

Intended for
Newcastle Coal Infrastructure Group

Document type
Report

Date
March 2018

ANNUAL ENVIRONMENTAL MONITORING REPORT 2016-2017 NCIG COAL EXPORT TERMINAL

**ANNUAL ENVIRONMENTAL MONITORING REPORT
2016-2017
NCIG COAL EXPORT TERMINAL**

Revision **Final**
Date **5/3/2018**
Made by **Kirsty Greenfield**
Checked by **Fiona Robinson**
Approved by **Fiona Robinson**
Description **Annual Environmental Monitoring Report**



Ref AS130540

Ramboll Environ
Level 2, Suite 19B
50 Glebe Road
PO Box 435
The Junction
NSW 2291
Australia
T +61 2 4962 5444
F +61 2 4962 5888
www.ramboll-environ.com

CONTENTS

1.	INTRODUCTION	1
1.1	Approvals, leases, licences and permits	1
1.2	Management plans and monitoring programs	2
1.3	Project Contacts	3
1.4	Project Background	3
2.	OVERVIEW OF ACTIVITIES	7
2.1	Operation	7
3.	SUSTAINABLE DEVELOPMENT POLICY	10
4.	ENVIRONMENTAL MANAGEMENT AND PERFORMANCE	11
4.1	Meteorology	13
4.1.1	Environmental Management	13
4.1.2	Environmental Performance	13
4.1.3	Monitoring summary	13
4.1.4	Reportable incidents	16
4.1.5	Further Improvements	16
4.2	Air Quality	16
4.2.1	Environmental Management	16
4.2.2	Environmental Performance	16
4.2.3	Reportable Incidents	22
4.2.4	Further Improvements	22
4.3	Water Quality	22
4.3.1	Environmental Management	22
4.3.2	Environmental Performance	24
4.3.3	Reportable Incidents	27
4.3.4	Further Improvements	27
4.4	Groundwater	29
4.4.1	Environmental Management Relating to EPL	29
4.4.2	Environmental Performance Relating to the EPL	29
4.4.3	Reportable Incidents	32
4.4.4	Further Improvements	32
4.5	Erosion and Sediment Control	32
4.5.1	Environmental Management	32
4.5.2	Environmental Performance	32
4.5.3	Reportable Incidents	34
4.5.4	Further Improvements	34
4.6	Land Contamination	34
4.6.1	Environmental Management	34
4.6.2	Environmental Performance	34
4.6.3	Reportable Incidents	35
4.6.4	Further Improvements	35
4.7	Noise and Vibration	35
4.7.1	Environmental Management	35
4.7.2	Environmental Performance	35
4.7.3	Reportable Incidents	38
4.7.4	Further Improvements	38
4.8	Heritage	38
4.8.1	Environmental Management	38
4.8.2	Environmental Performance	39
4.8.3	Reportable Incidents	39
4.8.4	Further Improvements	39
4.9	Ecology	39
4.9.1	Environmental Management	39

4.9.2	Environmental Performance	39
4.9.3	Compensatory Habitat and Ecological Monitoring Program	48
4.9.4	Reportable Incidents	53
4.9.5	Further Improvements	53
4.10	Traffic Management	53
4.10.1	Environmental Management	53
4.10.2	Environmental Performance	53
4.10.3	Reportable Incidents	54
4.10.4	Further Improvements	54
4.11	Waste Management	54
4.11.1	Environmental Management	54
4.11.2	Environmental Performance	54
4.11.3	Reportable Incidents	55
4.11.4	Further Improvements	55
4.12	Community Relations	55
4.12.1	Environmental Management	55
4.12.2	Environmental Performance	55
4.12.3	Reportable Incidents	60
4.12.4	Further Improvements	60
4.13	Environmental Monitoring Program	60
5.	COMPLIANCE AUDITS	63
6.	STANDARDS	64
7.	ACTIVITIES PROPOSED IN NEXT AEMR PERIOD	65
8.	REFERENCES	66
9.	LIMITATIONS	67
9.1	User Reliance	67

APPENDICES

Appendix 1 Meteorological (Other than Rainfall) Summary

Appendix 2 Dust Deposition Monitoring Results

Appendix 3 Surface Water Monitoring Results

Appendix 4 GroundWater Monitoring Results

Appendix 5 CHEMP Quarterly Reports and Minutes

**Appendix 6 Annual Report (2016/17) Research Program on the
Green and Golden Bell Frog on Kooragang Island**

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) (O6_0009) which was granted on 13 April 2007.

This is the ninth AEMR prepared for the NCIG Project and it covers the period July 2016 to June 2017 (inclusive), which includes the seventh year of terminal operation.

The AEMR reviews the performance of the Project 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. 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

The Project is being undertaken under 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
Project Approval (O6_0009)	Department of Planning and Environment	13 April 2007	5 years unless substantially commenced
Modification of Minister's Approval MP06_0009	Department of Planning and Environment	27 November 2007	N/A (conditions appended to the Project Approval)
Modification of Minister's Approval MP06_0009 MOD2	Department of Planning and Environment	13 May 2013	N/A (conditions appended to the Project Approval)
Project Lease	State Property Authority	22 January 2008	35 years
Environmental Protection Licence (EPL) (No. 12693)	NSW Environment Protection Authority	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	Department of the Environment and Energy	11 October 2007	Perpetuity
Maritime Services Act 1935 s13JE	NSW Roads and Maritime Services	02 October 2007	Perpetuity
Environmental Representative	Department of Planning and Environment	03 October 2007	Perpetuity
Project Ecologist	Department of Planning and Environment	02 May 2007 & 25 October 2007	Perpetuity
Licence for Minor Operations – Green and Golden Bell Frog Research Area (Trial Site)	National Parks and Wildlife Service	25 June 2012	5 years (until 24 June 2017)
Licence for Minor Operations – Green and Golden Bell Frog Compensatory Habitat	National Parks and Wildlife Service	31 March 2013	5 years (until 30 March 2019)
Determination Notice for External Proponents – Green and Golden Bell Frog Compensatory Habitat (Ref No. CCHR 1317_17)	National Parks and Wildlife Service	7 March 2013	Perpetuity

Table 1.1 Project Approval, Leases, Licences and Permits			
Instrument	Relevant Authority	Date Granted	Duration of Approval
Determination Notice for External Proponents – Green and Golden Bell Frog Trial Ponds (Ref. No. CCHR 1112_28)	National Parks and Wildlife Service	1 June 2012	Perpetuity
Deed for the provision of compensatory habitat for migratory shorebirds on Kooragang Island (Area E)	(the Minister for) National Parks and Wildlife Service	22 February 2016	Cessation of NCIG CET, surrender of Project Approval 06_0009 or expiry of the lease
Determination (National Parks and Wildlife Service) – Shorebird Compensatory Habitat project at Fish Fry Flats (Appl No. CCHR 1415_21)	National Parks and Wildlife Service	28 June 2015	Perpetuity
Licence for Minor Operations – Shorebird Habitat Compensation Area E, Kooragang Island	National Parks and Wildlife Service	30 December 2014	35 years (until 29 December 2039)

1.2 Management plans and monitoring programs

In accordance with the PA 06_0009, the Project is currently being undertaken consistent with a number of approved environmental management plans and monitoring programmes, including:

Operations Management Plans

- Operation Environmental Management Plan
- Operation Dust and Air Quality Management Plan
- Operation Noise Management Plan
- Operation Spontaneous Combustion Management Plan
- Operation Water Management Plan

Other Management Plans and Programs

- Ecological and Land Management Plan
- Waste Management Plan
- Site Water Management Plan (incorporated into the Operation Water Management Plan)
- Green and Golden Bell Frog Management Plan (incorporated into the Ecological and Land Management Plan)
- Materials Management Areas Procedure
- Compensatory Habitat and Ecological Monitoring Program
- Green and Golden Bell Frog 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 PWCS)
- Materials Transport Procedure

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 Project Contacts

Contact Details for the Project are provided below:

Chief Executive Officer
Aaron Johansen
Phone: (02) 4920 3954
Email: ajohansen@ncig.com.au

Manager – HSEC
(Environmental Representative)
Nathan Juchau
Phone: (02) 4920 3965
Email: njuchau@ncig.com.au

1.4 Project Background

The Newcastle Coal Infrastructure Group (NCIG) Coal Export Terminal (CET) (the Project) is located on Kooragang Island in Newcastle, New South Wales (NSW) (Figure 1). The Project includes the construction and operation of a CET 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.

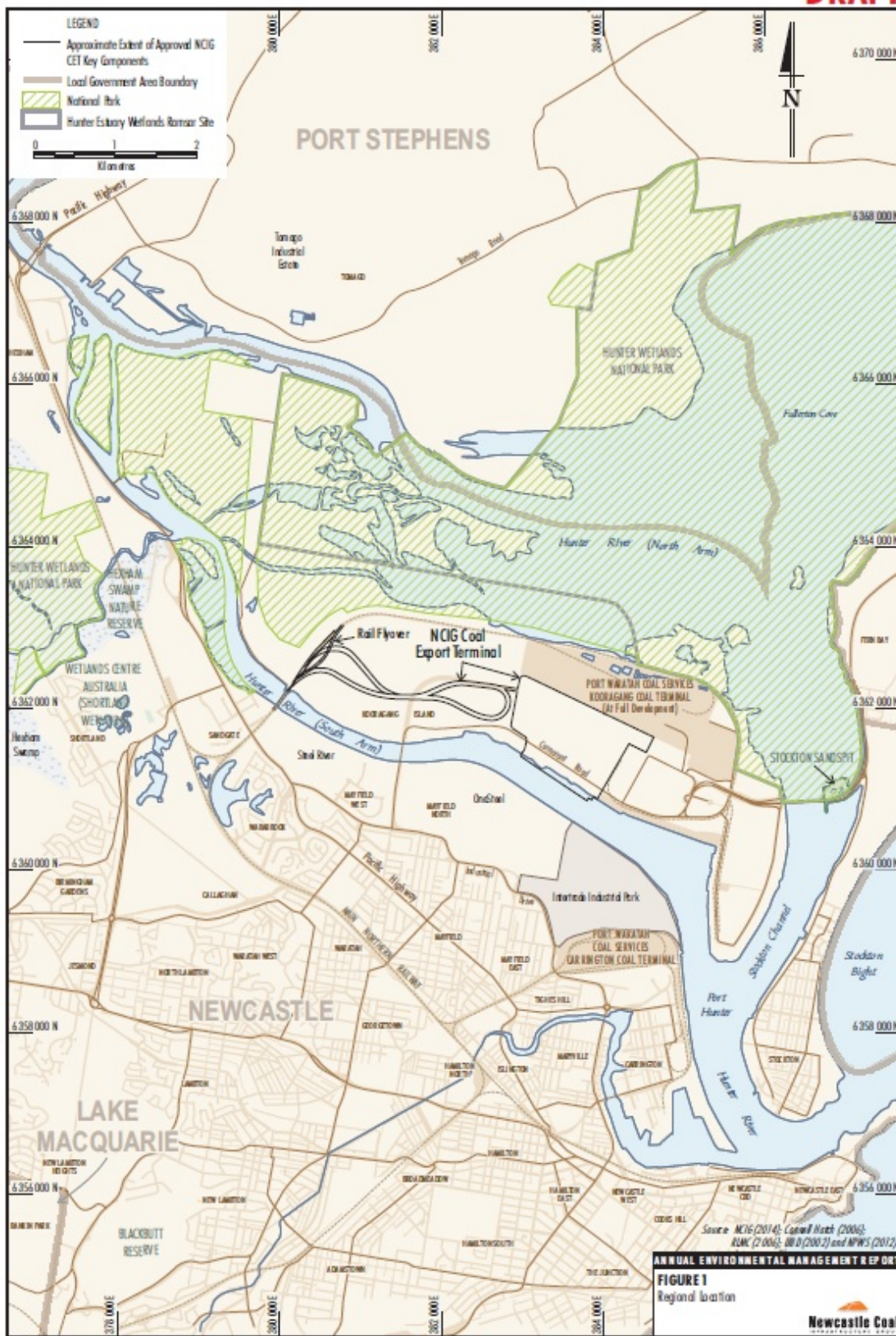


Figure 1: Project location

NCIG is the proponent of the Project and is a consortium of the following five companies:

- Banpu Public Company Limited;
- Hunter Valley Energy Coal Limited;
- Peabody Energy Corporation;
- Yankuang Group; and
- Whitehaven Coal Mining Pty Ltd.

NCIG was formed in response to a call for Expressions of Interest for the development of land on Kooragang Island by the NSW State Government in 2004. The outcome of this process was that in 2006 NCIG was awarded the right to develop the parcel of land that is now the Project site. PA 06_0009 was granted in April 2007 and construction of Stage 1 of the coal export terminal commenced in April 2008. Stage 1 of construction was completed and subsequently handed to NCIG for operation in July 2010. Stage 2AA construction commenced in the first half of 2010, with mechanical completion achieved in June 2012. Stage 2F construction commenced in June 2012 and was completed in June 2013. The Rail Flyover commenced in October 2013 and was completed in August 2015.

The project general arrangement is shown on **Figure 2**. The general arrangement is designed to support the planned maximum coal throughput of 66 Mtpa. The main activities associated with the construction of the Project include:

- re-use of dredged materials from the south arm of the Hunter River as preload and engineering fill for construction of the coal storage area, rail corridor and wharf facilities (*NB/ NCIG did not conduct dredging operations during the reporting period*);
- construction of a coal storage area including coal stockpiles, conveyors, transfer points and combined stacker/reclaimers;
- construction of wharf facilities, ship loaders, conveyors and buffer bins;
- foundation preparation, formation construction and capping of a rail corridor traversing the existing Kooragang Island Waste Emplacement Facility (KIWEF) for the development of the rail spurs, rail sidings and rail loops;
- construction of rail spurs, rail sidings and rail loops, rail overpass, train unloading stations and connecting conveyors;
- development of water management infrastructure including site drainage works, stormwater settlement ponds, primary and secondary settling ponds, site water pond, water tanks and stockpile spray system;
- installation of electricity reticulation and control systems;
- development of access roads and internal roads;
- construction of administration and workshop buildings; and
- other associated minor infrastructure, plant, equipment and activities.

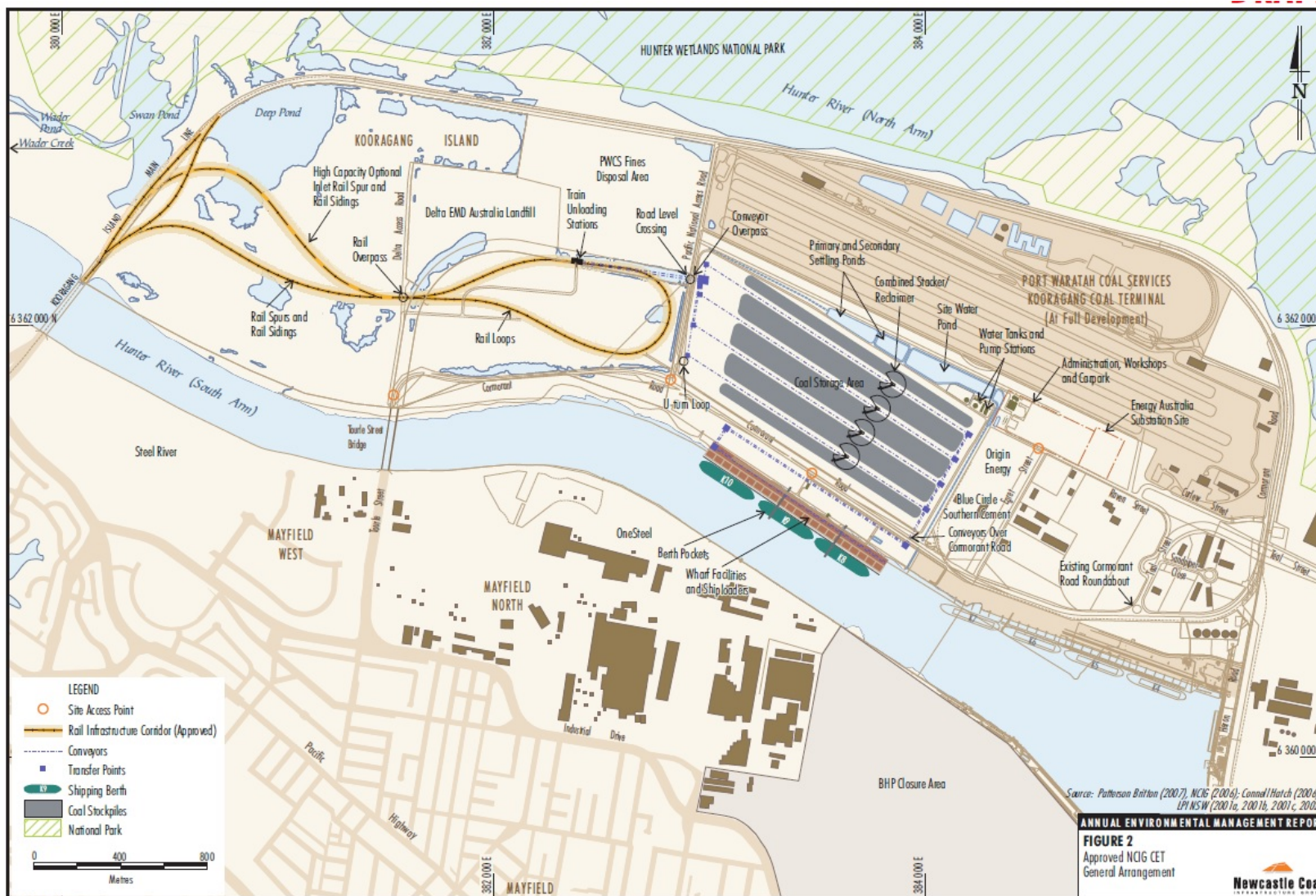


Figure 2: Project General Arrangement

2. OVERVIEW OF ACTIVITIES

2.1 Operation

June 2016 to June 2017 reporting period included a continuation of terminal operations. This means that all mechanical equipment within the approved project were 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:

- Provided 66 million tonnes of capacity.
- Loaded 54 million tonnes of coal.
- Record financial year average Gross Load Rate (GLR) 5,400tph onto 557 vessels.
- Financial year record Gross Unload Rate (GULR) of 7,990 tph.

Operational activities are shown in **Figures 3 to 6**.



Figure 3: NCIG Site Overview Facing East



Figure 4: NCIG Site Overview Facing North



Figure 5: Stockyard with Stacker Reclaimers in Operation

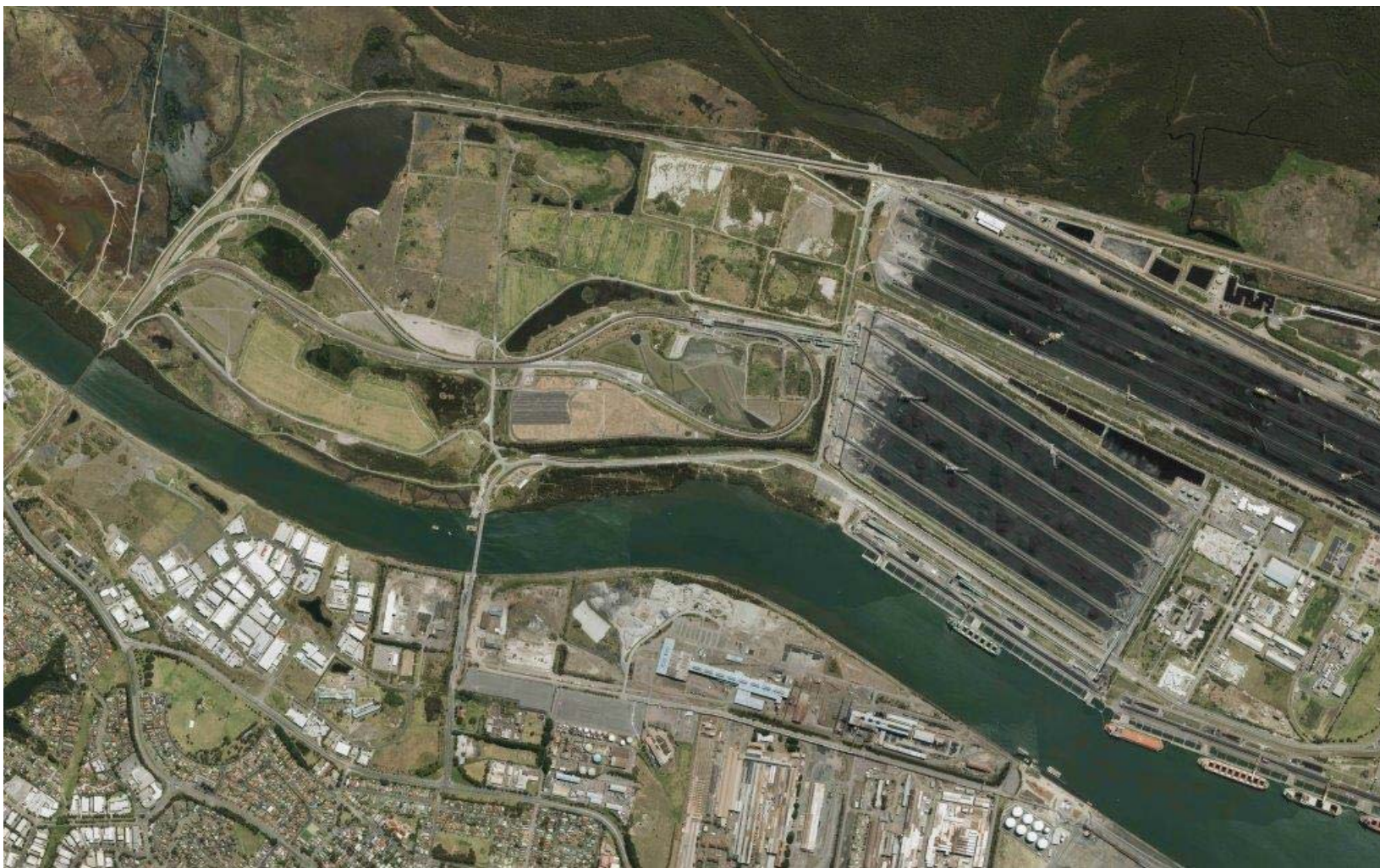


Figure 6: Aerial Photograph of NCIG Terminal

3. SUSTAINABLE DEVELOPMENT POLICY

NCIG updated their Sustainable Development Policy in June 2016. NCIG's approach to environmental management is guided by this policy, which is included in **Figure 7**.



Sustainable Development Policy Creating a Sustainable Business

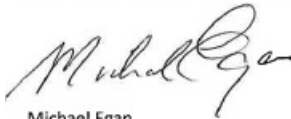
The Newcastle Coal Infrastructure Group (NCIG) is positioned to play an important role in the coal export industry of the Hunter Valley. In fulfilling this role NCIG acknowledges that it is of vital importance to balance the needs of all stakeholders in our business. Through the consideration of shareholders, 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 traditional right of indigenous people and value cultural heritage;
- Regularly review our performance and 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.



Michael Egan

Chairman

Revision: C 21 June 2016

Figure 7: NCIG Sustainable Development Policy

4. ENVIRONMENTAL MANAGEMENT AND PERFORMANCE

Environmental monitoring is undertaken at NCIG for meteorology, dust, surface water, groundwater and noise, as discussed in the following sections. All environmental monitoring sites are shown in **Figure 8**.

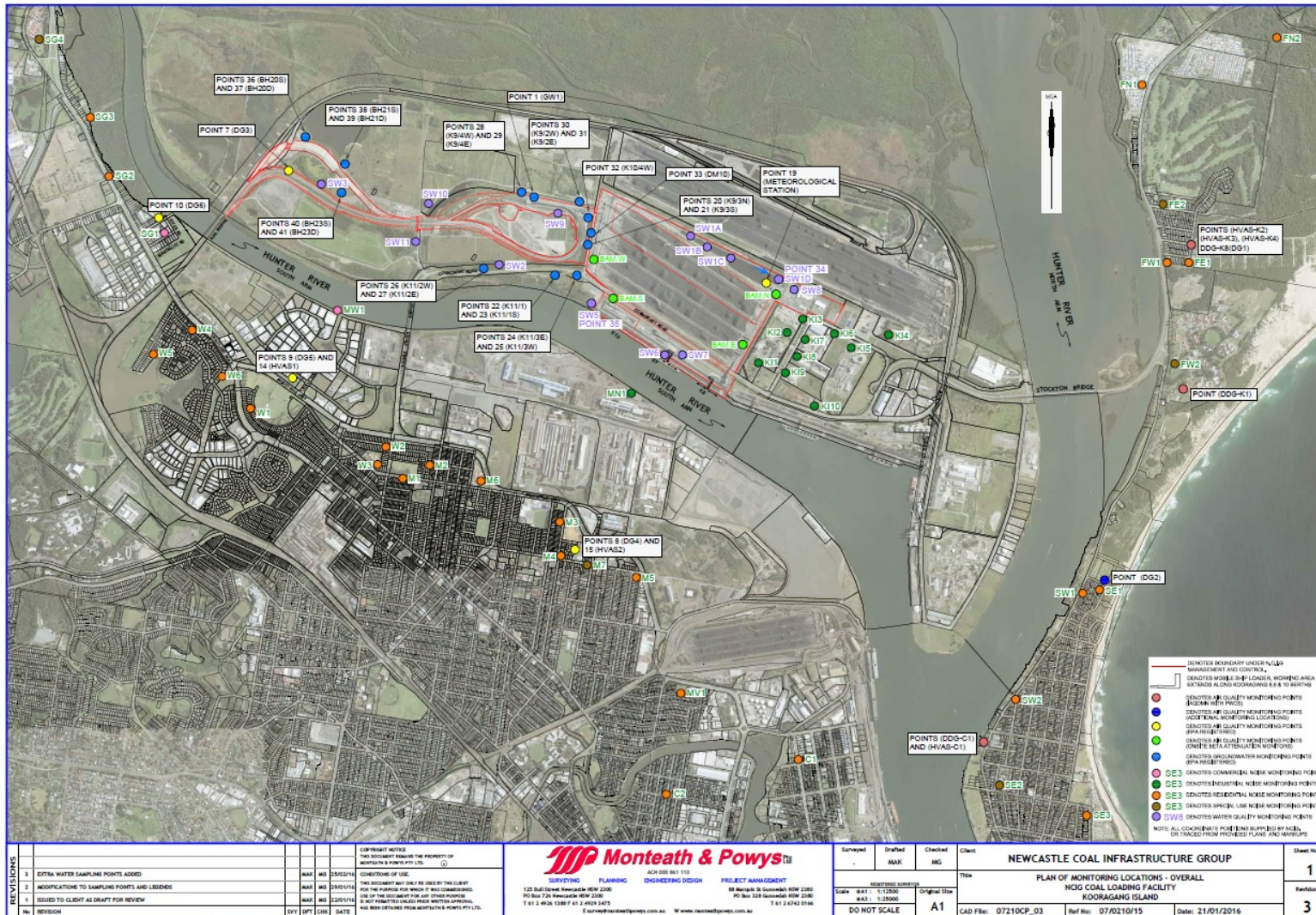


Figure 8: Environmental Monitoring Sites

4.1 Meteorology

4.1.1 Environmental Management

In accordance with Condition 2.8, Schedule 2 of PA 06_0009, an on-site automated meteorological monitoring station was operated during the reporting period to monitor weather conditions representative of the site. This station was installed on the NCIG site in accordance with the requirements of the OEMP.

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.

4.1.2 Environmental Performance

Table 4.1 outlines the monitoring locations, meteorological parameters recorded and frequency of monitoring for the Project in accordance with the CEMP.

Monitoring Parameter	Monitoring Sites	Frequency	Criteria
<ul style="list-style-type: none"> • Temperature • Relative humidity • Net solar radiation • Rainfall • Wind speed and direction • Sigma theta (rate of change of wind direction). 	Project automated meteorological station ¹ .	Continuously monitored and the data averaged over 15 minute periods.	N/A

¹ The location of the monitoring sites is shown on Figure .

4.1.3 Monitoring summary

The meteorological monitoring results for the reporting period are summarised below. Monthly statistical information for rainfall is detailed in **Table 4.2**.

Month	Total rainfall (mm)*	Daily average (mm)	Daily maximum (mm)
July 2016	29.4 (72.5)	1.0	26.6
August 2016	44.4 (74.3)	1.4	11.4
September 2016	54.0 (60.3)	1.9	13.6
October 2016	80.8 (72.7)	2.6	32.0
November 2016	45.4 (82.8)	1.5	28.8
December 2016	47.4 (79.5)	1.5	14.8
January 2017	63.6 (101.1)	2.1	20.6
February 2017	104.2 (118.3)	3.7	30.6
March 2017	209.6 (119.8)	7.0	50.4
April 2017	88.4 (111.9)	2.9	21.6
May 2017	19.2 (112.3)	0.6	7.4
June 2016	181.0 (121.4)	6.0	74.2
Annual	967.4 (1127)		

* values in brackets refer to 66-year Williamstown data – sourced from the Bureau of Meteorology.

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

The monthly and daily rainfall recorded at the project site is shown in **Figure 9**. A total of 967 mm of rain was received on the site during the reporting period with the highest rainfall recorded in March 2017. The lowest rainfall was recorded in May 2017 followed by July 2016.

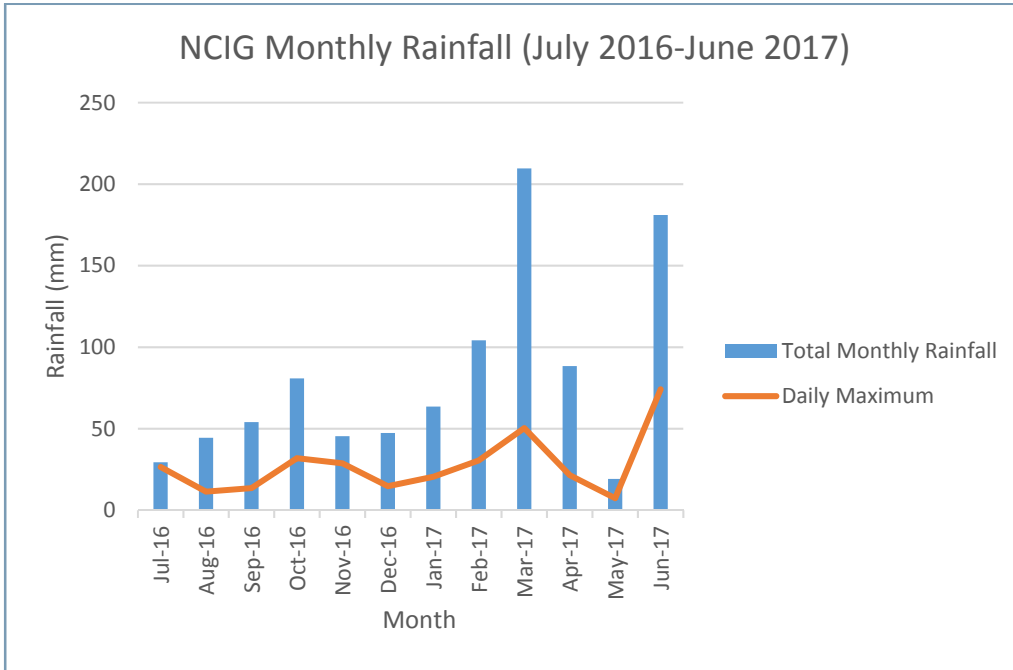


Figure 9: Total and maximum daily rainfall by month

Figure 10 illustrates the variation in average temperature during the reporting period. These variations from the winter to summer seasons are the normal expected seasonal variations. Figure 11 illustrates seasonal wind conditions throughout the reporting period.

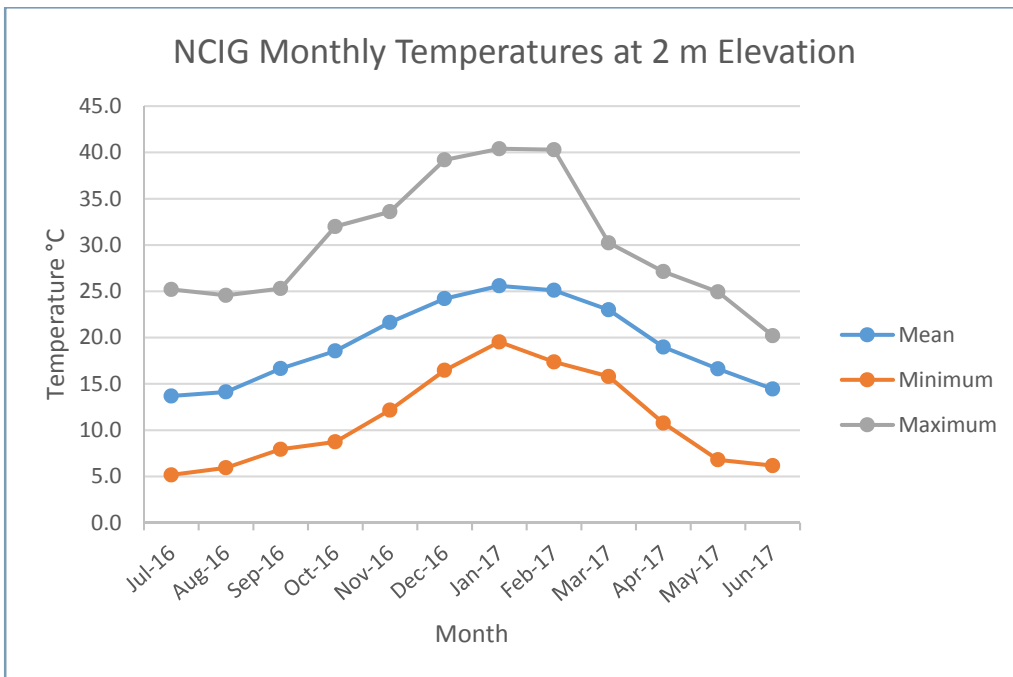
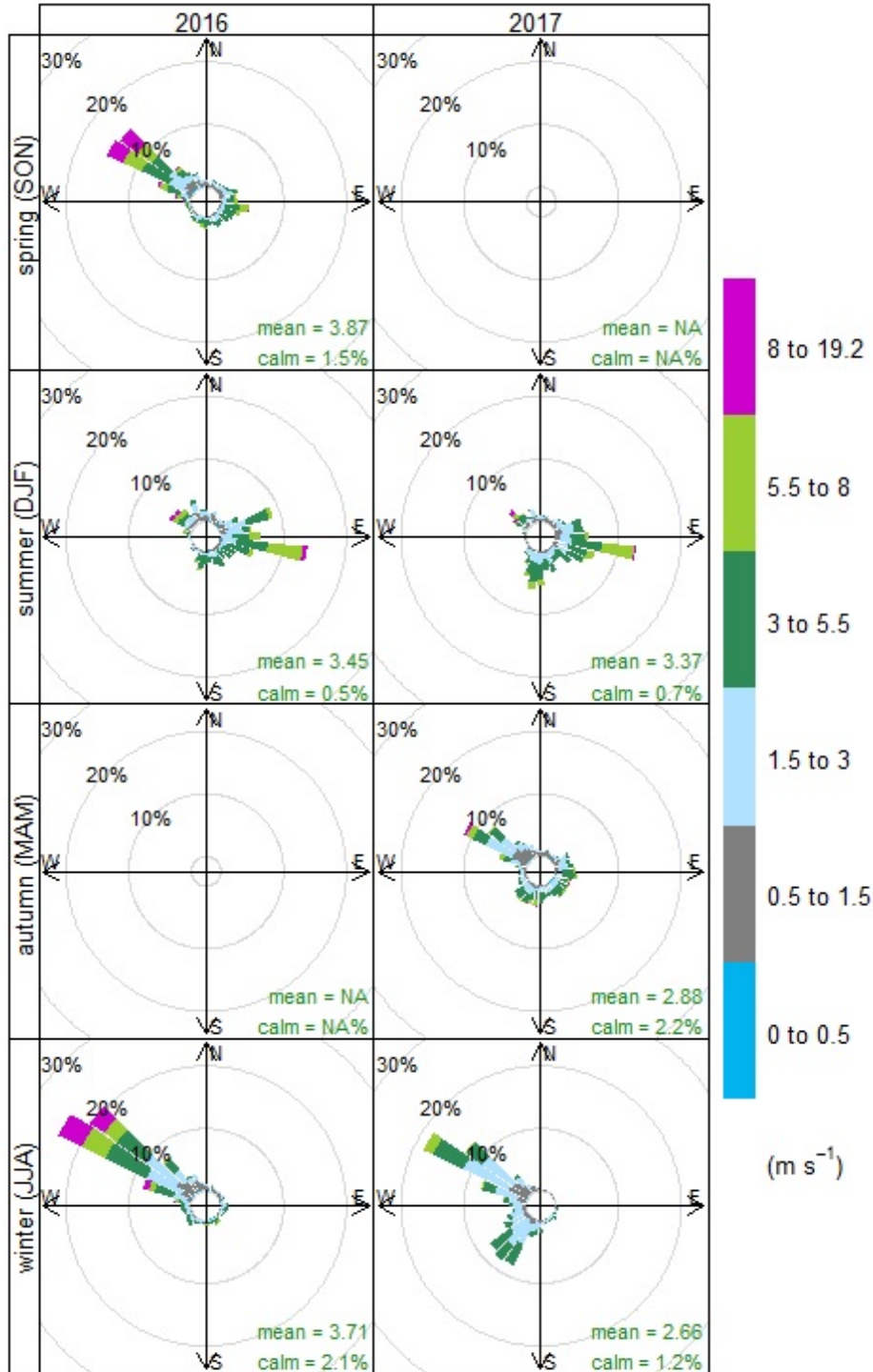


Figure 10: Temperature by month



Frequency of counts by wind direction (%)

Figure 11: Seasonal Wind Conditions

4.1.4 Reportable incidents

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

4.1.5 Further Improvements

NCIG are now receiving additional forecast data for rainfall, with forecast data provided 7 days in advance. This information is used to assist with surface water management. A screenshot of the rain forecasting is shown in **Figure 12**.

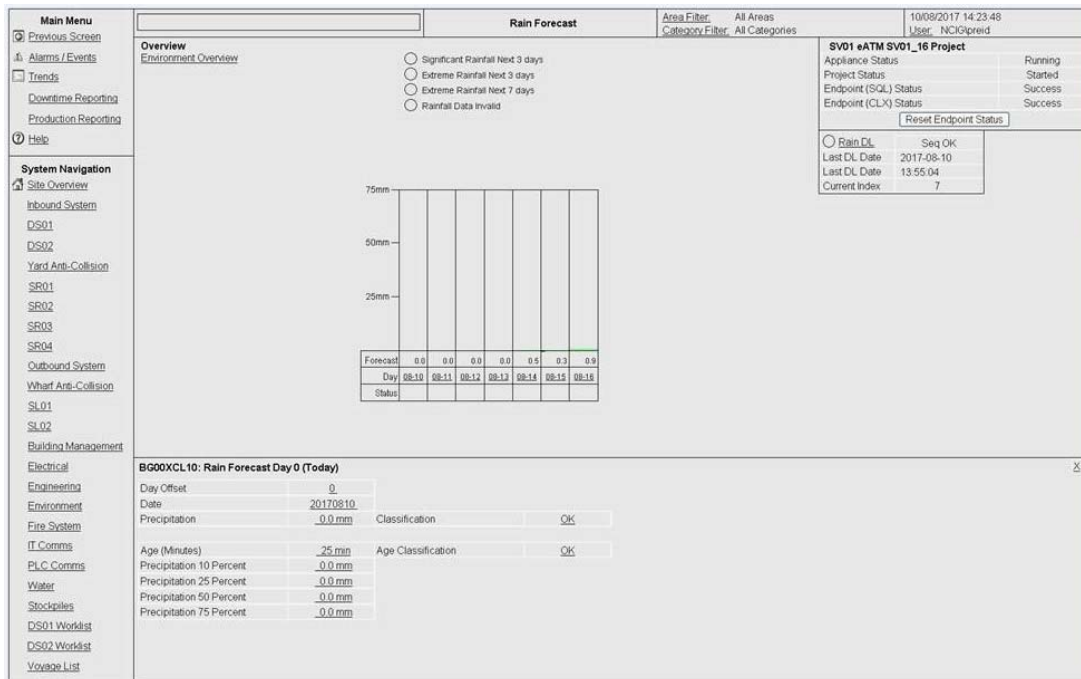


Figure 12: Rain Forecasting

4.2 Air Quality

4.2.1 Environmental Management

Onsite dust management is conducted consistent with the Operations Dust and Air Quality Management Plan 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.

4.2.2 Environmental Performance

Table 4.3 outlines the monitoring locations, air quality parameters recorded, frequency of monitoring and air quality criteria for the Project in accordance with the CEMP. Depositional Dust Monitoring results are provided with in Appendix 2.

Table 4.3 Summary of the Air Quality Monitoring Programme					
Monitoring Parameter	Units	Frequency	Location	Methodology	
Depositional Dust Monitoring					
Depositional Dust (EPL Monitoring Points 7, 8, 9, 10)	g/m ² /month	Monthly	<ul style="list-style-type: none"> Kooragang – DG3 (EPL MP 7) Mayfield – DG4 (EPL MP 8) Steel River – DG5 (EPL MP 9) Sandgate – DG6 (EPL MP 10) 	AS/NZS 3580 ¹	
Depositional Dust (additional monitoring locations)			<ul style="list-style-type: none"> Stockton – DG2 		
Depositional Dust (Integrated AQMN with PWCS)			<ul style="list-style-type: none"> Fern Bay – DDG-K8 (DG1) Stockton Prawners Club – DDG-C1 Stockton Hospital – DDG-K1 		
High Volume Air Sampling					
Total Suspended Particles (TSP) (EPL Monitoring Points 14, 15)	µg/m ³	6-daily	<ul style="list-style-type: none"> Steel River – HVAS1 (EPL MP 14) Mayfield – HVAS2 (EPL MP 15) 	DEC Approved Methods ²	
Particulate Matter <10 µm (PM10) (EPL Monitoring Points 14, 15)					
Total Suspended Particles (TSP) (Integrated AQMN with PWCS)			<ul style="list-style-type: none"> Stockton Prawners Club – HVAS-C1 		
Particulate Matter <10 µm (PM10) (Integrated AQMN with PWCS)			<ul style="list-style-type: none"> Fern Bay – HVAS-K2 (TSP), HVAS-K3 (PM10), HVAS-K4 (Directional TSP) 		
Newcastle Local Air Quality Monitoring Network (operated by OEH, funded by industry)					
Particulate Matter <10 µm (PM10)	µg/m ³	Hourly (average daily values reported)	<ul style="list-style-type: none"> Stockton Carrington Mayfield Newcastle Wallsend Beresfield 	DEC Approved Methods	
Particulate Matter <2.5 µm (PM2.5)					
Wind Speed	ms ⁻¹				AS 2922 ³
Wind Direction	Degrees				AS 2922 ³
Onsite Beta Attenuation Monitoring (BAM)					
Total Suspended Particles (TSP)	µg/m ³	Continuous	<ul style="list-style-type: none"> BAM E BAM N BAM S BAM W 	DEC Approved Methods ²	

1 Dust deposition is analysed in accordance with Australian standard AS/NZS 3580.10.1-2003 Methods for Sampling and Analysis of Ambient Air – Determination of Particulate Matter – Depositional Matter – Gravimetric Method (Standards Association of Australia 2009).

2 PM10 is monitored in accordance with the Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales (Department of Environment and Conservation NSW 2006).

3 AS 2292-1987 Ambient Air – Guide for the siting of sampling units.

The depositional dust monitoring (insoluble solids) results for the reporting period are displayed in **Figure 13** and **Figure 14** below.

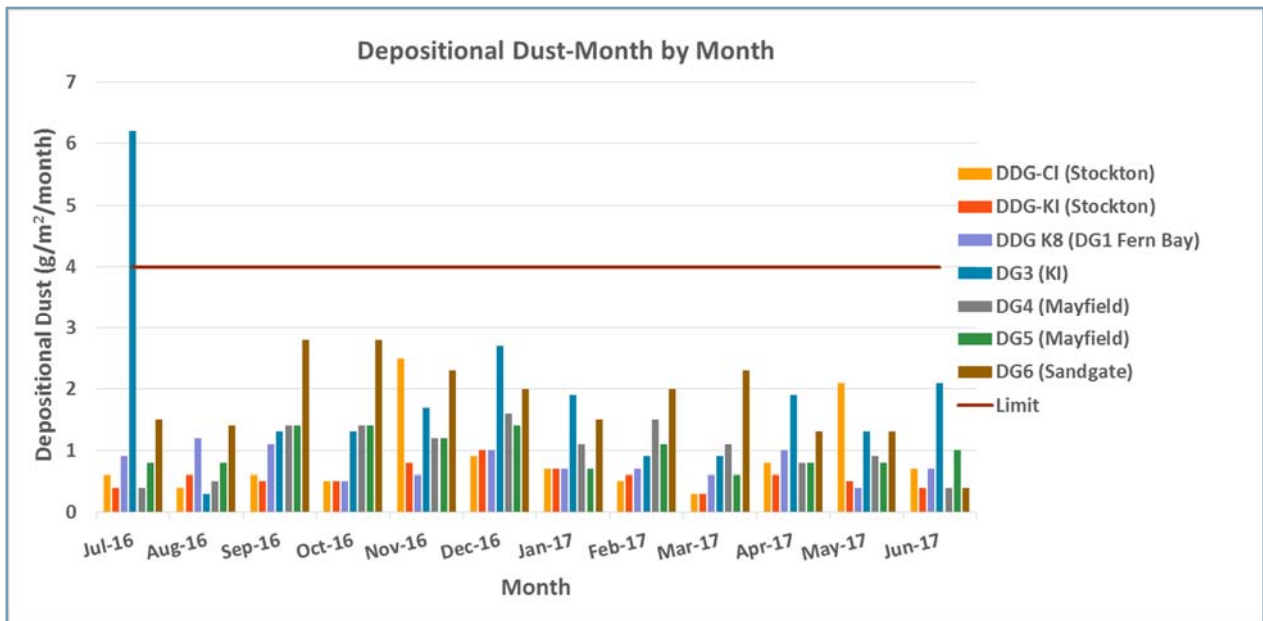


Figure 13: Monthly Depositional Dust

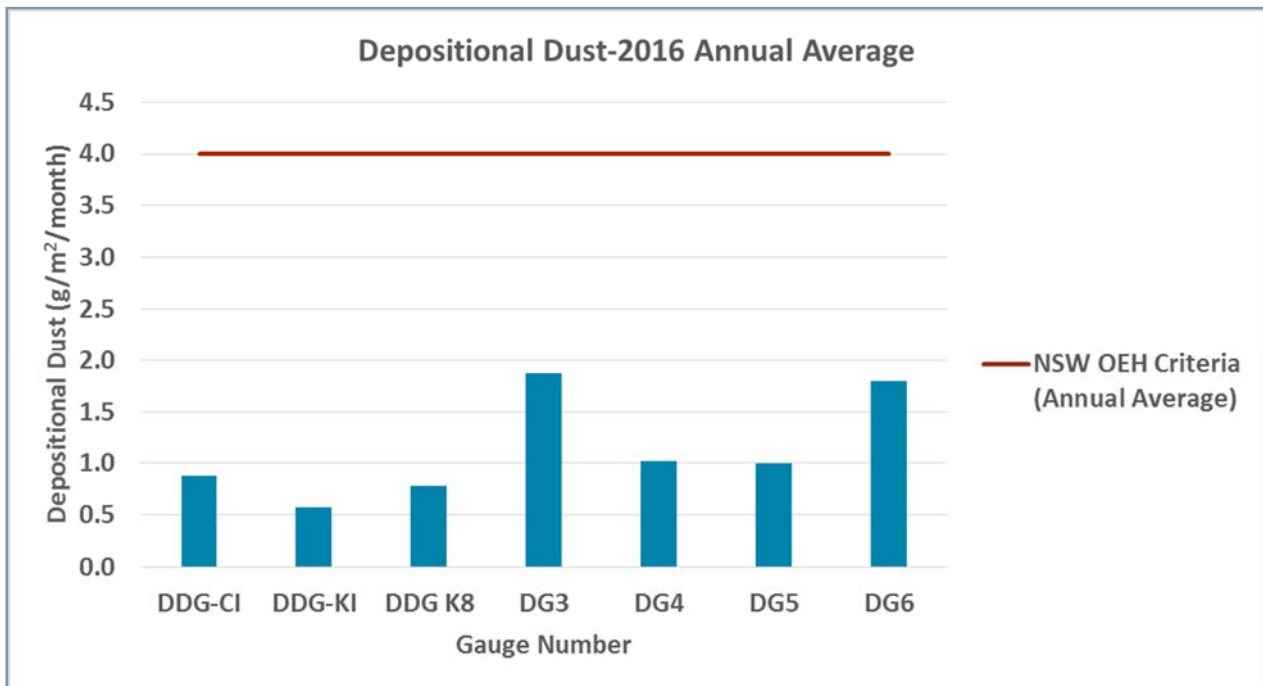


Figure 14: Annual Average Depositional Dust

Average depositional dust results were below the monthly criteria of 4 grams per square metre per month ($\text{g/m}^2/\text{month}$) at all depositional dust gauge locations (**Figure 14**). **Figure 13** shows that individual monthly samples from DG3 exceeded the $4\text{g/m}^2/\text{month}$ criteria in July 2016. The spike in depositional dust at DG3 was due to contamination of the gauge with bird droppings.

Air quality monitoring results from High Volume Air Sampling (HVAS), as they relate to both Total Suspended Particulate (TSP) and Particulate Matter with an equivalent aerodynamic diameter less than 10 Microns (PM_{10}), are displayed in **Figure 15** and **Figure 16**.

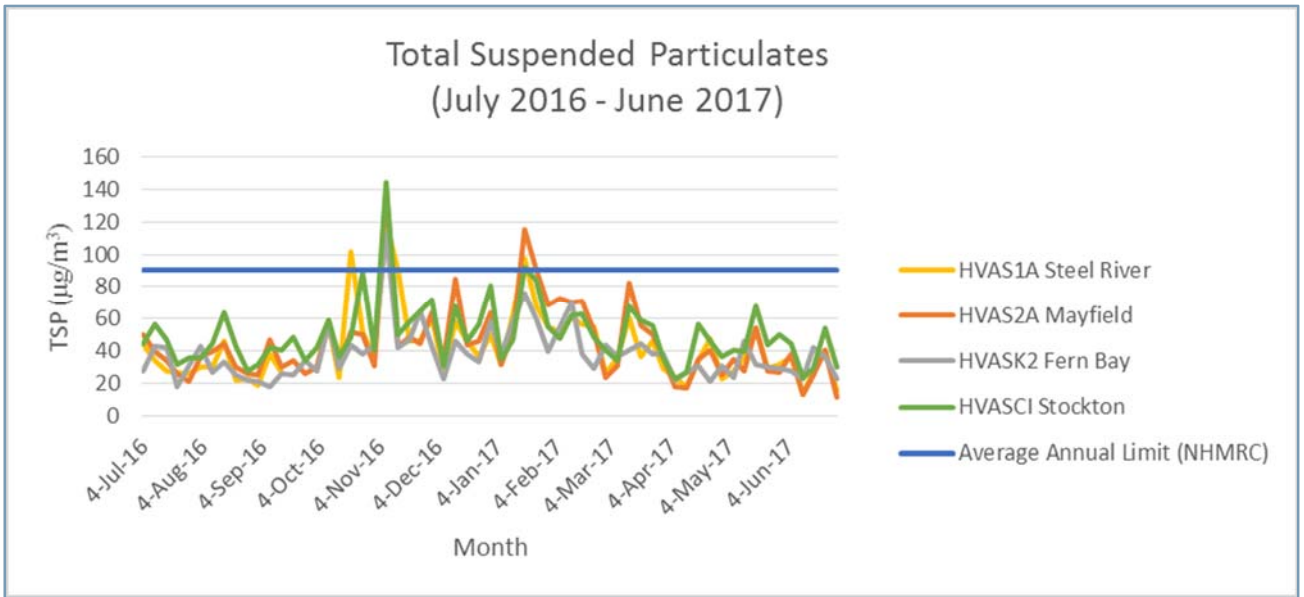


Figure 15: Total Suspended Particulates (TSP)

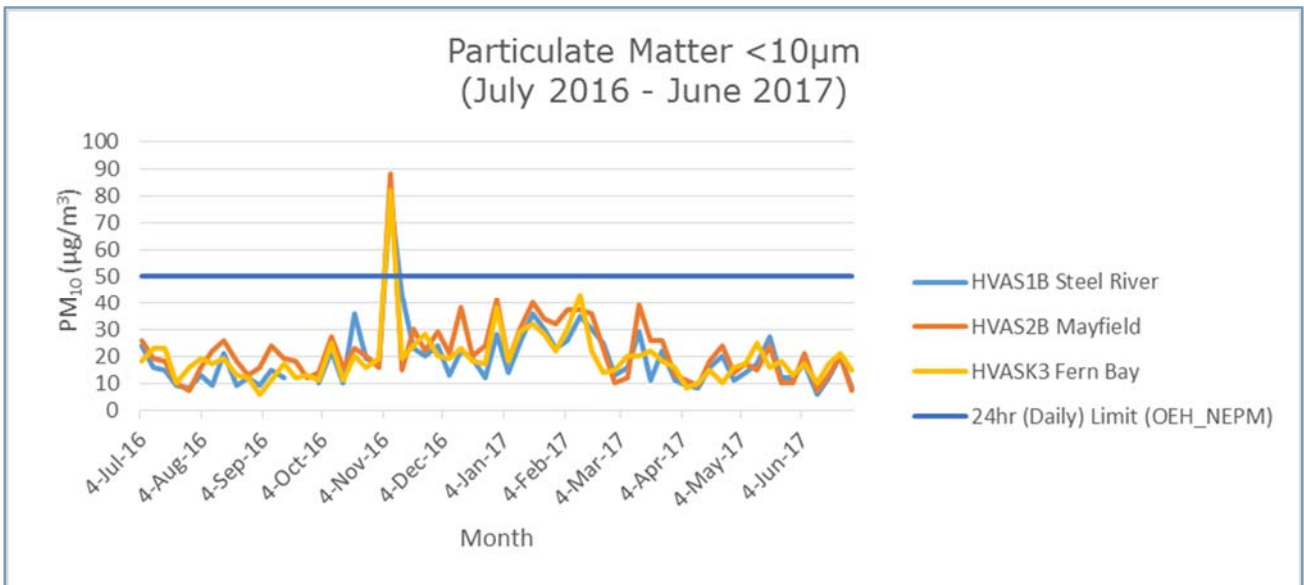


Figure 16: Particulate Matter <10 µm (PM₁₀)

Annual average TSP and PM₁₀ concentrations are included in **Table 4.4**.

Table 4.4: Annual Average TSP and PM ₁₀ Concentrations (µg/m ³)						
Annual Average July 2016 – June 2017	HVAS1 Steel River	HVAS2 Mayfield	HVAS-K2 Fern Bay	HVAS-K3 Fern Bay	HVAS-K4 Fern Bay	HVAS-C1 Stockton
TSP average criteria (NSW DEC, 2005)			90			
TSP	43	45	38	-	32	50
PM10 annual average criteria (NEPM 2015)			25			
PM ₁₀	19	22	-	20	-	-

Cells with "-" have no TSP or PM₁₀ concentration results because monitoring was not required at these locations.

The annual average TSP concentrations for the five monitoring locations were below the NHMRC Annual Average Limit of 90 µg/m³, as shown in **Table 4.4**. Daily TSP concentrations exceeded the NHMRC Annual Average Limit of 90 µg/m³ on the following occasions:

- HVAS1: 20 October 2016, 13 November 2016 and 18 January 2017.
- HVAS2 and HVASCI: 13 November 2016 and 18 January 2017.
- HVAS-K2: 13 November 2016.

The average annual PM₁₀ concentrations for the three monitoring locations were below the NEPM criteria. Daily concentrations of PM₁₀ were below the NEPM criteria of 50µg/m³ with the exception of 7 November 2016 at HVAS1, HVAS2 and HVAS-K3. Meteorological conditions for this day were reviewed to assess the likelihood that NCIG had contributed to the elevated level as shown in **Table 4.5**.

Table 4.5: Daily PM ₁₀ event greater than 50µg/m ³ guideline value		
Event	Wind patterns	Comments
<p>7 November 2016</p> <p>79 µg/m³ at HVA51 Steel River Estate</p> <p>88 µg/m³ at HVA52 Mayfield</p> <p>82 µg/m³ at HVA5-K3 Fern Bay</p>	<p>Frequency of counts by wind direction (%)</p>	<p>NCIG is to the northeast of the Mayfield air quality monitor, to the east of the Steel River Estate air quality monitor and to the west of the Fern Bay monitor.</p> <p>Prevailing winds on this day were from the northwest. Therefore, activities at NCIG were unlikely to have contributed to the measured results at Mayfield and Steel River on this day.</p> <p>There was no rainfall on this day or the preceding day. Wind speeds ranged from 0.85 to 6.18 m/s. Measured PM₁₀ concentrations at Beresfield (upwind of Kooragang Island) on the day was 42.8 µg/m³ (EPA, 2017). A number of bushfires had been experienced across the region for the previous two days. These continued on the 7th, including at Cessnock, which is likely to have contributed to high particulate levels across Newcastle.</p> <p>The 24-hour average TSP concentration measured by the BAM on NCIG's eastern boundary was 148.4 µg/m³, while the 24-hour average TSP concentration measured by the western BAM (upwind of the NCIG site) was 99.3 µg/m³. Both of these values are above the NHMRC Average Annual criteria (90 µg/m³), although the NHMRC criteria is intended to apply to residential areas.</p> <p>An assessment was made of the NCIG Integrated Dust Management System on this day. All stockyard sprays were operating and the system operated as was designed and intended, confirming that the system was in compliance with EPL operating conditions (O1, O2, O3). There was also no visible dust generated on the day, confirmed through ongoing site inspections.</p> <p>Therefore:</p> <ul style="list-style-type: none"> - It is likely that bushfires have contributed to elevated PM₁₀ levels across the Newcastle area. There is the potential that NCIG activities may have also contributed to high PM₁₀ levels observed at Fern Bay, although not to the same degree. <p>Outcome: Compliance with EPL conditions, but potential contribution to elevated levels at Fern Bay</p>

In accordance with Condition 3.2 e) of PA 06_0009, NCIG utilises real-time monitoring data to inform environmental management decisions associated with the project. 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 are used to assist the management of operation to ensure compliance with project obligations.

Dust from coal handling operations was managed primarily through suitable design of plant and machinery, including enclosures and housed areas at the dump station, conveyors, transfer houses, the buffer bin and feeders throughout the site. Additional measures include operation of dust suppression and moisture addition sprays at transfer points positioned both in transfer houses and on the machines (i.e. Stacker/Reclaimers and the Ship loader). Dust suppression spray guns have also been positioned along the stockyard berms directly adjacent the coal stockpiles. These operate on an automatic sequence, which takes into account varying weather conditions and evaporation rates of water from stockpiles. The onsite weather station is also connected to the system. This system is managed in accordance with the Operations Dust and Air Quality Management Plan (ODAQMP), including programming logic known as an Integrated Dust Management System.

Stockpiling procedures were changed during the 2015-16 reporting period to improve efficiency and reduce dust generation. Initial stacking operations for each product is conducted at 12m to complete stockpile footprint. Subsequent stacking then conducted at 24m. This change results in a lower stockpile height for a significant period, which results in a reduction in dust emissions (as PM₁₀) due to lower wind speeds.

The Newcastle Air Quality Monitoring Network was commissioned by the Office of Environment and Heritage (OEH) during the 2015-16 reporting period, including real-time air quality measurements at Mayfield, Stockton, Carrington and Newcastle. The network is collectively funded by industrial Environment Protection Licence holders operating in the Newcastle area. This includes measurements of PM₁₀, PM_{2.5} and other industrial air pollutants. NCIG regularly reviews results from the monitoring network, particularly during adverse weather conditions.

4.2.3 Reportable Incidents

On 18 January 2017 EPA contacted NCIG regarding a spike in dust concentrations at the Stockton monitor of the Newcastle Air Quality Monitoring Network (NAQMN). NCIG responded confirming that the NCIG Integrated Dust Management System was operating as intended, with stockyard sprays utilised throughout the day. The EPA recognised in their response

4.2.4 Further Improvements

A review of other dust management technologies and controls will be completed during the next reporting period.

4.3 Water Quality

4.3.1 Environmental Management

In accordance with Condition 7.6 c), Schedule 2 of PA 06_0009, an Operations Water Management Plan (OWMP) was developed which defines the surface water, stormwater and groundwater controls on the Site during operation. The OWMP includes specific measures designed to avoid sediment-laden, coal-laden or hydrocarbon-impacted surface water from entering Deep Pond, wetland areas or the Hunter River. The OWMP also includes a monitoring programme of surface water utilised on and around the Site. The OWMP identifies water management infrastructure and water requirements for activities such as dust suppression and plant washdown. A site water balance is included, which accounts for water captured on site through rainfall and volumes of water that may be required from the local potable water system.

The OWMP identifies that surface water runoff from disturbance areas during construction and operation of the Project could potentially contain sediments, soluble salts, fuels, oils, grease and

other contaminants, in particular coal residue. The potential surface water quality impacts that relate to these contaminants from each area of the Project site are summarised in Error! Reference source not found..

Table 4.6: Potential Surface Water Quality Impacts		
Project Site	Potential Impact Scenarios	Potential Contaminant
Rail infrastructure Corridor	Uncontrolled drainage of sediment laden runoff to downstream waterbodies within the Kooragang Island Waste Emplacement Facility (KIWEF) during construction of rail embankments.	Sediments, soluble salts, heavy metals, organic contaminants, fuels, oils and grease.
	Uncontrolled drainage of runoff from access roads and construction areas to downstream waterbodies within the KIWEF.	
	Uncontrolled drainage of runoff from exposed soils within the existing KIWEF to downstream waterbodies.	
	Potential erosion and sedimentation resulting from runoff from the rail corridor and associated drainage system.	
	Release/spill into downstream waterbodies.	Coal, diesel, lubricants and hydrocarbons.
Coal Storage Area	Uncontrolled drainage to downstream waterbodies during construction of the coal storage area.	Sediments, soluble salts, heavy metals, organic contaminants, fuels, oils, lubricants and low pH water.
	Uncontrolled drainage of runoff from access roads and construction areas to downstream waterbodies.	
	Spillage/overflow of site water to downstream waterbodies.	
	Release/spill into downstream waterbodies due to rupture of fuel tank (diesel/petrol).	Sediments, coal, diesel, lubricants and hydrocarbons.
Wharf Facilities and Ship Loader Area	Uncontrolled drainage of sediment laden runoff to the south arm of the Hunter River during construction of the berths and wharf structure,	Sediments, soluble salts, fuels, oils and grease.

	excavation on or near the banks of the South Arm of the Hunter River and during piling operations.	
	Uncontrolled drainage of runoff to the south arm of the Hunter River from access roads and wharf construction areas including excavation on or near the banks of the South Arm of the of the Hunter River.	
	Release/spill into South Arm of the Hunter River.	Sediments, coal, diesel, lubricants, hydrocarbons.

This identification of surface water flows was utilised to develop the monitoring programme defined in the OWMP which aim to ensure adjacent water bodies are not impacted by NCIG activities. The OWMP was approved by the Department of Planning (now NSW Department of Planning and Environment) as part of the Operations Environmental Management Plan (OEMP) respectively.

The surface water management strategies, as detailed in the OEMP, are:

- the separation of surface water runoff generated from within the active CET and Project construction areas from that generated from surrounding areas;
- containment and reuse of water onsite;
- the implementation of adequate water management controls to minimise the potential for impacts to off-site water resources such as adjacent wetland areas, Deep Pond and the Hunter River (**Figure 6**).

The management of erosion and sedimentation is outlined in Section 4.5.

4.3.2 Environmental Performance

Table 4.7 outlines the monitoring locations, frequency of monitoring and monitoring parameters for the Project in accordance with the OEMP and OWMP. These monitoring elements form the Surface Water Monitoring Program for the Project.

Monitoring Locations	Frequency	Parameters	Units	Required Limit of Reporting
SW1-a, SW1-b, SW1-c, SW1-d (operational sites) SW2, SW3 (reference sites)	Monthly	<ul style="list-style-type: none"> • pH • Electrical conductivity (EC) • Total Dissolved Solids (TDS) • Turbidity • Dissolved Oxygen (DO) • Temperature • Reduction/ oxidation potential (Redox) 	<p>-</p> <p>µS/cm</p> <p>mg/L</p> <p>NTU</p> <p>% and mg/L</p> <p>°C</p> <p>mV</p>	<p>0.1</p> <p>10</p> <p>Not specified</p> <p>10</p> <p>1</p> <p>Not specified</p> <p>Not specified</p>

between sites. Turbidity values were variable across all sites, which is likely due to discrete weather events (i.e. rainfall) and the settlement process within onsite ponds.

Biannual surface water sampling was completed by RCA in December 2016 and June 2017, with 10 surface water samples collected for analysis and comparison of the results to the trigger levels adopted in the Surface Water Monitoring Plan. The Surface Water Monitoring Program was originally developed in 2012 as an outcome of the Independent Environmental Audit (IEA), as a precautionary measure to assess potential pollutants from the NCIG terminal, that were not investigated as part of monthly water quality monitoring measurements. Surface water samples were collected from operational locations, including the Trade Waste Pond, Wharf Sump, Hunter River Wharf, Rail Settling Basin (WT01) and Clear Water Pond; and from reference locations, including Deep Pond, Delta Pond, Pond I, Black Swan Pond and the Hunter River and compared to trigger values that were either site-specific trigger values or ANZECC triggers for protection of 95% Aquatic Species. Concentrations of TRH, PAHs, nitrate, ammonia and some heavy metals were below the trigger values (where available). Concentrations of phosphorous exceeded the marine trigger value at the majority of sampling locations, including the Hunter River (reference site). Concentrations of various metals, including aluminium, boron, copper, manganese, iron, molybdenum, nickel and zinc exceeded the trigger values (where available) at the Hunter River Wharf, Wharf Sump, Trade Waste Pond, Rail Settling Basin, Clearwater Pond (operational sites) and at Black Swan Pond, Delta Pond, Deep Pond, Pond I and the Hunter River (reference sites).

In accordance with the Surface Water Monitoring Program, NCIG commissioned a review of the surface water monitoring plan, which was completed by Ramboll Environ in August 2017. The 2017 review followed on from a previous review completed in 2016. The 2017 review included data screening of water quality data from June and December 2016 to remove parameters with insufficient data (>60% non-detects), comparison of surface water quality against established (default) water quality triggers and calculation of site-specific trigger values for parameters that exceeded ANZECC (2000) 95% freshwater trigger values (aluminium, boron, zinc, total phosphorous, electrical conductivity, dissolved oxygen, pH and turbidity). Median concentrations of each parameter were then compared to the site-specific trigger values and a trend analysis of the Hunter River reference location completed. The surface water monitoring review recommended continuation of the six-monthly sampling regime to provide early warning of changing conditions and continued monitoring of aluminium, boron, zinc, total phosphorous, electrical conductivity, dissolved oxygen, pH and turbidity for at least another year to expand the database and strengthen reliability of the site-specific trigger values.

NCIG commissioned a review of the site water balance, surface water reuse efficiency and analysis of stormwater pond expansion, which was completed by AK Environmental in July 2017. The site water balance was developed for the period 19 May 2012 to 6 May 2017 and identified that the annual rate of captured stormwater reuse is 536 ML/year, compared to an average 502 ML/year of imported potable supply. AK Environmental identified two pathways via which surface water reuse efficiency is lost, evaporation and stormwater lost to the Hunter River during an overtopping event. Three overtopping events have occurred since improvements were made to Clearwater Pond by installing 2.73 mAHD hungry boards (weir walls) in January 2014. These overtopping events are associated with single large storm events, during which Clearwater Pond capacity rises rapidly from a 0% capacity base level. Evaporation losses are already minimised from Clearwater Pond and the Secondary Settling Pond by pumping of these ponds to draw down and reuse captured stormwater. The hungry boards (weir walls) at Clearwater Pond are to be raised to 2.83 mAHD to increase pond system capacity by approximately 5.3 ML. AK Environmental assessed the overtopping frequency of Clearwater Pond by re-scaling capacity to 100% at 2.83 mAHD and identified that the additional capacity would have significantly reduced the volume of the January 2016 discharge event but would have only retained a minor portion of the much larger April 2015 event. AK Environmental

identified that increasing the height of the hungry boards may provide an additional 7.6 ML/year of stormwater for onsite use.

4.3.3 Reportable Incidents

There were no reportable incidents during the reporting period.

A discharge event occurred on 11 June 2017, with discharge water quality monitored at monitoring point 34. One water quality sample was collected and analysed for pH, total suspended solids and oil and grease. The results are provided in **Table 4.8**.

Pollutant	Unit of Measure	Recorded Value
Oil and Grease	mg/L	<5
pH	pH units	8.25
Total Suspended Solids	mg/L	42

4.3.4 Further Improvements

NCIG are looking to make additional improvements to manage sediment within the NCIG Surface Water Management System. A project is planned for 2017/2018 to identify ways to improve the management of sediment across site.

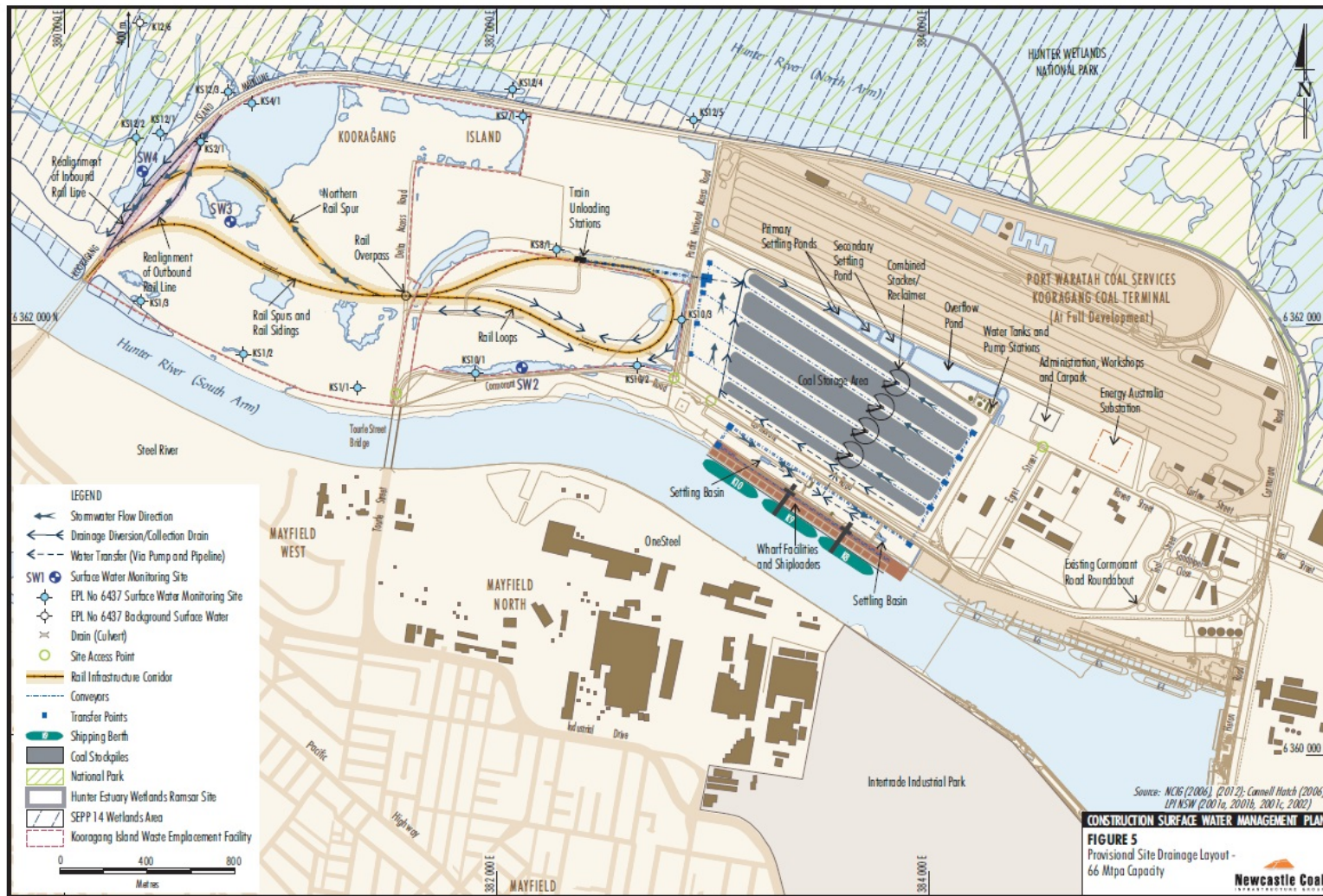


Figure 17: Permanent site drainage layout

		<ul style="list-style-type: none"> Total Recoverable Hydrocarbons C10-C14 Total Recoverable Hydrocarbons C15-C28 Total Recoverable Hydrocarbons C29-C36 Benzene Toluene Ethyl benzene m+p-Xylene o-Xylene Total Polyaromatic Hydrocarbons (PAHs) Phenol Ammonia Cyanide (free) Cyanide (total) Potassium Sodium 	<p>µg/L</p> <p>µg/L</p> <p>µg/L</p> <p>µg/L</p> <p>µg/L</p> <p>µg/L</p> <p>µg/L</p> <p>µg/L</p> <p>µg/L</p> <p>µg/L</p> <p>µg/L</p> <p>µg/L</p> <p>µg/L</p> <p>µg/L</p> <p>mg/L</p> <p>mg/L</p>
--	--	--	---

¹The location of monitoring sites is shown on Figure .

A summary of the groundwater monitoring results recorded during the reporting period is provided in **Appendix 4** and **Table 4.10**.

Table 4.10: Summary of Groundwater Monitoring Results (EPL)				
Monitoring Sites	Dates of Sampling	Exceedances of EPL Requirements?	Exceedances of CEMP/ OWMP	Comments
GW1 (Monitoring Point 1)	5/12/16 6/6/17	N/A	Mn, Zn	Manganese and zinc are two of nine priority analytes. On-going monitoring recommended.
K9/3N (Monitoring Point 20)	5/12/16 6/6/17	No	Mn, Zn	
K9/3S (Monitoring Point 21)	5/12/16 6/6/17	No	Mn, Zn	
K11/1 (Monitoring Point 22)	5/12/16 6/6/17	No	pH, Mn, Zn	
K11/1S (Monitoring Point 23)	5/12/16 6/6/17	No	Mn, Zn	
K11/3E, K11/3W, K11/2E, K11/2W, K9/4E, K9/4W, K9/2E, K9/2W, K10/4W, DM10 (Monitoring Points 24-33).	Not required	N/A	N/A	Not required to be sampled as the triggers for further evaluation were not met (Section E1.1 of EPL 12693).

An assessment of the monitoring records found the following:

- that the trigger for further evaluation (as outlined in Section E1.1 of EPL 13693) were not met at any of the required monitoring locations;
- that exceedances of criteria outlined in the OWMP (ANZECC (2000) trigger level for the protection of 95% of marine water species) occurred at Monitoring Points 1, 20, 21, 22 and 23, for manganese and zinc;
- The manganese and zinc exceedances are similar for the previous reporting periods.

4.4.3 Reportable Incidents

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

4.4.4 Further Improvements

It is intended that proposed variations to the EPL groundwater monitoring conditions will be accepted by the EPA in 2017/2018

4.5 Erosion and Sediment Control

4.5.1 Environmental Management

In accordance with Condition 2.43, Schedule 2 of the PA 06_0009 NCIG took all reasonable measures to prevent soil erosion and the discharge of sediments and pollutants from the site during construction activities.

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.

All erosion, sediment and pollution control infrastructure is being maintained on the Site at or above design capacity during construction of the Project and will continue to be until such time as all ground disturbed by the works has been stabilised and rehabilitated so that it no longer acts as a source of sediment, in accordance with Condition 2.44, Schedule 2 of PA 06_0009.

All stockpiled construction materials have been managed to minimise erosion or dispersal of the materials in accordance with Condition 2.45 of PA 06_0009. All fill/preload material brought to the Project site is managed in a manner that minimises erosion and dispersal of those materials to the downstream waters (e.g. south arm of the Hunter River).

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 Project 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 Project are documented in the approved Construction Surface Water Management Plan (CSWMP) and the OWMP.

4.5.2 Environmental Performance

Table 4.11 outlines the monitoring locations, erosion and sediment control parameters recorded, frequency of monitoring and criteria for the Project in accordance with the CEMP. While construction of the NCIG Project was effectively completed prior to the reporting period, a number of erosion and sediment controls remained in-situ during the period until stabilisation of surfaces was achieved.

Table 4.11: Summary of the Erosion and Sediment Control Monitoring Program

Monitoring Parameter	Monitoring Sites	Frequency	Criteria
Structural stability and effectiveness in controlling sediment migration.	Drainage, erosion and sediment control infrastructure	Monthly and following significant rainfall events (i.e. greater than 20mm in 24 hours)	N/A

The management of erosion and sedimentation for the NCIG Project is detailed by the Erosion and Sediment Control Plan (ESCP), part of the Operations Water Management Plan. Activities that have the potential to cause or increase soil erosion at the Site have been identified and are primarily due to exposure of soils during construction activities.

The general erosion and sediment control principles adopted take into account the general recommendations for site drainage works presented in *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom, 2004) which underpin the goal of protecting adjacent wetland areas, Deep Pond and the Hunter River. These principles involve:

- Minimising surface disturbance and restricting access to undisturbed areas.
- Separation of runoff from disturbed and undisturbed areas where practicable.
- Construction of surface drains to facilitate the efficient transport of surface runoff or utilisation of existing stormwater systems.
- Construction of the site drainage network including perimeter bunds, internal bunds, primary settling ponds and hydraulically controlled discharge structures.
- Construction of primary and secondary settling ponds, site water pond and sediment dams to contain runoff up to specified design criterion.
- Installation of a silt curtain in the south arm of the Hunter River local to the disturbance area during construction of the shipping berth batters, wharf structure and during piling operations (in the River) that may create excessive material disturbance.
- Installation of silt curtains in Swan Pond and Deep Pond during construction of the Rail Flyover to contain mobilised sediments generated from ground disturbance.

In ensuring the erosion and sediment control principles are adhered to, development activities on the Project have been typically undertaken in the following order:

- Construction of sediment fences (down slope of disturbance areas) where required.
- Installation of silt curtains in identified water bodies, including the Hunter River, where required.

General construction works are only commenced once erosion and sediment control measures are in place. These measures may include:

- Construction of drainage diversions (typically upslope of disturbance areas) – these were only constructed where they significantly reduced the runoff catchment of disturbance areas and connected to the site drainage network where practicable.
- Construction of the primary and secondary settling ponds and a clearwater pond.
- Construction of collection drains (down slope of disturbance areas) where required to convey runoff to the site drainage network (including primary and secondary settling ponds and a site water pond).

ESCPs detailing specific erosion and sediment control measures, were developed in a progressive manner prior to the development of each Project component requiring land disturbance. This was undertaken through a risk assessment process associated with the individual task proposed and are modified as required to ensure that the goal of protecting water bodies from erosion and sedimentation is achieved.

Temporary erosion and sediment controls (e.g. silt fences and sediment control structures) were installed prior to the commencement of construction activities on the Project site. Routine (i.e. monthly) inspections of sediment control structures, as well as inspections following significant rainfall events (e.g. 20 millimetres (mm) or more in a 24 hour period), are conducted by NCIG personnel. During these inspections, sediment control structures were inspected for capacity,

structural integrity and effectiveness. Any deficiencies identified by these inspections are assessed, prioritised and rectified in the appropriate timeframe.

A network of permanent stormwater structures has been constructed to manage runoff around the site. All long-term site water management structures are lined with low permeability materials (e.g. compacted clay) to minimise the potential for leakage. Water management structures are designed with sufficient capacity for a 1 in 100 year average recurrence interval (ARI) rainfall event.

4.5.3 Reportable Incidents

No environmental incidents or complaints relating to erosion or sediment control were made during the reporting period.

4.5.4 Further Improvements

No scheduled improvement to erosion and sediment control is required for the next period as the construction of the permanent surface water management infrastructure on the terminal site was completed during this reporting period.

4.6 Land Contamination

4.6.1 Environmental Management

In accordance with Condition 2.53, Schedule 2 of PA 06_0009 NCIG engaged an appropriately qualified person to audit construction of the rail infrastructure over land used as part of the KIWEF against the commitments contained in the NCIG Project Environmental Assessment and supporting documents. These works were completed during the 2015/16 reporting period and were reported in the 2016 AEMR (Ramboll Environ May 2017).

Prior to any excavation on the Project, a comprehensive surface and sub-surface soil sampling and analysis programme was undertaken in order to characterise the material to be excavated. The sampling programme was undertaken in accordance with the NSW EPA (2004b) *Guidelines for the Assessment, Classification and Management of Liquid and Non-Liquid Waste*. The aim of the programme was to identify the risk associated with contamination across the stockyard and rail areas and to determine the suitability of the site for the development of the NCIG project. The findings of this process were that there existed a manageable risk associated with contamination and that the site was suitable for the proposed development.

In accordance with Condition 2.54, Schedule 2 of PA 06_0009 NCIG did not direct any contaminated materials removed from the site to a waste management facility that was not lawfully permitted to accept the materials.

4.6.2 Environmental Performance

In accordance with Condition 2.53, Schedule 2 of the PA 06_0009 a Summary Report was provided by Ramboll Environ in August 2015, who audited the capping of the waste emplacement area during the flyover construction between October 2013 and June 2015. Specifically, Ramboll Environ was engaged to audit:

- Where rail loop modification works cross/ disturb landfill capping, the capping is established to the required specification, as presented below; and
- Where material is imported to site for use as capping materials, such material complies with the environmental specification.

The capping at the former waste emplacement area comprises:

- A seal bearing surface (subgrade);
- A 0.5m thick sealing layer with an effective permeability of not greater than $1 \times 10^{-8} \text{m/s}$; and
- A drainage system along the rail corridor to maximise rainfall runoff and minimise infiltration.

The Summary Report concluded that Auditor review of compaction and survey records for all areas indicated that capping complied with Condition 2.53 of PA 06_0009 and that the consistent, ongoing management and record keeping, including the inspection/ test plan protocols and hold point records, undertaken by the main contractor, Aurecon-Hatch, throughout the project have given additional confidence that capping works have been undertaken in compliance with the Approval conditions.

4.6.3 Reportable Incidents

No environmental incidents or complaints relating to land contamination were made during the reporting period.

4.6.4 Further Improvements

There are no further improvements required for contamination management, as construction activities have ended.

4.7 Noise and Vibration

4.7.1 Environmental Management

In accordance with Condition 2.9, Schedule 2 of PA 06_0009 NCIG and its contractors minimised noise emissions from plant and equipment operated on the Project site as outlined in the *NSW Industrial Noise Policy* (EPA, 2000).

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 4.13** below, 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 $L_{Aeq(15 \text{ minute})}$ night noise limits.
- Measured at one metre from the dwelling façade to determine compliance with $L_{A1(1 \text{ minute})}$ noise limits.
- Subject to the modification factors provided in Section 4 of the New South Wales 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 noise performance criteria established. This includes 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 Operations Noise Management Plan (ONMP).

4.7.2 Environmental Performance

Table 4.12 outlines the monitoring locations, noise and vibration monitoring parameters recorded, frequency of monitoring and noise and vibration criteria for the Project in accordance with the ONMP.

Table 4.12: Summary of the Noise and Vibration Monitoring Programme

Monitoring Parameter	Monitoring Sites	Frequency	Criteria
Attended and unattended noise monitoring	N1, N3, N5, N13 and N14 ¹ .	Monthly for the first 3 months then quarterly.	See below.
Unattended continuous noise monitoring.	Selected locations.	Minimum period of one week per quarter.	See below.
Attended noise monitoring	All static and mobile elements of terminal operations.	6-monthly	See ONMP.

¹ The location of monitoring sites is shown on Figure 6.

The noise impact assessment criteria as defined by the Project approval and EPL12693 are provided in **Table 4.13** and **Table 4.14**

A Noise Audit Report was completed in October 2013 to confirm cumulative Stage 1, Stage 2AA and Stage 2F noise performance of the NCET as per Conditions 3.6 and 3.7 of PA 06_0009 Schedule 2.

Noise and vibration monitoring was undertaken by specialist acoustic consultants on a six monthly basis during the reporting period.

Table 4.13 Residential Noise Impact Assessment Criteria

Location	Site ID	Day, Evening Night	Night	
		At all times	10.00 pm to 7.00am Monday to Saturday	10.00pm to 8.00 on Sundays and Public Holidays
		L _{Aeq} (15 minute)	L _{Aeq} (night)	L _{A1} (1 minute)
Fern Bay West	N1	41	37	57
Fern Bay East	N17	39	36	55
Stockton West	N3	41	37	57
Stockton East	N16	38	35	56
Mayfield West	N5	45	40	55
Mayfield	N9	44	39	62
Carrington	N15	36	33	52

The maximum allowable noise conditions apply under:

- a) wind speeds of up to 3 m/s at 10 metres above ground level
- b) temperature inversion conditions of up to 3 degrees (°C) pert 10 metres and 2 m/s at 10 metres above ground level.

Table 4.14 Industrial Noise Impact Assessment Criteria

Non-residential Location	Land use	Intrusive			Acceptable Amenity			Maximum Amenity
		L _{Aeq} (15 minute)			L _{Aeq} (period) ¹			L _{Aeq} (9 hour)
		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.

The monitoring undertaken principally consisted of:

- Attended noise monitoring – operator attended noise survey was conducted at each noise logger location to assist in defining noise sources and the character of noise in the area and therefore to qualify unattended noise logging results. These measurements were conducted over 15 minute periods using a Bruel & Kjaer Type 2270 (S/N 3003729) and Bruel and Kjaer Type 2250L (S/N 3004635) Type 1 integrating sound level meters.
- Vibration monitoring – In accordance with the CNMP, vibration monitoring was conducted during construction piling activities within 180m of adjacent industrial receivers (i.e. Blue Circle Southern). As mentioned, this did not take place during the monitoring period.

During the reporting period, off-site noise and on-site sound power monitoring was undertaken and reported biannually, with reports for the period ending December 2016 and June 2017. These reports concluded that off-site noise monitoring indicated compliance was achieved at both selected residential and industrial locations under prevailing conditions.

NCIG conducted a noise measurement assessment of Buffer Bin BN01 at NCET during the reporting period. Noise mitigation measures were implemented on the bin in response to an increase in noise levels which occurred as an unintended result of modifications to the inlet chute on the bin. The noise measurement assessment was completed by SLR to assess the noise reductions afforded by the noise mitigation measures. The assessment included analysis of sound power levels pre- and post-mitigation, with a 14 dB decrease in the maximum south power level, a 3 dB decrease in the average operating noise level and an 11 dB decrease in the instantaneous noise level from the bin. The results of this assessment were used to update the NCET computer noise model and predict offsite noise levels. SLR concluded that with the applied mitigation measures in place, the maximum predicted offsite noise levels from the NCET site are predicted to remain compliant with the NCET 66 Mtpa PA Intrusive Noise Criteria at all receiver locations.

4.7.3 Reportable Incidents

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

4.7.4 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.

4.8 Heritage

4.8.1 Environmental Management

The now OEH advised that as the Project construction site has been the subject of extensive disturbance over a period of more than 50 years, it considers that no Aboriginal heritage objects of significance will be present (DEC, pers. comm. 15 February 2007).

Notwithstanding, the management of items of Aboriginal cultural heritage significance during construction of the Project incorporated the following elements:

- During induction training, NCIG personnel were advised of their responsibility to advise management if they uncover any item that could be of Aboriginal heritage significance.
- If potential archaeological material is identified, construction activities proximal to the potential archaeological material will cease and OEH's North East Branch - Environment Protection and Regulation Division, Regional Archaeologist will be contacted to determine appropriate management requirements.
- If items of Aboriginal cultural heritage significance are salvaged on-site, they will be stored in a keeping place on-site for the duration of the Project.

- At the cessation of the Project, if any salvaged Aboriginal objects are stored on-site their ongoing management will be determined in consultation with the Aboriginal community and the OEH.

4.8.2 Environmental Performance

During the reporting period induction training was attended by all NCIG personnel. This training included information relating to aboriginal heritage and the potential identification of items of archaeological significance.

During the reporting period there were no items of potential Aboriginal cultural heritage significance identified.

4.8.3 Reportable Incidents

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

4.8.4 Further Improvements

No improvement to heritage is required for the next period.

4.9 Ecology

4.9.1 Environmental Management

In accordance with Conditions 2.16 and 2.19, Schedule 2 of PA 06_0009 NCIG employed two qualified ecologists (Dr David Goldney and Dr Arthur White), approved by the Director-General, to undertake a pre-construction survey of areas affected by construction works for the presence of *Litoria aurea* (the Green and Golden Bell Frog). These ecologists also provided advice on the mitigation and management of impacts to listed threatened species that may be affected by the NCIG Project works.

While Green and Golden Bell Frog individuals were not identified during the pre-construction survey, previous surveys have identified the presence of the species on the Project site. Therefore a management plan for the relocation of Green and Golden Bell Frog individuals was prepared in accordance with Condition 2.16, Schedule 2 of PA 06_0009. The Green and Golden Bell Frog Management Plan (GGBFMP) was developed in consultation with DECC (now OEH) and the Regional Land Management Corporation (now HDC). This plan has now been incorporated into the Ecological and Land Management Plan.

In accordance with Condition 2.17, Schedule 2 of PA 06_0009 NCIG has designed and constructed relevant rail infrastructure associated with the Project to include culverts, underpasses or other similar measures to permit the movement of *Litoria aurea* and other amphibian species under the NCIG rail infrastructure. The culverts and underpasses were installed to include suitable habitat for the Green and Golden Bell Frogs and to provide protection from predators in accordance with guidance provided by Dr Arthur White.

In accordance with Condition 2.18, Schedule 2 of PA 06_0009 all employees and contractors involved in construction of the Project are trained in site hygiene management in accordance with *Hygiene Protocol for the Control of Disease in Frogs* (NPWS, 2001) prior to the commencement of work.

A Vegetation Clearance Protocol (VCP) was also prepared to satisfy those commitments of the Project Environmental Assessment (EA) that relate to vegetation clearance during construction of the Project. This protocol has now been incorporated into the Ecological and Land Management Plan for any maintenance or construction works that may disturb native vegetation of important habitat.

4.9.2 Environmental Performance

The Green and Golden Bell Frog *Litoria aurea* is listed as Endangered under the *Threatened Species Conservation Act, 1995* (TSC Act) and Vulnerable under the EPBC Act. The Green and Golden Bell Frog is estimated to have disappeared from 90% of its former range within NSW.

Known and potential Green and Golden Bell Frog habitat is located across the Project site and surrounds. Disturbance to Green and Golden Bell Frog habitat occurred as a result of construction activities which primarily involved completely infilling Big Pond and partial disturbance of Ponds H, K and Q. Most of the known and potential Green and Golden Bell Frog habitat recorded across the Project site and surrounds (i.e. Ponds A, B, C, D, E, F, G, I, J, L, O, T, U, V, AA, AC, AD) has not been directly disturbed by Project activities.

In order to minimise Project-related impacts on the Green and Golden Bell Frog the following management procedures were implemented in accordance with the GGBFMP:

- environmental induction training;
- site hygiene management;
- delineation of disturbance areas;
- pre-clearance surveys;
- Green and Golden Bell Frog relocation procedures; and
- construction works procedures.

In June 2017, a Memorandum of Understanding (MOU) on the Green and Golden Bell Frog on Kooragang Island was executed between the Office of Environment and Heritage (NSW) and NCIG, PWCS, HDC, BHP Billiton and University of Newcastle. 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 Office of Environment and Heritage for conservation activities to protect the Green and Golden Bell Frog. The MOU was developed to assist with data sharing from Green and Golden Bell Frog population and habitat monitoring programs completed by University of Newcastle for different stakeholders.

Monitoring and characterisation of the Green and Golden Bell Frog population on Kooragang Island, in and surrounding the industrial part of the island has been completed for the seventh year by University of Newcastle. This work is being co-funded by NCIG, PWCS and HDC. Monitoring continued throughout the summer season and the annual report was finalised in September 2017, including population estimates for the island. A copy of the report is included in **Appendix 6**. The population estimate for this monitoring excludes animals in the NCIG and BHPB Compensatory Habitat sites. Monitoring of the Green and Golden Bell Frog was conducted in areas adjacent to the NCIG Project site, particularly areas surrounding the NCIG Rail Facility, as shown in **Figure 18**.

The objectives of the monitoring on Kooragang Island are to:

- Calculate a robust valuation of total Green and Golden Bell Frog 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 Green and Golden Bell Frog population, including assessing where individuals are concentrated and evidence of movement between wetlands and across infrastructure barriers.

Kooragang Island Wetlands

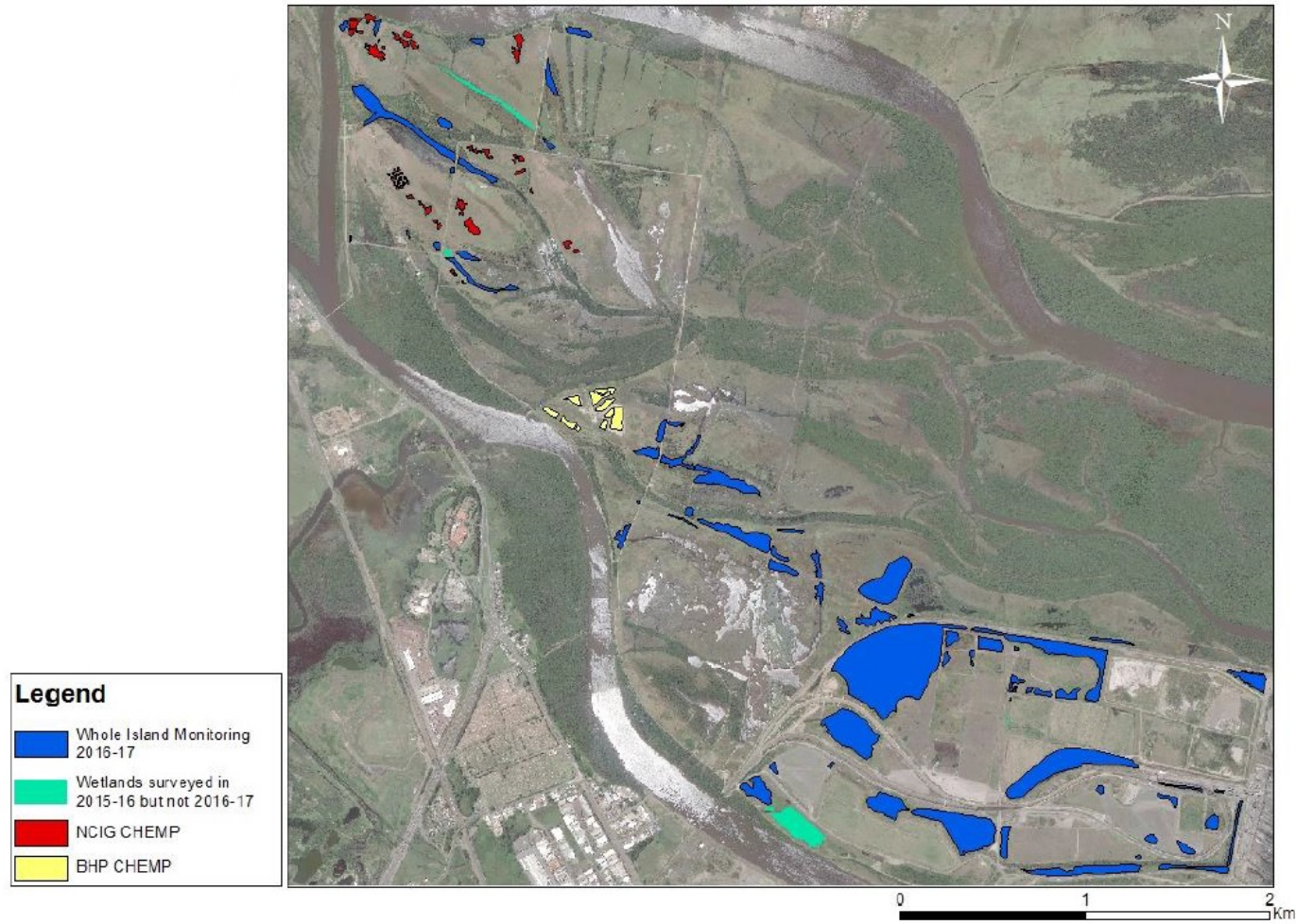


Figure 18: Green and Golden Bell Frog Surveyed Areas

Two methods were used to estimate the population per surveyed pond, namely Visual Encounter Surveys (VES) and Capture-Mark-Recapture (CMR) Surveys. 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 2-6 people. Models for population estimates were generated for each surveyed pond using established statistical designs and computer-based modelling software (eg. MARK). These estimates were correlated with results of visual encounter surveys, using a number of assumptions and limiting factors, to generate population estimates for remaining ponds. A total of 73 wetlands were surveyed during the 2016/2017 breeding season, including 17 in the Northwest region of the island, 23 in the Central region and 38 in the Southern (Industrial Zone) region. Three rounds of surveys were completed, Round 1 in late-November to December 2016, Round 2 in January to early February 2017 and Round 3 in February to late-March 2017.

A summary of the results from the 2016/2017 surveys are as follows:

- Population estimates of mid- to large-sized juvenile and adult bell frogs varied between survey rounds, from between 1700 and 3900 bell frogs in Round 1 to between 1280 and 3280 bell frogs in Round 3.
- The population range estimate is consistent with population range estimates from 2012 to 2016, indicating a stable population on Kooragang Island.
- Many wetlands on Kooragang Island failed to recharge due to low winter rainfall in 2016 and low rainfall over summer 2017 led to 33 of the surveyed wetlands being dry by the end of summer.
- Due to the low rainfall and drying of wetlands, bell frogs were identified at a small number of wetlands than usual, with higher numbers of frogs in the wetlands that were recharged. More than 80% of the bell frogs were identified in the southern part of Kooragang Island.
- Drying of the wetlands reduced the distribution of *Gambusia holbrooki*, an invasive fish species that prey on amphibian tadpoles and eggs.
- Breeding events were recorded at eight wetlands via the detection of metamorphs and/ or tadpoles, with sizable breeding events detected at ponds K104, K111 and K114.
- Longitudinal data from 2012 to 2017 of individuals recaptured over multiple seasons indicates that few frogs survive into their 3rd year and almost none into their 4th year.

Figure 19 below shows summary statistics from 2010 to 2016, including population size, number of ponds surveyed, sex ratio, age structure, breeding sites, calling sites and ponds with the most bell frog individuals.

Survey	KI Pop. Size	No. of Ponds	Sex Ratio (M/F)	Age Struct. (A/J)	Breeding Sites	Calling Sites	Most Ind.
2010/11	1153	23 (16)	1.25/1	1/3	10	5	K22
2011/12	928	55 (25)	1/1.09	1/1	unk.	11	K22
2012/13	834	55 (20)	1.4/1	4.7/1	5	11	K22/23
2013/14	1238	55 (25)	unk.	unk.	5	9	K22
2014/15	2964	58 (28)	1.43/1	1/1.3	6	4	K23
2015/16	1432	78 (42)	7.4/1	1.4/1	7	14	K104
	* Peak population size (best estimate for month with greatest no. of individuals).	* Total no. of wetlands surveyed. (Total wetlands with <i>L. Aurea</i> present in brackets)			*Number of wetlands with amplexus, tadpoles or recent metamorphs.	*Number of wetlands with calling males.	*Wetland with most captured individuals.

Figure 19: Summary Statistics of Green and Golden Bell Frog Populations Estimates from 2011 to 2017

A monitoring programme was also conducted during the reporting period to survey the utilisation of Deep Pond, adjacent to the NCIG rail infrastructure area, by bird species with the primary focus on shorebirds. This Avifauna Monitoring Programme was undertaken by the Hunter Bird Observers Club and the resulting information was provided to NCIG by way of agreement.

Prior to the construction of the rail flyover, one survey was completed for Deep Pond. The rail flyover, completed in August 2015, now separates Deep Pond into Deep Pond North and Deep Pond South. As such, from 2015 two monthly surveys have been completed.

The results of the monthly surveys conducted on Deep Pond North and Deep Pond South during the 2016 calendar year are illustrated by **Table 4.15** and **Table 4.16**. The aim of the monitoring programme is to identify the pattern of usage of Deep Pond North and Deep Pond South by all birds over the annual cycle and determined the extent of any potential impact by the NCIG activities on this usage.

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

- No migratory shorebird species were recorded at Deep Pond North or Deep Pond South in 2016, compared to two species in 2015, four species in 2014, eight species in the period 2011 to 2013 and seven species in the period 2008 to 2011.
- Two species of resident shorebirds were recorded at Deep Pond North and Deep Pond South in 2016 and these species, Masked Lapwing and Black-fronted Dotterel, were primarily recorded utilising open areas surrounding the ponds, not in the ponds themselves.
- The low numbers of migratory shorebirds and resident shorebirds is considered likely to be due to high water levels in Deep Pond North and Deep Pond South, resulting in lower usage.
- Numerous waterfowl such as ducks, swans and grebes and other waterbirds such as herons, egrets and ibis were recorded in 2016.
- Several species listed as Vulnerable under the Threatened Species Conservation Act 1995 were observed utilising Deep Pond North during 2016, including a White-bellied Sea Eagle, a Little Eagle and a Spotted Harrier.

Table 4.15: Avifauna 2016 Monitoring Results – Deep Pond North

Species	8/1/16	19/2/16	18/3/16	8/4/16	20/5/16	17/6/16	22/7/16	19/8/16	16/9/16	14/10/16	11/11/16	9/12/16	Total
Musk Duck <i>Biziura lobata</i>	1		1	2									4
Black Swan <i>Cygnus atratus</i>	28	25	19	17	5	13	2	45	17	11	16	62	260
Pink-eared Duck <i>Malacorhynchus membranaceus</i>			10	12	18								40
Australasian Shoveler <i>Anas rhynchos</i>	8		116	85	152	14							375
Grey Teal <i>Anas gracilis</i>				35	640							60	735
Chestnut Teal <i>Anas castanea</i>		26	25	53	294						1	34	433
Pacific Black Duck <i>Anas superciliosa</i>	5	22	26	15	28			2				4	102
Hardhead <i>Aythya australis</i>	56	56	27	40	14	1						2	196
Australasian Grebe <i>Tachybaptus novaehollandiae</i>		2	16	10	19	3	2	3					55
Hoary-headed Grebe <i>Poliiocephalus poliocephalus</i>			1	59	23	5	11						99
Little Pied Cormorant <i>Microcarbo melanoleucos</i>		1		3	1		1	2		1	2	4	15
Little Black Cormorant <i>Phalacrocorax sulcirostris</i>		3	5	10	1					1	6		26
Australian Pelican <i>Pelecanus conspicillatus</i>		6	6		7					5	6	12	42
Eastern Great Egret <i>Ardea alba</i>					1								1
Intermediate Egret <i>Ardea intermedia</i>					3								3
White-faced Heron <i>Egretta novaehollandiae</i>					2								2
Australian White Ibis <i>Threskiornis molucca</i>			3								1	20	24
Royal Spoonbill <i>Platalea regia</i>					3						2	1	6
Little Eagle <i>Hieraaetus morphnoides</i>			1										1
Whistling Kite <i>Haliastur sphenurus</i>					2								2
Swamp Harrier <i>Circus approximans</i>					2		1						3
Purple Swamphen <i>Porphyrio porphyrio</i>				3									3

Table 4.15: Avifauna 2016 Monitoring Results – Deep Pond North

Species	8/1/16	19/2/16	18/3/16	8/4/16	20/5/16	17/6/16	22/7/16	19/8/16	16/9/16	14/10/16	11/11/16	9/12/16	Total
Eurasian Coot <i>Fulica atra</i>	115	221	109	60	112	70							687
Black-fronted Dotterel <i>Elseyornis melanops</i>			2		2				1				5
Masked Lapwing <i>Vanellus miles</i>				2								2	4
Caspian Tern			1										1
Total 2016	213	362	368	406	1329	106	17	52	18	19	34	201	3,124

Table 4.6: Avifauna 2015 Monitoring Results – Deep Pond South

Species	8/1/16	19/2/16	18/3/16	8/4/16	20/5/16	17/6/16	22/7/16	19/8/16	16/9/16	14/10/16	11/11/16	9/12/16	Total
Wandering Whistling-Duck <i>Dendrocygna arcuata</i>	1												1
Musk Duck <i>Biziura lobata</i>				1									1
Black Swan <i>Cygnus atratus</i>		2	5	4	3			1		5	5		25
Pink-eared Duck <i>Malacorhynchus membranaceus</i>	2												2
Australasian Shoveler <i>Anas rhynchos</i>			3										3
Grey Teal <i>Anas gracilis</i>	2			17									19
Chestnut Teal <i>Anas castanea</i>					2						1		3
Northern Mallard <i>Anas platyrhynchos</i>			2		1								3
Pacific Black Duck <i>Anas superciliosa</i>	3	2	81	19	38					2			145
Hardhead <i>Aythya australis</i>	2		5	7	1								15
Australasian Grebe <i>Tachybaptus novaehollandiae</i>		2	14	6	11	7	9		5				54
Hoary-headed Grebe <i>Poliiocephalus poliocephalus</i>					5								5
Little Black Cormorant <i>Phalacrocorax sulcirostris</i>	1		1	3									5
Little Pied Cormorant <i>Microcarbo melanoleucos</i>		1	1	1							1		4
Australian Pelican <i>Pelecanus conspicillatus</i>				1							3	5	9
Great Egret <i>Ardea alba</i>					1						1		2
White-faced Heron <i>Egretta novaehollandiae</i>				1	1								2
Australian White Ibis <i>Threskiornis molucca</i>					2								2
Swamp Harrier <i>Circus approximans</i>					1	1						1	3
Purple Swamphen <i>Porphyrio porphyrio</i>			10	6	19			1				2	38
Eurasian Coot <i>Fulica atra</i>	60		115	153									328
Black-fronted Dotterel <i>Elsayornis melanops</i>			1										1

Table 4.6: Avifauna 2015 Monitoring Results – Deep Pond South

Species	8/1/16	19/2/16	18/3/16	8/4/16	20/5/16	17/6/16	22/7/16	19/8/16	16/9/16	14/10/16	11/11/16	9/12/16	Total
Masked Lapwing <i>Vanellus miles</i>			1										1
Whistling Kite <i>Haliastur sphenurus</i>					1								1
Total 2016	71	7	239	219	86	8	9	2	5	7	11	8	672

4.9.3 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 Compensatory Habitat and Ecological Monitoring Program (CHEMP), which details how habitat and ecological values lost as a result of the project will be off-set, and how ecological monitoring will be undertaken to inform on-going ecological management. This plan was initially submitted to DECCW (now EPA) and DoP (now NSW Planning and Environment) in 2008. Through discussions and agreed amendments, the first version of the CHEMP was approved by the then DoP on 16 November 2010.

A number of works have been undertaken in relation to the CHEMP between June 2016 and June 2017. The following points highlight the major works undertaken and milestones achieved during this reporting period.

Consultative Board –Consultative Board meetings were held on 12 December 2016 and 9 August 2017. The purpose of the Consultative Board meetings are to provide information on the Compensatory Habitat planning works completed to date and provide guidance on works to be completed, particularly in the coming 12 months. The Board consists of representatives from NSW Planning and Environment, NSW Office of Environment and Heritage (National Parks and Wildlife Service), Hunter-Central Rivers Local Land Service, the University of Newcastle, the DoPI-Approved Ecologist for the NCIG Project, Hunter Bird Observers Club (HBOC) and NCIG. At each meeting, papers have been presented on a range of topics for the consideration and discussion of Board members. The topics discussed included updates on the following:

- Compensatory habitat management;
- Compensatory habitat monitoring;
- Captive breeding and release program;
- Green and Golden Bell Frog breeding;
- Migratory shorebird habitat management;
- Migratory shorebird Habitat Monitoring.

Compensatory Habitat Management – NCIG continued monitoring and management of compensatory habitat in accordance with the approved Green and Golden Bell Frog Compensatory Habitat Management Plan. Conservation Volunteers Australia (formerly Wetland Care Australia) conducted the following work during the reporting period:

- Baiting program for foxes.
- Draining of constructed Green and Golden Bell Frog ponds that were bunded in mid-2016 to manage *Gambusia holbrooki* that have infested constructed ponds and can have an effect of bell frog breeding.

Compensatory Habitat Monitoring – The University of Newcastle completed Green and Golden Bell Frog monitoring at the compensatory habitat and former NCIG trial ponds in October 2016, February 2017 and March 2017. Monitoring involved visual encounter surveys and capture-mark-recapture surveys, which are completed at night across the seven CHEMP stages of wetlands. The survey results indicate that Bell frog distribution is highly varied across the CHEMP wetlands, with the largest number of frog captures occurring in Stage 7. No frogs were captured in Stage 2, which is inhabited by fish that may be limited the suitability of this stage for frogs. In total, 148 captures were made of 97 individual adult Bell frogs in 2016-17, compared to 32 captures of 29 individual adults in 2015-16 survey period. These surveys indicated that the population of Green and Golden Bell Frogs within the CHEMP wetlands is stable and was greater than the population of the 2015-16 sampling period.

Monitoring also identified that the summer of 2016 was wet, which resulted in overland flooding across the island. Autumn 2016 remained wet, resulting in inhabitation of large numbers of *Gambusia holbrooki* in the CHEMP wetlands. Bunded ponds were drained, as outlined above, to

remove these fish. Winter and spring of 2016 and summer of 2017 were dry and by February 2017, ephemeral wetlands in the CHEMA wetlands had dried out.

Captive Breeding and Release Program – The University of Newcastle are captively-breeding Green and Golden Bell Frogs for release into the NCIG Compensatory Habitat. Animals bred in September 2016, with the progeny being maintained at the breeding facility at the university. These animals will gradually be released into the landscape commencing in December 2016, with any subsequent progeny to be released over the following months. This is the fifth consecutive season that captively bred animals have been released into either the NCIG trial site or Compensatory Habitat, with successful breeding occurring through the landscape as a result.

Green and Golden Bell Frog Breeding – In December 2016, NCIG made a submission to the Department of Planning and Environment in recognition of a second breeding event during the 2015/16 season. The submission recognises the attainment of the performance indicator detailed in Condition 2.20 (i)(iii) with regard to a viable breeding population of Green and Golden Bell Frogs. The Department responded by letter in June 2017 indicating that the Department is satisfied that the requirements of Conditions 2.20 (b)(i) and 2.20 (i)(iii) have been met.

The Fyke netting program identified two separate breeding events in February 2017 and March 2017 and indicated that at least five breeding events occurred over the 2016-2017 summer based on trapping of bell frog tadpoles. The field surveys undertaken during ideal breeding conditions were completed on ten separate occasions during the reporting period and data indicating breeding activity, such as recoding of calls and identification of breeding females and spawn, were identified on seven occasions.

Migratory Shorebird Habitat Management – Creation of the migratory shorebird habitat was completed in November 2016 and included:

- Removal of 17 hectares of mangroves using a power tool (hand removal) and plant/machinery methods.
- Installation of a hydrological control device (Smart Gate) at Fish Fry Creek culvert.
- Installation of two Mangrove Propagule Exclusion Devices (MPEDs) in Fish Fry Creek.
- Installation of bird diverters using a bucket truck at the Ausgrid power lines.
- Installation of bird diverters using a helicopter at the Transgrid power lines.
- Other minor infrastructure works such as rock protection along Fish Fry Creek, security gates and fences and access tracks.

Further improvements to the habitat within the reporting period included fixing of minor mechanical and electrical defects on the Smart Gate at Fish Fry Creek, followed by modification of the programming logic for gate operation as recommended by University of NSW Water Research Laboratory.

Photographs of the migratory shorebird habitat during construction are included in **Figure 20** to **Figure 23**.



Figure 20: Fish Fry Flats following mangrove removal.



Figure 21: MPED 2 screen installed at Fish Fry Creek.



Figure 22: Completed Smart Gate at Fish Fry Creek.



Figure 23: Rock protection along Fish Fry Creek.

Migratory Shorebird Habitat Monitoring – Monitoring commenced at the migratory shorebird habitat during and following mangrove removal, including bird monitoring and a benthic study. Post-mangrove removal shorebird monitoring was undertaken by Kleinfelder in December 2016 followed by fortnightly general flora and fauna monitoring from January to April 2017. During this monitoring, shorebird species were observed across all ponds, including Fish Fry Flat, Swan Pond, Wader Pond and North-West Pond. Photographs of selected shorebirds species are included in **Figure 24** and **Figure 25**.

The benthic study was completed at Area E by Environmental Resources Management (ERM) in January 2017. The aim of the benthic study was to compare species richness and abundance across Area E following mangrove removal to the results of the baseline study when the mangroves were in-situ. The results indicated that the habitat in Area E remains in transition following mangrove removal and the species in Area E do not yet represent the epibenthic and macroinvertebrate communities typical of mudflats. Further benthic monitoring will be completed in the future.



Figure 24: Juvenile Curlew Sandpipers using Area E (Fish Fry Flats)



Figure 25: Royal Spoonbill using Area E (Fish Fry Flats)

4.9.4 Reportable Incidents

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

4.9.5 Further Improvements

Works for 2016/ 2017 will include the following:

- Revision of the NCIG Green and Golden Bell Frog Compensatory Habitat Management Plan.
- Combined fox baiting program including NCIG Green and Golden Bell Frog habitat, BHP Green and Golden Bell Frog habitat and NCIG shorebird habitat.
- Installation of Design Tidal Regime pending NPWS approval and completion of program modifications.
- Mangrove propagule removal to be completed in spring 2017.
- Re-installation of MPED 1 and 2 prior to mangrove fruiting season.

4.10 Traffic Management

4.10.1 Environmental Management

PA 06_0009 contains a range of requirements that pertain to road transport (Conditions 2.21 to 2.37, Schedule 2). These requirements are addressed where relevant in the Construction Traffic Management Protocol.

4.10.2 Environmental Performance

The road improvements proposed to conform to the Conditions of the Project Approval for the construction phase of the CET are generally those permanent works that would be required during the future operation of the proposed coal loader.

Traffic management during the construction phase focussed on the immediate imposition of movement restrictions at key intersections to limit the potential for delays to traffic flows on Cormorant Road.

NCIG developed a Vehicle Traffic Management Plan (VTMP) in accordance with the Construction Traffic Management Protocol. The plan provided the approved traffic routes for NCIG construction traffic across the site. This plan also dictated the approved traffic routes for construction traffic on adjacent public roads, including the prevention of right-hand turns onto Cormorant Road from Egret Street, Pacific National Road and the NCIG Wharf Access Road intersection, in order to minimise any disruption to through traffic on this road. Each contractor on the NCIG project site also developed VTMPs to ensure that construction traffic is adequately managed on internal and external roads.

There were no road improvements performed during the reporting period. It is noted that NCIG have been working in consultation with Roads and Maritime Services (RMS) on the design of the Cormorant Road duplication where this interacts with NCIG operations.

In addition to the above, a Vehicle Traffic Management Plan has been developed for operational vehicles which came into effect at the commencement of NCIG operational activities.

4.10.3 Reportable Incidents

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

4.10.4 Further Improvements

No improvement to traffic management is required for the next period.

4.11 Waste Management

4.11.1 Environmental Management

Measures to avoid and minimise the generation of wastes and promote waste re-use and recycling have been adopted during construction of the Project and include:

- waste avoidance – practices were developed that reduce the amount of waste on-site, via selective purchasing procedures and the use of bulk purchasing, where practicable;
- material reuse – reuse of recyclable or reusable materials where practicable; and
- recycling – materials such as metals, oil, timber, plastics, glass and paper were recycled where practicable.

In accordance with Conditions 2.54 and 2.56, Schedule 2 of the PA 06_0009, all waste materials removed from the site were directed to a waste management facility lawfully permitted to accept the materials.

In accordance with Condition 2.57, Schedule 2 of the PA 06_0009, waste was not received at the site during the reporting period. In addition, NCIG complied with the requirements of EPL No. 6437 as it relates to the on-going management of the Kooragang Island Waste Emplacement Facility.

4.11.2 Environmental Performance

The principles of waste management, being waste avoidance, material reuse and recycling have been adopted by NCIG and all construction 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 with paper, aluminium, steel, plastics, timber and glass being the primary materials collected. Recycled concrete has also been incorporated into the pavement design for the rail and stockyard areas as a means of improving reuse of waste materials.

A 12,000 litre (L) waste oil tank was installed prior to operations to enable the collection and storage of waste hydrocarbons during NCIG operational activities, before being removed by licensed waste transporters on a periodic basis. A purpose built oil/water separator system has also been installed at the workshop and truck washdown areas, which is inspected and maintained on a regular basis during operations.

A Waste Management Plan has been developed and incorporated into the environmental management system for the operations of the NCIG Terminal. Waste volumes are tracked on a monthly basis, with the assistance of NCIG's waste management contractor.

During the reporting period, NCIG completed a waste management review of the Waste Management Plan, which identified that recycling rates were consistently above 50%. It also identified that general waste bins on the NCIG site contained amounts of recyclable waste, particularly bottles, cans, cardboard boxes, paper towels and soft plastics. The review recommended that NCIG undertake a general waste audit to verify how much of the currently landfilled waste can potentially be diverted by placing co-mingled recycling bins and soft plastics collection bins next to existing general waste bins.

During the reporting period there was no waste material stored, treated, processed or reprocessed or disposed of on the Kooragang Island Waste Emplacement Facility that would constitute a breach of the conditions of EPL 6437.

4.11.3 Reportable Incidents

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

4.11.4 Further Improvements

A waste improvement project will be implemented during the next reporting period, which is likely to be focussed around recycling soft plastic material.

4.12 Community Relations

4.12.1 Environmental Management

During Project construction the following complaints handling system was implemented which remains in place during Project operations:

- In accordance with Conditions 6.2, Schedule 2 of the PA 06_0009, NCIG established a telephone number, postal address and email address prior to the commencement of construction for community complaints and enquiries. Current details are provided below:
 - 24-hour complaints telephone hotline: 1800 016 304
 - Postal address for written complaints: PO Box 644
Newcastle NSW 2300
 - Email address for electronic complaints: enquiries@ncig.com.au
- In accordance with Condition 6.2, Schedule 2 of PA 06_0009, the community were informed of the phone, email and postal addresses via the NCIG website (www.ncig.com.au), notices in local newspapers and signage adjacent to the Project.
- 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 maintained a website for the provision of electronic information associated with the Project including all relevant Management Plans.

4.12.2 Environmental Performance

The general structure of Complaint Response Procedure is shown on **Figure 26**. Upon receiving a complaint all details relating to the issue of concern were recorded in the Complaints Register including:

- the date and time, where relevant, of the complaint;
- the means by which the complaint was made (telephone, mail or email);
- any personal details of the complainant that were provided, or if no details were provided, a note to that effect;
- the nature of the complaint; and
- a record of any operational or meteorological conditions that may have potentially contributed to the complaint.

Within two working days of a complaint being registered, an initial response was provided to the complainant and a preliminary assessment commenced to determine likely causes of the

complaint using relevant available information (i.e. climatic conditions, environmental monitoring results and current construction activities). **Table 4.17** provides a summary of the complaints received during the reporting period. In every case the investigation of the complaint determined that the issue of concern was not as a result of an exceedence of relevant Project Approval or EPL criteria.

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; and
- details of the finding of the investigation and the reason(s) why no action was taken.

Every effort was made to ensure that the concerns of the complainant were addressed in a manner that resulted in a mutually acceptable outcome.

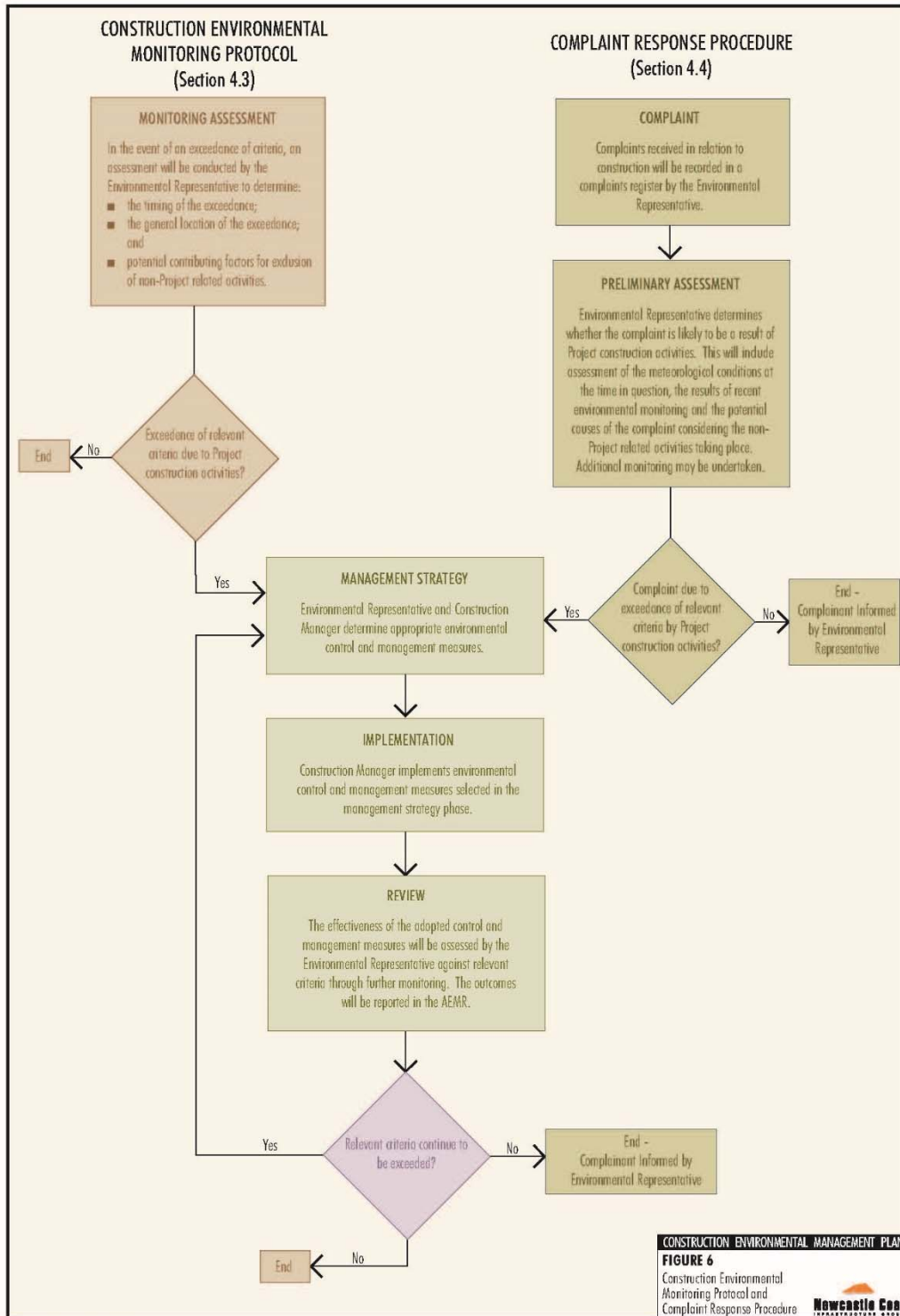


Figure 26: Complaint Response Procedure

Table 4.17: Community Complaints Register Summary

Date of complaint	Environmental concern raised	Issue	Action taken
6-July-16	Residual coal	NCIG's EPA Officer contacted NCIG via email enquiring about a coal wagon observed at Warabrook by a member of the community with residual coal. The observation was between 8.30-9.15am on 1 July 2016. The EPA officer wanted to know if this wagon had been discharged at NCIG and which mine it had come from.	Responded that the stated wagon had not gone through the NCIG facility. Provided information that the wagon had previously gone through the NCIG facility.
11-July-16	Stockpile sprays	Plant manager from Boral Cement rang and explained that an employee had complained about mist from NCIG stockpile sprays had landed on his car. Concern raised about the quality of this water and dust.	Discussed issue with complainant. Committed to inspecting area of shared boundary on the next westerly windy day to determine extent of issue. Then call to discuss.
5-Nov-16	Dust	A member of the public was travelling east along Cormorant Rd around 2.00pm during windy conditions and reported it to be dusty. Also reported that they could not see any stockyard sprays operating at the time. Person then contacted NCIG when they reached home at Stockton. They felt their suburb was also being impacted by coal dust.	Discussed issue with complainant. Described how the dust management system operates. Committed to investigating the status of the dust management system at the time of the complaint.
22-Nov-16	Dust	EPA contacted PWCS regarding a report from a passing motorist. They drove over Stockton bridge, observed dust and could not see stockyard sprays operating. Complainant angry that PWCS has KPI to save water, management gets a bonus, so that why sprays are not on. PWCS pointed out that stockpile along Cormorant Road are managed by NCIG so EPA said he may call NCIG.	Manager HSEC phoned EPA to discuss any concerns. EPA confirmed they had inspected NCIG stockpiles from Cormorant Road and observed that the sprays had just run and that there was no dust evident. No further action required.
13-Dec-16	Dust	An email was received from the EPA regarding an Environment Line Report from a member of the public regarding coal dust blowing on Kooragang Island and only two sprays working - believed to be either NCIG or PWCS. The report was sent from the EPA to both NCIG and PWCS and asked if information could be provided on the status of the respective dust management system at the time.	Provided email report to EPA on status of dust management system and stockpiles sprays for the duration of the day. Showed that the system was fully operational and that sprays were operating as intended. Also reiterated that stockpile sprays are often not visible from Cormorant Rd as they operate on a cycle.
21-Jan-17	Dust	Manager at Boral Cement (Egret St) made an external enquiry on the enquiries line regarding possible dust.	Spoke to Boral site manager. The issue with dust was that he thought dust may have come from the Boral site onto NCIG due to equipment failure. No issues had been reported at NCIG relating to this event.

Table 4.17: Community Complaints Register Summary

Date of complaint	Environmental concern raised	Issue	Action taken
6-Feb-17	Dust	Enquiry received from EPA regarding onsite dust management system on 18/1/17. Over the corresponding 24 hour period, high particulate levels were recorded by the Stockton monitor in the Newcastle Air Quality Monitoring Network. EPA require information on the operation of the NCIG dust management during this period.	Written Response provided to EPA regarding operation of dust management system for the duration of 18/1/17. Showed that system was operating as intended throughout the event. No response has been received from EPA.
1-Mar-17	Site tours	Enquiry made about whether NCIG conducted bus tours for the public.	Spoke with member of the public. Advised that NCIG does not run routine site tours for the general public. Also advised that PWCS does run bus tours for the public, and that NCIG will be having a Community Open Day at end of April, where bus tours will be run for the duration of the event.

NCIG has developed an initiative titled the Community Support Program (CSP). This process involves engagement with local community groups and providing support to community based events and projects. The Program seeks applications on a six monthly basis from community groups that are seeking support for their endeavours. NCIG would undertake an assessment process and provide primarily financial support to these community events and projects. NCIG participated with the community groups in these project and events wherever possible. Through this process groups within the Fern Bay, Stockton, Mayfield and greater Newcastle area were assisted by NCIG. For example, NCIG assisted the Hunter Wetlands National Park Saltmarsh Habitat Project run by Conservation Volunteers Australia, in the 2016/17 reporting period. A Community Open Day was held on 30 April 2017, which was attended by over 500 community members, businesses and suppliers. Visitors were taken on a bus tour around the site, including the wharf, dump station and stockyard. They could also visit one of the information stalls and interactive displays, with staff on hand to answer questions about the operations, health and safety, environment and community. A mock control room was set up for people to see a ship being loaded.

The NCIG website was updated in January 2017 to make it easier to communicate with the coal terminal. The new website design is easier for users to navigate with updated information about the organisation's facilities and operations. A key focus of the website is to answer commonly asked questions and provide opportunities for interested community members to get in contact with Newcastle Coal staff.

A Corporate Sustainability Report was prepared for 2016 and this report is available on the NCIG website. The Corporate 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 chronology of community liaison held during the reporting period is outlined in **Table 4.18** below.

Table 4.18: Community Liaison Summary

Date	Type
September 2016	Community Support Program – submissions called, 29 successful applicants. Community Newsletter
March 2017	Community Support Program – submissions called, 21 successful applicants.
April 2017	Community Newsletter

4.12.3 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.

4.12.4 Further Improvements

No further improvements are planned for the next reporting period.

4.13 Environmental Monitoring Program

An Environmental Monitoring Programme was implemented to monitor the environmental performance of the Project during construction and operation in accordance with the PA 06_0009, environmental licences and other statutory conditions. The programme was established and implemented at the commencement of construction works.

The Environmental Representative was responsible for the implementation of the construction environmental monitoring programme and is responsible for ensuring that adequate environmental monitoring is maintained throughout the Project construction.

The details of the monitoring undertaken are provided in the previous sections, however, an overview Operations Environmental Management Plan (OEMP), is provided in **Table 4.19**.

Table 4.19: 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 ¹ .	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.	Monthly and following significant rainfall events (i.e. greater than 20 mm in 24 hours).	N/A
Noise			

Attended and unattended noise monitoring.	Fern Bay, Stockton, Mayfield, Carrington per Section 4.2 ONMP.	Quarterly.	See Section 4.7.2.
Attended noise monitoring in case of complaint.	Reference locations proximal to the Project ¹ .	At the commencement of operation.	
Air Quality			
Dust monitoring.	DG1, DG2, DG3, DG4, DG5, DG6 ¹ .	Monthly	See Section 4.2.2
	HVAS1, HVAS2, HVAS3, HVAS4.	Every 6 days	
	BAM1, BAM2, BAM3, BAM4.	Continuous	
	PWCS	Through regular consultation.	
Surface Water			
pH, electrical conductivity (EC), total dissolved solids (TDS) and total suspended solids (TSS).	Secondary settling ponds ⁴ .	Monthly.	See Section 4.3.2
	Surface water monitoring sites ⁴ .	Monthly.	
Water level.	Primary and secondary settling ponds ⁴ .	Following heavy rainfall (i.e. more than 20 mm of rainfall in a 24 hour period).	
Drainage, erosion and sediment control.	All areas of NCIG	Monthly.	
Groundwater			
pH, EC, TDS, TSS, sulfate, polycyclic aromatic hydrocarbons (PAH), As III, Cd, Cu, Pb, Hg, Zn, Cr VI, Mn and Ni (refer Table 5).	GW1, K9/3S, K9/3N, K11/1S, K11/1. ¹ .	6 Monthly.	See Section 4.4.2
Groundwater level.		6 Monthly	

¹ The location of monitoring sites is shown on Figure 6.

² Dust deposition will be 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.

³ PM₁₀ will be monitored in accordance with the Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales (EPA,2001).

4 The location of monitoring sites is detailed in the OWMP (Appendix C) and Figure 6.

5. COMPLIANCE AUDITS

Audits were undertaken in relation to NCIG Construction activities which considered the compliance status of the Project for the reporting period. These reviews were conducted to meet the requirements of Condition 5.1 of development Approval 06-009 a) as outlined below:

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:

Compliance Tracking Program Updated April 2017

A Compliance Tracking Program was set up for the NCIG CET in accordance with Condition 5.1, Schedule 2 of PA 06_009. The Compliance Tracking Program was updated in April 2017. The Compliance Tracking Program indicated that project compliance has been achieved for each condition of the Project Approval.

Independent Environmental Audit

An Independent Environmental Audit will be conducted on a 3-yearly basis (as agreed by the Director-General's delegate in a letter dated 14 July 206) in accordance with Conditions 5.1(c), Schedule 2 of Project Approval (06_009). The Independent Environmental Audit 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 Independent Environmental Audit was conducted within 12 months of the commencement of construction. This has been conducted annually until 2015, with the most recent Independent Environmental Audit conducted in November/ December 2015. The next Independent Environmental Audit will be conducted in November 2018.

6. STANDARDS

Accreditation of the NCIG Environmental Management System (EMS) against the ISO14001 standard was achieved in May 2017. This included a Stage 1 (preliminary) and Stage 2 (detailed) onsite audit. It is intended that accreditation will be maintained against this standard ongoing

7. ACTIVITIES PROPOSED IN NEXT AEMR PERIOD

Significant activity is proposed to be undertaken in the next AEMR period in accordance with the Project Approval and environmental management and monitoring programmes. The principle elements are:

- Continued operation and maintenance of the full 66Mtpa Coal Export Terminal.
- Internal planning for optimisation of existing plant to provide additional capacity, if required in the future.
- Review of monitoring locations in EPL12693.
- Assessment of options to improve management of sediment onsite
- Monitoring of carry-back coal from coal wagons.
- Commence MERI of the migratory shorebird habitat at Area E.
- Further development and continuous improvement of the NCIG Environmental Management System.
- Review of the NCIG Community Engagement Strategy

8. REFERENCES

AK Environmental (July 2017) Review of Site Surface Water Reuse Efficiency and Cost-benefit Analysis of Stormwater System Pond Expansion

Biosphere Environmental Consultants Pty Ltd (November 2016) Natural Breeding Events NCIG Green and Golden Bell Frog Compensatory Habitat Area, Ash Island

Cross Connections Consulting (May 2017) Resource Efficiency Review, Summary Report

Cross Connections Consulting (June 2017) Waste Management Review Kooragang Site, Draft Report

Hunter Bird Observers Club (March 2017) Deep Pond (Kooragang Island) Avifauna Data Summary 2016

NCIG (2016) Corporate Sustainability Report

NCIG (December 2016) Compensatory Habitat and Ecological Monitoring Program – Quarterly Report (Combined Quarter 3 and Quarter 4, 2016)

NCIG (December 2016) NCIG Green and Golden Bell Frog Compensatory Habitat Milestone Report

NCIG (June 2017) Compensatory Habitat and Ecological Monitoring Program – Quarterly Report (Quarter 1, 2017)

NSW Office of Environment and Heritage (July 2017) Newcastle Coal Infrastructure Group – Compensatory Habitat Successful Performance for Project Approval (MP06_0009) & Conservation Bond Reduction

NSW Planning and Environment (June 2017) Newcastle Coal Infrastructure Group (NCIG) Coal Export Terminal (MP06_0009) Compensatory Habitat Program (Condition 2.20)

Ramboll Environ (August 2017) Draft NCIG Surface Water Monitoring Data Review 2017

RCA (December 2016) Six Monthly Surface Water Report, Kooragang Island, Newcastle

RCA (June 2017) Six Monthly Surface Water Report, Kooragang Island, Newcastle

SAI Global (April 2017) Stage 2 Audit for Newcastle Coal Infrastructure Group Pty Ltd

SLR (July 2016) Newcastle Coal Infrastructure Group Coal Export Terminal, Buffer Bin (BN01) Inlet Chute Modification, Post Mitigation Noise Investigation

SLR (May 2017) Newcastle Coal Export Terminal, Biannual Off-site Noise and On-site Sound Power Monitoring, July to December 2016

SLR (August 2017) Newcastle Coal Export Terminal, Biannual Off-site Noise and On-site Sound Power Monitoring, January 2017 to June 2017

University of Newcastle (August 2017) Research Program on the Green and Gold Bell Frog (*Litoria aurea*) on Kooragang Island Annual Report (2016-2017)

University of NSW Water Research Laboratory (March 2017) Shorebirds Compensatory Habitat: SmartGate Hydrological Triggers

9. LIMITATIONS

Ramboll Environ Australia Pty Ltd (Ramboll Environ) prepared this report in accordance with the scope of work as outlined in our proposal to NCIG dated July 2016 and in accordance with our understanding and interpretation of current regulatory standards.

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

Ramboll Environ did not independently verify all of the written or oral information provided to Ramboll Environ during the course of this investigation. While Ramboll Environ 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 Environ 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 Environ Australia's express written permission.

APPENDIX 1 METEOROLOGICAL (OTHER THAN RAINFALL) SUMMARY

Table A1.1 Meteorological statistics by month

Month	Wind speed			Monthly average -	Sigma theta		Solar radiation		
	Monthly average	Hourly min	Hourly max		Hourly min	Hourly max	Monthly average	Hourly min	Hourly max
	m/s	m/s	m/s		-	-	W/m ²	W/m ²	W/m ²
July 2016	4.5	0.1	15.7	12.5	2.6	76.4	109.7	0.0	572.5
August 2016	2.8	0.0	8.9	10.9	2.0	45.4	131.0	0.0	712.7
September 2016	3.9	0.0	17.1	10.6	2.4	43.7	178.7	0.0	907.8
October 2016	4.1	0.4	14.1	13.2	1.7	65.6	233.1	0.0	975.3
November 2016	3.4	0.4	13.3	18.2	3.4	79.6	299.4	0.0	1057.7
December 2016	3.4	0.4	9.8	18.9	5.2	81.0	271.9	0.0	1440.0
January 2017	3.4	0.3	13.0	17.8	3.9	77.3	244.1	0.0	1027.5
February 2017	3.3	0.3	8.0	18.0	3.7	79.4	245.1	0.0	994.5
March 2017	3.3	0.2	8.6	18.6	5.5	71.5	164.6	0.0	922.5
April 2017	2.8	0.1	13.3	19.3	4.1	87.4	160.3	0.0	861.2
May 2017	2.4	0.1	8.1	18.8	3.2	72.7	123.5	0.0	623.2
June 2017	2.6	0.3	7.8	17.9	3.1	80.8	82.9	0.0	554.0

Table A1.2 Meteorological statistics by month

	Temperature at 2m elevation (T2)			Temperature at 10 m elevation (T10)			Number of hours when $T_{10} > T_2$	
	Monthly average	Hourly min	Hourly max	Monthly average	Hourly min	Hourly max	Hours	% of month
	°C	°C	°C	°C	°C	°C		
July 2016	13.7	5.2	25.2	13.2	4.5	24.9	33	4
August 2016	14.1	5.9	24.6	13.4	5.2	24.1	9	1
September 2016	16.6	7.9	25.3	15.9	7.3	24.6	4	1
October 2016	18.6	8.7	32.0	17.9	8.2	31.3	28	4
November 2016	21.6	12.2	33.6	20.7	11.3	32.4	5	1
December 2016	24.2	16.5	39.2	23.4	15.5	37.7	1	0
January 2017	25.6	19.5	40.4	24.7	18.8	39.3	1	0
February 2017	25.1	17.4	40.3	24.3	16.7	39.2	2	0
March 2017	23.0	15.8	30.2	22.3	14.7	29.7	0	0
April 2017	19.0	10.8	27.1	18.1	10.2	26.5	2	0
May 2017	16.6	6.8	24.9	15.8	6.3	24.3	2	0
June 2017	14.5	6.2	20.2	13.8	5.3	19.1	7	1

APPENDIX 2

DUST DEPOSITION MONITORING RESULTS

Table A2.2 Dust Deposition by Month

Month	Limit	DDG-CI (Stockton)	DDG-KI (Stockton)	DDG K8 (Fern Bay)	DG3 (KI)	DG4 (Mayfield)	DG5 (Mayfield)	DG6 (Sandgate)
Jul-16	4	0.6	0.4	0.9	6.2	0.4	0.8	1.5
Aug-16	4	0.4	0.6	1.2	0.3	0.5	0.8	1.4
Sep-16	4	0.6	0.5	1.1	1.3	1.4	1.4	2.8
Oct-16	4	0.5	0.5	0.5	1.3	1.4	1.4	2.8
Nov-16	4	2.5	0.8	0.6	1.7	1.2	1.2	2.3
Dec-16	4	0.9	1	1	2.7	1.6	1.4	2
Jan-17	4	0.7	0.7	0.7	1.9	1.1	0.7	1.5
Feb-17	4	0.5	0.6	0.7	0.9	1.5	1.1	2
Mar-17	4	0.3	0.3	0.6	0.9	1.1	0.6	2.3
Apr-17	4	0.8	0.6	1	1.9	0.8	0.8	1.3
May-17	4	2.1	0.5	0.4	1.3	0.9	0.8	1.3
Jun-17	4	0.7	0.4	0.7	2.1	0.4	1	0.4

*KI – Kooragang Island

**Insect and bird droppings

***NS – No Sample

APPENDIX 3

SURFACE WATER MONITORING RESULTS

Table A3.1 Surface Water Results for pH

pH		Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17
SW1(a)	Pond 1	8.46	7.99	7.91	8.22	8.55	7.8	8.15	8.79	7.39	8.14	8.48	8.31
SW1(b)	Pond 2	8.65	8.13	8.14	8.24	8.49	8.13	7.87	7.93	7.22	8.07	8.56	8.3
SW1(c)	Pond 3	8.43	8.17	8.24	8.24	8.47	8.26	7.89	8.15	7.31	8.06	8.51	8.28
SW1(d)	Clearwater	8.41	8.22	8.15	8.15	8.1	8.33	7.79	8.53	7.37	8.15	8.5	8.53
SW2	Black Swan Pond	8.91	8.2	9.36	9.6	6.08	9.01	8.43	9.85	8.21	7.79	8.01	8.54
SW3	Deep Pond	8.23	8.52	9.59	8.57	9.12	8.35	8.88	9.96	9.51	9.02	9.27	9.13

Table A3.2 Surface Water Results for Electrical Conductivity

EC (mS/cm)		Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17
SW1(a)	Pond 1	2.42	1.28	0.421	2.31	2.2	1.38	1.67	1.9	1.37	0.695	2.04	1.91
SW1(b)	Pond 2	2.07	1.53	1.6	1.76	1.71	1.96	1.16	0.944	1.32	0.954	1.96	1.82
SW1(c)	Pond 3	1.76	1.74	1.91	1.69	1.49	1.97	1.35	1.13	0.983	0.864	1.66	1.81
SW1(d)	Clearwater	1.09	1.88	2.29	4.29	3.17	6.67	5.27	3.04	0.813	0.815	1.04	1.78
SW2	Black Swan Pond	1.6	1.7	1.64	1.63	1.56	2.55	3.7	3.74	2.66	1.03	2.29	1.58
SW3	Deep Pond	1.32	1.78	1.33	2.02	1.88	2.75	3.12	5.07	4.57	2.16	2.26	2.21

Table A3.3 Surface Water Results for Turbidity

Turbidity (NTU)		Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17
SW1(a)	Pond 1	157	592	>1000	>1000	100	843	576	205	646	381	86	127
SW1(b)	Pond 2	51	219	414	354	94	109	124	161	120	137	30	61
SW1(c)	Pond 3	37	125	214	241	172	86	100	130	198	72	76	256
SW1(d)	Clearwater	31	58	54	514	91	48	27	42	62	43	18	163
SW2	Black Swan Pond	6	3	6	6	7	83	277	751	16	9	2	2
SW3	Deep Pond	5	25	4	113	9	181	8	408	939	6	2	1

Table A3.4 Surface Water Results for Temperature

Water Temp (°C)		Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17
SW1(a)	Pond 1	13	17.7	18	21.6	28.4	30.8	27	35	23	22	19	14.5
SW1(b)	Pond 2	11.8	15	17.8	18.2	25.2	30	26	31	22	21	19	14
SW1(c)	Pond 3	12	14.6	17.8	17.7	24.7	30.4	26	32	24	21	19	14.4
SW1(d)	Clearwater	12	15.8	17.4	21.2	26.2	33.5	25	33	23	21	19	16.8
SW2	Black Swan Pond	11.8	15.7	18.5	17.8	21.5	24.4	25	33	21	21	18	14.4
SW3	Deep Pond	12	15	17.8	19.6	25.3	31.3	24	35	20	21	21	16.6

APPENDIX 4 GROUNDWATER MONITORING RESULTS

				Bore GW1							
Reporting Units	95% Marine Waters ANZECC Trigger Level		EP Licence Trigger Level (Site specific)	2/12/2013	6/06/2014	1/12/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017
	Sourced from CEMP	Sourced from OVMP									
EPA Point Number				1	1	1	1	1	1	1	1
Sample Number				12136902001	061410481001	121410481001	061510481007	121510481019	061610481017	121610481019	061710481017
Date of Sampling				2/12/2013	6/06/2014	1/12/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017
Time of Sampling				13:15	11:10	11:20	10:35	11:20	11:56	11:50	12:40
Sampler				K. Hawes	K. Hawes	K. Hawes	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South
Groundwater Level	metres			1.49	1.57	1.57	1.29	1.50	1.47	1.57	1.47
Temperature	°C			20.5	17.5	21.8	19.0	24.2	20.7	23.9	19.0
Analyte											
pH	pH units	7.0-8.5	7.0-8.5	7.95	7.2	7.2	7.7	7.48	7.47	7.09	7.30
EC	µS/cm			9900	11160	9980	11800	12400	12100	12000	13600
TDS	mg/L			7288	7327	7052	6606	6578	6955	7146	6948
TSS	mg/L			42	21	38	26	29	14	61	<5
Metals - Dissolved											
Al	mg/L		ID	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01
Cd	mg/L	0.0055		0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0005	<0.0001
Co	mg/L		0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	mg/L		0.0013	0.003	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Pb	mg/L	0.0044		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn	mg/L	0.08	0.08	0.132	0.004	0.39	0.009	0.341	0.23	0.232	0.24
Ni	mg/L	0.07	0.07	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.002	<0.001
Zn	mg/L	0.015	0.015	0.038	0.022	0.016	0.042	<0.005	<0.005	0.167	<0.005
Fe	mg/L		ID	<0.05	<0.05	0.15	<0.05	<0.05	0.014	<0.05	<0.05
As III	µg/L	ID		<1	<1	<2	<2	<0.5	<0.5	<1.0	<0.5
Hg	mg/L	0.0004		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Hexavalent Cr	mg/L	0.0044		<0.01	<0.01	<0.01	<0.01	<0.01	<0.004	<0.01	<0.01
Cations - Dissolved											
Mg	mg/L		ID	119	115	107	109	117	100	128	120
Na	mg/L		ID	1920	2220	2150	2070	2150	1900	2070	2130
K	mg/L		ID	114	130	128	113	111	130	119	117

Cells with a green shade indicate that the trigger level associated with this result has not been exceeded												
Cells with a yellow shade indicates that the LOD is greater than the trigger value, and although undetected by the laboratory could exceed criteria												
Cells with a red shade indicate that the trigger level associated with this result has been exceeded												
Indicates no guideline specified (site specific or ANZECC)												
ID = Insufficient data to provide trigger value												
Bore GW1												
	Reporting Units	95% Marine Waters ANZECC Trigger Level		EP Licence Trigger Level (Site specific)	2/12/2013	6/06/2014	1/12/2014	19/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017
		Sourced from CEMP	Sourced from OVMF									
PAH												
Polynuclear Aromatic Hydrocarbons - 16 analytes	µg/L		ID		<10	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5
TPH												
C6-9 Fraction	µg/L				<20	<20	<20	<20	<20	<40	<20	<20
C10-14 Fraction	µg/L				<50	<50	<50	<50	<50	<50	<50	<50
C15-28 Fraction	µg/L				<100	<100	<100	<100	<100	<200	<100	<100
C29-36 Fraction	µg/L				<50	<50	<50	<50	<50	<200	<50	<50
BTEX												
Benzene	µg/L				<1	<1	<1	<1	<1	<0.5	<1	<1
Toluene	µg/L				<2	<2	<2	<2	<2	<0.5	<2	<2
Ethyl Benzene	µg/L				<2	<2	<2	<2	<2	<0.5	<2	<2
m+p Xylene	µg/L				<2	<2	<2	<2	<2	<1	<2	<2
o Xylene	µg/L				<2	<2	<2	<2	<2	<0.5	<2	<2
Cyanide												
Free	µg/L				<4	<4	<4	<4	<4	<4	<4	<4
Total	µg/L				<4	<4	<4	<4	<4	<4	<4	<4
Ammonia	µg/L				470	20	630	140	2450	1700	1400	1500
Phenol	µg/L				<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0
Sulfate	mg/L				628	571	547	484	622	640	651	645

Cells with a green shade indicate that the trigger level associated with this result has not been exceeded													
Cells with a yellow shade indicates that the LOD is greater than the trigger value, and although undetected by the laboratory could exceed criteria													
Cells with a red shade indicate that the trigger level associated with this result has been exceeded													
Indicates no guideline specified (site specific or ANZECC)													
ID= Insufficient data to provide trigger value													
Bore K93 N													
	Reporting Units	95% Marine Waters ANZECC Trigger Level		EP Licence Trigger Level (Site specific)	13/06/2013	21/2/2013	6/06/2014	11/2/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017
		Sourced from CEMP	Sourced from OWMP										
EPA Point Number					20	20	20		20	20	20	20	20
Sample Number					06136902002	12136902002	061410481002	121410481002	061510481008	121510481020	061610481018	121610481020	061710481018
Date of Sampling					13/06/2013	21/2/2013	6/06/2014	11/2/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017
Time of Sampling					12:55	15:15	10:20	11:45	11:05	11:55	8:40	9:18	10:12
Sampler					K. Hawes	K. Hawes	K. Hawes	K. Hawes	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South
Groundwater Level	metres				2.57	2.62	2.80	2.90	2.57	2.80	2.70	2.96	2.78
Temperature	°C				20.3	21.0	18.5	22.0	20.5	22.5	19.4	21.7	20.1
Analyte													
pH	pH units	7.0-8.5	7.0-8.5		7.5	7.77	7.47	7.41	7.61	6.95	6.89	6.39	7.03
EC	µS/cm				7560	6560	7390	5950	6620	24800	22600	24900	24900
TDS	mg/L				4376	4575	4088	3921	3687	14208	13596	14496	13297
TSS	mg/L				44	27	152	142	160	13	21	18	21
Metals - Dissolved													
Al	mg/L		ID		0.02	<0.01	0.03	0.02	0.02	<0.01	0.011	<0.01	0.02
Cd	mg/L	0.0055			<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Co	mg/L		0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	mg/L		0.0013		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pb	mg/L	0.0044			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn	mg/L	0.08	0.08		0.541	0.49	0.234	0.528	0.397	0.73	1.9	1.26	1.49
Ni	mg/L	0.07	0.07		<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002
Zn	mg/L	0.015	0.015		<0.005	0.01	0.005	<0.005	0.008	<0.005	<0.005	0.02	0.036
Fe	mg/L		ID		0.14	<0.05	<0.05	<0.05	0.06	0.08	0.022	<0.05	0.21
As III	µg/L	ID			<1	<1	<1	<2	<1	<0.5	<0.5	<1.0	<0.5
Hg	mg/L	0.0004			<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Hexavalent Cr	mg/L	0.0044			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.004	<0.01	<0.01
Cations - Dissolved													
Mg	mg/L		ID		109	90	70	130	62	439	370	337	355
Na	mg/L		ID		1890	1340	1310	1910	1200	4620	4200	4020	3900
K	mg/L		ID		113	58	64	87	59	177	220	163	162

Cells with a green shade indicate that the trigger level associated with this result has not been exceeded													
Cells with a yellow shade indicates that the LDR is greater than the trigger value, and although undetected by the laboratory could exceed criteria													
Cells with a red shade indicate that the trigger level associated with this result has been exceeded													
Indicates no guideline specified (site specific or ANZECC)													
ID= Insufficient data to provide trigger value													
Bore K93 N													
	Reporting Units	95% Marine Waters ANZECC Trigger Level		EP Licence Trigger Level (Site specific)	13/06/2013	2/12/2013	6/06/2014	1/12/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017
		Sourced from CEMP	Sourced from O'WMP										
PAH													
Polynuclear Aromatic Hydrocarbons - 16 analytes	µg/L		ID	1	<0.5	<1.0	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5
TPH													
C6-9 Fraction	µg/L			20	<20	<20	<20	<20	<20	<20	<40	<20	<20
C10-14 Fraction	µg/L			50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15-28 Fraction	µg/L			100	<100	<100	<100	<100	<100	<100	<200	<100	<100
C29-36 Fraction	µg/L			50	<50	<50	<50	<50	<50	<50	<200	<50	<50
BTEX													
Benzene	µg/L			700	<1	<1	<1	<1	<1	<1	<0.5	<1	<1
Toluene	µg/L			180	<2	<2	<2	<2	<2	<2	<0.5	<2	<2
Ethyl Benzene	µg/L			5	<2	<2	<2	<2	<2	<2	<0.5	<2	<2
m+p Xylene	µg/L			75	<2	<2	<2	<2	<2	<2	<1	<2	<2
o Xylene	µg/L			350	<2	<2	<2	<2	<2	<2	<0.5	<2	<2
Cyanide													
Free	µg/L			4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Total	µg/L			81.1	<4	<4	<4	<4	<4	<4	<4	<4	<4
Ammonia	µg/L				3580	510	100	3300	4970	3220	3300	3200	2820
Phenol	µg/L			400	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0
Sulfate	mg/L				400	433	312	350	289	1300	1100	1200	987

Cells with a green shade indicate that the trigger level associated with this result has not been exceeded Cells with a yellow shade indicates that the LOR is greater than the trigger value, and although undetected by the laboratory could exceed criteria Cells with a red shade indicate that the trigger level associated with this result has been exceeded Indicates no guideline specified (site specific or ANZECC) ID= Insufficient data to provide trigger value				Bore K93 S										
Reporting Units	95% Marine Waters ANZECC Trigger Level		EP Licence Trigger Level (Site specific)	13/06/2013	21/2/2013	6/06/2014	11/2/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017		
	Sourced from CEMP	Sourced from OWMP												
EPA Point Number				21	21	21	21	21	21	21	21	21		
Sample Number				06136902003	12136902003	061410481003	121410481003	061510481009	121510481021	061610481019	121610481021	061710481019		
Date of Sampling				13/06/2013	21/2/2013	6/06/2014	11/2/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017		
Time of Sampling				12:40	15:25	10:05	12:10	11:15	12:05	8:45	9:30	10:20		
Sampler				K. Hawes	K. Hawes	K. Hawes	K. Hawes	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South		
Groundwater Level	metres			2.00	2.00	1.98	2.20	1.80	2.00	1.97	2.10	2.00		
Temperature	°C			19.3	21.5	18.0	22.0	19.3	25.7	19.6	23.4	18.8		
Analyte														
pH	pH units	7.0-8.5	7.0-8.5	7.6	7.89	7.32	7.47	7.99	7.70	7.71	7.26	7.68		
EC	µS/cm			8960	7520	7790	8100	4030	6990	6720	6330	6890		
TDS	mg/L			4770	5003	4708	5345	2372	4423	3295	4338	3328		
TSS	mg/L			4350	2902	1960	2460	3150	1807	1096	596	192		
Metals - Dissolved														
Al	mg/L		ID	0.02	0.01	<0.01	0.01	0.08	<0.01	<0.005	<0.01	0.28		
Cd	mg/L	0.0055		0.0003	0.0003	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001		
Co	mg/L		0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001		
Cu	mg/L		0.0013	0.004	0.012	<0.001	0.002	0.005	<0.001	<0.001	<0.001	<0.001		
Pb	mg/L	0.0044		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001		
Mn	mg/L	0.08	0.08	0.39	0.328	0.279	0.425	0.113	0.285	0.46	0.309	0.375		
Ni	mg/L	0.07	0.07	0.002	0.005	<0.001	0.001	0.002	0.001	<0.001	0.001	0.002		
Zn	mg/L	0.015	0.015	0.013	0.102	<0.005	0.025	0.009	<0.005	<0.005	0.022	0.029		
Fe	mg/L		ID	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.067	0.83	3.85		
As III	µg/L	ID		<1	<1	<1	<2	<1	19	1	<1.0	2.8		
Hg	mg/L	0.0004		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		
Hexavalent Cr	mg/L	0.0044		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.004	<0.01	<0.01		
Cations - Dissolved														
Mg	mg/L		ID	139	83	80	102	37	80	82	69	53		
Na	mg/L		ID	2380	1270	1490	2010	800	1330	1500	1150	1100		
K	mg/L		ID	129	55	72	119	38	69	96	62	52		

Cells with a green shade indicate that the trigger level associated with this result has not been exceeded															
Cells with a yellow shade indicates that the LOD is greater than the trigger value, and although undetected by the laboratory could exceed criteria															
Cells with a red shade indicate that the trigger level associated with this result has been exceeded															
Indicates no guideline specified (site specific or ANZECC)															
ID= Insufficient data to provide trigger value															
					Bore K93 S										
	Reporting Units	95% Marine Waters ANZECC Trigger Level		EP Licence Trigger Level (Site specific)	13/06/2013	2/12/2013	6/06/2014	1/12/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017		
		Sourced from CEMP	Sourced from OWMP												
PAH															
Polynuclear Aromatic Hydrocarbons - 16 analytes	µg/L		ID	1.1	<0.5	<1.0	<1.0	<0.5	<0.5	<0.5	<1	<0.5	<0.5		
TPH															
C6-9 Fraction	µg/L			20	<20	<20	<20	<20	<20	<20	<40	<20	<20		
C10-14 Fraction	µg/L			50	<50	<50	<50	<50	<50	<50	<50	<50	<50		
C15-28 Fraction	µg/L			100	<100	<100	<100	<100	<100	<100	<200	<100	<100		
C29-36 Fraction	µg/L			50	<50	<50	<50	<50	<50	<50	<200	<50	<50		
BTEX															
Benzene	µg/L			700	<1	<1	<1	<1	<1	<1	<0.5	<1	<1		
Toluene	µg/L			180	<2	<2	<2	<2	<2	<2	<0.5	<2	<2		
Ethyl Benzene	µg/L			5	<2	<2	<2	<2	<2	<2	<0.5	<2	<2		
m+p Xylene	µg/L			75	<2	<2	<2	<2	<2	<2	<1	<2	<2		
o Xylene	µg/L			350	<2	<2	<2	<2	<2	<2	<0.5	<2	<2		
Cyanide															
Free	µg/L			4	<4	<4	<4	<4	<4	<4	<4	<4	<4		
Total	µg/L			218	<4	<4	<4	<4	<4	<4	6	<4	<4		
Ammonia	µg/L				1610	1170	1300	2050	690	1130	1700	2100	800		
Phenol	µg/L			400	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0		
Sulfate	mg/L				538	380	386	494	263	373	300	281	256		

Cells with a green shade indicate that the trigger level associated with this result has not been exceeded														
Cells with a yellow shade indicates that the LOR is greater than the trigger value, and although undetected by the laboratory could exceed criteria														
Cells with a red shade indicate that the trigger level associated with this result has been exceeded														
Indicates no guideline specified (site specific or ANZECC)														
ID = Insufficient data to provide trigger value														
Bore KIWI														
	Reporting Units	95% Marine Waters ANZECC Trigger Level		EP Licence Trigger Level (Site specific)	13/06/2013	2/7/13 *Retest*	2/12/2013	6/06/2014	1/12/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017
		Sourced from CEMP	Sourced from OWMP											
EPA Point Number					22	22	22	22	22	22	22	22	22	22
Sample Number					06136903004	07136902001	12136902004	061410841004	121410481004	061510481010	121510481022	061610481020	121610481022	061710481020
Date of Sampling					13/06/2013	2/07/2013	2/12/2013	6/06/2014	1/12/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017
Time of Sampling					12:10	14:55	16:00	9:55	12:50	12:23	14:55	12:35	13:45	14:29
Sampler					K. Hawes	C. South	K. Hawes	K. Hawes	K. Hawes	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South
Groundwater Level	metres				1.49	1.41	1.30	1.53	1.89	1.21	1.86	1.54	1.84	1.62
Temperature	°C				19.2	22	18	16	19.25	18.1	21.4	19.5	23.3	18.2
Analyte														
pH	pH units	7.0-8.5	7.0-8.5		7.3		8.25	7.24	7.48	7.60	7.68	7.55	6.81	7.27
EC	µS/cm				854		879	1016	1116	843	821	801	980	1120
TDS	mg/L				504		550	606	718	470	530	571	678	753
TSS	mg/L				208		850	470	162	910	895	69	77	53
Metals - Dissolved														
Al	mg/L		ID		0.04		<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01
Cd	mg/L	0.0055			<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Co	mg/L		0.001		<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	mg/L		0.0013		<0.001		0.009	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pb	mg/L	0.0044			<0.001		0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn	mg/L	0.08	0.08		0.17		1.16	0.391	0.724	0.155	0.25	0.27	0.487	0.699
Ni	mg/L	0.07	0.07		0.001		0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.001	0.002
Zn	mg/L	0.015	0.015		0.046		0.006	0.032	0.007	0.005	<0.005	0.01	0.023	0.008
Fe	mg/L		ID		0.19		<0.05	0.11	0.23	0.18	<0.05	0.007	0.49	0.1
As III	µg/L	ID			<1		<1	<1	<2	<1	<0.5	<0.5	<0.5	2
Hg	mg/L	0.0004			<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Hexavalent Cr	mg/L	0.0044			<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.004	<0.01	<0.01
Cations - Dissolved														
Mg	mg/L		ID		15		12	10	13	12	12	11	14	21
Na	mg/L		ID		85		52	49	122	62	62	41	84	62
K	mg/L		ID		12		4	5	9	8	6	6.8	7	7

Cells with a green shade indicate that the trigger level associated with this result has not been exceeded Cells with a yellow shade indicates that the LOD is greater than the trigger value, and although undetected by the laboratory could exceed criteria Cells with a red shade indicate that the trigger level associated with this result has been exceeded Indicates no guideline specified (site specific or ANZECC) ID= Insufficient data to provide trigger value					Bore KIWI									
Reporting Units	95% Marine Waters ANZECC Trigger Level		EP Licence Trigger Level (Site specific)	13/06/2013	2/7/13 "Retest"	2/12/2013	6/06/2014	1/12/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017	
	Sourced from CEMP	Sourced from OVMWP												
PAH														
Polynuclear Aromatic Hydrocarbons - 16 analytes	µg/L	ID	2.2	<0.5		<1.0	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	
TPH														
C6-9 Fraction	µg/L		20	<20	<20	<20	<20	<20	<20	<20	<40	<20	<20	
C10-14 Fraction	µg/L		50	130	<50	<50	<50	<50	<50	<50	<50	<50	<50	
C15-28 Fraction	µg/L		100	<100	<100	<100	<100	<100	<100	<100	<200	<100	<100	
C29-36 Fraction	µg/L		50	<50	<50	<50	<50	<50	<50	<50	<200	<50	<50	
BTEX														
Benzene	µg/L		700	<1		<1	<1	<1	<1	<1	<0.5	<1	<1	
Toluene	µg/L		180	<2		<2	<2	<2	<2	<2	<0.5	<2	<2	
Ethyl Benzene	µg/L		5	<2		<2	<2	<2	<2	<2	<0.5	<2	<2	
m+p Xylene	µg/L		75	<2		<2	<2	<2	<2	<2	<1	<2	<2	
o Xylene	µg/L		350	<2		<2	<2	<2	<2	<2	<0.5	<2	<2	
Cyanide														
Free	µg/L		4	<4		<4	<4	<4	<4	<4	<4	<4	<4	
Total	µg/L		16.6	<4		<4	<4	<4	<4	<4	<4	<4	<4	
Ammonia	µg/L			0.11		250	140	350	70	200	210	360	60	
Phenol	µg/L		400	<1.0		<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	
Sulfate	mg/L			32		75	76	63	46	38	43	9	106	

Cells with a green shade indicate that the trigger level associated with this result has not been exceeded															
Cells with a yellow shade indicates that the LOR is greater than the trigger value, and although undetected by the laboratory could exceed criteria															
Cells with a red shade indicate that the trigger level associated with this result has been exceeded															
Indicates no guideline specified (site specific or ANZECC)															
ID= Insufficient data to provide trigger value															
Bore KIWI S															
Reporting Units	95% Marine Waters ANZECC Trigger Level		EP Licence Trigger Level (Site specific)	11/12/2012	13/06/2013	2/12/2013	6/06/2014	1/12/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017		
	Sourced from CEMP	Sourced from DVMP													
EPA Point Number				23	23	23	23	23	23	23	23	23	23		
Sample Number				12126902005	06136902005	12136902005	061410481005	121410481005	061510481011	121510481023	061610481021	121610481023	061710481021		
Date of Sampling				11/12/2012	13/06/2013	2/12/2013	6/06/2014	1/12/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017		
Time of Sampling				10:40	11:50	15:45	9:20	12:30	12:11	14:45	12:28	13:33	14:40		
Sampler				K. Hawes	K. Hawes	K. Hawes	K. Hawes	K. Hawes	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South	K. Hawes/C. South		
Groundwater Level	metres			2.40	2.13	2.52	2.47	2.54	1.99	2.54	2.52	2.19	2.44		
Temperature	°C			19.0	19.3	18.5	16.5	19.3	19.1	22.8	19.7	26.8	18.4		
Analyte															
pH	pH units	7.0-8.5	7.0-8.5	7.4	7.4	7.8	6.74	7.36	7.66	8.02	7.54	7.26	7.61		
EC	µS/cm			15250	17250	12490	15240	13210	16700	16200	15200	13500	14400		
TDS	mg/L			12000	10772	9163	10132	10189	39425	9034	7611	8382	7609		
TSS	mg/L			8	16	48	7	<5	5	24	7	<5	<5		
Metals - Dissolved															
Al	mg/L		ID	0.01	<0.01	0.02	<0.01	<0.01	0.01	<0.01	0.005	0.01	<0.01		
Cd	mg/L	0.0055		0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		
Co	mg/L		0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Cu	mg/L		0.0013	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Pb	mg/L	0.0044		0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Mn	mg/L	0.08	0.08	0.408	0.39	0.317	0.209	0.506	0.186	0.236	0.37	0.208	0.201		
Ni	mg/L	0.07	0.07	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Zn	mg/L	0.015	0.015	<0.005	<0.005	0.009	<0.005	<0.005	<0.005	<0.005	<0.005	0.021	<0.005		
Fe	mg/L		ID	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.016	<0.05	<0.05		
As III	µg/L	ID		<5	<2	<1	<1	<1	<1	<0.5	<0.5	<1.0	<0.5		
Hg	mg/L	0.0004		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		
Hexavalent Cr	mg/L	0.0044		<0.010	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.004	<0.01	<0.01		
Cations - Dissolved															
Mg	mg/L		ID	177	158	125	142	135	142	148	140	137	92		
Na	mg/L		ID	3830	3530	2600	2860	2930	3060	2850	2800	2500	2400		
K	mg/L		ID	199	174	136	146	152	143	129	170	120	128		

Cells with a green shade indicate that the trigger level associated with this result has not been exceeded.															
Cells with a yellow shade indicates that the LOR is greater than the trigger value, and although undetected by the laboratory could exceed criteria.															
Cells with a red shade indicate that the trigger level associated with this result has been exceeded.															
Indicates no guideline specified (site specific or ANZECC)															
ID= Insufficient data to provide trigger value															
					Bore K1W1 S										
	Reporting Units	35% Marine Waters ANZECC Trigger Level		EP Licence Trigger Level (Site specific)	11/12/2012	13/06/2013	2/12/2013	6/06/2014	1/12/2014	18/06/2015	7/12/2015	2/06/2016	5/12/2016	6/06/2017	
		Sourced from CEMP	Sourced from DWMP												
PAH															
Polynuclear Aromatic Hydrocarbons - 16 analytes	µg/L		ID	1.5	<0.5	<0.5	<1.0	<1.0	<0.5	<0.5	<0.5	<1	<0.5	<0.5	
TPH															
C6-9 Fraction	µg/L			20	<20	<20	<20	<20	<20	<20	<20	<40	<20	<20	
C10-14 Fraction	µg/L			50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	
C15-28 Fraction	µg/L			100	<100	<100	<100	<100	<100	<100	<100	<200	<100	<100	
C29-36 Fraction	µg/L			50	<50	<50	<50	<50	<50	<50	<50	<200	<50	<50	
BTEX															
Benzene	µg/L			700	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	
Toluene	µg/L			180	<2	<2	<2	<2	<2	<2	<2	<0.5	<2	<2	
Ethyl Benzene	µg/L			5	<2	<2	<2	<2	<2	<2	<2	<0.5	<2	<2	
m+p Xylene	µg/L			75	<2	<2	<2	<2	<2	<2	<2	<1	<2	<2	
o Xylene	µg/L			350	<2	<2	<2	<2	<2	<2	<2	<0.5	<2	<2	
Cyanide															
Free	µg/L			4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	
Total	µg/L			75.6	5	<4	<4	<4	<4	<4	<4	5	<4	<4	
Ammonia	µg/L				6110	5360	5840	5560	5830	5690	5860	5900	5300	5830	
Phenol	µg/L			400	<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	
Sulfate	mg/L				682	567	472	485	493	435	430	410	338	416	

APPENDIX 5

CHEMP QUARTERLY REPORTS AND MINUTES

Compensatory Habitat and Ecological Monitoring Program – Quarterly Report

DATE: 6 July 2016

AUTHOR: Philip Reid (NCIG), Alex Callen, Michael Mahony, John Clulow (Uni of Newcastle), Kleinfelder Consulting, Tim Mouton (Wetland Care Australia)

APPROVAL: Nathan Juchau

INTRODUCTION

This report provides an update of activities relating to the NCIG Compensatory Habitat and Ecological Monitoring Program since the previous Quarterly Report from April 2016. The report aims to provide information on key components of the program and how these are being implemented. An update will be provided to members of the Consultative Board every 3 months, in the form of a Quarterly report and presentations (every 6 months) coinciding with Board Meetings.

1. Research Area Ponds and Associated Monitoring (Alex Callen)

There is no further update on the Trial Site since the April report, as stated previously, the local Trial Site population had dropped noticeably during the last summer season, with the population estimated at approximately 21 Adults in February 2016. Subsequently, a small number of metamorphs (121) were released in the Trial Site during March that were remaining from experimental work in the laboratory.

Alex Callen concluded the fieldwork component of her PhD research project in June, which is the end of her formal engagement with NCIG. Alex will spend the coming months writing her thesis, which will be based on results and observations gained from the Trial Site over the past 3.5 years.

2. Annual Kooragang Island Green and Golden Bell Frog Monitoring (Michael Mahony)

As discussed in the previous quarterly report, monitoring of the industrial area of Kooragang was conducted during the 2015/16 summer season. This included two (2) monitoring events (revised down from three due to access limitations), and took place at multiple water bodies across the industrial part of Kooragang Island and some areas of Ash Island (southern end near the Kooragang Main Rail Line). The 2015/16 monitoring has been jointly-funded by NCIG, Port Waratah Coal Services and the Hunter Development Corporation, due to potential impacts from future capping of the former Kooragang Island Waste Emplacement Facility (KIWEF).

Results from the monitoring indicate a 'raw count' population size (individuals that are known to be alive) of 1,021 frogs. This number will be refined using capture-mark-recapture data over the monitoring period and ecological modelling. This and discussion points will be made in a final report from the university which will be finalised this month.

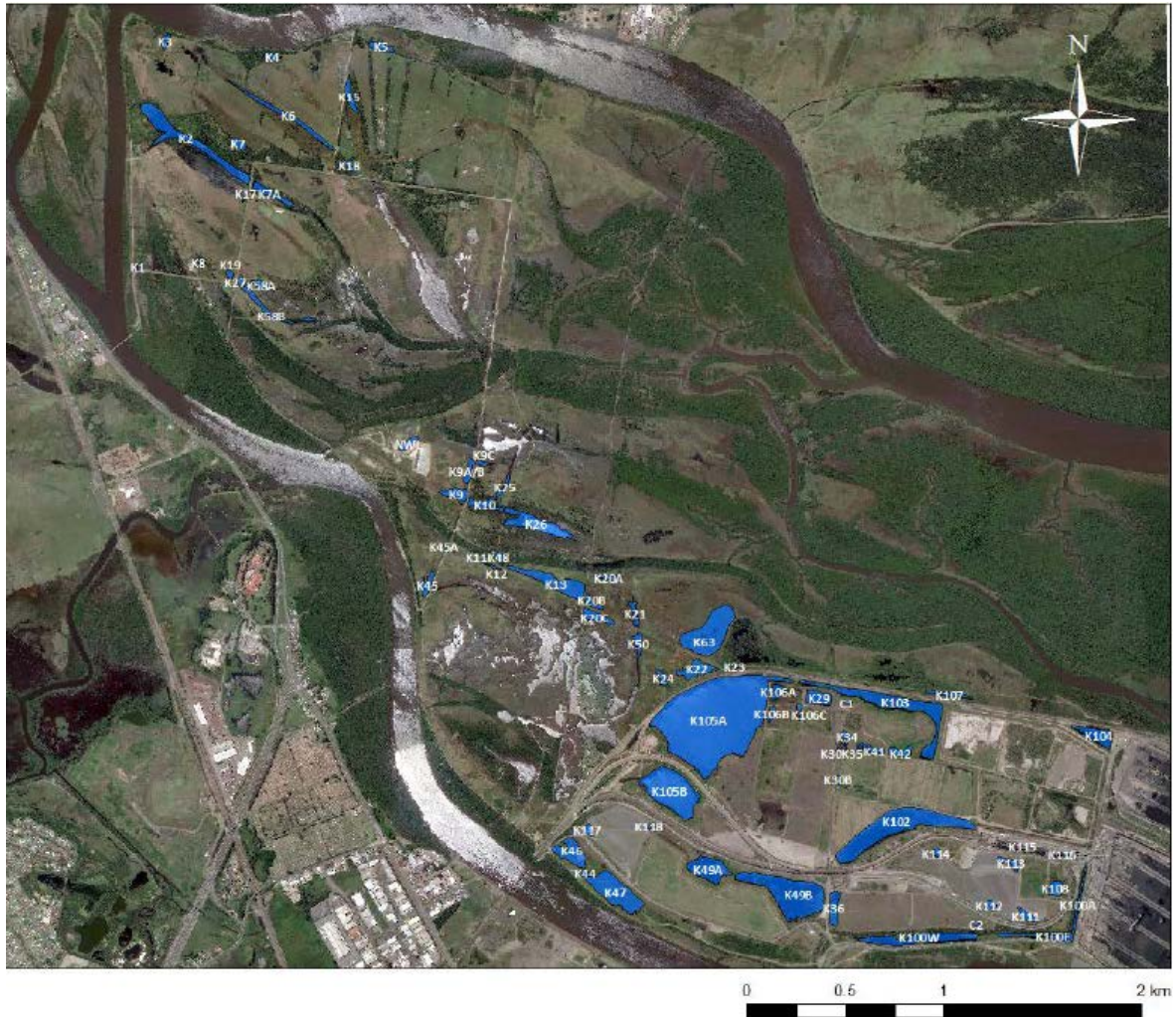


Table 3-1 – Release of Green and Golden Bell Frog (*L. aurea*) tadpoles and metamorphs by month into NCIG compensatory habitat, Ash Island, for the summer of 2015/2016.

Year/Month	Tadpoles released	Metamorphs released
2015/October	400	
2015/November	150	
2015/December	3514	1100
2016/January	1050	2326
2016/February	745	309
2016/March	1079	45
Sub-totals	6938	3780
Total released	10718	

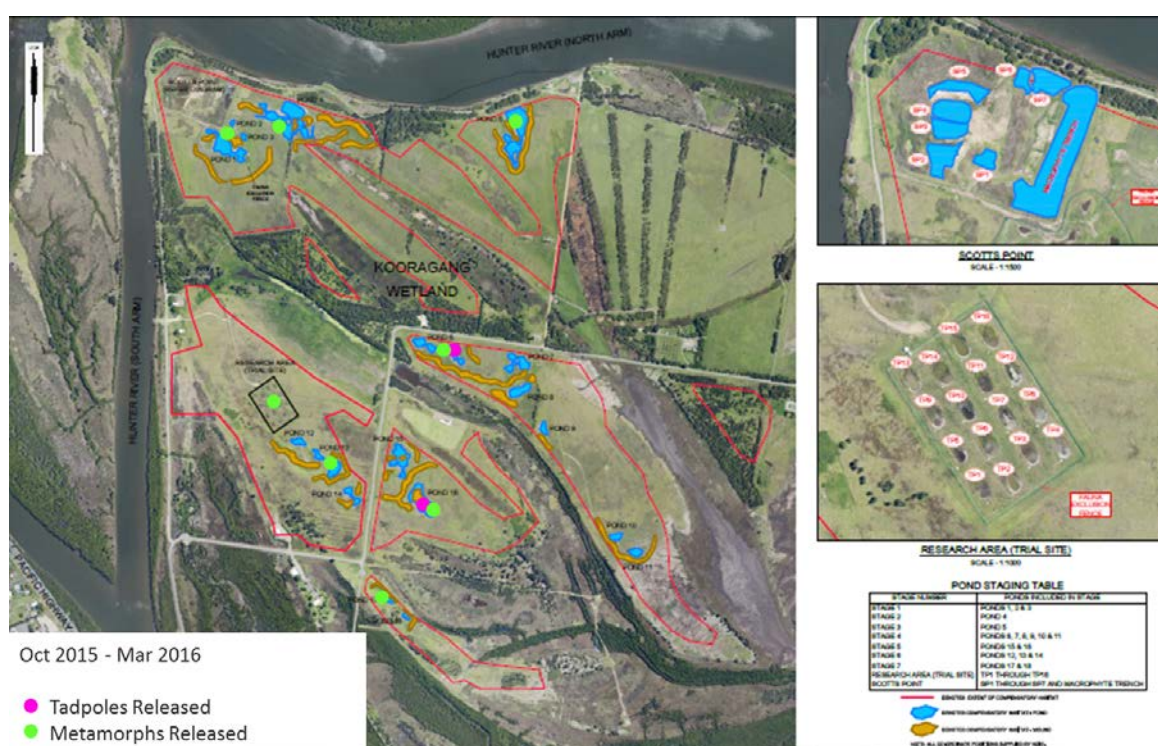


Figure 2: Captive-bred Green and Golden Bell Frog Release Sites

Captive breeding and release of animals into the NCIG Compensatory Habitat is schedule for the 2016/17 season.

4. Green and Golden Bell Frog Compensatory Habitat

4.1. Green and Golden Bell Frog Compensatory Habitat Monitoring

4.1.1. Overview

Major summer rainfall occurred in the lower Hunter region in early and mid-January 2016, and resulted in a total that almost doubled the long-term monthly average. All of the wetlands of the NCIG Compensatory Habitat were fully charged and many of the “permanent” and “ephemeral” wetlands became

interconnected. At the same time other permanent and ephemeral wetlands in the local area were also recharged, and there was significant overland or surface flow that connected many of the wetlands. Major summer rains combined with daily average temperatures above 20°C are considered to be ideal for breeding of the Bell Frog. This was the case in the population of Bell Frogs on Kooragang Island to the east of the NCIG Compensatory Habitat Area, where choruses of adult males and dispersal of adults to ephemeral wetlands that were flooded at this time were observed. This aim of this report is to provide a summary of the observations made during January, February and March 2016 in the NCIG Compensatory Habitat Area.

4.1.2. Materials and Methods

Details of the monitoring methodology were provided in the previous Quarterly Report.

4.1.3. Results

Frog Surveys: Choruses of adult male bell frogs were detected at twelve of the NCIG Compensatory Wetlands (Table 4-1). In the period between the 8th and 22nd of January a total of 23 adult males and 9 females were observed. Observations of adults were restricted to wetlands in stages 4, 5 and 7 (Tables 4-1 and 4-2). The survey effort was equivalent in all wetlands and was based on a standardised habitat search. Large wetlands take proportionally longer to survey than smaller wetlands. Surveys in wetlands in stages 1, 2, 3 and 6 did not result in the detection of any adults, and no choruses were heard in wetlands in these stages over the period of surveys. Aural surveys are conducted at the time of visual encounter surveys using direct listening and response to call playback. These techniques are known to be effective in detecting calling males. Because the male call carries up to 50 metres on a still night, it is often possible to hear males calling in wetlands away from the location of survey, and we consider that in such circumstance that all calling activity would be detected in the precinct that encompasses the NCIG Compensatory Habitat Wetland. Once calling was heard an active search of the habitat was conducted and call playback employed. Thus we are confident that the sites where calling occurred represent the only sites where male bells frogs were actively calling.

Examination of the wetland locations where calling was detected reveals that activity was focused in the southern and central region of the NCIG Compensatory Habitat.

Demography of the adults collected show that the population consists largely of first year males and females (< 12 months since metamorphosis)(see Figures 3 and 4). The number of males observed was larger than the number of females, but this most likely reflects the fact that males are more easily detected than females rather than a real difference in the sex ratio. It is also likely that females under the age of 12 months are dispersed in the habitat and not found around wetlands. The age-class structure is a significant feature since only second year females (12 to 24+ months) are reproductive, and the observations are that there are few adults in this category in the system.

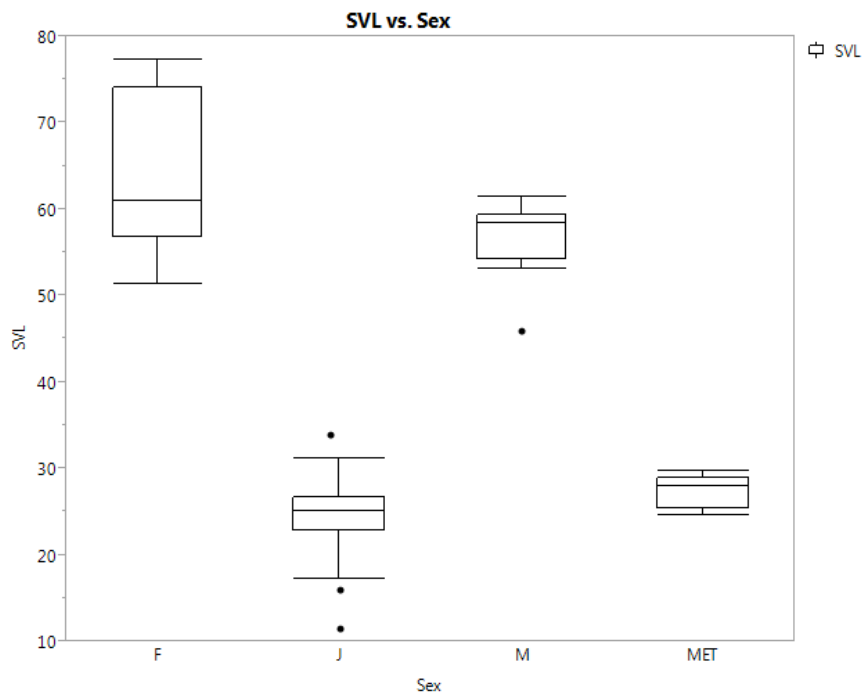


Figure 3. Graph of body length (SVL) for age and gender classes, of bell frogs collected in the precinct of the NCIG Compensatory Habitat Wetlands.

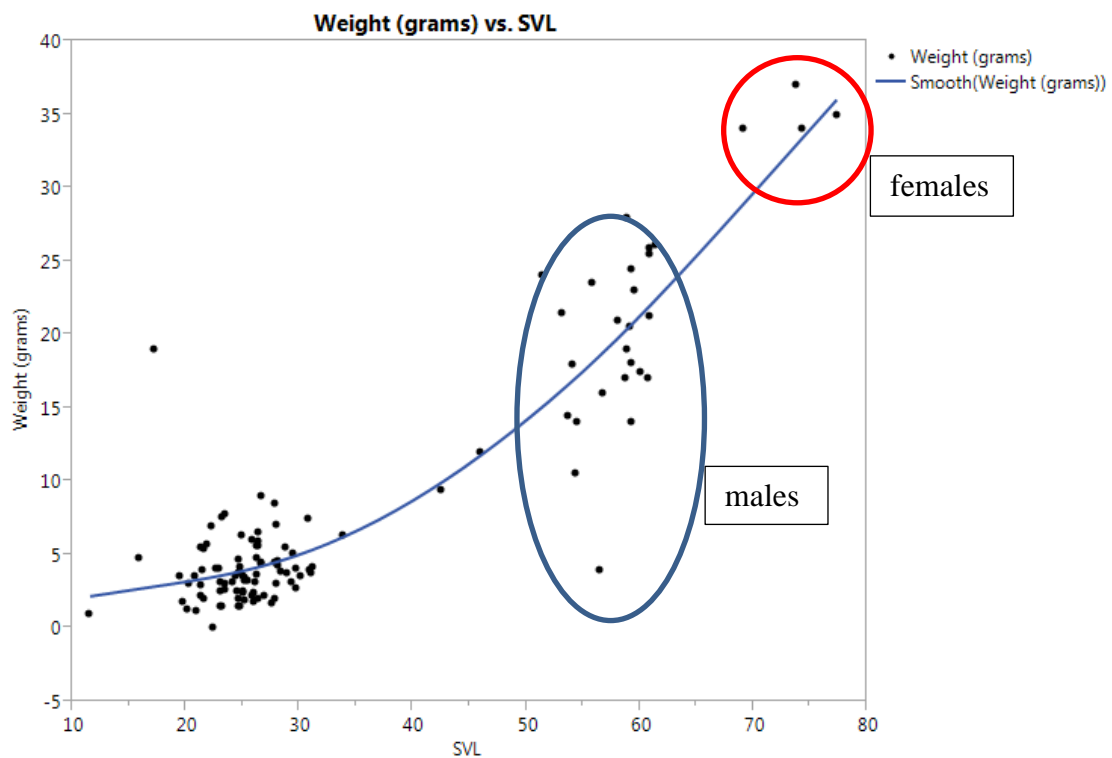


Figure 4. Graph of body length (SVL) against body weight for all bell frogs collect in the precinct of the NCIG Compensatory Habitat Wetlands. The juveniles are at the lower left , adult males in the middle and females at the top right.

Tadpoles and Metamorph Surveys: No bell frog tadpoles were detected in surveys conducted across all the NCIG Compensatory Habitat Wetlands prior to the rainfall in early January.

Tadpole surveys were conducted in all wetlands in February 2016 in the time period 4 to 8 weeks after the rainfall in January. Bell frog tadpoles and metamorphs were detected in two wetlands, K7A and K27, which are adjacent to the NCIG Compensatory Wetlands stages 4 and 7 respectively. No tadpoles or metamorphs were detected in the NCIG Compensatory Habitat Wetlands. Geographical presentation of the frog, metamorph and tadpole monitoring results is shown in Figure 5.

Tables 4-1 and 4-2. Occurrence of calling male Green and Golden Bell Frogs in the NCIG Compensatory Habitat Wetlands, wetland location of calling and dates and numbers of calling males and females observed in January and February 2016.

Wetland Stage (Pond Number)	January 2016	February 2016
4-1	Calling	Calling
4-2	Calling	Calling
4-3	Calling	Calling
4-5	Calling	
4-7	Calling	
4-9	Calling	
4-10	Calling	Calling
4-11	Calling	Calling
5-1	Calling	Calling
7-1	Calling	Calling
7-2		Calling
7-3	Calling	

Date	Number of Males	Number of Females
8/1/16	3	
11/1/16	5	
13/1/16	7	3
15/1/16	3	2
16/1/16	2	2
22/1/16	2	2

Bell Frog chorusing and subsequently tadpoles and metamorphs were detected in ephemeral wetlands adjacent to the NCIG stage 4 wetlands, and stage 7 wetlands (Table 4-3). In both cases adult males were observed calling in the constructed wetlands, with breeding confirmed in the adjacent ephemeral wetlands.

Table 4-3. Observations of Green and Golden Bell Frog breeding on the western end of Kooragang Island in January 2016

Wetland Stage (Pond Number)	January 2016	February 2016	Observations
K7A Adjacent to but outside the NCIG Stage 4	Calling & Breeding	Tadpoles observed (late February)	Breeding occurred in the small ephemeral swales adjacent to the larger wetland that has a saline (tidal) influence to the east.
K27 (K58A, K58B) Adjacent to but outside the NCIG Stage 7	Calling & Breeding	Tadpoles and metamorphs observed (late February)	Breeding occurred in the small ephemeral swale adjacent to the constructed wetlands. The swale has a distinct saline influence as evidenced by its plant community.

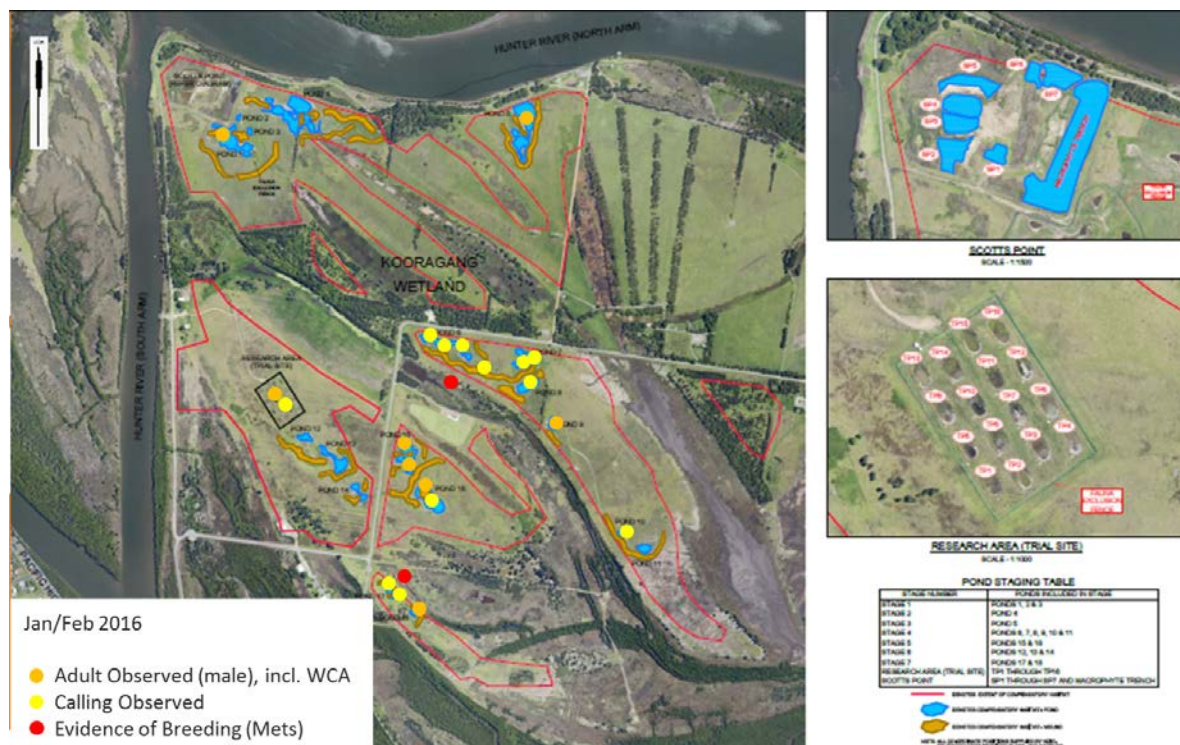


Figure 5: Green and Golden Bell Frog, Metamorph and Tadpole Survey Results (including Wetland Care Australia observations)

Gambusia surveys: The invasive fish the Plague Minnow (also commonly called the Mosquito Fish)(*Gambusia holbrooki*) was found at over 80% of the NCIG Compensatory Habitat Wetlands. This fish was also found to occur in several of the natural wetlands and ephemeral swales (salt marshes and flooded meadows) in the local area. Abundance or density of the fish and the stages of development varied considerable among wetlands. In several of the permanent wetlands the development class structure of the population was composed of mature adults males and females, with a smaller number of juveniles and sub-adults, and in

these cases the density of fish was high. In several of the ephemeral wetlands the population was dominated by sub-adults and juveniles with a fewer adults, and the density was low.

Repeated *Gambusia* surveys were conducted across all ponds within the 7 stages of the compensatory habitat in preparation for the first tadpole releases in October 2015. Only Stage 5 was completely devoid of *Gambusia*, although in some other stages, there were isolated ponds that avoided inundation in the April storms, and as such, were *Gambusia* free in the October monitoring round. All ponds in Stages 2 and 7 were colonised with *Gambusia*, as were most ponds in stages 1 and 3 (4 of 5 ponds and 3 of 4 ponds respectively). Eight of the 11 ponds in Stage 4 and 1 of 4 ponds in Stage 6 also contained *Gambusia*.

4.1.4. Discussion

Choruses of Bell frogs were observed in three wetlands in two of the wetland stages during surveys in January and February of 2016. The choruses were observed in wetlands in Stages 4, 5 and 7. In total calling was observed in 8 of the 11 wetlands in stage 4, one in stage 5 and three in stage 7. A total of 22 males were observed calling and 9 females were observed in these wetlands at the same time. These are minimum numbers of adults, since they were individuals that were caught and marked, and not all individuals are encountered in surveys. Adult bell frogs were not observed in any of the wetlands in stages 1, 2, 3 and 6 despite equivalent survey effort to that where the frogs were observed. We are confident that this pattern of wetland occupancy reflects the reality of the situation across the two month period when bell frogs were most active following the charging of the wetlands.

An observation that comes from the two breeding events that were recorded, is that they were in ephemeral wetlands that have a short hydroperiod (i.e. less than 8 weeks, e.g. wetlands K27 and K7A), and have a vegetation community that is indicative of a salt influence. Both are identified from historical aerial photographs as being from salt swales. Another important observation is that the adult bell frogs make use of the more permanent wetlands created by the compensatory habitat, migrate into the swales to breed, and once that has occurred they migrate back to the more permanent wetlands. This is a clear example of the use of a mosaic habitat structure in the life cycle of the bell frog, and is a feature that has previously been identified.

Although no breeding was observed in the NCIG Compensatory Habitat Wetlands it is likely that no breeding would have occurred on the western end of the island and in the precinct of the NCIG Compensatory Wetlands without the occurrence of permanent freshwater bodies that the compensatory wetlands provide, and the release over a period of two years of bell frog tadpoles / metamorphs to the area/precinct. There is direct evidence that the more permanent freshwater wetlands are providing important foraging and sheltering habitat for the bell frog, and that the mosaic of the wetlands provides for connectivity in the landscape. What is less easy to understand is why the adult frogs make a choice of highly ephemeral wetlands (i.e. < 8 weeks hydroperiod) for breeding. Biological

explanations for such life history strategies focus on the advantages that ephemeral situations have with respect to few predators and competitors, and high levels of nutrients. On Kooragang Island two other features that are potentially linked to bell frog survival can be added; the occurrence of some level of salinity which may infer an advantage over the amphibian disease pathogen chytrid, and a high average water temperature which promotes rapid tadpole growth and development. Balanced against these advantages is the need for rapid development to prevent desiccation and failure to metamorphose if the hydroperiod is too short.

The occurrence of male choruses also signifies that there are adult males in the ecosystem, and provides information about survival of individuals to the adult stage. The age class structure of the adults collected (see Tables 4-1 and 4-2 and Figures 3 and 4) shows that most of the adults were in the first year of their life. There are three possible means by which the males observed in the chorus can be accounted for. Firstly, and most likely, these males are the offspring of breeding observed in the Compensatory Habitat and natural habitats in 2015, or tadpoles released to the Compensatory Habitat in 2015 and possibly a small number from 2014. Secondly they may be offspring and/or escapees from the Trial Site that emigrated prior to being caught for microchipping. Thirdly they may be individuals that have migrated from further east on Ash/Kooragang Island. If either of the first two explanations is correct the captive breeding program has been successful in reintroducing a population of bell frogs to the western portion of Ash Island.

The number of adult females observed was less than males although the numbers of females did increase towards the end of the activity period. It is likely that the adult sex ratio is equal (50:50) and that there is no differential mortality between the sexes. Therefore the lower number of females is likely to reflect unequal detection. This can be explained by the observation that females are not occupying habitat at the wetlands (edge or emergent vegetation), and it may be that pre-reproductive females avoid these habitats so that they are not mobbed by male frogs. If there is not a differential mortality then the number of adult females should be equivalent to the number of males and therefore there should be about the same number as there are males. However, it is the number of second year females that are important in terms of reproduction (body length > 72 mm), and only five females in this age class were detected.

Further information regarding monitoring of the Green and Golden Bell Frog Compensatory Habitat can be found in Appendix A.

4.2. Compensatory Habitat Management

Monitoring and management of compensatory habitat continued during the reporting period in accordance with the approved Green and Golden Bell Frog Compensatory Habitat Management Plan. Work during the reporting period has been conducted by Wetland Care Australia (WCA) and includes:

- Pond inspections, including visual inspections, photo points, water quality monitoring and monitoring for evidence of pests

- Slashing around frog fence in Stage 1
- Weed sweep targeting priority weeds

A copy of the May monitoring and maintenance report is provided in Appendix B.

A modification was made to the NCIG Green and Golden Bell Frog Compensatory Habitat Management Plan to address proposed shaping of bunds around aquatic habitat and use of agents (eg. Rotenone or lime) to manage *Gambusia*. The purpose of the bunding is to exclude constructed aquatic habitat from surrounding surface water during flood events, which carries *Gambusia*. For this to be effective, ponds would need to be pumped out (already allowed for in the management plan) and dosed with an agent, for example a piscicide, targeting *Gambusia*. This is required as the majority of NCIG aquatic habitat has become infested with *Gambusia* during flood events in April 2015 and January 2016.

This modification to the management plan was subsequently determined to be permissible by NPWS in June, providing relevant regulatory approvals were obtained for use of Rontene. Creation of bunds commenced in June with the Trial Site and Stage 7 complete (see Plate 1) and Stages 1, 4 and 5 scheduled to be done in early July. The opportunity will also be used to create minor scrapings in mounds and elevated areas for marginal ephemeral aquatic habitat, observed to be favourable breeding habitat across the island during the 2015/16 season.



Plate 1: Creation of Bunds around Stage 7 Ponds to control *Gambusia*

5. Shorebird Compensatory Habitat

5.1. Migratory Shorebird Habitat Construction

It was reported in the previous quarterly report that early works for the Migratory Shorebird Habitat Construction Project commenced in April. Construction works

commenced in full in May, including removal of mangroves. Mangrove removal work has continued throughout the period, with approximately 70% of mangroves removed to date. Figure 6 provides a geographical presentation of mangrove removal, including Phase 1 (tree felling) and Phase 2 (trimming of stumps and pneumatophores). The following photos provide a visual representation of the mangrove removal process to date.



Figure 6: Mangrove Removal Works Area (current as at 23/6/16)



Plate 2: Competency training for manual removal crews



Plate 3: Long reach excavator removing mangroves with hydraulic shear



Plate 4: Hydraulic shear attachment removing mangroves



Plate 5: Positrack removing mangroves with hydraulic shear



Plate 6: Ride-on mower used to complete Phase 2 clearing



Plate 7: Completed Phase 2 clearing area



Plate 8: Mulcher used for mulching felled mangroves



Plate 9: Forestry saws with different sawing implements



Plate 10: Forestry saw being used for Phase 2 clearing



Plate 11: Chainsaw being used for Phase 1 clearing



Plate 12: "Bog mats" used by trucks for accessing felled trees



Plate 13: Utilisation of drop boards at Fish Fry Creek to manipulate tide level in work zone



Plate 14: NPWS delegation visiting site



Plate 15: Remaining dead mangroves in Fish Fry Flats to be removed



Plate 16: Oblique aerial image, Fish Fry Flats (30/5/16)



Plate 17: Comparison photos, Area E – September 2015 (top) and June 2016 (bottom)



Plate 18: Technical Advisory Group (Will Glamore, Phil Straw, Arthur White)



Plate 19: Excavator and positrack removing felled mangroves



Plate 20: Phase 2 cleared area, eastern end of Wader Creek



Plate 21: Spoonbills utilising Fish Fry Creek

Design and commissioning of the Smart Gate and Mangrove Propagule Exclusion Device (MPED) continued throughout the period. The preferred supplier (AWMA) was chosen and discussions continue to refine the design in consultation with Dr Will Glamore.

6. Shorebird Monitoring

6.1. Overview

Kleinfelder was engaged by NCIG to monitor bird activity at Swan Pond and Fish Fry Flats during the mangrove removal works to determine if the activity is having a negative impact on birds within the immediate area. This monitoring continues on from shorebird monitoring conducted by Avifauna Consulting prior to habitat construction.

6.2. Methods

Bird counts were undertaken one morning per week by a qualified ecologist following the ecological pre-clearance inspections of the mangroves within the mangrove removal area. Bird counts commenced for half an hour between 7:00 am and 10:00 am. All birds observed foraging or roosting on the water, ground, or in trees, or flying over or Swan Pond and Fish Fry Flats were recorded.

6.3. Results

The number of individual birds counted at Swan Pond showed considerable variation from week to week (Figure 6). The total number of individuals recorded in the last three weeks was about half that recorded in the first three weeks of mangrove removal works, driven mainly by a reduction in the numbers of wading birds recorded. During the first three weeks of survey large numbers of Red-necked Avocets (*Recurvirostra novaehollandiae*) and Black-winged Stilts (*Himantopus himantopus*) were observed throughout Swan Pond.

A possible cause for the decline in the recorded numbers of wading birds is the timing of the survey. The availability of prey to wading birds is dependent on the tides, which will determine their distribution within the estuary. Surveys were conducted in the morning after conducting a pre-clearance inspection of the mangrove removal area, and not necessarily at the same tidal level. Therefore the lower numbers could be a result of survey times and foraging behaviour rather than disturbance caused by the activity. Additionally other factors such as strong winds and heavy rainfall in the region will also influence the distribution of waders within the estuary.

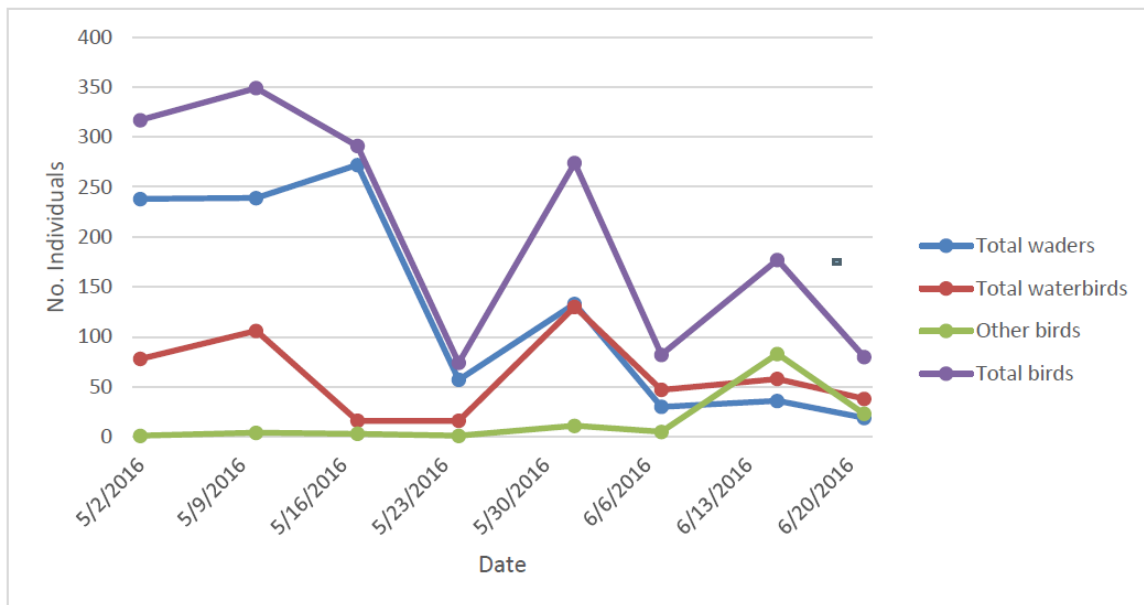


Figure 6: Number of individual waders, water birds and other species counted at Swan Pond during each monitoring event.

The number of individual birds counted at Fish Fry Flats also varied from week to week (Figure 7). No general pattern of decline can be seen in the Fish Fry Flats bird counts. However, after weeks of fluctuation, there was a decrease in the number of waterbirds recorded. This may be a result of the disturbance caused by mangrove removal works within the area. Continued monitoring will determine any long-term impacts resulting from the clearing activities.

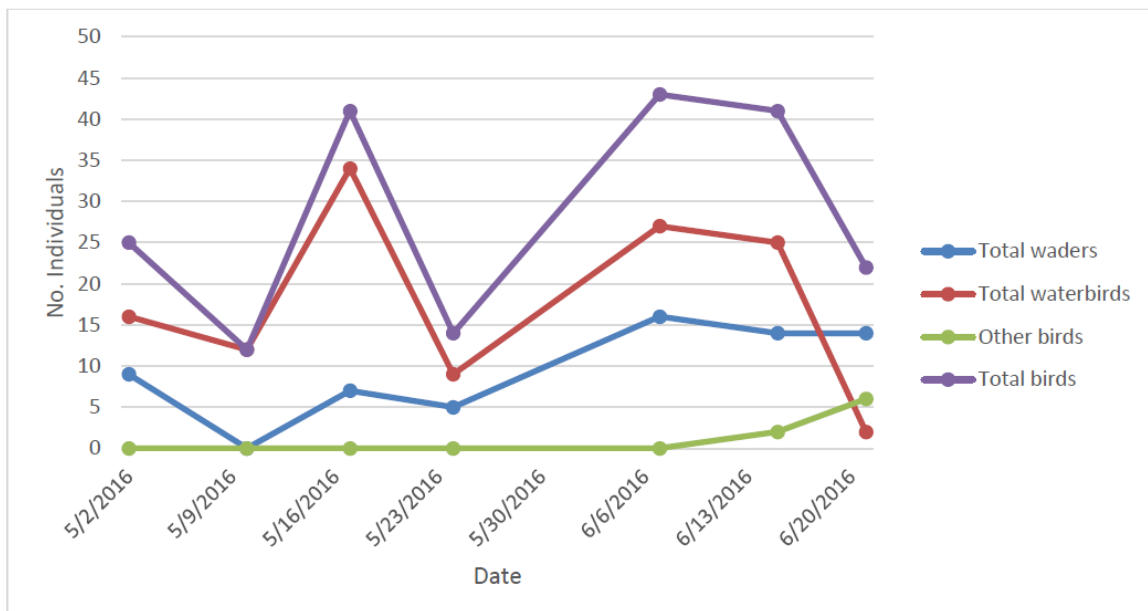


Figure 7: Number of individual waders, water birds and other species counted at Fish Fry Flats during each monitoring event.

The numbers of species observed each week at both Swan Pond (Figure 8) and Fish Fry Flats (Figure 9) remained generally constant, despite some slight variation.

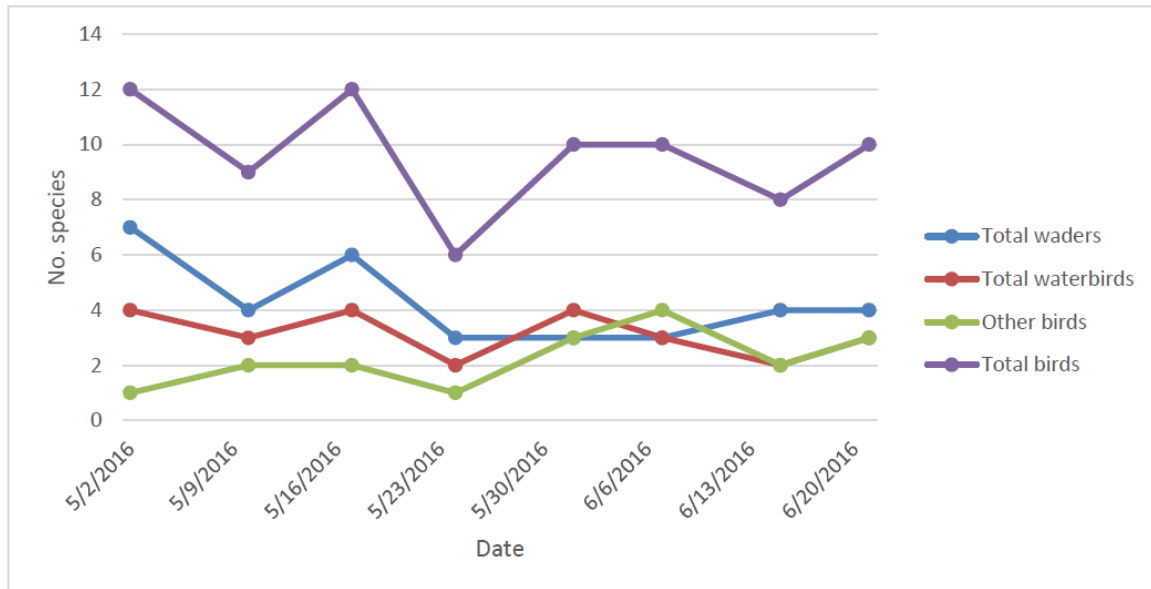


Figure 8: Number of wader, waterbird and other species recorded at Swan Pond during each monitoring event.

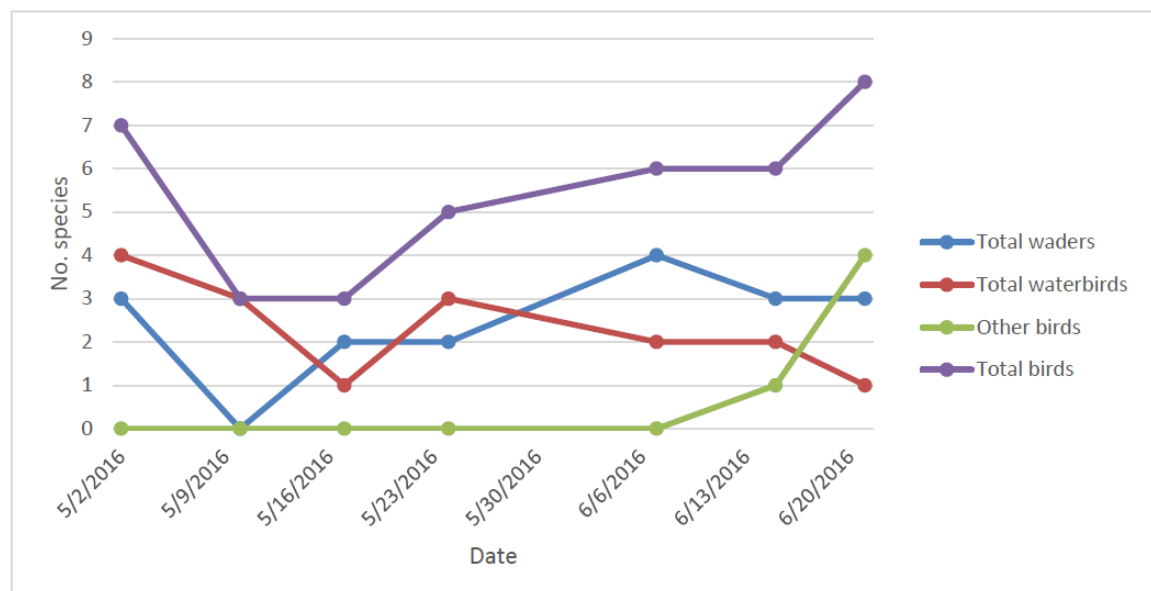


Figure 9: Number of wader, waterbird and other species recorded at Fish Fry Flats during each monitoring event.

The complete report, including full species list and counts can be found in Appendix C.

7. NCIG Compensatory Habitat Schedule

A copy of the NCIG Compensatory Habitat Schedule of Works for Migratory Shorebirds is provided as part of this report. This has been updated to reflect construction timing updated during the works.

ID	Task Name	Duration	Start	Finish	Predecessors	Qtr 1, 2016			Qtr 2, 2016			Qtr 3, 2016			Qtr 4, 2016					
						Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
0	NCIG Shorebirds Compensatory Habitat	195 days	Mon 8/02/16	Fri 4/11/16		Shorebirds Compensatory Habitat 4/11														
1	Procure Tree Shear and Winch	0 wks	Mon 8/02/16	Mon 8/02/16		8/02 Procure Tree Shear and Winch														
2	Delivery and Commissioning/Compliance	8 wks	Mon 8/02/16	Fri 1/04/16	1	Delivery and Commissioning/Compliance 1/04														
3	Project Management Plans	10 days	Wed 17/02/16	Tue 1/03/16		Project Management Plans 1/03														
4	Submission of Robson Project Management Plans / CEMP	0 days	Fri 19/02/16	Fri 19/02/16		19/02 Submission of Robson Project Management Plans / CEMP														
5	NCIG Approval Of PMP's and CEMP	1 wk	Fri 19/02/16	Thu 25/02/16	4	NCIG Approval Of PMP's and CEMP 25/02														
6	Robson Final submission of PMP's and CEMP	3 days	Fri 26/02/16	Tue 1/03/16	5	Robson Final submission of PMP's and CEMP 1/03														
7	BBRA	0 days	Wed 17/02/16	Wed 17/02/16		17/02 BBRA														
8	Site Establishment	21 days	Mon 4/04/16	Mon 2/05/16		Site Establishment 2/05														
9	Early Mobilisation to Site	4 days	Mon 4/04/16	Thu 7/04/16		Early Mobilisation to Site 7/04														
10	Maintain and Upgrade Access Tracks	5 days	Fri 8/04/16	Thu 14/04/16	9	Maintain and Upgrade Access Tracks 14/04														
11	Deliniate Sensitive Zones (NO-GO Zones)	5 days	Fri 15/04/16	Thu 21/04/16	10	Deliniate Sensitive Zones (NO-GO Zones) 21/04														
12	Slash Kikuyu Paddock in preparation for Mulch Laydown	4 days	Fri 22/04/16	Wed 27/04/16	11	Slash Kikuyu Paddock in preparation for Mulch Laydown 27/04														
13	Install Erosion And Sediment Controls	3 days	Thu 28/04/16	Mon 2/05/16	12	Install Erosion And Sediment Controls 2/05														
14	Mangrove Removal Works (2500m2/day)	99 days	Tue 3/05/16	Fri 16/09/16		Mangrove Removal Works (2500m2/day) 16/09														
15	Mechanical Removal	89 days	Tue 3/05/16	Fri 2/09/16	13	Mechanical Removal 2/09														
16	Manual Removal	89 days	Tue 3/05/16	Fri 2/09/16	15SS	Manual Removal 2/09														
17	Mulching mangrove stockpile	7 days	Thu 8/09/16	Fri 16/09/16	16FF+2 wks	Mulching mangrove stockpile 16/09														
18	Smartgate System	165 days	Mon 7/03/16	Fri 21/10/16		Smartgate System 21/10														
19	Procurement of Smart Gate	30 wks	Mon 7/03/16	Fri 30/09/16		Procurement of Smart Gate 30/09														
20	Install Smart Gate	2 wks	Mon 3/10/16	Fri 14/10/16	19	Install Smart Gate 14/10														
21	Commision Smartgate	1 wk	Mon 17/10/16	Fri 21/10/16	20	Commision Smartgate 21/10														
22	Magrove Seed Control Screen	155 days	Mon 7/03/16	Fri 7/10/16		Magrove Seed Control Screen 7/10														
23	Procurement Of Mangrove Seed Control Screen	30 wks	Mon 7/03/16	Fri 30/09/16		Procurement Of Mangrove Seed Control Screen 30/09														
24	Install Mangrove Seed Control Screen	1 wk	Mon 3/10/16	Fri 7/10/16	23	Install Mangrove Seed Control Screen 7/10														
25	Contingency	2 wks	Mon 24/10/16	Fri 4/11/16	14,18,22	Contingency 4/11														

Project: NCIG Shorebirds Compensato
Date: Tue 5/07/16

Task		Rolled Up Progress		Inactive Task		Manual Summary Rollup		Critical Split	
Milestone		Split		Inactive Milestone		Manual Summary		Progress	
Summary		External Tasks		Inactive Summary		Start-only		Deadline	
Rolled Up Task		Project Summary		Manual Task		Finish-only			
Rolled Up Milestone		Group By Summary		Duration-only		Critical			

Appendix A – Green and Golden Bell Frog Compensatory Habitat Monitoring and Research Report Data (University of Newcastle).

Table 1. Dip-net and water quality surveys of the NCIG Compensatory Habitat Wetlands in September and October 2015. These surveys were conducted to assess the suitability of wetlands for prospective release of captive breed tadpoles and metamorphs. *Gambusia* were observed in wetlands in all stages, except stage 5, and high densities were observed in wetlands in stages 1, 2, 3, and 4, with lower densities in stages 6 and 7. Water quality was considered suitable (i.e. within the known threshold ranges for Green and Golden bell frog eggs and tadpoles). Abbreviations: Temperature Co– T; Dissolved Oxygen – DO; Salinity% – Sal%; Ephemeral waterbody – Eph.

Date	Stage	Pond	T	DO	Sal %	pH	Depth	Eph	Breed	Dipnet
2015										
26/09/2015	1	1 (1-1)	17.2	15.3	1.92	8.47	1.4			<i>Gambusia</i>
26/09/2015	1	2 (1-2)	16.4	11.26	1.06	7.47	0.2			<i>Gambusia</i>
26/09/2015	1	3 (1-3)	16	13.24	1.28	7.85	0.4			<i>Gambusia</i>
26/09/2015	1	1b (1-4)	17.6	12.22	1.8	8.27	1.0			<i>Gambusia</i>
26/09/2015	1	1a (1-5)	16.6	12.18	1.71	8.19	0.0			1 <i>Lim peroni</i> tad
3/10/2015	2	4a (2-1)	22.6	9.6	1.76	7.64	0.2			<i>Gambusia</i>
3/10/2015	2	4 (2-2)	22.7	8.08	1.63	5.59	1.4			<i>Gambusia</i> large fish,
3/10/2015	2	4b (2-3)	24.1	7.25	1.52	5.86	0.4			<i>Gambusia</i>
3/10/2015	2	4d (2-4)	23.7	7.59	1.37	6.07	0.2			0
3/10/2015	2	4c (2-5)	23.6	10.47	1.3	6.26	1.4			<i>Gambusia</i>
26/09/2015	3	5 (3-3)	17.9	11.98	1.74	9.13	1.4			1 <i>Crinia</i> signifera tad,
26/09/2015	3	5a (3-1, 3-2)	16.6	15.66	1.76	9.38	0.4			<i>Gambusia</i>
26/09/2015	3	5b (3-4)	17.6	13.92	1.7	9.3	0.2			<i>Gambusia</i>
26/09/2015	3	5c (3-5)	19	9.84	0.66	7.65	0.2			0
3/10/2015	4	11 (4-11)	23.2	16.31	3.69	8.05	1.0			<i>Gambusia</i>
3/10/2015	4	10 (4-10)	23.1	8.44	1.77	7.75	0.4			<i>Gambusia</i>
3/10/2015	4	9 (4-9)	22.4	9.11	2.23	7.43	0.2			0
3/10/2015	4	8 (4-8)	23.7	8.65	0.44	7.22	1.0			<i>Gambusia</i>
3/10/2015	4	7b (4-7)	23.1	9	0.16	6.14	0			<i>Gambusia</i>
3/10/2015	4	7a (4-6)	22.1	7.32	0.16	5.8	0.2			<i>Gambusia</i>
3/10/2015	4	7 (4-7)	23.6	9.13	0.16	6.14	0.6			0
3/10/2015	4	6c (4-3)	23.5	16.48	0.34	7.28	1.2			0
3/10/2015	4	6 (4-3)	23.2	12.73	0.34	6.79	1.2			<i>Gambusia</i>
3/10/2015	4	6b (4-2)	23.9	11.27	0.32	6.81	0.2			<i>Gambusia</i>
3/10/2015	4	6a (4-1)	23.4	10.02	0.32	6.42	0.8			<i>Gambusia</i>
4/10/2015	5	15e (5-5)	22.8	11.19	0.24	6.43	0.0			0
4/10/2015	5	15f (5-7)	23.3	11.06	0.3	6.31	0.0			0
4/10/2015	5	15g (5-6)	20.3	9.61	0.3	7.79	0.0			1 <i>Lim peroni</i> tad
4/10/2015	5	15h (5-8)	23.3	10.12	0.3	6.33	0.6			big fish
4/10/2015	5	16a (5-3)	20.6	10.02	0.15	8.01	0.2			0
4/10/2015	5	16b (5-4)	21.8	8.07	0.15	7.65	0.2			1 <i>Lim peroni</i> tad
4/10/2015	5	16c (5-2)	24.3	8.23	0.13	7.66	0.3			0
4/10/2015	5	16d(5-1)	25	8.3	0.12	7.94	0.4			0
5/10/2015	6	13 (6-4)	24.3	8.51	0.32	5.39	1.2			0






5/10/2015	6	12 (6-6)	24.5	8.23	0.21	7.57	0.2		0
5/10/2015	6	13a (6-4)	22.7	11.92	0.31	7.42	0.2		0
5/10/2015	6	14 (6-1)	25.1	11.32	0.21	4.73	0.4		<i>Gambusia</i>
5/10/2015	6	14a (6-2)					0.2		
5/10/2015	7	17 (7-1)	23.6	11.89	1.99	9.61	0.4		<i>Gambusia</i>
5/10/2015	7	17a (7-2)	23.4	8.38	2.01	8.7	0		<i>Gambusia</i>
5/10/2015	7	18 (7-3)	24.3	10.19	2.04	8.39	0.2		4 <i>Gambusia</i>

Table 2. Observation and capture details of Green and Golden Bell Frogs on the western end of Kooragang Island in the NCIG Compensatory Habitat and nearby wetlands. Wetlands adjacent to compensatory habitat highlighted.

Date	Pond	Sex	Callin g	RECAP	PIT TAG	Easting	Northing	Weight (g)	SVL mm
8/1/2016	5.1	M	Y	N	956000003468888	378729	6365316	14.5	53.7
8/1/2016	5.1	M	Y	N	956000003445115	378729	6365316	21.5	53.1
8/1/2016	K27	M	Y	N	00078A9172	378651	6365054	21	58.1
11/1/2016	4.11	M	N	N	900108001466693	379298	6365128	26.1	61.4
11/1/2016	4.11	M	Y	N	900108001466692	379295	6365128	25.9	60.9
11/1/2016	4.4	M	Y	N	900108001466734	378820	6365638	24.5	59.3
11/1/2016	5.1	M	Y	Y	956000003468888	378728	6365300		
11/1/2016	5.1	M	N	Y	956000003445115	378728	6365300		
13/1/2016	4.1	F	N	N	108001466678	378723	6365676	24	51.4
13/1/2016	7.1	F	N	N	108001466671	378552	6365104	21.3	60.9
13/1/2016	7.1	M	Y	N	108001466675	378631	6365032	16	56.7
13/1/2016	7.1	M	Y	N	108001466727	378631	6365027	28	58.9
13/1/2016	7.1	M	Y	N	108001466682	378634	6365018	17	58.7
13/1/2016	7.2	F	N	N	00078A9367	378676	6364971	25.5	60.8
13/1/2016	7.2	M	Y	N	108001466716	378676	6364971	23.5	55.8
13/1/2016	K27	M	Y	N	108001466687	378626	6365078	10.5	54.3
13/1/2016	K27	M	Y	N	108001466699	378641	6365067	18.1	59.3
13/1/2016	K27	M	Y	N	108001466703	378641	6365058	14.1	59.2
15/2/2016	5.1	J	N	N		378746	6365267	6.9	22.3
15/2/2016	5.1	J	N	N		328739	6365262	5.7	21.8
15/2/2016	5.1	J	N	N		378744	6366266	7.8	23.5
15/2/2016	5.1	J	N	N		378743	6365325	5.1	29.4
15/2/2016	5.1	J	N	N		378747	6365229	8.5	27.88
15/2/2016	5.1	J	N	N		378747	6365229	1.8	19.66
15/2/2016	5.1	J	N	N		378740	6365235	5.6	26.25
15/2/2016	5.1	J	N	N		378761	6365234	4.1	22.94
15/2/2016	5.1	J	N	N		378764	6365250	2.2	21.3
15/2/2016	5.1	J	N	N		378718	6365248	4.2	24.8
15/2/2016	5.1	J	N	N		378718	6365248	9	26.6
15/2/2016	5.3	J	N	N		378691	6365279	4.7	24.67
15/2/2016	5.3	J	N	N		378691	6365285	5.5	21.3

15/2/2016	5.3	J	N	N		378702	6365293	6.5	26.4
15/2/2016	5.3	J	N	N		378702	6365293	5.9	26.4
15/2/2016	5.3	J	N	N		378702	6365285	2.2	25.8
15/2/2016	5.3	J	N	N		378701	6365281	4.8	15.9
15/2/2016	5.4	J	N	N		6378714	6365302	4	21.41
15/2/2016	5.4	J	N	N		6378707	6365302	3.8	28.9
15/2/2016	5.4	M	N	N	108001466478	6378714	6365302	4	56.5
15/2/2016	5.5	J	N	N		378691	6365277	6.3	24.85
15/2/2016	5.6	F	N	N	000791EA89	378660	636530	35	77.3
15/2/2016	5.8	F	N	N	000792067D	378661	6365416	34	74.3
15/2/2016	5.8	J	N	N		378675	6365409	5.5	28.7
15/2/2016	5.8	M	N	N	000791E8C1	378653	6365416	17.5	60
15/2/2016	5.8	M	N	N	000791E8DD	378651	6365417	12	45.95
15/2/2016	5.8		N	N		378658	6365389		
15/2/2016	5.8		N	N		378658	6365389		
16/2/2016	3.1	F	N	N	00079206C1	378973	6366264	34.00	69.12
16/2/2016	3.4	J	N	N		378981	6366161	2.00	21.62
16/2/2016	3.4	J	N	N		378981	6366156	1.00	11.52
16/2/2016	7.1	M	Y	N	00078A90E2	378624	6365018	19.00	58.89
16/2/2016	7.1	M	N	N	00078A9082	378632	6365012	4.00	30.86
16/2/2016	7.3	F	N	N	00078A8FFE	378682	6364976	37.00	73.70
16/2/2016	7.3		N	N	00078A92C9	378674	6364968	23.00	59.50
16/2/2016	K27	J	N	N	00078A92DE	378672	6365046	14	54.5
16/2/2016	K27	MET	N	N		378672	6365046	7	28
16/2/2016	K27	MET	N	N		378672	6365046	2.7	29.7
16/2/2016	K27	MET	N	N		378672	6365046	3.7	26.2
17/2/2016	6.1	J	N	N		378493	6365361		
17/2/2016	6.1	MET	N	N		1514213	3250634	3	27.9
						1			
22/2/2016	4.10	F	N	Y	000791E977	379210	6365179	20.5	59.12
22/2/2016	4.10	M	N	N	00078A91EB	379238	6365172	18	54.1
22/2/2016	4.10	M	N	N	108001466639	379213	6365179		

Table 3. Observation of habitat use and association of Green and Golden Bell Frogs on the western end of Kooragang Island in the NCIG Compensatory Habitat and nearby wetlands.

Date	Pond	Sex	Calling	Easting	Northing	Habitat	Height from water (mm)	Distance from edge (mm)
8/1/2016	5.1	M	Y	378729	6365316	Pasp dial, water	0	0
8/1/2016	5.1	M	Y	378729	6365316	Pasp dial, water	0	0

8/1/2016	K27	M	Y	378651	6365054	Sprob, Sarcro	0	0
11/1/2016	4.11	M	N	379298	6365128	Bolb,Typha	30	0
11/1/2016	4.11	M	Y	379295	6365128	Typha	2	1.5
11/1/2016	4.4	M	Y	378820	6365638	Pasp dial, water	0	0
11/1/2016	5.1	M	Y	378728	6365300	Pasp dial, water	0	0
11/1/2016	5.1	M	N	378728	6365300	Pasp dial, water	0	0
13/1/2016	4.1	F	N	378723	6365676	Cynodon, Juncus usitatus	0	1
13/1/2016	7.1	F	N	378552	6365104	Typha	130	30
13/1/2016	7.1	M	Y	378631	6365032	Cynodon, Juncus usitatus	0	0
13/1/2016	7.1	M	Y	378631	6365027	Cynodon, Juncus usitatus	0	0
13/1/2016	7.1	M	Y	378634	6365018	Cynodon, Juncus usitatus	0	0
13/1/2016	7.2	F	N	378676	6364971	Typha	50	0
13/1/2016	7.2	M	Y	378676	6364971	Typha	80	0
13/1/2016	K27	M	Y	378626	6365078	Sprob, Sarcro	0	0
13/1/2016	K27	M	Y	378641	6365067	Sprob, Sarcro	0	0
13/1/2016	K27	M	Y	378641	6365058	Sprob, Sarcro	0	0
15/2/2016	5.1	J	N	378746	6365267	Carex app	5	1.5
15/2/2016	5.1	J	N	328739	6365262	Carex app	0	0.5
15/2/2016	5.1	J	N	378744	6366266	Pasp dial, pen clad	20	0.5
15/2/2016	5.1	J	N	378743	6365325	Pasp dial, pen clad	0	1
15/2/2016	5.1	J	N	378747	6365229	Pasp dial, water	0	0
15/2/2016	5.1	J	N	378747	6365229	Pasp dial, water	0	0
15/2/2016	5.1	J	N	378740	6365235	Pasp dial, water	0	0
15/2/2016	5.1	J	N	378761	6365234	Pasp dial, water	0	5
15/2/2016	5.1	J	N	378764	6365250	Pasp dial, water	5	5
15/2/2016	5.1	J	N	378718	6365248	Pasp dial, water	0	0.5
15/2/2016	5.1	J	N	378718	6365248	Pasp dial, water	5	0.5
15/2/2016	5.3	J	N	378691	6365279	Pasp dial, water	10	1
15/2/2016	5.3	J	N	378691	6365285	Pasp dial, water	10	1
15/2/2016	5.3	J	N	378702	6365293	Pasp dial, water	10	1
15/2/2016	5.3	J	N	378702	6365293	Pasp dial, water	10	1
15/2/2016	5.3	J	N	378702	6365285	Pasp dial, water	10	1
15/2/2016	5.3	J	N	378701	6365281	Pasp dial, water	10	1
15/2/2016	5.4	J	N	6378714	6365302	open water	0	0
15/2/2016	5.4	J	N	6378707	6365302	open water	0	
15/2/2016	5.4	M	N	6378714	6365302	open water	0	
15/2/2016	5.5	J	N	378691	6365277	Pasp dial, water	10	1
15/2/2016	5.6	F	N	378660	636530	Typha	100	3
15/2/2016	5.8	F	N	378661	6365416	Typha	100	0
15/2/2016	5.8	J	N	378675	6365409	Pasp dial, water	0	1.2
15/2/2016	5.8	M	N	378653	6365416	Typha	100	0
15/2/2016	5.8	M	N	378651	6365417	Typha	120	0

15/2/2016	5.8		N	378658	6365389	Pasp dial, water	0	2
15/2/2016	5.8		N	378658	6365389	Pasp dial, water	0	2
16/2/2016	3.1	F	N	378973	6366264	Kikuyu	30.00	250.00
16/2/2016	3.40	J	N	378981	6366161	open water	0.00	500.00
16/2/2016	3.40	J	N	378981	6366156	open water	0.00	300.00
16/2/2016	7.10	M	Y	378624	6365018	Kikuyu	600.00	1500.00
16/2/2016	7.10	M	N	378632	6365012	Rock	0.00	100.00
16/2/2016	7.3	F	N	378682	6364976	open water		1000.00
16/2/2016	7.3		N	378674	6364968	open water	300.00	1000.00
16/2/2016	K27	J	N	378672	6365046	Sitting on algae	0	0
16/2/2016	K27	MET	N	378672	6365046	Sitting on algae	0	0
16/2/2016	K27	MET	N	378672	6365046	Sitting on algae	0	0
16/2/2016	K27	MET	N	378672	6365046	Sitting on algae	0	0
17/2/2016	6.1	J	N	378493	6365361	cyp.	5	2
17/2/2016	6.1	MET	N	15142131	3250634	Kikuyu	0.4	0
22/2/2016	4.10	F	N	379210	6365179	Typha	100	0
22/2/2016	4.10	M	N	379238	6365172	Junc usitat	15	2
22/2/2016	4.10	M	N	379213	6365179	Typha	105	0

Releases of captive bred bell frog tadpoles and metamorphs into NCIG Compensatory Habitat, Ash Island, during the period of October 2015 to March 2016. The bell frog progeny released were produced from the captive breeding colony maintained at the University of Newcastle. The captive colony is entirely derived from bell frogs collected from Kooragang Island under licence from NSW NPWS. See also previous Quarterly Report (NCIG Bell Frog Release and Monitoring, Quarterly Report, April 2016).

Table 4 Numbers of green and golden bell frog (*L. aurea*) metamorphs released into NCIG compensatory habitat October 2015 - March 2016. VIE = implanted with coloured VIE markers. VIE colours indicated for stages: R (red); Pnk (pink); Grn (green); Purp (purple); Orange (Org); Yell (yellow). Total metamorphs released = 3780. Metamorphs produced from *L. aurea* breeding colony at the University of Newcastle.

Metamorphs														
	Stage 1	Stage 1	Stage 2	Stage 2	Stage 3	Stage 3	Stage 4	Stage 4	Stage 5	Stage 5	Stage 6	Stage 6	Stage 7	Stage 7
	VIE Red	No VIE	VIE R/Pnk	No VIE	VIE Grn	No VIE	VIE Purp	No VIE	VIE Pnk	No VIE	VIE Org	No VIE	VIE Yell	No VIE
2015-Oct														
2015-Nov														
2015-Dec										1090				
2016-Jan		896			201		306		403				312	
2016-Feb	208		35		54						275			
2016-Mar														

Table 5 Numbers of green and golden bell frog (*L. aurea*) tadpoles and metamorphs released into NCIG Compensatory Habitat from October 2015 – March 2016. Tadpoles produced from *L. aurea* breeding colony at the University of Newcastle.

	Tadpoles	Tadpoles	Metamorphs (All Stages)	Total
	Stage 4	Stage 5		
2015-Oct	400			400
2015-Nov		150		150
2015-Dec		3514	1090	4604
2016-Jan		1050	2118	3168
2016-Feb		745	572	1317
2016-Mar		1079		1079
Total	400	6538	3780	10718

Appendix B – NCIG GGBF Compensatory Habitat Project, Monitoring and Maintenance Report, May 2016 (Wetland Care Australia).

NCIG GGBF Compensatory Habitat Project

Monitoring and Maintenance Report

May 2016

Version	Author	Date
1	T.Mouton	31/05/2016

WetlandCare Australia
44 Bishopsgate Street
Wickham NSW 2293



Introduction

The Newcastle Coal and Infrastructure Group (NCIG) developed a 78ha Compensatory Habitat and Ecological Monitoring Program (CHEMP), to offset areas lost as a result of the NCIG CET. The compensatory habitat comprises 18 constructed ponds. WetlandCare Australia has prepared a Green and Golden Bell Compensatory Habitat Management Plan (GGBF CHMP) based on requirements contained in the CHEMP, which sets out the methodology of site management and monitoring requirements for the ponds. The GGBF CHMP has been approved by the Office of Environment and Heritage, and forms part of the NCIG project approval. This monitoring report contains a monthly summary of site works and monitoring results undertaken as part of the GGBF CHMP.

Works Undertaken

The program of monitoring and maintenance continued throughout April and May 2016. The following works were undertaken this period:

Monitoring

- Pond inspections and monitoring, involving:
 - Visual inspection of pond condition and structure
 - Water quality monitoring
 - Monitoring for evidence of pest species (feral animals and noxious weeds)

Results from these inspections and management recommendations are contained in Appendix A.

Maintenance

- Slashing around the frog fence in Stage 1, and weed sweep through licence areas targeting priority weeds was undertaken in during May.

Appendix B contains the schedule of works undertaken during May, and works forecast for the following month in June. Appendix C contains details of target weed control areas.

Key Outcomes

Monitoring

Water Quality

- Salinity (Target range < 4 ppt tadpoles; < 6 ppt frogs)
 - All ponds were within the acceptable salinity range for tadpoles and frogs.
 - Pond Salinity ranged from 0.12 – 3.48 ppt
- pH (Target range 4-9)
 - All ponds were within the acceptable pH range for tadpoles and frogs.
 - Pond pH ranged 7.63 – 8.58.
- DO (Target range 4-17)
 - All ponds were within the acceptable DO range for tadpoles and frogs.
 - Pond DO ranged 4.03 – 10.58 mg/L. (See note in Appendix A regarding low reading in northern section of Pond 4)
- Depth
 - Water levels have remained relatively stable from previous monitoring
- Temperature (Target range 16-31^oC tadpoles; 4-35^oC frogs)

- Water temperature dropped in all ponds due to cooler conditions, however were within the temperature target range

Pest Species

- Gambusia were observed in 14/18 ponds.
- Visibility was poor in a number of ponds due to dark stained and/or turbid water, which made detection of Gambusia difficult. No Gambusia were observed in Ponds 4, 10, 17 due to poor visibility, however given previous results it is likely they are still present.
- Visibility in Pond 15 was ok, which was observed to be Gambusia free.
- A more comprehensive weed survey was undertaken during monitoring this period, in order to inform programmed weed control works. This survey covered areas outside the direct vicinity of ponds, within the broader licence areas. A number of small infestations of Alligator Weed, *Juncus acutus*, Blackberry, and Lantana were observed. These infestations are recorded in Appendix C, and have been targeted during spraying conducted in May.
- Fox activity increased since previous monitoring, with prints and/or scats recorded at 7/18 ponds (Stages 3, 4, 5, 6), compared to 1/18 in the previous period.

Other Observations

- Azolla was observed covering approximately 80% of the open water surface of the northern section of Pond 4.
- *Casuarina glauca* regrowth was observed within the buffer of Pond 18.
- Ponds 2, 5a, and 18 are nearing the upper limit of emergent vegetation coverage.

Maintenance

- Slashing 1m from the frog fence in Stage 1 was undertaken.
- Weed control was undertaken throughout NCIG licence areas, targeting weeds as detailed in Appendix C. Weeds targeted include Alligator Weed, Sharp Rush, Blackberry, and Lantana.

Discussion & Recommendations

The region has experienced prevailing dry conditions over the last month, however pond levels have remained relatively stable. Water quality results improved significantly during this period, with all parameters falling within acceptable limits. Dissolved oxygen levels showed particular improvement in a number of ponds compared to previous monitoring. This may be a result of dropping water temperatures in the ponds, which increases the solubility of oxygen, and reduction in organic decay.

One anomaly in the water quality results was in the northern section of Pond 4, which produced a low DO reading of 0.58 compared to 7.9 in the southern pond. The northern section is dominated by native aquatic vegetation (*Ceratophyllum demersum* – Hornwort and *Azolla*). This is potentially impacting DO concentrations due to over consumption of oxygen by plant respiration. Thinning of these aquatic species may be required to reduce BOD in this pond.

Casuarina glauca regrowth within the buffer of Pond 18 has been removed during weed control in May. Ponds 2, 5a, and 18 have reached the upper limit of emergent vegetation coverage (70%), predominantly *Typha sp*, and will require thinning prior to warmer months.

Fox activity has increased within pond stages. Numbers may be on the rise again as ground baiting has not been undertaken since December 2015, 5 months ago. Fox baiting should recommence as soon as practicable once this stage of monitoring has been completed at the end of June.

Appendix A - Monitoring Results



Date	10 May 2016
Breeding Season (Oct-Dec)?	Yes / No
Name of Inspector/s	Tim Mouton, Trent Neilson
Site	NCIG Ponds / KWRP Ponds / Research Ponds
WEATHER	Warm/Sunny
Temperature	23.2
Total rainfall over preceding 3 days	0.4 mm
Total rainfall over preceding month	3.6 mm

WATER QUALITY INSPECTION

Parameter	Target Range	1	2	3	4	5A	5B	6	7	8	9	10	11	12	13	14	15	16	17	18
Target Condition	Permanent ponds wet	Wet			Wet	Wet	Wet	Wet		Wet			Wet		Wet			Wet		
Wet/Dry		Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet
Design Depth m		1.4	0.2	0.4	1.4	1.4		1.2	0.6	1.0	0.2	0.4	1.0	0.2	1.2	0.4	0.6	2.2	0.4	0.2
Measured Depth m		1.5+	0.5	1.2	0.5	0.5	1.5+	1.5+	1.4	1.4	1.1	0.9	1.4	1.2	1.5+	1.15	0.4	1.5+	1.1	0.6
Temp °C	T: 16-31 F: 4-35	19.5	19.3	19.1	17.1	23.1	19.6	18.9	18.6	18.8	19.1	18.2	18.7	17.2	17.9	17.0	17.2	18.0	17.2	16.6
pH	4-9	8.03	7.80	7.88	7.65	8.26	8.38	7.76	7.89	7.98	8.13	8.02	7.74	7.72	8.00	8.30	7.96	7.63	8.58	7.76
Salinity uS/cm		1436	1449	1655	2226	447	1666	377	195	473	1097	1182	5433	281	329	419	187	337	1422	2687
Salinity ppt	T < 4 F < 6	0.92	0.93	1.06	1.42	0.29	1.07	0.24	0.12	0.30	0.70	0.76	3.48	0.18	0.21	0.27	0.12	0.22	0.91	1.72
DO mg/L	4-17	4.03	7.53	4.75	0.58 /7.90	9.29	9.55	6.72	8.79	7.74	7.04	7.96	6.45	6.81	4.18	5.80	10.58	5.71	4.61	4.48
Turbidity NTU	Not critical	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% Open Water	Min. 30% Max 70%	75	30	80	65	30	80	60	75	100	100	80	70	85	60	60	75	75	95	30

Meets all Targets	Y	N	N	Y	N	Y	Y	N	Y	N	N	N	N	Y	N	Y	Y	N	N	N	Y
-------------------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Notes: The northern section of Pond 4 showed a low DO reading of 0.58 compared to 7.9 in the southern pond. The northern section is dominated by native aquatic vegetation (*Ceratophyllum demersum* – Hornwort). This is potentially impacting DO concentrations due to over consumption of oxygen by plant respiration.

Date	Breeding Season (Oct-Dec) Yes / No		Name of inspector/s Tim Mouton, Trent Neilson		
Site	NCIG Ponds / KWRP Ponds / Research Ponds				
POND STRUCTURE INSPECTION					
POND	Is there evidence of leakage?	Is there evidence of erosion/sedimentation?	Action Required?	Define action	Date Complete
1.	No	No	No		
2.	No	No	No		
3.	No	No	No		
4.	No	No	No		
5.	No	No	No		
6.	No	No	No		
7.	No	No	No		
8.	No	No	No		
9.	No	No	No		
10.	No	No	No		
11.	No	No	No		
12.	No	No	No		
13.	No	No	No		
14.	No	No	No		
15.	No	No	No		
16.	No	No	No		
17.	No	No	No		
18.	No	No	No		

All Actions Complete: Signed _____ Date _____

Date	Breeding Season (Oct-Dec) Yes / No		Name of inspector/s Tim Mouton, Trent Neilson			
Site	NCIG Ponds / KWRP Ponds / Research Ponds					
POND NATIVE VEGETATION INSPECTION						
POND	Emergent Vegetation % Cover of water body	Emergent Vegetation Density	Emergent vegetation Condition	Buffer Width	Buffer Density (Weed + Native)	Buffer Density (Native) %
Target	40-70% Cover of water body	> 50%	Good	1.5 m	> 50% total veg cover	> 50% native cover
1.	25% Macrophyte	60	Very Good			
2.	70% Macrophyte	70	Very Good			
3.	20% Macrophyte	10	Average			
4.	35% Macrophyte	70	Good			
5A.	70% Macrophyte	40	Good			
5B.	15-20% Macrophyte	30	Average			
6.	30-40% Macrophyte	50	Good			
7.	20-25% Macrophyte	0	Average			
8.	0% Macrophyte	0	Very Poor			
9.	0% Macrophyte	0	Very Poor			
10.	20% Macrophyte	85	Very Good			
11.	30-40% Macrophyte	50	Very Good			
12.	15% Macrophyte	60	Average			
13.	40-50% Macrophyte	70	Very Good			
14.	40% Macrophyte	70	Very Good			
15.	25% Macrophyte	20	Good			
16.	20-25% Macrophyte	30	Good			
17.	5% Macrophyte	0	Very Poor			
18.	70% Macrophyte	60	Good			
Notes	<p>Moderate increases in macrophyte densities were observed in the majority of ponds, in particular <i>Typha sp.</i> Ponds 2, 5a, and 18 are nearing the upper limit of emergent vegetation coverage, and may require management of <i>Typha sp.</i> should densities continue to increase.</p> <p>The northern section of Pond 4 was observed to contain an abundance of native aquatic vegetation (<i>Ceratophyllum demersum</i> – Hornwort and Azolla).</p> <p><i>Casuarina glauca</i> regrowth was observed within the buffer of Pond 18.</p>					

POND NATIVE VEGETATION ACTION REQUIRED			
POND	Action Required	Due Date	Completion Date
7, 8, 9, 17	Additional planting of macrophytes should be undertaken, within buffers and pond banks, within ponds showing poor growth and recruitment of macrophytes.	Ongoing	
2, 5a, 18	Ponds are nearing the upper limit of macrophyte growth and will require culling of Typha prior to warmer months.	September 2016	
18	Casuarina glauca regrowth is also present within the pond buffer which requires removal.	May 2016	May 2016

COMMENTS:

All Actions Complete: Signed _____ Date _____

WEEDS	Alligator Weed Density Class	Juncus acutus Density Class	Blackberry Density Class	Action Required	Date Action Complete
POND				See Maintenance Guidelines in NCIG GGBF CH POM	
General			Priority weeds requiring control, as detailed below, are mapped in Appendix C		
1.		2		Scattered tussocks to the north and south of Stage 1	May 2016
2.					
3.					
4.	3	2		1 small tussock present at western extent of pond Moderate Alligator Weed infestation on the northern extent of Stage 4, looks to have been previously sprayed, possibly by NPWS	
5.	2			1 small patch on pond bank. This infestation has previously been sprayed and observed to be resprouting. Scattered tussocks of Juncus present over the eastern bund	May 2016
6.					
7.					
8.	2			Small patch of Blackberry was observed adjacent to rock cobble on western bank.	May 2016
9.					
10.			2	Patch of Blackberry on the eastern side of access track, between Ponds 9 and 10	May 2016
11.					
12.					
13.					
14.					
15.					
16.					
17.		3		Moderate infestation of Juncus present on the northern boundary of Stage 7 Patch of Lantana present to the south of Pond 17	May 2016
18.					

NB: Weed Density Classes. Class 2 = less than 1%. Class 3 = 1-10%. Class 4 = 11-50%. Class 5 > 50% **Actions Complete:** Signed _____ Date _____

PREDATOR INSPECTION

	Gambusia	Fox Evidence	Action Required	Action Required	Date Complete
POND	Yes/No	scats/prints/kill s	Y/N		
1.	Yes	No		Gambusia dominant	
2.	Yes	No		Gambusia dominant	
3.	Yes	No		Gambusia dominant	
4.	No	No		Very poor visibility, potentially still present	
5.	Yes	Yes (tracks)		Gambusia moderate	
6.	Yes	No		Gambusia dominant	
7.	Yes	Yes (tracks)		Gambusia sparse (poor visibility)	
8.	Yes	Yes (scat)		Gambusia dominant	
9.	Yes	Yes (tracks)		Gambusia sparse (poor visibility)	
10.	No	No		Very poor visibility, potentially still present	
11.	Yes	No		Gambusia dominant	
12.	Yes	Yes (tracks)		Gambusia sparse (poor visibility)	
13.	Yes	Yes (tracks)		Gambusia dominant	
14.	Yes	No		Gambusia moderate	
15.	No	Yes (tracks)			
16.	Yes	No		Gambusia moderate	
17.	No	No		Very poor visibility, potentially still present	
18.	Yes	Yes		Gambusia very dominant	

Actions Complete: Signed _____ Date _____

Appendix C - Weed Control Areas



Appendix C – NCIG Shorebird Compensatory Habitat Monitoring (Kleinfelder Consulting)



Swan Pond and Fish Fry Flats Bird Monitoring Report



Newcastle Coal Infrastructure Group

Migratory Shorebird Habitat Establishment
Ash Island, NSW

23 June 2016

Swan Pond and Fish Fry Flats Bird Monitoring Report

Migratory Shorebird Habitat Establishment

Ash Island, NSW

Kleinfelder Document Number: NCA16R42496

Project No: 20170226

All Rights Reserved

Prepared for:

NEWCASTLE COAL INFRASTRUCTURE GROUP

EGRET & RAVEN ST

KOORAGANG ISLAND, NSW 2304

Only Newcastle Coal Infrastructure Group, its designated representatives or relevant statutory authorities may use this document and only for the specific project for which this report was prepared. It should not be otherwise referenced without permission.

Document Control:

Version	Description	Date	Author	Technical Reviewer	Peer Reviewer
1.0	Draft for client review	23 June 2016	F. Rainsford	L. Foster	C. Evans

Kleinfelder Australia Pty Ltd

95 Mitchell Road

Cardiff, NSW 2282

Phone: 1300 881 869

Fax: 1300 881 035

ABN: 23 146 082 500

Contents

1.	INTRODUCTION	1
2.	METHODS	2
2.1	WEATHER CONDITIONS.....	3
3.	RESULTS	4
4.	MANAGEMENT RECOMMENDATIONS	7
5.	REFERENCES	8

Tables

Table 1: Weather conditions during the survey period at Williamtown.....3

Figures

Figure 1. Number of individual waders, water birds and other species counted at Swan Pond during each monitoring event.4

Figure 2. Number of individual waders, water birds and other species counted at Fish Fry Flats during each monitoring event.5

Figure 3. Number of wader, waterbird and other species recorded at Swan Pond during each monitoring event.6

Figure 4. Number of wader, waterbird and other species recorded at Fish Fry Flats during each monitoring event.6

Appendices

Appendix 1. Bird Counts – Swan Pond

Appendix 2. Bird Counts – Fish Fry Flats

Appendix 3. Staff Contributions

Appendix 4. Licensing

1. INTRODUCTION

Newcastle Coal Infrastructure Group (NCIG) are undertaking the establishment of compensatory habitat for migratory shorebirds at Ash Island, NSW. The establishment of the shorebird habitat is a condition stipulated under the *Environment Planning and Assessment Act 1979* (EP&A Act) for the NCIG Coal Export Terminal (CET) Project approval (06_0009) brought about by the NCIG CET High Capacity Optional Inlet Rail Spur and Rail Sidings (Northern Rail Spur) and the Rail Flyover Modification.

Kleinfelder was engaged by NCIG to monitor bird activity at Swan Pond and Fish Fry Flats during the mangrove removal works to determine if the activity is having a negative impact on birds within the immediate area.

2. METHODS

Bird counts were undertaken one morning per week by a qualified ecologist following the ecological pre-clearance inspections of the mangroves within the mangrove removal area. Bird counts commenced for half an hour between 7:00 am and 10:00 am. All birds observed foraging or roosting on the water, ground, or in trees, or flying over or Swan Pond and Fish Fry Flats were recorded.

2.1 WEATHER CONDITIONS

Weather conditions during survey events are provided in **Table 1** below.

Table 1: Weather conditions during the survey period at Williamstown.

Date	Min temp (°C)	Max temp (°C)	Rainfall (mm)	RH (%) at 9:00 am	Wind Direction at 9:00 am	Wind Speed (Km\hr) at 9:00 am
02/05/16	13.4	24.8	2.6	84	Calm	Calm
10/05/16	17	23.4	0.2	53	NW	31
17/05/16	11.8	26.7	0	60	NW	19
24/05/16	9.4	21.2	0	42	WNW	31
01/06/16	10.5	19	10.6	93	NW	13
07/06/16	12	19.1	0	55	NW	17
15/06/16	7	21.1	0	85	NW	17
21/06/16	13.5	17.8	0	51	WNW	54

Source: Bureau of Meteorology 2016.

3. RESULTS

The number of individual birds counted at Swan Pond showed considerable variation from week to week (**Figure 1**). The total number of individuals recorded in the last three weeks was about half that recorded in the first three weeks of mangrove removal works, driven mainly by a reduction in the numbers of wading birds recorded. During the first three weeks of survey large numbers of Red-necked Avocets (*Recurvirostra novaehollandiae*) and Black-winged Stilts (*Himantopus himantopus*) were observed throughout Swan Pond.

A possible cause for the decline in the recorded numbers of wading birds is the timing of the survey. The availability of prey to wading birds is dependent on the tides, which will determine their distribution within the estuary. Surveys were conducted in the morning after conducting a pre-clearance inspection of the mangrove removal area, and not necessarily at the same tidal level. Therefore the lower numbers could be a result of survey times and foraging behaviour rather than disturbance caused by the activity. Additionally other factors such as strong winds and heavy rainfall in the region will also influence the distribution of waders within the estuary.

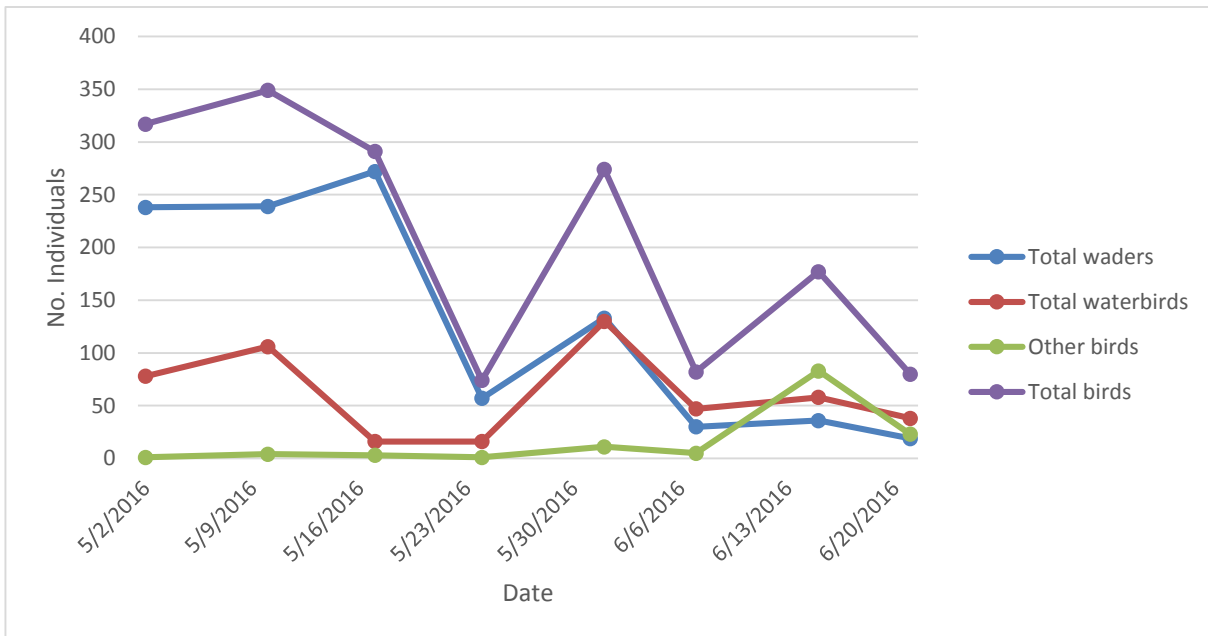


Figure 1. Number of individual waders, water birds and other species counted at Swan Pond during each monitoring event.

The number of individual birds counted at Fish Fry Flats also varied from week to week (**Figure 2**). No general pattern of decline can be seen in the Fish Fry Flats bird counts. However, after weeks of fluctuation, there was a decrease in the number of waterbirds recorded. This may be a result of the disturbance caused by mangrove removal works within the area. Continued monitoring will determine any long-term impacts resulting from the clearing activities.

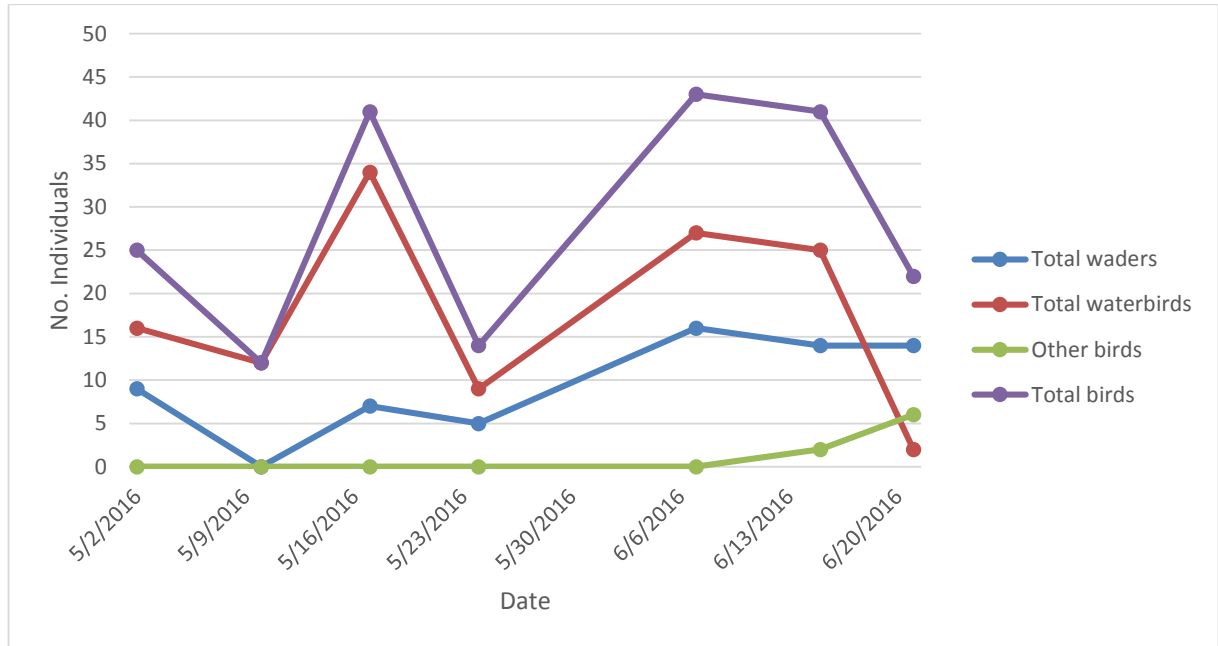


Figure 2. Number of individual waders, water birds and other species counted at Fish Fry Flats during each monitoring event.

The numbers of species observed each week at both Swan Pond (**Figure 3**) and Fish Fry Flats (**Figure 4**) remained generally constant, despite some slight variation.

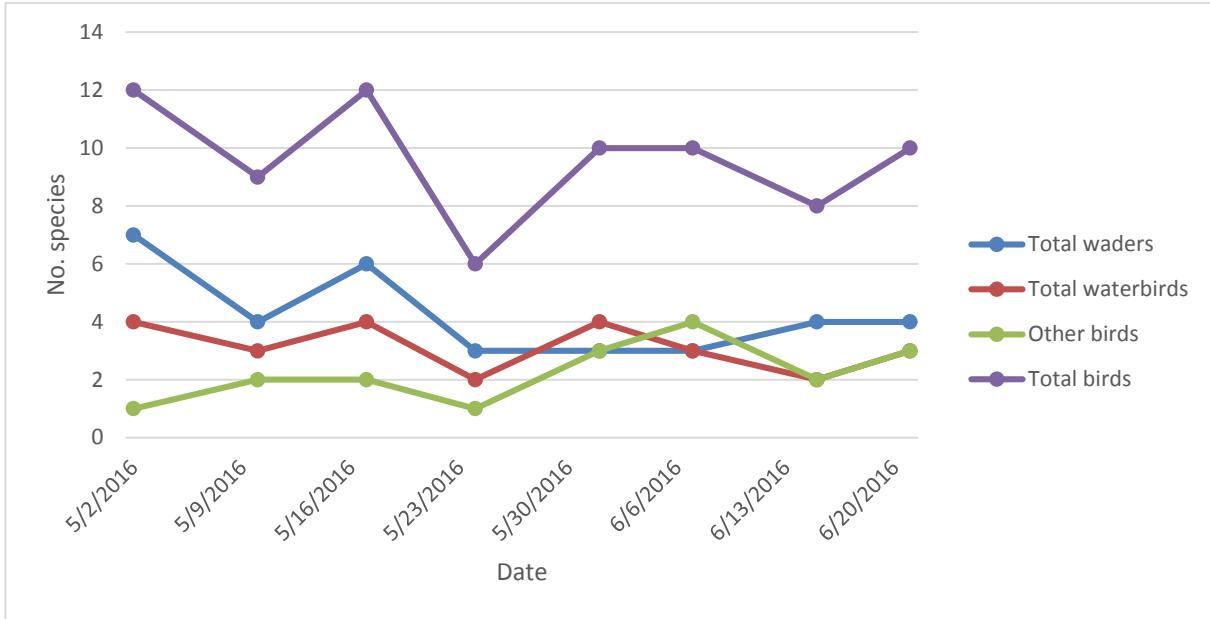


Figure 3. Number of wader, waterbird and other species recorded at Swan Pond during each monitoring event.

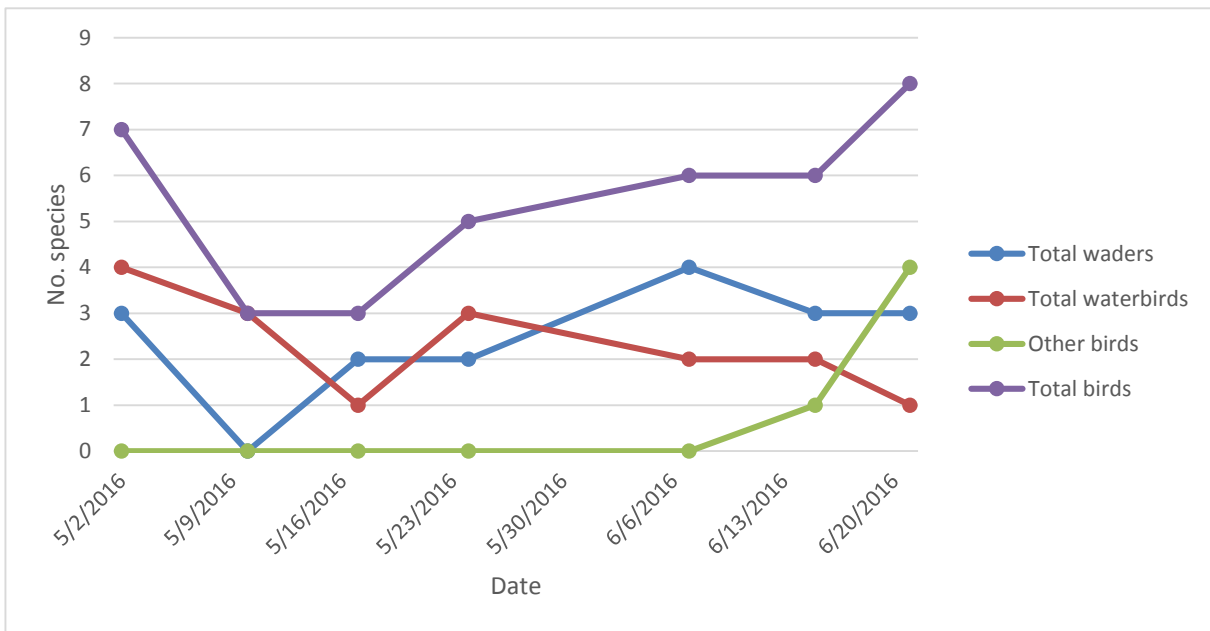


Figure 4. Number of wader, waterbird and other species recorded at Fish Fry Flats during each monitoring event.

A full species list and count of individuals for Swan Pond can be found in **Appendix 1**, and for Fish Fry Flats in **Appendix 2**.

4. MANAGEMENT RECOMMENDATIONS

Continued monitoring of bird activity within Swan Pond and Fish Fry Flats should continue throughout the duration of the mangrove removal works. Longer-term monitoring, as outlined in the Monitoring, Evaluation, Reporting and Improvement (MERI) Plan (Kleinfelder 2016), should determine the long-term impacts of the activity.

5. REFERENCES

Kleinfelder 2016. Monitoring, Evaluation, Reporting and Improvement (MERI) Plan for the Migratory Shorebird Habitat Establishment. Newcastle, NSW.

APPENDIX 1. BIRD COUNTS – SWAN POND

Family	Species Name	Common Name	02-05-16	10-05-16	17-05-16	24-05-16	01-06-16	07-06-16	15-06-16	21-06-16
Accipitridae	<i>Circus approximans</i>	Swamp Harrier						1		
Accipitridae	<i>Haliaeetus leucogaster</i>	White-bellied Sea-eagle	1							
Accipitridae	<i>Haliaeetus morphnoides</i>	Little Eagle		1						
Anatidae	<i>Anas castanea</i>	Chestnut Teal	64	93			53			
Anatidae	<i>Anas gracilis</i>	Grey Teal					65	29		
Anatidae	<i>Anas superciliosa</i>	Pacific Black Duck		4	3					
Anatidae	<i>Cygnus atratus</i>	Black Swan	6	9	5		8	17	52	24
Ardeidae	<i>Ardea ibis</i>	Cattle Egret								2
Ardeidae	<i>Ardea intermedia</i>	Intermediate Egret							1	2
Ardeidae	<i>Ardea modesta</i>	Eastern Great Egret	3		4	3				
Ardeidae	<i>Egretta novaehollandiae</i>	White-faced Heron	2		1			1	2	
Charadriidae	<i>Euseyornis melanops</i>	Black-fronted Dotterel	3		1					6
Charadriidae	<i>Vanellus miles</i>	Masked Lapwing	3	10	2	4	5	15	2	9
Columbidae	<i>Ocyphaps lophotes</i>	Crested Pigeon						2		
Corvidae	<i>Corvus coronoides</i>	Australian Raven						1		
Hirundinidae	<i>Hirundo neoxena</i>	Welcome Swallow					8		82	6
Laridae	<i>Chroicocephalus novaehollandiae</i>	Silver Gull								5
Laridae	<i>Gelochelidon nilotica</i>	Gull-billed Tern					4			

Family	Species Name	Common Name	02-05-16	10-05-16	17-05-16	24-05-16	01-06-16	07-06-16	15-06-16	21-06-16
Laridae	<i>Hydroprogne caspia</i>	Caspian Tern	2		1	4				
Monarchidae	<i>Grallina cyanoleuca</i>	Magpie-lark		3	1	1	2	1		
Motacillidae	<i>Anthus novaeseelandiae</i>	Australasian Pipit			2		1			2
Pelecanidae	<i>Pelecanus conspicillatus</i>	Australian Pelican	6		7	12		1	6	9
Recurvirostridae	<i>Himantopus himantopus</i>	Black-winged Stilt	123	24	72	50	34	14	31	
Recurvirostridae	<i>Recurvirostra novaehollandiae</i>	Red-necked Avocet	80	201	192		94			
Sturnidae	<i>Sturnus vulgaris</i>	Common Starling							1	15
Threskiornithidae	<i>Platalea regia</i>	Royal Spoonbill	24							
Threskiornithidae	<i>Threskiornis spinicollis</i>	Straw-necked Ibis		4						

APPENDIX 2. BIRD COUNTS – FISH FRY FLATS

Family	Species Name	Common Name	02-05-16	10-05-16	17-05-16	24-05-16	07-06-16	15-06-16	21-06-16
Alcedinidae	<i>Ceyx azureus</i>	Azure Kingfisher							1
Anatidae	<i>Anas castanea</i>	Chestnut Teal	6	8	34		25	22	
Ardeidae	<i>Ardea intermedia</i>	Intermediate Egret							2
Ardeidae	<i>Ardea modesta</i>	Eastern Great Egret	1		4				
Ardeidae	<i>Ardea pacifica</i>	White-necked Heron						1	
Ardeidae	<i>Egretta garzetta</i>	Little Egret					2		
Ardeidae	<i>Egretta novaehollandiae</i>	White-faced Heron	1			1	4	6	6
Cacatuidae	<i>Calyptorhynchus funereus</i>	Yellow-tailed Black Cockatoo							2
Columbidae	<i>Geopelia striata</i>	Bar-shouldered Dove							1
Halcyonidae	<i>Todiramphus sanctus</i>	Sacred Kingfisher						2	
Pelecanidae	<i>Pelecanus conspicillatus</i>	Australian Pelican	2			4			
Phalacrocoracidae	<i>Microcarbo melanoleucos</i>	Little Pied Cormorant	2	1		3	2	3	2
Phalacrocoracidae	<i>Phalacrocorax sulcirostris</i>	Little Black Cormorant	6	3		2			
Rhipiduridae	<i>Rhipidura albiscapa</i>	Grey Fantail							2
Threskiornithidae	<i>Platalea regia</i>	Royal Spoonbill			3		2		
Threskiornithidae	<i>Threskiornis moluccus</i>	Australian White Ibis				4	8	7	6
Threskiornithidae	<i>Threskiornis spinicollis</i>	Straw-necked Ibis	7						

APPENDIX 3. STAFF CONTRIBUTIONS

The following staff were involved in the compilation of this report.

Name	Qualification	Title/Experience	Contribution
Feach Moyle	BSc (Hons), ADAS	Principal Ecologist	Field surveys
Frederick Rainsford	BEnvSc & Mgt (Hons) GradCert Ornithology	Ecologist (Ornithologist)	Field surveys; report preparation
Luke Foster	BSc Env & Mgt MEnvSci&Mgt (Wildlife Ecology)	Ecologist (Mammologist)	Report review

APPENDIX 4. LICENSING

Kleinfelder employees involved in the current study are licensed or approved under the National Parks and Wildlife Act 1974 (License Number: SL100730, Expiry: 31 March 2017) and the Animal Research Act 1985 to harm/trap/release protected native fauna and to pick for identification purposes native flora and to undertake fauna surveys.

Compensatory Habitat and Ecological Monitoring Program – Quarterly Report (Combined Quarter 3 and Quarter 4, 2016)

DATE: 12 December 2016

AUTHOR: Philip Reid (NCIG), Alex Callen, Michael Mahony, John Clulow (Uni of Newcastle), Kleinfelder Consulting, Tim Mouton (Wetland Care Australia)

APPROVAL: Nathan Juchau

INTRODUCTION

This report provides an update of activities relating to the NCIG Compensatory Habitat and Ecological Monitoring Program since the previous Quarterly Report from July 2016. The report aims to provide information on key components of the program and how these are being implemented. Normally an update will be provided to members of the Consultative Board every 3 months, in the form of a Quarterly report and presentations (every 6 months) coinciding with Board Meetings. This report brings together two Quarterly Reports (Quarter 3 and Quarter 4, 2016).

1. Kooragang Island Green and Golden Bell Frog Population Monitoring

Work has recommenced by the University of Newcastle to monitor and characterise the Green and Golden Bell Frog population on Kooragang Island, in and surrounding the industrial part of the island (see monitoring locations on Figure 1). This work is being co-funded by NCIG, Port Waratah Coal Services (PWCS) and the Hunter Development Corporation (HDC). This monitoring will continue throughout the summer season with the report finalised mid-2017, including a population estimate for the island. Note, the population estimate for this monitoring excludes animals in the NCIG and BHPB Compensatory Habitat sites.

2. Captive Breeding and Release Program

Green and Golden Bell Frogs are once again being captively-bred at the University of Newcastle for release into the NCIG Compensatory Habitat. Animals bred in September 2016, with the progeny being maintained at the breeding facility at the university. These animals will gradually be released into the landscape commencing in December, with any subsequent progeny to be released over the following months. It is likely that animals will be released as metamorphs directly into ponds close to where breeding activity has been observed over the past 2 seasons. This is the fifth consecutive season that captive-bred animals have been released into either the NCIG Trial Site or Compensatory Habitat, with successful breeding occurring within the landscape as a result.



Figure 1: Kooragang Island Green and Golden Bell Frog Monitoring Survey Locations

3. NCIG Green and Golden Bell Frog Compensatory Habitat Monitoring (John-Paul King)

3.1. Compensatory Habitat Monitoring

Green and Golden Bell Frog monitoring was recommenced by the University of Newcastle in August 2016, including both the broader compensatory habitat and the former NCIG Research (Trial) Ponds. Observations have shown an encouraging number of juveniles and adults using the habitat, including reproductively mature males and females. Full results for the monitoring will be available at the end of the season.

3.2. Green and Golden Bell Frog Breeding

As discussed at the previous Compensatory Habitat Consultative Board Meeting (7 July 2016), a second breeding event was observed directly adjacent the NCIG

Compensatory Habitat in the January/February 2016. This occurred from mature adult using constructed habitat.

NCIG has made a submission to the Department of Planning and Environment in recognition of this second breeding event following the successful breeding in the 2014/15 season. The submission recognises the attainment of the performance indicator detailed in Condition 2.20 i) iii), particular with regard to a viable breeding population of Green and Golden Bell Frogs.

3.3. Compensatory Habitat Management

Conservation Volunteers Australia (formerly Wetland Care Australia) has recommenced fox baiting on behalf of NCIG at the Green and Golden Bell Frog Compensatory Habitat. This commenced in November and has been highly successful with numerous baits taken to date. This will conclude in January 2017.

After constructing several bunds around existing NCIG ponds, Conservation Volunteers Australia has also pumped down water in a selection of bunded ponds during early December. This work is to specifically manage *Gambusia* that have infested the majority of constructed ponds and can have an effect on the bell frog breeding cycle. To date, NCIG has successfully drawn down the water level of six (6) ponds, which will now be monitored for recharge and *Gambusia*. Where required, the water column will be treated with lime to remove any remnant *Gambusia* from the system. All appropriate controls have been employed during the pump-out work, including screening of remnant water for all animals, including tadpoles and other benthic fauna, and water quality observations. These controls are detailed in the NCIG Green and Golden Bell Frog Compensatory Habitat Management Plan.



Plate 1: Creation of Bunds around Stage 7 Ponds to control *Gambusia*

4. Shorebird Compensatory Habitat

4.1. Migratory Shorebird Habitat Construction

The delivery of the Migratory Shorebird habitat at Area E was completed in first week of November. Key components of the habitat delivery included:

- Removal of 17 hectares of mangroves using a power tool (hand removal) and plant/machinery methods
- Installation of a hydrological control device (Smart Gate) at Fish Fry Creek culvert
- Installation of two Mangrove Propagule Exclusion Devices (MPEDs) in Fish Fry Creek
- Installation of bird diverters using a bucket truck (Ausgrid power lines)
- Installation of bird diverters using a helicopter (Transgrid power lines)
- Other minor infrastructure such as rock protection along Fish Fry Creek, security gates and fences and access tracks

The following pictures provide photographic representations of the process.



Plate 2: Progressive mangrove removal, Area E



Plate 3: Phase 2 clearance, ride-on mower



Plate 4: Completed phase 2 clearance



Plate 5: Dura-mat use to remove felled mangroves



Plate 6: Wader Creek, mangroves partially removed



Plate 7: Retrieval of felled mangroves using winch



Plate 8: Visit by NPWS Staff



Plate 9: Mulched mangroves



Plate 10: Fish Fry Creek with mangroves partially removed



Plate 11: Removal of felled mangroves with boat



Plate 12: Surcharge concrete loading of Fish Fry Creek culvert



Plate 13: Preparation of Fish Fry Creek culvert



Plate 14: Fish Fry Flats, mangroves removed



Plate 15: Installation of concrete pits for MPED 1



Plate 16: Completed surcharge loading and concrete path to Fish Fry Creek culvert



Plate 17: Installation of MPED 2 screens



Plate 18: Installed MPED 2 screen (debris-style screens)



Plate 19: Installed MPED 1



Plate 20: Felling of final mangrove



Plate 21: Completed MPED 1 and MPED 2 instal



Plate 22: Area E mangrove removal complete, October 2016



Plate 23: Intallation of Ausgrid bird diverters



Plate 24: Intallation of Transgrid bird diverters



Plate 25: Preparation for installation of Smart Gate



Plate 26: Intallation of Smart Gate



Plate 27: Rock protection along Fish Fry Creek



Plate 28: Completed Smart Gate installation, Fish Fry Creek

As the delivery of the Migratory Shorebird habitat was successfully completed, a submission has been made to the Department of Planning and Environment advising of the completion. This letter is specifically in regards to Conditions 2.20 b) ii) (migratory shorebird habitat) and 2.20 f) (ameliorative works).

5. Shorebird Monitoring

Kleinfelder has commenced post-mangrove removal shorebird monitoring of Area E. Results for the May to October period (including the mangrove removal period) is contained within Appendix A. The following photographs show notable bird observations and regrowth of target vegetation species which constitute an endangered saltmarsh community.



Plate 28: *Sarcocornia quinqueflora* regrowth, Area E



Plate 29: *Sporobolus virginicus* regrowth, Area E



Plate 30: Juvenile Curlew Sandpiper using Area E (Fish Fry Creek)



Plate 31: Whimbrel using Area E (Fish Fry Creek)



Plate 32: Royal Spoonbill using Area E (Fish Fry Creek)



Plate 33: Red-capped Plover using Area E (Wader Creek)



Plate 34: Bar-tailed Godwit and Whimbrel using Area E (Fish Fry Creek)

Bird monitoring in Area E will continue fortnightly throughout the summer period. NCIG is also discussing with the University of New South Wales (Water Research Laboratories) the scope for an ongoing research project to commence in the new year. This research project will be in alignment with the Shorebird Monitoring Evaluation Reporting and Improvement (MERI) Plan and would focus on monitoring of ecological and environmental factors such as water and sediment levels, vegetation (saltmarsh and mangroves), benthic organisms and potentially other aquatic ecological factors.

Appendix A – NCIG Shorebird Compensatory Habitat Monitoring (Kleinfelder Consulting)

Compensatory Habitat and Ecological Monitoring Program – Quarterly Report (Quarter 1, 2017)

DATE: 16 June 2017

AUTHOR: Philip Reid (NCIG),
John-Paul King, Michael
Mahony, John Clulow
(Uni of Newcastle), Will
Glamore (Uni of NSW),
ERM Consulting, Tim
Mouton (Wetland Care
Australia)

APPROVAL: Nathan Juchau

INTRODUCTION

This report provides an update of activities relating to the NCIG Compensatory Habitat and Ecological Monitoring Program since the previous Quarterly Report from December 2016. The report aims to provide information on key components of the program and how these are being implemented. Updates are provided to members of the Consultative Board every 3 months, in the form of a Quarterly report and presentations (every 6 months) coinciding with Board Meetings. This report provides information for Quarter 1, 2017.

1. Kooragang Island Green and Golden Bell Frog Population Monitoring

Work has recommenced by the University of Newcastle to monitor and characterise the Green and Golden Bell Frog population of Kooragang Island, in and around the industrial part of the island (monitoring locations depicted in Figure 1). This work is being co-funded by NCIG, Port Waratah Coal Services (PWCS) and the Hunter Development Corporation (HDC). Monitoring undertaken over the summer season suggests a healthy and stable population through the industrial area of the island.

Note – draft report has been released by the university summarising this work and providing a population estimate for the island. The final report is expected to be finalised mid-2017, which will include data from the NCIG compensatory habitat site, as provided by John-Paul King.

2. Captive Breeding and Release Program

Green and Golden Bell frogs are once again being bred in captivity at the University of Newcastle for release into the NCIG Compensatory Habitat. Animals were gradually released into the landscape commencing in December, with subsequent progeny released over following months.

This is the fifth consecutive season that captive bred animals have been released into either the NCIG trial site or Compensatory Habitat, with successful breeding occurring throughout the landscape as a result.

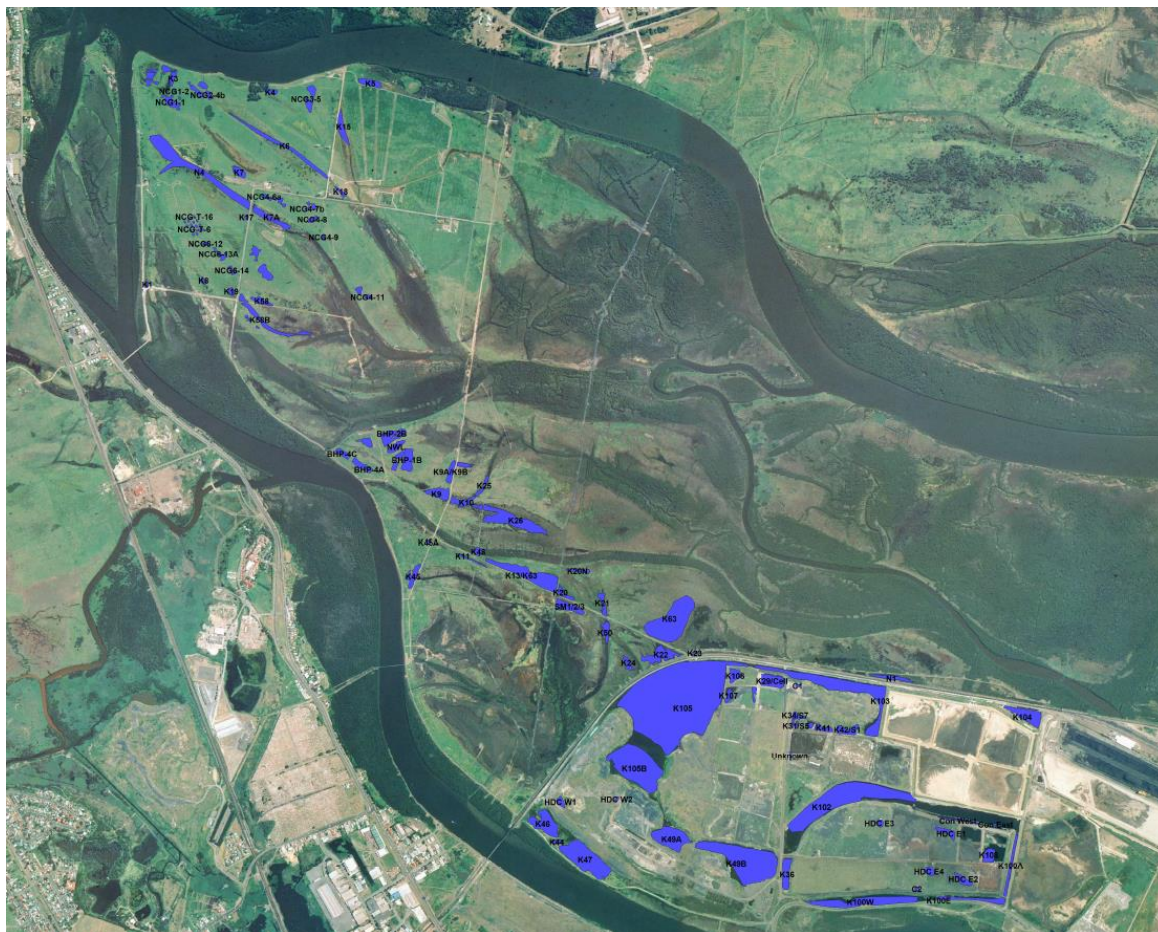


Figure 1: Kooragang Island Green and Golden Bell Frog Monitoring Survey Locations

3. NCIG Green and Golden Bell Frog Compensatory Habitat Monitoring (John-Paul King)

3.1. Compensatory Habitat Monitoring

Green and Golden Bell Frog monitoring was undertaken by the University of Newcastle focusing on the compensatory habitat and former NCIG research (trial) ponds, from October 2016 to March 2017. Observations show an encouraging number of both adults and juveniles using the habitat, including reproductively mature males and females. Results from newly implemented sampling techniques such as Capture-Mark-Recapture have been successful indicating that the population within the CHEMEP wetlands is stable and greater than that of the 2015-2016 sampling period.

Major autumn rain in 2015 resulted in recharge of all wetlands and localised flooding on the Island, which likely resulted in overland flow and connection of minor waterbodies with wetlands (not observed). This cycle extended into a wet summer

in 2016 (where as much as 225mm fell in a single day) resulting in further overland flooding across the Island. The Autumn of 2016 remained wet and during this period all ephemeral wetlands remained charged resulting in all CHEMP wetlands being inhabited by large numbers of *Gambusia holbrooki*. The winter spring and early summer of 2017, on average, were dry with 7 out of 9 months being below the long-term mean. This drying cycle resulted in the gradual drying of wetlands. By the end of February 2017 all true ephemeral wetlands dried out. Refer to Figure 2 for summary of rainfall data.

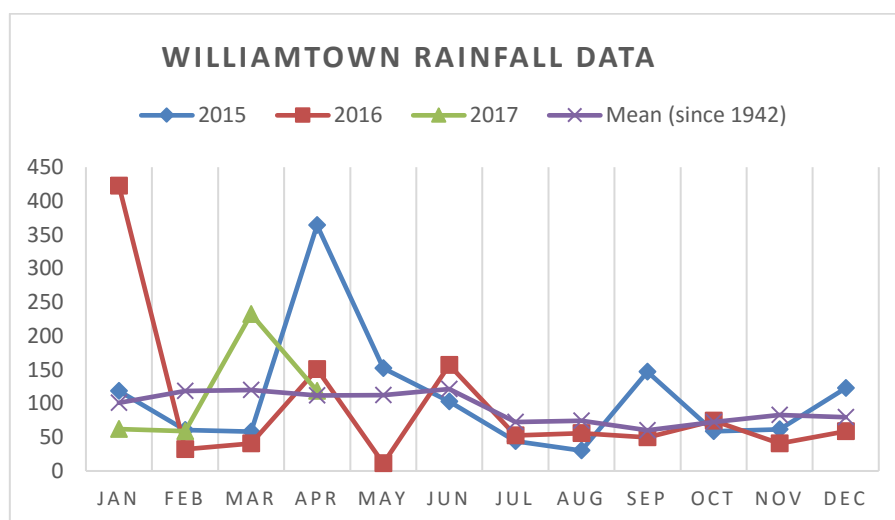


Figure 2. Williamstown RAFF base rainfall data.

There were two types of survey used for frog monitoring:

- Visual Encounter Survey (VES)
- Capture-Mark-Recapture (CMR)

All surveys involved the systematic searching of all 42 CHEMP wetlands at night using >150 lumen LED head torches. Surveys commenced at least 30 minutes after dusk, where five minutes quite unlighted listening for calls preceded 10 minutes of call playback alternating with quite listening time. This is directly followed by Visual Encounter Surveys which involves the searching of the whole wetland for a 30 person minute sample (e.g. two people sampling would mean that the sample runs for 15 minutes, however time taken for processing is removed from this sampling period¹). Care is taken to ensure that there is no overlap in sampling.

Frogs missed during VES are also included in these records. When an individual is captured, it is placed in an oxygenated plastic bag, labelled with a unique capture code, the habitat where the captured is recorded, along with location and if visible, the distance to the nearest bell frog. The animal is then stored for further sampling at completion of the VES.

In Capture-Mark-Recapture (CMR) sampling wetlands were surveyed for three consecutive nights three independent times over the course of the season (Oct-

¹ Analysis of time spent processing and managing frogs during VES samples showed that up to 30% of the VES is spent not searching. Therefore, sampling time is determined by survey time minus process time for all samples.

March). The CHEMP wetlands chosen for CMR comprise a range of varying size and characteristics that are in close proximity to each other (<150m). Together these wetlands comprise a closely grouped stage. Within the CHEMP wetlands stages 1, 2, 3, 5 and 7 are closely grouped stages and sampling undertaken in the 2015-2016 season showed that individuals recorded at stages 5 and 7 would move between ponds regularly over the course of the season. Presumably in response to changes in conditions and to partake in breeding events (as yet there is insufficient data to verify this). From a functional perspective, these wetlands form a wetland and given that both these stages had the greatest representation of animals compared with other stages they were chosen for the CMR sampling.

Effectively there is no stopping rule or constraint applied with CMR sampling, thus there was no maximum search time; rather, CMR sampling aims to survey the maximum number of GGBF individuals physically possible within time and budgetary constraints.

A Fyke netting program commenced this season with the objective of improving efficiency for tadpole and pest species data collection. This program was also complimented with dip netting to collect data on macro-invertebrates. Fyke nets (n=4) were set overnight and checked in the morning and set at a wetland for at least two consecutive days. Two rounds of trapping at all CHEMP wetlands was undertaken this season during February 2017 and March-April 2017. Targeted trapping of wetlands was also undertaken to collect data on the recovery of wetlands post the mechanical draining program. This was done to provide information on the effect that draining has on macro diversity and abundance. This program was supported with before sampling of the same wetlands. Another aspect of the trapping was the targeting of wetlands where evidence of breeding had been recorded as part of the nocturnal bell frog monitoring. This targeted trapping was undertaken in stage 4, 5 and 7 on three separate occasions. Overall, these programs totalled 960 hours of trapping over 120 trapping events.

In addition to planned and systematic sampling, a program of surveys during ideal breeding conditions was also undertaken. When conditions were right, additional diurnal and nocturnal sampling was undertaken to listen for calls, search for amplexing pairs, egg spawn, tadpoles, and metamorphing frogs. Within this monitoring program the purpose of this sampling was to verify and quantify breeding events in CHEMP wetlands. Overall, 4 separate surveys were undertaken between January and March in this program and in total 64 man hours were spent searching for evidence of breeding.

In total, 148 captures were made of 97 individual adult Bell frogs (Refer to Figure 3). By comparison, the 2015-2016 sampling recorded only 32 captures of 29 adults. The greater numbers this year can be attributed to three factors:

1. Sampling was extended this season compared to the sampling period last season;
2. Increased sampling undertaken for CMR in stage 5 and Stage 7 which was not undertaken last year due to poor numbers and limited time;
3. The program undertaken last year monitoring the movement of metaphors included the introduction of over 1000 mets into the wetlands late in the

season. Some of these were recorded this year and have likely contributed to the population size (No=15).

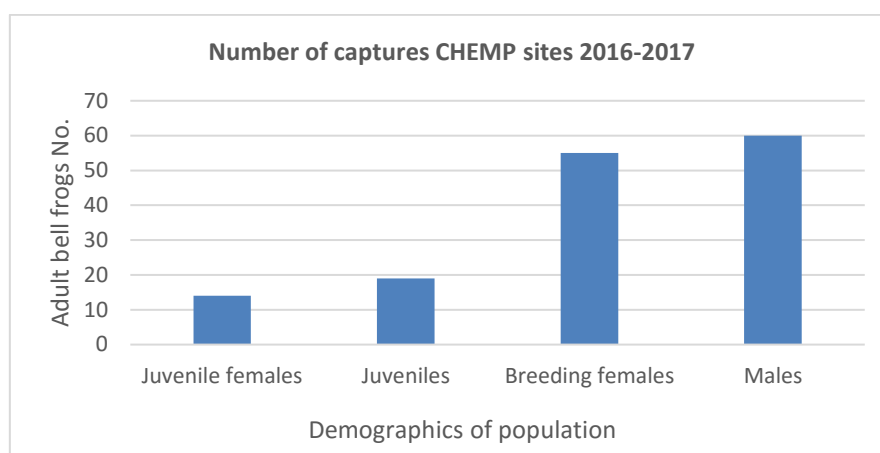


Figure 3- Captures recorded 2016-2017 in CHEMP wetlands.

Bell frog distribution is highly varied across the CHEMP wetlands ($m = 20.7$ s.d. $=23.99$). Bell frog was absent from Stage 2 again this year (Not yet recorded at stage 2). There are large fish in Stage 2 which may be limiting the suitability of this stage for bell frog. Habitat otherwise appears highly suitable for bell frog (unpublished habitat data analysis). Stage 1 and 3 have reduced numbers compared to 4, 5 and 7. An interesting result this year was the temporal patterns in stage 6. The first two samples within 6 recorded only 1 individual. Following the natural desiccation of 6-1 causing the loss of *Gambusia holbrooki*, following recharge 7 individual bell frog were recorded in 6-1. Refer to Table 1 for details.

Table 1 - Bell frog captures relative to CHEMP stages

Stage	Males	Females	Juvenile Females	Juveniles
Stage 1	1	0	2	1
Stage 2	0	0	0	0
Stage 3	2	0	1	1
Stage 4	12	11	6	8
Stage 5	11	12	2	3
Stage 6	5	1	1	0
Stage 7	33	28	2	2

CMR sampling was undertaken in October 2016, February 2017 and March 2017. January was the planned time for this second survey but was postponed due to extensive wetland drying. The purpose of CMR sampling is to estimate population size (this will be completed for the Island wide reporting) but as can be seen in Table 2 recapture data was excellent, which may be a function of the wetlands being small and detectability of animals high, especially during breeding events. Overall, numbers increased at the end of the season (March sampling) likely because of animals being more active during breeding (Table 2). This is particularly

evident in Stage 5 were wetlands 5-1, 5-2, 5-3, 5-4 were dry and not occupied in first two samples. Following heavy rains in early March these wetlands were recharged and animals breed in these wetlands.

Table 2 - Captures relative to Stages

Survey location	CMR schedule	Date	Ist night survey	2nd Night Survey	3rd night survey
			GGBF Captured	Recaptured	Recaptured again
Stage 5 Wetlands	CMR round 1	14/11/2016 to 16/11/2016	12	8	8
	CMR round 2	23/02/2017 to 25/02/2017	13	9	9
	CMR round 3	10/03/2017 to 12/03/2017	16	14	15
		Date			
Stage 7 Wetlands	CMR round 1	14/11/2016 to 16/11/2016	22	16	15
	CMR round 2	20/02/2017 to 23/02/2017	32	26	25
	CMR round 3	13/03/2017 to 15/03/2017	35	28	30

3.2. Green and Golden Bell Frog Breeding

Fyke trapping recorded bell frog tadpoles at Stage 5 (5-1, 5-2, 5-3) and Stage 7 (7-2). Two separate breeding events were recorded at 7-2 (February and March) resulting in clear evidence of at least five breeding events in 2016-2017 summer. Tadpole numbers ranged from the thousands in Stage 5 to a high of 81 tadpoles being recorded in CHEMP 7-2 (2/20/2017). Of the 40 CHEMP wetlands sampled in Fyke netting only 9 wetlands were free of *Gambusia holbrooki*, of which, 5 had been mechanically drained (5-1, 5-2, 5-3, 5-4, 7-2). Three ephemeral wetlands (3-1, 3-2, 5-6) dried out over the summer and had not been recolonised by *Gambusia holbrooki*. All breeding events recorded in 2017 occurred in wetlands mechanically drained and free of *Gambusia holbrooki*. Two wetlands (4-9, 7-1) that were drained never completely dried and as a consequence have been recolonised by *Gambusia holbrooki*.

Field surveys in response to ideal breeding conditions were undertaken on ten separate occasions. Data indicating breeding activity was recorded on seven occasions (Refer to Table 3). Following rain in late February early March spawn was identified in three wetlands (5-1, 5-3, 7-2).

Table 3 - Opportunistic data collected on breeding activity.

	Stage/Wetland	Calling heard	Number males calling	Breeding females	Spawn
1/02/2017	7-2	Y	2	Y	
20/02/2017	4-9	Y	3	Y	
	5-1	Y	1	Y	
	6-6	Y	2		
	7-2	Y	6	Y	

	5-1	N (but two males recorded)	(many Crinia)	Yes
	5-2	Y	2	Y
	5-3	N		Yes
	5-4	Y	3	
10/03/2017	5-5	Y	1	
	6-1	Y	5	
	7-2 (drained recharge)	Y	6	Y Yes
	4-9 (drained recharge)	Y	3	
Males were heard calling in mangroves south of stage 4, but none calling in stage 4 except the <i>Gambusia holbrooki</i> free wetland 4-9.				
Met Data				
	Mets recorded in 7-2	In water (stage 42)	On land/ Veg (stage 42)	
March	4/03/2017	34	12	
	5/03/2017	21	8	
	9/03/2017	7	3	
	10/03/2017	9	4	

The wetland bunding and draining program implemented over the 2016 winter and early in the 2017 season was successful, with 100% of recorded breeding occurring within CHEMP bunded and drained wetlands. The nocturnal sampling and newly implemented CMR program shows that the population within the CHEMP wetlands is stable and based on capture rates greater than 2015-2016. Whilst the draining program was successful in terms of breeding, one potential problem identified is that the draining may have triggered accelerated growth and increased cover in the emergent macrophyte *Typha orientalis*. Whether this expansion continues, and if it becomes a problem for these wetlands is yet unknown. All methods used this season will remain unchanged for the upcoming 2017-2018 season. Several additional experimental programs will commence with aim of improving efficiencies in constructed frog habitats.

NCIG made a submission to the Department of Planning and Environment in December 2016 in recognition of the second breeding event during the 2015/16 season. The submission recognises the attainment of the performance indicator detailed in Condition 2.20 i) iii), particular with regard to a viable breeding population of Green and Golden Bell Frogs. The Department has indicated their agreement with attainment in consultation with the Office of Environment and Heritage. A letter from the Department is expected in the near future, confirming this position.

3.3. Compensatory Habitat Management

Conservation Volunteers Australia (formerly Wetland Care Australia) completed a successful baiting program in January 2017 on behalf of NCIG at the Green and Golden Bell Frog compensatory Habitat. The program ran for two months with a

93% strike rate of baits taken, suggesting fox activity to be high in the area. The program will recommence in late 2017 in preparation for the following summer period.

A program was implemented to drain constructed Green and Golden Bell Frog ponds that were bunded in mid 2016. This was a collaborative effort between Conservation Volunteers Australia and the University of Newcastle, and aimed to specifically manage *Gambusia* populations that infest many constructed ponds and have an effect on the Bell Frog breeding cycle. To date, six (6) ponds were successfully drawn down, with monitoring for recharge and *Gambusia* completed. Where required, the water column was treated with lime to assist in dessication of the pond. All appropriate controls have been employed during the pump-out work, including screening of remnant water for all animals, including tadpoles and other benthic fauna, and water quality observations. These controls are detailed in the NCIG Green and Golden Bell Frog Compensatory Habitat Management Plan.

The program implemented over the 2016 winter and early 2017 season was a success, with 100% of recorded breeding occurring in bunded and drained CHEMP wetlands. It is anticipated that more ponds will be bunded in preparation for the 2017/18 season, due to the success of this effort.

Importantly whilst the draining program was successful in terms of breeding, one potential problem identified is that draining may have triggered accelerated growth and increased cover in emergent macrophytes, e.g. *Typha orientalis*. Whether this expansion continues, and if it becomes a problem for these wetlands is currently unknown. Ongoing monitoring programs will continue to measure the potential impacts of *Typha orientalis*. Appropriate controls may include removal of excess emergent vegetation to retain open water where required.



Plate 1: Pond dewatering setup (Pond 16)



Plate 2: Screening at outlet



Plate 3: Dried Pond



Plate 4: Pond dewatering setup (with screen on inlet)

4. Shorebird Compensatory Habitat

4.1. Migratory Shorebird Habitat Management

Since completion of the migratory shorebird habitat creation in November 2016, some minor mechanical and electrical defects required rectification for the Smart Gate at Fish Fry Creek. This was completed in May 2017.

Since achieving this and testing the functionality of the Smart Gate, NCIG is now working with the manufacturer of the gate and their subcontractors to modify the programming logic for the gate operation. This is currently being completed in order to have more flexibility with gate opening and closing, based on both time and water height. A proposal had been developed by the Uni of NSW for comprehensive use of the gate over a 12 month period. This will be submitted to NPWS once programming logic has been updated.

4.2. Migratory Shorebird Habitat Monitoring

Following the successful construction of Area E (Migratory Shorebird Habitat) in November 2016, Kleinfelder Consulting completed post-mangrove removal shorebird monitoring in December 2016, with General Flora and Fauna commencing in January 2017. The monitoring was undertaken fortnightly, from January to April 2017, with shorebird species observed across all ponds, including Fish Fry Flats as well as neighbouring ponds such as Swan Pond, Wader Pond and North-West Pond.

The first Benthic study in Area E was undertaken in January 2017, following mangrove removal, by Environmental Resources Management (ERM) on behalf of NCIG. The aim of the study was to assess species richness and abundance across Area E, following significant physical change in comparison to baseline studies while mangroves were in situ. Results indicate that compensatory habitats are still in transition following the large scale mangrove removal suggesting a potential lag in the system; that is, total infauna species have remained relatively stable and the mangrove removal has not immediately created the epibenthic and macroinvertebrate communities typical of mudflats. Further monitoring is planned for MONTH to assist in understanding the trends in change over time.

NCIG has also collaborated with the University of New South Wales (Water Research Laboratories) to undertake a research project in alignment with the Shorebird Monitoring, Evaluation, Reporting and Improvement (MERI) Plan. This research project focuses on monitoring of ecological and environmental factors such as water and sediment levels, vegetation (saltmarsh and mangroves), benthic organisms and potentially other aquatic ecological factors. Survey work for this commenced in January 2017, with follow up vegetation, ground surface and benthic surveys to follow later in the year.

As the delivery of the Migratory Shorebird habitat was successfully completed, a submission has been made to the Department of Planning and Environment advising of the completion. This letter is specifically in regards to Conditions 2.20 b) ii) (migratory shorebird habitat) and 2.20 f) (ameliorative works). (Note – this was

submitted along with submission for the Green and Golden Bell Frog breeding performance indicator).

4.3. Benthic Survey Results

The first Benthic study in Area E was undertaken in January 2017, following mangrove removal, by Environmental Resources Management (ERM) on behalf of NCIG. The aim of the study was to assess species richness and abundance across Area E, following significant physical change in comparison to baseline studies while mangroves were in situ. Results indicate that compensatory habitats are still in transition following the large scale mangrove removal suggesting a potential lag in the system; that is, total infauna species have remained relatively stable and the mangrove removal has not immediately created the epibenthic and macroinvertebrate communities typical of mudflats. Further monitoring is planned for mid 2017 to assist in understanding the trends in change over time. This is an important part of understanding the potential food source potential that Area E may provide for wader birds (both migratory and endemic).

Appendix A – NCIG GGBF Compensatory Habitat Maintenance, 6 month maintenance overview (Conservation Volunteers Australia)

NCIG GGBF Compensatory Habitat Maintenance 2016 - 2017

6 Month Maintenance Overview - December 2016

Monitoring

- Weed survey of all pond stages was undertaken in November to inform weed spaying maintenance locations. Weed infestations are small and scattered throughout the site.

Weed Control

- A weed sweep throughout all pond stages was undertaken during November, targeting priority weeds Sharp Rush, Blackberry, and Alligator Weed (see maps attached for site coverage details).
- A targeted sweep for Alligator Weed was undertaken in November, throughout Stage 1 and KWRP ponds (see maps attached for site coverage details).
- CVA Better Earth volunteer teams undertook three sessions of hand weeding within macrophyte buffers of ponds during October and November.
- Slashing was undertaken around Stage 1 frog fence during December.

Fox Control

- The Fox Baiting program was undertaken throughout November and December. The program has been very successful to date, with baits taken consistently each run. A total of 49 baits were laid and 46 taken (93% strike rate), showing that fox activity is still high.

Gambusia Control (Pond Dewatering)

- A dewatering program to control Gambusia infestations was undertaken throughout December during dry conditions, within ponds 16, 17 and 8. The dewatering process was effective at drawing water levels down in each pond as per the proposed methodology.
- Pond 16 (Stage 5) – Dewatering has been successful throughout all sections of this pond, with water levels taken back to wet substrate and screened for Gambusia. Since the completion of dewatering the pond substrate has dried with the majority of water removed.
- Pond 17 (Stage 7) – Dewatering was initially successful in getting the pond level back to wet substrate over the course of 2 days, however consistent groundwater recharge has increased water levels. Lime was spread over the pond surface after dewatering was completed.
- Pond 8 (Stage 4) – Dewatering was initially successful in getting the pond level back to wet substrate. Groundwater recharge was occurring after the completion of dewatering. Lime was spread over the pond surface after dewatering was completed.
- Monitoring for Gambusia will be undertaken early 2017 once water levels have recharged to determine how effective dewatering has been in controlling Gambusia.

Observations

- 2 adult *Litoria aurea* were observed by field crew in Pond 18 on 14/11/16.
- Alligator Weed was observed throughout Stage 1 (outside the frog fence) and KWRP pond areas. Infestations were scattered and targeted during weed control undertaken in November.

PHOTOS



Pond 16 dewatering setup



Screen at outlet

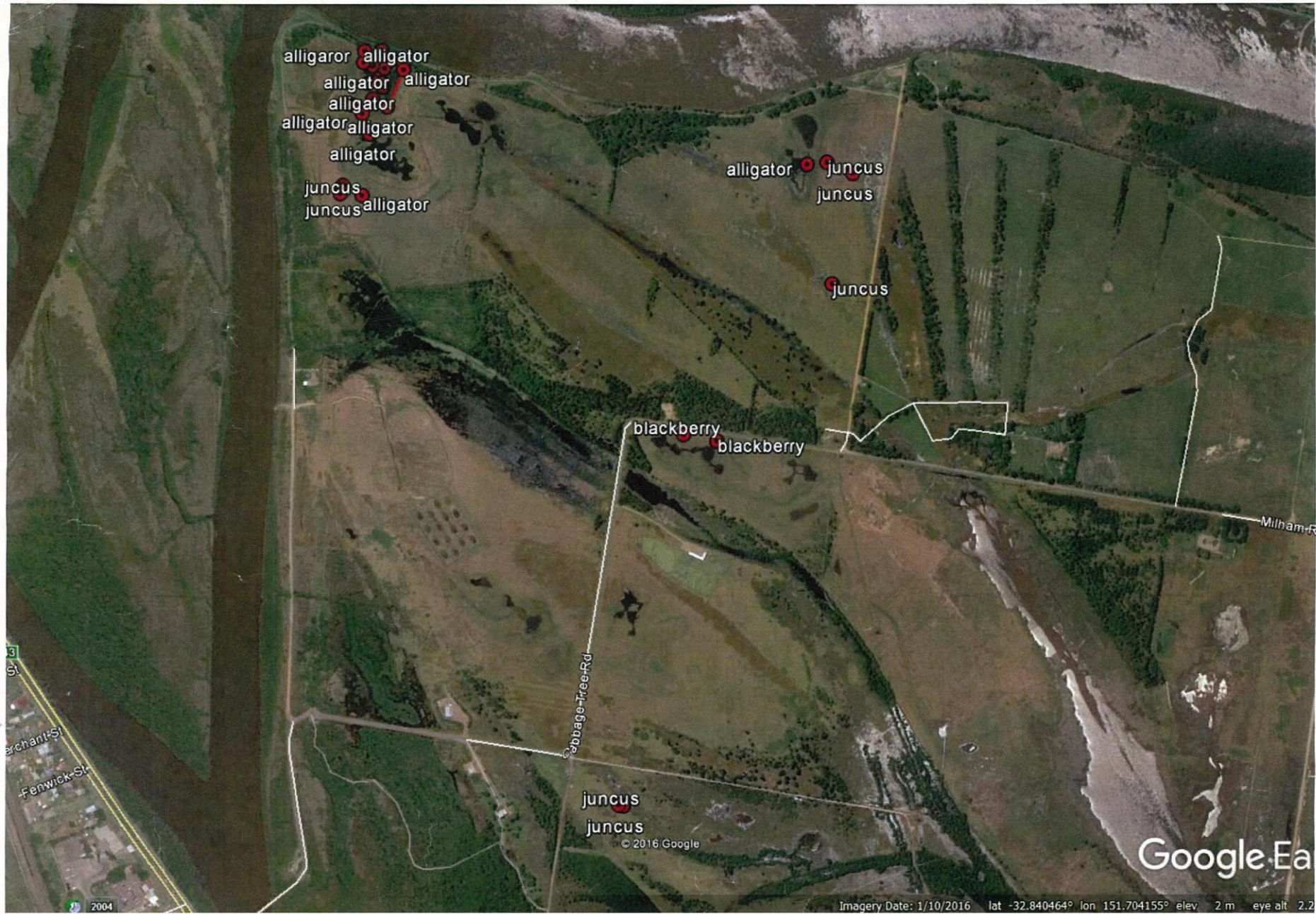


Pond 16 drying post dewatering

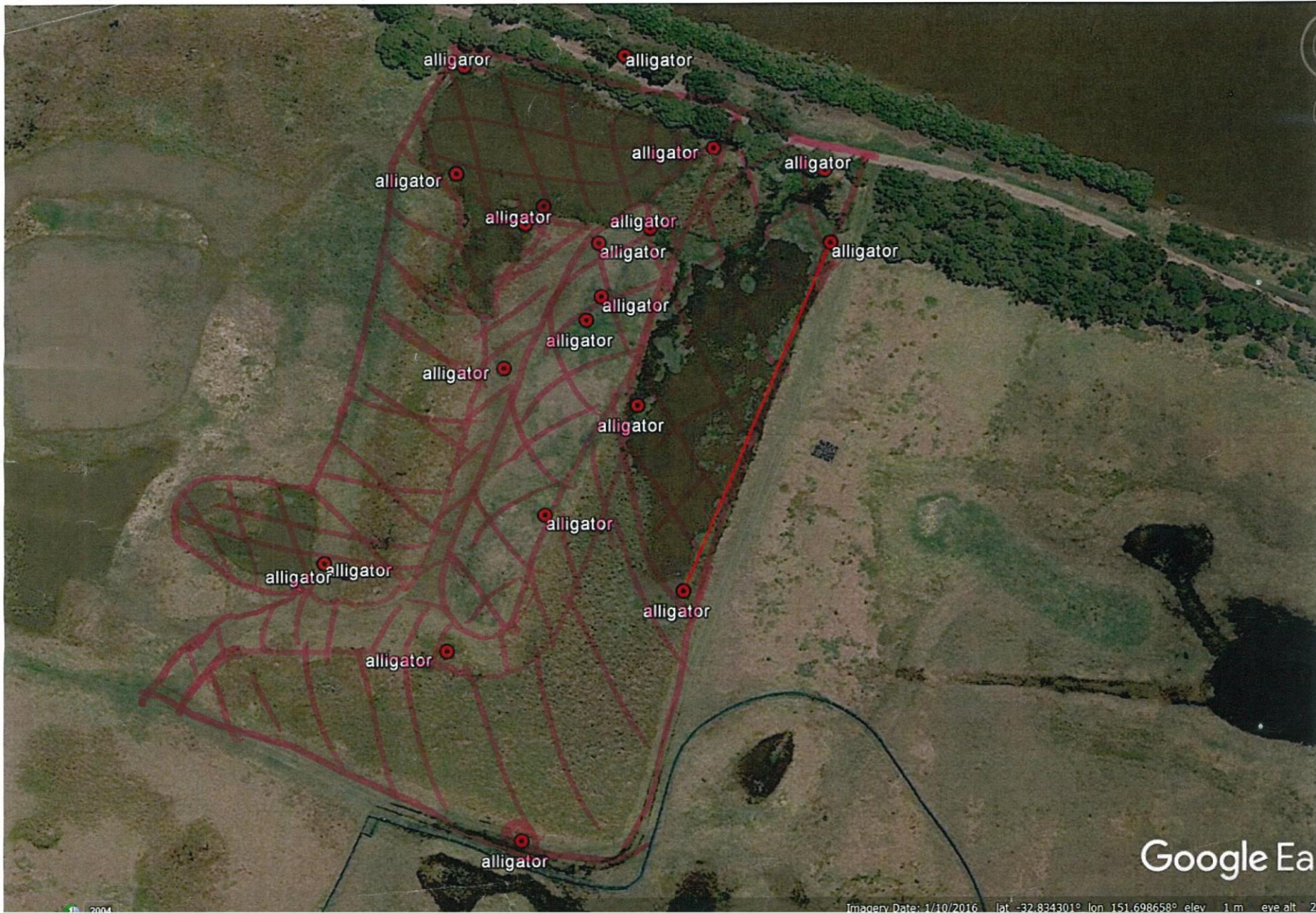


Pond 8 dewatering setup

WEED CONTROL AREAS



WEED CONTROL AREAS



SITE REPORTS

NPWS Lower Hunter Area Weed Treatment Recording Sheet

AMS - Data

AMS Equipment ID No:	AMS Work Order No:	AMS Site Name: HWNP	Reserve Name: Ash Island
----------------------	--------------------	--	---

Activities Undertaken/ Situation

NCIG license Areas - weed treatment

NPWS Staff and Equipment (Operations)

Date:	Work centre:	Description:	Duration:	Number:

External Contractors and Equipment (Components)

Contractor Company Name:		Contact Number:	Purchase Order:	
Date	Contractor or equipment	Duration	Number	
29/11/16	CVA Bush regen	2	7.5	

Pest and Weed Information System (PWIS) – Data

Operator data

Operator name/s: Will McCaffrey Dylan Robson	Date/s: 29/11/16	Time/s: 7:00 - 3:00
---	---	--

Spatial Data – Arc Map

Specific Location (in order of treatment):		Easting or Latitude	Northing or Longitude
Spatial Data Capture Method: GPS Map / eye ball Other _____		Datum (circle): GDA94 AGD66 Map supplied	Spatial Data Captured By: Will McCaffrey

Weed Information

Weeds Targeted (common name)	Weed Density	Additional info
Juncus Acutus	sparse	
Aligator weed	Heavy	
Weed Density: Sparse >1%: Light 1 – 10% Medium 10-50% : Heavy 51-70%; Very Heavy 70%<		
Situation (circle): bushland grassland <u>wetland</u> rainforest trail/road along river/creek		

Spray Data

Full product name/s of chemical/s used:	Rate /100L water:	Total Used (ml or L):
Metsulfuron / metsun	10g/100L	5g
Glyphosate / Weedmaster	50ml	1L
Additive/Wetters Used (specify):	Nil	
Dye Used (specify):	Nil	
Spray Equipment Used (circle):	Total Spray Mix Applied:	
Spray gun Quik Spray <u>Backpack</u> Splatter gun Spray bottle	100L	
Other: _____		
Method (circle):		
<u>Foliar (spot) spray</u> Boom spray Basal bark Stem injection Cut & paint Splatter gun		
Other: _____		

Weather Conditions

Showers		Light Cloud			
Overcast		<input checked="" type="checkbox"/> Clear Sky			
Time	Temperature (°C)	Relative Humidity (%)	Wind Speed (km/h)	Direction (from)	Variability (e.g. gusting)
Start: 7:30	19.4	60	6		9
Finish: 3:00	26.2	70	9		6
Comments (e.g. any problems with the application)					

General Information

Observations General / Interesting Sightings

white bellied sea Eagles

Accident/ Incident/ Near Miss Report

No accidents / incidents

Requirements for follow work

monitor weed treatment for follow up works

Entered in

AMS

PWIS



NPWS Lower Hunter Area Weed Treatment Recording Sheet

AMS - Data

AMS Equipment ID No:	AMS Work Order No:	AMS Site Name: <div style="text-align: center; font-size: 1.2em;">HWNP</div>	Reserve Name: <div style="text-align: center; font-size: 1.2em;">Ash Island</div>
----------------------	--------------------	---	--

Activities Undertaken/ Situation

NCIG license areas - weed treatment: *Aligator weed*
Juhcus Acutus

NPWS Staff and Equipment (Operations)

Date:	Work centre:	Description:	Duration:	Number:

External Contractors and Equipment (Components)

Contractor Company Name:		Contact Number:	Purchase Order:	
Date	Contractor or equipment	Duration	Number	
28/11/16	CVA Bush Regen	7.5	2	

Pest and Weed Information System (PWIS) – Data

Operator data

Operator name/s: <div style="font-size: 1.2em; color: blue;">Will Mc Caffrey Dylan Robson</div>	Date/s: <div style="font-size: 1.2em; color: blue;">28/11/16</div>	Time/s: <div style="font-size: 1.2em; color: blue;">7:00 - 3:00</div>
--	---	--

Spatial Data – Arc Map

Specific Location (in order of treatment):	Easting or Latitude	Northing or Longitude
Spatial Data Capture Method: GPS Map / eye ball Other _____	Datum (circle): GDA94 AGD66 Map supplied	Spatial Data Captured By: <div style="font-size: 1.2em; color: blue; text-align: center;">Will Mc Caffrey</div>

Weed Information

Weeds Targeted (common name)	Weed Density	Additional info
Aligator weed	Heavy	
juvencus Aquaticus	light	
Weed Density: Sparse >1%: Light 1 – 10% Medium 10-50% : Heavy 51-70%; Very Heavy 70%<		
Situation (circle): bushland grassland <u>wetland</u> rainforest trail/road along river/creek		

Spray Data

Full product name/s of chemical/s used:	Rate /100L water:	Total Used (ml or L):
Weedmaster Duo/Glyphosate Metsulfuron	50:1 10g/100L	10g
Additive/Wetters Used (specify):	Nil	
Dye Used (specify):	Nil	
Spray Equipment Used (circle): Spray gun Quik Spray <u>Backpack</u> Splatter gun Spray bottle Other: _____		Total Spray Mix Applied: 100L
Method (circle): <u>Foliar (spot) spray</u> Boom spray Basal bark Stem injection Cut & paint Splatter gun Other: _____		

Weather Conditions

<input type="checkbox"/> Showers			<input type="checkbox"/> Light Cloud			
<input type="checkbox"/> Overcast			<input checked="" type="checkbox"/> Clear Sky			
Time	Temperature (°C)	Relative Humidity (%)	Wind Speed (km/h)	Direction (from)	Variability (e.g. gusting)	
Start: 8:00	19.3	60	7	S	12	
Finish: 2:30	28	73	12	SE	19	
Comments (e.g. any problems with the application)						

General Information

Observations General / Interesting Sightings

high diversity of wetland species throughout treatment area

Accident/ Incident/ Near Miss Report

No accidents / incidents

Requirements for follow work

continue Aligator weed treatment

Entered in

AMS

PWIS



WetlandCare Australia

DAILY SITE REPORT			
Date	14/11/16		
Job site	Ash Island Bell Frog Ponds		
WCA / CVA Crew names	Elise Budden Team Leader		
Labour Hours	Crew number <u>7</u> x Hours on site <u>6</u> = Total <u>42</u>		
Number of volunteers	6		
Number of indigenous	⊖ No. On Country:		
Weather conditions	Complete weather info on Chemical Operators Data Sheet		
Photos taken Yes/No	Yes		
WEED TREATMENT – <input type="checkbox"/> Primary <input type="checkbox"/> Secondary <input checked="" type="checkbox"/> Maintenance			
CHEMICAL <input type="checkbox"/> Foliar Spraying <input type="checkbox"/> Stem Injection <input type="checkbox"/> Cut & Paint <input type="checkbox"/> Stem scrape <input type="checkbox"/> Foliar Wipe <input type="checkbox"/> Basal Bark (Complete Chemical Operators Data Sheet)	MANUAL <input checked="" type="checkbox"/> Hand Pulling <input checked="" type="checkbox"/> Chipping <input type="checkbox"/> Crowning <input type="checkbox"/> Cutting Tracks <input type="checkbox"/> Slashing <input type="checkbox"/> Mowing <input type="checkbox"/> Other	TARGET SPECIES 	PLANT STATUS <input checked="" type="checkbox"/> Healthy <input type="checkbox"/> Stressed <input type="checkbox"/> Flowering <input checked="" type="checkbox"/> Seeding <input type="checkbox"/> Mature <input type="checkbox"/> Immature CONTROL STATUS <input type="checkbox"/> New Infestation <input type="checkbox"/> Active Infestation <input checked="" type="checkbox"/> Under Control
ACTIVITIES & OBSERVATIONS			
Weeding wild Aster, Purpletop, Fireweed within two metre buffer of ponds. Chipping out grass (Couch) around native Juncus. Completed Ponds 5, 17, 18 *Two adult Litoria aurea sighted at Pond 18. 4-5 cm long			
FOLLOW-UP REQUIREMENTS			
ACCIDENT / INCIDENT			
Yes / <input checked="" type="checkbox"/> No			

WetlandCare Australia

DAILY SITE REPORT			
Date	15/11/16		
Job site	Ash Island Bell Frog Ponds		
WCA / CVA Crew names	Elise Budden - Team Leader		
Labour Hours	Crew number <u>5</u> x Hours on site <u>6</u> = Total <u>30</u>		
Number of volunteers	4		
Number of indigenous	0 No. On Country:		
Weather conditions	Complete weather info on Chemical Operators Data Sheet		
Photos taken <input checked="" type="checkbox"/> Yes / <input type="checkbox"/> No			
WEED TREATMENT - <input type="checkbox"/> Primary <input type="checkbox"/> Secondary <input checked="" type="checkbox"/> Maintenance			
CHEMICAL <input type="checkbox"/> Foliar Spraying <input type="checkbox"/> Stem Injection <input type="checkbox"/> Cut & Paint <input type="checkbox"/> Stem scrape <input type="checkbox"/> Foliar Wipe <input type="checkbox"/> Basal Bark (Complete Chemical Operators Data Sheet)	MANUAL <input checked="" type="checkbox"/> Hand Pulling <input checked="" type="checkbox"/> Chipping <input type="checkbox"/> Crowning <input type="checkbox"/> Cutting Tracks <input type="checkbox"/> Slashing <input type="checkbox"/> Mowing <input type="checkbox"/> Other	TARGET SPECIES	PLANT STATUS <input checked="" type="checkbox"/> Healthy <input type="checkbox"/> Stressed <input type="checkbox"/> Flowering <input checked="" type="checkbox"/> Seeding <input type="checkbox"/> Mature <input type="checkbox"/> Immature CONTROL STATUS <input type="checkbox"/> New Infestation <input type="checkbox"/> Active Infestation <input checked="" type="checkbox"/> Under Control
ACTIVITIES & OBSERVATIONS			
Removing wild Aster, Fireweed, Purpletop. Chipping out Kikuyu & Couch around Typha & Juncus kraussii. Completed Ponds 6, 7, 8, 9, 10, 11.			
FOLLOW-UP REQUIREMENTS			
Pond 4 remaining to weed.			
ACCIDENT / INCIDENT			
Yes / <input checked="" type="checkbox"/> No			

Appendix B – Shorebird Monitoring tabulated results (General Flora and Fauna)

Appendix C – Area E Benthic Survey Report (ERM Consulting)

Compensatory Habitat Consultative Board Meeting – Minutes
Meeting No: 11
7th July, 2016 1100 – 1430
Venue: NCIG Administration Building / Migratory Shorebird Habitat
Construction Project

Attendees:	Apologies:
<p>Mr Deon Von Rensburg – Office of Environment and Heritage (NPWS) Dr Jose Rodriguez – Newcastle University Ms Peggy Svoboda – Hunter Central Rivers Local Land Services Dr John Clulow – University of Newcastle Mr Mick Roderick – Hunter Bird Observers Club Mr Phil Straw – Avifauna Ecologist Mr Nathan Juchau – Newcastle Coal Infrastructure Group Mr Philip Reid – Newcastle Coal Infrastructure Group Mr Allan Greer – Newcastle Coal Infrastructure Group</p>	<p>Prof Michael Mahony – Newcastle University Ms Alex Callen – University of Newcastle Dr Arthur White – DoP-approved Ecologist Miss Jacqui McLeod – NSW Department of Planning and Environment Mr Alan Stuart – Hunter Bird Observers Club Mrs Karen Fitzherbert - Hunter/Central Rivers Local Land Services</p>

Item	Description	Action Owner
1.0	Welcome / Introductions	
1.1	Meeting Open 1115hrs	
2.0	GGBF Habitat Update, including Captive Breeding and Management/Maintenance	
2.1	<p>JC delivered a presentation on recent findings from GGBF Research Area (Trial Site), Compensatory Habitat monitoring and breed and release program. Key points:</p> <ul style="list-style-type: none"> - Results from the Trial Site show very low numbers compared with previous seasons. Analysis of results is ongoing. However, understanding is that dramatic drop in numbers was caused mostly by Chytrid. Fence has since been removed. - A.Callen has formally ended her engagement with NCIG, but continues to write her thesis. - Numerous animals observed throughout the broader Compensatory Habitat, both adults and juveniles. Two breeding events observed in February 2016 in habitat adjacent the NCIG constructed habitat. Based on observations, the adults observed in NCIG habitat and the breeding is operating as one system. Areas of breeding were highly ephemeral wetlands. Breeding is most likely to have resulted from captive-bred animals introduced into the landscape by NCIG. - <i>Gambusia</i> was an issue in releasing captive-bred animals, in that only a limited number of ponds were <i>Gambusia</i>-free for release of tadpoles. Small experiments conducted with metamorph release shows that metamorphs will travel long distances. 	
2.2	PR spoke about maintenance and weed/vegetation monitoring of GGBF Compensatory Habitat. This has focussed on weed and pest management to date. Recent modifications also made to GGBF ponds, i.e. bunding, and changes to the management plan to treat ponds that have been pumped out for <i>Gambusia</i> .	

3.0	Migratory Shorebird Compensatory Habitat Update	
3.1	AG provided an update on the status of migratory shorebird habitat construction. Key points were: <ul style="list-style-type: none"> - Removal of mangroves well underway. Progress is on track - Smart Gate for hydrological control and Mangrove Propagule Exclusion Device (MPED) concept design commenced - Bird monitoring being conducted during construction period. 	
3.2	DVR made comment of Tomago project and there is opportunity for the NCIG Area E Migratory Shorebird Habitat project to gain from learnings from this. DVR also made comments of SETS remaining in Area E from previous sediment accretion studies. These are expected to be monitored by Uni of Wollongong facilitated by NPWS in the future	
4.0	Visit to NCIG Migratory Shorebird Compensatory Habitat construction project	
4.1	Meeting attendees inducted and shown various parts of the project including: <ul style="list-style-type: none"> - Various work fronts - Mangrove removal activity from Fish Fry Flats - Fish Fry Creek culvert for installation of Smart Gate and MPED - Mangrove mulch pile 	
5.0	Next Meeting	
5.1	- TBA.	
5.2	Minutes to be distributed to attendees and those not present.	PR
5.3	Meeting close 1430hrs.	

Compensatory Habitat Consultative Board Meeting – Minutes

Meeting No: 12

13th December, 2016 1100 – 1430

Venue: NCIG Administration Building, NCIG Migratory Shorebird Compensatory Habitat (Area E)

Attendees:	Apologies:
<p>Mr Doug Beckers – Office of Environment and Heritage (NPWS) Mrs Karen Fitzherbert - Hunter/Central Rivers Local Land Services Dr Arthur White – DoP-approved Ecologist Dr Jose Rodriguez – Newcastle University Prof Michael Mahony – Newcastle University Dr John Clulow – University of Newcastle Mr John-Paul King – University of Newcastle Mr Mick Roderick – Hunter Bird Observers Club Mr Nathan Juchau – Newcastle Coal Infrastructure Group Mr Philip Reid – Newcastle Coal Infrastructure Group Miss Erin Jacobi-McCarthy – Newcastle Coal Infrastructure Group</p>	<p>Miss Jacqui McLeod – NSW Department of Planning and Environment Mr Alan Stuart – Hunter Bird Observers Club</p>

Item	Description	Action Owner
1.0	Welcome / Introductions	
1.1	Meeting Open 1115hrs	
2.0	GGBF Compensatory Habitat Update, including Captive Breeding and Management/Maintenance	
2.1	<p>JPK delivered a presentation on recent monitoring results from the GGBF Compensatory Habitat. Key points:</p> <ul style="list-style-type: none"> - Two rounds of Visual Encounter Surveys (VES) conducted at all compensatory wetlands - Fyke (trapping for tadpoles) netting conducted in Stages 4, 5 and 7 - Gambusia and macroinvertebrate sampling at Stage 7 - WQ and vegetation data collected for all wetlands - 55 individual GGBF captured, including 15 gravid females - Calling males recorded at Stages 4 and 7 - Wetland bunding and draining conducted, specifically adjacent locations where sexually mature adults were previously recorded. This was to manage Gambusia. - Separate pond draining also conducted to release captive-bred tadpoles into compensatory habitat (3 cohorts of captive-bred animals) - Further actions include additional bunding and draining, further VES and Capture-Mark-Recapture to be completed, additional fyke netting 	
2.2	Particular points discussed were that adult sightings have increased compared to the previous season. However, JPK pointed out this may be due to sampling efforts starting earlier in the season. Also observed that there have been no GGBF observed at Stage 2 to date – ponds in this stage also have a large fish population.	

2.3	MM mentioned that conditions at the time of the meeting were dry and GGBF were occupying locations of permanent water, including K22/23 ponds near the Kooragang main rail line.	
2.4	JPK pointed out that the current method of monitoring has changed in comparison to previous seasons, so that data is compatible with data collected from the industrial part of Kooragang Island, from which better population estimates can be made. DB asked whether data is being shared with BHP. PR replied that detailed data is not currently shared but that general observations, including breeding events are shared at various times throughout the season. Also pointed out that NCIG, BHP, OEH and other industries were in the process of signing a Memorandum of Understanding to share data in the future. This was likely to be signed by all parties in late FY17.	
2.5	MR asked whether there had been any Australasian Bittern observations during monitoring work as habitat appeared suited to this species. JPK had not observed any to date.	
2.6	DB requested that NCIG prepare a short checklist-style document to assist with and document management plan controls utilised when management works were being conducted for the GGBF Compensatory Habitat	PR to prepare Comp Habitat management checklist
3.0	Migratory Shorebird Compensatory Habitat Update	
3.1	PR provided an update on the status of migratory shorebird habitat. Key points were: <ul style="list-style-type: none"> - Removal of mangroves and installation of MPEDs was completed in September. - Bird diverters were installed on Ausgrid and Transgrid powerlines during September and October. - Fish Fry Creek Smart Gate was installed in October. - A number of photos of shown including progress photos of the construction project, before and after aerial images and migratory waders using the area post-construction - Preliminary monitoring results showed there was initial spike in bird abundance using Area E post-mangrove removal. This was an initial response to the modified environment, with both endemic and migratory species using the exposed mudflat areas - Identified that there would be a meeting held with all key shorebird habitat stakeholders to identify the best path forward with regard to objectives for the habitat 	
3.2	MR highlighted that inland NSW currently had high bird numbers in response to recent rain events. This has a flow-on effect for bird abundance in the Hunter, with less bird observed compared to normal.	
3.3	DB asked if there was an MPED on Wader Creek. PR responded that there is an MPED specially made for the box drain at the end of the creek, which had recently been removed for cleaning, as there were no mangrove propagules present in the system. MM highlighted that extensive mangroves first appeared in the Area E system after the flood mitigation controls were removed from Fish Fry Creek.	
3.4	MR asked about whether NPWS and Port of Newcastle were planning to remove the remaining mangroves from Swan Pond to ease propagule pressure	
3.5	Theory that there may be potential sediment loss in the system after removal of the mangroves. PR pointed out that this would be assessed through regular (6-monthly) surveys of the site.	
4.0	Visit to NCIG Migratory Shorebird Compensatory Habitat (Area E)	

4.1	Meeting attendees travelled to Area E to inspect the completed mangrove removal area, bird diverters, MPEDs and the Smart Gate.	
5.0	Next Meeting	
5.1	- TBA.	
5.2	Minutes to be distributed to attendees and those not present.	PR
5.3	Meeting close 1430hrs.	

APPENDIX 6
ANNUAL REPORT (2016/17) RESEARCH PROGRAM ON THE GREEN AND
GOLDEN BELL FROG ON KOORAGANG ISLAND

Research Program on the Green and Golden Bell Frog (*Litoria aurea*) on Kooragang Island

Annual Report (2016-2017)

Conducted by the Amphibian Research Group, University of Newcastle,
on behalf of *Port Waratah Coal Services, Newcastle Coal Infrastructure
Group, and Hunter Development Corporation*

*Report prepared by Colin McHenry, Bede Moses, Cassandra Maynard, Simon
Clulow, John-Paul King, and Michael Mahony*

August 2017

Executive Summary

1 *Green and Golden Bell Frog population on Kooragang Island wetlands*

We surveyed 73 wetlands:

- There were three rounds of surveys at each wetland
 - i. Round 1 was late-November to December 2016
 - ii. Round 2 was January to early February 2017
 - iii. Round 3 was February to early March 2017

The population of >40 mm SVL individuals (i.e. mid- to large-sized juveniles, and adults) was estimated to be between 1,700 and 3,900 in Round 1, reducing slightly to between 1,280 and 3,280 by round 3.

- The robust population estimates are that the population was approximately 2580, 2120, and 2030 in rounds 1, 2, and 3 respectively.
- This is consistent with the range of population estimates generated from 2012 to 2016, and suggests that while small, the Kooragang Island population is stable.

2 *The 2016-17 surveys: seasonal context*

It was an unusually dry period during the spring and summer seasons; this had a strong effect on the pattern of results.

- Hydrology:
 - i. Low winter rainfall meant that many wetlands were not recharged during winter and were drying or dry by late spring 2016.
 - ii. Low rainfall over the summer led to 33 of the surveyed wetlands being dry by the end of summer
- GGBF distribution:
 - i. Frogs were found at a smaller number of wetlands than usual; i.e. the ones that still contained water.
 - ii. Although their distribution contracted, they were present in very high numbers at some of these (e.g. >200 frogs detected at K29 in a single night).
 - iii. Because we survey many of the wetlands that still contained water, it is likely that the dry season increased the probability of detection this year. Hence, although the population estimate for this year's survey is higher than for last year, it is possible that the high rainfall in 2015-16 led to frogs being highly dispersed across the landscape, and thus having a lower detection probability. Given the very different rainfall patterns in the last two years, it is too simplistic to assume that the actual population has increased since last year.
- *Gambusia*:
 - i. The drying of so many wetlands reduced *Gambusia* distribution across the landscape, after flooding in 2015 and early 2016 resulted in the fish being widely distributed across the island

The pattern of rainfall and hydrology had consequences for distribution, demography, and breeding of *L. aurea*; specific instances are evident throughout the results

3 Biology of Green and Golden Bell Frogs

The unusually dry spring and summer seasons, and the large number of animals captured, provided a large dataset and further added to our understanding of *L. aurea* biology. This knowledge is important for effective management efforts on the island.

Habitat

- *L. aurea* are most common at wetlands that have open water surrounded by emergent vegetation (reeds and rushes). *Typha*, *Phragmites*, and *Juncus* all provide important microhabitat.
- Around the edges of wetlands, frogs are often found in thick grass, and in trees (wattles, she-oaks, and mangroves)
- The largest *L. aurea* numbers occur at permanent wetlands that are surrounded by a range of smaller semi-permanent and ephemeral wetlands. This mosaic of habitat types appears to provide the best conditions for persistence in good numbers at a given location. Conversely, regions of the island with a small number of permanent wetlands have low numbers of frogs.

Distribution

- More than 80% of the *L. aurea* were detected in the southern part of the island, i.e. in the industrial zone.
 - i. Note that this is based upon the 73 wetlands that are surveyed under the island-wide monitoring program, and does not include the CHEMP wetlands in the northern and central parts of the island. Surveys of those CHEMP wetland populations are detailed in other reports.
 - ii. In summary, those CHEMP wetlands do contain good (and growing) numbers of *L. aurea*, although the majority of the island's population remains located within the industrial zone.
- The majority of frogs were detected at the permanent wetlands (consistent with the low rainfall in this season).
- Within the industrial zone, the largest numbers were in the middle part of the northern rail corridor (i.e. around K29).
 - i. The number of frogs detected at K104 decreased from last year, but the number at K29 greatly increased,
 - ii. There were more *L. aurea* found in the southern half of the industrial zone this year (compared with last year), perhaps an outcome of the improved connectivity resulting from the wetlands constructed during capping by HDC in 2015.

Demography

- The low rainfall, and contraction of *L. aurea* to a small number of permanent wetlands, resulted in high capture rates, particularly at the wetlands surveyed for Capture-Mark-Recapture surveys.
- This resulted in a large dataset that provides insight into the population demographics.
 - i. A large number of females were captured. As many of these had not laid eggs (due to lack of rainfall), we were able to check for gravidity in many of these. As a result, it appears that females are capable of becoming gravid at a smaller size than we had previously believed.

- This strongly implies that females are starting to breed in their second year (previously, we understood that they could not breed until their third year).
 - Accordingly, it appears that the proportion of reproductively viable females – crucial for population viability – may be larger than we had understood previously.
- ii. In some cases (K29 and K104), we were able to identify cohorts of young animals, track them as they grew through the season, and tie them to the specific rainfall events in which they were laid.
- This in turn reveals that eggs laid in late spring can become small adults by the end of their first season, whilst eggs laid in mid-summer overwinter as juveniles
 - It is possible that frogs that over-winter at different life-stages have different vulnerability to chytrid.

Growth and longevity

- Longitudinal data from individuals recaptured over multiple seasons shows that mortality between years is high. Very few animals survive to their 3rd year and almost none to their 4th (unlike the situation in the chytrid-free population at Broughton Island).

Movement

- Year to year, *L. aurea* display high levels of site fidelity, being mostly recaptured at the same permanent wetlands that they were first marked at (even though they disperse to nearby ephemeral wetlands after rain for breeding).
- Based on marked individuals, we detected very few instances of movement between wetlands. Most of the detected movements were to/from K29 and surrounding wetlands. We detected one instance of an animal moving across the Port Waratah rail line, and one instance of a frog moving out of the NCIG rail loop.
- Most detected movements are less than 0.5 km.

Reproduction

- Reproduction was detected at 8 wetlands. Most of these breeding events appear to have been small. Only three sizeable breeding events were detected; at K104, K111, and K114.
- The relationship between *Gambusia* and breeding was complicated this year by the lack of ephemeral, *Gambusia*-free wetlands. Despite the presence of *Gambusia*, metamorphs were detected at K29 and K104, which are both infested with *Gambusia* – and at K104 those metamorphs were present in good numbers.
 - The highest numbers of metamorphs were detected at HDC wetlands K111 and K114 (which lack *Gambusia*).
- Although not monitored directly, it is possible that the autumn rain event (from the tropical cyclone Debbie) allowed a large breeding event. If so, this should be detectable as a cohort of mid-sized juveniles in November 2017.

4 Regional summary

1. North-west Island

- Bell frog numbers remain low at the 'natural' wetlands monitored under the island-wide program, with only one animal detected through the season.
 - Numbers were lower than the previous season, due largely to the fact that many of those wetlands had dried.
- Separate surveys indicate that only the NCIG CHEMP wetlands contain bell frogs in reasonable numbers in this part of the island.

2. Central Island

- Many of the wetlands along Bell Frog Lane dried out, leaving only K23 with a significant number of frogs.
- As with the NW island, the CHEMP wetlands on the western edge of this zone are providing permanent wetlands and contain a large proportion of the frogs in the Central zone.

3. Southern Island

- Still home to the majority of the island's GGBF population, particularly in the northern part of the industrial site. The 'key ingredients' of this region appear to be:
 - i. A large number of permanent wetlands,
 - ii. many of which contain open water (i.e. not 'choked' by *Typha* and *Phragmites*),
 - iii. surrounded by a mosaic of semi-permanent and ephemeral wetlands,
 - iv. in addition to any aspects of water quality (e.g. salinity) that may act to suppress chytrid.
- As with the CHEMP wetlands in the Central and NW regions, the constructed wetlands (C1, C2, K111-K114, K117, K118) are home to growing numbers of bell frogs. The two largest breeding events detected this year occurred in two of these constructed wetlands.
- Although K108 was dry for the whole season, the increase in nearby wetlands (as a result of the constructed wetlands) seems to have improved connectivity in the southern part of the industrial site.

5 Implications for management of *L. aurea* on Kooragang Island

1. At a local scale, the best chance for persistence of bell frogs in good numbers seems to involve a mosaic of habitats that include:
 - i. A larger permanent wetland edged by emergent vegetation, but with some significant area of open water
 - ii. Nearby ephemeral wetlands that provide suitable breeding sites in wet years
 - iii. Other nearby semi-permanent wetlands that provide breeding or refuge sites in dry years.
 - iv. This mosaic of wetlands should be within a 0.5 km radius
 - v. It is not essential for the permanent wetland to be free of *Gambusia*, but the nearby ephemeral and semi-permanent wetlands should be *Gambusia*-free as much as possible.
2. At present, the NCIG CHEMP wetlands are very important for the GGBF in the NW island.
3. The BHP CHEMP wetlands are playing an important role in the Central part of the island.
4. The 'Northern Rail Corridor' remains the most important part of Kooragang Island for GGBF, with more than 50% of the animals detected with in this part of the industrial zone.

5. Bell frogs show high levels of site fidelity. This has important implications for any future mitigation of human activity on key wetlands (e.g. in the northern rail corridor).
6. Dispersal is evidently sufficient to allow colonisation of new ponds within a 0.5 kilometre radius, as evidenced by the presence of bell frogs at three constructed wetlands from which they were absent last year.
7. Female bell frogs may be reproducing earlier (in their second year) on Kooragang Island than occurs in the chytrid-free population on Broughton Island, perhaps as a result of rapid adaptation. If confirmed, this means that the survival of females into their third and fourth years may be less critical than previously believed.
8. Notwithstanding the previous point, very few animals survive to their third year. For the best chances of securing the Kooragang Island population against periods of prolonged drought, there should be sufficient permanent and semi-permanent wetlands capable of providing *Gambusia*-free breeding habits though a succession of dry years.

Contents

Executive Summary	2
1. Introduction.....	9
1.1 Background to the study	9
1.2 Background to the problem: the green and golden bell frog decline	11
1.3 Future Directions and Research Significance	13
1.4 Summary of Historical Findings	15
1.5 Specific Research Objectives	18
2. Methods	19
2.1 Wetland sample sites	19
2.2 Jurisdiction.....	22
2.3 Long-term monitoring approach	24
2.4 Survey techniques	24
2.5 Search effort	26
2.6 Methodological approaches used to address objectives	29
3. Results	36
3.1. Survey Counts.....	36
3.2. Seasonal context: environmental factors.....	39
3.3. Distribution.....	49
3.4. Demographics.....	55
3.5. Longitudinal data: persistence, growth, and movement	70
3.6. Breeding and recruitment	78
3.7. Population size	80
4. Discussion	85
4.1 Analysis of Historical Findings	85
4.2 Survey Counts and Population Estimate	86
4.3 Environmental and landscape factors	87
4.4 Distribution and spatial patterns.....	90
4.5 Demographics.....	93
4.6 Longitudinal Studies	95
4.7. Breeding and Recruitment	97
5 References	99

1. Introduction

1.1 Background to the study

Historical Context and Research Objectives

In 2010, the University of Newcastle was first commissioned to investigate the population ecology of the Green and Golden Bell Frog (*Litoria aurea*) on Kooragang Island. Members and affiliates of the University's Conservation Biology Lab have continued to undertake this survey annually, totaling seven years of consecutive monitoring. Over one thousand people hours of field work have been conducted, leading to the capture of more than three thousand *L. aurea* individuals. This rich, historical data set represents one of the most comprehensive investigations of this threatened species to date. Indeed, continuous monitoring of this scale - especially of amphibian species – remains rare in an Australian context.

Over the monitoring period the wetlands surveyed have remained largely the same. With the construction and alteration of several wetlands, the absolute number of wetlands surveys has increased, and the focus of each seasons' survey has sometimes shifted to track significant changes in population demographics. Nevertheless, the primary aims and methodology of consecutive surveys has remained consistent. The following objectives continue to be prioritized:

1. Calculating a robust valuation of total *L. aurea* population size within the Kooragang Island Management Zone.
2. Determining the demographic composition of these populations; specifically, the ratio of adults to sexually immature juveniles and the ratio of males to females.
3. Defining the spatial distribution of *L. aurea* populations. Where are individuals concentrated? Is there evidence of movement between wetlands and across infrastructure barriers?

Since its inception, the project has employed two primary field survey techniques for data collection. These two methods are 'Capture-mark-recapture (CMR)' and 'Visual Encounter Survey (VES)' respectively. Throughout seven years of continuous monitoring, the scope of the program has necessarily expanded to address questions regarding why *L. aurea* continues to persist in some habitats but has failed to successfully colonize others. Such investigation has helped inform best practice habitat creation for relevant stakeholders, improving ecological outcomes for this federally listed threatened species.

Site context

Kooragang Island lies at the northern boundary of the Newcastle City Council area, a city located on NSW's Central Coast (Figure 1A). 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, and indeed prior to human development, separated the current landmass into smaller islands. The natural hydrology of the island has been considerably altered, with agricultural development such as draining of land for pastures and industrial activity such as road construction altering tidal inflow. Nonetheless, the island supports a diversity of wetlands ranging from saltmarsh and tidal flats to freshwater swales and large permanent freshwater wetlands.

The Kooragang Island Management Zone - henceforth simply referred to as the 'study area' - has historically been divided into three regions in previous survey reports. The North-West region, colloquially referred to as 'Ash Island', was historically a distinct landmass until reclamation works in the 1960's

Kooragang Island Bell Frog Survey 2016-2017

amalgamated several islands to form today's 'Kooragang Island'. The Central and Southern regions are separated from one another by the industrial railway and associated exclusion corridor, which dictates that each region be accessed via different roadways. The North-West and Central regions fall primarily within the Hunter Wetlands National Park, with the Southern region conversely zoned for industrial use. Some segments of the National Park are leased to stakeholders undertaking various rehabilitation projects. Substantial effort has been expended to recreate *L. aurea* habitat within the boundaries of the National Park, which was historically cleared and use as grazing land. Wetland infrastructure in the Industrial zone of the management site is primarily human made, and has significant success supporting large numbers of *L. aurea*, as determined in previous surveys.

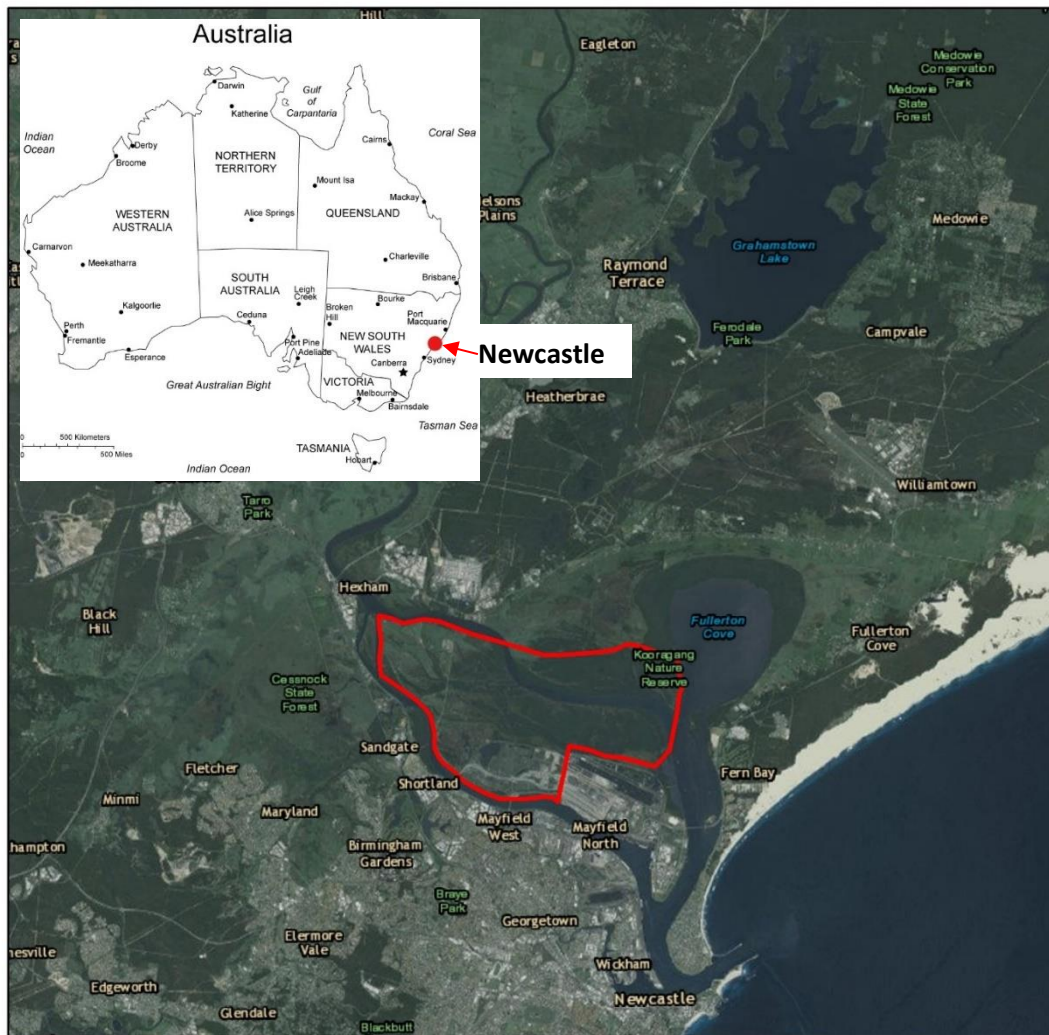


Figure 1A – Contextual map describing the location of the Kooragang Island Management Zone within Australia, and the Greater Newcastle Area. The Management Zone is bounded in red.

1.2 Background to the problem: the green and golden bell frog decline

Historically, *Litoria aurea* was common and widespread along Australia's East Coast, stretching from northern New South Wales to southern Victoria, as well as into inland tablelands (Pyke et al., 2002). Rapid declines were observed from the early 1970's, leading to a dramatic reduction in both distribution and abundance (Mahony et al., 2013, Pyke and White, 1996, Pyke et al., 2002). Today, *L. aurea* persists in less than 10% of its historical distribution and occupies fewer than forty sites, most of which are geographically isolated from one another (White and Pyke, 1996, Mahony et al., 2013). Populations that were once reported on the Central Tablelands are now presumed extinct, having not been observed since the early 1970s (White and Pyke, 1999, White and Pyke, 1996). Additionally, until a recent rediscovery of a small population in Queanbeyan (Wassens and Mullins, 2001) *L. aurea* was also presumed extinct in the Southern Tablelands, having not been observed there since 1980 (Osborne et al., 1996). Many populations have also been lost along the foothills and coastal plain of the Hunter, Sydney and Shoalhaven regions where once the species was abundant (Daly, 1996, White and Pyke, 1996). There is considerable evidence that the *L. aurea* was once common in the Hexham Swamp/Kooragang Island area of Newcastle (Hamer et al., 2004). The species apparently declined rapidly in the 1980s and by the 1990s the only confirmed breeding site south of the Hunter River was in small wetlands at Sandgate. This population disappeared some time prior to 2006.

These reductions have triggered the species to be listed endangered in NSW, and vulnerable at a federal level. Kooragang Island is considered one of the two key extant populations in the Lower Hunter region (DECC, 2007); the other population near Maitland has only sporadic reports of observations.

Causes of the decline

(a) Disease: chytridiomycosis

Recent declines in global amphibian populations far exceed those of other vertebrate groups, with over 30% of species now listed as threatened (Beebee and Griffiths, 2005). Significant losses were first reported in the 1980's, and have continued to escalate into the 21st century (Hussain, 2012). The Pandemic fungal disease 'chytridiomycosis' is heavily implicated in these declines, with conservative estimates suggesting it has driven over 200 species to, or to the edge of extinction (Skerratt et al., 2007). The chytrid fungus (*Batrachochytrium dendrobatidis*) infects the skin of effected amphibians, and at high infection loads can impair osmoregulation in adult frogs, stressing the circulatory system enough to cause mortality (Voyles et al., 2007).

The NSW National Parks and Wildlife Service Draft Recovery Plans for *L. aurea* lists disease (specifically chytridiomycosis) as a threat to the persistence of these species, and several observations of infection and die-offs are referred to therein (DEC, 2005a; DEC, 2005b). That the range contraction of the threatened bell frog species occurred rapidly suggests a causal agent that was able to act over short time periods was involved (Hamer et al., 2009). In the laboratory *Litoria aurea* is particularly susceptible to the chytrid fungus, with 100% of captive individuals exhibiting terminal signs of the disease following experimental exposure (Stockwell et al., 2010). Whilst it is unlikely the disease kills all infected wild individuals, the chytrid fungus clearly poses substantial threat to the persistence of wild populations of *L. aurea*. Indeed, our research group considers the rapid spread of chytridiomycosis to be the primary factor which has driven *L. aurea* towards extinction. Multistate modelling of the Kooragang Island population

supports this assertion, demonstrating significantly lower over-winter survival rates in infected (0.1) versus uninfected (0.56) individuals. This was in turn predicted to cause infected populations to decline at twice the rate of healthy ones (Stockwell, 2011). The chytrid fungus has also been implicated as the primary causal agent in the overwinter extinction of a reintroduced *L. aurea* population in the Hunter Region of NSW (Stockwell et al., 2008). The culmination of this evidence suggests that large-scale seasonal die-offs are common in *L. aurea* populations during cold periods, often remaining unobserved due to low frog detectability and reduced survey frequency. Such die-offs have serious implications for the ability of surviving populations to persist with infection, particularly given the potential for stochastic events such as drought or extreme weather events to introduce additional pressure (Stockwell, 2011)

The majority of surviving *L. aurea* populations are found in coastal environments. This has led to the historical assertion 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 *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. Indeed, any salt concentration above 2 ppt were found to be beneficial (Stockwell et al., 2015b, Stockwell et al., 2015a). These results confirm that *L. aurea* has a survival advantage in areas with a saline influence, with this salinity offering a refuge from the effects of the chytrid fungus. The deliberate addition of salt to water bodies, both in captivity and experimental reintroduction, has been demonstrated to increase bell frog survival rates where the chytrid fungus is present (Stockwell, 2011). Thus, consideration of salinity is likely to prove a useful strategy when designing new wetland infrastructure within the Kooragang Island Management Zone.

(b) The invasive mosquito fish *Gambusia holbrooki*

Field observations have long recognized that *Litoria aurea* are less likely to breed successfully in wetlands infested with the invasive species *Gambusia holbrooki*, also known as the mosquito fish or plague minnow. Laboratory experiments have demonstrated predation of *Gambusia* upon amphibian tadpoles and eggs (Stanback, 2010, Mahony et al., 2013) even though dissection of wild caught mosquito fish shows little evidence of this consumption. More recent dietary analysis using stable isotopes has successfully confirmed both the predominately carnivorous diet of *Gambusia*, and a high rate of predation on native Australian tadpole species (Remon et al., 2016). *L. aurea* tadpoles do not show any avoidance or refuge seeking behaviors when introduced to *Gambusia*, further increasing their susceptibility (Hamer et al., 2002b). These findings stress the importance of designing wetland infrastructure to control for *Gambusia* infestation.

Whilst the timing of the earliest *L. aurea* declines was coincident with the expansion of *Gambusia* into NSW (White and Pyke, 1996), numerous sites exist where *L. aurea* declined despite local water bodies being free of the predatory fish (Mahony et al. 2013). Indeed, several studies - including this annual survey report - have noted the co-occurrence of *L. aurea* tadpoles and *Gambusia* in the same water body; albeit on rare occasions (Sanders et al., 2015, Hamer et al., 2002a). Thus, the introduction of *Gambusia* is unlikely to be the primary causative factor in *L. aurea* declines. Nevertheless, mosquito fish certainly place additional strains on fragile populations, and efforts should continue to mitigate their impact and prevalence on Kooragang Island.

The presence of mosquito fish in permanent water bodies may also have resulted in a shift in the type of habitat utilised for breeding. 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 mosquito fish (Pyke and White 1996; Hamer, Lane et al. 2002; Pyke, White et al. 2002). However, breeding in ephemeral water bodies carries the risk of wetland drying before tadpoles can metamorphose (Hamer, Lane et al. 2002).

(c) Habitat destruction and fragmentation

There are correlations between the destruction of suitable habitat and local extinction of *Litoria aurea*. Many historic bell frog sites have been altered, particularly through infilling or drainage of wetlands for agriculture, trampling of waterways by feral horses and pigs as well as other urban and industrial development (Clancy, 1996, Daly, 1996, van de Mortel and Buttemer, 1996, Lewis and Goldingay, 1999). Habitat fragmentation reduces the probability that the smaller and disjunct populations which survive can persist through extreme events such as drought or outbreaks of disease. Furthermore, separation halts genetic exchange which would usually occur within meta-populations; resulting genetic bottle-necks can have grave implications for the long-term survival of affected species (Goldingay, 1996, White and Pyke, 1996, White and Pyke, 1999).

The creation of underpasses to facilitate the movement of wildlife across roads and infrastructure has become part of best common practice to try and reduce habitat fragmentation. Nevertheless, surprisingly little empirical data exists confirming the movement of amphibians through associated culverts and funnel fencing. Data is almost non-existent for Australian species, which do not undertake mass migrations on a seasonal basis (Koehler et al., 2014). The Growling Grass Frog (*Litoria raniformis*) is a close relative of *L. aurea* and has also undergone rapid population decline in the past 30 years. Recent research has documented the species moving through constructed culverts for the first time (Koehler et al., 2014), which implies *L. aurea* would likely do the same given suitable infrastructure.

The first four years of this research (years 2010-2014) found evidence of *L. aurea* individuals moving between the Central and Southern region of the Kooragang Island Management Zone. This suggests that the rail line and associated infrastructure are not a complete barrier to dispersal. It is important to note that whilst the last three years of surveys have shown no evidence of movement by the same corridor, this does not preclude the possibility that movement has continued; albeit unobserved. Observed instances of migration are discussed in greater detail in section 1.4 titled 'Summary of Historical Findings'.

1.3 Future Directions and Research Significance

Understanding habitat preference

Conservation efforts must be informed by a thorough understanding of *Litoria aurea's* population demography and habitat requirements. The Green and Golden Bell Frog is an opportunistic colonising species with high dispersal ability and fecundity (Lane et al., 2007, Pyke et al., 2002) which also suggests that it should readily establish populations in all suitable habitats. This has caused confusion as to why the species fails to occupy all seemingly suitable water bodies within the Kooragang Island management zone, and furthermore why its preferences appear to change both within and between seasons. Significant research effort has been devoted to characterizing the specific habitat features which are

integral to the survival of *L. aurea* (Pyke and White, 1996, White and Pyke, 1996, Christy and Dickman, 2002, Pyke et al., 2008). One study on Kooragang Island in 2002, found that *L. aurea* were more likely to be found in waterbodies which had a greater diversity of vegetation along their banks. The presence of the plant species *Juncus kraussii*, *Schoenoplectus littoralis* and *Sporobolus virginicus* were most positively correlated with *L. aurea* presence (Hamer et al 2002) . Research in this area continues within the Kooragang Island Management Zone, with studies underway from the University of Newcastle now focusing on the importance of specific vegetation assemblages.

It remains possible that the water bodies where *L. aurea* is regularly observed do not represent its ideal habitat. Instead, the species may be forced into sub-optimal areas by pressures such as habitat fragmentation and presence of *Gambusia holbrooki*. Nevertheless, the culmination of evidence to date implies that *L. aurea* is a habitat generalist, not a specialist, and is hence capable of persistence under a variety of environmental conditions (Hamer and Mahony, 2007)

The importance of long term monitoring

Several attempts have been made historically to create artificial habitat for *L. aurea* to create bell frog habitat to date. All have used similar habitat templates (Mahony et al, 2013; Pyke and White 1996), and only one has resulted in the establishment of a breeding population (Pyke et al. 2006, Stockwell et al. 2006b). More recent habitat construction and enhancement of the extent and connectivity of wetland mosaics on Kooragang Island have proven to be more successful, with occupancy of wetlands by adults and successful reproduction in numerous wetlands. There remains the matter of demonstrating that these successes continue, and that they have provided a strengthening of the viability of the local population.

Despite the intensive research effort that has gone into understanding bell frog habitat requirements, very little has included a temporal (across time) component which is vitally important for improving understanding. Similarly, past studies have often been focused at a smaller spatial scale, i.e. a single wetland, as opposed to the extensive landscape which we continue to address in these annual surveys. Clearly, an understanding of how *L. aurea* utilizes its landscape both temporally and spatially is required if their habitat is to be managed and protected effectively.

The value of this long-term monitoring project within the Kooragang Island Management Zone cannot be overstated. It is our objective to continue to improve our understanding of *L. aurea* habitat requirements and population ecology, granting the species the best chance of survival in perpetuity.

1.4 Summary of Historical Findings

Estimates of *L. aurea* population size on the Kooragang/Ash Island complex exist prior to our own annual studies. A survey of 32 wetlands in the years 2000 and 2001 estimated a total of 1995 (± 315) and 905 (± 145) male individuals respectively (Hamer and Mahony, 2007). As can be observed in the summary table below (table 1A) these findings are largely consistent with our own population estimates, suggesting a relatively small, but nevertheless stable, population. Direct comparison of our annual dataset against earlier estimates is complicated by differences in methodology, and the fact that studies from the years 2000 and 2001 estimated male population size only.

Table 1A – Summary statistics for repeat annual surveys beginning 2010 and continuing to 2016. Table highlights fluctuations in estimated population size, number of wetlands surveyed, population demographics and breeding activity from year to year.

Clarification of included parameters are supplied for each column where the title is not self-explanatory.

Survey	KI Pop. Size	No. of Ponds	Sex Ratio (M/F)	Age Struct. (A/J)	Breeding Sites	Calling Sites	Most Ind.
2010/11	1153	23 (16)	1.25/1	1/3	10	5	K22
2011/12	928	55 (25)	1/1.09	1/1	unk.	11	K22
2012/13	834	55 (20)	1.4/1	4.7/1	5	11	K22/23
2013/14	1238	55 (25)	unk.	unk.	5	9	K22
2014/15	2964	58 (28)	1.43/1	1/1.3	6	4	K23
2015/16	1432	78 (42)	7.4/1	1.4/1	7	14	K104
	* Peak population size (best estimate for month with greatest no. of individuals).	* Total no. of wetlands surveyed. (Total wetlands with <i>L. Aurea</i> present in brackets)			*Number of wetlands with amplexus, tadpoles or recent metamorphs.	*Number of wetlands with calling males.	*Wetland with most captured individuals.

History of migration and breeding events within the KI Management Zone

The connectivity of *L. aurea* habitat on Kooragang Island is a key variable in assessing the populations stability. Several thousand micro-chips have been emplaced in wild *L. aurea* by the University of Newcastle in order to track the movement of individuals across the landscape within and between survey seasons. Low recapture rates between consecutive years imply that, as predicted by previous research (Stockwell, 2011), many adult frogs do not survive over-winter. Nevertheless, migrations between adjacent wetlands are commonly observed within seasons, and there has been evidence of individuals migrating more than two kilometers within a season. A summary of migration is presented below for each survey period. Notable instances of mass recruitment i.e. observations of large numbers of tadpoles and/or metamorphs are also included in this summary, along with their location.

2010/11 Season

Movements between separate water bodies were observed for six individuals. The distance of these movements ranged from 70m to 581m. Five of these movements were localized within the Central region of the Management Zone, between K22/K23 and adjacent wetlands on the same side of the rail corridor. One individual was observed moving from K22 to K106C (formerly the 'small cell') which required crossing

the industrial rail corridor. This data point establishes that the rail infrastructure which separates the Central and Southern regions of the KI Management Zone is not a complete barrier to dispersal.

Tadpoles and/or metamorphs were found at three wetlands in the Southern (Industrial) Region, and an additional three wetlands in the Central Region. K29 ('The Cell'), was one of these wetlands, with the presence of metamorphs suggesting successful breeding even though this wetland has historically been infested with *Gambusia holbrooki*.

2011/12 Season

Movements between wetlands were detected on ten occasions with long-range movements of up to 1263m observed. Most of these movements occurred across the railway corridor, between the K22/23 complex and K29 (AKA the cell) and adjacent wetlands. Movements also occurred between wetlands in the northern half of the Southern (Industrial) region. Some of these migrations also extended West to K104 and South, to wetlands adjacent to Cormorant Road, suggesting this is the most likely migration corridor for individuals. Movement distance was found to be significantly greater for juveniles as compared to adults, though a limited data set warrants further investigation to confirm this trend.

No observations of breeding were included in this report.

2012/13 Season

Numerous movements were observed, with most of this activity occurring between K22 and K23 (approximately 80m). One long-range movement was observed between K104 (in the NW of the industrial region) and K22 (within the central region), a movement of more than two kilometers. This suggests that the frogs were still migrating successfully across the rail corridor.

Tadpoles were found in 5 wetlands across the KI Management Zone, including 3 wetlands from the Southern (Industrial) region. Calling activity was also widespread and akin to breeding activity, was concentrated in the Industrial region.

2013/14 Season

Unlike previous years, no long-range movements (> 1km) were observed to occur across the management zone. Numerous short-range movements between wetlands K22 and K23 were observed, as were three moderate-range movements between the K22/K23 the and K29 (AKA the cell), approximately 460m as the crow flies. These movements all occurred in the period between the 2012/2013 and 2013/2014 monitoring seasons, with these moderate-range movements indicating that the industrial railway was still being crossed successfully.

Breeding and calling patterns were akin to the previous year, with the additional caveat that tadpoles found in K108 (AKA the 'rail loop wetland') may have been survivors from the previous year only.

2014/15 Season

No long-range or medium-range movements were observed to occur in this season. As with previous years, numerous short range movements between wetlands K22 and K23 were observed. There was no movement's between K22/23 and K29 (AKA the cell) as had been seen in previous years, and thus no migration observed across the industrial railway.

The artificially created cluster wetland 'C1' adjacent to K29 (AKA the cell), supported a successful breeding colony of at least three females, demonstrating its efficacy as created habitat. Conversely, no *L. aurea* were detected at a second cluster wetland 'C2' located in the far South-West of the Island. A significant

breeding event occurred at K104, with a total of 647 juveniles being detected through VES. Most of the juveniles were found between February and March suggesting that breeding occurred in the middle of the season.

2015/16 Season

For the second year in a row, no long or medium-range movement were observed. The only migrations seen occurred back and forth between K22 and K23. There was no evidence of movement across the rail corridor into the Southern 'Industrial' Zone.

There was a large recruitment of metamorphs observed in K106A and K106B; on February 11 2016 we detected large densities of tadpoles and metamorphs in shallow flooded grass. We estimated density to be > 5 per square meter, i.e. >10,000 tadpoles and metamorphs across these two wetlands. Mating pairs were seen at K104A (the rail service road on the north edge of K104 that tends to form long lasting ephemeral wetland) following heavy rain in early January – but the high water levels connected this to the main body of water in K104, allowing *Gambusia* into K104A, and only a very small number of metamorphs were observed at the end of that summer) . The explosion of activity in the K104 area is likely due to the large breeding event observed in the previous (2014/2015) season. Breeding was successful in the 'C1' cluster wetland, but there were no adults detected at the 'C2' cluster wetland; both these findings were consistent with the previous year.

1.5 Specific Research Objectives

The specific medium to long-term objectives of the Kooragang and Ash Islands (KI/AI) *L. aurea* population ecology research program is to enhance our understanding of the species ecology, population dynamics and demography through sustained annual breeding season surveys (2010/2016). This ongoing research enables us to build a picture of the *L. aurea* population on KI/AI both spatially and temporally, which in turn provides important information to assist in understanding the population dynamics, and one day improve the long-term resilience of *L. aurea* populations.

Specific objectives:

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

2. Methods

2.1 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) 55 additional wetlands had been added by the 2015-16 surveys, making a total of 78 wetlands surveyed. In 2016-17 we did not survey five of the wetlands that had been surveyed in the previous year (K6, K27, K30B, K44, and K47; these had consistently had very low numbers of *L. aurea*). Thus, we surveyed a total of 73 wetlands in 2016-17 (Figure 2.1.1).

Wetlands recently constructed under the Compensatory Habitat Environmental Management Programs (CHEMPs) under the management of NCIG and BHP, are surveyed separately to the Whole Island Monitoring Program. However, some data from those surveys are presented here to provide a more comprehensive overview of the Kooragang Island population of *L. aurea* (Figure 2.1.1, Figure 2.1.2). Importantly, these programs have increased the number of breeding wetlands and the population of *L. aurea* in the central and north-west of the island.

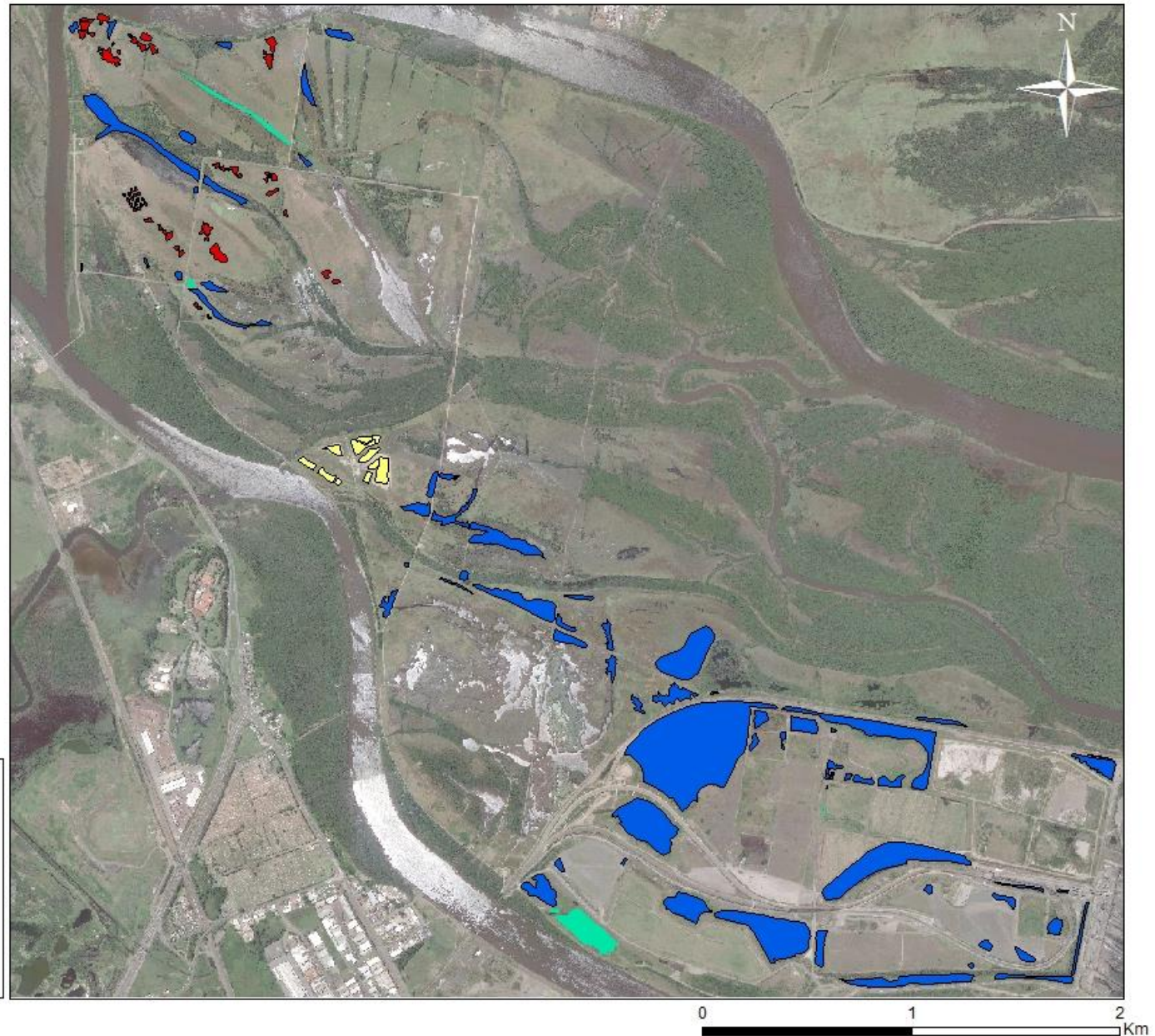
To maintain consistency, identification and sample site nomenclature follows Hamer's numbering scheme and has been extended to the additional wetlands; refer to Figure 2.1.2 and Figure 2.1.3 for details of and numbering.

Wetlands are grouped into three geographical zones; 1) North-Western, 2) Central, and 3) Southern.

1. **North-western:** this zone includes the 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:** this zone also includes part of the National Park Estate. It ranges from the south 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 22 wetlands sampled as part of this program. Compared to the North-western zone this zone 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. **Southern:** Wetlands in this zone are located on industrial and commercial lands leased or owned by organisations undertaking a range of business activities on the site. Within this zone there are 38 wetlands sampled as part of this program, with a wide variety of types and sizes represented in the overall area of 346ha. As could be expected given the industrial/commercial nature of this zone it has 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 removed from industrial activities. Compared to the rest of the site, this has undergone the greatest level of historical disturbance and continues to be impacted by human activity.

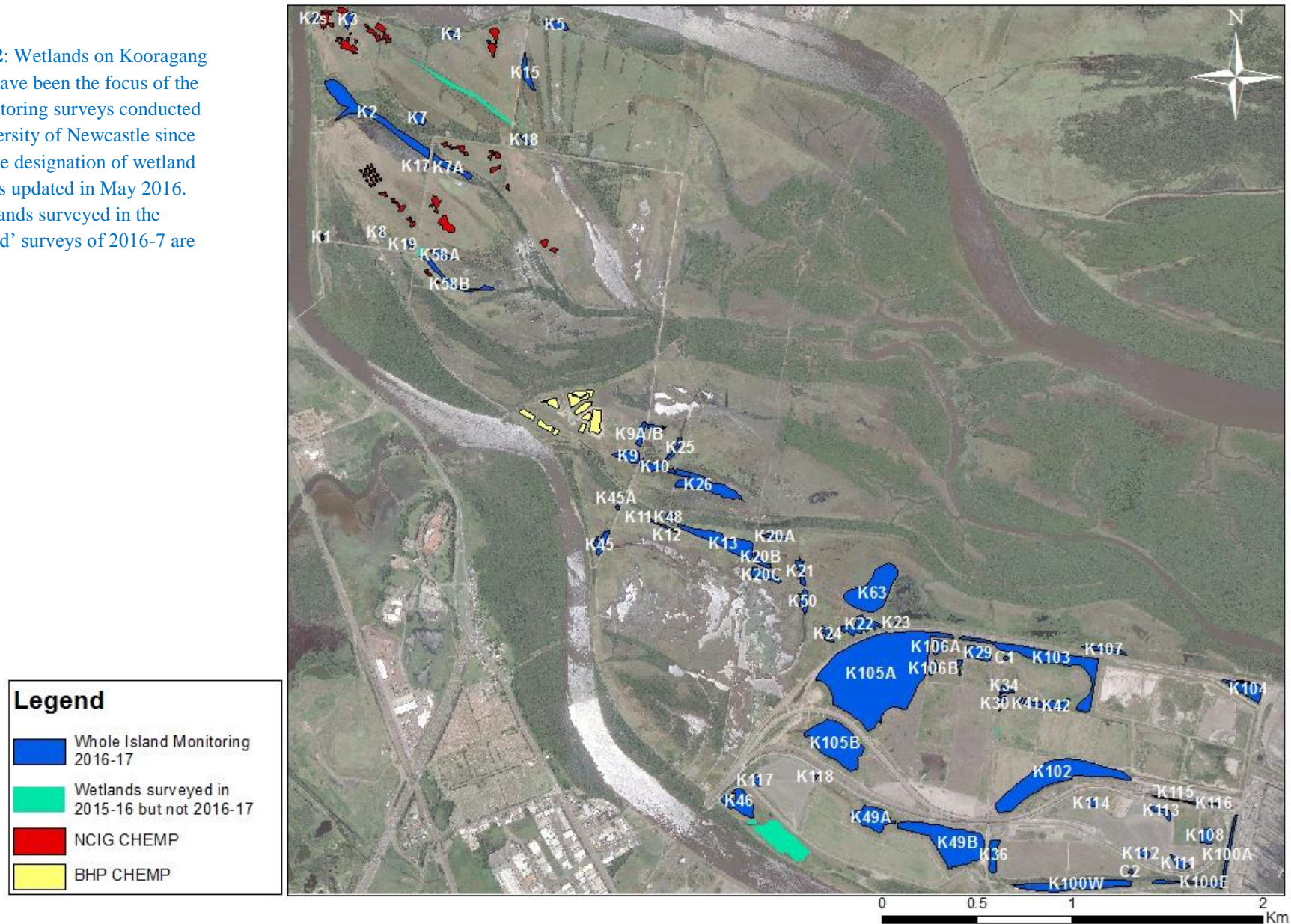
Kooragang Island Wetlands

Figure 2.1.1: Wetlands of Kooragang Island - showing those 73 wetlands surveyed in the 'whole island' surveys of 2016-7, along with 5 wetlands (K6, K27, K30B, K44, K47) that were not included in these surveys in this year. The positions of NCIG and BHP CHEMP wetlands are also shown.



Kooragang Island wetlands (with UoN labels)

Figure 2.1.2: Wetlands on Kooragang Island that have been the focus of the annual monitoring surveys conducted by the University of Newcastle since 2010-11. The designation of wetland numbers was updated in May 2016. The 73 wetlands surveyed in the ‘whole island’ surveys of 2016-7 are labelled.



Southern Kooragang Island wetlands (with UoN labels)

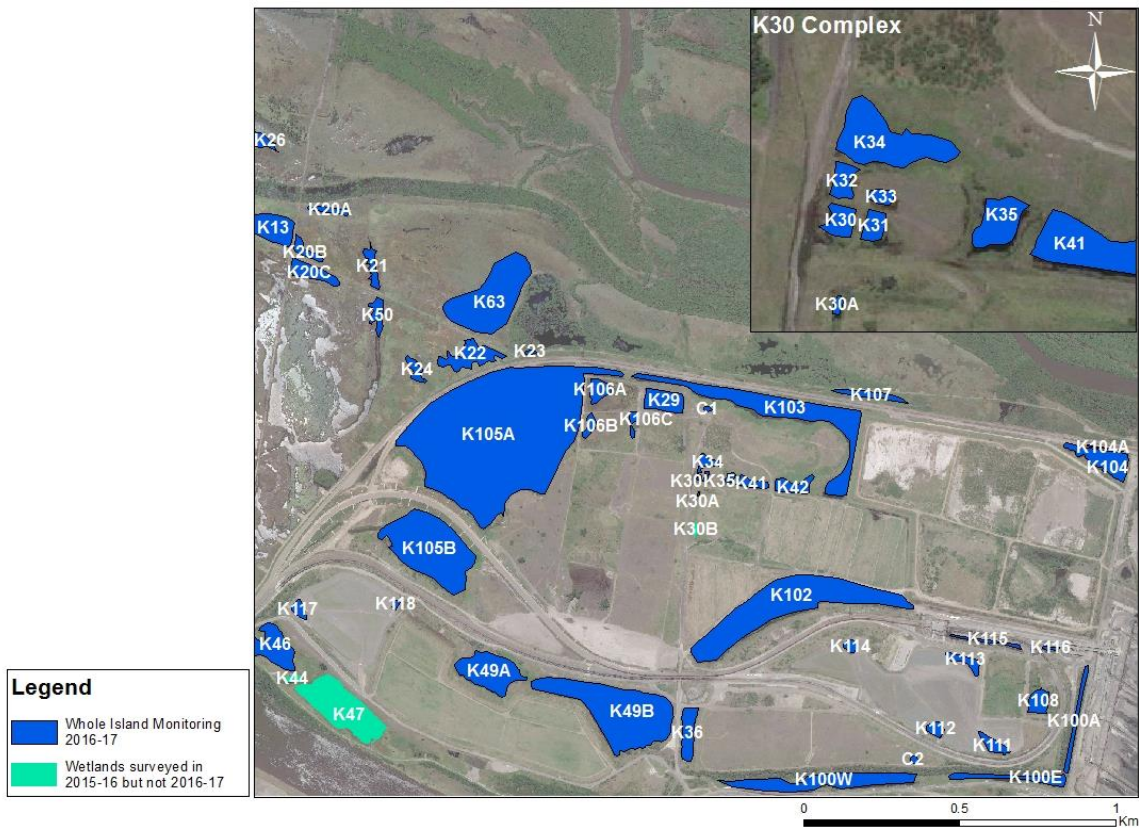


Figure 3.1.3: Surveyed wetlands in and around Terminal 4 on southern Kooragang Island for the 2016-17 Season.

2.2 Jurisdiction

Wetlands sampled on the site for the Whole Island Monitoring Program fall under the following seven categories (see figure 3.1.4.).

- National Parks and Wildlife (NPWS): 32 wetlands (North and Central zones)
- Port of Newcastle (PoN): 4 wetlands (Central zone)
- Port Waratah Coal Services (PWCS): 21 wetlands (Industrial Zone)
- Newcastle Coal Infrastructure Group (NCIG): 3 wetlands (Industrial Zone), plus 18 wetlands in the NCIG compensatory habitat.
- Hunter Development Corporation (HDC): 7 wetlands (Industrial Zone)
- Wetlands previously managed by BHP, but which are now managed by HDC (BHP): 3 wetlands (Industrial Zone)
- Road & Maritime Service (RMS): 2 wetlands (Industrial Zone).

In mid-2016 we were informed that land within the industrial zone was under the management of the Port of Newcastle (State Environmental Planning Policy No 74. 2003—Newcastle Port and Employment Lands under the Environmental Planning and Assessment Act 1979. The new planning framework reflects

that the port has a private, rather than a public, operator, and the Port of Newcastle lease). This includes a strip of land approximately 100 m wide to the west and north of the industrial railway, and therefore includes significant wetlands occupied by the *L. aurea* population especially wetlands K22, K23, K24 and K107 which have been monitored for the past five years and historically were included in monitoring by Hamer (2002). The K22-K23 wetlands provide one of the only persistent wetlands for breeding over a period of more than 10 years monitoring.

In the final stages of compiling the present report, we were informed that K100A was actually under NCIG jurisdiction – up to that point, it was thought to lie under the responsibility of RMS. We have updated the presentation of results accordingly.

Kooragang Island Wetlands: Jurisdiction

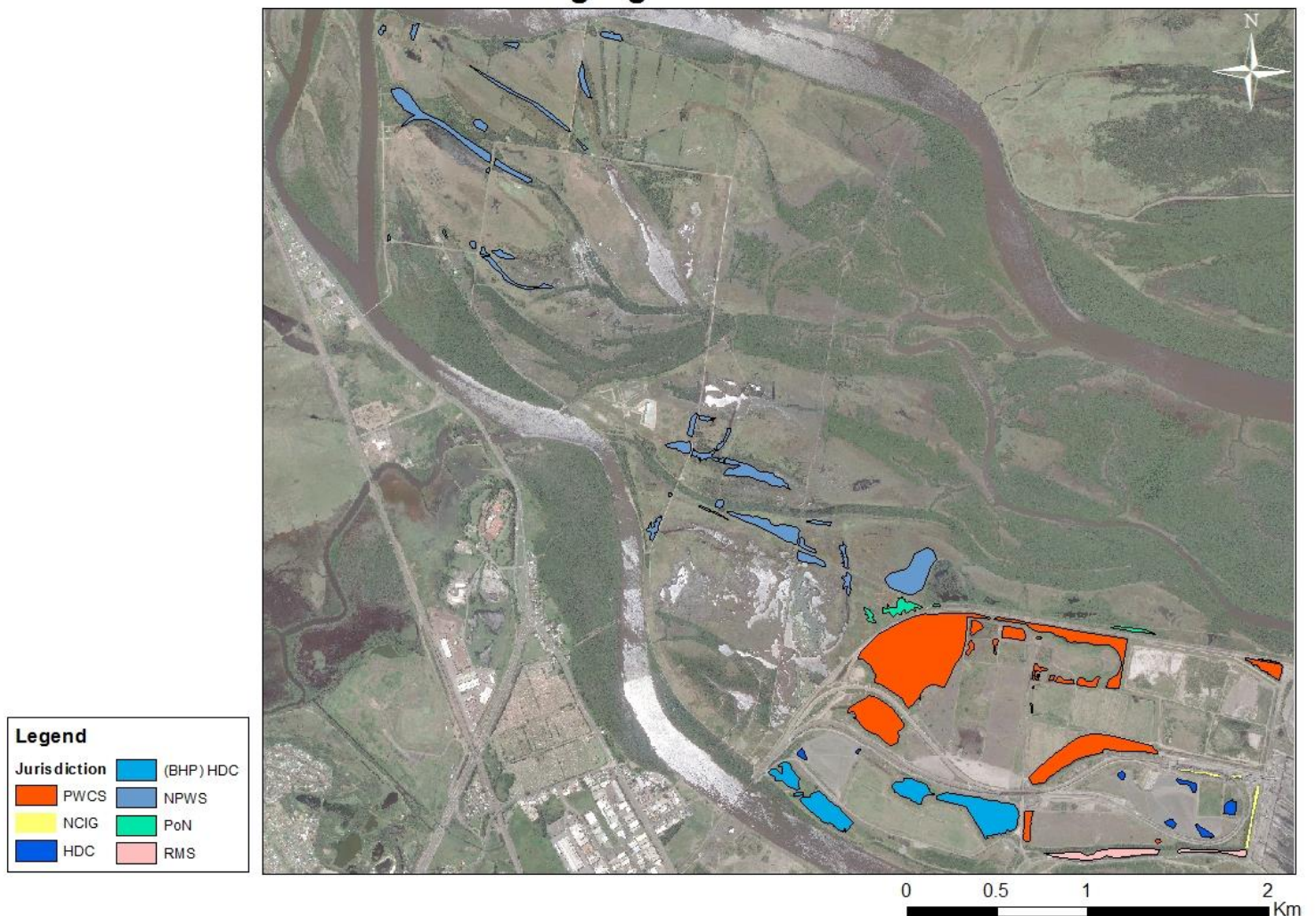


Figure 3.1.4: Surveyed wetlands in the Kooragang Island Management Zone, summarized by jurisdiction.

2.3 Long-term monitoring approach

The Island wide monitoring of the *L. aurea* distribution and abundance has followed a standard method for six years and was established to enable tracking of these population attributes against time. In the past two years' significant habitat compensatory projects and other landscape works have occurred on the site that materially should affect the distribution and abundance of the *L. aurea* population. To include these activities in the island wide monitoring would provide a bias of the outcomes, since additional wetlands would be included. However, not including these additional wetlands would fail to capture the entire population. Furthermore, 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. Finally, several newly constructed wetlands created by HDC following capping works within the NCIG rail loop area were included in surveys.

2.4 Survey techniques

There were two types of survey used:

- i. Visual Encounter Survey (VES)
- ii. Capture-Mark-Recapture (CMR)

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 as *L. aurea* tend to associate with vegetation (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, average wind speed, maximum wind speed, & 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 terrestrial habitat)
 - Size (adult/juvenile)
 - Was 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), or, if the vegetation structure made using the bags too difficult, by hand. 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 tagged.
- ii. If the frog had a passive induction transponder (PIT) tag, the number was recorded.
- iii. Visual inspection of frog for injuries, and nuptial pads (to identify males from females).
- iv. Snout-Vent-Length was measured using callipers.
- v. Body weight was measured using a 10g, 60g or 100g spring balance (Pesola). The frog was weighed in the bag, and then the bag was weighed separately.
- vi. The frog was swabbed for Chytrid fungus by the standard protocol used by the UoN Amphibian Research Lab (2 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 samples (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). Metamorph *L. aurea* 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. An example of the datasheet used to record data during processing is shown. 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 November 2016 and March 2017. In Visual Encounter Surveys, the entire 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.

In addition to VES, Capture-Mark-Recapture (CMR) surveys were undertaken at three wetlands. The purpose of the CMR surveys is to provide a locally intense capture effort that can be used to generate an estimate of population size at that location (see Section 2.6), as well as provide large sample sets for demographic and longitudinal data (Sections 3.4, 3.5). In CMR sampling wetlands were surveyed

intensively typically for 3 to 4 consecutive nights. For long-term population data comparisons wetlands were chosen for CMR sampling based on their known status as important *L. aurea* wetlands and their inclusion in previous population estimations. To effectively capture a suitable representation of individuals from a wetland in some cases necessitated multiple surveys per night over consecutive nights. When multiple surveys were required at a wetland, frogs were processed as early as possible the next day and released that evening. As a consequence, the next survey would commence the following evening (i.e. a 2-day gap between consecutive surveys).

Effectively there is no stopping rule or constraint applied with CMR sampling, thus there was no maximum search time; rather, CMR sampling aims to survey the maximum number of *L. aurea* individuals physically possible within time and budgetary constraints. The population estimate for a CMR wetland is compared with the VES results from that wetland to enable the VES results from the whole-island survey to be converted into an estimate of population size for the whole island. To this end, each CMR survey night involved a VES survey for the first 30 minutes, where-after the following 60-90 minutes is termed 'post-VES'. Only one of these VES surveys per round is designated a primary VES; the other two are termed **secondary** VES. Only during the post-VES part of each survey was the rule against non-overlap of search effort relaxed.

2.5 Search effort

	2015-16	2016-17
Wetlands surveyed	78	73
Total wetland surveys	223	256
Nights of field surveys	38	42
Search time (mins)	5,305	5,293
Total search effort (person.minutes)	15,060	16,995

There were 3 rounds of surveys; the first from late November to late December, the second in January, and the third from February until early March. During each Round, one VES was performed at each wetland, and a CMR survey was performed at K22-23, K29, and K104.

Search effort was consistent between wetlands. Search effort was not determined by wetland area, as we had a maximum search time of 30 minutes at each wetland (for VES). For large wetlands such as K105 ('Deep wetland'), we targeted areas of good potential habitat (i.e. emergent macrophyte stands on the eastern shoreline).

Kooragang Island Bell Frog Survey 2016-2017

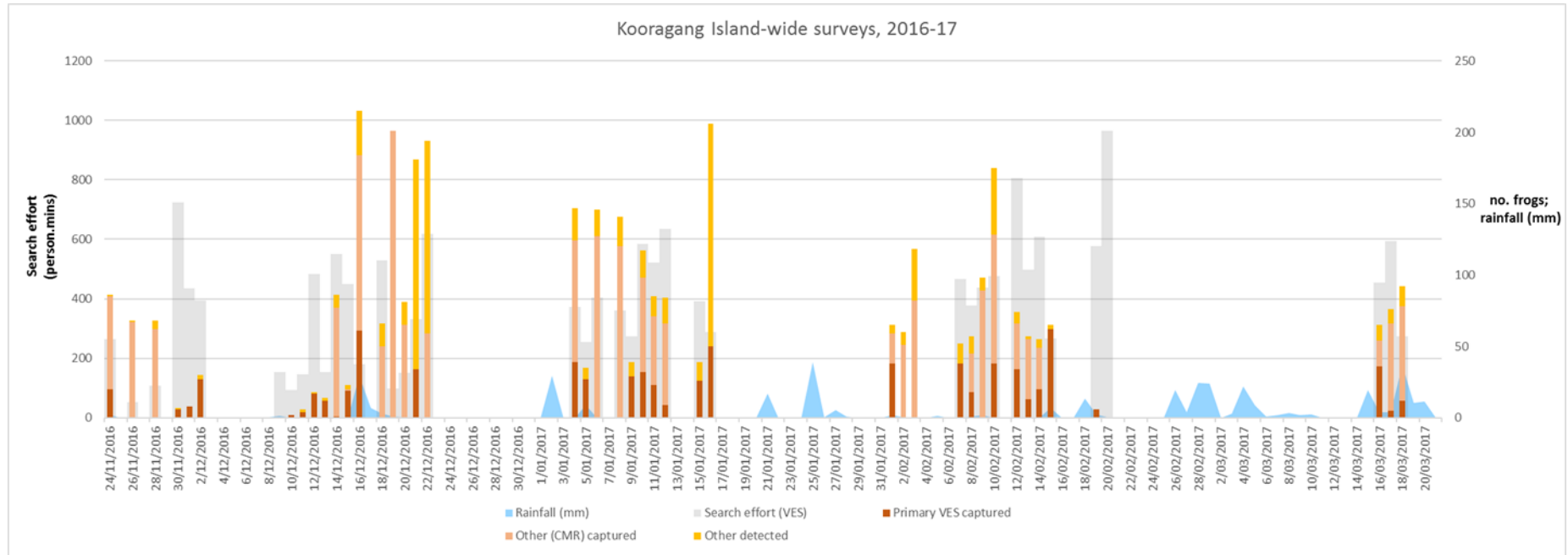


Figure 2.5.1: Search effort and *L. aurea* captures and detections across the 2016-17 survey period, shown alongside rainfall. Captures in primary VES are distinguished from captures in other periods (i.e. CMR surveys). ‘Other detected’ is animals not captured (pooled across all survey types).

Total Search Effort, 2016-17 (whole island)

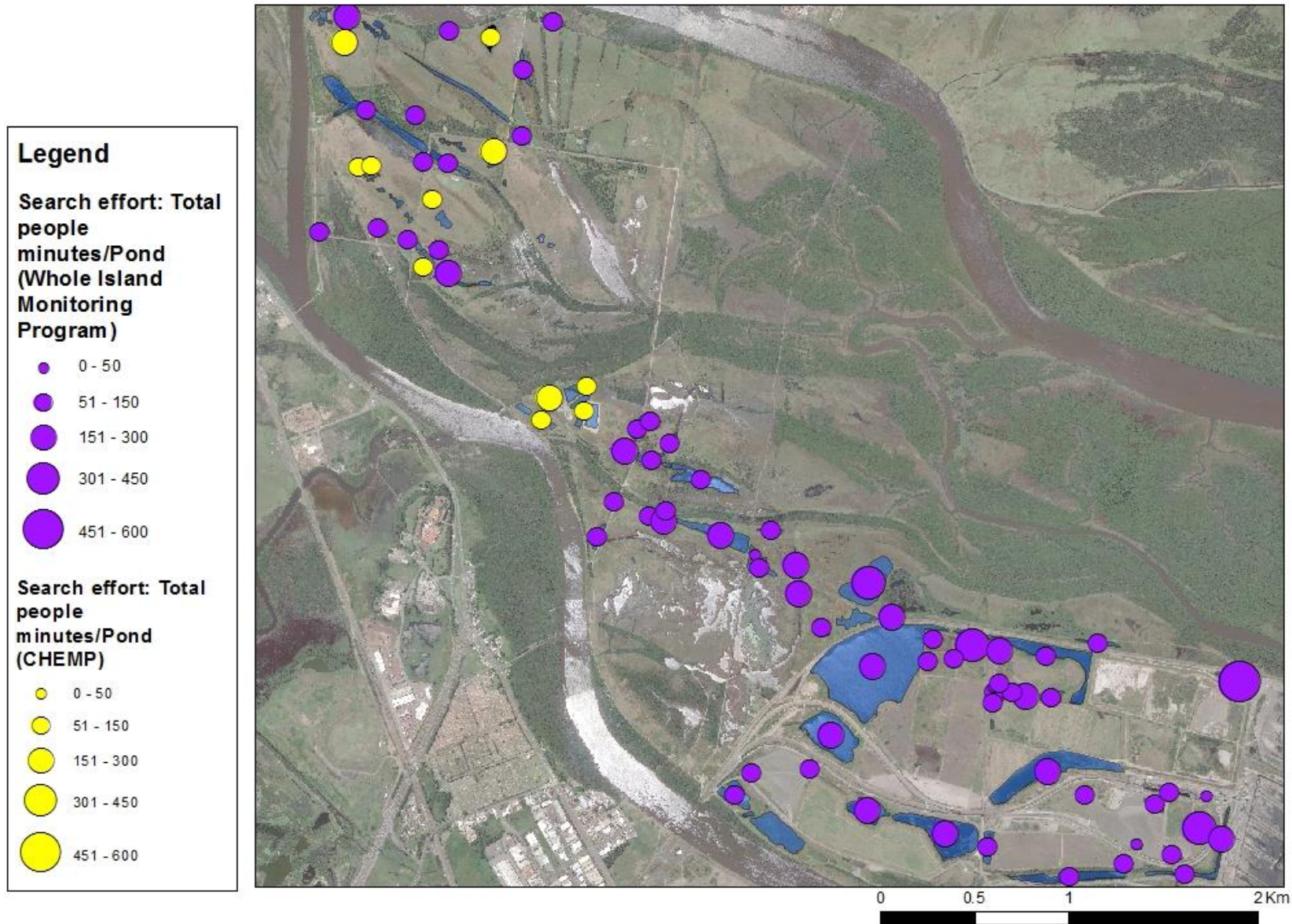


Figure 2.5.2: Search effort (person.minutes) across the 73 wetlands surveyed as part of ‘whole island’ monitoring in 2016-17

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

Note that the CHEMP wetlands shown here are only those included in the Save Our Species (SOS) 2016-17 surveys – they do not include all CHEMP wetlands

2.6 Methodological approaches used to address objectives

Robust modelling approach (Pollock's robust design)

Robust modelling of population size is based upon 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).

In practice, there are several factors that affect the number of frogs detected at a wetland on a given night, and the total population size at a wetland is only one of these factors. Temperature, humidity, wind speed may all affect the number of frogs that are active during a survey; only active frogs are likely to be detected. An animal may also become warier after it has been captured for the first time – i.e. there is a difference between the capture probabilities of an animal on its first capture and subsequent recaptures – which can be a problem for straightforward population estimates. The statistical approaches of robust modelling can nevertheless account for the effects of these parameters, given sufficiently high quality CMR data. A more detailed overview of the Robust Modelling approach is given in Pollock (1982).

For CMR to be analysed using Robust Modelling, sets of surveys need to be conducted over multiple periods at each location. A basic survey period is termed a primary period; within each primary period, a series of surveys (secondary surveys) are conducted over a short time; these secondary surveys should ideally be no more than 48 hours apart, and should continue until the recapture rate within one survey is at least 20% (and ideally up to 70%). The target recapture rate is dependent on the number of individuals captured. A higher number of captures means that a lower recapture rate is acceptable.

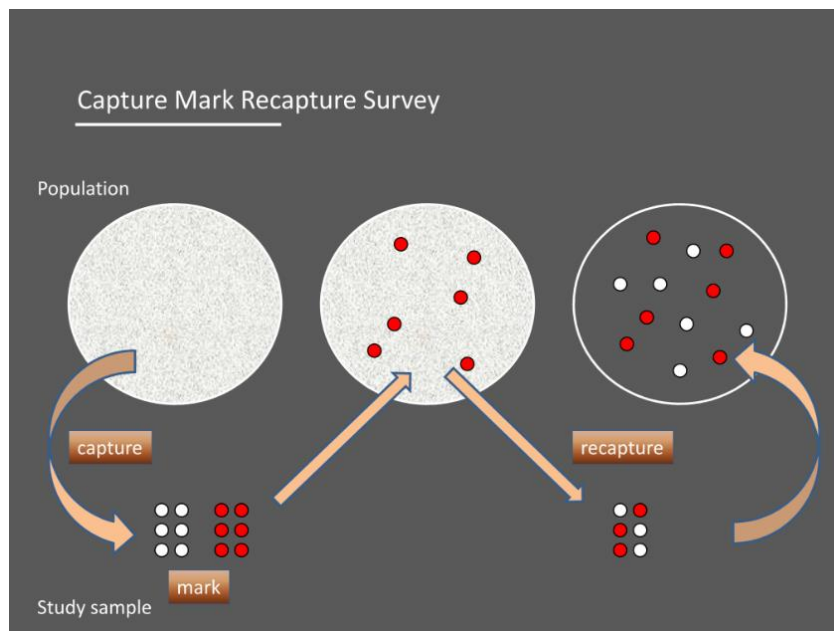


Figure 2.6.1. A simple illustration of capture-mark-recapture survey (based on two capture events only). Left circle: nothing is known about the population size, during the first capture event animals are caught, marked and released. Middle circle: the number of marked animals within the population is 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. *Note that this is an over-simplistic depiction of current mark-recapture methods, with Robust Design allowing far more powerful modelling to be completed incorporating closed methods (as depicted here) and open methods in conjunction with one another.

Using the survey techniques outlined in Section 2.4, we compiled CMR data from three locations over two primary survey periods.

- K22/23 (the two wetlands were treated as a single population, based on data from previous years)
- K29 ('The Cell')
- K104

N.B. Historically, CMR surveys have occurred at K108 (the rail loop) instead of K104. However, as K108 was completely dry for the majority of this survey season, CMR efforts were necessarily moved to K104 instead.

See [Table 3.7.1](#) for details of survey periods at each of these.

On its own, robust modelling provides estimates for specific wetlands. In order to extrapolate these into population estimates for the whole island, we use VES survey data.

This approach to population estimates relies upon a consistent survey method across all wetlands to be included in the analysis. As the VES and CMR surveys in the NCIG compensatory wetlands and the BHP-Billiton compensatory wetlands were conducted using different survey methods, they cannot be included in the quantitative estimate given in this report – however, the results of those surveys are included qualitatively in the interpretation and discussion of overall *L. aurea* numbers on Kooragang Island.

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 individuals: survey effectiveness can vary among observers. *L. aurea* are generally cryptic, and difficult to see in the different vegetation structures that they are sitting in. To overcome detection bias we used a core of experienced observers within the survey teams but this remains an important methodological limitation.

Within and between sites: *L. aurea* are cryptic and are difficult to see; moreover, they 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 K1, K8, K19, K7, K18, K15, K5, K4; also K13, K20, K24, K108, K46) 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 in round 2, K114 in round 3), 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. Thus if a particularly complex habitat was being surveyed the entire wetland was surveyed and the time taken recorded. 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 early summer, one in mid-summer, and a final survey round in late summer/early autumn. Despite this design the summer season of 2016 was punctuated with several large rainfall events that occurred in the middle of and before timetabled surveys. Such events do effect bell 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. For example, at permanent wetland K104 an ephemeral wetland occurs adjacent to the permanent wetland and the frogs disperse only a short distance, whereas at K22 the frogs move over 70 metres to K63, which covers a large area.

Demographic composition and effective population size

To construct the age-class structure of the bell frog population we determined the age of individual frogs collected by using a growth curve for bell frogs developed on Kooragang Island (see Hamer et al., 2007 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 animals that overwinter as tadpoles and metamorphose early in the season are known and add 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. In addition to body length the body mass of frogs can be related to age and can also be related to animal condition.

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

In previous years, we categorised animals into these overall age classes by using body length (measured as SVL), based on the analysis of Hamer et al. (2008).

Adulthood is defined as the capacity to reproduce. In 2015-16, for males this was designated at a SVL of >44 mm), and for females at SVL > 68 mm). Adult bell frogs are sexually dimorphic; females reach a large body size and mass than the equivalent aged males. This provides the scheme used to interpret age/sex class data in last year's analysis:

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 bell frog can be considered a sub-adult 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', 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 (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 last year); we used a length of 58 mm in this analysis. Note that this is quite

Kooragang Island Bell Frog Survey 2016-2017

different to the categories used to analyse demography last year and an accurate comparison of the 2015-16 results with the 2016-17 results would require the previous data to be reanalysed.

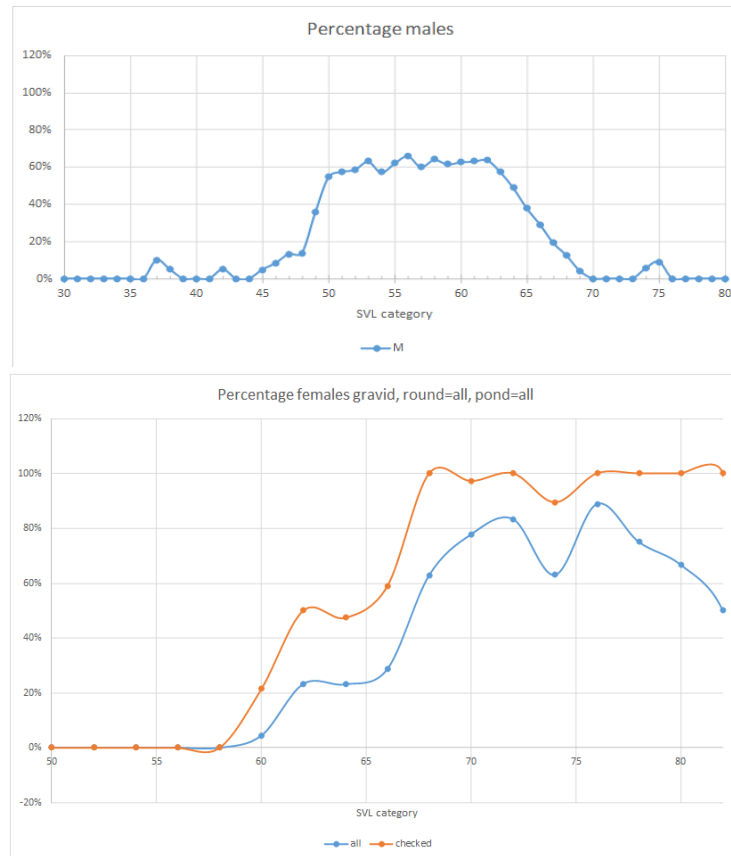


Figure 2.6.2: Proportion of animals that can be confirmed as reproductively mature (i.e. adults), plotted against SVL. Top, males; Bottom, females. In the lower chart, the red line represents the number of females found to be gravid, as a proportion of the animals inspected for gravidity, whilst the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

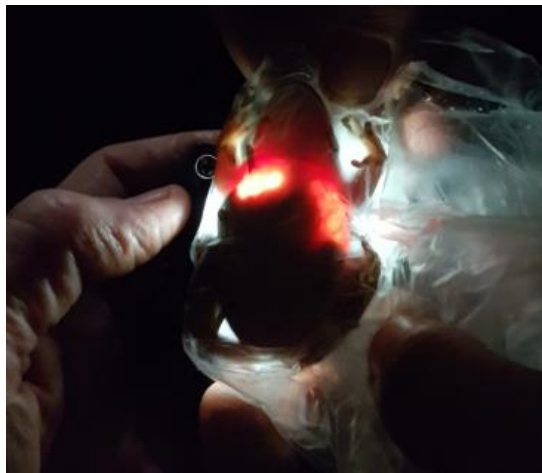


Figure 2.6.3: Illustration of the 'candle-light' method of checking for gravidity in females. A large, bilateral mass in the mid to upper trunk region indicates enlarged ovaries and thus gravidity.

The categories used this year are thus:

- Nuptial pads apparent → adult male (typically > 44-48 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.

Effective population size

For the purpose of reducing the demographic information on *L. aurea* to the most important determinant of persistence, the survival of rate of adult females is crucial (Pickett et al., 2013). From the perspective of population studies the effective population size is the number of individuals in a population who contribute offspring to the next generation. The effective size of a population, N_e , determines the rate of change in the composition of a population caused by genetic drift, which is the random sampling of genetic variants in a finite population. The importance of N_e as an evolutionary factor is emphasized by findings that N_e values are often far lower than the census numbers of breeding individuals in a species.

Species with historically low effective population sizes, such as isolated populations of threatened species, show evidence for reduced variability and reduced effectiveness of selection in comparison with other species (Charlesworth 2009). In an ecological sense, the size of a population can be measured by simply counting the number of adults in a locality. From the perspective of the *L. aurea* population on Kooragang Island the census value is obtained by the population estimate using robust CMR methods. Effective population size is considered as the number of adult females and males in the population, although the number of offspring is limited directly by the number of adult females. Adult males are important in the genetic determination of effective population size since they are involved in transmission of genetic diversity.

Here we focus on the number of adult females observed in CMR and VES surveys since they truly represent the effective demographic population size. In comparison the numbers of juveniles or eggs that are laid and grow into tadpoles do not provide a direct indication on the status of the population. This is not to say that recording their numbers and distribution is not important since they provide critical understanding of vital population rates such as fecundity and mortality in the embryonic and larval stages.

Data Analysis

Outside of the statistical method for determining a robust population estimate for Kooragang Island (See section 2.6.1), data was primarily analysed using a combination of summary statistics and various graphical descriptions; pie charts, histograms, and GIS overlays provide a more intuitive means of digesting the survey's findings. To this end, this year's key findings are primarily summarized using a combination of graphical techniques, with relevant summary statistics presented in adjacent tables or else succinctly summarized in the main body of the Results. GIS data was prepared using ARCGIS, robust modelling was performed using the program MARK; Excel was used for all other data analysis.

Tables and figures within the results are accompanied by descriptive captions where their meaning is not immediately apparent. For the sake of brevity, we will not include a detailed description of how each graph or figure was created here in the methods; the results section is designed to stand alone in this regard. Nevertheless, we include below a summary describing the key focus for each sub-section of the results, and the primary methodologies by which we analyse and present associated data:

- **Section 3.1. - Survey Counts:** Tables of summary statistics, stacked column graphs.
- **Section 3.2. - Seasonal Context & Environmental factors:** GIS mapping of critical environmental variables, tables of summary statistics, histograms.
- **Section 3.3. - Distribution:** GIS mapping of search sensitivity and detections, descriptive statistics of spatial patterns.
- **Section 3.4. - Demographics:** Pie charts summarizing sex and life stage, histograms comparing size (SVL) within specific wetlands and for pooled data.
- **Section 3.5. - Longitudinal data: persistence, growth, and movement:** Tables of summary statistics for recaptures, GIS mapping of movements across KI management zone. Regression curves summarizing growth.
- **Section 3.6. - Breeding and recruitment:** GIS mapping of breeding sites, graphical correlation of breeding phenology against rainfall.
- **Section 3.7. - Population size:** Table of summary statistics presenting results of complex statistical modelling.

3. Results

3.1. Survey Counts

	Round 1	Round 2	Round 3
	Total	Total	Total
Detections	1,385	1,414	927
Captures	958	863	273
Tagged	871	732	332
Unique	705	593	273

Table 3.1.1: Summary data from all surveys in 2016-17 season. ‘Detections’ refers to total encounters (i.e. captures and non-capture observations). Tagged animals are those that had a PIT, and includes first time captures of animals >40 mm SVL, and subsequent recaptures of those animals. Because some individuals are encountered and captured multiple times, ‘Detections’, ‘Captures’, and ‘Tagged’ will all provide overestimates of the number of unique individual frogs actually encountered (‘Unique’).

There were slightly more frogs detected in the second round than in the first round, and numbers were lower by round 3. However, captures were highest in round 1. Similarly, the highest number of unique individuals – 705 – was in the first round, with only 273 unique animals captured by the third round.

Region (detections)	VES	Total
Northern island	1	1
Central island	178	711
Southern island (T4)	1194	3014

Jurisdiction (detections)	VES	TOTAL
NPWS wetlands	56	56
PoN wetlands	123	656
PWCS wetlands	656	2,473
NCIG wetlands	83	86
HDC wetlands	403	403
BHP (HDC) wetlands	46	46
RMS wetlands	6	6

Table 3.1.2: Location (summary) and jurisdiction of *L. aurea* detected.

The Whole Island Monitoring Program detected very small numbers of *L. aurea* in the northern part of the island; only 1 frog was seen during these surveys. (There are more *L. aurea* present in the northern part of the island, but these are mainly located in the recently constructed NCIG CHEMP wetlands – see [Figure 3.2.2](#)). The Central region has moderate numbers (note that the BHP CHEMP survey numbers – see again [Figure 3.2.2](#) - are in addition to these). By far the greatest number of bell frogs can be seen around the industrial Terminal 4 site on the southern end of the island. In broad terms, this distribution pattern is consistent with the 2015-16 results.

Kooragang Island Bell Frog Survey 2016-2017

In terms of jurisdiction, the largest number of frogs were seen on PWCS wetlands (2,473). Although the total number of *L. aurea* detections was higher at PoN wetlands than HDC, this is biased by the conduct of CMR surveys at K22/23 which significantly increased total search effort. Comparison of these two sites using VES data only shows that HDC wetlands have a higher rate of encounter. Additionally, a disproportionate number of the animals seen at the HDC wetlands were metamorphs and small juveniles, and so the importance of these wetlands for the adult population is not quite as high as indicated from the VES results).

	VES	Total
Frogs detected	1,373	3,726
Frogs captured	658	2,605

	Captures	Unique
PIT tagged frogs	1,930	1,228

Demographic summary	Captured		PIT tagged		Unique		Recapture index
	Number	%	Number	%	Number	%	
juveniles (SVL<49.5mm)	537	23%	290	15%	207	17%	1.40
subadult females (49.5mm<SVL<58mm)	364	15%	311	16%	203	17%	1.53
adult males (>49.5mm, nups)	1,022	43%	938	49%	569	46%	1.65
adult females (>58mm, no nups)	431	18%	391	20%	249	20%	1.57
gravid females	167	7%	194	10%	114	9%	1.70
	2,354		1,930		1,228		

Table 3.1.3: Summary of demographic data.

The numbers of bell frogs detected and captured this year were 2 to 3 times greater than last year; we detected 3,726 *L. aurea* (compared with 1,283 in 2015-16), captured 2,605 (compared with 677) and identified 1,228 frogs from PIT (compared with 539 last year).

With 249 adult females identified by PIT tags, the proportion of adult females was about 20% of all unique individuals captured. Nearly half of these were thought to be gravid. This represents a much larger number of reproductive females than was detected in the 2015-16 surveys.

Males had a high probability of being recaptured; 569 individual males were captured 938 times, a ratio of 1:1.65 for number of captures per individual present (shown here as a recapture index of 1.65). Juveniles had the lowest recapture index (1.4). Perhaps surprisingly, gravid females had the highest recapture index of all demographic groups. Note that juveniles below 40 mm SVL cannot generally be tagged with PIT chips, and so cannot be identified as unique individuals; thus, juveniles will be underrepresented in counts of tagged and unique individuals.

VES per wetland per round

Survey results for VES at each wetland in each round are shown in [Figure 3.1.1](#) (the Northern wetlands are omitted).

Kooragang Island Bell Frog Survey 2016-2017

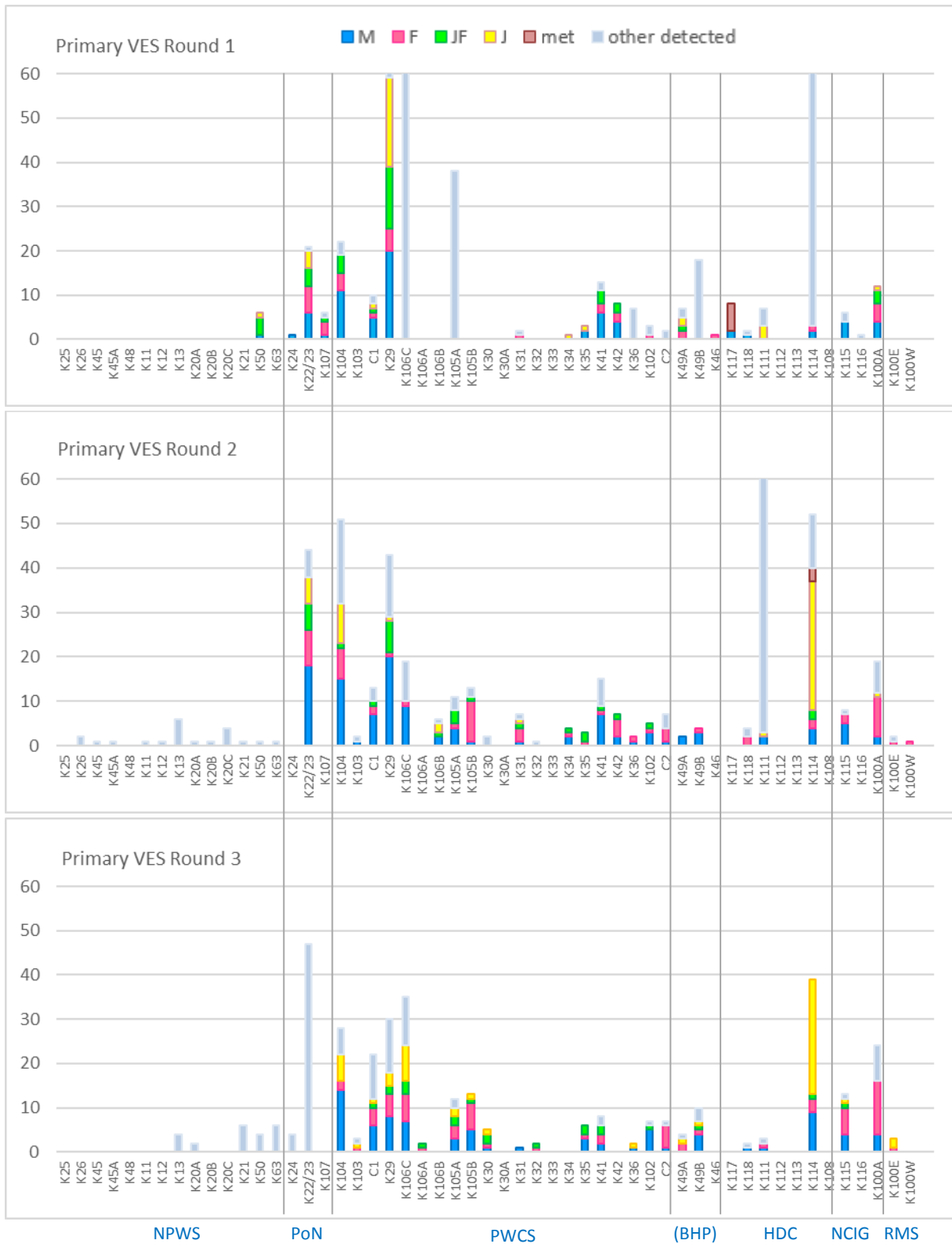


Figure 3.1.1: Results for Primary VES surveys across the three rounds of the 2016-17 surveys, showing number of *L. aurea* detected (y axis). Results for the Northern region of the Island are not shown (due to a very small number of captures), and a maximum value of the y axis has been set to 60 to best display the majority of data.

3.2. Seasonal context: environmental factors

Overview

The breeding season of 2016-17 was remarkable for a lack of rainfall through late Spring and all of Summer. Weekly rainfalls did not exceed 50 mm at any point in the period (in marked contrast to the previous year) (Figure 3.2.1). After a winter of low rainfalls, nearly all of the wetlands had low water levels at the start of the survey period, and by January many were drying out completely. Although there was good rain during autumn (from the tail end of Cyclone Debbie), at the time of the last round (February), 33 of the wetlands had no water.

The outcome of this rainfall pattern on the population can be seen throughout the results of the survey this year (Section 3.3). As the smaller wetlands dried, bell frogs appear to have concentrated at the remaining sites with water, and remained close to these at least until late summer. This led to bell frogs being found at a smaller number of wetlands (compared to last year), but paradoxically to a higher number of captures.

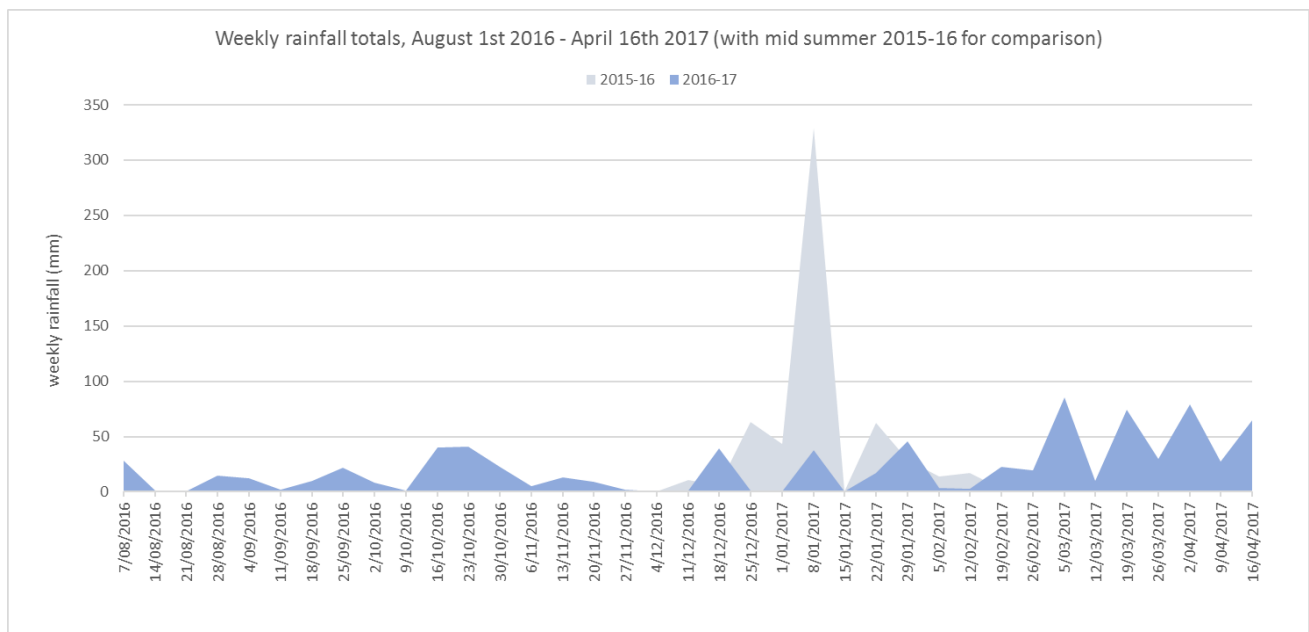


Figure 3.2.1: Weekly rainfall before, during, and after the 2016-17 summer survey season on Kooragang Island, taken from BoM records for Newcastle. Data for the summer of the preceding season is shown for comparison (grey)

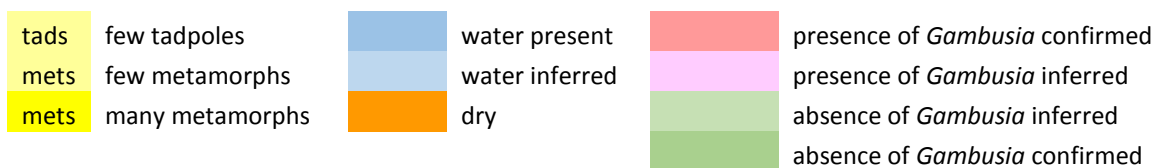
Kooragang Island Bell Frog Survey 2016-2017

Table 3.2.1: Summary of water presence at each wetland per round, along with presence of *Gambusia* and observed breeding. 18 wetlands were dry at the start of the survey period, and 33 were dry by the end. The drying event in turn resulted in the removal of *Gambusia* from many wetlands.

	Pond	Hydrology			<i>Gambusia</i>			Breeding (mets/tads)
		R 1	R 2	R 3	R1	R 2	R 3	
Northern Kooragang Island	K2							
	K3							
	K4							
	K5							
	K15	0			0			
	K18							
	K7	#N/A			#N/A			
	K7A							
	K17							
	K19							
	K58A							
	K58B							
	K8							
	K1							
Central Kooragang Island	NPWS	K9A/B						
		K9C						
		K9						
		K10						
		K25						
		K26						
		K45						
		K45A						
		K48						
		K11						
		K12						
		K13	0			0		
		K20A	0			0		
		K20B	0			0		
		K20C	0			0		
		K21	0			0		
		K50						
K63							tads	
(Central)	PoN	K24						
		K22						
		K23						tads
		K107						

Kooragang Island Bell Frog Survey 2016-2017

		Pond	Hydrology			Gambusia			Breeding (mets/tads)
			R 1	R 2	R 3	R1	R 2	R 3	
Terminal 4 (south eastern Kooragang Island)	PWCS	K104							mets
		K103							
		C1							tads
		K29							mets
		K106C							
		K106A							
		K106B							
		K105A							
		K105B							
		K30							
		K30A							
		K31							
		K32							
		K33							
		K34							
		K35							
		K41							
		K42							
		K36							
		K102							
	C2								
	BHP (HDC)	K49A							
		K49B							
		K46							
	HDC	K117							mets
		K118							
		K111							mets
		K112							
		K113							
		K114							mets
	K108								
	NCIG	K115							
		K116							
RMS	K100A								
	K100E								
	K100W								



Hydrology

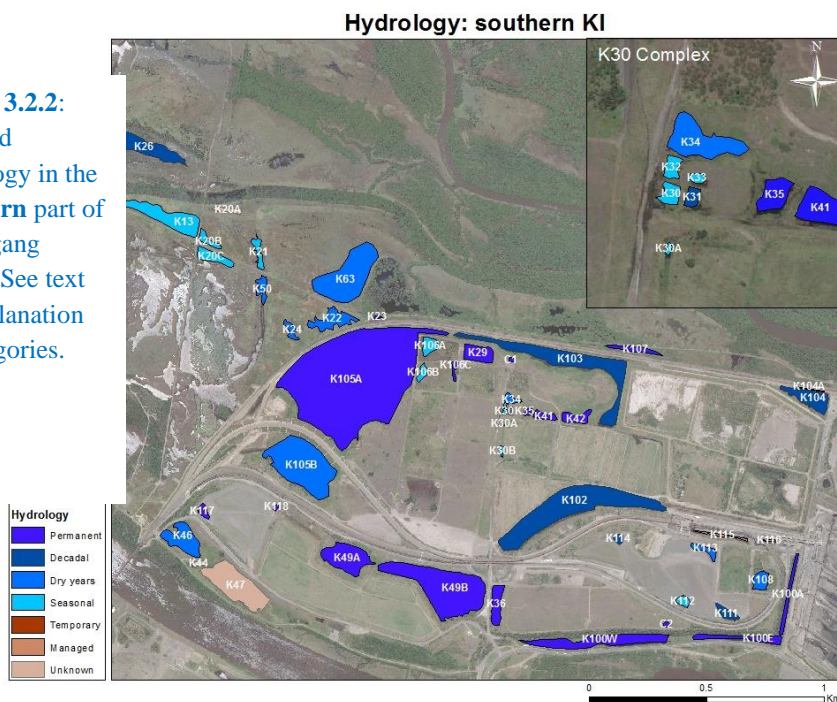
The hydrology of the wetlands on Kooragang Island is an important component of the mosaic of environmental factors that affect bell frog abundance and distribution. Given this, it is important to characterise the hydrology accurately. Wetland hydrology on Kooragang Island has changed as land use, vegetation, and drainage patterns have been altered, and thus our understanding of each wetland's characteristics is being refined and updated each year.

On an estuarine island such as Kooragang, two of the major dimensions of wetland physiomy are salinity and water permanence (see the overview in last year's report). Detailed assessments of salinity profiles are beyond the scope of this report (although this is being addressed by current work). We do collect data on water permanence that is used to update our understanding of wetland hydrology across the island.

The scheme presented here is a qualitative categorisation based upon: (1) presence/absence of water at the time of survey, (2) water depth, and (3) the seasonal context of recent rainfall. Last year we used 4 categories:

1. **Permanent:** The wetland hold water at all times, even in drought.
2. **Decadal:** The wetland hold water at all times except for in drought
3. **Seasonal:** The wetland holds water for an extended period after being recharged by winter rains, but will usually dry up at some point during the year
4. **Temporary:** the wetland holds water for a few weeks/months after good rains.

Figure 3.2.2: Wetland hydrology in the Southern part of Kooragang Island. See text for explanation of categories.



The dry 2016-17 season prompted us to add another category of wetlands in between seasonal and decadal:

5. **'Dry years':** wetlands that usually hold water year-round, but which dry out in a year that is dry but not a full drought.

We also added a category the fact to account for the observation that some of the surveyed wetlands are operational wetlands:

6. **Managed:** e.g. settling wetlands actively managed by their operators.

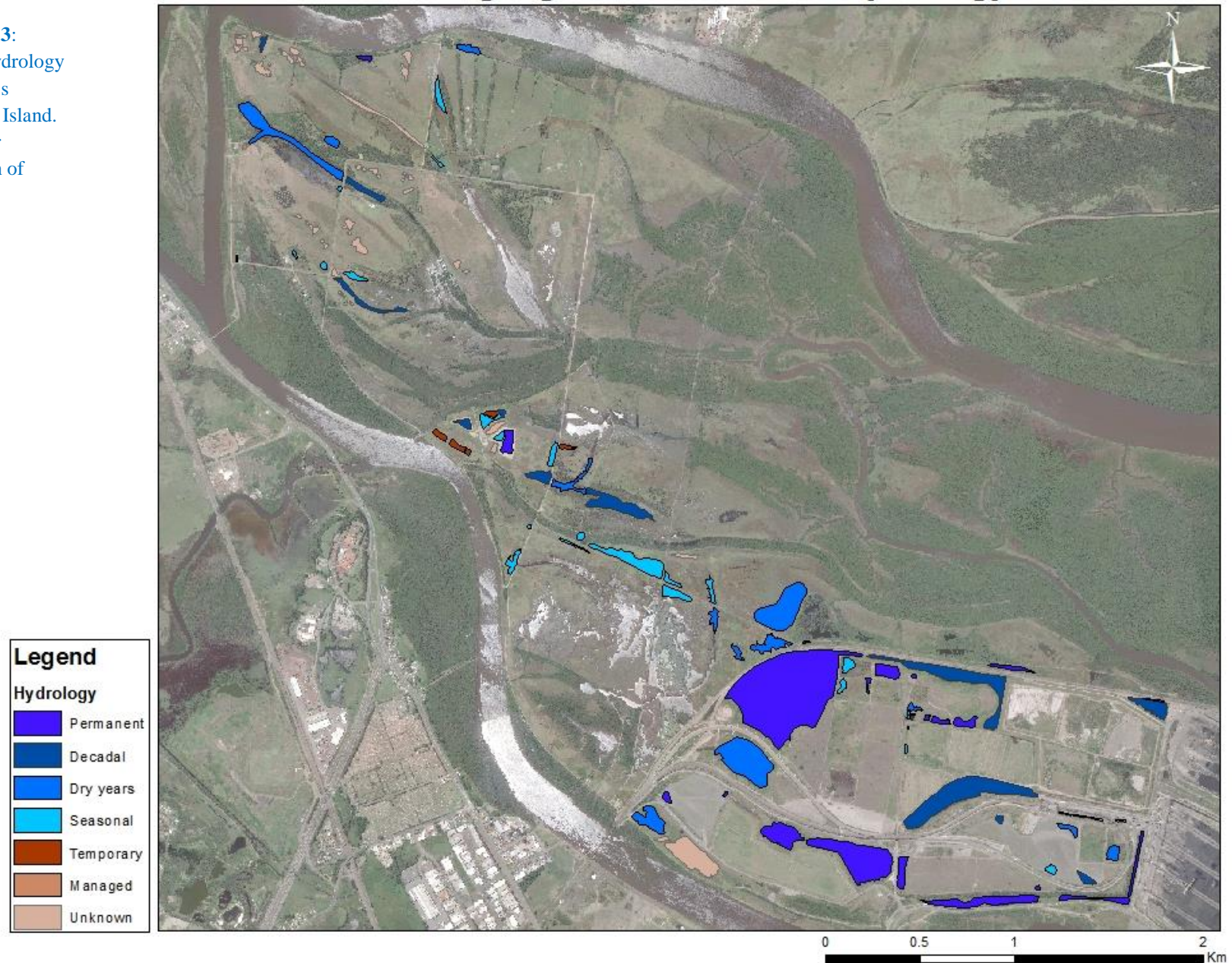
		Pond score	
Northern Kooragang Island		K2	Dry years
		K3	Decadal
		K4	Permanent
		K5	Dry years
		K15	Seasonal
		K18	Seasonal
		K7	Dry years
		K7A	Decadal
		K17	Seasonal
		K19	Seasonal
		K58A	Seasonal
		K58B	Decadal
		K8	Seasonal
		K1	Seasonal
Central Kooragang Island	NPWS	K9A/B	Seasonal
		K9C	Temporary
		K9	Decadal
		K10	Dry years
		K25	Dry years
		K26	Decadal
		K45	Seasonal
		K45A	Seasonal
		K48	Seasonal
		K11	Seasonal
		K12	Dry years
		K13	Seasonal
		K20A	Seasonal
		K20B	Seasonal
		K20C	Seasonal
		K21	Seasonal
		K50	Dry years
		K63	Dry years
	PoN	K24	Dry years
		K22	Dry years
	K23	Permanent	
	K107	Permanent	

		Pond score	
Terminal 4 (south eastern Kooragang Island)	PWCS	K104	Decadal
		K104A	Temporary
		K103	Decadal
		C1	Permanent
		K29	Permanent
		K106C	Permanent
		K106A	Seasonal
		K106B	Seasonal
		K105A	Permanent
		K105B	Dry years
		K30	Seasonal
		K30A	Seasonal
		K30B	Seasonal
		K31	Decadal
		K32	Seasonal
		K33	Seasonal
		K34	Dry years
		K35	Permanent
		K41	Permanent
		K42	Permanent
		K36	Permanent
		K102	Decadal
		C2	Permanent
		BHP (HDC)	K49A
		K49B	Permanent
		K46	Dry years
	HDC	K117	Permanent
		K118	Permanent
		K111	Decadal
		K112	Seasonal
		K113	Dry years
		K114	Decadal
	NCIG	K115	Managed
		K116	Managed
RMS	K100A	Permanent	
	K100E	Permanent	
	K100W	Permanent	

Table 3.2.2: categorisation of wetland hydrology, updated from last year. See text for explanation

Kooragang Island wetlands: Hydrology

Figure 3.2.3:
Wetland hydrology
in the across
Kooragang Island.
See text for
explanation of
categories.



By February 2017 water levels had become low in several wetlands that had in the previous very wet year been relatively deep. At other wetlands, the drop in water levels at several shallow edged wetlands exposed the outer muddy edges of the wetland base, meaning that the water was a long way from the usual wetland edge. In large open wetlands such as K105A, this meant that the water's edge was some distance from the emergent vegetation that frogs usually inhabit.

There is a marked difference in the distribution of permanent and seasonal wetlands in the three zones surveyed. In the northern zone 14 wetlands are surveyed and only one is permanent, three are decadal and seven are seasonal. The central zone is somewhat similar with 10 of the 18 wetlands surveyed seasonal, two permanent wetlands and two decadal. In marked contrast in the south-east zone (industrial zone) of the 38 wetlands surveyed 16 are permanent, 5 decadal and 8 seasonal. These descriptions do not provide the full picture since there are four permanent wetlands in the BHP compensatory habitat in the central zone, but these wetlands were constructed only two year ago. Similarly, there are numerous permanent wetlands in the NCIG compensatory habitat in the north west of the island that were not included in the surveys, but for which we have detailed information on hydrology over the past two years

Gambusia

During two large flood events in 2015-16, high water levels and surface flows in lower relief areas on Kooragang Island allowed *Gambusia* to disperse into numerous wetlands which had previously been free of these fish. By the end of the 2015-16 season we recorded *Gambusia* in 65 of the 78 surveyed wetlands.

The low levels of winter rain through 2016 led to many seasonal wetlands drying out by the start of the summer; in November 2016, 18 of the 73 surveyed wetlands were dry, and by February a further 15 had dried out, giving a total of 33 wetlands that dried. This led to a substantial reduction in the number of wetlands containing *Gambusia*, compared with the previous year. In November 2016, *Gambusia* was thought to be present in 31 wetlands, and this number fell to 24 by February 2017 (Table 3.2.1)

Southern Kooragang Island wetlands: *Gambusia* distribution

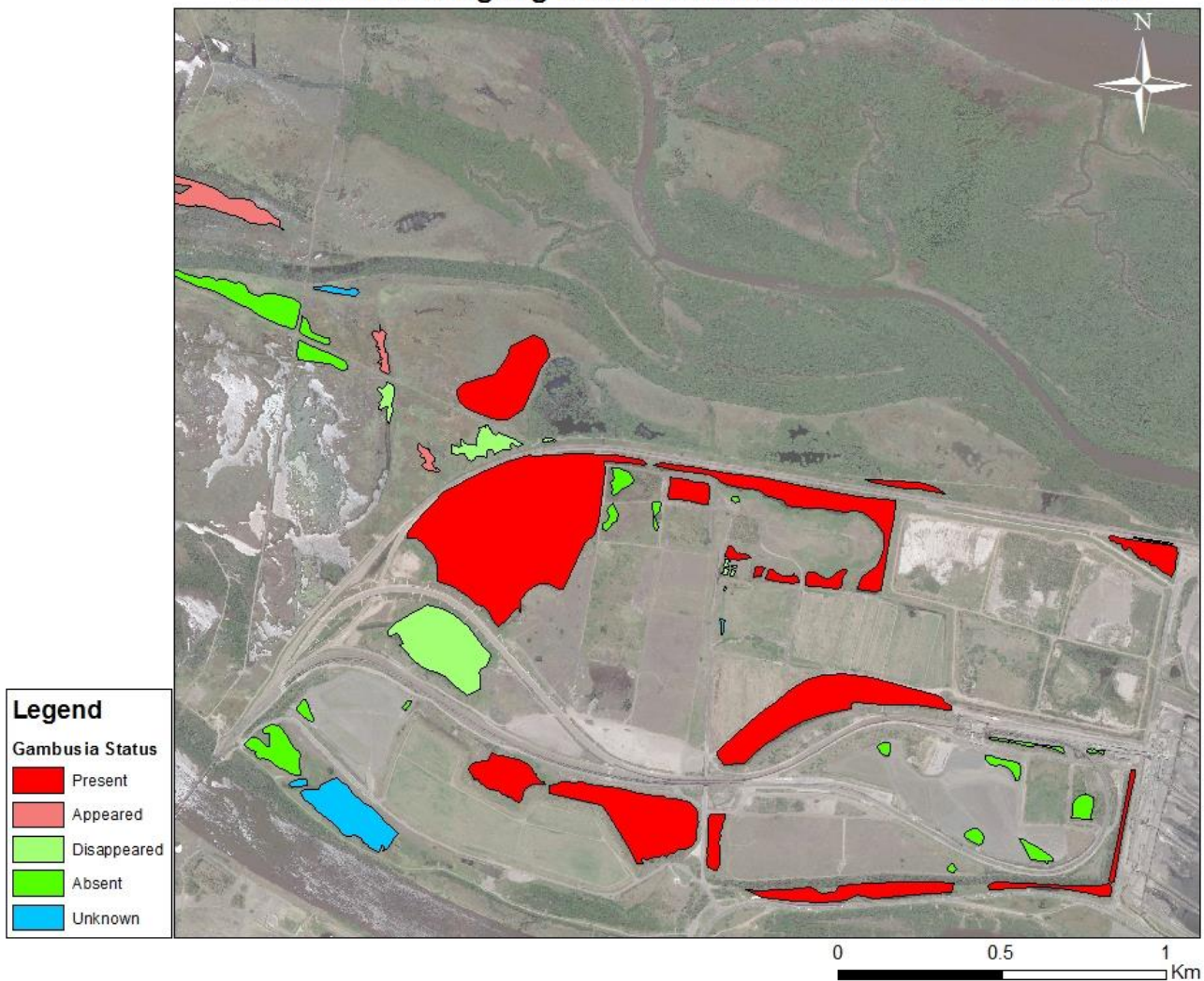
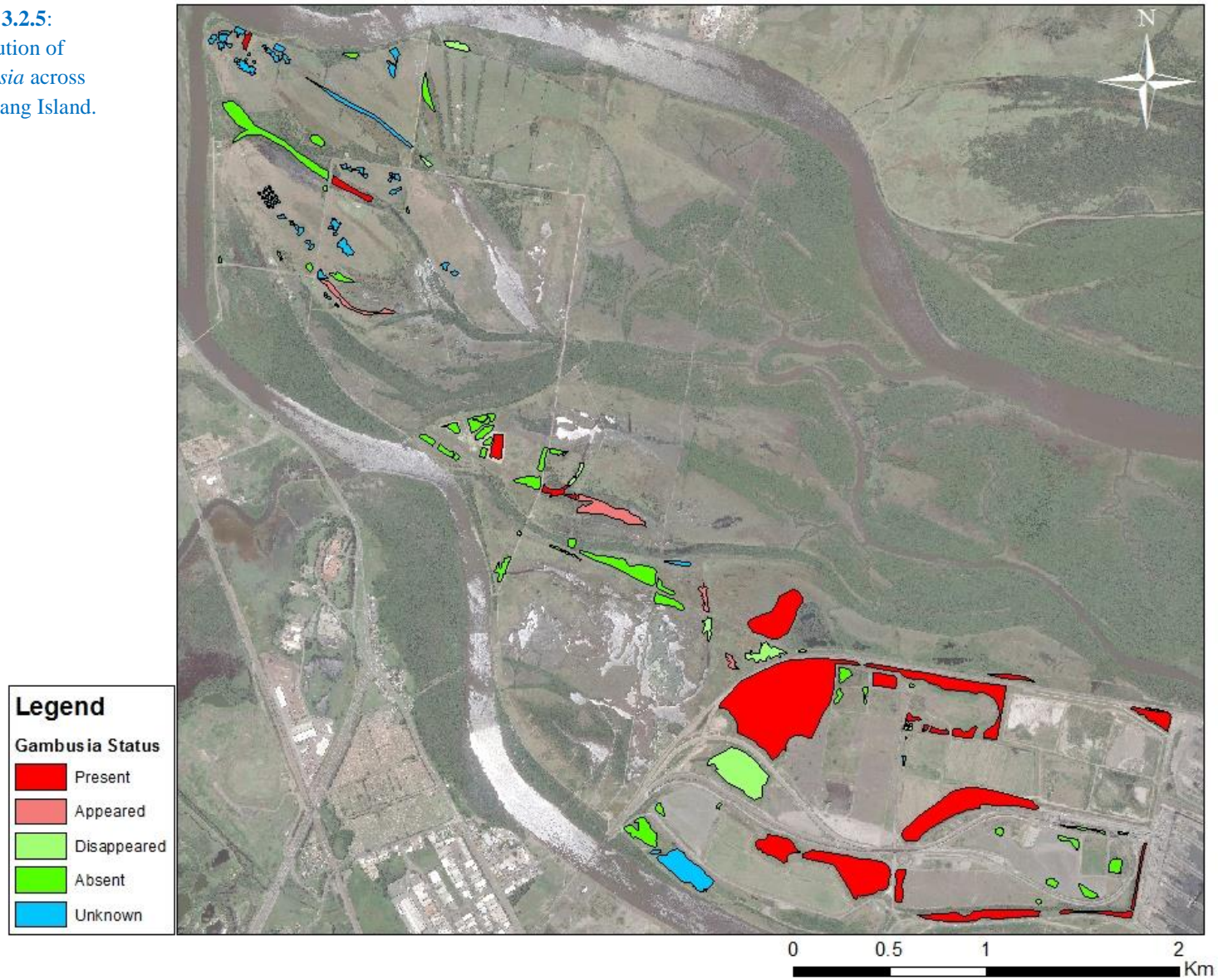


Figure 3.2.4: *Gambusia* distribution across the southern wetlands. Wetland scored as ‘disappeared’ are mostly those that dried during the season. Where scored as ‘appeared’, it is likely that *Gambusia* was always present but was not detected in the first round of surveys.

Kooragang Island wetlands: *Gambusia* distribution

Figure 3.2.5:
Distribution of
Gambusia across
Kooragang Island.



Vegetation (microhabitat)

Structures	<i>n</i> (captures)
trees	59
emergent vegetation	502
water	33
ground	253
man-made structure	3
ground vegetation	95
shrubs	31

Table 3.2.3: Broad microhabitat categories of bell frog captures, pooled across the 2016-17 season

Bell frogs were mostly commonly found on tall emergent vegetation (reeds and rushes) situated around the edges and in shallow parts of wetlands (Table 3.2.3). They are often found on the ground (either bare ground or low vegetation) near the water's edge. They are also regularly found in trees where these occur adjacent to or nearby the wetlands; usually *Casuarina* or *Acacia*, but occasionally mangroves.

Of the emergent vegetation, they were captured most often on *Typha*, but *Phragmites* and *Juncus* also provide important vegetation structure (Table 3.2.4).

Almost all instances of bell frogs on *Juncus* are on the introduced species *Juncus acutus*. Despite being subject to control under NPWS weed programs, *Juncus acutus* provides important microhabitat for *L. aurea* around the edges of wetlands across Kooragang Island.

Other non-native species that are regularly used by bell frogs include pampas grass, bitou, and lantana.

Table 3.2.4: Detailed microhabitat of bell frogs captures, pooled across the whole season.

Species	<i>n</i> (captures)
<i>Acacia</i>	2
<i>Casuarina</i>	26
tree	13
branch	3
dead branch	9
fallen tree	1
mangrove	5
<i>Bolboshoenus</i>	4
<i>Juncus</i>	87
<i>Phragmites</i>	88
<i>Scheonoplectus</i>	45
<i>Typha</i>	259
reed	19
water	33
bank	44
ground	107
mud	31
rock	67
gravel	1
road	2
concrete	1
cable tray	1
metal	1
rope	1
mangrove root	3
<i>Foeniculum</i>	2
<i>Hydrocotyle</i>	8
daisy	1
<i>Paspallum</i>	12
grass	65
dead grass	4
<i>Ricinus</i>	1
bitou	14
shrub	1
pampas	6
<i>Lantana</i>	9

3.3. Distribution

The distribution of *L. aurea* across the island can be visualised using GIS, using two metrics:

- (i) Search Sensitivity, which is the number of frogs detected per unit search effort (person.minutes), and
- (ii) Demographic GIS plots, which show the numbers of captured males, females, and juveniles, as well as 'other detected' animals, at each wetland.

Search sensitivity is primarily a measure of animal density. It does not reflect the absolute numbers of frogs at each wetland, as these are of different sizes and thus different carrying capacities (for example, [Figure 3.3.1](#) shows that the highest scores for search sensitivity were at K106C and K114, which are small wetlands). It does, however, provide a convenient indication of habitat quality of the different wetlands.

For example:

- K100A is more suitable for bell frogs than are K100E or K100W,
- Large open wetlands (K105A, K102, K103, K49A, K49B) have lower densities than smaller wetlands with more vegetation cover.

**Search Sensitivity (frogs detected per unit search effort),
2016-17 surveys (southern island)**

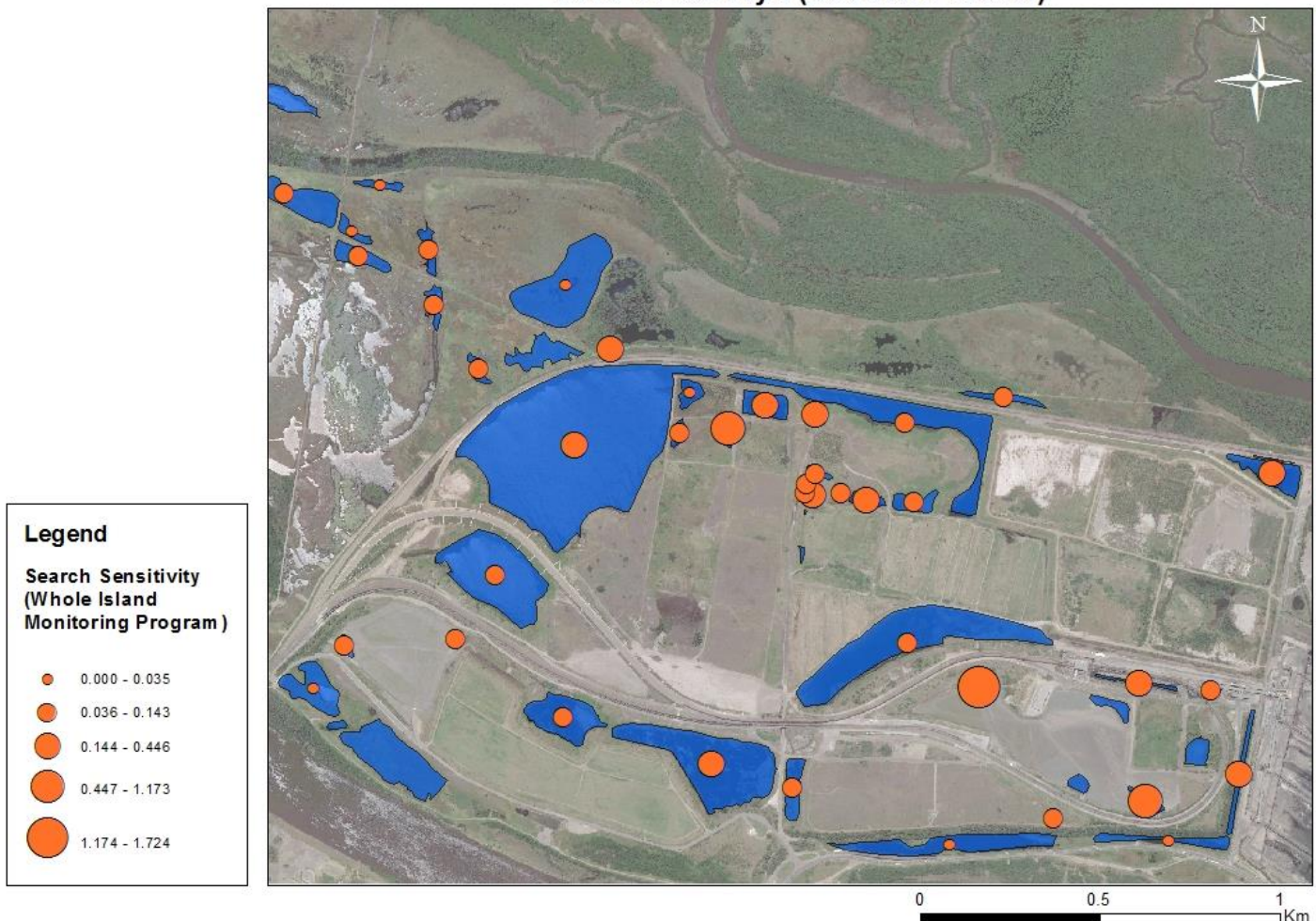


Figure 3.3.1: Search sensitivity of wetlands in the Southern end of the island. See [Figure 3.2.2](#) for explanation and text for discussion.

Search Sensitivity (frogs detected per unit search effort), 2016-17 surveys (whole island)

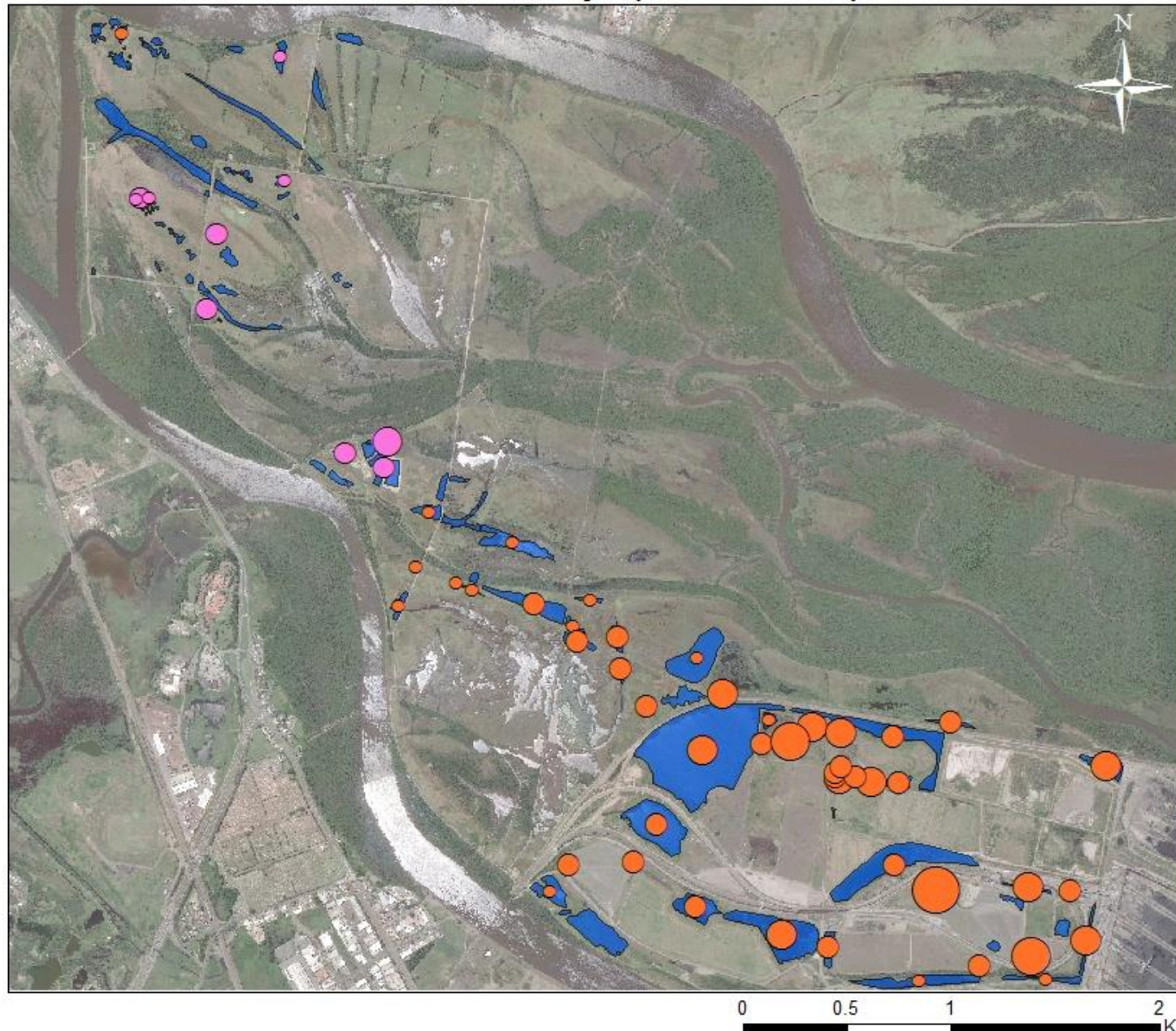


Figure 3.3.2: Search sensitivity (frogs detected per (person.minutes) across the 73 wetlands surveyed as part of ‘whole island’ monitoring in 2016-17

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

Note that the CHEMP wetlands shown here are only those included in the Save Our Species (SOS) 2016-17 surveys – they do not include all CHEMP wetlands

Search Sensitivity across the whole island is shown in [Figure 3.3.2](#); data for the NCIG and BHP CEMP surveys are included to provide an overall picture of bell frog density across the island. The potential importance of these programs in the Northern and the eastern part of the Central regions is evident; the Whole Island Monitoring Program recorded very low numbers of bell frogs east of bell Frog Lane, but both BHP and NCIG CEMP found higher densities at their respective constructed wetlands. In particular, without the NCIG CEMP the population at the northern island would be extremely low.

Demographic GIS plots differ from Search Sensitivity plots in that they indicate the actual numbers of bell frogs detected during primary VES. They also show a demographic breakdown of those survey numbers.

In **round 1** VES, the highest number of frogs was recorded at K114; however, these were predominantly juveniles. The wetland with the highest number of adults was K29. The other CMR wetlands, K104 and K22/23, had medium numbers of frogs; the numbers at K104 were much lower than last year. Both K105A and K106C had very high numbers in round 1.

Bell frogs detected, 2016-17 surveys, Round 1 (southern island)

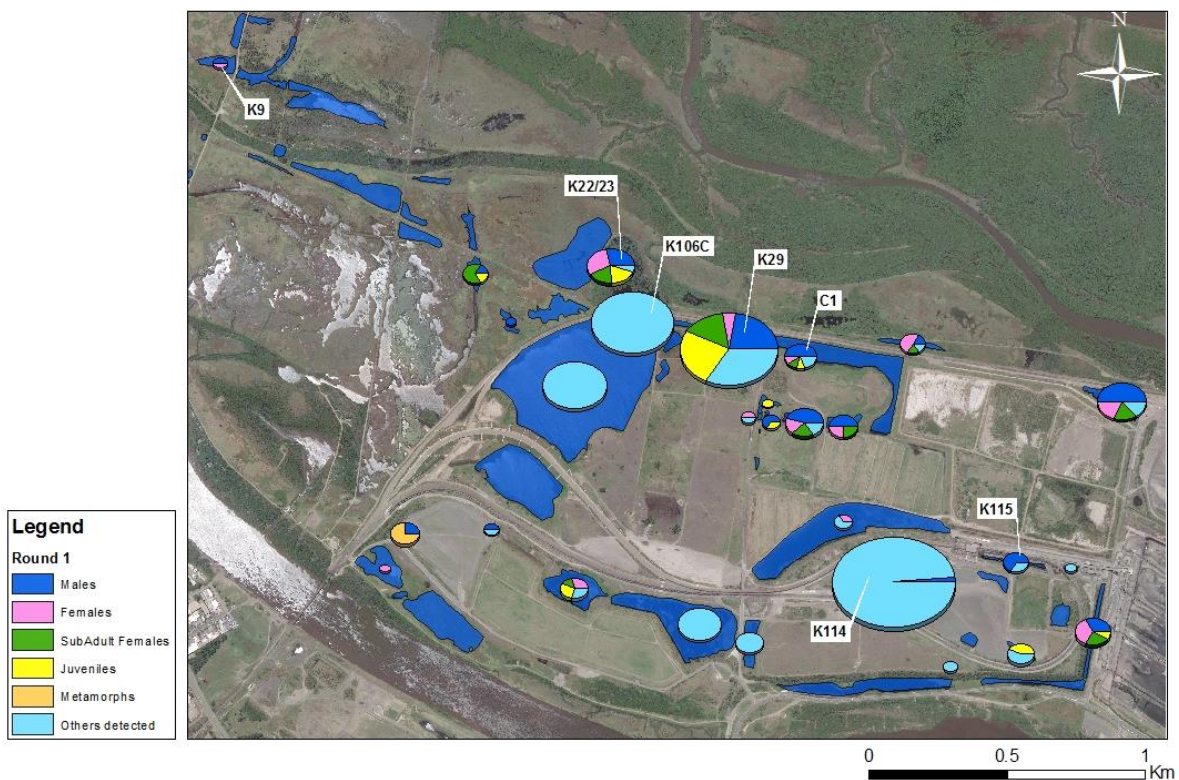
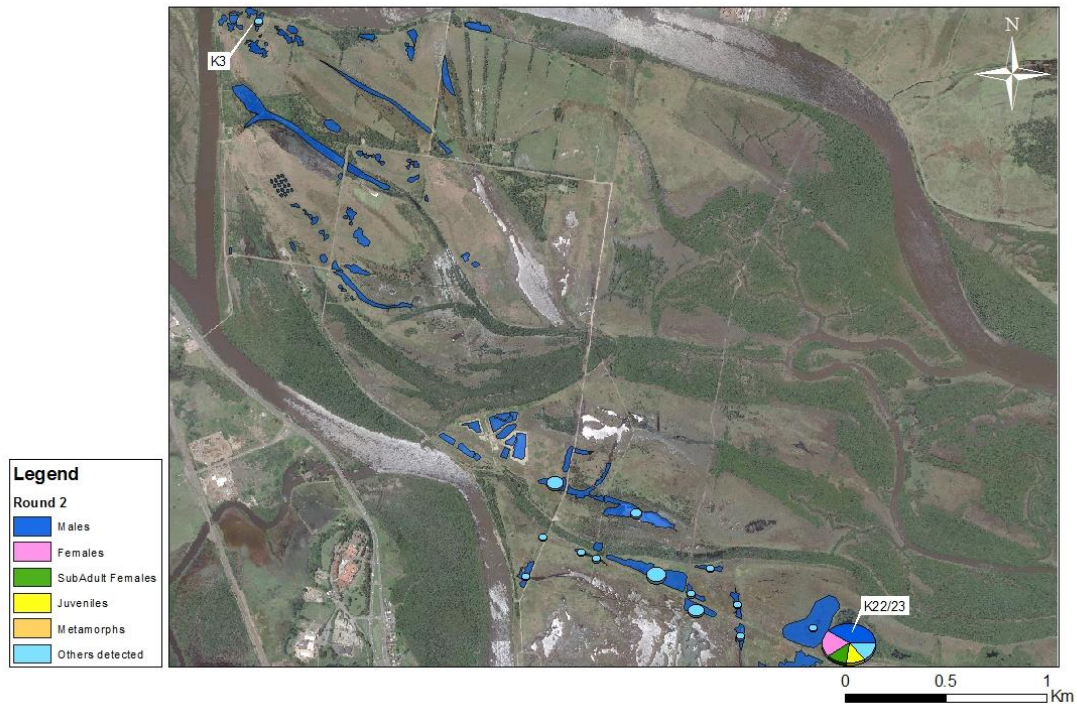


Figure 3.3.3: Demographic GIS plots for the Southern and Central region of the island, round 1. No animals were detected NW of K9 in the first round. ‘Others detected’ mainly denotes animals that were seen but not captured.

In **round 2**, a single frog was sighted in K3 at the northern end of the island, the only detection of a *L. aurea* during VES in the Northern region during the whole island monitoring program. *L. aurea* in the

Bell frogs detected, 2016-17 surveys, Round 2 (Northern and Central KI)



Bell frogs detected, 2016-17 surveys, Round 2 (southern island)

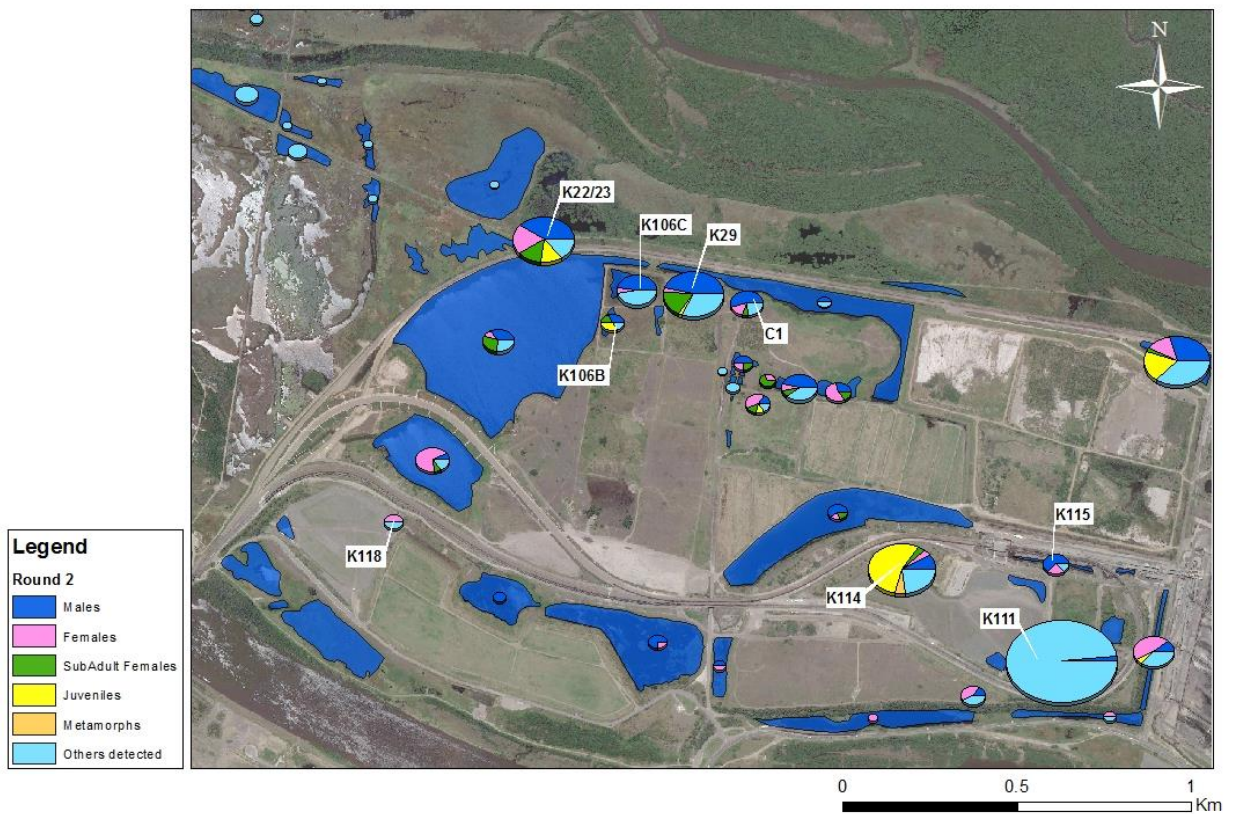


Figure 3.3.4: Demographic GIS plots for round 2. See text for discussion.

Central region was predominantly restricted to K22/23. Within the industrial zone, numbers at K29 were lower than round 1, but those at K104 were higher. Numbers at K114 remained high, and there was a very high number of animals (predominantly juveniles) detected at K111.

In **round 3**, numbers at K29 continued to fall, but large numbers were found at K106C. Numbers at K22/23 were similar to round 2, but numbers at K104 dropped slightly. *L. aurea* disappeared from K111 almost entirely, but numbers at K114 remained high.

Bell frogs detected, 2016-17 surveys, Round 3 (southern island)

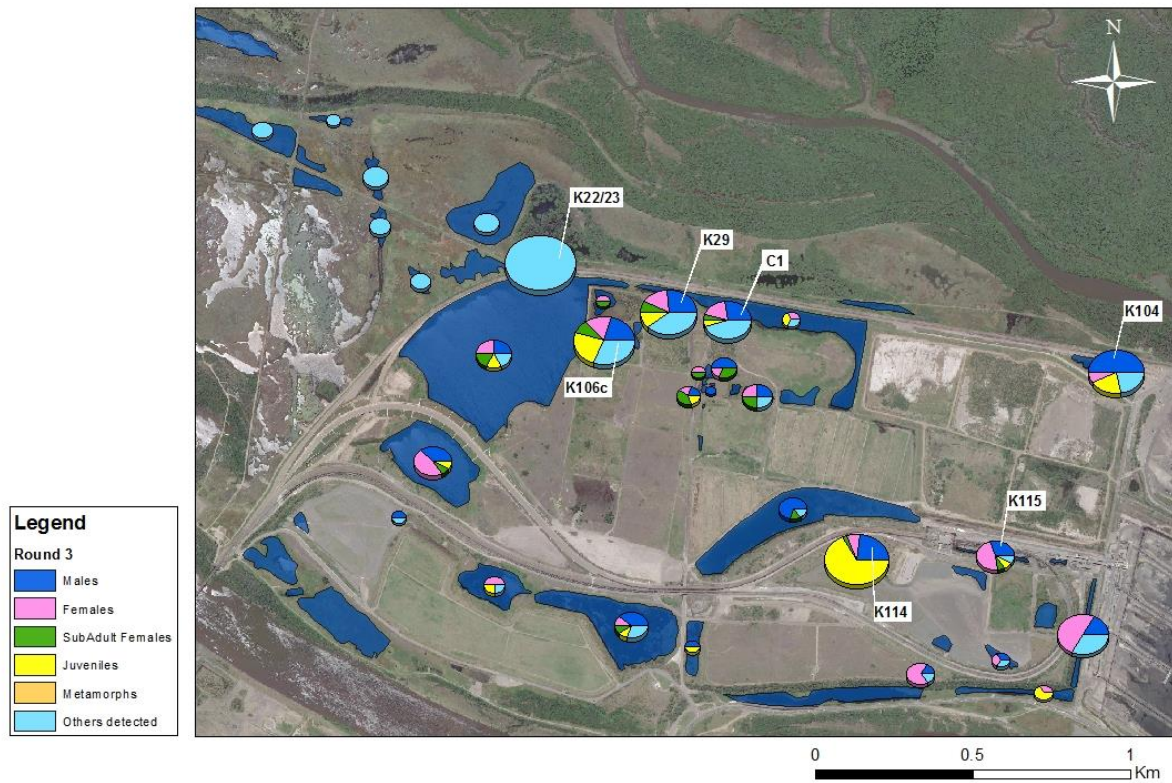


Figure 3.3.5: Demographic GIS plots for the Southern region and the western part of the Central region, round 3 (there were no animals detected NW of this map in that round).

Spatial patterns

Northern Region: Numbers were lower this year than in the 2015-16 surveys but the northwest end of the island has had low numbers of bell frogs for some time. Last year we wrote:

“The outcome of VES in the northwest zone follows the trend of the last season (2014/2015). Detection and distribution of bell frogs has increased in this zone, although the numbers are low relative to occupied wetlands in the southern zone. Surveys conducted in 2012/2013 and 2013/2014 (Clulow et. al. 2012, 2013, 2014) failed to detect bell frogs in VES surveys in the 14 “natural” wetlands”

In the same section, we also noted that the recently established (at that time) NCIHG compensatory habitat was already helping to improve numbers at this end of the island. This has indeed occurred, with *L. aurea* occurring within those CHEMP habitats at higher levels than in the surrounding ‘natural’ wetlands (Figure 3.3.2).

Central region: Once a stronghold of *L. aurea* on Kooragang Island, the wetlands near Bell Frog Track (named for those once high densities) have had reduced numbers in recent years. That many of these wetlands dried out this year will not have helped stem this trend. K22/23 once contained the highest numbers of bell frogs on the island; there are now a number of wetlands on the other side of the railway that have larger numbers, but it continues to be an important population (the nearby K24 and K63 appear to provide breeding habitat). At the eastern end of this region, the BHP CHEMP wetlands are already providing for good numbers of bell frogs (Figure 3.3.2).

Southern region: As with last year, the northern rail corridor (K104, K29, K106, K105A) is home to the majority of bell frogs on the island, but the numbers in the southern part of the industrial zone are higher than recent years. In particular, the newly constructed HDC wetlands seem to provide suitable habitat and GBBF are now present in all of these (that contain water). As we predicted last year, the new wetlands at the southwestern end of the industrial zone (K117 and K118) have been colonised by *L. aurea*, and C2 now has frogs for the first time; last year, we predicted that the improved connectivity across the southern part of the industrial zone should lead to those wetlands containing bell frogs.

For the second year running, K108 (the ‘rail loop’ wetland) contained low numbers of *L. aurea* – this year it was totally dry for the whole season, and we did not detect a single frog. This wetland once contained high densities of bell frogs. It remains to be seen if numbers will return to this wetland once it has been recharged.

Connectivity of K104 is poor and numbers there seem to reflect breeding activity the previous year. Very high numbers their last year followed a large breeding event in 2014-15. However, despite the high numbers of adults at the wetland last year, breeding seems to have been low in 2015-16 and this year numbers are well down.

3.4. Demographics

Proportions of juveniles, adult males, and adult females

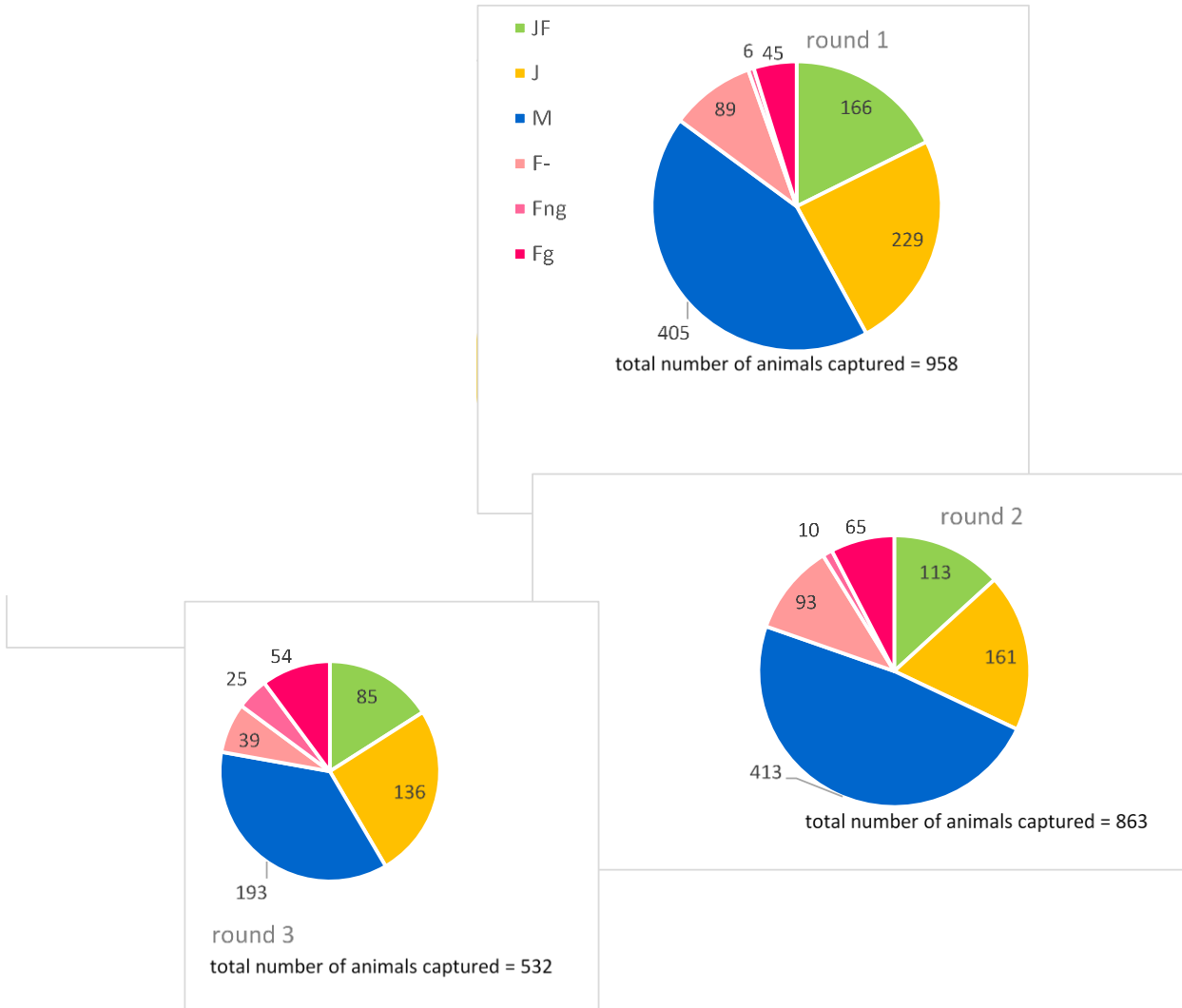
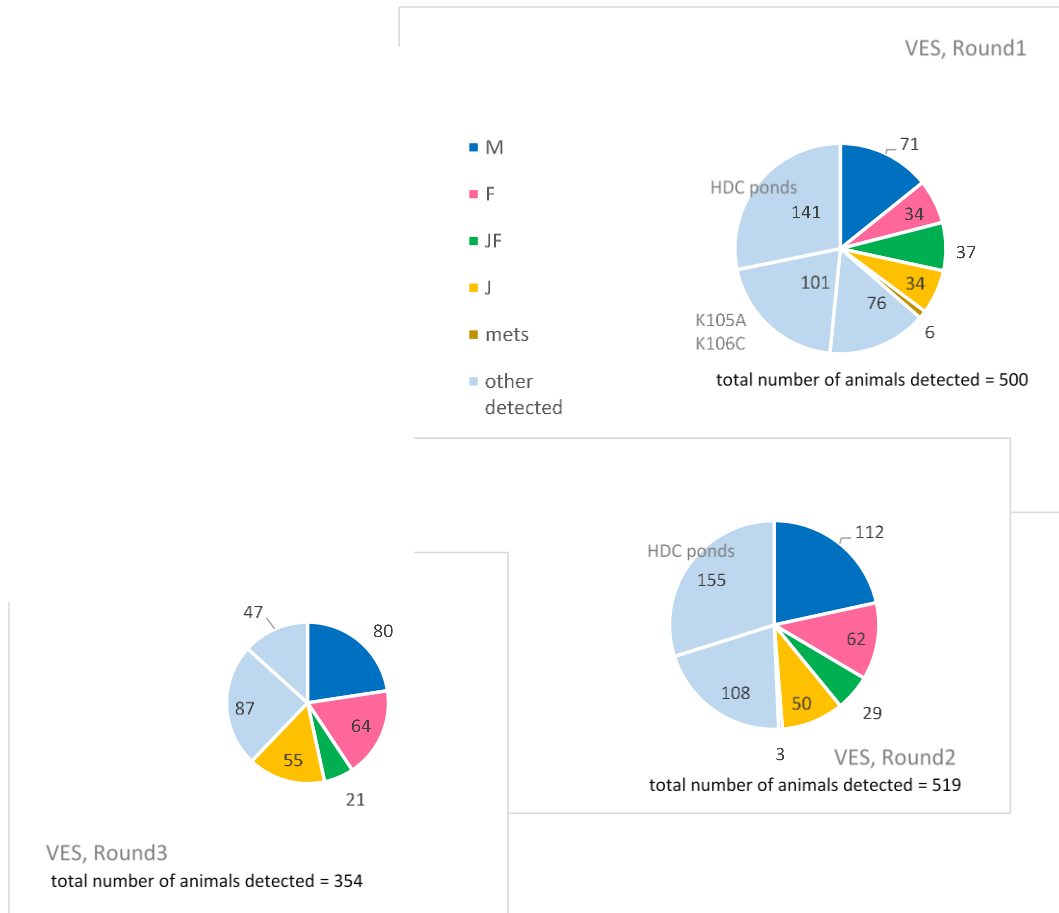


Figure 3.4.1: Summary demographics of all captured *L. aurea* (i.e. VES and CMR, including recaptures and non-tagged individuals), by round. M, adult males; J, juveniles; JF, subadult females; Fg, gravid adult females; Fng, non-gravid adult females; F-, adult females where gravidity was not checked.

Adult males were captured most often. About a third of captured animals were females (subadults and adults), and approximately a quarter were juveniles.

This is a much larger amount of adult females than the 2015-16 survey, both in terms of absolute numbers and proportions of captures. We checked about half the captured females for gravidity; a large proportion of those checked were gravid. Presumably, this resulted from the low levels of rainfall during the summer, with gravid females not laying clutches for extended periods and remaining close to permanent wetlands.

VES Demographics



Figure

3.4.2: *L. aurea* detected and captured during primary VES only, by round. M, adult males; F, adult females; JF, subadult females; J, juveniles; met, metamorphs; other detected, *L. aurea* detected but not included in demographic analysis (usually, because they were not captured). Most of the animals detected at the HDC wetlands in round 1 and 2 were juveniles, while most of the animals detected in round 1 at K105A and K106C were adults.

Overall, about half the animals detected were captured and had demographic data collected. In general, the 'Other Detected' category refers to animals that were missed (but see below). Capture rates are usually higher than that - generally, only about a third to a quarter of detected animals are not captured - but the capture rates shown here are low due to a combination of:

- Performing visual counts only for VES in several wetlands during round 1, due to logistical constraints (resulting from the very high numbers of animals captures in K29). In particular, the surveys at K105A and K106C detected large numbers of animals (mainly adults) in round 1.
- Very large numbers (>100) of frogs at the HDC wetlands K111 and K114. Although a mix of all life stages from metamorphs to adults were present in these surveys, only a small proportion were captured during VES at these wetlands in round 1 and round 2. Most of the animals detected were small juveniles, indicating breeding events early in the season.
- For Round 3, detailed capture data for wetlands from the Central and North-eastern regions of the islands had not been included in the present analysis; those captures are included here as 'Other Detected'. The majority of these captures of were during the CMR survey at K22/23.

Unique individuals

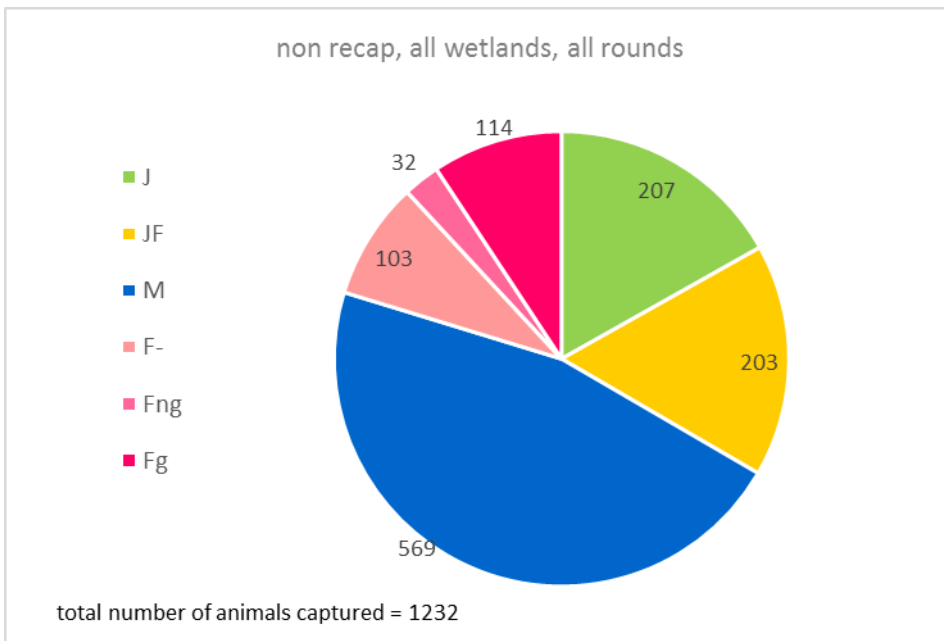


Figure 3.4.3A: Proportions and numbers of PIT-marked individuals captured during 2016-17 VES and CMR surveys. See Fig 3.4.1 for legend.

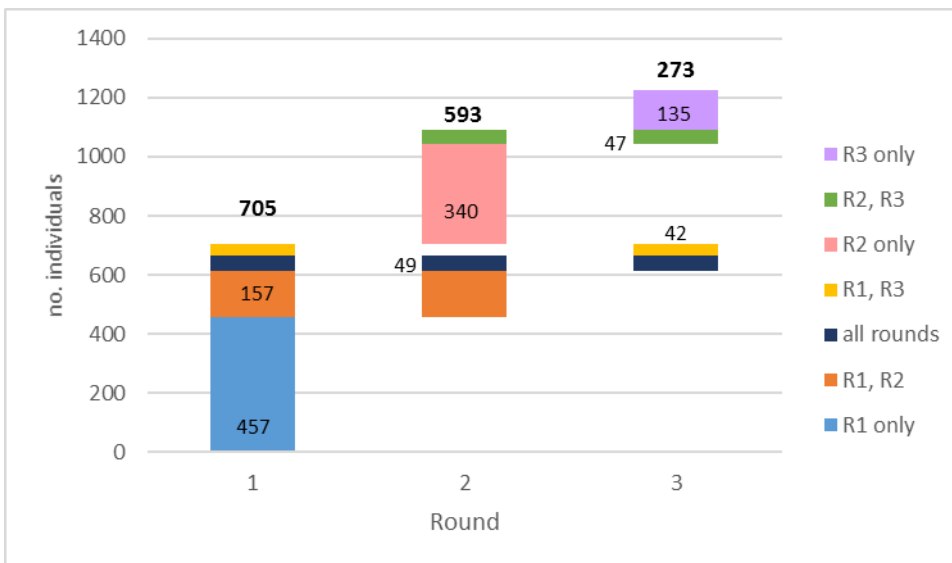


Figure 3.4.3B: Unique PIT-marked individuals captured in each round, showing those animals caught in multiple rounds versus only one round.

A total of 1, 232 individual frogs, whose identity could be checked by PIT tags, were captured and identified in the 2016-17 study.

The number of individuals identified per round were: 705 in the round 1, 593 in round 2, and 273 in round 3. Of these, 300 were found in more than one round: 457 were found in round 1 only, 340 in round 2 only, and 135 in round 3 only. Of animals caught in round 1, 248 (35%) were caught in subsequent rounds; of *L. aurea* caught in round 2, 96 (16%) were caught in round 3.

Size classes and cohorts

All captures

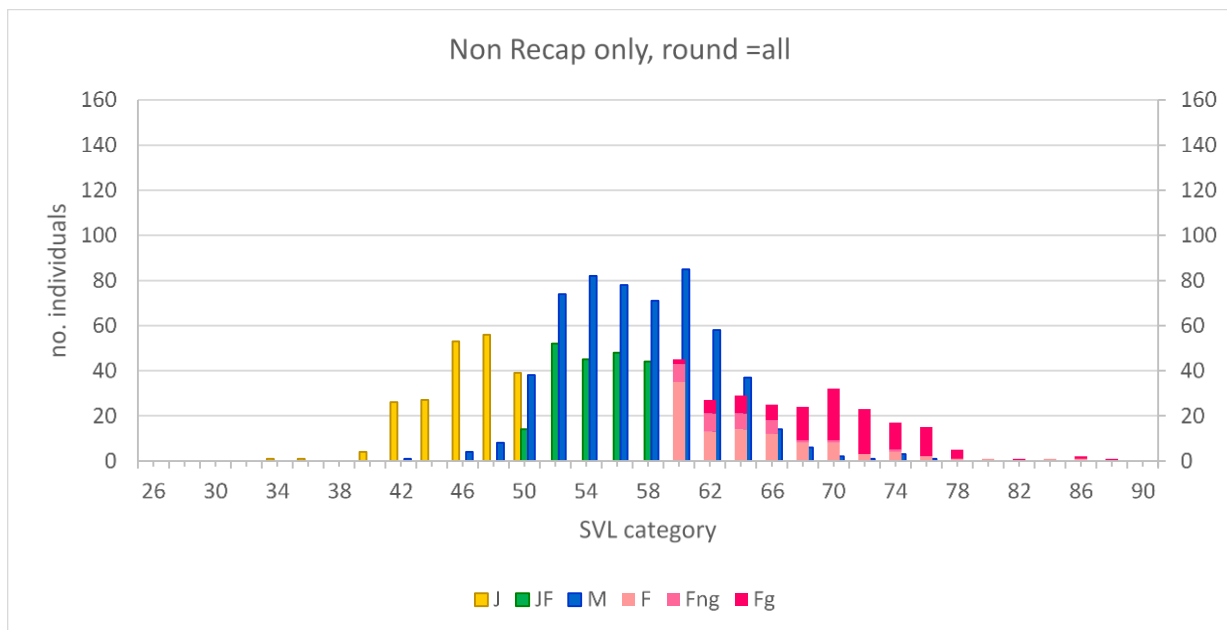
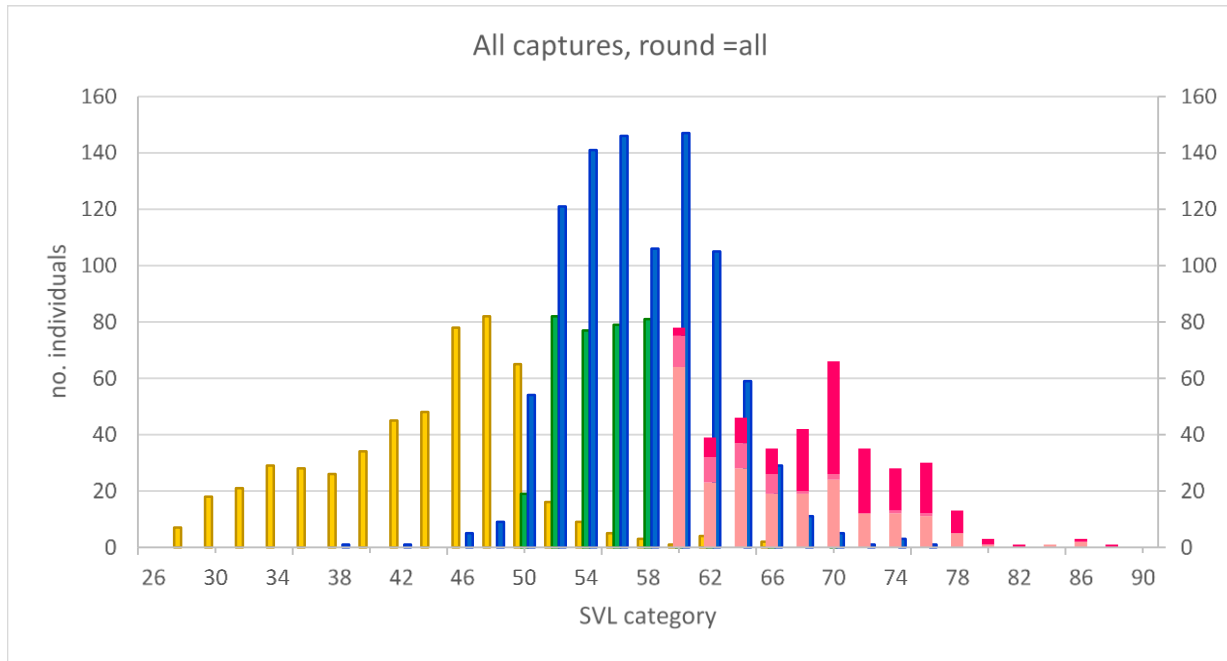


Figure 3.4.4: Frequency distribution of different sized animals captured, for VES and CMR surveys. Size is measured by snout-vent length (SVL), and size categories are measurements ‘binned’ into 2 mm groups, i.e. the frequency of animals 56 mm > SVL >= 58 mm is shown in the column labelled ‘58’. **Top;** all captures where demographic data was recorded. **Below:** ‘Non Recap’ shows only unique PIT tagged individuals (generally, SVL > 40 mm), i.e. with recapture data removed. See Fig. 3.4.1 for legend.

Although the number of unique individuals captured (1,232) is about half the total number of captures, the proportions different sex and size classes is similar between the two summaries, suggesting that data on total captures can be used to visualised the range of individual’s presence without being

distorted to heavily by 'trap happy' individuals that are prone to recapture. Exceptions to this were adult males, which were caught in slightly higher proportions to their actual numbers. Juvenile animals that are too small to chip with a PIT tag are shown in the 'all captures' data but not in the 'non-recap' data as these animals cannot be identified as individuals, even if captured multiple times.

All captures, by round

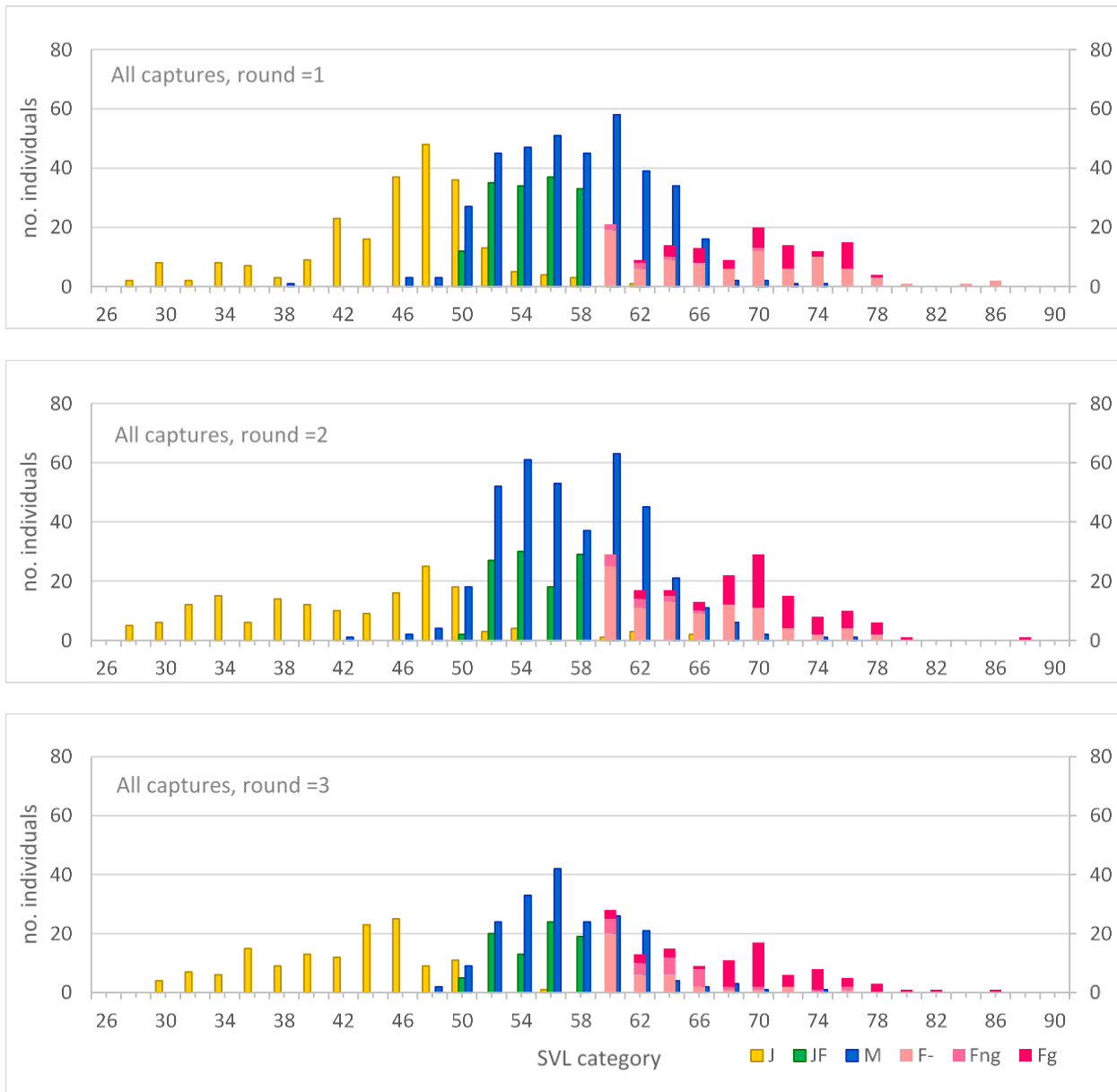


Figure 3.4.5: Frequency distribution of size classes, showing all captures for each survey round (VES and CMR). See Fig 3.4.1 for legend and Fig. 3.4.4. for explanation of size classes.

The high numbers of large juveniles in round 1 (late Nov to Dec) likely represent animals that overwintered as tadpoles, or which metamorphosed in late summer 2016 (e.g. the large number of metamorphs seen at K106A and B in Feb 2016). The pulse of mid-sized juveniles in round 2 are probably animals that were laid in early Spring 2016 and which were detected as metamorphs in round 1; these animals are large juveniles by round 3.

The largest number of adult females were captured in round 2, even though overall capture numbers were lower than round 1 (see Fig 3.4.1). Although overall capture numbers are smaller still in round 3, the proportion of large adult females remained high.

Kooragang Island Bell Frog Survey 2016-2017

Captures by wetland – K29

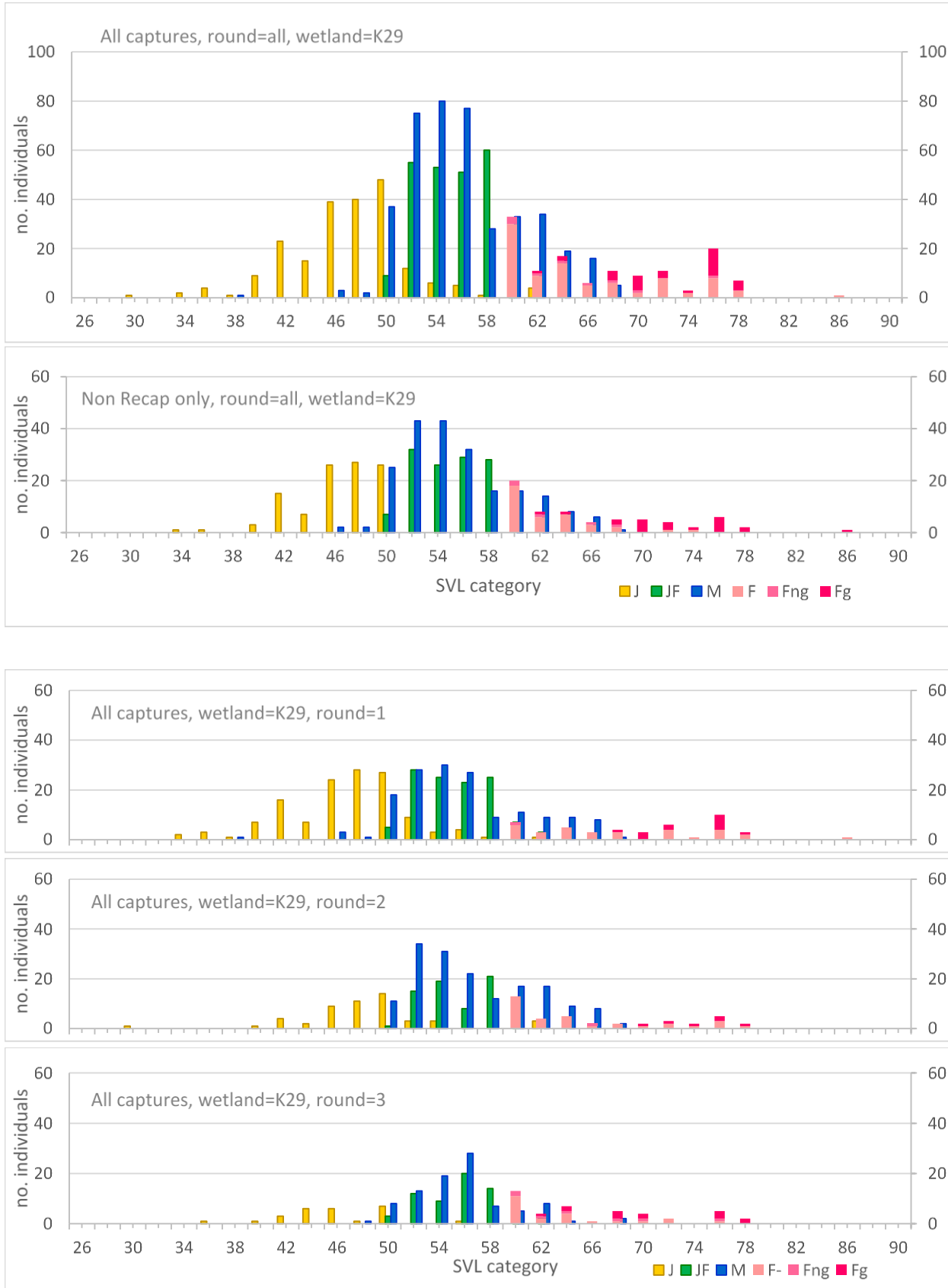


Figure 3.4.6: Frequency distribution of size classes at K29. Top: Data for all captured animals (above) and tagged individuals (below), summed across all three rounds. Bottom: Frequency distribution per round. See Fig. 3.4.1 for legend and Fig. 3.4.4. for explanation of size classes.

K29: The large number of large juveniles at K29 may represent those animals that metamorphosed at the nearby K106 wetlands in February 2016. This cohort gives a pulse of small adult males in the second and third rounds.

Although present in small numbers, large adult females remain present at K29 for all three rounds.

Overall numbers at K29 were the highest for any wetland surveyed this year; on a single night in round 1 we detected over 200 *L. aurea*. This is notable contrast with the surveys in 2015-16, which detected some 20 bell frogs in 6 nights of surveys. Although less than in round one, numbers in round 3 were still high. It seems that the low rainfall this season dissuaded frogs from moving away from this permanent wetland throughout the summer.

K104: In contrast to K29, the first round at K104 captured large numbers of small juvenile (large numbers of metamorphs were also seen in these surveys), suggesting a spring recruitment (October) event at this wetland. This pulse can be seen in subsequent rounds; they become large juveniles by round 3 (in February), indicating that *L. aurea* born early in the season can become small adults by the end of their first summer.

K104 had the largest population of any wetland in 2015-16, but *L. aurea* were far less abundant this year. The large numbers of *Gambusia*, combined with high water levels (which connected normally ephemeral and thus *Gambusia*-free wetlands with the main water body) appears to have resulted in low recruitment in the 2015-16 season, and the small numbers of adults this year (compared to last) may represent the surviving adults without significant recruitment.

Spring versus summer cohorts

Between them, the demographic pattern of smaller frogs at K29 and K104 provides information on the growth of frogs in their first year, and in particular shows the different pattern for spring versus summer breeding events. It is highly likely that the cohort of juveniles at K29 were laid following heavy rain in early January 2016, where after they were detected as metamorphs (in very high numbers at K106A and B) on February 11th 2016. These animals apparently overwintered as small juveniles, and reach adulthood (if males) or sub adulthood (if females) by the end of the 2016-17 summer.

Conversely, the cohort of small juveniles at K104 were laid in mid to late October 2016 (see Section 3.6), and have become large juveniles by February 2017. Some of these animals may become small adult males by mid-autumn, but their contribution to breeding that year is unlikely to be high.

The seasonal growth pattern thus complicates simple relationships between size and age. Animals that metamorphose in February will become small adults 10-12 months later. However, frogs that metamorphose in December may become small adults much more rapidly, 4-5 months later. Estimate of age based on SVL for smaller frogs is therefore dependent on the time within the season that the measurement is taken.

Kooragang Island Bell Frog Survey 2016-2017

K104

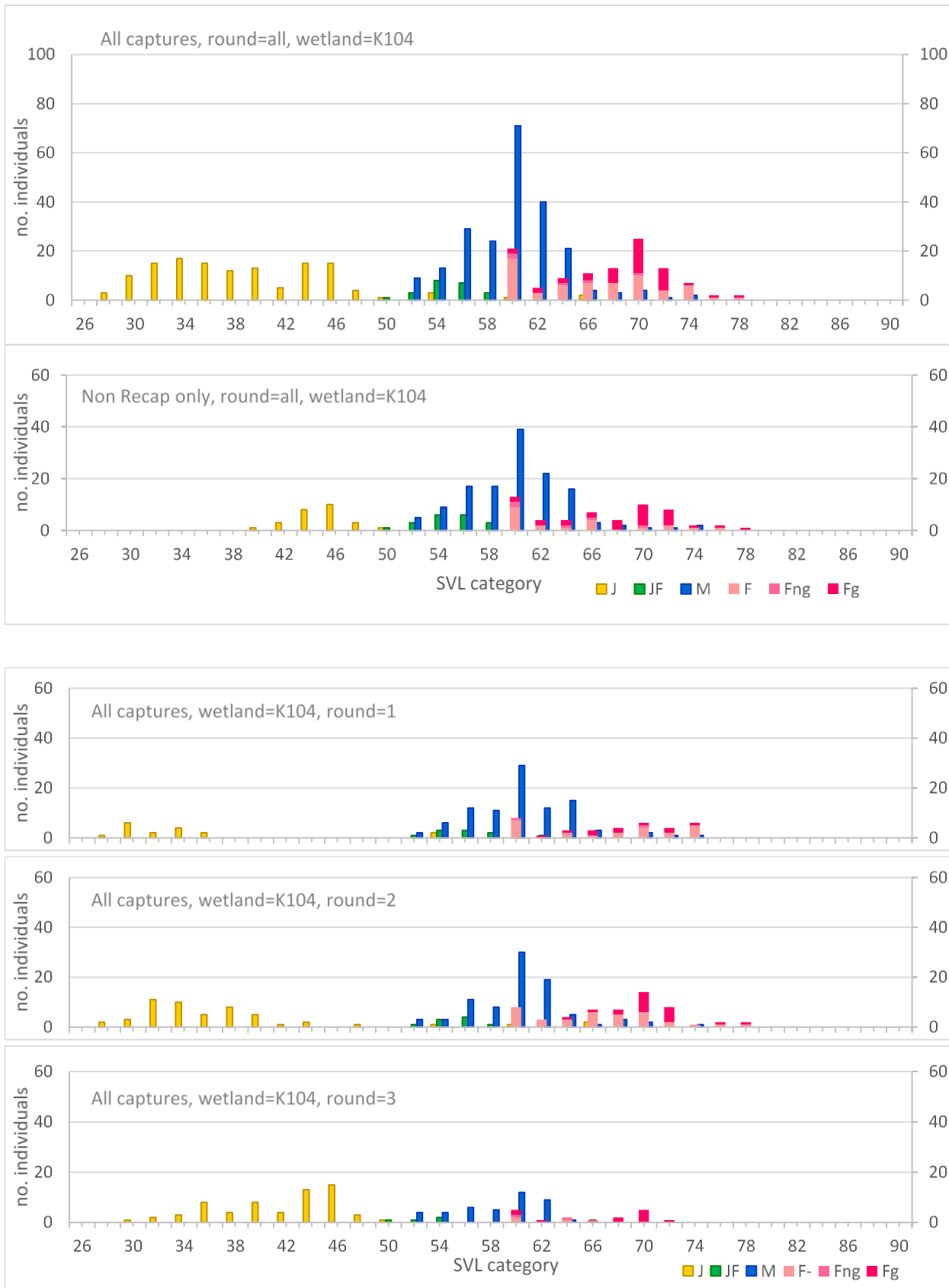


Figure 3.4.7: Frequency distributions for K104 wetland. Refer to Fig., 3.4.6 for explanation of charts.

Kooragang Island Bell Frog Survey 2016-2017

K22/23

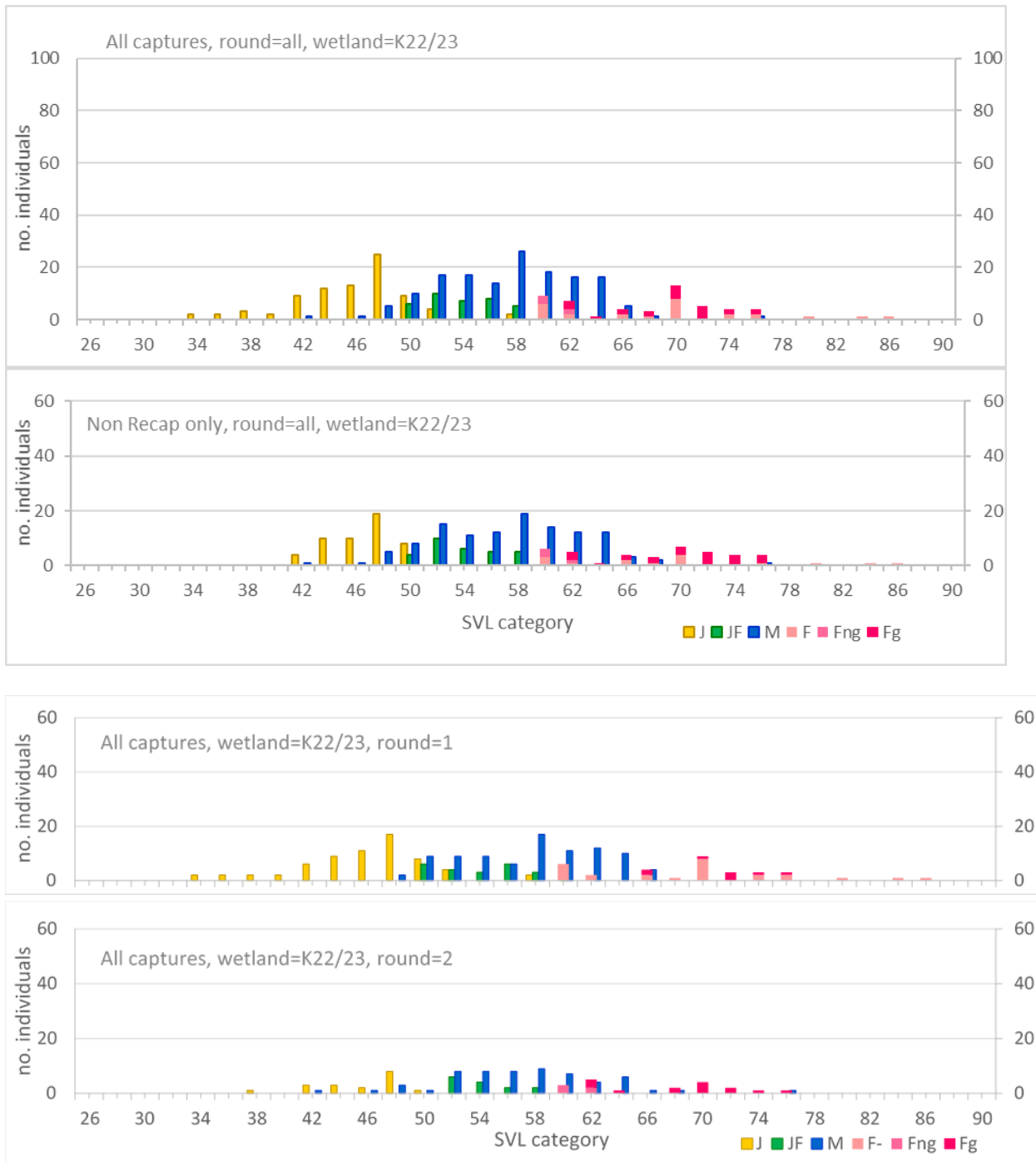
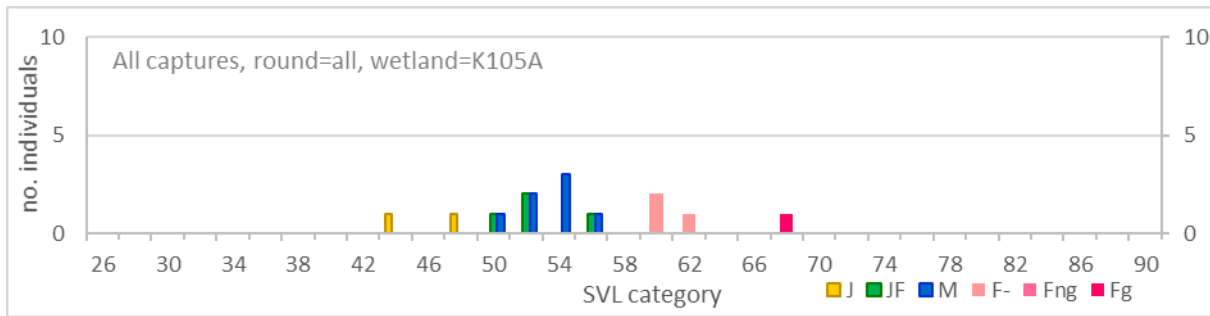


Figure 3.4.8: Frequency distributions for K22/23 wetland. Refer to Fig., 3.4.6 for explanation of charts.

K22/23: A pulse of large juveniles in the first round may represent animals that metamorphosed in the late summer of the previous year (there were a large number of very small juveniles detected at this wetland in February 2016). By the second round overall numbers are low. Data for the third round is not included in the present analysis.

K105A



K105B

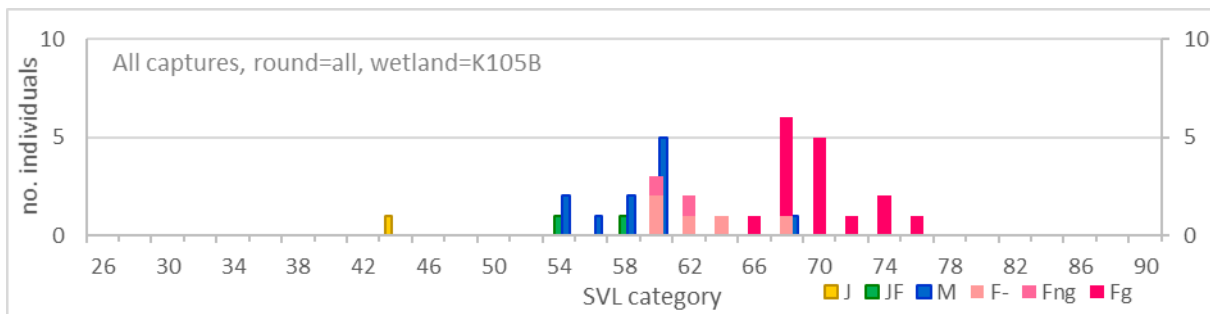


Figure 3.4.9: Frequency distributions for the large K105 wetlands west of K29. Refer to Fig., 3.4.6 for explanation of charts.

K105A, K105B: These are large shallow wetlands in the north west corner of the industrial zone; they were a single waterway prior to the construction of the NCIG rail line. The smaller one, K105B, is almost completely surrounded by suitable *L. aurea* habitat, and contained a very high proportion of large adult gravid females. K105A has patches of reed stands (*Typha*, *Shoenolectus*, *Bulboshoenus*, *Juncus*) around its edge interspersed with open rocky areas that are less suitable for *L. aurea*. As a consequence, K105A may have a lower overall density of *L. aurea*, even though they can occur in high numbers at this wetland in suitable patches of habitat.

Rainfall was low and over the course of the 2016-17 summer surveys many wetlands dried partially or even completely. By February 2017 (round 3), the water’s edge at K105A was tens of metres from the normal edge of the wetland, and K105B had completely dried. Bell frogs were still present at K105B after the wetland had dried, although they were in highest numbers on the northern edge of the wetland, closest to the permanent water in K105A.

Note that, for logistical reasons, K105B was not surveyed in the first round, and K105A was surveyed using a ‘count’ only (i.e. no captures made during the VES).

K106C

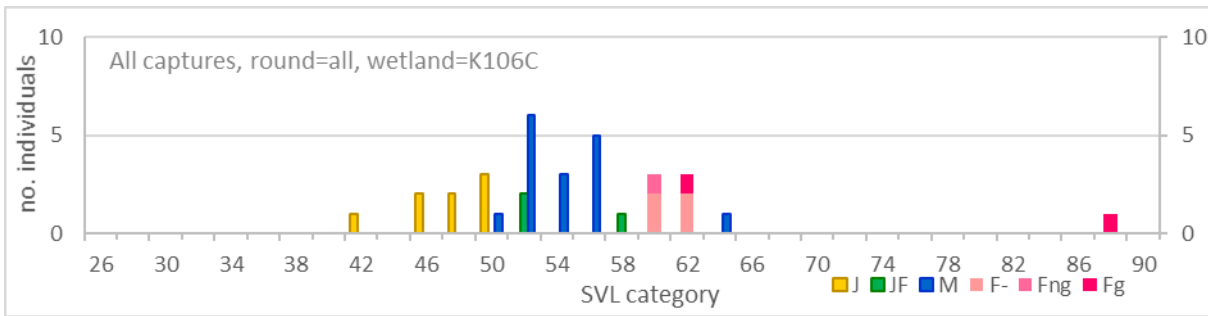


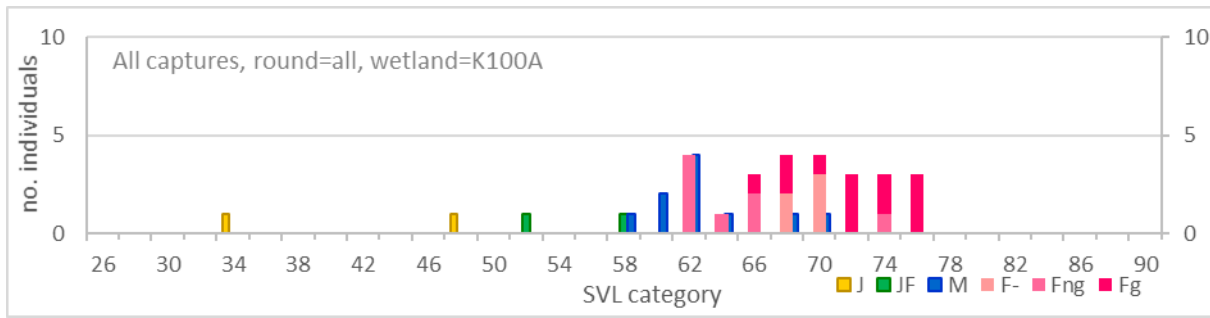
Figure 3.4.10: Frequency distributions for the small K106C wetland immediately west of K29. Refer to Fig., 3.4.6 for explanation of charts.

K106C: This is a very small wetland immediately south-west of K29, in the next ‘cell’ over. It is a deep waterhole, not more than 4 metres across, and shaded by tall trees and bushes. It lies within the same bunding as K106B, which is a shallow ephemeral wetland that (together with the adjacent K106A) saw a large breeding event following high rainfall in early January 2016.

K106C was surveyed in round one using a VES count only (for logistical reasons); that survey detected 60 *L. aurea* in the space of 10 minutes, which is one of the highest densities of bell frogs on the island (note that, due to lack of captures, the results of that survey are not included in the above figure). That density of frogs, which can be visualised by the Search Sensitivity result (Figure 3.21) is comparable with the highest densities of frogs recorded this year (at the HDC wetlands K111 and K114); however, unlike the HDC wetlands, the animals at K29C are mainly adults (and included the largest female captured this year). Even though this wetland is small, it (together with K29) is presumably an important part of the habitat mosaic for *L. aurea* in the northern part of T4.

Potential factors that may underlie its importance are: its depth, the lack of *Gambusia*, its cover by vegetation (some of the densest tall vegetation in this part of T4), its proximity to a large permanent wetland (K29), and its proximity to large shallow ephemeral wetlands that provide suitable breeding habitat (K106 A and B).

K100A



K115

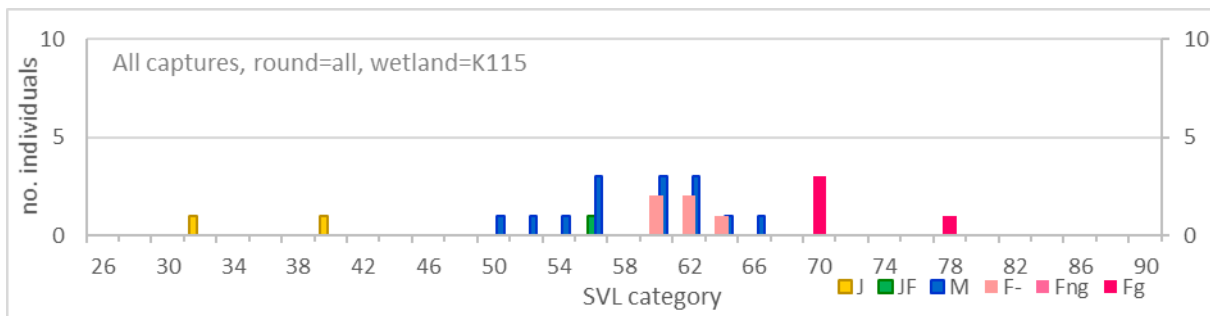


Figure 3.4.11: Frequency distributions for selected wetland immediately near the NCIG rail loop. Refer to Fig., 3.4.6 for explanation of charts.

K100A and K115: The NCIG wetlands K100A and K115 are close to the eastern end of the NCIG rail loop. In particular, they are close to the ‘rail loop’ wetland (K108), which has historically held high numbers of *L. aurea*, and the new constructed HDC wetlands (K111-114).

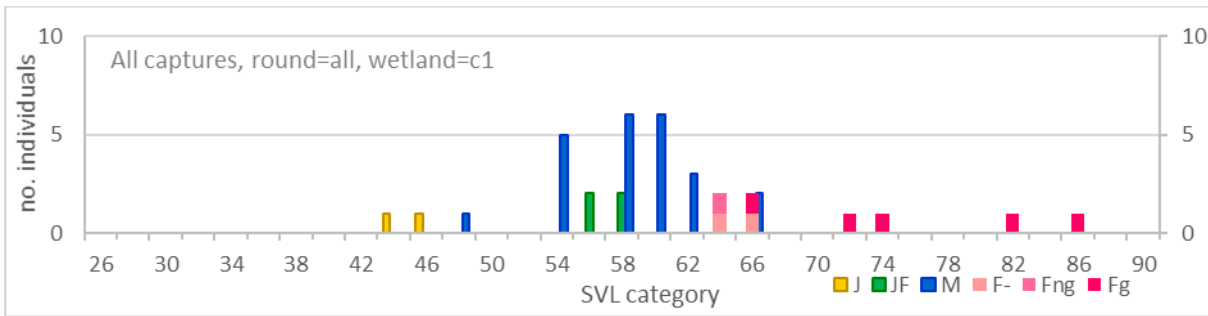
With the dry summer this year, K108 was dry during every survey period, while only two of the HDC wetlands (K111 and K114) held water. In this context, the deep water of K100A and K115 may have acted as a refuge for *L. aurea* that would in wetter summers be more dispersed across the east part of the rail loop.

K100A is well shaded by tall trees. Last year it held very few bell frogs; this year, it had much larger numbers. It is possible that these animals may have moved from the nearby K108 as it dried.

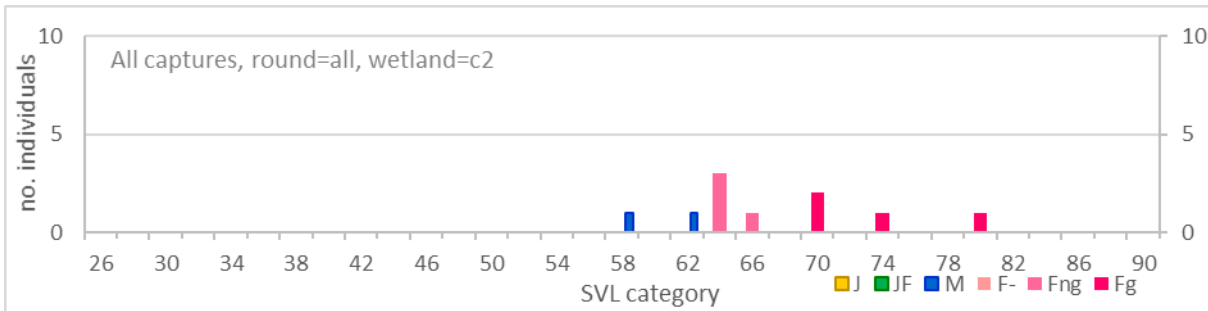
K115 is a managed settling wetland under the NCIG dump station and conveyor. Although deep, it has been almost completely cleared of vegetation apart from a discrete stand of *Typha* at its western end. This patch contained large numbers (for its size) of *L. aurea* and this wetland may be an important part of the habitat mosaic in this part of the site, especially during dry years.

Kooragang Island Bell Frog Survey 2016-2017

C1



C2



K114

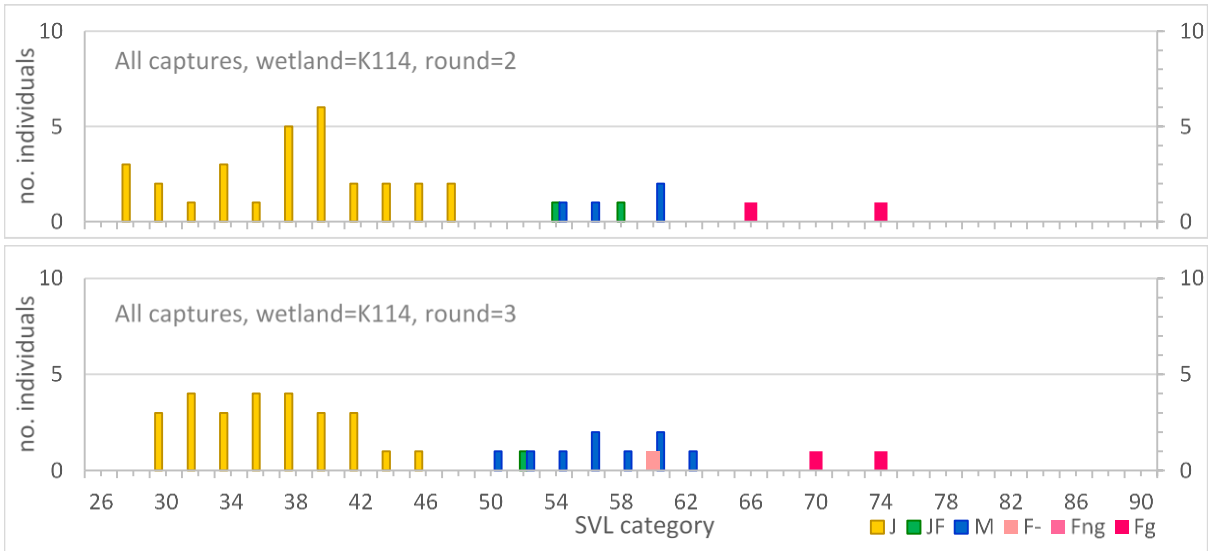


Figure 3.4.12: Frequency distributions for selected constructed wetlands. Refer to Fig., 3.4.6 for explanation of charts.

Constructed wetlands: There are six constructed wetlands within the T4 site. C1 and C2 (the ‘cluster wetlands’) are each groups of six plastic water tanks set into elevated ground with planted vegetation. They were constructed by PWCS specifically for the purpose of providing *L. aurea* habitat. C1 is located in the northern end of T4, close to K29, whilst C2 is located on the south side.

C1 has held large numbers (for its size) of *L. aurea* for a number of years; presumably, its proximity to other establish wetlands that contain bell frogs (K29, K103, K106C) allowed the frogs to disperse to it

readily. In contrast, when first constructed C2 was relatively isolated; it is close to K100W but that wetland has never held high numbers of bell frogs, and *L. aurea* have never been detected at C2 during VES (although one individual was seen during the day time in early summer 2015). However, the construction of four wetlands by HDC, following capping within the rail loop in 2015, has improved the connectivity of C2 and this season *L. aurea* were detected in all three survey rounds. Notably, the frogs detected included some large adult gravid females.

Of those HDC wetlands, K112 and K113 were dry for the whole 2016-17 season. The other two wetlands, K111 and K114, had large numbers (>100) of GBBF detected in the first two rounds, including large numbers of metamorphs and small juveniles. By the third round numbers at K111 were lower, but K114 still held >100 *L. aurea* (Fig. 3.4.2). For logistical reasons, most surveys at these wetlands this season were VES counts only, but captures were made at K114 in rounds 2 and 3. It is difficult to discern a progression of distinct cohorts between rounds 2 and 3; there appear to have been more than one breeding event at that wetland this season.

Although they are different designs, the cluster wetland and the HDC wetlands are both evidently successful designs with respect to providing *L. aurea* habitat (bell frogs were only absent from those wetlands lacking water).

3.5. Longitudinal data: persistence, growth, and movement

The best measures of how animals grow, how they move around the study site, and how long they live comes from repeated data collection from the same individuals over time. (This provides what is known as a longitudinal dataset, and it enabled by the use of PIT tags).

Persistence

Table 3.5.1: Summary of *L. aurea* marked in the Island-Wide Monitoring Program in the 2014-15, 2015-16, and 2016-17 seasons. The larger table shows the 62 individuals who were marked in at least 2 of these seasons. The data from the earliest year are shown as a single column; the two subsequent years are shown using one column per survey round.

PIT	2014-15	2015-16_1	2015-16_2	2016-17_1	2016-17_2	2016-17_3
999005005004401	5	0	1	0	1	0
999005005001330	1	0	0	1	0	0
999005005004465	2	0	0	2	0	0
999005005000282	0	0	0	2	1	0
999005005004458	0	0	0	2	0	0
0007633558	3	0	0	1	1	0
00076334C8	1	0	0	2	2	0
000763350F	1	0	0	1	0	0
0007633CA4	1	0	0	1	0	0
0007634238	1	0	0	1	0	0
0007635435	2	0	0	2	0	0
000763490E	4	0	0	2	0	0
956000003472226	1	0	0	0	1	0
0007633653	3	0	0	0	1	0
0007633BE7	1	1	0	0	1	0
000763490B	2	0	1	1	1	0
000763453D	1	0	2	2	1	0
0007634260	1	0	1	1	0	0
0007634312	1	0	1	2	0	0
0007633B1C	3	1	1	0	0	0
000763486A	1	1	0	0	0	0
0007635770	1	1	0	0	0	0
00076334CD	2	1	0	0	0	0
0007634B42	2	1	0	0	0	0
0007634B48	2	1	0	0	0	0
0007634F8B	2	1	0	0	0	0
00076334A8	1	0	2	0	0	0
000763369F	6	0	1	0	0	0
999005005004457	6	0	1	0	0	0
956000003457950	0	1	2	1	0	1
0007634053	0	1	2	2	0	0
956000003457072	0	1	1	2	0	0
956000003487863	0	1	1	0	1	0
0007633FFB	0	2	1	2	0	0
956000003449262	0	3	2	1	2	1
000763393E	0	1	0	1	0	2

PIT	2014-15	2015-16_1	2015-16_2	2016-17_1	2016-17_2	2016-17_3
956000003460875	0	1	0	0	1	1
000763370B	0	1	0	1	0	0
956000003438340	0	1	0	1	0	0
956000003439534	0	1	0	1	0	0
956000003453369	0	1	0	1	0	0
956000003452280	0	1	0	0	1	0
956000003486756	0	1	0	0	1	0
000763501C	0	2	0	2	0	0
956000003470835	0	2	0	0	1	0
956000003472431	0	3	0	1	2	0
0007633287	0	0	1	1	2	1
956000003491378	0	0	1	1	3	1
956000003486327	0	0	1	2	2	2
956000003456640	0	0	1	0	1	2
956000003439539	0	0	1	1	0	0
956000003439808	0	0	1	1	0	0
956000003455553	0	0	1	1	0	0
956000003460542	0	0	1	1	0	0
956000003468504	0	0	2	1	0	0
956000003486561	0	0	1	1	0	0
956000003490237	0	0	1	2	0	0
956000003443343	0	0	1	0	1	0
956000003470961	0	0	2	0	1	0
956000003446167	0	0	1	0	0	1
956000003469701	0	0	1	0	0	1
956000003488702	0	0	1	0	0	1

Marked animals (2014-15 to 2016-17)	
Time between first and most recent capture	<i>n</i>
3 seasons	17
1 < x < 2 seasons	44
1 round < x < 1 season	226
< 1 round	1833
Total	2120

Of the 2,120 frogs that have been PIT tagged in the three most recent survey seasons, only 17 animals were captured across those three years. A further 44 frogs have been captured in two consecutive years only, while 226 have been captured across different rounds within the same season only. 1833 have been recaptured within the same round only, or not at all.

Persistence of individuals at a given wetland site is a function of survivorship and dispersal. Given the apparent high levels of site fidelity in bell frogs (see next section), the low levels of persistence between years is likely to be due primarily to low levels of survivorship.

The timeframes linked to persistence shown here are an underestimate of actual age: these frogs would have been >40 mm SVL juveniles when first tagged, which means that they would have been at least 5 months old (and possibly older) at that time.

Although it appears that at least some females are first reaching reproductive capacity, (see Section 2.6.3 and Section 3.4), only a small proportion of animals survive to their second year.

Movement

Movement can occur at different spatial and temporal scales. It is likely that all bell frogs move between permanent wetland and neighbouring ephemeral wetlands as part of their normal reproductive behaviour; however, since the frogs are sampled principally at the permanent wetlands, we very rarely detect these movements. Furthermore, previous investigation has shown that these movements occur within days of large rainfall events and the frogs return to permanent sites when ephemeral wetlands begin to decline (Hamer et. al., 2008). Thus, if surveys do not coincide with heavy rainfall events these short-term movements are not detected.

Despite hundreds of recaptures between rounds within a survey season, and ~60 recaptures across seasons, only 6 instances of movement between wetlands have been detected in the 2014-2017 dataset (Figure 3.5.1). This implies a high level of site fidelity for bell frogs.

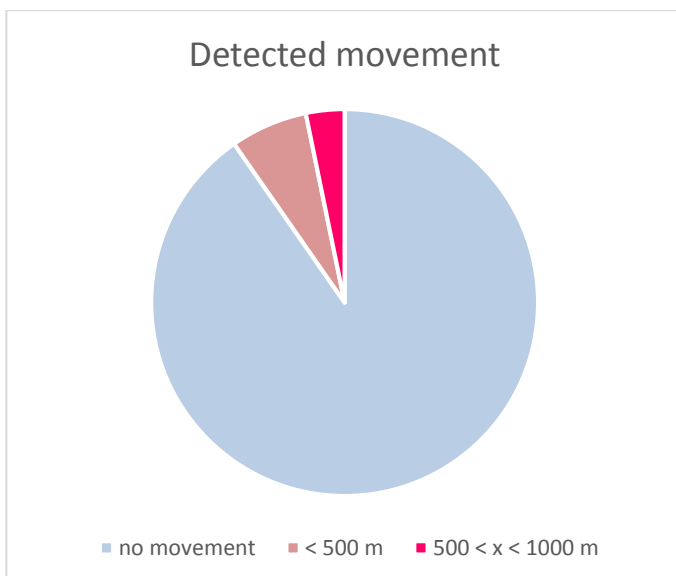


Figure 3.5.1: amount of movement detected for the 62 frogs that were recaptured across the three most recent survey years (i.e. 2014-15 to 2016-17). Only 6 movements between wetlands were detected. Overall, *L. aurea* shows a high level of philopatry.

Within the structure of the surveys that we do make, detectable movement falls into three categories:

1. Between seasons, between wetlands
2. Within seasons, between wetlands, between rounds
3. Within wetlands, within rounds (CMR surveys only)

Movement between wetlands, between years

Animal ID (PIT #)	Sex	Year of first capture	Starting point	Year of recapture	Destination	Distance
0007633CA4	M	2014-15	K103	2016-17	K22/23	520 m
000763393E	M	2015-16	K106C	2016-17	K29	110 m
956000003486327	F	2015-16	K115	2016-17	K104	690 m
956000003446167	F	2015-16	K29	2016-17	C1	120 m

Table 3.5.2: Detected movement between years

Although hundreds of bell frogs are marked with PIT tags each year, recaptures of animals between years are rare. In the three years from the 2014-15 season to the 2016-17 season, only 4 movements between wetlands having been detected following recapture of tagged individual frogs.

These four movements are of interest. Two involve movement around K29; given the (a) number of individuals captured at this wetland over the years, and (b) the large numbers of wetlands close to it, we might expect that if we are going to detect movement anywhere it will be in that area. The other two movements are across rail lines; one from K103, across the PWCS wetland, to K22/23, and the other from K115 under the NCIG dump station conveyor, all the way to K104 (this latter instance is the largest distance detected in this data).

Movement within seasons, between rounds, between wetlands

Animal ID (PIT #)	Sex	Round(s)	Starting point	Round(s)	Destination	Distance
0007A0A936	F	1	K29	3	C1	120 m
0007A0E85F	M	1, 2	K29	3	K35	300 m

Table 3.5.3: Detected movement between rounds in the 2016-17 survey season.

Both the within-season movements detected this year were around the K29 area; one involving an adult female moving to the (nearby) C1 wetland, and the other involving a male moving to the (slightly further away) K35 wetland. Both instances are consistent the range of movement we might expect for bell frogs within a season. It is possible the dry year increased the likelihood of frogs moving from one permanent wetland to another and thus of the movement being detected.



Figure 3.5.2: Movement of tagged frogs detected during the current season. Top; yellow arrows show movements of four individual frogs between years; i.e. from 2014-15 or 2015-16 and this year (see Table 3.5.2). Bottom: pink arrows show two movements detected between rounds within the 2016-17 season (Table 3.5.3). Detected movements involve frogs captured at K22/23, K29 or K104, as large numbers of frogs are captured and tagged at these wetlands during CMR surveys.

Movement within a wetland, within a round

Movement at this scale cannot be detected at most wetlands, as we do not routinely log the precise location of captured animals within night's survey at a wetland (this location is recorded, but only temporarily - i.e. flagging tape at capture point - so that animals can be released at the point of their capture). However, at K29 we had only one person consistently surveying the top of the bank, whilst others surveyed within the wetland. Since the top of the bank at K29 is a 'watershed' between K29 and surrounding wetlands - and is not suitable habitat for long-term persistence of *L. aurea* - we assume that frogs captured there are *en route* to a nearby wetland. By matching capture codes with recaptures, and helped by the very large number of captures at K29 this season, we can identify a number of animals that were captured and then recaptured either on their way into K29, or on their way out.

K29	Tagged frogs captured		Animals recaptured within round		
	On bank	In Wetland	Moving in	Moving out	Staying in wetland
1	17	271	6	0	78
2	28	240	6	3	61
3	41	98	-	10	22

Table 3.5.4: Detected movement within rounds at K29 in the 2016-17 survey season.

We expect that we might see differences in movement patterns at different times of the season. Given that K29 is an overwintering site, in a 'normal' year we might expect frogs to leave K29 in the early part of the season, breed in ephemeral wetlands nearby, and then return late in the season. Consistent with this, in the (very wet) 2015-16 breeding season K29 was almost devoid of bell frogs in January 2016, with some frogs starting to return during February - the large breeding event in the nearby K106 wetland likely involved frogs from K29.

2016-17 was an abnormal year, however. Low rain during early- and mid-summer meant that the ephemeral wetlands close to K29 (such as K106) were dry by October 2016 and did not recharge until significant rainfall in late March 2017. During this time, very high numbers of bell frogs remained at K29. By round 3 (February 2017), however, *L. aurea* numbers in K29 had started to decline. Moreover, and unlike earlier rounds, 10 frogs (3 males, 3 subadult females, and three adult females) were found to be leaving the wetland (i.e. caught first in the wetland, and then subsequently on the top of the surrounding bank). This is an appreciable proportion of the frogs that were recaptured during this round; it seems that, having waited through December and January for a significant rainfall event, the frogs were starting to move into the surrounding landscape towards the end of summer.

Kooragang Island Bell Frog Survey 2016-2017

Growth

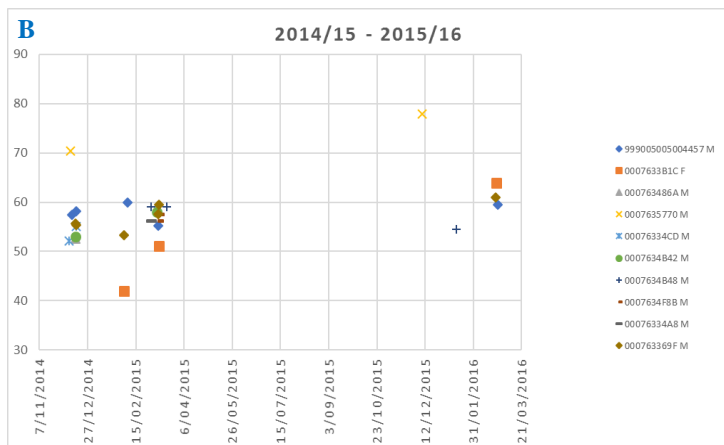
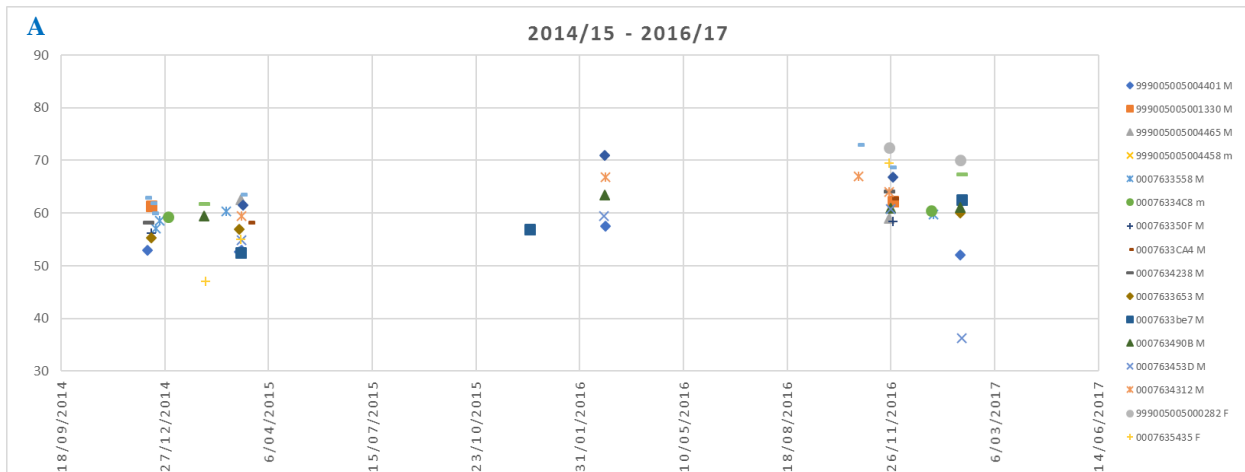
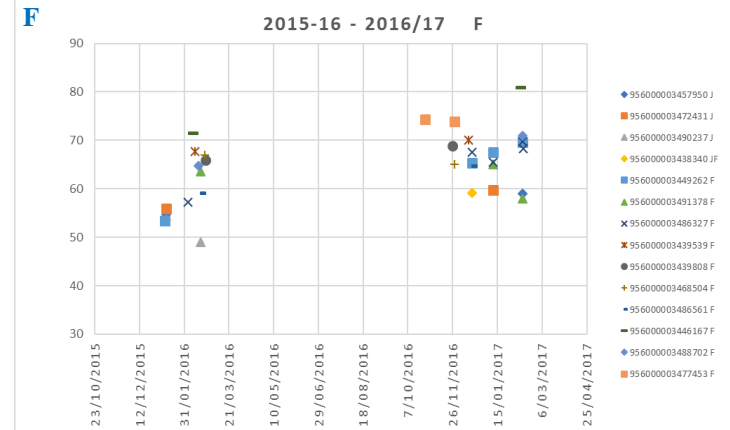
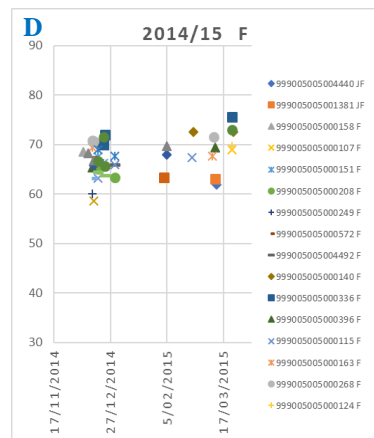
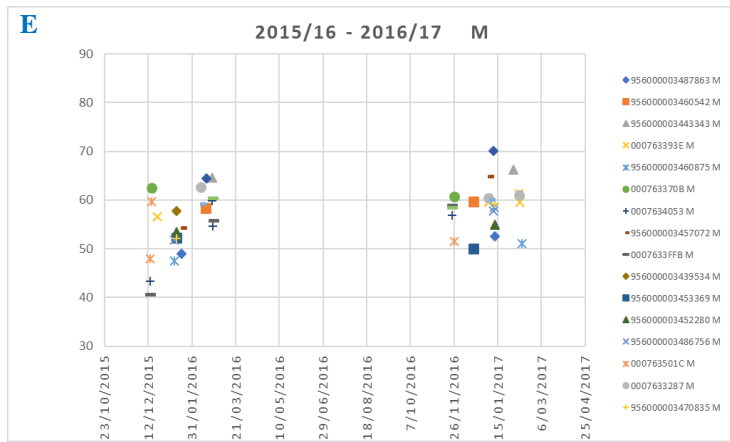
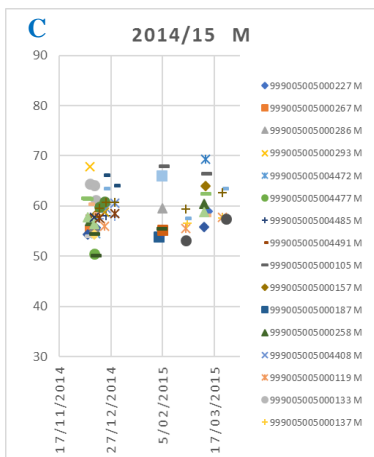


Figure 3.5.3: SVL for individual recaptured frogs, plotted against date of capture. Data are shown from three survey seasons: 2014/15, 2015/16, and 2016/17. A: frogs captured across all three seasons; B, frogs captured across the first two seasons; C, D – males and females captured in the 2014-15 season; E, F – males and females captured in the latter two seasons. Y-axis shows SVL (mm).



Data on growth can be visualised by individual animals (Figure 3.5.3), but pooled growth data can be analysed quantitatively (Figures 3.5.4, 3.5.5).

Growth across surveys seasons can be traced for 56 frogs (Figure 3.5.3 A, B, E, F) Figure 3.5.3 also shows a sample of within-season data for 32 frogs in the 2014-15 survey season (Figure 3.5.3 C, D).

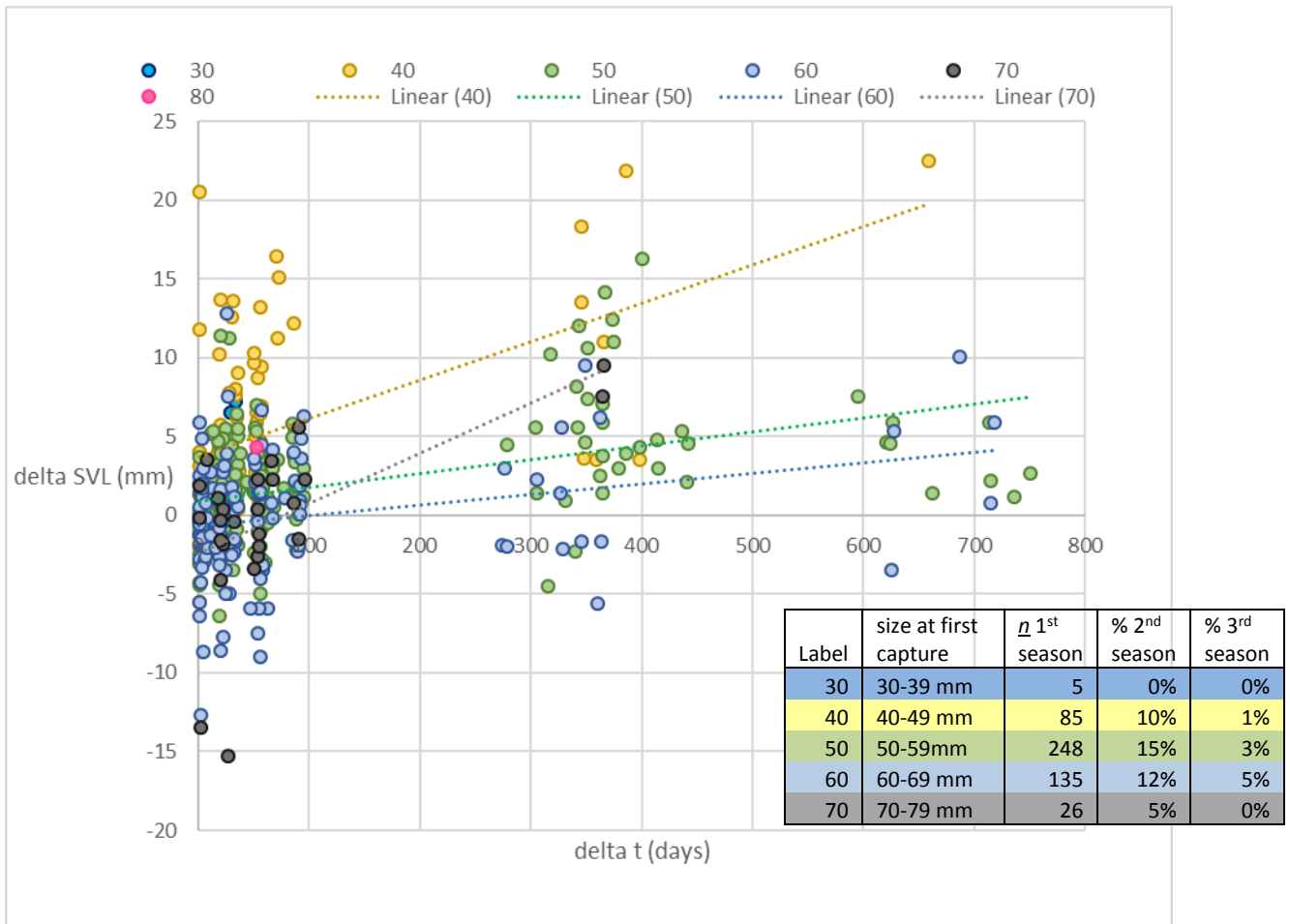


Figure 3.5.4: Pooled growth (delta SVL) plotted against time (delta t) since first capture. Data is grouped into series according to size at first capture: for example, series ‘40’ comprises frogs 40mm <= SVL < 50 mm. Frogs that were small at first capture showed more and faster growth at first capture. The wide scatter at the left side of the chart suggests a high degree of error in measuring SVL. Insert table shows number of frogs in each starting-size class in the first season of capture, and percentage persistence to subsequent survey seasons. Note linear regressions are shown for illustrative purposes only; these do not represent growth curves.

Pooled data shows that the degree and rate of growth is highest for animals first tagged at 40-49 mm SVL, as expected. The rate of growth is less for frogs that were first caught at 50-59 mm and 60-60 mm SVL, although the degree of growth detected is higher for the 50-59 mm group (again, as expected). Persistence to the next season is higher for these two size groups; animals that were < 50 mm or > 70 mm have lower persistence to the next season. This is a function of (1) higher mortality rates of smaller (i.e. younger) animals, and (2) higher mortality rates of larger (i.e. older) animals. This pattern is consistent with the low rates of between-season recaptures shown in Table 3.5.1.

Figure 3.5.4 also shows a wide scatter at the left side of the chart. This may indicate high levels of measurement error.

The same pooled growth data can be visualised by plotting the amount of growth (delta SVL) against size at first capture. Since the smaller animals shown grow more rapidly, this plot is expected to show a strongly negative relationship. Figure 3.5.5 shows that this pattern is consistent at within-season and between-season timescales.

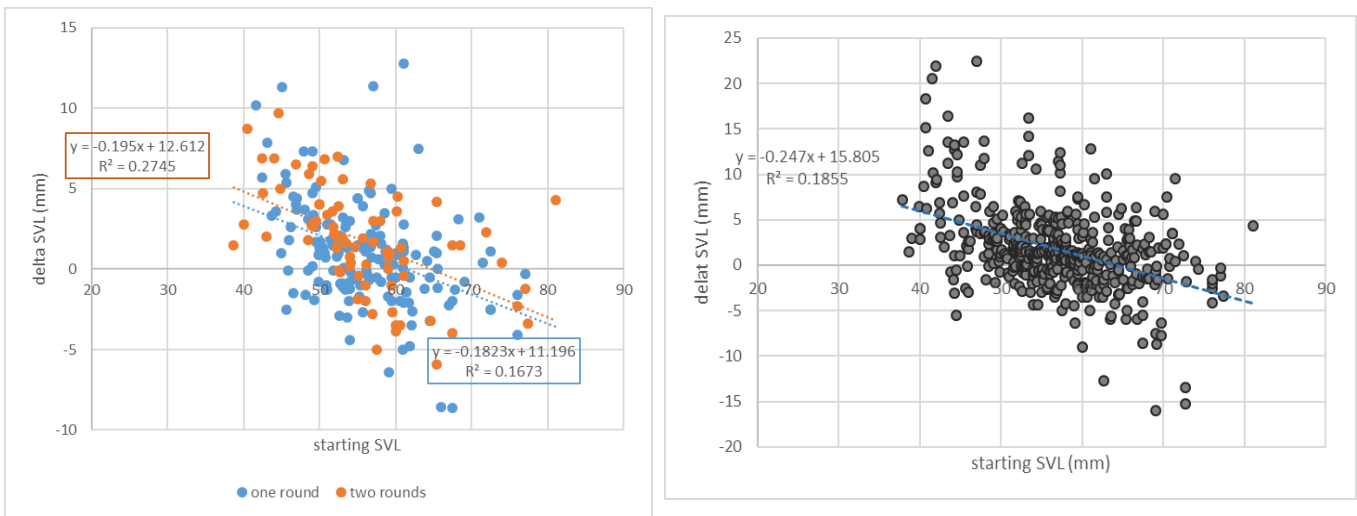


Figure 3.5.5: Pooled growth (delta SVL) plotted against SVL at first capture, for 2016-17 data (left) and all 2014-17 data (right). As expected, smaller animals grow more than larger animals. For the within-season data (left), where there were two rounds (45-60 days) in between recaptures, the amount of growth detected is consistently higher than if there is only one round (15-30 days).

3.6. Breeding and recruitment

Detections of *L. aurea* metamorphs and/or tadpoles constitutes direct evidence of successful breeding. During the 2016-17 survey seasons, tadpoles and metamorphs were detected at 8 wetlands, all of which were within or close to the T4 industrial site. Tadpoles were detected at 3 wetlands (K23, K63, C1), and metamorphs at 5 (K29, K104, K111, K114, K117) (Table 3.2.1, Figure 3.6.1).

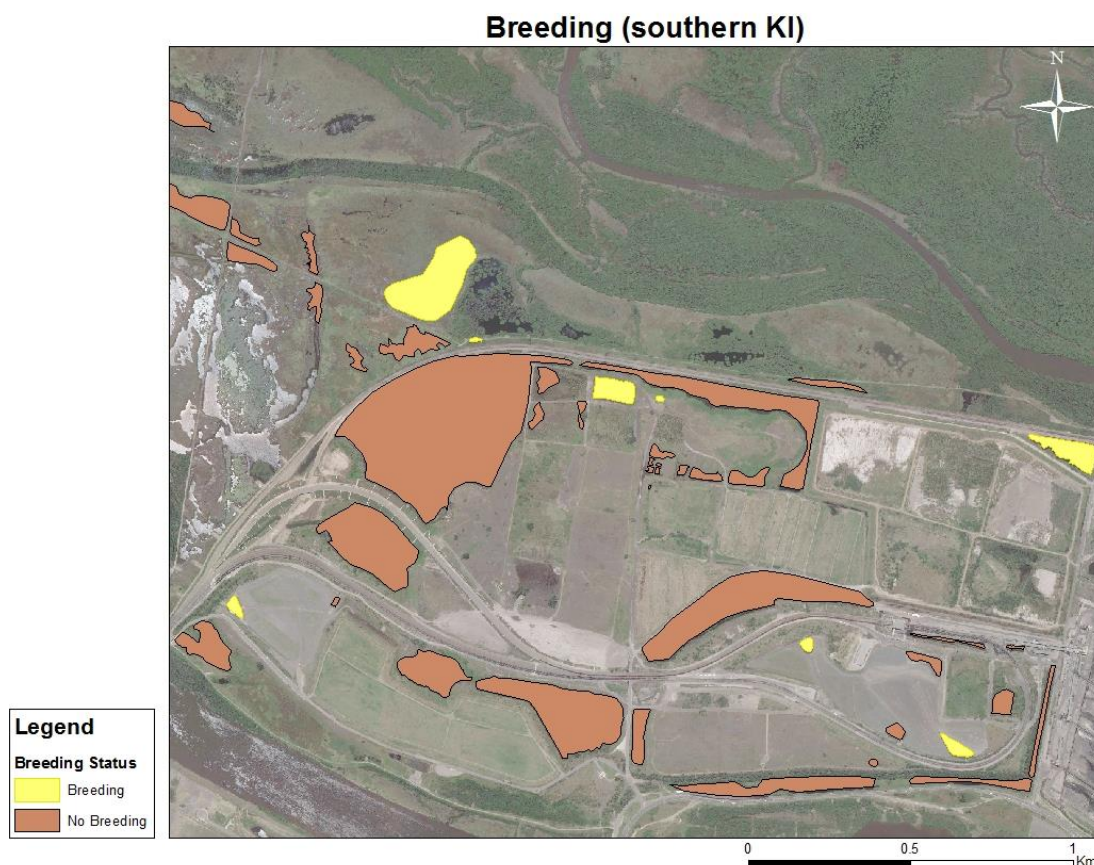


Figure 3.6.1: *L. aurea* breeding (i.e. detection of tadpoles and/or metamorphs) during the 2016-17 survey season.

Correlating breeding events with breeding behaviour and rainfall.

Metamorphosis in bell frogs is a relatively short stage of their life-cycle, and consistently occurs 4 to 7 weeks after eggs are laid. The detection of metamorphs therefore provides information on when a given cohort was laid.

Each instance of metamorph observation was preceded by a period of ~40 mm weekly rainfall total about 5 to 7 weeks' prior (Figure 3.6.2). These higher periods of rainfall (within a context of low rainfall across the whole season) were accompanied by *L. aurea* calls, which were generally heard up to 3 or 4 days after rain.

Kooragang Island Bell Frog Survey 2016-2017

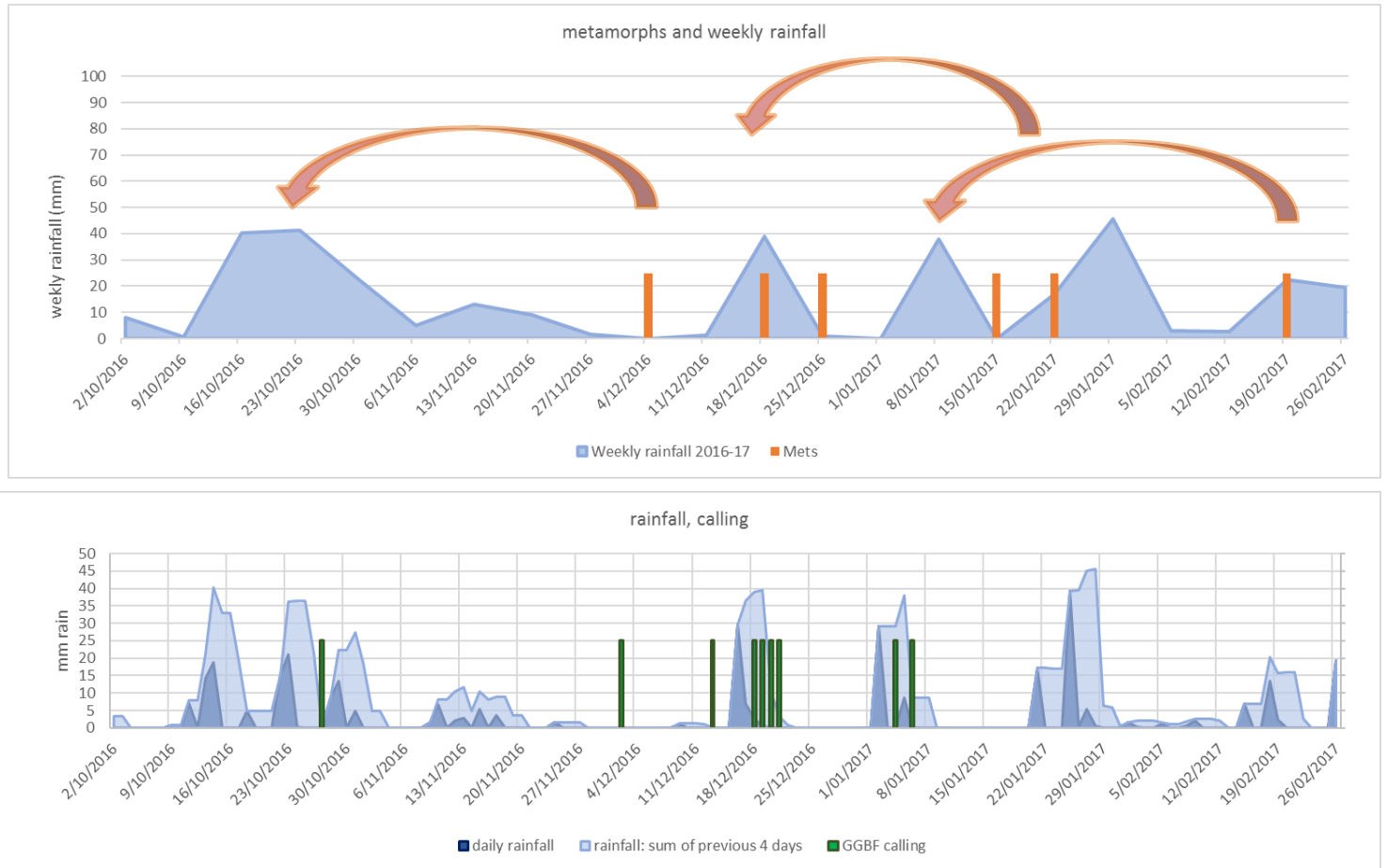


Figure 3.6.2: Observation of metamorphs (top) and nights where calling was heard (bottom), and correlation with rainfall.

In two instances, calling was heard at a wetland 4-7 weeks prior to metamorphs being observed at that same wetland (Table 3.6.1). In particular, the timing of rainfall, calling, and observation of metamorphs at K104 allows the cohort of juveniles tracked in the demographic analysis (Figure 3.4.7) at this wetland to be aged with some confidence.

Calling heard			Mets observed	
27/10/2016	K104	Chorusing	2/12/2016 K117 16/12/2016 K29 15/12/2016 K104 18/12/2016 K104 20/12/2016 K104	
2/12/2016	K117	Calling		
2/12/2016	K118	Calling		
2/12/2016	K49A	Calling		
13/12/2016	C1	Chorusing		
18/12/2016	K104	Calling		
19/12/2016	K29	Calling		
20/12/2016	K104	Calling		
21/12/2016	K111	Calling		
21/12/2016	K114	Calling		
4/01/2017	K29	Chorusing	16/01/2017 K114 15/02/2017 K111	
6/01/2017	K29	Calling		

Table 3.6.1: Instances of *L. aurea* calling and observation of metamorphs in the 2016-17 survey season.

3.7. Population size

Population estimate of wetlands surveyed using Capture-Mark-Recapture

Capture-Mark-Recapture (CMR) surveys were conducted at 3 wetlands; K22/23, K29, and K104.

		Round 1		
Wetland	Dates	no. surveys	<i>L. aurea</i> captured	Final recap. rate (%)
K22/23	24-28 Nov 2016	3	214	39%
K29	14-19 Dec 2016	3	461	34%
K104	15-22 Dec 2016	3	129	41%

		Round 2		
Wetland	Dates	no. surveys	<i>L. aurea</i> captured	Final recap. rate (%)
K22/23	1-2 Feb 2016	2	110	8%
K29	4-8 Jan 2017	3	361	42%
K104	10-12 Jan 2017	3	203	42%

		Round 3		
Wetland	Dates	no. surveys	<i>L. aurea</i> captured	Final recap. rate (%)
K22/23	-	-	-	-
K29	8-10 Feb 207	3	224	27%
K104	12-14 Feb 2017	3	125	50%

Table 3.3.2: Surveys, captures, and recapture rates at the three sites where CMR surveys were conducted. Note the high numbers of captures in the first round, especially at K29.

Each session of CMR surveys within a round includes several surveys, if possible made on consecutive nights to minimise immigration/emigration. The very high numbers of captures (up to 201 in a single night at K29) mean that during the first round, animals were processed the next day and then released the night following capture. In these cases, the next survey was done the night following release. During the second and third rounds most animals had already been tagged, making it feasible to process and release on the same night as capture.

Each round of CMR survey was counted as complete when the within-round recapture rate >20% (i.e. when, on a given survey night, at least 20% of the animals captured had already been captured in that round). Note this not the same as 20% of animals being 'recaptures', i.e. animals that have previously been captured at some point in their lives. The information provided by a CMR survey round is maximised if there are at least 3 survey nights within the round.

The results of the CMR surveys were analysed by Robust modelling using the program MARK (Table 3.3.3).

Rank	Model	AIC _c	ΔAIC _c	weight (w)	Model likelihood	No. of parameters
K22-23						
#1	$\phi, G''=0 p(.) c(\text{ses}) f0(.)$	-1204.10	0.00	0.34	1.00	6
#2	$\phi, G''=0 p(.) c(\text{ses}) f0(t)$	-1203.34	0.77	0.23	0.68	7
#3	$\phi, G''=0 p(\text{ses}) c(\text{ses}) f0(.)$	-1202.73	1.37	0.17	0.50	7
#4	$\phi, G''=0 p(\text{ses}) c(\text{ses}) f0(t)$	-1202.28	1.82	0.14	0.40	8
#5	$\phi, G''=0 p(t^*\text{ses}) c(t) f0(t)$	-1200.35	3.75	0.05	0.15	11
K29						
#1	$\phi(t) G'=G''=0 p(t) c(.) f0(t)$	-3447.52	0.00	1	1	9
#2	$\phi(t) G'=G''=0 p(.) c(.) f0(t)$	-3400.51	47.01	0	0	7
#3	$\phi(t) G'=G''=0 p(.) c(t) f0(t)$	-3398.50	49.01	0	0	8
#4	$\phi(t) G'=G''=0 p(.) c(\text{ses}) f0(t)$	-3397.93	49.59	0	0	9
#5	$\phi(t) G'=G''(.) p(.) c(t) f0(t)$	-3396.46	51.06	0	0	9
K104						
#1	$\phi(t) G'=G''=(.) p=c(t) f0(t)$	-684.18	0.00	0.32	1.00	9
#2	$\phi(t) G'=G''=0 p=c(t) f0(t)$	-683.45	0.73	0.22	0.69	9
#3	$\phi(t) G'=G''=0 p=c(t) f0(.)$	-682.12	2.06	0.12	0.37	7
#4	$\phi(t) G'=G''=(t) p=c(t) f0(t)$	-682.06	2.12	0.11	0.35	10
#5	$\phi(t) G'=G''=0 p=c(.) f0(t)$	-680.79	3.40	0.06	0.18	7

Table 3.3.3: Candidate set of models, ranked by ascending ΔAIC_c, used to estimate apparent survival probability (φ), capture (p) /recapture (c) probability, and number of uncaptured individuals in each wetland population (f0) of green and golden bell frogs at the CMR sites on Kooringang Island, 2016-17. In most models, net immigration/emigration (G', G'') was set to zero. (.) indicates that the value of a parameter was constant, (t) that it varied with time, and (sess) that it varied between between primary sessions but was fixed for secondary sessions within each primary session.

Selecting the best ranked model for each CMR site allowed estimates of total population size for each site, in each round (Table 3.3.4)

	1 st Primary Session (round 1)				2 nd Primary Session (round 2)				3 rd Primary Session (round 3)		
Wetland model #	N-hat (pop. size)	95% confidence levels		S	N-hat (pop. size)	95% confidence levels		S	N-hat (pop. size)	95% confidence levels	
		Lower	Upper			Lower	Upper			Lower	Upper
K22/23											
#1	229	193	302	0.28	176	140	302	-			
K29											
#1	662	547	848	0.88	440	362	568	0.86	270	221	353
K104											
#1	150	123	193	0.94	223	185	281	0.85	142	116	184

Table 3.3.4: Population estimates for the wetlands surveyed using Capture-Mark-Recapture, analysed by Robust Modelling. Results from the best models as ranked by AICc scores (c.f. Table 3.1) are presented. N-hat values are population estimates for each wetland, listed by each model for each round. The range of the 95% confidence levels is reasonably narrow for all population estimates. ‘S’ indicates survival probability between rounds (per week).

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

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. Using the CMR surveys as a benchmark, we can create a conversion factor ($1/\langle \text{proportion detected} \rangle$) 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 3.3.5)

Wetland	Conversion factor (VES_detected -> population_estimate)				
	min-lower	mean-lower	mean-N-hat	mean-upper	max-upper
K22-23	3.2	5.0	6.1	8.6	10.0
K29	3.2	6.9	8.4	10.8	24.4
K104	2.6	3.8	4.6	5.9	8.0

Table 3.3.5: Conversion factors (calculated as $\langle \text{population estimate/number detected in VES} \rangle$) for the three CMR wetlands. ‘min’, ‘mean’, and ‘max’ relate to the minimum, mean, and maximum values for that ratio respectively, as a result of different VES counts at each wetland during each round. ‘lower’, ‘N-hat’, and ‘upper’ relate to the range of population estimates calculated for each wetland 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).

There is some uncertainty as to the precise value of that conversion factor; this uncertainty has two dimensions. The first stems from the fact that we conduct several VES surveys at each CMR wetland during each round (typically, one primary VES and two secondary VES), we have several different values for animals detected during VES for each estimate of population at that wetland. This leads to a range of ratios at each wetland, for each round; from these we calculate the minimum, the mean, and the maximum value for that ratio.

The second dimension of this uncertainty results from the range of estimates for the population estimate at each of the CMR surveyed wetlands. The robust modelling provides a preferred value ('N-hat', and also lower and upper 95% confidence intervals. Combining the min, mean, and max values for the detected/population ratio with these different estimates of CMR population size provides a range of values for the conversion factor. We use 5 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> ratio, 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.

It is important to note that, although using this range of estimates decreases precision of the final population estimate, it increases accuracy of that estimate. Precision could be increased by only using a single ratio of detection/population size (for example, by only running one VES survey during the survey period at a CMR wetland), but that single value may very easily not represent the typical situation at that wetland (for example, a VES on a warm windless night just after rain will probably detect a very high proportion of the frogs present at that wetland, giving an unusually low value for the ratio of animals detected/actual population). The resulting population estimate would have a smaller range of values (giving the illusion of precision), but is less likely to be accurate.

The range of values for conversion factors are then used to generate estimates of population size at the 69 wetlands that were surveyed only by VES. Given that the three CMR wetlands have different physical characteristics, we used the conversion factor from the most appropriate CMR sites for each of those 69 wetlands. Where the wetland was small with a wide perimeter of vegetation we used the conversion factors for K22/23 (as this wetland has those characteristics). Where the wetland was larger, open, with a narrower perimeter of vegetation, we used K104 as the model for conversion factor. Because K29 was somewhat unique this year (with such a large population), we did not use it as a model for any other wetlands.

The population estimate was also restricted to animals >40 mm SVL, i.e. not including tadpoles, and small juveniles.

The last 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. The final table of estimates, incorporating the conversion factors and those area weightings, is shown in **Appendix X**. The total population for the 69 wetlands are shown in [Table 3.3.6](#).

	min-lower	mean-lower	mean-N-hat	mean-upper	max-upper
Round 1	857	1270	1539	2024	2629
Round 2	703	1057	1279	1724	2160
Round 3	799	1187	1438	1914	2438

Table 3.3.6: Population estimates for 69 VES wetlands, based on the ratio of VES(detected): CMR(population) at the CMR survey sites. See text for explanation.

The population estimates for the 3 CMR sites (which between them incorporate 4 wetlands) are summed ([Table 3.3.7](#)).

	lower	N-hat	upper
Round 1	863	1041	1343
Round 2	687	839	1151
Round 3	482	594	850

Table 3.3.7: Total population estimates for CMR surveyed wetlands, for each round

Combining the estimates for the VES and CMR surveyed wetlands provides a range of estimates for the actual population size across all 73 wetlands surveyed on Kooragang Island over the 2016-2017 season ([Table 3.3.8](#)).

	min-lower	mean-lower	mean-N-hat	mean-upper	max-upper
Round 1	1720	2133	2580	3367	3972
Round 2	1390	1744	2118	2875	3311
Round 3	1281	1669	2032	2764	3288

Table 3.3.8: Estimates of total population size across all surveyed wetlands. See text for discussion.

These estimates should be interpreted as follows:

- It is **highly likely** that the population of *L. aurea* at the 73 surveyed wetlands was between the ‘min-lower’ and ‘max-upper’ limits (i.e. between 1,720 and 3,972 in December 2016).
- It is **probable** that the population was between the ‘mean-lower’ and the ‘mean-upper’ figures (i.e. between 2,133 and 3,367 in December 2016)
- The best guess for the **approximate** population is the ‘mean-N-hat’ figure, i.e. 2,580 in December 2016.

It is not correct to say that that the population was 2,580 in round 1; rather, the population was **approximately** 2,580.

4. Discussion

4.1 Analysis of Historical Findings

Historical data: Estimated and effective population size

Total population estimates for *L. aurea* on Kooragang Island have been relatively constant over the past seven years, fluctuating between 834 (2012/13) and 2964 individuals (2014/15). The distribution of *L. aurea* within the Kooragang Island Management Zone is also largely consistent, with specific groups of wetlands showing high occupancy levels whilst others rarely support frogs. These results imply a stable population within the Management Zone. However, absolute population size and distribution do not tell the full story on their own. Indeed, they can be quite misleading when considered in isolation. Equally important to the population's viability is its demography. Population demography breaks down total abundance into classes such as age and gender, providing specific insights into the stages of the life cycle where mortality occurs. Such analysis is particularly critical for frogs given the two separate phases in their life cycle: the aquatic embryo and tadpole stages, and the terrestrial juvenile and adult stages. Only the adult life-stage is capable of breeding, and as in most frog species, the number adult females is particularly critical for the persistence of the local population of *L. aurea*.

Adult females are, by definition, old enough to reproduce and thus contribute to recruitment within a population. Historically, adult females have made up as little as 2% of the total *L. aurea* on Kooragang Island. Thus, in the Kooragang Island Management Zone, the annual production of eggs which lead to tadpoles and new juveniles is based on as few as 20 to 50 adult females which have reached their second year of life. Up to 80% of the population is made up of first year frogs - juvenile males and females - indicating that the population experiences rapid turnover. This turnover is not as drastic as observed in species which are truly 'annual', whereby no adults are older than one year of age. Nevertheless, it is troubling for the same reasons. The critical issue for 'annual' populations is that if reproductive efforts fail for a single year, the entire population is likely to disappear. In the case of *L. aurea* there are certainly a small number of individuals re-caught from year to year, indicating that adults may be reproductively active for several seasons. Nevertheless, a series of poor breeding years - perhaps due to unfavourable climate conditions - could have a significant impact on total population size and distribution. So why is it that the Kooragang Island population has so few reproductive females and such a high turnover rate?

The most likely answer is that the amphibian disease chytridiomycosis increases mortality to the extent that the chances of an individual frog - male or female - surviving more than one year is extremely low. *Litoria aurea* is known to be highly susceptible to chytridiomycosis and the disease is widespread on Kooragang Island (Stockwell, 2013). Local density of the disease causing Chytrid fungus is maintained by co-occurring frog species which are less susceptible to chytridiomycosis and thus act as carriers for the disease. As a result, few females reach reproductive age which occurs in their second season (18 to 24 months after metamorphosing). Impacts of the disease are not limited to females, but since males reach reproductive maturity in their first year (10 to 12 months) there are more males of reproductive age.

The age class structure of *L. aurea* on Kooragang Island is not the natural situation for this species. Comparison of the age-class demography of the *L. aurea* population on Kooragang Island population against that on Broughton Island reveals that the number of adults as a proportion of the total population on Broughton Island is an order of magnitude higher. Furthermore, there are females that are up to five

years of age in the Broughton population (Campbell et al. 2015). The primary difference between the two populations is that the Chytrid fungus does not occur on Broughton Island (Stockwell et al. 2015b), and the absence of this disease dramatically improves the rate of survivorship. Frogs live longer, and their greater reproductive output leads to a higher density of *L. aurea* in suitable wetlands.

Historical data: Implications for population stability

Given the harmful impacts of the Chytrid fungus, it is interesting to consider how *L. aurea* has managed to persist within the Kooragang Island Management Zone; especially given the loss of the species throughout most of its historical habitat (Mahony et al., 2013). We postulate that there is some form of habitat or environmental facilitation that occurs on Kooragang Island which swings the balance slightly in favour of the frog. Understanding how that habitat facilitation operates is thus the key to maintaining the population and strengthening its resilience. This annual island wide monitoring investigation provides a critical view of the habitats that are used, the sites where successful breeding and recruitment occur, and the favoured wetlands used for foraging and sheltering by adults. Landscape features such as habitat connection and diversity clearly play a significant role in ongoing survival. Recent studies have also confirmed the advantages of slightly saline water chemistry in providing an environmental refuge from the Chytrid fungus (Stockwell et al., 2015b).

Viewed through the prism of population demography the Kooragang Island *L. aurea* population is still in a tenuous situation, with few females reaching reproductive maturity; though an increase in the proportion of females achieving breeding size for this latest survey season is a step in the right direction. Until more effective means to mitigate the impact of disease are discovered, the most effective landscape strategy is to enhance the resilience of the population by managing other factors that limit survivorship during *L. aurea*'s life cycle. There are factors that can be managed. Construction of permanent freshwater wetlands, connectivity among wetlands and the strategic placement of permanent and ephemeral wetlands, and a mixture of fresh and saline influences in ephemeral wetlands, provide the most effective means to enhance the necessary habitat features for *L. aurea*. Limiting mortality in the larval stage by managing the invasive fish *Gambusia* is another.

4.2 Survey Counts and Population Estimate

The mean population estimate for the most recent 2016-17 breeding season was highest during the first survey round in December, with an estimate of approximately 2,580 individuals. Estimates decreased modestly over consecutive survey rounds with an estimate of 2,032 individuals for the third survey period in February. This marginal population decrease of roughly 20% throughout the season may be attributable to mortality, but could equally be a result of background variability in detection probability, perhaps from more adults seeking refuge as the drying of wetlands progressed.

It is also important when interpreting these population estimates to note that they only include *L. aurea* individuals greater than 40mm snout vent length only. Historically, we have determined that leaving out metamorphs and small juveniles gives much more realistic population estimates. This is because of a single female *L. aurea* may lay several thousand eggs at a time, temporally 'doubling' the number of individuals within the Kooragang Island management zone. It is unrealistic to include all these offspring, as the overwhelming majority do not survive to adult-hood.

Care must also be taken when directly comparing population estimates from year to year, as inter-seasonal differences in detection probability, surveyed wetlands and environmental conditions cannot be entirely accounted for in the estimation procedure. To limit this effect, we model population estimates on three separate occasions and for three wetlands that are for most part independent sampling units. Nevertheless, this season's results are consistent with the last six years' findings, with historical population estimates having ranged from circa 800 to 3000 individuals. Only the 2014-15 season had a higher estimated number of individuals, and by this and other metrics discussed below, this has been a positive season for Kooragang Island's *L. aurea* population.

When considering all seven year's populations estimates in conjunction, it is clear that despite modest fluctuations between seasons, the Kooragang Island Population remains stable, albeit at a relatively low number of reproductive adult individuals.

4.3 Environmental and landscape factors

Implications of poor rainfall for recruitment

Comparison of this year's rainfall data against the same period last year (Figure 3.2.1) shows a significant lower seasonal total rainfall. Also evident in this comparison is an absence of large rainfall events or 'pulses' in the most recent 2016-17 season. This lack of significant rainfall is likely to have negatively impacted breeding and recruitment within the Kooragang *L. aurea* population. Whilst evidence of breeding was observed in eight wetlands this year, the absolute number of offspring was lower when compared against last year's data. Given the exceptionally low survivorship of tadpoles to adulthood, this is an important distinction. It is interesting to postulate whether a single and concentrated, 'en-masse' breeding event (as observed following flooding in 2015-16) is preferential to several smaller, temporally spaced recruitments (as witnessed with this season's consistently low rainfall). The pattern is further complicated by the differences in wetlands where breeding can occur in a dry season, which are mostly permanent wetlands, compared to those where breeding occurs in a wet season, which are mostly ephemeral wetlands. Analysis of next season's demographics will provide an opportunity to analyse this postulate, with last year's abnormally wet breeding season juxtaposed against this year's abnormally dry one.

Given that absolute population estimate for this year was very robust, paradoxically, the drying out of almost half of wetlands surveyed last year (33 of 78) may be advantageous for recruitment in future years; provided we do not witness a second year of low rainfall. Firstly, as many as half of the island's wetlands will be free of *Gambusia*. This will mean that the early autumn rains of 2017 (outside the period of the island wide monitoring) should have occurred in wetlands with no or very low densities of *Gambusia*, and we would expect that this should be reflected in the number of juveniles in spring 2017. It may be that tadpoles have overwintered in intermediate wetlands (dried in January and February of 2017), but recharged in the autumn rainfall (March and April 2017), and there will be metamorphosing frogs in the spring of 2017 (September). Secondly, the drying of wetlands will also clear many of them of the Chytrid fungus. Where enough soil moisture remains to allow persistence of adult's over-winter, many may do so without the added pressure of chytridiomycosis, thus emerging in better fitness for next year's breeding season. Nevertheless, it is likely that co-occurring species such as *Litoria fallax* (which have a higher disease threshold for the chytrid fungus) may reintroduce the fungus next summer. Finally, previous

survey results have indicated that 'edge' vegetation surrounding a partially clear water body is preferential to a wetland fully covered with emergent plants for *L. aurea*. A prolonged dry season may help naturally clear emergent vegetation, leaving more open water-bodies and improving habitat.

The drying of 33 surveyed wetlands this season also presents an opportunity to assess how rapidly, and by what means *Gambusia* re-invades local wetlands. Through targeted surveys at the beginning of the approaching season, it will be possible to investigate the seasonal timing of reinvasion, and its connection with rainfall events.

Island-wide Hydrology

Comparison of hydrology across the three regions of the Kooragang Island Management Zone shows significant differences in wetland ephemerality. Wetlands in the Central Region are significantly more ephemeral, with only four of the eighteen wetlands holding water reliably. Ephemerality is also common in Northern Region wetlands, though the creation of compensatory habitat in this region (BHP compensatory wetlands) has helped improve water availability in dry periods. The more permanent wetlands, such as K23 clearly provide refuge to the regional population during marginal rainfall periods. Nevertheless, the poor rainfall this breeding season in conjunction with capture results has highlighted that breeding and recruitment in the Central and Northern Region is contingent upon significant rainfall. In high rainfall breeding seasons, highly ephemeral wetlands and adjacent grass floodplains provide ideal, nutrient rich and *Gambusia* free breeding habitat. This could lead to a robust recruitment event as observed in K9C in the 2015-16 season. Conversely, years of poor rainfall, like the most recent season, restrict the options and *L. aurea* may breed in sub-optimal habitat with high *Gambusia* infestation and poor water quality. Thus, the Central Island population is more sensitive to rainfall, and could be at considerable risk from consecutive years without flooding. It is the large distance which separates permanent wetlands in the Central Region that appears to make the population volatile from season to season.

From a theoretical perspective there should be no differences in female reproductive output from year to year given the assumption that nutrition remains the same. Adult females provision eggs during the winter and spring period, and therefore females should be capable of producing a full clutch when habitat conditions are appropriate and a weather trigger occurs. If a suitable weather trigger does not occur early in the breeding season, the females presumably do not lay their eggs. However, there will be a time when they deposit eggs without the necessary trigger. In this case, it may be into a habitat that is not preferred, such as permanent wetland with fish, which is better than not producing a clutch at all. In the breeding season of 2016-17 the lack of significant rainfall over three months meant that adult females had only the choice of permanent wetlands for breeding. A large rainfall event occurred in March of 2017 after the period of surveys and it is likely that many females chose to breed in ephemeral wetlands at this time.

Importance of emergent vegetation; including *Juncus acutus*

Vegetation is an important landscape feature for *L. aurea*, with adult frogs typically found perched on tall emergents (Table 3.2.4). Whilst native *Typha* and *Phragmites sp.* are the most commonly used vegetation, our results indicate that the invasive species *Juncus acutus* - abundant within the Kooragang Island Management Zone - is also commonly used by *L. aurea*. Indeed, while *J. acutus* was very slightly

less important than *Phragmites sp.* in this data set (88 versus 89 respective encounters), given the difficulty of searching for frogs amongst this sharp and dense vegetation, it is likely that our results underestimate the importance of *J. acutus* as a micro-habitat.

Given its invasive status, it might seem on face value removal of dense *Juncus acutus* from wetlands is a positive methodology for encouraging growth of native vegetation; we would recommend such activity proceed with caution, and only in a staged manner so that replacement vegetation has an opportunity to develop. Removal of vegetation, especially during the over-wintering season, could not only directly harm *L. aurea* if done through mechanical means, but may also leave local populations without a critical refuge whilst they are not active enough to find alternative shelter. Furthermore, whilst native vegetation may colonise cleared regions within a few years, the speed of colonisation may not be rapid enough to support a stable population; especially where *L. aurea* are already dealing with chronic disturbances including *Gambusia* infestation and *chytridiomycosis*. At the very least, removal projects should aim to replace *J. acutus* with native *Juncus sp.*, and furthermore, monitor this new vegetation to ensure it is establishing successfully.

Influence of rainfall seasonality on development rate

Results indicate that the development rate of *L. aurea* offspring from eggs to juveniles is flexible, and can vary contingent upon the timing of the initial breeding event. Rain events early in the breeding season (spring), can result in rapid growth and development of tadpoles, which metamorphose as early as December, and grow to adult size by March; an entire life cycle for males in a single breeding season. This style of rapid development is what we observed in early in the 2016-17 season. A middle case is observed for mid-summer rains (as observed in last year's 2015-16 breeding season) with offspring metamorphosing by February, but over-wintering as juveniles rather than adults; thus, individuals take more than one breeding season to make it to adulthood. Conversely, late season breeding (e.g. autumn rains) may lead to offspring which over-winter as tadpoles, and do not metamorphose until temperatures warm up the following spring, and as a consequence are juveniles though the summer with males reaching maturity late in the breeding season (autumn).

The capacity of tadpoles to alter growth rate in response to environmental conditions is well established (Denver, 1997). However, there is limited empirical evidence of this occurring in wild *L. aurea*. The implications of different growth rates for survival of offspring is interesting to consider. Research has demonstrated that whilst rapid development and metamorphosis may aid tadpoles in escaping aquatic predators and reaching adult-hood more quickly, there are negative trade-offs in terms of survivorship and reproductive fitness (Smith, 1987, Denver, 1997). Essentially, slower development and more time spent in the aquatic tadpole stage allows frogs to metamorphose at a larger size, and with greater fat reserves. These two factors make individuals more resistant to environmental stressors, such as disease, and leave more surplus energy for reproduction (Smith, 1987). Furthermore, tadpoles are not susceptible to *chytridiomycosis* and as the disease is most threatening in colder environments, overwintering as a tadpole could greatly enhance survivorship for *L. aurea* individuals. Of course, an entire winter spent as a tadpole does have its risks, especially when extended dry spells as witnessed this year may cause wetlands to dry up. Tadpoles may also need to avoid predation by *Gambusia* if this invasive species is present. Thus, there is no right or wrong time for *L. aurea* to be breeding, but clearly, reproductive effort spaced out across multiple times within a season is likely to improve the odds of offspring surviving to themselves become reproductively active.

4.4 Distribution and spatial patterns

Changes in Island-Wide and regional distribution

Comparison of this year's island-wide distribution against last season's survey results reveals several major differences. Significant inter-seasonal variation in which wetlands are most occupied indicates the importance of considering historical data from repeat surveys to ascertain which wetlands are most critical to the Kooragang Island *L. aurea* population. Our results from seven years of repeated surveys clearly show that even very significant wetlands can be underused for one or more years, yet still be of high conservation value. This highlights the importance of a diverse, and large array of wetlands in supporting the survival of management populations in perpetuity. Major distributional changes relative to last year's findings are summarized below:

- K104 was less prominent in population counts this year as compared to last year's results. In the 2015-16 season, almost half the animals encountered were found in K104; this year that figure has reduced to ~10%. This wetland gradually reduced in size during this current season's extended dry period until it almost dried completely. It is likely that adults dispersed away to more permanent wetlands such as K29 and K103, however it is not clear when this may have occurred, since any dispersal would present a significant risk for individuals. It is also possible that recruitment from the adults occupying this wetland was negligible in 2015-16, since we observed dispersal of *Gambusia* to the surrounding ephemeral wetlands (of the type used for breeding) during the heavy rainfall events in that summer.
- Occupancy shifted west along the Northern Rail Corridor, moving from K104 towards K105 and K29 which are more permanent water bodies. Most of this season's detections were made in the two aforementioned wetlands and surrounding water bodies (those wetlands within 100 linear metres).
 - This 'shift' in distribution has also contributed to a spike in occurrence in the K30 complex wetlands which are roughly 100m south-east of K29. These wetlands were mostly devoid of detections in the 2015-16 season.
- K108 (the rail loop wetland) was found to have low occupancy in the 2016-17 season, which is consistent with last year's results, but in contrast to its historical importance to the islands population. To our knowledge 2016-17 was the first season that this wetland has been dry for most of spring and summer. Perhaps a year without water may result in a reduction in the coverage of emergent vegetation which is at greater than 90%. Another advantage of the drying is that the population of *Gambusia* in this wetland may be eliminated.
 - It is likely that the majority of *L. aurea* detected in the HDC capping wetlands (K111-K114) this year are colonizers which originally resided in K108. Thus, given that K108 dried up entirely for the first time in summer surveys, the timing of constructions of these wetlands likely helped to prevent a major regional population reduction.
- The HDC capping wetlands (K111-K114) within the NCIG rail loop are effective *L. aurea* habitat and have increased their carrying capacity substantially since last year. Since the wetlands are

only recently completed (constructed in 2015), they have not yet developed dense, mature stands of emergent vegetation. Nonetheless, *L. aurea* occupy them and they have been used for breeding (McHenry et al., 2016). This year's evidence adds to the proposition that ecologically they are an early colonising or early successional species (Pyke and White 2008).

Life history strategy: high dispersal capacity and/or philopatry?

Typically, early colonising species have a high reproductive output, good dispersal capacity and show phenotypic plasticity. These general features are shown by *L. aurea* – females produce large egg clutches relative to many of their relatives among the Australian tree frogs; the capacity for adult and juveniles to move across terrestrial habitats and among wetlands has been amply demonstrated on Kooragang Island; and there is often low competition and few established predators in early successional habitat. There are ecological trade-offs for being a colonising and opportunistic species; often when habitats are stabilised (climax in a succession) colonising species are at a competitive disadvantage with species adapted to stable (permanent) habitats. Colonising species have a strategy of occupying sites that have some chance of failing. For *L. aurea* this occurs when the breeding site selected is so ephemeral that it will not support full tadpole growth and development. While there is a considerable literature that reports *L. aurea* as being capable of dispersing there is little information on the context of that dispersal. On Kooragang Island most dispersal is associated with heavy rainfall events that trigger movement of adults to ephemeral wetlands. Heavy rainfall or cumulative rainfall is likely to be the prime trigger since it also indicates to the frogs that the ephemeral wetlands that are used will not dry prematurely. We are somewhat intrigued by the emphasis that is placed on dispersal, while noting that it is important for reproduction, it is also apparent that many *L. aurea* on Kooragang Island do not move any great distance in a season. The great majority of recaptured frogs are in the same wetland where they were first caught and marked. This has two important implications for management; favoured wetlands provide important habitat for foraging and shelter over long periods, and movement when it occurs is related to a specific component of the life history, and that is to reproduce. Once again, this is what is referred to as the importance of the habitat mosaic (Hamer et al. 2008). To date there has been little quantification around aspects of this observed habitat of the *L. aurea*, but the long-term study on Kooragang Island demonstrates that its important constituents are the mix of permanent and ephemeral wetlands and the distance between them, and less so on the size of the wetlands. While these latter features may be correlated with permanency and ephemerality, it is not necessarily the case. On Kooragang Island K23 is a relatively small permanent wetland and K22 is a relatively large ephemeral wetland, whereas in other cases K29 is a relatively large permanent wetland and nearby ephemeral wetlands are relatively small.

Inter-seasonal variation in search sensitivity: Central Island Region

Survey methods are standardised and did not differ from last year's methods for the wetlands immediately west of K22/K23 along Bell Frog Lane (K13, K63, K20 complex etc.). Despite this methodical consistency, search sensitivity was significantly higher for this season when compared to last year's. It is important to note here that the absolute number of detections was still low (<10), but nevertheless, given the topography of this region, it is interesting to speculate about why search sensitivity is higher. The most likely explanation is a retraction of the local population to the several semi-permanent water bodies which we survey in this area. After significant rainfall events - like the one observed in the previous 2015-16 survey - this low-lying region becomes an extensive floodplain and we suspect that last year's low search sensitivity was due to dispersal of adults into adjacent and highly ephemeral flooded grasslands.

It is not possible to ascertain for certain whether frogs retracted to the permanent wetlands that are surveyed as this year's survey season became progressively dryer, or alternatively adults overwintered at these permanent wetlands in 2016 and simply had no opportunity to disperse given the lack of large rainfall pulses. If this is the case one would predict a dispersal to late in the summer season to permanent wetland that provide overwintering habitats.

The success of new capping wetlands

Results for both search sensitivity and total detections demonstrate that the new HDC capping wetlands (K111-K114) are performing exceptionally well. Detection probability for this year was only marginally higher than that determined for last year's results (2015-16), when pooled across all four wetlands. However, whilst last year's surveys delivered a robust number of encounters (16 total), this year that number has increased to more than 200 individuals. Much of this increase can be attributed to a high density of metamorphs and juveniles in wetlands K111 and K114, but the total number of adults has increased as well.

Not all four of these capping wetlands are performing equally well; this is likely attributable to inter-seasonal variations in rainfall. K114 is by an order of magnitude the most occupied wetland, with K111 also making a significant contribution. In contrast K113 (which was an important breeding site in 2015-16) and K112 were both without detections in 2016-17. When considering the overall seasonal rainfall and hydrology of these wetlands, this makes sense as both wetlands were almost completely dry during survey rounds. Nevertheless, the first season in which we observed these wetlands (2015-2016) the seasonal rainfall was above average, and this year's results, made in a year of well below average seasonal rainfall, demonstrates the difference that can occur from one breeding season to another. Rather than simply comparing the value of wetlands on a short-time frame, the outcomes demonstrate the functionality of wetlands as *L. aurea* habitat under different climatic conditions.

The grouping of wetlands is still clearly working well as a habitat mosaic, and perhaps in a more normal rain year, the drying out of wetlands K112 and K113 is likely to be useful since this provides ephemeral wetlands for breeding. We have ample evidence that *L. aurea* will rapidly occupy and breed in ephemeral wetlands, and that therefore they are important part of the habitat mosaic that supports viable populations of this frog (McHenry et. al, 2016, Clulow et. al 2012). Whether ephemeral wetlands provide a habitat with higher reproductive output for the *L. aurea* is unknown, but several studies have demonstrated that ephemeral wetlands have fewer competitors, higher available nutrients and lower number of predators than permanent wetlands (Egan and Paton, 2004, Babbitt and Tanner, 2000). It is a reasonable biological assumption that this is the case for *L. aurea*, and this supports efforts to develop a habitat mosaic of permanent and ephemeral wetlands of varied sizes and spatial placement when constructing compensatory habitat for *L. aurea*. That this strategy works effectively in situations where wetlands are constructed to meet other management objectives such as siltation or drainage wetlands is a bonus. The success of capping wetlands K111-K114 is evidence that with our growing knowledge of *L. aurea*'s habitat preferences, we can take advantage of earthworks within the Industrial areas to build an increasingly robust meta-habitat within the Kooragang Island Management Zone.

Return to occupancy for K29- in spite of Gambusia

Wetland K29 provided strong outcomes this year in terms of both captures and detections. Historically this has been deemed a critical wetland for *L. aurea*'s persistence (Clulow et. al. 2014). However, last years (2015-16 season) results were an exception to this trend, with only 29 individuals being detected during standardised VES and CMR surveys. It is informative to see this wetland with high occupancy again in 2016-17, with the results implying that last year's was in many ways an anomaly. We postulate that this was likely due to very high rainfall and associated flooding in the breeding season of 2016, which resulted in the opportunistic dispersal of adult frogs away from this wetland to suitable nearby breeding sites, notably K106A/B. It is most likely that this site continues to be favoured because it is a permanent wetland, and may also offer a warm and protected refuge due to its construction below the land surface.

It is also important to note the presence of a considerable number of juveniles detected in K29 across all three survey rounds. Whilst it is of course possible that juveniles migrated to K29 from surrounding water bodies, given the very steep topography that separates K29 from adjacent wetlands, it is equally likely that breeding occurred unobserved in K29 during the previous 2015/2016 season. Furthermore, the detection of several metamorphs within the wetland is all but conclusive evidence that breeding occurred in the wetland during the current 2016/17 season. Whilst juveniles have been observed to migrate considerable distances (see 2011-12 results) metamorphs are almost certainly incapable of crossing the steep topography at the edges of K29. Hence, we can conclude that not only did breeding go unobserved despite intensive survey effort, but tadpoles managed to survive to metamorphosis in the presence of high *Gambusia* density. *Gambusia* has been demonstrated both experimentally and in the field to prey on *L. aurea* tadpoles (Remon et al., 2016, Stanback, 2010). Thus, the survival of any offspring to juvenile stage is encouraging, and suggests that K29 functions as more than just a refuge for adult *L. aurea*.

4.5 Demographics

Population composition

Pie Charts depicting the population's demographics (Figures 3.4.1 & 3.4.2) illustrate that the composition was remarkably similar across the distinct separate survey rounds. This suggests that the population's composition has remained consistent throughout the entire breeding season. Several previous surveys have shown that significant 'pulses' of new metamorphs and juveniles (typically following major rainfall events) have been added to the population between survey rounds; this has necessarily altered demographic composition within a given year. Instead, this year's data suggests that most population recruitment occurred either during late summer in 2015-16 or alternatively, in early spring of 2016-17, before and during our first survey round. The demographic information also implies less migration of specific demographic groups (e.g. adult females) in and out of surveyed wetlands throughout the breeding season, and again is evidence of limited dispersal into ephemeral wetlands and floodplains during the 2016-17 breeding season.

As in previous years, males dominate the capture results. Nevertheless, compared to last year's findings - where males out-numbered females 7:1 - this seasons male to female ratio (of circa 1.3: 1) has returned towards a more historical 'normal' (historically there has been a slight dominance of males, but this ratio has generally not exceeded 1.5:1). This is a positive change for the Kooragang Island population. Historical

data analysis (see section 4.1) has demonstrated conclusively that the number of breeding age females is the limiting factor for *L. aurea*'s recruitment within the Kooragang Island Management Zone. Thus, while total population numbers were high for the previous 2015-16 season, a very high proportion of these individuals were males, and this placed the population in a delicate position. A return to historical male to female ratio's is thus an encouraging finding.

Site Fidelity and probability of recapture

A declining proportion of new or 'unique' captures across consecutive capture-mark-recapture survey rounds implies strong site fidelity. As shown in Figure 3.4.3B, less than half of the individuals captured in the third round of surveys were unique. This indicates that many of the frogs did not move away from the wetland where they were captured in the first and second rounds. Once again this contrasts with the outcomes from the previous year (2015-16) when there was considerable movement from permanent wetlands to ephemeral wetlands following the charging of the latter. In 2016-17 most adults did not disperse from permanent wetlands because there were no spring and summer rainfall events that recharged the ephemeral wetlands. This finding is consistent with findings for island-wide demographics, visualized by survey round (Figures 3.3.3-3.3.5) Analysis of island wide results in this manner does not show significant changes in total population, or population composition within wetlands as the year progressed.

The capture-mark-recapture data also provide evidence of the survival and persistence of *L. aurea* at the permanent wetlands and the maturation of juveniles to adults. Capture rates were relatively consistent across the survey period, which is most likely a reflection of the stability of the system in the absence of significant rainfall, and it serves to impress the importance of the permanent wetland component of the ecosystem mosaic for the *L. aurea*, especially in dry breeding seasons.

Increased average size and proportion of adult females

Information derived from the size and age-class structure of the population shows a shift towards larger adults (relative to last season's results), and that adult females are making up a greater proportion of the population as the 2016-2017 season progressed. This evidence suggests that high recruitment during the wet summer of 2015-16 translated into a larger number of frogs reaching adulthood in 2016-17. The proportion of adults (specifically females) over 70mm is higher than in 2015-16. This is a positive outcome and should bode well for future breeding. Findings also suggest the overwinter survival of a considerable proportion of sub-adult females who were caught last year; a positive sign given the high historical mortality rate attributed to *chytridiomycosis*.

Mature females were caught across all three rounds indicating a relatively high survival rate. Mature females were also found consistently in all the major habitat complexes. This is another positive observation for the population, implying that there is the potential for breeding to occur throughout much of the Southern and Central regions of the island. This makes for a significantly more robust population, and will guard against localized events threatening breeding efforts for the whole island.

Wetland K105B was found to be particularly critical for harbouring large and gravid females. Formerly joined with K105A as one large wetland (nee K105), construction of the NCIG railway physically separated the two large water bodies. K105B has clearly become important breeding habitat, and was likely colonized by adults from K105A. Thus, connectivity between K105A/B and the nearby habitat K29 was

important to the population this year. We will continue to monitor this connectivity with the aim to obtain more direct evidence of migrations, facilitated by the PIT tags we have emplaced this season.

4.6 Longitudinal Studies

Individual persistence

The emplacement of several hundred PIT identification tags in captured *L. aurea* each season is a significant expenditure in terms of both time and physical resources. Nevertheless, this technology allows us to capture invaluable longitudinal data on survival and migration which cannot be obtained by other means. A total of sixty-two animals tagged in previous seasons (2014-2015, and 2015-16 season respectively) were recaptured this year, allowing us to analyse growth, survival and site specificity within the Kooragang Island population.

Firstly, almost all recaptured frogs (approximately 90%) were found in the same wetland that they had initially been captured. This suggests a high level of site fidelity (philopatry) both within and between breeding seasons. Thus, while we have observed adults moving in and out of permanent wetlands (such as K29) into surrounding ephemeral water-bodies, it seems that their preference is to return to their point of origin.

Secondly, the fact that approximately a quarter of the 62 animals recaptured over between 2014-15 and 2016-17 were first encountered in the 2014-15 season, indicates that an appreciable proportion of these animals are at least three years in age. A threshold of 40mm snout-vent length is applied when emplacing PIT tags to prevent potential harm to smaller animals. Thus, most animals are already at least six-months old (and perhaps 12 months if they were bred late in a season) by the time they are first tagged. Females which have reached three years of age are capable of breeding and are thus critical to recruitment within the Kooragang population. Evidence that a small proportion of adults are surviving for more than one breeding season is encouraging, and will improve the resilience of the population to a poor rainfall year like this most recent 2016-17 season. However, it is also important that females are apparently becoming gravid at a SVL of 60 mm, which should indicate that they are in their second year.

Litoria aurea which have survived for multiple breeding seasons, and over-wintered multiple times are likely to have persisted because they possess one or more of the following attributes:

1. Due to genetic variability in the population, it is possible that they are more resistant to *chytridiomycosis*, affording a higher chance of survival during over-wintering than the average individual.
2. They can accrue sufficient food to build fat reserves during good seasons to survive fluctuations in food availability, particularly whilst overwintering.
3. They have adopted strategies, such as inhabiting 'salt-refuges', which allow them to keep chytrid infection loads below lethal concentrations.

Any of these factors, genetic, phenotypic or behavioural tendencies can potentially be passed on to offspring. The longer these adults survive, the greater the chance that they contribute to recruitment. Given the high generational turn-over, we may see these advantageous characteristics become more

prevalent in the population. Tracking the movements and survival of these adults is thus critical to understanding how robust the Kooragang Island population will be in perpetuity.

Movement and wetland connectivity

The recorded movement of an individual from K103 (caught in 2014-15 season) to K22/23 (caught in 2016-17 season) is a valuable finding (see Figure 3.5.1). Long and medium range movements throughout the first four years of this annual survey (seasons 2010-2014) consistently showed evidence that the Industrial Railway which separates the Central and Southern Regions of the management zone was successfully being crossed by adults. Conversely, the next two years of survey (2014-2016) did not show any evidence of movement across this same railway corridor. This necessarily raised concerns as to the connectivity of critical habitat on either side of the corridor. It is important to note that given the high site fidelity of individuals, we do not have sufficient data to determine whether the railway has significantly decreased habitat connectivity. Nevertheless, there is proof that at the very least, the railway is not an absolute barrier to movement for *L. aurea*. As the individual in question was caught two years apart, we cannot know with surety during which season, or indeed which year the migration took place; our significant tagging efforts this past season will aid in detecting future migrations with more temporal certainty.

The movement of a female caught in K115 last year (2015-16 season) within the NCIG rail loop, to K104 (captured 2016-17 season) is also of interest. Movement across this rail loop has been recorded historically but not for several years; two instances were observed between K104 (the rail loop) and wetlands situated to the north in the 2011-12 survey. This finding provides evidence that construction of the railway loop 'fly-over' has not prevented *L. aurea* from migrating into and out of the enclosed area. Proof of this connectivity is particularly important given the recent construction of capping wetlands by HDC within the rail loop. These HDC wetlands (K111-K114) have been very effective across the last few seasons in supporting adults, as well as harbouring breeding events. The fact that they remain connected to other significant wetlands in the North-Western corner of the Management Zone is important for protecting the overall population in the event of local extinction, or failure to breed successfully in either sector.

A total of four movements were recorded in and out of K29. Two of these movements occurred between seasons (First caught 2015/16; re-caught 2016-2017), the other two occurred within the most recent 2016-17 season. These movements are important for two reasons. Firstly, they indicated *L. aurea* moving into and out of K29 from both the East (Wetlands C1 and K35) and the West (Wetland K106C). This implies good connectivity of habitat across this whole Northern Corridor. Secondly, they show that this habitat mosaic – underpinned by the permanent availability of water in K29 - enables *L. aurea* to respond to environmental variability through migration. This migration can occur both within a single breeding season, or between consecutive breeding seasons.

Whilst K29 has a permanent *Gambusia* infestation and thus does not represent ideal breeding habitat, the migratory evidence presented above demonstrates conclusively its significance to the stability of the local population. Historical results have led researchers to question whether K29 might in fact act as a 'sink' for the local meta-population. In this context, a sink is defined as a wetland where adults from surrounding water bodies move to and where conditions are not conducive to survival and/or reproduction. Thus, the animals may waste their reproductive effort, and ironically, the 'sink' wetland decreases population stability. However, this year's result show evidence of successful breeding within K29. How effective this is in relative terms (i.e. compared to breeding in an ephemeral wetland without

Gambusia) cannot be determined for the information collected. Furthermore, the movement of reproductively active adults out of K29 demonstrates that movement occurs in both directions. The culmination of this evidence suggests K29 is not a population 'sink', which further elevates its conservation value. Monitoring the movement of adults along the upper edge of K29 (see results - table 3.5.4) has also allowed for speculation about their movement into and out of K29. Interpretation of these results lends even greater evidence to the narrative developed above; that K29 is an important 'stop' along the way for *L. aurea* moving along the Northern Rail corridor.

4.7. Breeding and Recruitment

Scale of breeding events

The absolute number of breeding sites – eight - is largely consistent with data from the previous six years, which has ranged from five to ten. What these figures alone do not capture is the total reproductive output for a given year, which is also driven by how 'substantial' a breeding event is, i.e. the total number of offspring. It is not easy to define the size of a breeding event in a rigorous manner. Thus, we have typically relied on observational evidence, with researchers making records of abnormal large breeding events. Significant rainfall in last year's season (2015-2016) facilitated a very large recruitment event, with the density of metamorphs in one wetland complex (K106A/K106B) so high, we estimated a total number of metamorphosing individuals to be more than ten thousand. As there were only seven observed breeding sites for the 2015-16 season, comparison of raw numbers alone would conclude that this most recent season (2016-2017) was superior for breeding; we know this not to be the case with reference to observational data.

Impacts of *Gambusia holbrooki*

A total of 8 wetlands had evidence of breeding this season (3 with tadpoles, 5 with metamorphs) with half of these wetlands also containing *Gambusia*. This is an important finding given that *Gambusia* have been shown both in the field and in captivity to prey upon *L. aurea* tadpoles (Stanback, 2010). The positive news is that in wetlands where metamorphs were found, we have unmistakable evidence that tadpoles managed to survive despite the presence of *Gambusia*. Conversely, it is likely that many eggs and tadpoles were preyed upon before metamorphosing; this is a waste of the limited population reproductive effort. Indeed, adults may have been constrained to breed in sub-optimal wetlands due to the lack of rainfall and hence a lack of predator free ephemeral alternatives. It will not be possible to resolve the implications of *Gambusia* for recruitment without next year's findings. Nevertheless, we must consider the likelihood that breeding in permanent wetlands with substantial *Gambusia* infestations may dramatically impede recruitment and result in a population downturn for the coming 2017-18 season.

Substantial Inter-seasonal variance in breeding sites

Only one breeding site was shared between this season and the previous 2015-16 season; that wetland being the constructed wetland 'C1' in the Southern management region. Analysing systematic differences between this and last season's breeding locations is very informative. The primary difference between these two data sets is the ephemerality of wetlands. In last year's season (2015-16), six of the seven wetlands in which we observed breeding (K58A, K9C, K113, K106A, K106B, K104A) are highly ephemeral.

Except for K113 (which contained water for only the first round of surveys) all six 'ephemeral' wetlands were dry for the entire duration of the 2016-2017 survey period. In contrast, all seven of the wetlands in which evidence of *L. aurea* breeding was observed during the 2016-17 season (K63, K22/23, K104, K29, C1, K114, K111, K117) are permanent and semi-permanent wetlands. These wetlands remained charged for the entirety of the survey period, despite poor rainfall.

Thus, we have witnessed a complete shift from *L. aurea* breeding in ephemeral wetlands during a high rainfall year, to breeding only occurring in persistent wetlands in a poor rainfall year. The conclusion, based on several years of investigation, is that *L. aurea* preferentially breed in ephemeral waterbodies when they have the opportunity, but if the year is too dry they will breed in permanent water bodies instead. This of course has implications for the presence of established predators and competitors such as *Gambusia* in these more permanent water bodies.

The shift of breeding activity away from ephemeral water bodies has also shifted breeding away from the Northern and Central survey regions. In the 2015-16 season, half of the breeding sites were within these, naturally more ephemeral regions. With many of these wetlands drying up, breeding activity has instead been focused almost entirely within the Southern 'industrial' region.

Late-season rainfall – implications for breeding

From early March to Mid-April of 2017, there was an average of nearly 50mm rain per week (see figure 3.2.1.). This late season precipitation fell outside of the projects survey season; thus we do not have direct evidence of how it impacted distribution and breeding. Nevertheless, when considered in the context of our survey results, it is likely to have had a significant impact on recruitment for the season. As discussed previously, the location and hydrology of breeding sites this year suggests that *L. aurea* were forced to congregate and breed in permanent wetlands by dry conditions. Significant rainfall in early autumn 2017, is likely to have re-charged surrounding ephemeral wetlands and provided the opportunity for a late-season breeding event. This is of course contingent on a number of factors; primary amongst these that adults had not already completely expended their reproductive efforts. Nevertheless, observations of breeding in the nearby NCIG CHEMA wetlands and BHP CHEMA wetlands during this wet period suggest that the same might be true island-wide. Thus, whilst the results of our data analysis alone clearly indicate a poor breeding year for *L. aurea*, it is likely that late-season breeding may offset some of this impact. We will not know with certainty if this is the case until the next round of annual surveys is undertaken.

.....

5 References

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

AMSTRUP, S. C., MCDONALD, T. L. & MANLY, B. F. J. 2005. Handbook of Capture-Recapture Analysis, New Jersey, Princeton University Press.

ANSTIS, M. 2002. Tadpoles of south-eastern Australia. A guide with keys Reed New Holland.

BABBITT, K. J. & TANNER, G. W. 2000. Use of temporary wetlands by anurans in a hydrologically modified landscape. *Wetlands*, 20, 313-322.

BEEBEE, T. J. & GRIFFITHS, R. A. 2005. The amphibian decline crisis: a watershed for conservation biology? *Biological Conservation*, 125, 271-285.

BURNHAM, K. P. & ANDERSON, D. R. 2002. Model Selection and Multi-model Inference: A Practical Information-Theoretic Approach, New York, Springer.

* CAMPBELL, L., CLULOW, S., CLULOW, J. & MAHONY, M. 2015. Research Program on the Green and Golden Bell Frog (*Litoria aurea*) on Kooragang Island.

CHARLESWORTH, B. 2009. Effective population size and patterns of molecular evolution and variation. *Nature Reviews Genetics*, 10, 195-205.

CHRISTY, M. T. & DICKMAN, C. R. 2002. Effects of salinity on tadpoles of the green and golden bell frog (*Litoria aurea*). *Amphibia-Reptilia*, 23, 1-11.

CLANCY, G. 1996. The green and golden bell frog *Litoria aurea* in the Station Creek area of Yuraygir National Park. *Australian Zoologist*, 30, 214-217.

* Clulow, S., Leu, S., Stockwell, S., Clulow, J. & Mahony M. . 2012. Research program on the green and golden bell frog (*Litoria aurea*) on Kooragang Island. Annual report prepared for PWCS. .

* Clulow, S., Stockwell, S., Clulow, J. & Mahony M. . 2013. Research program on the green and golden bell frog (*Litoria aurea*) on Kooragang Island. Annual report prepared for PWCS.

* Clulow, S., Stockwell, S., Clulow, J. & Mahony M. . 2014. Research program on the green and golden bell frog (*Litoria aurea*) on Kooragang Island. Annual report prepared for PWCS.

DALY, G. 1996. Some problems in the management of the Green and Golden Bell Frog *Litoria aurea* (Anura: Hylidae) at Coomonderry Swamp on the south coast of New South Wales. *Australian Zoologist*, 30, 233-236.

DEC (2005a) Draft Recovery Plan for the Green and Golden Bell Frog (*Litoria aurea*). DEC NSW, Hurstville, NSW.

DEC (2005b). Green and Golden Bell Frog Profile in NSW Threatened Species Database, DEC NSW. Available from: <http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/index.aspx>

- DENVER, R. J. 1997. Proximate mechanisms of phenotypic plasticity in amphibian metamorphosis. *American Zoologist*, 37, 172-184.
- EGAN, R. S. & PATON, P. W. 2004. Within-pond parameters affecting oviposition by wood frogs and spotted salamanders. *Wetlands*, 24, 1-13.
- GOLDINGAY, R. 1996. The Green and Golden Bell Frog *Litoria aurea*—from riches to ruins: conservation of a formerly common species. *Australian Zoologist*, 30, 248-256.
- HAMER, A. J. & MAHONY, M. J. 2007. Life history of an endangered amphibian challenges the declining species paradigm. *Australian Journal of Zoology*, 55, 79-88.
- HAMER, A. 1998. Aspects of the ecology of the green and golden bell frog *Litoria aurea* on Kooragang Island. New South Wales, Australia.
- HAMER, A. J. 2002. Ecology of the endangered green and golden bell frog *Litoria aurea*: roles of habitat determinants, spatial dynamics, population demography and threatening processes. PhD Thesis, The University of Newcastle.
- HAMER, A., LANE, S. & MAHONY, M. 2002a. The role of introduced mosquitofish (*Gambusia holbrooki*) in excluding the native green and golden bell frog (*Litoria aurea*) from original habitats in south-eastern Australia. *Oecologia*, 132, 445-452.
- HAMER, A. J., LANE, S. J. & MAHONY, M. J. 2002b. Management of freshwater wetlands for the endangered green and golden bell frog (*Litoria aurea*): roles of habitat determinants and space. *Biological Conservation*, 106, 413-424.
- HAMER, A. J., LANE, S. J. & MAHONY, M. J. 2008. Movement patterns of adult green and golden bell frogs *Litoria aurea* and the implications for conservation management. *Journal of Herpetology*, 42, 397-407.
- HUSSAIN, Q. A. 2012. Global amphibian declines: a review. *International Journal of Biodiversity and Conservation*, 4, 348-357.
- KOEHLER, S., GILMORE, D. & NEWELL, D. 2014. Translocation of the threatened growling grass frog *Litoria raniformis*: a case study. *Australian Zoologist*, 37, 321-336.
- LANE, S., MAHONY, M. J. & HAMER, A. 2007. Habitat correlates of five species of amphibians and of species richness in a wetland system in New South Wales. *Applied Herpetology* 4, 65-82.
- LEWIS, B. & GOLDINGAY, R. 1999. A Preliminary Assessment of the Status of the Green and Golden Bell Frog in north-eastern NSW. *frogs*, 94.
- MAHONY, M. J., HAMER, A. J., PICKETT, E. J., MCKENZIE, D. J., STOCKWELL, M. P., GARNHAM, J. I., KEELY, C. C., DEBOO, M. L., O'MEARA, J. & POLLARD, C. J. 2013. Identifying conservation and research priorities in the face of uncertainty: a review of the threatened bell frog complex in eastern Australia. *Herpetological Conservation and Biology*, 8, 519-538.

- * McHENRY, C.R., KING, J.P., MOSES, B., MAHONY, M. 2016. Research Program on the Green and Golden Bell Frog (*Litoria aurea*) on Kooragang Island. Annual report prepared for PWCS, NCIG, HDC.
- NICHOLS, J. D. 2005. Modern open-population capture-recapture models. In: AMSTRUP, S. C., MCDONALD, T. L. & MANLY, B. F. J. (eds.) Handbook of Capture-Recapture Analysis. New Jersey: Princeton University Press.
- OSBORNE, W., LITTLEJOHN, M. & THOMSON, S. 1996. Former distribution and apparent disappearance of the *Litoria aurea* complex from the Southern Tablelands of New South Wales and the Australian Capital Territory. *Australian Zoologist*, 30, 190-198.
- PENMAN, T. D. 1999. Natural Factors affecting the early life stages of the green and golden bell frog, *Litoria aurea*: Lesson 1829. BSc Honours, University of New South Wales.
- POLLOCK, K. H. 1982. A capture-recapture design robust to unequal probability of capture. *Journal of Wildlife Management*, 46, 757-760.
- PYKE, G. & WHITE, A. 1996. Habitat requirements for the green and golden bell frog *Litoria aurea* (Anura: Hylidae). *Australian Zoologist*, 30, 224-232.
- PYKE, G., ROWLEY, J., SHOULDER, J. & WHITE, A. 2008. Attempted introduction of the endangered Green and Golden Bell Frog to Long Reef Golf Course: a step towards recovery? *Australian Zoologist*, 34, 361-372.
- PYKE, G., WHITE, A., BISHOP, P. & WALDMAN, B. 2002. Habitat-use by the green and golden bell frog *Litoria aurea* in Australia and New Zealand. *Australian Zoologist*, 32, 12-31.
- REMON, J., BOWER, D. S., GASTON, T. F., CLULOW, J. & MAHONY, M. J. 2016. Stable isotope analyses reveal predation on amphibians by a globally invasive fish (*Gambusia holbrooki*). *Aquatic Conservation: Marine and Freshwater Ecosystems*, 26, 724-735.
- SANDERS, M. R., CLULOW, S., BOWER, D. S., CLULOW, J. & MAHONY, M. J. 2015. Predator presence and vegetation density affect capture rates and detectability of *Litoria aurea* tadpoles: wide-ranging implications for a common survey technique. *PloS one*, 10, e0143733.
- SKERRATT, L. F., BERGER, L., SPEARE, R., CASHINS, S., MCDONALD, K. R., PHILLOTT, A. D., HINES, H. B. & KENYON, N. 2007. Spread of chytridiomycosis Has Caused the Rapid Global Decline and Extinction of Frogs. *EcoHealth*, 4, 125.
- SMITH, D. C. 1987. Adult recruitment in chorus frogs: effects of size and date at metamorphosis. *Ecology*, 68, 344-350.
- STANBACK, M. 2010. *Gambusia holbrooki* predation on *Pseudacris feriarum* tadpoles. *Herpetol Conserv Biol*, 5, 486-489.
- STOCKWELL, M. 2011. Impact and mitigation of the emerging infectious disease chytridiomycosis on the endangered Green and Golden Bell Frog.
- STOCKWELL, M. P. & MAHONY, M. 2007. Levels of the amphibian chytrid fungus (*Batrachochytrium dendrobatidis*) in populations of the green and golden bell frog (*Litoria aurea*) and sympatric

amphibian species at Sydney Olympic Park in 2006/2007. Report prepared for the Sydney Olympic Park Authority July 2007.

STOCKWELL, M. P., CLULOW, J. & MAHONY, M. J. 2012. Sodium chloride inhibits the growth and infective capacity of the amphibian chytrid fungus and increases host survival rates. *PLoS One*, 7, e36942.

STOCKWELL, M. P., CLULOW, S., CLULOW, J. & MAHONY, M. 2006a. Impact of the amphibian chytrid fungus on the reintroduction of *Litoria aurea* to the Hunter Region of NSW. Wildlife Disease Association Conference. 24-29 September, Naracoort SA.

STOCKWELL, M. P., CLULOW, S., CLULOW, J. & MAHONY, M. 2006b. Investigating the role of reintroduction and translocation programs in the presence of chytrid. Australasian Wildlife Management Conference. 4-7 December, Auckland NZ.

STOCKWELL, M., CLULOW, J. & MAHONY, M. 2015a. Evidence of a salt refuge: chytrid infection loads are suppressed in hosts exposed to salt. *Oecologia*, 177, 901.

STOCKWELL, M. P., STORRIE, L. J., POLLARD, C. J., CLULOW, J. & MAHONY, M. J. 2015b. Effects of pond salinization on survival rate of amphibian hosts infected with the chytrid fungus. *Conservation Biology*, 29, 391-399.

STOCKWELL, M., CLULOW, J. & MAHONY, M. 2010. Host species determines whether infection load increases beyond disease-causing thresholds following exposure to the amphibian chytrid fungus. *Animal Conservation*, 13, 62-71.

STOCKWELL, M., CLULOW, S., CLULOW, J. & MAHONY, M. 2008. The impact of the amphibian chytrid fungus *Batrachochytrium dendrobatidis* on a green and golden bell frog *Litoria aurea* reintroduction program at the Hunter Wetlands Centre Australia in the Hunter Region of NSW. *Australian Zoologist*, 34, 379-386.

VAN DE MORTEL, T. F. & BUTTEMER, W. 1996. Are *Litoria aurea* eggs more sensitive to ultraviolet-B radiation than eggs of sympatric *L. peronii* or *L. dentata*? *Australian Zoologist*, 30, 150-157.

VOYLES, J., BERGER, L., YOUNG, S., SPEARE, R., WEBB, R., WARNER, J., RUDD, D., CAMPBELL, R. & SKERRATT, L. F. 2007. Electrolyte depletion and osmotic imbalance in amphibians with chytridiomycosis. *Diseases of aquatic organisms*, 77, 113-118.

WASSENS, S. & MULLINS, B. 2001. Rediscovery of a green and golden bell frog population in the Southern Tablelands. *HERPETOFAUNA-SYDNEY-*, 31, 58-63.

WHITE, A. & PYKE, G. 1996. Distribution and conservation status of the green and golden bell frog *Litoria aurea* in New South Wales. *Australian Zoologist*, 30, 177-189.

WHITE, A. & PYKE, G. 1999. Past distribution of *Litoria aurea* and *Litoria castanea* in the Bathurst-Orange area of New South Wales. *HERPETOFAUNA-SYDNEY-*, 29, 2-9.

WHITE, A. 2006. A trial using salt to protect green and golden bell frogs from chytrid infection. *HERPETOFAUNA-SYDNEY-*, 36, 93.

WHITE, G. C. & BURNHAM, K. P. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study*, 46 (Suppl), S120-S139.