event, might see a different response by GGBF in the system. Further investigation and research (including replication of disturbance events) will be required to develop a clearer understanding of the benefits, or otherwise, or such adaptive management actions in the landscape for optimising GGBF population density in the system.

4.3 A brief overview of population status of GGBF in the NCIG constructed habitats (Jan 2018 – April 2020)

A more complete statistical and modelling analysis of GGBF and landscape data (2018-2020) is being undertaken by D. Lenga which will more fully delineate the population and habitat status of the GGBF population within the constructed habitat system. However, some general conclusions, which may inform future management actions and research aimed at optimising outcomes for GGBF in the system can be drawn from the summary data across this period are presented in Tables A2.1, A2.2 and A2.3. Table A2.3 is particularly informative as a summary of occupancy and breeding events in the system.

It should be noted that introduction of captive-bred GGBF into the constructed habitats ceased in 2017 (NCIG, 2017), so beyond this period, the population has relied on natural recruitment (breeding, and potential migration into the system).

(i) Breeding events have been demonstrated in the system in each breeding season from 2017/2018 (Table A2.3).

(ii) The frequency of breeding events is relatively low in the system, given the large area (approximately 75 ha) and the number of constructed wetlands available to the GGBF. This may be associated with 3 seasons of below average (Tables A2.5; Fig A2.1) rainfall and above average temperatures (Table A2.6) during substantial periods of the year (especially 2018/2019; 2019/2020). However, the argument for this being a purely climate-driven outcome is challenged by records of larger, and often explosive breeding events in other parts of the Kooragang-Ash Island system (McHenry et al, 2019; 2020).

(iii) GGBF population persists across the constructed habitats system (Table A2.3). The population has persisted across the system, although the density of records, and most breeding events are concentrated in around half of the Stages (4, 5, 6, 7). Of these, the smaller Stage 7, which is closest to the BHP managed habitats (centre of the Island) and Industrial sections of the Kooragang-Ash Island system has the highest level of GGBF breeding activity and occupancy. Various factors (not fully understood) may contribute to this variability across the landscape. Stages 1 to 3 were heavily burnt during Feb, 2018, but GGBF were located in the post-fire landscape. Nevertheless, breeding and occupancy has been low in those stages since September, 2018.

(iv) As with breeding, climate does not fully explain the low population density in the constructed habitats. The “sensitivity” metric is a measure of frequency with which GGBF are encountered during surveys. The density of GGBF in the NCIG habitats is lower than in the BHP habitats (centre of the Kooragang-Ash Island system) and in the Industrial Area of the island (eastern section of the Kooragang-Ash Island system) using this metric; see Tables 3.1.2; 3.9.3 (McHenry et al, 2019), also McHenry et al, 2020 (draft report). Further analysis of the data and modelling may shed further insight into the spatial heterogeneity across the constructed habitats, but further research is likely to be required to fully understand the drivers of GGBF dynamics in the NCIG CHEMP constructed habitats.

4.4 Ongoing Research and Monitoring Questions:

Important questions regarding the dynamics of the NCIG CHEMP system were identified in the previous report (Lenga & Clulow, 2019). These continue to be relevant and are re-stated here.

(1) <u>Trend in NCIG CHEMP breeding activity and population trends in comparison to other Ash Island/Kooragang Sites.</u>

There is a strong indication from the data for Island-wide surveys of GGBF breeding activity and population densities that the breeding activity and population densities in the “Northern” section of the Island complex (containing NCIG CHEMP and National Park wetlands) is lower than in other components of the system including BHP CHEMP wetlands (“Central Section”) and NCIG/PWCS/HDC industrial area tenures in the “Southern Section” of the system (McHenry et al, 2019; McHenry et al, 2020), as discussed above.

It is important to understand the reasons for this difference, and the opportunities for adaptive management in the system, if the utilisation of the NCIG CHEMP constructed habitats by GGBF is to be maintained at a high level, and the probability of the persistence of GGBF in that part of the system into the future is to be optimised.

Ongoing research questions (potentially part of an ongoing adaptive management research approach) include:

(i) Whether the population is stable and in equilibrium or whether it could indicate a trend towards declining GGBF population in part or all of the system
(ii) Investigation of adaptive management actions that might be employed in the system to encourage breeding activity and increasing population densities. These might include ongoing habitat disturbance and resetting of succession in waterbodies, reduction in *Gambusia*, use of fire, addition of aboveground breeding mesocosms etc).

(2) Effects of Management Actions – Vegetation Clearance/Successional Disturbance

As described above, initial management actions under the CHEMP Management Plan were undertaken in March, 2019 to reduce macrophyte cover in various waterbodies in the system. This is potentially an important, ongoing management action in the system to promote GGBF breeding activity and population recruitment, although the outcomes one year on have not indicated a significant response by GGBF in the system. It is important to understand the impacts of this management approach going forward, in particular, whether there is a measurable response in the system i.e. evidence of increased breeding and recruitment in the system as a result. There is a strong case, that to better understand the impacts of this management approach (active management of vegetation, and disturbance in the system), monitoring responses and outcomes should be continued, and this management action should be replicated in a controlled, experimental way to understand its value as an ongoing management approach. This management approach generates costs, and a better understanding of its benefits (or otherwise) could inform management plans into the future, including decisions to retain or modify this approach.

References

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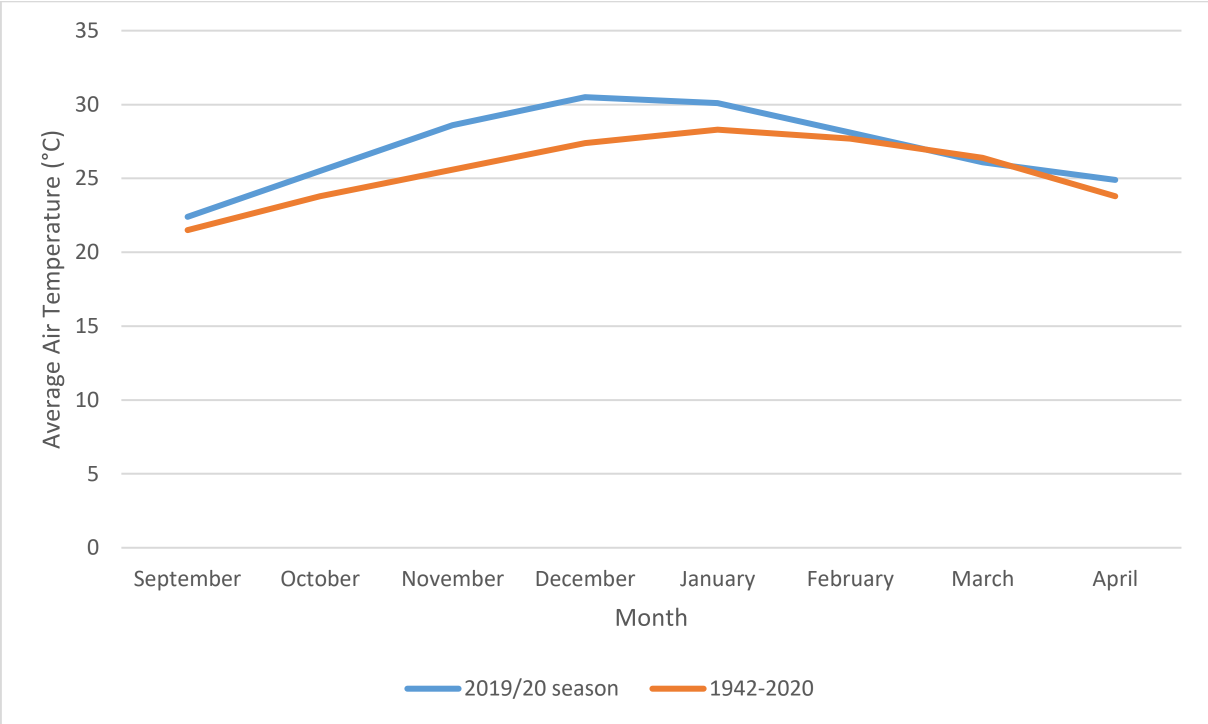


Figure 1. Average monthly air temperatures September 2019 to April 2020 and long-term average air temperatures for 1942-2020 from the Williamstown weather station (061078).

Table 1. The total amount of rainfall (mm) for months September 2019 to May 2020 compared to the average long-term rainfall (mm) for the months September to May from 1942 to 2020. Recorded from the Williamstown weather station (061078).

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Total Rainfall in 2019/20 season (mm)	75.4	45	51.8	0.8	67.2	171.6	106.2	53.6	105.6
Average Rainfall for 1942-2020 (mm)	60.6	73.5	81.9	77.5	98.3	117.8	120.7	109.8	108.6

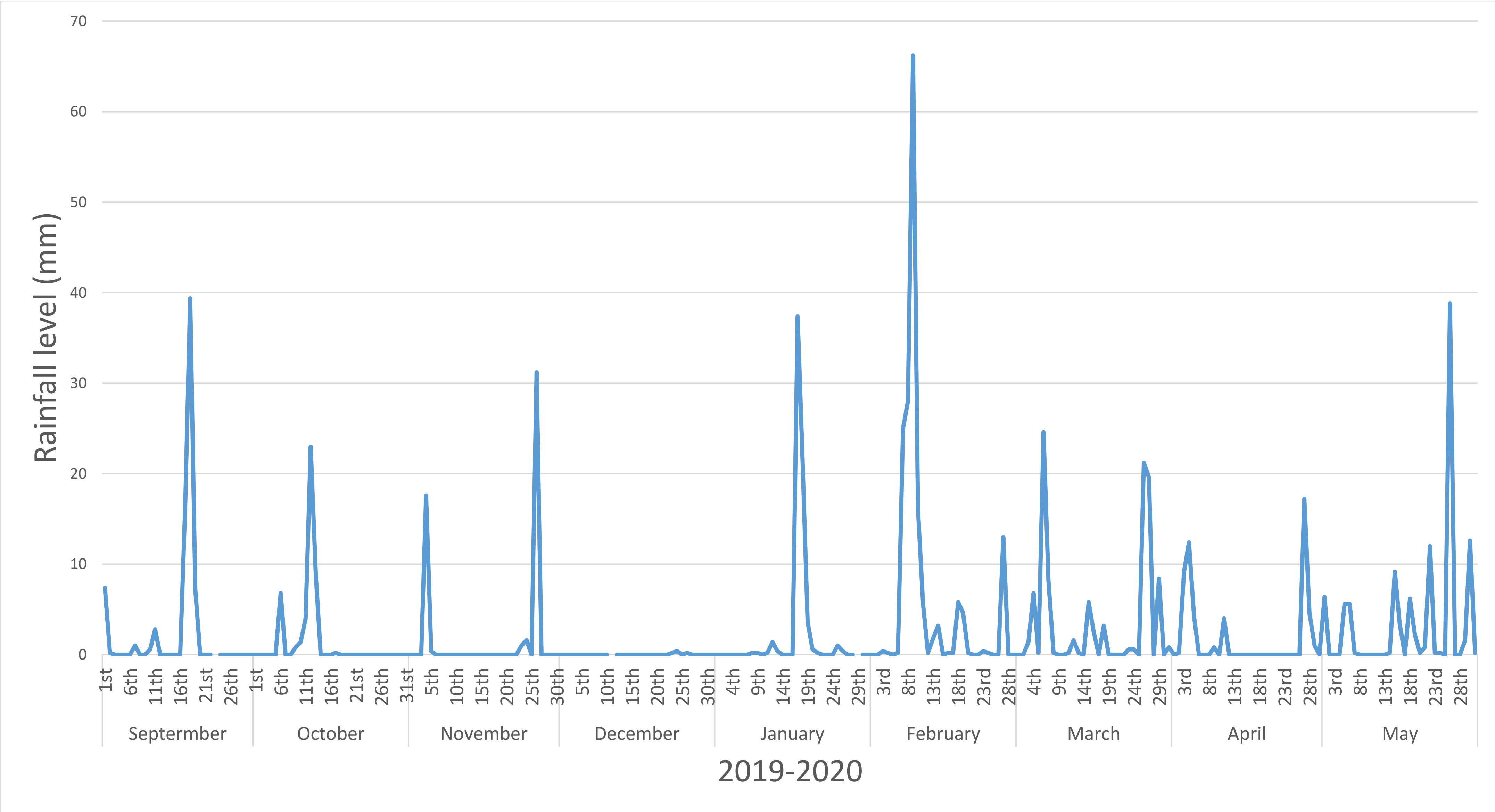


Figure 2. Daily rainfall (mm) for the months of September 2019 to May 2020 from the Williamstown weather station (061078).

Table 2. Pond structure and water chemistry. Summary of data collected for all NCIG compensatory habitat ponds surveyed between the months of September 2019 to April 2020. Pond type (ephemeral, permanent or semi- permanent), and presence/absence and relative abundance of *Gambusia* shown. The total number of GGBF recorded at each pond over the 8 months of data collection are shown. Water quality data for each pond is shown as means and standard deviations, as well as the minimum and maximum water depth recorded for the season at each pond. Missing values usually due to no water in dry ponds. Abbreviations: Temp = Water Temperature; Sal = Salinity; DO = Dissolved Oxygen.

Ponds	Type	Number of GGBF	Gambusia Abundance	Average of pH	StdDev of pH	Average of Temp °C	StdDev of Temp °C	Average of Sal (ppt)	StdDev of Sal (ppt)	Average of DO (mg/L)	StdDev of DO (mg/L)	Min of Water depth (cm)	Max of Water depth (cm)
1.1	permanent	0	High	6.44	0.62	21.65	3.32	0.76	0.35	4.19	1.44	250.00	260.00
1.2	ephemeral	0	None	6.39	-	19.80	6.22	0.23	0.05	2.15	0.64	5.00	70.00
1.3	ephemeral	0	None	6.00	-	20.25	6.29	0.52	0.04	2.88	1.99	220.00	280.00
1.4	ephemeral	1	High	6.70	-	22.40	4.67	0.95	0.52	3.71	1.48	0.00	255.00
1.5	ephemeral	0	None	6.26	-	19.85	3.89	0.22	0.04	2.30	0.90	10.00	60.00
1.6	ephemeral	0	None	5.97	-	20.35	4.17	0.27	0.16	1.65	0.69	5.00	40.00
2.1	semi-permanent	0	None	6.00	-	17.10	-	0.99	-	2.21	-	280.00	280.00
2.2	ephemeral	0	None	6.00	-	16.80	-	2.23	-	2.63	-	276.00	276.00
2.3	permanent	0	None	6.00	-	17.00	-	1.45	-	2.81	-	280.00	280.00
2.4	ephemeral	0	None	6.00	-	16.70	-	0.79	-	1.67	-	30.00	30.00
2.5	ephemeral	2	None	6.00	-	16.50	-	3.05	-	2.21	-	50.00	50.00
3.1	ephemeral	1	None	6.41	0.58	25.00	9.62	0.17	0.04	3.75	1.87	0.00	20.00
3.2	ephemeral	0	None	6.41	0.58	25.00	9.62	0.17	0.04	3.75	1.87	0.00	20.00
3.3	permanent	0	High	-	-	20.80	4.81	1.17	1.01	5.96	4.71	250.00	250.00
3.4	ephemeral	0	Low	6.78	1.10	22.10	7.92	0.61	0.06	4.63	3.20	-	-
3.5	ephemeral	0	None	6.00	-	17.40	-	0.14	-	2.24	-	70.00	70.00
4.1	permanent	0	Low	-	-	14.80	-	0.24	-	1.58	-	250.00	250.00
4.2	permanent	1	High	-	-	11.60	-	0.24	-	1.33	-	240.00	240.00
4.3	permanent	0	High	-	-	16.70	-	0.25	-	2.66	-	0.00	0.00

4.4	permanent	0	High	-	-	16.50	-	0.37	-	3.11	-	-	-
4.5	ephemeral	0	None	-	-	15.10	-	0.20	-	2.78	-	100.00	100.00
4.6	ephemeral	1	High	-	-	14.50	-	0.14	-	3.53	-	100.00	100.00
4.7	permanent	0	High	6.55	-	19.00	4.95	0.17	0.01	2.59	0.72	-	-
4.8	permanent	2	High	7.07	-	19.90	6.36	0.33	0.02	5.21	2.26	230.00	276.00
4.9	ephemeral	10	None	7.53	-	21.80	7.35	3.56	1.98	4.60	2.44	0.00	267.00
4.10	permanent	3	High	-	-	14.70	-	2.60	-	12.90	-	266.00	266.00
4.11	permanent	1	High	-	-	17.30	-	10.40	-	4.47	-	-	-
5.1	ephemeral	0	None	6.66	0.41	25.55	5.02	0.10	-	5.85	-	15.00	80.00
5.2	ephemeral	0	None	6.59	0.53	24.60	3.82	0.14	-	6.38	-	250.00	250.00
5.3	ephemeral	0	None	6.59	0.82	22.35	2.76	0.10	-	1.07	-	60.00	60.00
5.4	ephemeral	6	None	6.53	0.98	23.20	1.84	0.18	-	1.24	-	250.00	250.00
5.5	ephemeral	0	None	6.56	0.58	21.80	1.70	0.17	-	1.11	-	250.00	250.00
5.6	ephemeral	1	None	6.82	0.74	22.40	1.98	0.23	-	2.46	-	100.00	100.00
5.7	permanent	0	High	6.80	0.33	21.45	1.63	0.30	-	3.52	-	220.00	250.00
5.8	permanent	0	High	7.22	0.88	25.75	3.46	0.20	-	1.60	-	250.00	250.00
6.1	ephemeral	2	None	6.77	-	20.20	-	-	-	-	-	100.00	100.00
6.2	ephemeral	2	None	7.09	-	19.70	-	-	-	-	-	250.00	250.00
6.3	permanent	0	High	6.89	-	20.70	-	-	-	-	-	250.00	250.00
6.4	ephemeral	0	None	6.45	-	22.50	-	-	-	-	-	30.00	30.00
6.5	ephemeral	0	None	6.15	-	18.70	-	-	-	-	-	40.00	40.00
6.6	permanent	9	None	6.29	-	19.70	-	-	-	-	-	260.00	260.00
7.1	permanent	3	High	7.03	0.71	23.15	3.75	2.34	-	2.75	-	250.00	250.00
7.2	ephemeral	17	None	7.21	1.83	22.73	4.48	1.34	-	5.64	-	240.00	255.00
7.3	ephemeral	17	Medium	6.59	-	27.10	-	3.11	-	3.02	-	240.00	240.00
K58B	ephemeral	5	None	7.55	1.44	26.20	4.10	7.07	-	2.87	-	20.00	20.00
K2	semi-permanent	0	None	6.10	0.13	22.15	3.46	0.35	0.22	1.87	1.82	30.00	30.00

K3	semi-permanent	0	None	6.00	-	22.05	4.88	0.36	0.23	2.30	0.23	20.00	70.00
K4	ephemeral	0	None	6.00	-	17.20	-	0.28	-	2.05	-	0.00	40.00
K5	permanent	0	None	6.17	0.23	21.25	6.43	3.38	3.51	2.58	1.05	50.00	60.00
K7	ephemeral	0	None	6.00	-	18.10	-	3.36	-	0.66	-	0.00	0.00
T-13	semi-permanent	2	None	6.64	-	25.50	-	0.36	-	3.01	-	120.00	120.00
T-14	ephemeral	0	None	6.63	-	24.00	-	0.34	-	2.91	-	10.00	10.00
T-15	permanent	0	None	6.22	-	23.70	-	0.64	-	0.83	-	120.00	120.00

Table 3. Breakdown of the GGBF frog counts at each pond in each round from the 2019/2020 season (Rounds 1-5) separated by sex/age class.

		Round 1 (Sep 2019)			Round 2 (Oct-Nov, 2019)			Round 3 (Jan 2020)			Round 4 (Feb 2020)		Round 5 (Mar, Apr 2020)			
Ponds	**Type**	**Adult Female**	**Juvenile Female**	**Adult Male**	**Adult Female**	**Juvenile Female**	**Adult Male**	**Adult Female**	**Juvenile**	**Adult Male**	**Adult Female**	**Male**	**Adult Female**	**Juvenile**	**Juvenile Female**	**Adult Male**
1.1	permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.2	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.3	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.4	ephemeral	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
1.5	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.6	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.1	semi-permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.2	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.3	permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.4	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5	ephemeral	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
3.1	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.2	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.3	permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.4	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.1	permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.2	permanent	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
4.3	permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.4	permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.6	ephemeral	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
4.7	permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

4.8	permanent	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
4.9	ephemeral	1	1	3	0	0	1	0	0	0	1	0	1	0	0	0
4.10	permanent	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0
4.11	permanent	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
5.1	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.2	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.3	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.4	ephemeral	0	0	0	0	0	0	0	0	2	2	1	0	0	0	0
5.5	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.6	ephemeral	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
5.7	permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.8	permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.1	ephemeral	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
6.2	ephemeral	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
6.3	permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.4	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.6	permanent	0	0	0	1	0	1	0	6	0	0	0	0	0	0	0
7.1	permanent	1	0	1	0	0	0	0	0	1	0	0	1	0	0	0
7.2	ephemeral	2	0	0	2	0	3	0	0	1	1	3	2	0	1	2
7.3	ephemeral	1	0	0	6	1	5	1	0	1	0	0	1	0	0	0
K58B	ephemeral	0	0	1	0	0	0	0	0	0	2	1	0	0	0	0
K2	semi-permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K3	semi-permanent	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
K4	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K5	permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K7	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

T-13	semi-permanent	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
T-14	ephemeral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T-15	permanent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4. Pre- and post-clearance records of GGBF in 9 disturbed (70-80% macrophyte clearance) waterbodies in Stages 3, 4, 5 and 7 of the NCIG CHEMP constructed habitats. Ponds were subject to vegetation removal on 11-13/3/19 (Lenga & Clulow, 2019). There was evidence of rapid re-occupation of pond 7.3 post-disturbance (see also Fig 3), and variable responses in other disturbed waterbodies.

	2018						2019									2020							
Pond	Jan	Feb	Mar	Sep	Oct	Dec	Jan	Feb	Mar-Pre	Mar-Post	Apr	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Total GGBF pre veg removal	Total GGBF post veg removal	Change	% increase
3.1 + 3.2	-	0	-	-	0	0	0	-	0	0	0	1	-	0	-	-	0	-	0	0	1	1	N/A
3.5	0	0	0	-	0	-	0	-	0	0	0	0	-	0	-	-	0	-	0	0	0	0	N/A
4.9	-	0	1	3	5	7	11	15	0	0	0	7	-	1	-	0	1	-	1	42	10	-32	-76%
5.2	0	0	1	-	0	1	-	0	0	0	0	0	-	0	-	0	0	-	0	2	0	-2	-100%
5.5	-	0	0	-	0	0	-	0	0	0	0	0	-	0	-	0	0	-	0	0	0	0	N/A
5.6	-	0	0	-	0	0	-	1	0	0	0	0	-	0	-	1	0	-	0	1	1	0	0%
7.2	0	0	4	9	1	7	11	9	0	1	0	1	4	0	1	1	3	5	-	41	16	-25	-61%
7.3	0	1	2	3	0	0	5	9	7	9	12	1	5	7	1	2	0	1	-	27	38	11	41%

Table 5. Post-disturbance survey data, showing the records of individual (marked) GGBF relocated from disturbed waterbodies prior to the macrophyte clearance (11-13/3/19; Lenga & Clulow, 2019). "-" indicates source ponds not re-surveyed on that date, "NA" indicates source pond resurveyed, but individual frog was not encountered. Most of the relocated frogs were removed from pond 7.3 to 7.1, and about 50% (4/9) were returned to 7.3 within one month (see Fig. 3). Three relocated individuals continued to be located in the disturbed ponds up to the end of 2019, and one was recorded in disturbed ponds to March, 2020.

			Post-Disturbance Surveys; Frog recorded in Pond:										
Frog ID	Source Pond Pre-clearance	Moved to Pond	18/03 2019	4/04 2019	10/04 2019	12/09 2019	24/09 2019	29/10 2019	7/11 2019	22/01 2020	17/02 2020	18/02 2020	20/03 2020
0007D2502C	7.3	7.1	NA	NA	-	-	NA	NA	NA	NA	NA	NA	NA
0007D184EE	7.3	7.1	7.1	NA	-	-	NA	7.3	NA	7.3	7.2	7.2	7.2
0007A09629	7.3	7.1	7.3	7.3	-	-	7.1	7.2	7.3	NA	NA	NA	NA
0007D247DD	7.3	7.1	NA	NA	-	-	NA	NA	NA	NA	NA	NA	NA
0007A0E463	7.3	7.1	7.3	NA	-	-	NA	7.3	NA	NA	NA	NA	NA
0007D6453D	7.1	7.1	7.3	7.3	-	-	NA	NA	NA	NA	NA	NA	NA
0007D1B5DF	7.3	7.1	NA	NA	-	-	NA	NA	NA	NA	NA	NA	NA
0007A0DADB	7.3	7.1	7.3	NA	-	-	NA	NA	NA	NA	NA	NA	NA
0007D1F2F2	7.3	7.1	NA	NA	-	-	NA	NA	NA	NA	NA	NA	NA
0007D29080	7.3	7.1	NA	NA	-	-	7.1	7.3	7.3	NA	NA	NA	NA
0007D3D47E	4.9	4.8	-	-	NA	4.9	-	-	-	-	-	-	-

Pond 7.1, -32.84608, 151.70306; Pond 7.2 -32.846271, 151.703174; Pond 7. 3 -32.846679, 151.703651; Pond 4.8, -32.84135, 151.70765

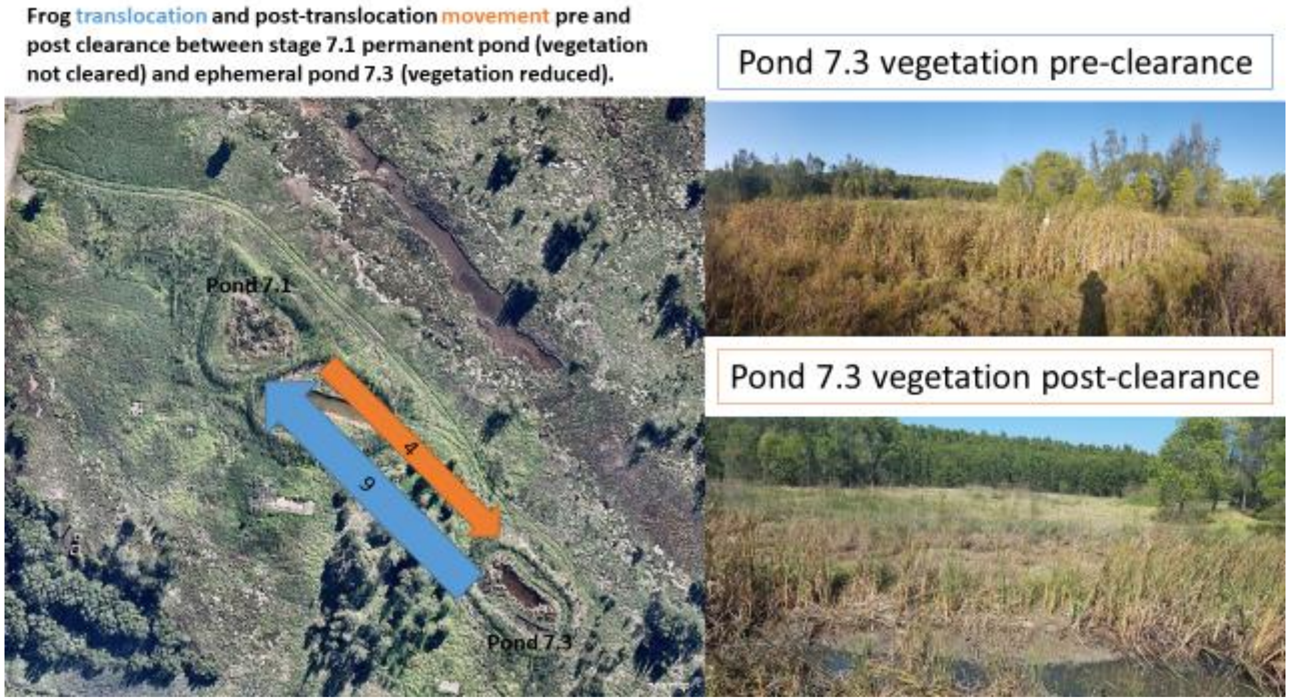
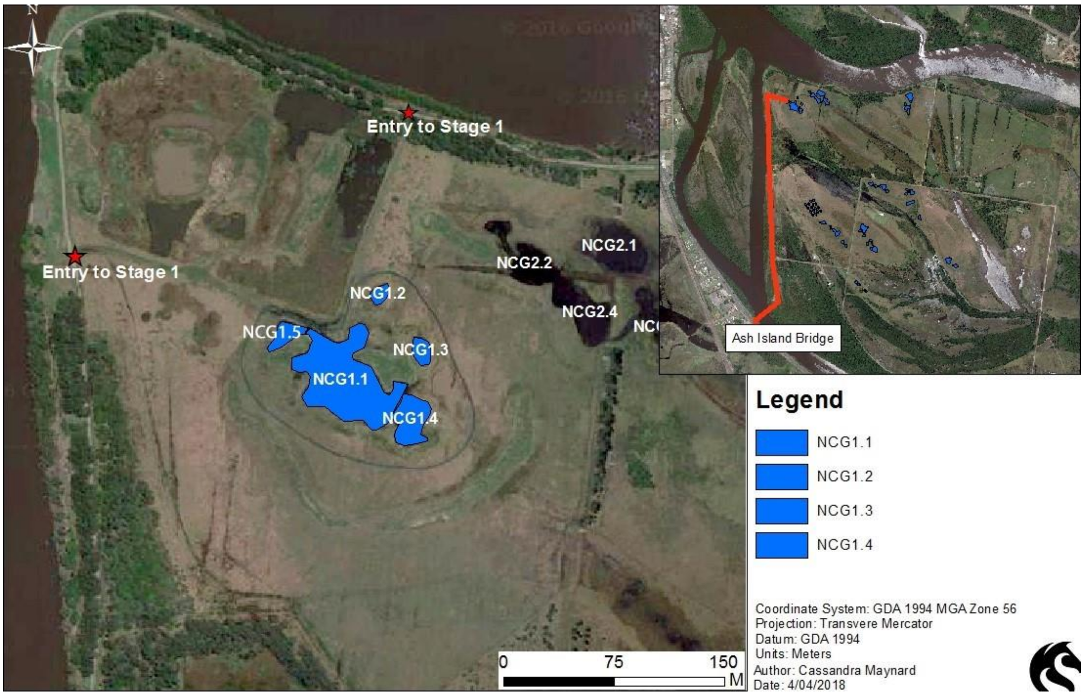
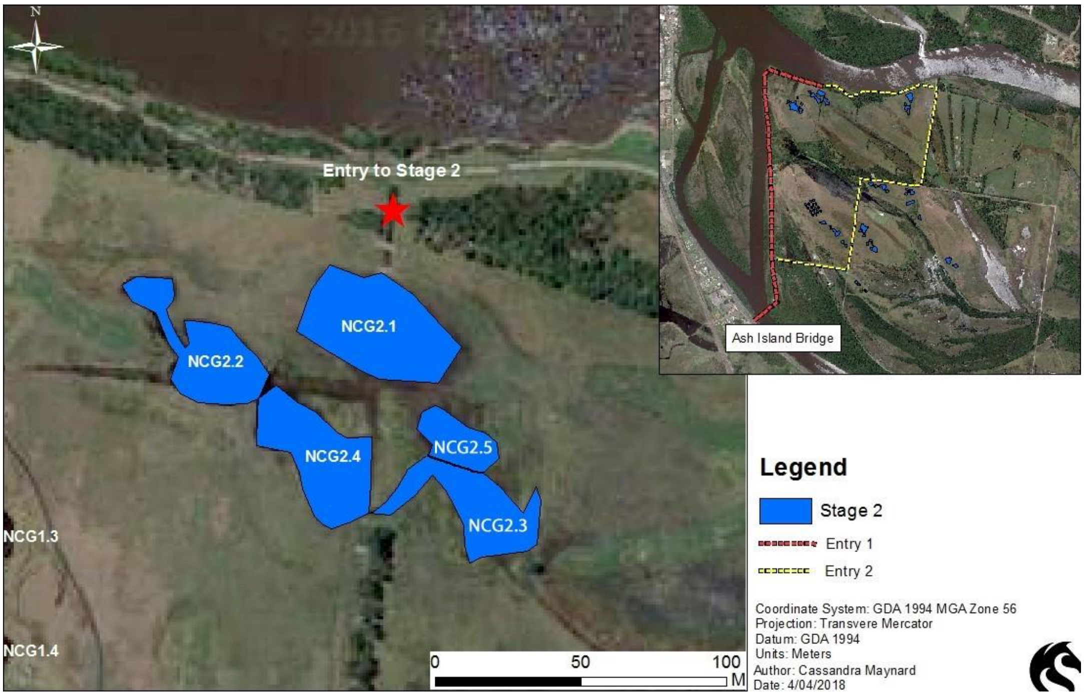
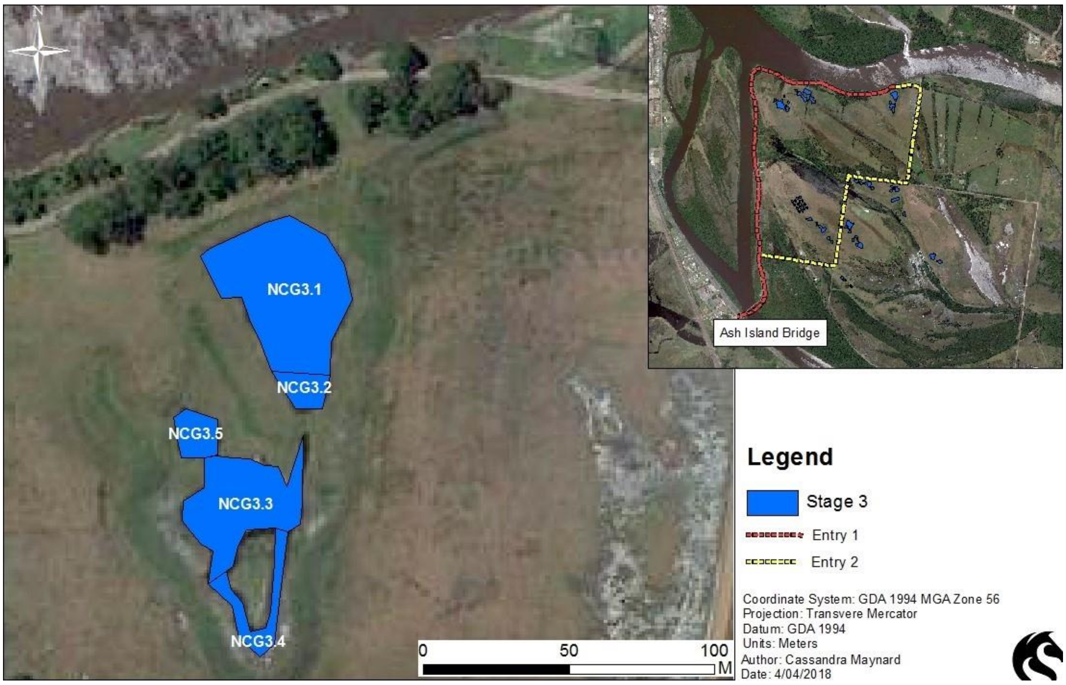


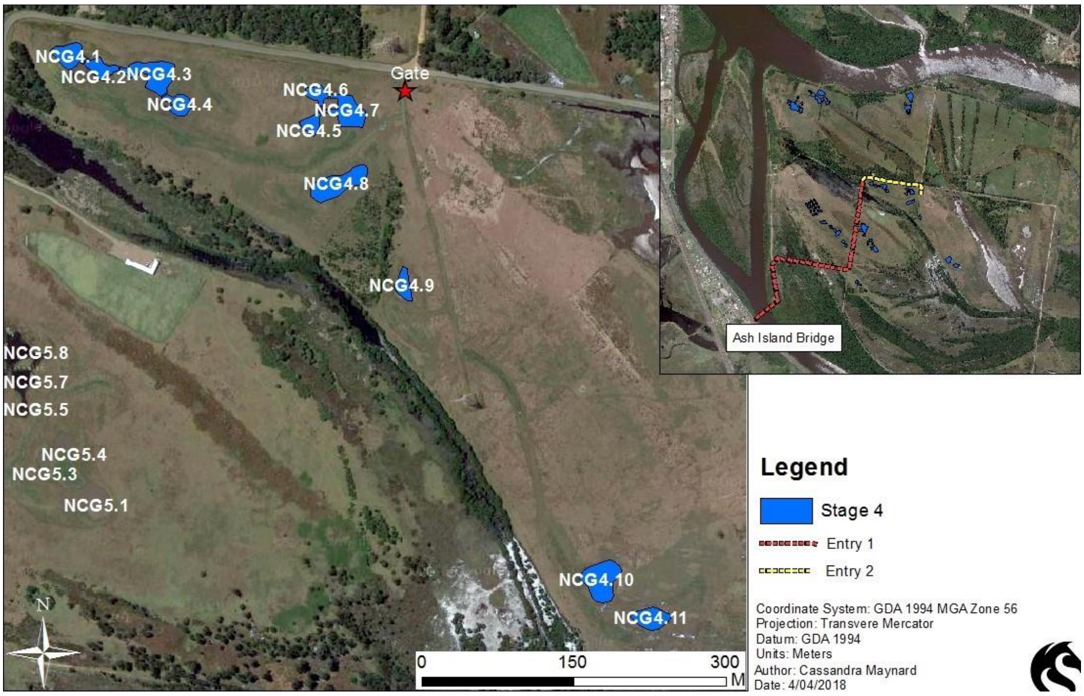
Fig 3. Movement of GGBF between ponds pre- and post-disturbance associated with aquatic vegetation reduction. Nine GGBF were translocated (blue line) to Pond 7.1 (undisturbed, permanent pond) from Pond 7.3 (vegetation removed, ephemeral pond) on 10/3/2019 prior to vegetation reduction in 7.3. Survey on 18/3/19 located 4 of these frogs in 7.3 indicating 4/9 had returned within 1 week to their source pond.

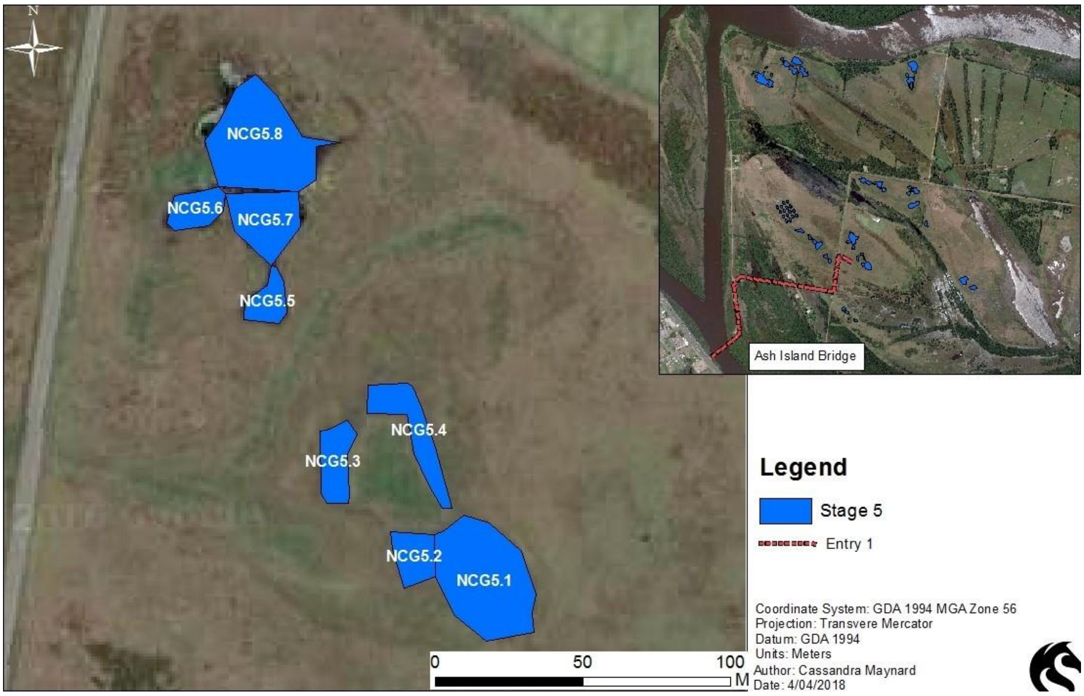
Appendix 1 Location and coding of NCIG Ash Island CHEMP constructed habitats

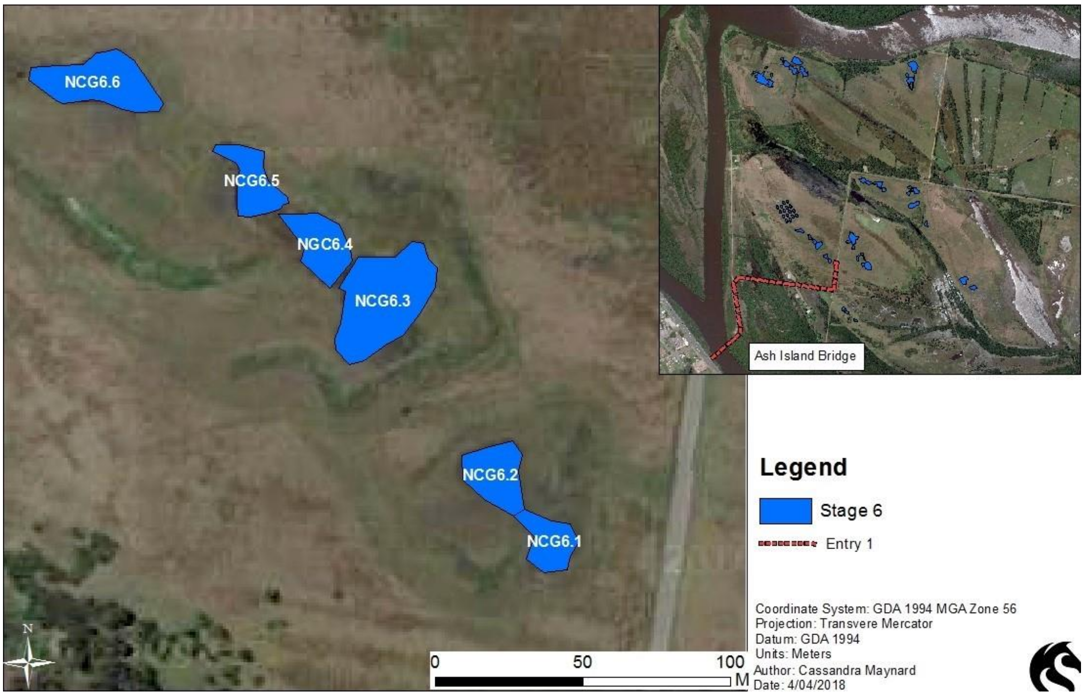


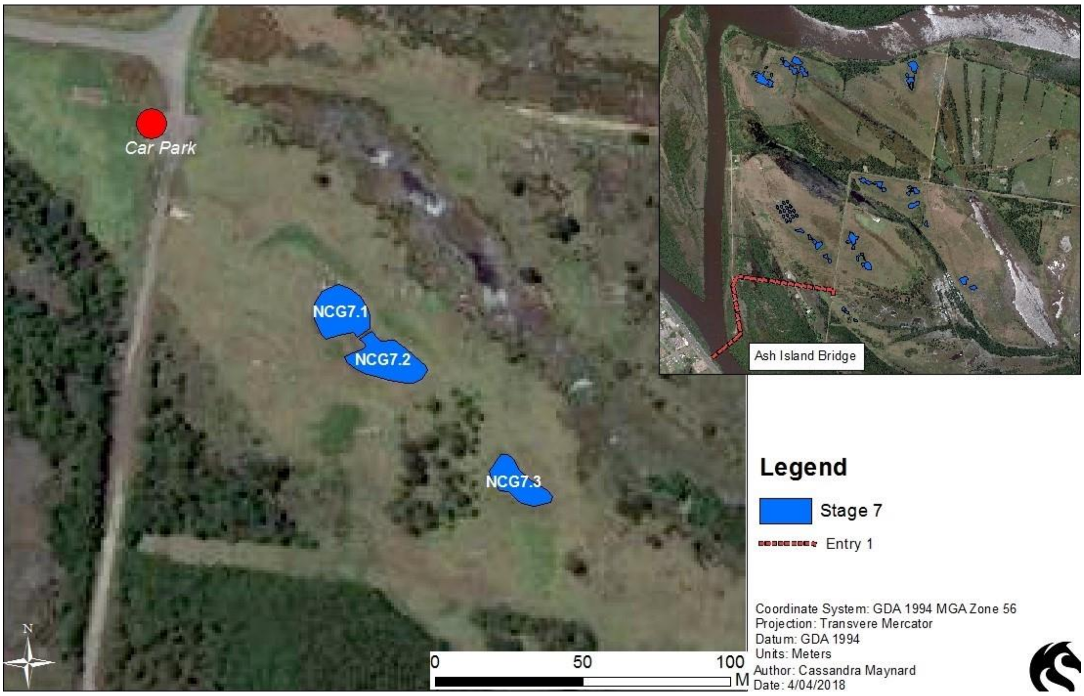



NCG3.1
NCG3.2
NCG3.5
NCG3.3
NCG3.4
Ash Island Bridge
Legend
Stage 3
Entry 1
Entry 2
Coordinate System: GDA 1994 MGA Zone 56
Projection: Transverse Mercator
Datum: GDA 1994
Units: Meters
Author: Cassandra Maynard
Date: 4/04/2018
0
50
100
M


NCG4.1
NCG4.2
NCG4.3
NCG4.4
NCG4.6
NCG4.7
NCG4.5
Gate
NCG4.8
NCG4.9
NCG5.8
NCG5.7
NCG5.5
NCG5.4
NCG5.3
NCG5.1
NCG4.10
NCG4.11
Ash Island Bridge
Legend
Stage 4
Entry 1
Entry 2
Coordinate System: GDA 1994 MGA Zone 56
Projection: Transverse Mercator
Datum: GDA 1994
Units: Meters
Author: Cassandra Maynard
Date: 4/04/2018
0
150
300
M


N
NCG5.8
NCG5.6
NCG5.7
NCG5.5
NCG5.4
NCG5.3
NCG5.2
NCG5.1
Ash Island Bridge
Legend
Stage 5
Entry 1
Coordinate System: GDA 1994 MGA Zone 56
Projection: Transvere Mercator
Datum: GDA 1994
Units: Meters
Author: Cassandra Maynard
Date: 4/04/2018
0 50 100 M


NCG6.6
NCG6.5
NGC6.4
NCG6.3
NCG6.2
NCG6.1
N
Ash Island Bridge
Legend
Stage 6
Entry 1
Coordinate System: GDA 1994 MGA Zone 56
Projection: Transvere Mercator
Datum: GDA 1994
Units: Meters
Author: Cassandra Maynard
Date: 4/04/2018
0 50 100 M


Car Park
NCG7.1
NCG7.2
NCG7.3
Ash Island Bridge
Legend
Stage 7
Entry 1
Coordinate System: GDA 1994 MGA Zone 56
Projection: Transvere Mercator
Datum: GDA 1994
Units: Meters
Author: Cassandra Maynard
Date: 4/04/2018
0
50
100
M
N

Appendix 2 Bell Frog, Water Chemistry and Rainfall data, Ash Island, CHEMP habitats (Jan 2018 – April 2020).

Table A2.1 Total summary of Capture-Mark-Recapture (CMR) data collected in the NCIG compensatory habitats on Kooragang Island, Newcastle from the months of January 2018 to April 2020 (rounds 1-19). Rounds 1-9 2018; Rounds 10-16 2019; Rounds 17-19 2020.

	Rounds																														
	1 2018/01				2 18/02		3 18/02-03			4 18/03			5 18/03			6 18/09			7 18/09			8 18/10		9 18/12				10 2019/01-02			
Ponds	F	J	JF	M	F	M	F	JF	M	F	JF	M	F	JF	M	F	J	M	F	J	M	F	M	F	J	JF	M	F	J	JF	M
1.1			1																												
1.2	2	1		3														1													
1.3					2	8			1																						
1.4							1		2																						
2.2																															
2.3					1																										
2.4									1																						
2.5																															
3.3							1																								
3.4																									1						
3.5	1																														
4.1									2			1			2																
4.2							1		1																						
4.4					1																										
4.5													1									1									
4.6																															
4.8						1			3	1																			1		
4.9							1		1	1		4	1		3	1		2				1	1	2			4	2			6
4.10																															
4.11																															
5.1																		1									2				
5.2													1		1												1				
5.4									2																						
5.5											1	1																			
5.6												1																			

5.8										1		1																	1	2	1
6.1																															
6.2									2			1																			
6.3	1									1																					
6.5								1		1																					
6.6									1			1																			
7.1					1	4											3	1							3				2	1	
7.2							2		2				1		2				1	2	2			2	1		3	2	2	1	4
7.3	2	1			3	1								1	1				2											1	3
K3																										1					
K58B														1	1								1								
T-13																												1		1	1
Total	6	2	1	3	8	14	6	1	18	5	1	10	4	2	10	1	3	5	3	2	2	2	2	4	5	1	10	5	6	6	15

	Rounds																												
	11 19/02				**12 19/03**			**13 19/03**				**14 19/04**			**15 19/09**			**16 19/10,11,12**			**17 2020/01**			**18 20/02**		**19 20/03-04**			
Ponds	**F**	**J**	**JF**	**M**	**F**	**JF**	**M**	**F**	**J**	**JF**	**M**	**F**	**JF**	**M**	**F**	**JF**	**M**	**F**	**JF**	**M**	**F**	**J**	**M**	**F**	**M**	**F**	**J**	**JF**	**M**
1.1																													
1.2																													
1.3																													
1.4																				1									
2.2												3		1															
2.3																													
2.4																													
2.5																	1												
3.3																													
3.4																													
3.5																													
4.1	1																												
4.2																	1												
4.4																													

4.5																													
4.6																					1								
4.8		1																			1								
4.9	2	1	1	2							1				1	1	3			1				1		1			
4.10												1	1			1		1			1								
4.11																	1												
5.1																													
5.2																													
5.4																							2	2	1				
5.5																													
5.6			1																		1								
5.8				1																									
6.1																	1												
6.2																	1								1				
6.3																													
6.5																													
6.6																		1		1		6							
7.1	3	2	2	1	1			1	3	1	2	2	1		1		1						1			1			
7.2				1							1				2			2		3			1	1	3	2		1	2
7.3			3	2	1	5	3	2		2	4	2	1	6	1			6	1	5	1		1			1			
K3																	1												
K58B																	1							2	1				
T-13																					1						1		
Total	6	4	7	7	2	5	3	3	3	3	8	8	3	7	5	2	11	10	1	11	6	6	5	6	6	5	1	1	2

Table A2.2. Total summary of Visual Encounter Survey (VES) data collected on the NCIG compensatory habitat on Kooragang Island, Newcastle from the months of January 2018 to April 2020.

	2018						2019								2020				Grand Total
Ponds	Jan	Feb	Mar	Sep	Oct	Dec	Jan	Feb	Mar	Apr	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
1.1		0	0	0	0	0	0			0	0		0			0		0	0
1.2		0	0	1		0	0			0	0		0			0		0	1
1.3		2	0	0	0	0	0			0	0		0			0		0	2
1.4		0	0	0		0	0			0	0		1			0		0	1
1.5						0	0			0	0		0			0		0	0
1.6											0		0			0		0	0
2.1		0	0		0	0		0		0	0		0			0			0
2.2		0	0		0	0		0		5	0		0			0			5
2.3		0	0		0	0		0		0	0		0			0			0
2.4		1	0		0	0		0		0	0		0			0			1
2.5						0		0		0	2		0			0			2
3.1+3.2		0			0	0	0		0	0	1		0			0		0	1
3.3	0	0	0		0	0	0		0	0	0		0			0		0	0
3.4	0	0	0		0	1	0		0	0	0		0			0			1
3.5	0	0	0		0		0		0	0	0		0			0		0	0
4.1		1	0		0	0	0	0			0				0				1
4.2		0	0		0	0	0	0			1				0				1
4.3		0	0		0	0	0	0			0				0				0
4.4		0	0		0	0	0	0			0				0				0
4.5		0	0		1	0	0	0		0	0		0		0				1
4.6		0	0		0	0	0	0		0	0		0		1				1
4.7		0	0	0	0	0	0	0		0	0		0		0	0		0	0
4.8		0	0		0	0	1	1	0	0	1		0		1	0		0	4
4.9		0	1	3	5	7	11	34	0	0	7		1		0	1		1	71
4.10					0	0		2		2	1		1		1				7
4.11											1				0				1

5.1	0	0	0	1	5	5		0	0	0	0		0		0	0		0	11
5.2	0	0	1		0	1		0	0	0	0		0		0	0		0	2
5.3	0	0	0		1	0		0		0	0		0		0	0		0	1
5.4	0	0	1		0	0		3		0	0		0		2	3		1	10
5.5		0	0		0	0		0	0	0	0		0		0	0		0	0
5.6		0	0		0	0		1	0	0	0		0		1	0		0	2
5.7		0	0		0	0		0		1	0		0		0				1
5.8		0	0		0	0		9		0	0		0		0				9
6.1	0	0	5		0			0			2				0	0			7
6.2	0	0	0		0			0			1				0	1			2
6.3	0	0	0		0			0			0				0	0			0
6.4	0		0												0				0
6.5		0	1												0				1
6.6		0	1		0			1			1		2		6	0			11
7.1	1	0	0	5	0	4	3	34	7	5	0	0	0	0	1	0	2		62
7.2	0	0	5	9	1	7	11	18	1	0	1	4	0	1	1	5	5		69
7.3	0	1	2	3	0	0	5	19	16	12	1	5	7	1	2	0	1		75
K58B			0	0	2	0	0	0	0	0	1	0	0	0	0	4	0		7
K2					0	0		0			0					0		0	0
K3						1	1				0		0			0		0	2
K4						0		0			0		0			0			0
K5					0			0			0					0			0
K7					0			0			0					0			0
T-13					0			3			0		0		1	0		1	5
T-14					0			0			0		0		0	0		0	0
T-15					0			0			0		0		0	0		0	0

Table A2.3 Records of amplecting behaviour (A) and/or confirmed breeding through detection of tadpoles (T) or metamorphs/juveniles (M) at ponds in Stages 1-7 of the NCIG Compensatory Habitat (Ash Island), and at unmodified ponds (K2-K7) and former NCIG Trial site ponds (T13-T15) during the period of Jan 2018 to April 2020. Ponds at which GGBF were detected during surveys are colour-coded light green. Breeding events highlighted orange. Stages 1, 2 and 3 are highlighted in red to indicate month (Feb 2018) in which these sites were heavily burnt by fire (arson, not hazard reduction). Ponds that are "stipled" were subject to aquatic vegetation reduction during March, 2019 (NPWS/NCIG Park Management Plan).

	2018						2019								2020				Grand Total
Ponds	**Jan**	**Feb**	**Mar**	**Sep**	**Oct**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	
1.1																			
1.2																			
1.3																			
1.4		A																	Breeding
1.5																			
1.6																			
2.1																			
2.2																			
2.3																			
2.4																			
2.5																			
3.1+3.2						T													Breeding
3.3																			
3.4						M													Breeding
3.5																			
4.1																			
4.2																			
4.3																			
4.4																			
4.5																			
4.6																			
4.7																			
4.8																			

4.9								M											Breeding
4.10																			
4.11																			
5.1																			
5.2						T (Nov)													Breeding
5.3																			
5.4																			
5.5																			
5.6																			
5.7																			
5.8								M											Breeding
6.1																			
6.2																			
6.3																			
6.4																			
6.5																			
6.6															M				Breeding
7.1				M		M	M		M										Breeding
7.2				M		M	M												Breeding
7.3							M		M										Breeding
K58B																			
K2																			
K3						M													Breeding
K4																			
K5																			
K7																			
T-13																			
T-14																			
T-15																			

Table A2.4 Pond structure and water chemistry. Summary of data collected for all NCIG compensatory habitat ponds surveyed between the months of January 2018 to April 2020. Pond type (ephemeral, permanent or semi- permanent), and presence/absence and relative abundance of *Gambusia* shown. The total number of GGBF recorded at each pond over the 8 months of data collection are shown. Water quality data for each pond is shown as means and standard deviations, as well as the minimum and maximum water depth recorded for the season at each pond. Missing values usually due to no water in dry ponds. Abbreviations: Temp = Water Temperature; Sal = Salinity; DO = Dissolved Oxygen.

Ponds	Type	Number of GGBF	Average of pH	StdDev of pH	Average of Temp °C	StdDev of Temp °C	Average of Sal (ppt)	StdDev of Sal (ppt)	Average of DO (mg/L)	StdDev of DO (mg/L)	Min of Water depth (cm)	Max of Water depth (cm)
1.1	permanent	0	7.25	1.55	23.78	5.05	0.83	0.24	10.96	29.85	66	266
1.2	ephemeral	1	7.01	0.64	21.06	5.69	10.93	25.58	3.17	1.97	0	70
1.3	ephemeral	2	5.67	0.98	21.01	5.19	0.83	0.57	2.09	2.11	23	112
1.4	ephemeral	1	7.02	1.28	22.13	4.69	8.70	22.62	3.11	2.98	81	166
1.5	ephemeral	0	6.41	0.26	18.25	4.59	0.37	0.18	2.08	1.30	0	60
1.6	ephemeral	0	6.39	0.59	17.50	5.75	0.35	0.19	2.50	1.55	5	40
2.1	semi-permanent	0	7.19	0.97	20.50	5.89	6.48	8.90	3.63	1.23	0	280
2.2	ephemeral	5	6.44	0.45	19.73	5.74	1.90	0.61	2.86	2.83	115	210
2.3	permanent	0	6.47	1.05	23.08	6.11	3.00	2.22	2.65	2.63	38	273
2.4	ephemeral	1	5.86	1.02	20.76	6.96	3.10	3.28	2.55	2.13	11	70
2.5	ephemeral	2	6.48	0.67	19.05	3.61	2.38	0.95	1.50	1.01	0	140
3.1	ephemeral	1	7.56	0.85	22.50	3.43	0.35	0.11	3.32	1.28	0	30
3.2	ephemeral	0	7.25	0.83	22.27	4.40	0.32	0.08	3.25	1.93	0	48
3.3	permanent	0	90.23	249.29	23.63	4.84	1.25	0.52	3.65	3.36	127	255
3.4	ephemeral	1	7.04	0.86	21.46	5.44	0.78	0.17	3.50	2.70	0	177
3.5	ephemeral	0	6.82	0.78	20.35	4.74	0.52	0.30	3.03	1.93	0	70
4.1	permanent	1	6.60	1.17	22.11	6.92	0.33	0.15	1.72	1.09	65	160
4.2	permanent	1	6.25	0.83	21.41	6.89	0.48	0.35	1.85	1.56	25	135
4.3	permanent	0	6.71	0.94	23.07	6.09	0.27	0.07	3.03	2.80	125	230
4.4	permanent	0	6.70	0.78	22.93	6.11	0.42	0.13	2.07	1.38	75	200
4.5	ephemeral	1	6.39	0.30	21.14	6.12	0.33	0.38	2.12	1.53	5	100
4.6	ephemeral	1	6.47	0.41	21.54	6.69	0.30	0.29	2.12	1.54	10	210
4.7	permanent	0	6.91	0.75	23.04	6.09	0.19	0.07	3.35	3.31	50	250

4.8	permanent	4	7.76	0.94	23.08	5.67	0.36	0.10	3.70	2.58	100	250
4.9	ephemeral	71	7.28	0.51	24.23	5.55	2.57	1.44	3.41	2.51	29	130
4.10	permanent	7	7.64	0.63	22.73	6.39	11.02	9.93	4.13	4.85	#VALUE!	#VALUE!
4.11	permanent	1	7.56	0.45	23.42	5.61	25.34	13.24	2.38	2.02	127	160
5.1	ephemeral	11	6.90	0.69	23.64	8.13	0.11	0.04	3.63	1.72	0	80
5.2	ephemeral	2	6.95	0.86	23.28	7.49	0.14	0.01	4.23	1.95	0	80
5.3	ephemeral	1	6.49	1.09	21.58	6.61	0.12	0.02	2.25	1.77	0	100
5.4	ephemeral	10	6.26	0.90	24.43	6.49	0.50	0.64	2.16	1.22	0	140
5.5	ephemeral	0	6.06	0.98	19.87	5.61	0.17	0.08	1.48	0.85	0	90
5.6	ephemeral	2	6.32	1.23	20.01	4.71	0.22	0.11	2.32	1.30	0	120
5.7	permanent	1	6.32	0.82	22.06	5.97	0.25	0.12	2.02	1.77	0	150
5.8	permanent	9	7.45	1.76	26.41	2.50	0.26	0.17	3.69	3.74	#VALUE!	#VALUE!
6.1	ephemeral	7	6.68	0.47	18.68	7.11	0.15	0.02	3.12	1.23	0	120
6.2	ephemeral	2	6.36	0.87	23.64	6.97	0.90	0.97	2.46	2.13	10	150
6.3	permanent	0	7.03	0.65	21.15	5.67	0.38	0.15	2.58	1.41	0	220
6.4	ephemeral	0	6.45	#DIV/0!	22.50	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0	30
6.5	ephemeral	1	6.18	0.04	19.45	1.06	0.52	#DIV/0!	1.17	#DIV/0!	0	40
6.6	permanent	11	6.58	0.49	22.78	6.66	0.57	0.54	5.60	9.10	4	120
7.1	permanent	62	7.53	1.07	22.28	4.55	3.73	2.00	2.94	3.21	60	140
7.2	ephemeral	69	7.14	1.13	21.34	5.04	1.54	1.60	2.97	2.51	15	260
7.3	ephemeral	75	6.82	0.63	20.61	5.95	3.70	1.59	2.48	2.21	5	100
K58B	ephemeral	7	7.14	0.79	25.40	2.89	42.38	24.31	21.60	41.07	0	20
K2	semi-permanent	0	6.20	0.21	22.63	2.59	0.57	0.42	1.46	1.46	0	40
K3	semi-permanent	2	5.89	0.28	22.63	3.18	0.35	0.14	1.29	1.18	20	110
K4	ephemeral	0	6.00	#DIV/0!	17.20	#DIV/0!	0.28	#DIV/0!	2.05	#DIV/0!	0	40
K5	permanent	0	6.17	0.23	21.25	6.43	3.38	3.51	2.58	1.05	0	60
K7	ephemeral	0	6.00	#DIV/0!	18.10	#DIV/0!	3.36	#DIV/0!	0.66	#DIV/0!	0	0
T-13	semi-permanent	5	6.32	0.45	25.00	0.71	0.62	0.37	1.61	1.98	#VALUE!	#VALUE!
T-14	ephemeral	0	6.63	#DIV/0!	24.00	#DIV/0!	0.34	#DIV/0!	2.91	#DIV/0!	0	10
T-15	permanent	0	6.34	0.17	23.85	0.21	0.87	0.33	0.66	0.25	#VALUE!	#VALUE!

Table A2.5 The total amount of rainfall (mm) for months January 2018 to May 2020 compared to the average long-term rainfall (mm) for the months September to May from 1942 to 2020. Above average (Green); 50-100% of average (orange); < 50% average (red).

	Jan	Feb	Mar	Apr	Sept	Oct	Nov	Dec
1942-2020	98.3	117.8	120.7	109.8	60.1	73.5	81.9	77.5
2018	**15.4**	**109.0**	**169.2**	**91.0**	**111.0**	**137.4**	**77.6**	**51.4**
2019	**14.6**	**33.6**	**145.8**	**36.0**	**75.4**	**45.0**	**51.8**	**0.8**
2020	**67.2**	**171.6**	**106.2**	**53.6**				

Table A2.6 The average air temperature (°C) for the months January 2018 to May 2020 compared to the long-term average air temperature (°C) for the months September to May from 1942 to 2020. Below average (green); above average (green).

	Jan	Feb	Mar	Apr	Sept	Oct	Nov	Dec
1942-2020	28.3	27.7	26.4	23.8	21.5	23.8	25.6	27.4
2018	30.6	29.1	27.8	26.3	21.3	23.1	26.5	29.9
2019	33.3	30.1	28.1	25.4	22.4	25.5	28.6	30.5
2020	30.1	28.1	26.1	24.9				

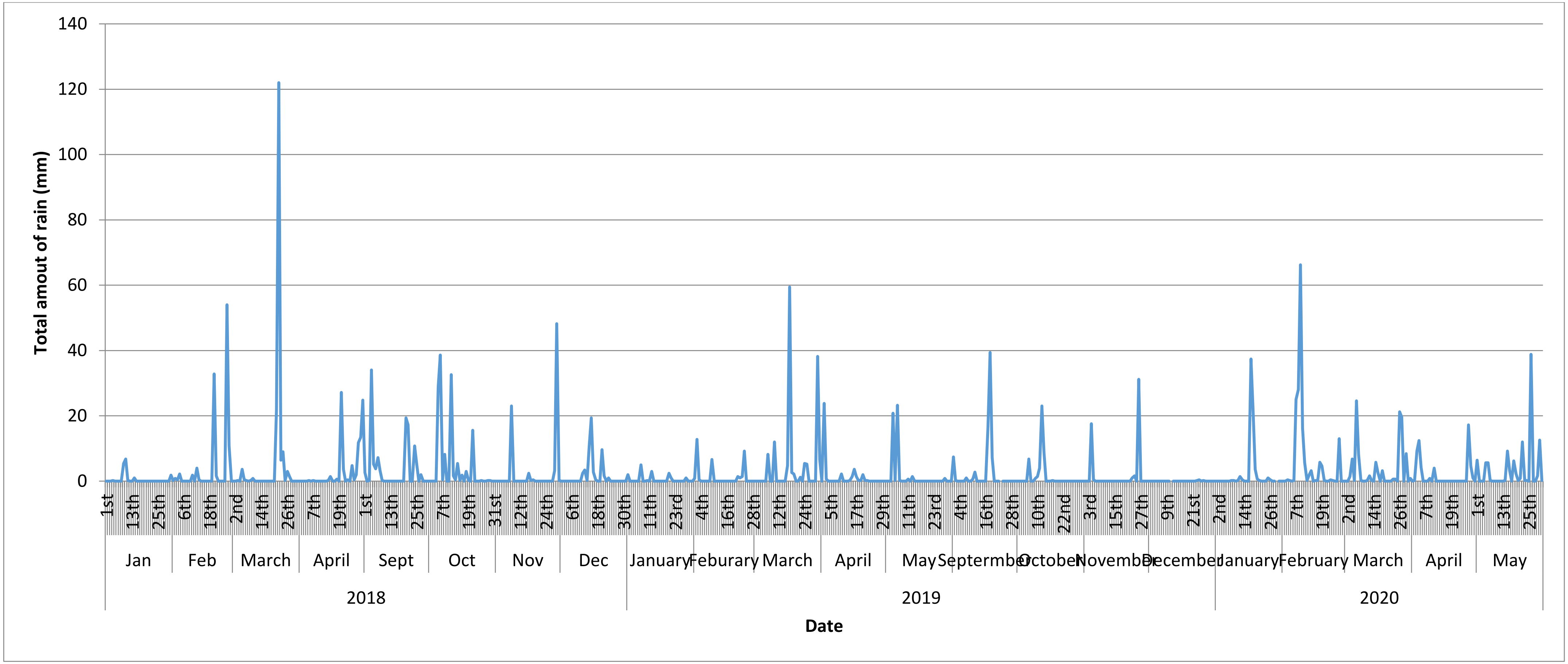


Figure A2.1 Daily rainfall (mm) for the months of January 2018 to May 2020 from the Williamstown weather station (061078).

APPENDIX 8

NCIG COMPENSATORY WETLANDS

Hunter Bird Observers Club
Affiliated with BirdLife Australia

Hunter Bird Observers Club Inc
PO Box 24, New Lambton, NSW 2305
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ABN 62 415 889 446

DEEP POND (KOORAGANG ISLAND)
AVIFAUNA DATA SUMMARY 2019

Surveys for waterbirds and shorebirds were conducted by the Hunter Bird Observers Club (HBOC) on Deep Pond during 2019, facilitated by the Newcastle Coal Infrastructure Group (NCIG). A summary of results of those surveys for this period is provided in this document. Significant observations of non-shorebirds/waterbirds are also included. Note that this is a broad overview summary and is not intended to be a detailed analysis of results. HBOC reserves the right to publish such analyses in the future.

HBOC personnel that conducted field surveys in 2019 were Mick Roderick, Ian Benson, Shaun McKay and Kristy Peters.

BC Act = *Biodiversity Conservation Act* (NSW) 2016
EPBC Act = *Environment Protection and Biodiversity Conservation Act* (Commonwealth) 1999

Shorebirds

Water levels were generally low, though there was always water present in Deep Pond North (DPN). Rain during autumn returned higher water levels that subsequently dropped off markedly towards the end of the year (eventually drying out completely in January 2020).

1. Migratory Shorebirds

Six species of migratory shorebird were recorded at Deep Pond (all on DPN) during formal surveys in 2019; an increase from four species during 2018, as listed below:

- Black-tailed Godwit ('Vulnerable' BC Act 2016) – present Jan/Feb and November, with peak a count of 58 birds in January.
- Sharp-tailed Sandpiper – present on DPN in Jan/Feb, April and November with a peak count of 140 birds in January.
- Common Greenshank – present Jan/Feb and November with a peak count of 25 birds in January.
- Marsh Sandpiper – present Jan/Feb and November with peak count 96 birds in November.
- Red-necked Stint – 4 birds present in May
- Double-banded Plover – 7 birds present in May

A total of twelve species of migratory shorebird have now been recorded on Deep Pond since 2008 (with fourteen species having been recorded between 1993-2008).

Notes and Comments

- Conditions were clearly favourable for shorebirds during early summer, then again in November. The January and November surveys in particular were peak months with a good diversity and number of birds present (e.g. 96 Marsh Sandpipers is a significant count for the estuary in recent years).
- The count of 140 Sharp-tailed Sandpipers in January is significant given the past usage of the sites by this species before major works were undertaken. Also, two birds were found using nearby Little Bittern Pond on the same day.
- May also had favourable conditions for small-legged shorebirds and was the only month when Red-necked Stints and Double-banded Plovers were found (both generally scarce on Deep Pond).
- Black-tailed Godwits continue to favour DPN when conditions are good there (or perhaps, less than optimal elsewhere).
- How the return of migratory shorebirds to Deep Pond has been influenced by conditions locally and/or conditions externally is difficult to be certain about. One would need to look at national shorebird and rainfall data to draw meaningful conclusions. However, it can be said with great confidence that when water levels in Deep Pond (North) are at an optimal level for shorebirds they will use the site if the species are present in the estuary at the time. This is evidenced by the use of the pond during January, February and November 2019.

2. Resident Shorebirds

Five species of resident shorebird were recorded at Deep Pond during 2019, being:

- Masked Lapwing – several records from both DPN and Deep Pond South (DPS).
- Black-fronted Dotterel – 26 birds in April, and 33 birds in May, with smaller numbers in June/July
- Black-winged Stilt – birds present most months with two counts of around 250 birds made
- Red-capped Plover – 6 birds noted in May (at same time as peak Black-fronted Dotterel count and presence of Red-necked Stints and Double-banded Plovers).
- Red-necked Avocet – present Jan/Feb, April and November, with peak count of 520 birds in November.

The above counts of resident shorebirds reinforces the point made about how shorebirds generally use Deep Pond. In simple terms, if the habitat is suitable on Deep Pond and less than optimal elsewhere the resident shorebirds will use the site.

Waterfowl and other waterbirds

Numerous waterfowl (e.g. ducks, swans, grebes etc) and other waterbirds (e.g. herons, egrets, ibis etc) utilise the Deep Pond area. With the water levels again fluctuating during 2019 there was a notable variation in the usage by waterbirds.

Notes

- 740 Grey Teal were recorded in February, with 560 birds there again in November (lesser numbers in between). 850 Eurasian Coot were counted in January.
- Two Whiskered Terns were present during the November survey; interestingly there was a single bird on the corresponding survey in 2018.
- Glossy Ibis are a very rare visitor to Deep Pond, but were recorded in January, February and November perhaps in response to unfavourable conditions elsewhere.
- Black Swans bred successfully once again, with active nests recorded on DPS and nearby Little Bittern Pond. A peak count of 198 birds was made on Deep Pond in October.

Nearby, a Black-necked Stork ('Endangered' BC Act) was recorded on Little Bittern Pond in Jan/Feb and on Blue-billed Duck Pond in December.

Other birds

- White-bellied Sea-Eagles ('Vulnerable' BC Act) were again regularly seen in and around Deep Pond.
- A Spotted Harrier ('Vulnerable' BC Act) was found nearby to Deep Pond during the May survey. This recorded coincided with a perceived influx of Spotted Harrier records in the Hunter Estuary at the time and in the previous ~6 months.
- Four Double-barred Finches found in October was a slightly unusual record (the only site in the Hunter Estuary where they are recorded with any regularity is Stockton Sandspit).

Summary

- As occurred in 2018, the count of migratory and resident shorebirds using Deep Pond in 2019 was quite high, both in terms of the number of species and individual birds.
- This reflects that Deep Pond (and in particular DPN) remains an important site for migratory shorebirds (and waterfowl), especially when conditions elsewhere in the region may not be favourable.
- Given the diversity of avifauna using the site, Deep Pond remains a unique and important habitat entity in the Hunter Estuary.

Prepared by Mick Roderick on behalf of the Hunter Bird Observers Club
10 March 2020

Avifauna Survey 2019 - Kooragang Island - Deep Pond North

Species	18 Jan 19	08 Feb 19	08 Mar 19	05 Apr 19	17 May 19	14 Jun 19	19 Jul 19	16 Aug 19	12 Sep 19	11 Oct 19	15 Nov 19	13 Dec 19	Total
Australasian Shoveler		9						4	8	5			26
Australasian Pipit	1												1
Australian Pelican	15	18							1	1			35
Australian White Ibis	20	3								1			24
Australian Wood Duck									2				2
Australian Reed-Warbler	2											4	6
Black Swan	110	22	2	33		7	58	73	103	198	6		612
Black-fronted Dotterel				26	33	6	2						67
Black-shouldered Kite												1	1
Black-tailed Godwit	58	43									36		137
Black-winged Stilt	250	247	2	55	37	2		3	66	51	250		963
Cattle Egret	5												5
Chestnut Teal	8	30						2			22		62
Common Greenshank	25	13									24		62
Common Myna	2										2		4
Double-banded Plover					7								7
Dusky Moorhen	6	1											7
Eastern Curlew													0
Eurasian Coot	850	60											910
Fairy Martin	2							1				2	5
Glossy Ibis		7											7
Golden-headed Cisticola												2	2
Great Egret	2												2
Grey Teal	90	740			14			112	4		560		1520
Hardhead	10									8			18
Little Black Cormorant	1												1
Little Pied Cormorant	1												1
Magpie-lark	1												1
Marsh Sandpiper	1	47									96		144
Masked Lapwing	14	14	14	2		8	11	21			6		90
Pacific Black Duck	65				2					2			69
Purple Swamphen	9	2		3									14
Red-capped Plover					6								6
Red-necked Avocet	120	33		35							520		708
Red-necked Stint					4								4
Royal Spoonbill	1	23											24
Sharp-tailed Sandpiper	140	41		2							12		195
Silver Gull	6			1									7
Spotted Harrier					1								1
Swamp Harrier		2									1		3
Welcome Swallow	30										2		32
Whiskered Tern											2		2
Whistling Kite	1		1										2
White-bellied Sea-Eagle			3										3
White-breasted Woodswallow											6		6
White-faced Heron		7	1										8
Total	1846	1362	23	157	104	23	71	216	184	266	1545	9	5806

Light grey shading indicates resident shorebird species

Dark grey shading indicates migratory shorebird species

Species in **bold font** are listed as threatened under the *Biodiversity Conservation Act* (NSW) 2016 and/or the EPBC Act 1999

Avifauna Survey 2019 - Kooragang Island - Deep Pond South

Species	18 Jan 19	08 Feb 19	08 Mar 19	05 Apr 19	17 May 19	14 Jun 19	19 Jul 19	16 Aug 19	12 Sep 19	11 Oct 19	15 Nov 19	13 Dec 19	Total
Australian Magpie											5		5
Black Swan						5	4	6	2		4	15	36
Black-winged Stilt											20	31	51
Fairy Martin	7							3					10
Glossy Ibis	10										13		23
Golden-headed Cisticola	1											2	3
Hardhead										1			1
Intermediate Egret										1			1
Little Grassbird												1	1
Masked Lapwing								13				1	14
Nankeen Kestrel			1										1
Pacific Black Duck				2		2				44			48
Purple Swamphen	13											2	15
Superb Fairy-wren												6	6
Swamp Harrier		1					1		1				3
Welcome Swallow	2										2	5	9
White-bellied Sea-Eagle											1		1
White-breasted Woodswallow											6		6
White-faced Heron	3												3
White-necked Heron						1					1		2
Yellow Thornbill	1												1
Total	45	1	1	2	0	9	5	22	3	46	52	63	249

Light grey shading indicates resident shorebird species

Dark grey shading indicates migratory shorebird species

Species in **bold font** are listed as threatened under the *Biodiversity Conservation Act* (NSW) 2016 and/or the EPBC Act 1999

APPENDIX 9

COMMUNITY SUPPORT PROGRAM

Organisation	Project
September 2019 Community Support Program	
Arnetts Football Club	Arnetts Program
Hunter Simba Football Club	Purchase of a defibrillator
Stockton Men's Bowling Club	Purchase of new shirts
Salt Ash Pony Club	Purchase of a water tank
Stockton Tennis Club	Junior Tennis Program
Newcastle Youth Orchestra	Dr Suess Green Eggs and Ham Concert
Soul Café	Volunteer with Soul – Volunteer Appreciation Events; Friday Chill
Hunter Hurricanes	Queens Wharf Harbour Water Polo
Orana Community Preschool	Upgrade of soft fall play area
Newcastle Rowing Club	Purchase of a rowing boat
Waterboard Cricket Club	Purchase of a heavy roller
Bikers for Kids	Newcastle Toy Run 2019 - Community Fun Day
Charlestown East Public School P&C	Special Needs Outdoor Area
Hunter Bible Church	Lambton Park Carols
Stockton SLSC	Stockton SLSC Youth Development Project
Variety	Spin 4 Kids
March 2020 COVID-19 Funding	
Soul Cafe	Funding provided was general in nature to assist the organisations with unplanned costs or increased demand due to COVID-19
Newcastle Meals on Wheels	
Zara's House	
Lifeline	
Jenny's Place	
Rick Banyard on behalf of Seafarers	
Got Your Back Sista	
Hunter Region Botanic Gardens	
Fern Bay Public School	
Stockton Public School	
Seafarer's WiFi Units	
Hunter Women's Centre	
Community Helping Community	
Variety	