Natural Resources
SA Murray-Darling Basin

Frog Monitoring in the Coorong, Lower Lakes and Murray Mouth (CLLMM) Region

Final Report

June 2015

Government of South Australia

Cite as
Mason, K & Durbridge, R, 2015, *Frog Monitoring in the Coorong, Lower Lakes and Murray Mouth Region 2014/15*, *Final Report,* Department of Environment Water and Natural Resources, Murray Bridge, South Australia.

Acknowledgements
This project was undertaken with significant support and input from a number of organisations and individuals. The contributions from the Goolwa to Wellington Local Action Planning Association Inc., the Signal Point Riverine Environment Group, the many landholders and volunteers who braved the cold nights, Raukkan Community Council, the Milang and Meningie Lakes Hubs, the Strathalbyn Natural Resources Centre and the Department of Environment, Water and Natural Resources are especially acknowledged. The author wishes to thank Irene Wegener and Rebecca Turner for their assistance in the editing and review process of this document.

Funded by the Department of Environment, Water and Natural Resources (DEWNR) and is part of the South Australia Government's *Murray Futures* program, funded in turn by the Australian Government's *Water for the Future* initiative'.

For more information
Natural Resources SA Murray-Darling Basin
Department of Environment Water and Natural Resources
PO Box 2343
MURRAY BRIDGE SA 5253
Phone: (08) 8532 9100
www.naturalresources.sa.gov.au/samurraydarlingbasin

Summary

Over the past four years the internationally recognised Ramsar Coorong, Lower Lakes and Murray Mouth (CLLMM) Icon Site has been undergoing stages of recovery to a functioning freshwater and estuary system after a prolonged period of reduced freshwater flows and low water levels. Observed signs of recovery in recent years include the expansion and diversification of submerged and emergent plant communities and improvements in diadromous and threatened fish species populations. A number of species that have not appeared to have experienced the same level of recovery include the Environment Protection and Biodiversity Conservation (EPBC) vulnerable-listed Southern bell frog (*Litoria raniformis*). The largest of the 12 frog species known to occur in the Lower Murray, *L. raniformis* is responsive to flooding; readily occupying shallow, newly inundated vegetated areas to breed.

Between September 2014 and March 2015 a monitoring project was undertaken to determine the spatial distribution of *L. raniformis* within Lake Alexandrina and Lake Albert and the tributaries and to identify potential threats to successful recruitment. It was hypothesised that 1) *L. raniformis* would be present in the CLLMM region in comparable abundance to previous years but the spatial distribution would have changed; 2) successful recruitment of *L. raniformis* will occur in areas with fewer introduced/alien fish species and 3) habitat preferences of *L. raniformis* will be similar to previous years.

In total, 38 volunteers and six community groups contributed over 300 hours undertaking frog monitoring across 78 sites. Targeted monitoring at four sites previously occupied by *L. raniformis* was also conducted in an attempt to detect evidence of recruitment and investigate habitat preferences and potential predation. Call recognition, active searching and tadpole surveys were undertaken at targeted sites. The location of community survey sites were well distributed across Lake Alexandrina, Lake Albert, and the Eastern Mount Lofty Ranges/Eastern Fleurieu. Frog surveys were generally well distributed between September and December, capturing expected peak calling times for a wide range of species, including *L. raniformis*. A total of eight frog species (including *L. raniformis*) were recorded in the study region in 2014/15. The highest diversity observed at a single monitoring location was six species and the average number of species recorded per site was 3.49. These results were generally comparable to the previous two years. The most widespread and abundant species was the common froglet (*Crinia signifera*) which was detected at 86 percent of sites, often in high abundance. Species known to occur in the CLLMM region but not detected in 2013 include Bibron's toadlet (*Pseudophryne bibronii*), and Sudell's frog (*Neobatrachus sudelli*)

Abundance of calling *L. raniformis* was considered to be extremely low across the study region. *L. raniformis* was detected at only one location within wetland habitat on the fringe of the Goolwa Channel near the township of Clayton Bay on two occasions. This location was known to be inhabited by the species from recent or historical data, the most recent record of one individual in September 2013 and January. The vegetative structural composition at the one location in which *L. raniformis* was detected calling was similar to that of previous years.

The lower water levels experienced throughout the latter half of the survey period resulted in the drying of fringing areas above 0.5-0.6 mAHD. This included some areas previously occupied by *L. raniformis*. Colonisation of opportunistic plants and consolidation of sediments occurred in some areas, outcomes considered to be beneficial to increase productivity in wetlands in the longer-term. Concurrently, the expansion and diversification of submerged and emergent plant communities in the region occasionally produced areas of similar vegetative structure to that of previously occupied sites. It was considered that suitable *L. raniformis* structural habitat was available in 2014/15. The response by *L. raniformis* to water level management during past years (2009-2013) and the knowledge of the species readiness to favour newly inundated areas suggests that water levels were the primary driver in *L. raniformis* occupancy in 2014/15. Calling activity may also have occurred in the two months directly prior to the survey period when higher

lake levels prevailed. The highest abundances of *L. raniformis* across all survey events between 2009 and 2014 was observed following the increase in water levels after a period of drying (in 2009 within what was the Goolwa Water Level Management Area and in 2010 upon the return of flows). Increasing the seasonal variability of water levels in the Lower Murray to cue breeding events and to increase the breadth of the littoral zone will likely increase the amount of area of suitable breeding habitat for *L. raniformis*. However, the level of variability required to cue the level of breeding behaviour as seen in the more successful years of 2009 and 2010 is not known. The results of this study identify the need to implement a variable hydrological regime in the region that aims to achieve increased habitat complexity for *L. raniformis* and cue breeding behaviour.

Contents

List of Figures

List of Tables

List of Appendices

Acronyms and abbreviations

AHD	Australian Height Datum
cm	centimetres
DEWNR	Department of Environment, Water and Natural Resources
DO	Dissolved Oxygen
EC	Electrical Conductivity
GWLMP	Goolwa Water Level Management Project
km	Kilometres
LAP	Local Action Planning Association
m	Metres
mg	milligrams
Natural Resources SAMDB	Natural Resources SA Murray-Darling Basin
NRM	Natural Resources Management
NTU	Nephelometric Turbidity Units
pH	(p)otential of (H)ydrogen
ppm	parts per million
SA	South Australia
µS	Micro Siemens

1.0 Introduction

The ecological services provided by frogs to ecosystems and human society throughout the South Australian Murray-Darling Basin (SAMDB) are often underestimated. Beyond the well-adopted understanding of their positive contribution to insect consumption, frogs are now considered to be major contributors to ecosystem functions such as decomposition and nutrient cycling, and to ecosystem structure through aquatic bioturbation (interactions between sediment particles and the water column) and soil burrowing (MEA 2005, Hocking & Babbitt 2014). Their abundance constitutes an integral element within food webs in the SAMDB, providing services throughout all stages of their dual aquatic and terrestrial life cycles (such as contributing to limiting algae growth; insect consumption and are prey for many water dependant and terrestrial species) (Robinson 2000, Baldwin et.al 2005, Hocking & Babbitt 2014).

Of the 12 species of frog known to occur in the SAMDB, the Southern bell frog (*Litoria raniformis*) is listed as nationally 'vulnerable' under the *Environment Protection and Biodiversity Conservation Act 1999*, 'vulnerable' in South Australia and Tasmania and 'endangered' in Victoria, New South Wales and the Australian Capital Territory. *L. raniformis* is a large ground-dwelling frog in a closely-related group of frogs referred to as the *Litoria aurea* complex. The species was formerly common and widespread throughout much of South-Eastern Australia but has suffered noticeable and documented declines in distribution and abundance over the past 25-30 years (Clemann & Gillespie 2010, Stratman 2007). Extremely low abundance of *L. raniformis* has been detected in the CLLMM region in the past three years (Mason 2014). The causes of decline in this area have not been determined but are thought to be influenced by the timing of water level fluctuations, which may have decreased detectability due to the increase in available habitat, and increased predation from foxes and introduced fish such as Eastern gambusia (*Gambusia holbrookii*) and redfin perch (*Perca fluviatilis*).

This project aimed to determine extant populations in the CLLMM region through an increased number and spatial distribution of monitoring sites by engaging extensive support from community volunteers. Building upon and supporting existing community groups and volunteers is considered to provide longer-term benefits for the conservation of frogs and wetland habitats in the CLLMM region. In addition to region-wide community monitoring, targeted monitoring at sites previously occupied by *L. raniformis*, with a greater emphasis on tadpole monitoring, was aimed at ascertaining the level of predation and/or other key threatening processes.

This project addressed the need to monitor key populations around Lake Alexandrina, Lake Albert and the lower reaches of the tributaries: the Finniss River and Currency Creek, and the responses of the species to water level management below Lock 1.

1.1 Project objectives

The primary aim of this project was to determine the effects of changes in habitat features and the management of water levels on frog populations within the Lower Lakes and Murray Mouth region. Targeted surveys of frog (particularly *L. raniformis*) populations and habitat condition assessment were undertaken to address the key questions and test the hypothesis outlined in Table 1.

The broad services of the project were to:

- Coordinate broad-scale surveys, targeted at *L. raniformis,* through the delivery of a volunteer-based frog monitoring program.
- Identify key extant frog populations.
- Assess evidence of recruitment and predation and habitat condition at targeted sites occupied by *L. raniformis*.

Table 1: Objectives, key questions and hypotheses for frog species monitoring in the Coorong, Lower Lakes and Murray Mouth.

Monitoring Objective	Key Questions	Hypotheses
To assess the current status and spatial distribution of *L. raniformis* populations in the CLLMM region. To investigate potential threats to successful recruitment of *L. raniformis*.	• What is the spatial occupancy and habitat preferences of *L. raniformis* in the CLLMM region following the increase in available habitat and how does this compare to previous years? • Has there been any evidence of successful recruitment at sites occupied by *L. raniformis*? • Has the observed increase in available *L. raniformis* habitat resulted in changes to habitat preference?	*L. raniformis* will be present in the CLLMM region in comparable abundance to previous years but the spatial distribution will have changed. Successful recruitment of *L. raniformis* will occur in areas with fewer introduced/alien fish species. Habitat preferences of *L. raniformis* will be similar to previous years.

1.2 The Coorong, Lower Lakes and Murray Mouth (CLLMM) region

The Coorong, Lakes Alexandrina and Albert and the Murray Mouth, together form the wetland and estuary system that is the terminus of the River Murray. The area was declared a Wetland of International Importance in 1985 under the Ramsar Convention as the Coorong and Lakes Alexandrina and Albert Wetlands (MDBC 2006). Terminating at the Southern Ocean in South Australia, the River Murray passes through the Lake Alexandrina, the Murray Estuary and, finally, the Murray Mouth. Together the Lakes cover approximately 648 square kilometres which makes them the largest freshwater body in South Australia (DEH 2000). The complex ecology of the area has been modified by a system of barrages which restrict connectivity between the Lower Lakes and the Murray Mouth and Coorong.

The Murray-Darling Basin experienced severe drought between 2001 and 2010 and as a result the Lower Lakes (and the River Murray channel and wetlands below Lock 1), which rely on flows from upstream, were directly affected by the quality and quantity of water reaching this area. Years of over-allocation, over-extraction and severe drought conditions led to several significant impacts on the Lower Lakes including unprecedented low lake levels, with Lake Alexandrina dropping to 1 m below sea level in April 2009. With the absence of any freshwater flows through the barrages, water quality of the system declined significantly. As lake water levels receded, the lake beds and fringing wetlands dried out and extensive areas of aquatic and riparian habitat were lost. Previously submerged sulfidic soils became exposed, presenting the threat of acidification. These acid sulfate soils became a major issue in many wetlands around the Lower Lakes and tributaries (Currency Creek and the Finniss River), with affected wetlands and lake bed areas requiring aerial liming, seeding or major bioremediation works to treat the acidification. In an attempt to prevent major acidification in the tributaries, the Goolwa Water Level Management Project was established. A blocking bank between Clayton Bay and Hindmarsh Island was constructed during 2009 across the Goolwa Channel, forming the 'Goolwa Water Level Management Area' (GWLMA). Water levels within the GWLMA were then maintained above the critical threshold for acidification by inflows from the Finniss and Currency Creeks and pumping from Lake Alexandrina.

During 2010, increased flow into the River Murray raised water levels in the Lakes and re-inundated fringing wetland habitats that had been dry for up to four years. The GWLMA blocking bank was partially removed in September 2010 reconnecting the Goolwa Channel to Lake Alexandrina. Since 2010, inflows into the Lakes have maintained water levels within a 'normal' operating range and provided flows through the barrages and the Murray Mouth. Observed signs of recovery in recent years include the expansion and diversification of submerged and emergent plant communities (Frahn et. al. 2013) and improvements in the abundance of diadromous and threatened fish species (Bice & Zampatti 2014, Wedderburn 2014).

1.3 Frog species in the CLLMM region

1.3.1 Frogs in the SA Murray-Darling Basin

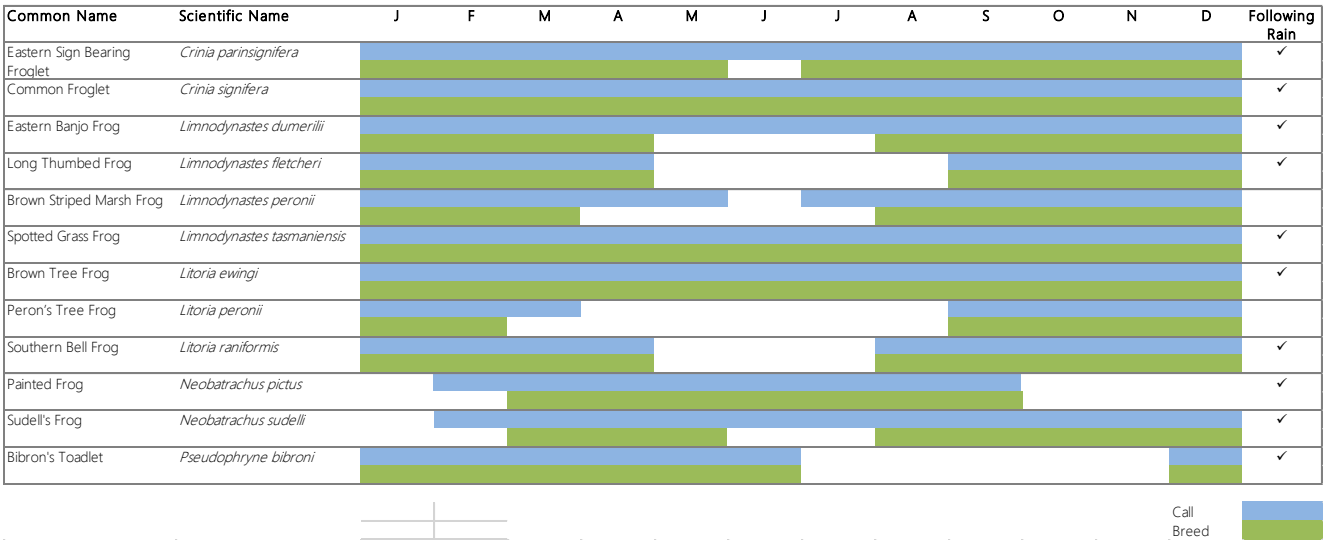
In the SAMDB there are 12 known frog species (Tyler & Walker 2011). Eight of these are known inhabitants of the CLLMM region (Table 2). The remaining four have rarely been recorded or have distributions more associated with areas outside the CLLMM region including the Riverland, the South-East or the Eastern Mount Lofty Ranges. These four include the Eastern sign-bearing froglet (*Crinia parasignifera*), the Brown-striped Marsh frog (*Limnodynastes peronii*), the Sudell's Frog (*Neobatrachus sudelli*) and the Bibron's Toadlet (*Pseudophryne bibroni*).

Male frogs are responsible for the unique call that can be heard during breeding and each species in the CLLMM region has a distinct call. Preferences in timing of calling and breeding throughout the year varies between species (Table 3) and monitoring is aligned to the August to December period when the majority of the species are known to call (reference – maybe Antsis 2013?). Environmental conditions such as rainfall, temperature, water levels and habitat quality can influence the timing of calling and breeding (Gonzalez *et al.* 2011).

Table 2: Frog species recorded within the SAMDB and CLLMM Regions.

Common Name	Species Name	Pond-dweller	Above ground-dweller	Burrower	CLLMM Region
Eastern sign bearing froglet	*Crinia parinsignifera*				
Common froglet	*Crinia signifera*				
Eastern banjo frog	*Limnodynastes dumerilii*				
Long thumbed frog	*Limnodynastes fletcheri*				
Brown striped marsh frog	*Limnodynastes peronii*				
Spotted grass frog	*Limnodynastes tasmaniensis*				
Brown tree frog	*Litoria ewingi*				
Peron's tree frog	*Litoria peronii*				
Southern bell frog	*Litoria raniformis*				
Painted frog	*Neobatrachus pictus*				
Sudell's frog	*Neobatrachus sudelli*				
Bibron's toadlet	*Pseudophryne bibroni*				

Table 3: Known timing of calling and breeding of frogs in the South Australian Murray-Darling Basin (adapted from Bjornsson 2005 with updated reference to Anstis 2013)



1.3.2 The Southern bell frog (*Litoria raniformis*)

The Southern bell frog (*Litoria raniformis*), also known the growling grass frog in the Eastern states of Australia, is a large species compared to other frogs, reaching 60-104 mm in length in females and 55-65 mm in males (Anstis 2013). The skin varies from dull olive-brown to bright emerald green, mottled with irregular brown to tan blotches within or without a cream or pale green vertebral stripe. The skins surface contains numerous dark brown to gold raised warts which can be arranged in longitudinal rows. The skin surface of the belly is generally white/cream and coarsely granular. A cream or tan-coloured skin fold exists from the eye to above the tympanum (hearing organ/gland on the side of the head) often traversing the side of the body. A distinguishing feature of *L. raniformis* compared to other frogs in the CLLMM region is the bright turquoise colouring of the skin on the inside of the back legs and groin (Robinson 1998, Stratman 2007, Anstis 2013).

Individuals are most active in spring and summer when they may be seen basking in the sun. In winter they can be found in groups beneath thick beds of reeds on the edges of wetlands (Stratman 2007). Generally feeding at night, *L. raniformis* eats small water bugs, beetles, termites and insect larvae. They can also be cannibalistic and eat other frogs including individuals of their own species (DEC 2005). They are opportunistic predators, sitting and waiting to ambush whatever prey comes within reach (Schultz 2006).

Along the River Murray *L. raniformis* adults tend to reside in or near temporary ponds and wetlands, or near permanent water bodies (Schultz 2006). The species is reliant on flooding of temporary wetlands, where individuals move to seasonally flooded or temporary wetlands for breeding, and then move back to permanent water bodies as refuges when temporary habitats dry out (Pyke 2002, Wassens et al. 2008, Mason and Hillyard 2011). Preferred breeding habitats are typically associated with seasonally flooded wetlands containing complex aquatic vegetation communities (Wassens 2011). In some parts of the Murray-Darling Basin the species has been shown to have a strong association with large areas of inundated lignum (*Duma florulenta*) (Schultz 2006) and with habitats containing aquatic and emergent vegetation, with an overstorey of river red gums (*Eucalyptus camaldulensis*) or black box (*E. largiflorens*) (Schultz 2006; Wassens et al. 2008). *L. raniformis* is considered to have a high reproductive potential but is reliant on flooding of temporary of ephemeral areas for breeding (Wassens 2008, Gonzalez et al., 2011). River regulation and reduced flows have reduced the hydrological variability within the SAMDB resulting in reductions in flood frequency and extent of flooding of ephemeral wetlands. This creates the potential to limit strong recruitment and dispersal of this species, even when permanent waterbodies remain unchanged (Wassens 2008).

During the breeding season, which can occur from spring to autumn, male *L. raniformis* call with a long, medium pitched modulated growl followed by series of short grunts to attract a mate (Tyler and Walker 2011).

Decline of the species in Australia is thought to be due to the degradation and fragmentation of habitat; introduction of alien predatory and competitive fish; infection by Chytridiomycosis disease (more commonly referred to as Chytrid Fungus); accumulation of chemicals in aquatic habitats; and possibly increased levels of ultra-violet-B (UV-B) radiation as a result of ozone depletion (Stratman 2007, Clemann and Gillespie 2010). As tadpoles, the species is sensitive to high fish densities and habitat disturbance (Pyke 2002), in particular competition/predation from Eastern gambusia (*Gambusia holbrookii*) and common carp (*Cyprinus carpio*) (Gonzalez et al., 2011).

Knowledge of the distribution and abundance of *L. raniformis* in the CLLMM region pre-2009 is limited. Historical records spanning more than 60 years were the basis for an inventory of the species conducted in 2009 (Mason 2010). Individuals were detected at a small number of sites in the Lower Lakes during this time, however, little was known of the species' status in the region prior to the drought and subsequent contraction of their habitats.

Based on records obtained from the Southern bell frog Inventory, Biological Survey Database, Frog Census, SA Museum, River Murray Baseline Database and ongoing monitoring, the species has been recorded at a total of 17 individual sites within the CLLMM region (Figure 1). Some of these records pre-dated 1980, with *L. raniformis* recorded from three localities prior to 1976 from Narrung, Wellington and the Milang district (Figure 1). Voucher specimens were collected at each of these sites, all of which are currently held in the SA Museum. Frog census data collected in September 2000 also resulted in the identification of *L. raniformis* at the Wellington ferry and Langhorne Creek.

A number of frog surveys were carried out as part of the River Murray Baseline Survey during 2004 and 2005. *L. raniformis* was only recorded at two, out of 13, wetlands surveyed (Holt *et al.* 2004; Simpson *et al.* 2006). Several males were heard calling in March 2004 and November 2005 at Tolderol Game Reserve and Pelican Lagoon, respectively (Figure 1). The landholders of Mundoo Island, provided photographs of an adult *L. raniformis* collected on the Island in 2005.

L. raniformis was recorded at three locations during the 2009 inventory. The largest population (10-50 individuals) was recorded at Clayton Bay, and smaller populations were detected in the Finniss River at 'Wally's Landing/Watchalunga' (2-9 individuals) and Mundoo Island (1 individual). Clayton Bay and Wally's Landing were located within inundated wetlands and shorelines following the implementation of the GWLMP.

Frog monitoring conducted in the region in 2010 detected *L. raniformis* at six locations in moderate to low abundances. Pelican Lagoon (Sites 1 & 2), Finniss 'Watchalunga/Wally's Landing', Finniss 'Sterling Downs', Clayton Bay 'Red Top Bay' and Mundoo Island. *L. raniformis* had been found at or near three of these sites in the past. A photograph of an adult discovered in a pump shed at Turvey's Drain was provided by landholders, north-east of Milang Township in 2010. No formal *L. raniformis* monitoring was conducted in 2011, however opportunistic survey events yielded moderate abundances at Nalpa Station 'Pomanda Point Causeway', approximately 4.5km south of Pelican Lagoon where they were recorded the previous year.

In 2012/13 *L. raniformis* was detected at two locations; Pomanda Point causeway in moderate abundances and one individual near Clayton Bay (Goolwa Channel). The most recent observations of *L. raniformis* in the CLLMM region in 2013/14 were at Wellington East Wetland, near the location of SA Museum and Frog Census records, where low numbers (3-5 individuals) were heard calling and one individual near Clayton Bay (Goolwa Channel).

Litoria raniformis is known to occupy a range of natural and artificial habitats including permanent and ephemeral wetlands, streams, riverine floodplains, farm dams, flooded paddocks, marshes, garden ponds, quarries and irrigation channels (Stratman 2007). However, the habitat preference of *L. raniformis* in the Lake Alexandrina, Lake Albert and tributaries region has generally consisted of lignum (*Duma florulenta*) shrublands, low sedgelands, inundated grasses, and dense floating aquatic plants such as filamentous algae (Mason 2014).

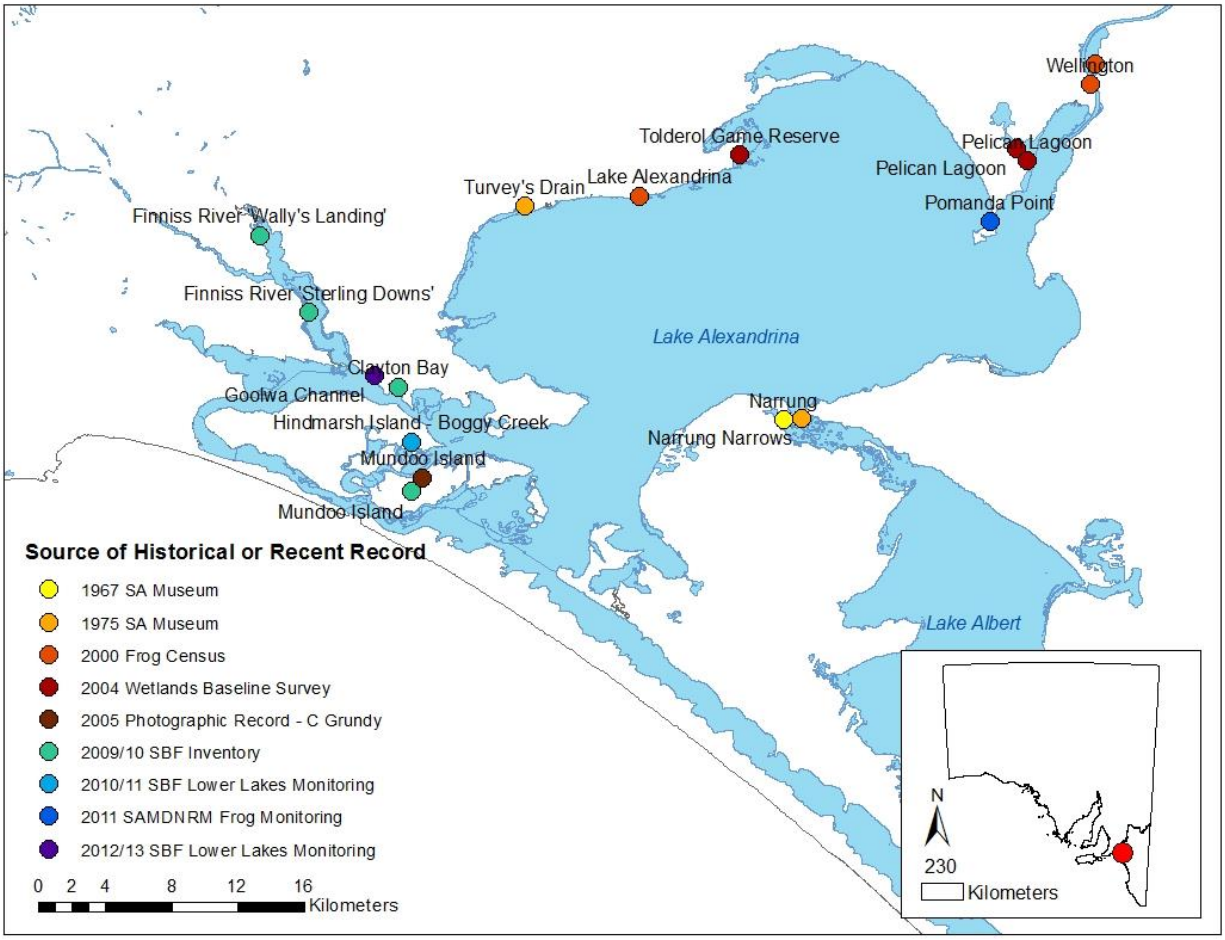


Figure 1: Known distribution of the Southern bell frog (*Litoria raniformis*) in the CLLMM region displaying earliest record of occupancy.

2.0 Methodology

2.1 Community-based frog monitoring

Since targeted monitoring for *L. raniformis* in the CLLMM region began in 2009, the level of interest and input from volunteers, groups and individuals in frog monitoring has grown. It has been observed that in communities in the CLLMM region, frogs are regarded as indicators of waterway health predominantly owing to a public understanding that these taxa are sensitive to water pollutants. Community frog monitoring has an established history in South Australia, previously being coordinated as the SA Frog Census by the Environmental Protection Authority (EPA) of South Australia. The methodology outlined by the EPA frog census is the basis for community monitoring in the CLLMM region.

Frog monitoring loan kits were available for landholders, volunteers and groups/organisations which contained similar equipment to that used in the targeted surveys. The same methodology as the targeted surveys was also used in the community monitoring but with the slight modifications of a shorter five-minute recording period and descriptive method used for recording atmospheric and habitat conditions. Identification of frog species from sound files was undertaken by project staff.

2.1.1 Community Survey method

1. Workshops, recuitment and induction
    - Eleven frog monitoring loan kits were compiled containing; Sony digital recorder (Model ICD-P620), Yoga shotgun microphone (Model EM-2700), head torch, datasheets, monitoring and equipment instructions, CD of frog calls and mini-field guide. The loan kit field datasheet (Appendix 1) was adapted from the Zoos SA Frog Atlas (formally the EPA Frog Census) datasheet.
    - Six workshops were held within the region covering species ecology and identification (with detailed species information provided by Steven Walker), monitoring methodology and health and safety procedures. Registration of volunteers was coordinated as part of the GWLAP procedures.
    - Nine articles and promotional flyers were disseminated through local media and social media avenues.
2. Priority sites/areas identified and landholders engaged
3. Trained volunteers 'Adopt-a-Site'
4. First round of nocturnal surveys (assisted by staff)
5. Independent monthly surveys.

In total 38 volunteers and six community groups contributed over 300 hours to the project undertaking frog monitoring at 78 sites (237 recordings between September and March). Over 15 landholders provided permission to access their properties for volunteers. See Figure 2, Table 8 for locations.

2.2 Targeted monitoring

In addition to the community monitoring, targeted monitoring at three sites previously occupied by *L. raniformis* was undertaken to determine recruitment success and investigate habitat preferences and potential predation. The following methodology was undertaken on a monthly basis between October 2014 and January 2015. See Figure 2, Table 8 for site locations.

2.2.1 Nocturnal surveys

It has been observed that the male *L. raniformis* can be variable in its calling behaviour and that more than one method to detect *L. raniformis,* on repeated occasions, is recommended (Heard *et al*. 2006). Following these recommendations, the following efforts were undertaken to increase chance of detection:

- Call recording and recognition of breeding male frogs: methodology outlined by Tucker (2004) was used with a modification that increased recording time from three minutes to five minutes (start and finish times were recorded). Humidity and air temperature were also recorded, and scores were given to amount of moon, wind, rain and cloud present at the time of each survey (Table 4).
- Active searching: scanning fringes of water body with small spotlight over a standard area of a 50-metre radius.
- Multiple survey events: four survey rounds, one in September, October/November, December and January.

An abundance score was given to all species recorded at each site (Table 5). Because frogs become difficult to count in higher abundances, scoring is an effective way to estimate numbers. Equipment used included a Olympus digital voice recorder (Model LS-11), combination hygrometer and thermometer (Model LM-81HT) and a spotlight head-torch.

Water quality parameters monitored at each location during the tadpole surveys included electrical conductivity (a proxy for salinity) (µS/cm), pH, turbidity (Nephelometric Turbidity Units: NTU) and temperature (degrees Celsius) using a TPS multi-parameter meter (model 90-FLT Field Lab Analyser).

Table 4: Atmospheric variables observed and recorded at each location and at each recording.

Variable	Characteristic	Score
Moon	No moon	0
	Quarter moon	1
	Half moon	2
	Three-quarter moon	3
	Full moon	4
Wind	No wind	0
	Slight breeze	1
	Strong breeze	2
	Moderate wind	3
	Strong wind	4
Rain	No rain	0
	Drizzle	1
	Showers	2
	Moderate rain	3
	Heavy rain	4
Cloud	0%	0
	<5%	1
	5-25%	2
	25-50%	3
	50-75%	4
	>75%	5

Table 5: Abundance scores for nocturnal frog surveys.

Score	Abundance
0	0
1	1
2	2-9
3	10-50
4	>50

2.2.2 Tadpole surveys

Tadpole surveys were conducted on a monthly basis during each nocturnal survey round. Fyke nets were used to capture tadpoles and were set in or around fringing and emergent vegetation at each site. Two single-winged fyke nets and 10 box traps (shrimp traps) were set at each survey location spread across a distance of approximately 50 metres of wetland fringe (depending on habitat type and water depth).

The traps were set pre-dusk and were left overnight for an average of 15 hours. All species caught, including frogs, fish and crustaceans, were identified and abundances were recorded. To avoid potentially transferring pathogens between sites, traps were cleaned in a diluted bleach solution before re-use.

See Figure 2 for map of survey sites.

2.2.3 Habitat assessment

Habitat assessments were conducted at target monitoring sites to describe and record current conditions. This assessment reviewed both physical and biological attributes of the site, and was based upon the habitat assessment detailed by Native Fish Australia (Hammer 2005). Alterations were made to the recorded variables to reflect the wetland types that were being surveyed (Table 6). Table 7 shows cover abundance scores used to assess habitat features including submerged, floating, emergent, fringing and surrounding habitat.

Table 6: Habitat variables recorded at each targeted survey site.

Habitat Variables	
Wetland type (e.g. lake edge, marsh/swamp)	Submerged biological and physical cover (%)
Pool condition (e.g. dry, concentrated)	Floating vegetative cover (%)
Flow environment (e.g. ephemeral)	Emergent vegetative cover (%)
Flow	Fringing vegetative cover (%)
Land use	Surrounding vegetation cover (%)
Bank slope	Canopy cover (%)
Water quality (salinity, temperature, pH and turbidity)	

Table 7: Cover abundance scoring used within habitat assessments.

Score	**Cover Abundance (%)**
0	0
1	<5
2	5-25
3	25-50
4	50-75
5	>75

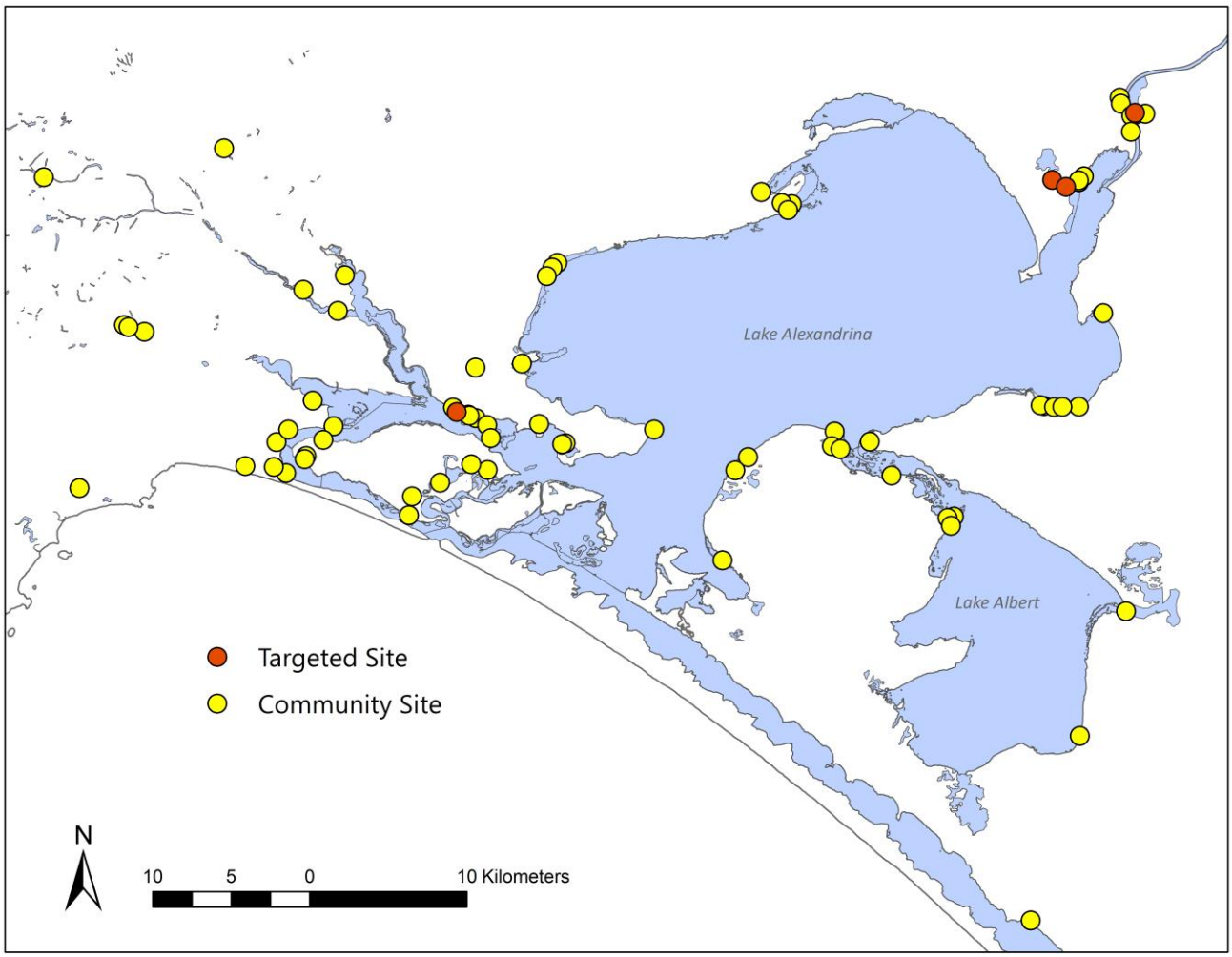


Figure 2: Map location of community and targeted frog monitoring sites.

Table 8: Location of community monitored and targeted survey sites (map datum GDA94)

Site	EASTING	NORTHING	Targeted monitoring site	Within 2km of the location of a historical ***L.raniformis*** record
442 Seven Mile Road	346790	6038507		
Alexandrina Station	347639	6071266		
Alexandrina Station near pump shed	347419	6071309		
Boggy Creek	312194	6067197		*
Clayton Bay Boardwalk	311433	6070489		*
Clayton Bay 'Ken and Sally's Swamp'	310974	6070702		*
Clayton Bay 'Red Top Bay'	311035	6070646		*
Clayton Bay 'Wetlands Beach'	311420	6073708		*
Cox Scrub Swamp	295402	6087668		
Dunn's Lagoon 'Ducks Hospital'	312161	6070048		
Dunns Lagoon 'Snug Cove'	312396	6069224		
Finniss River 'Wally's Landing'	303094	6079590		*
Goolwa Channel 'Knappsteins Site 1'	309991	6071160		*
Goolwa Channel 'Knappsteins Site 2'	310220	6070872	*	*
Goolwa 'Murray Smith Reserve'	298739	6068971		
Goolwa North 'Alison Avenue'	301877	5570094		
Goolwa North 'Currency Creek Rd'	301056	6071614		
Goolwa North 'Daniel Avenue'	302385	6069981		
Goolwa North 'Mark Lane West'	299494	6069770		
Goolwa South 'Bird Viewing Hut'	299358	6066990		
Goolwa South 'Golf Club'	298575	6067383		
Hindmarsh Island 'Captain Sturt Reserve'	301727	6069108		
Hindmarsh Island 'Denver Rd'	309173	6066386		
Hindmarsh Island Effluent Ponds	300649	6068078		
Hindmarsh Island 'Grey Paddock'	307186	6064311		
Hindmarsh Island Marina	300536	6067883		
Hindmarsh Island 'Murray Mouth Rd'	307388	6065514		
Hindmarsh Island 'Shadows Lagoon'	311160	6067547		
Loveday Bay	327167	6061433		
Low Point	351405	6077178		
Masondrina	349862	6071217		
Masondrina 'Lady Jude paddock'	348287	6071188		
Masondrina 'Lady Jude Windmill'	348812	6071211		
Meningie 'Hyde Avenue'	349921	6050259		
Milang Bay Wetland	316639	6080378		
Milang N.E. Wetland	316318	6080069		
Milang S.W. Wetland	315969	6079535		
Mount Compass Stormwater ponds new	283915	6085833		
Mt Jagged 'Back Dam'	289037	6076421		
Mt Jagged 'Currency and Crayfish Creek'	290337	6075995		
Mt Jagged 'Front Dam'	289315	6076285		
Murrundi Wetland North	352464	6090900		*
Murrundi Wetland South	352531	6090510		*

Narrung Narrows	341892	6064229		
Narrung Narrows Lot 3 Narrung Stud Rd	341493	6064135		
Narrung Narrows opposite 401 Narrung Stud rd	341493	6064135		
Narrung Narrows 'Warneke'	337928	6066842		
Narrung Pump	334295	6069631		
Narrung Wetland Pump Shed	334130	6068706		
Narrung Wetland Structure	334672	6068525		
Nurra Nurra Point	341706	6063639		
Pelican Lagoon - B (Lignum site)	348715	6084862	*O	*
Pelican Lagoon North Site 1	348163	6085663	*	*
Pelican Lagoon North Site 2	349862	6085522		*
Pelican Lagoon North Site 3	350180	6085888		*
Pelican Lagoon North Site 4	349868	6085634		*
Pelican Lagoon North Site 5	349033	6085223	*	*
Point Malcolm Lighthouse	336550	6068990		
Point Sturt 'Griffin'	315484	6070128		
Point Sturt 'Huczko Wetland'	322809	6069768		
Point Sturt 'Salty's'	317169	6068898		
Point Sturt 'Salty's 2'	316946	6068839		
Pomanda Point 'Causeway Gate'	346888	6079498	*O	*
Reedy Point Kindaruar	314378	6073958		
Teringie Site 1	328783	6068008		
Teringie Site 2	327971	6067163		
Tokuremoar Eastern side	296761	6067432		
Tolderol Bay 5	331267	6083914		*
Tolderol Bay 6	331570	6084123		*
Tolderol Bay 7	330926	6084193		*
Tolderol Main Channel	331334	6083738		*
Tookayerta Creek 'Winery Road'	300454	6078660		
Tookayerta 'Watkins'	302650	6077320		
Victor Harbour 'Stan Farquar Wetland'	286195	6066036		
Waltowa Structure Lake side	352860	6058196		
Waltowa Structure Wetland side	352872	6058193		
Wellington East 'Lake'	353489	6089835		*
Wellington East stormwater pond	354090	6089870		*
Wellington East Wetland	353434	6089933	*	*
Wellington East Wetland Site B	353214	6089741		*
Wellington 'Tolmer Rd'	353177	6088730		*
Wetland near Tolderol entrance gate	329637	6084886		*

O = Opportunistic

3.0 Results

3.1 Community frog monitoring

A total of 38 volunteers and six community groups undertook 237 frog surveys across 78 sites between September 2014 and March 2015. The location of survey sites were well distributed across Lake Alexandrina, Lake Albert, and the Eastern Mount Lofty Ranges/Eastern Fleurieu. The highest concentration of survey sites was in the western area of the survey region and near the townships of Narrung and Wellington (see Figure 2 for map location).

Frog surveys were generally well distributed between September and December (Figure 3), capturing expected peak calling times for a wide range of species, including *L. raniformis*. The least surveyed areas include the western and southern side of Lake Albert and the northern side of Lake Alexandrina. Across all community frog survey sites, 52 percent were surveyed on more than one occasion (Figure 4) and 15 percent were surveyed on more than five occasions. A total of 33% were surveyed on only one occasion, predominantly in September.

Frog surveys were recorded between 6.20pm and 1.50am, with the majority between 8pm and 11pm (Figure 5). Almost all recordings reached the recommended recording time of five minutes, and many exceeded this. Where recordings exceeded the standardised recording time, only the first five minutes of each recording were included in the analysis for the purpose of standardising the survey effort, however the full length of all recordings were listened to for species detection. No additional species per site or changes in abundance were observed beyond the first five minutes for all recordings and all frogs heard on the recordings were clear enough to be identified. The quality of the recordings were good to excellent with little human-induced noise. Generally noise that interfered with call identification was due to wind or birds.

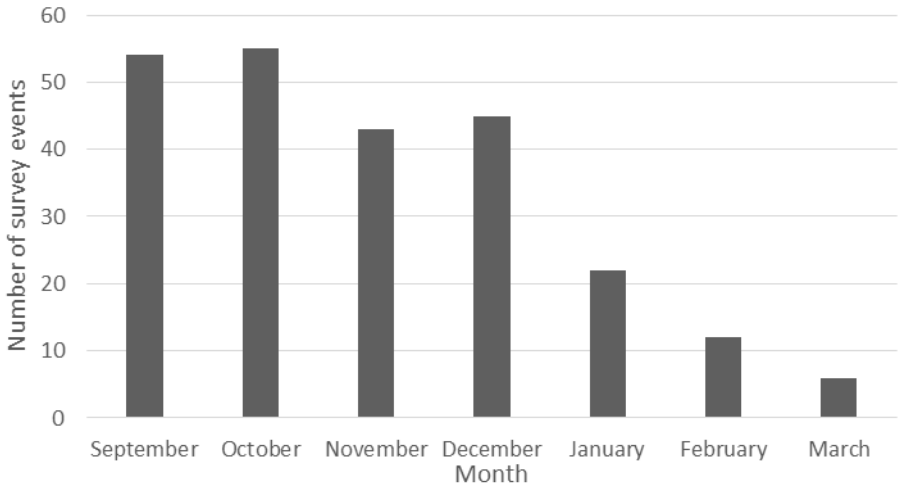


Figure 3: Number of community frog survey events undertaken per month between September 2014 and March 2015.

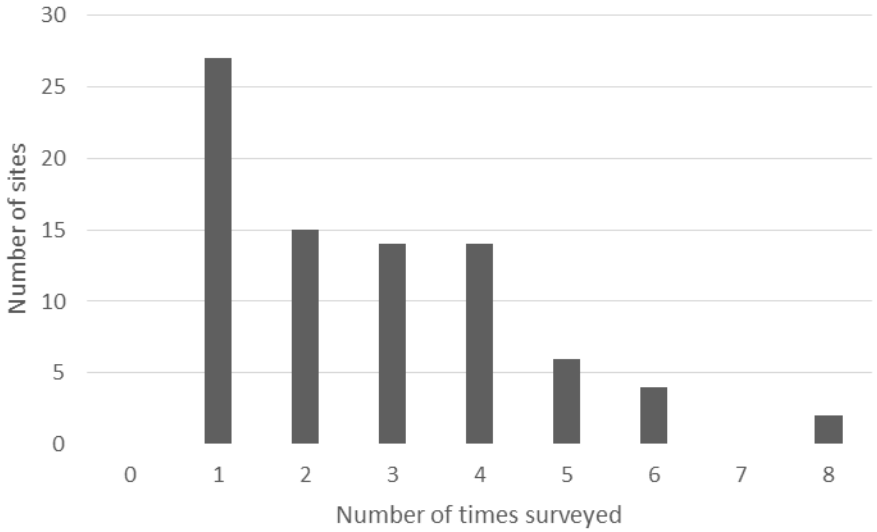


Figure 4: Number of times each site was surveyed (excluding targeted monitoring sites) between September 2014 and March 2015.

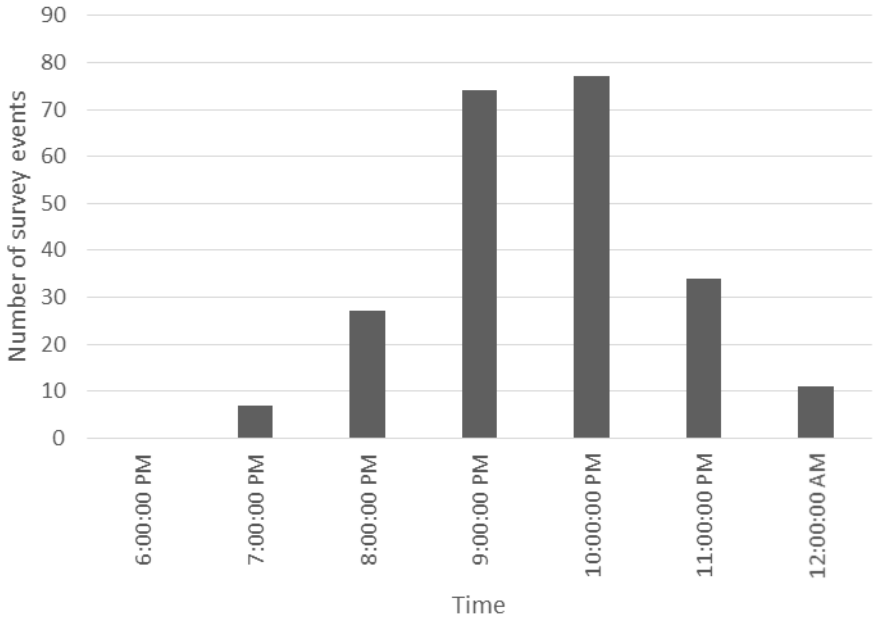


Figure 5: Distribution of community frog survey start times between 6.00pm and 1.00am in the period of September 2014 to March 2015.

3.2 Abundance and distribution of frog species

A total of eight frog species (including *L. raniformis*) were recorded in the study region in 2014/15. The highest diversity observed was six species at six sites (Goolwa 'Bird Viewing Hut', Low Point, Masondrina, Pelican Lagoon North Site 2, Pelican Lagoon North Site 4 and Wellington East Stormwater Pond) (Figure 7). For individual species maps see Appendix 3. The average number of species recorded per site was 3.49 (Figure 6). No frogs were recorded at four sites; Hindmarsh Island 'Captain Sturt Reserve', Hindmarsh Island Marina, Loveday Bay and Pelican Lagoon B, the latter of which was dry.

The most widespread and abundant species was the common froglet (*Crinia signifera*) which was detected at 86 percent of sites and in abundances of greater than 50 individuals at 39 percent of occupied sites (Figure 8). The abundance of common froglet in 2014/15 is comparable to previous years (Figure 9, Figure 10). The spotted grass frog (*Limnodynastes tasmaniensis*), brown tree frog (*Litoria ewingi*) and Eastern banjo frog (*Limnodynastes dumerilii)* were detected at 52 percent, 53 percent and 58 percent of sites respectively. For the brown tree frog, these results are comparable to 2013/14 when the species was again well distributed in the region recorded at 63 percent of sites. In 2014/15, the Eastern banjo frog and spotted grass frog were less distributed than in previous years, being recorded at 72 percent and 83 percent of sites respectively in 2013/14. A table of the full results for each species per monitoring site can be found in Appendix 2. Individual species abundance maps are presented in Appendix 3.

The detected distribution of long-thumbed/barking marsh frogs (*Limnodynastes fletcheri*) has continued to increase since monitoring began in 2009. In 2014/15, it was recorded at 51 percent of sites compared to 17.5 percent of sites in 2009. Abundance of long-thumbed frogs per site was greater within the western (Hindmarsh Island, Goolwa Channel and Finniss River areas) and within the north-eastern side of Lake Alexandrina. *L. fletcheri* was detected in abundances of 10 to 50 (score of 3) at 15 locations and greater than 50 individuals (score of 4) at six locations.

The brown tree frog (*Litoria ewingii*) was generally well distributed throughout the study area, detected at 63 percent of sites. It was observed calling in low abundances with a score of 2 (2-9 individuals) recorded at 44 percent of sites which is comparable to observations in 2013. Individuals were occasionally spotlighted during active searches between October 2014 and January 2015, often during or after rain.

The Peron's tree frog (*Litoria peronii*) was successfully identified at 11 sites (13 percent) in areas nearby or in the townships of Goolwa and Wellington, at Pelican Lagoon and on the eastern side of Lake Alexandrina at 'Masondrina'. Calling was observed throughout the survey period between September 2014 and January 2015 with the highest abundance score of 3 (10-50 individuals) recorded at five locations across Wellington East Wetland and Goolwa North 'Alison Ave', a stormwater dam.

Painted frog (*Neobatrachus pictus*) was detected by active searching (spotlighting) at four sites, the highest abundances recorded in January at Tokureamour Reserve and an effluent pond in the township of Goolwa where 13 and 10 individuals were spotlighted respectively.

Species known to occur in the CLLMM region but not detected in 2013 include Bibron's toadlet (*Pseudophryne bibronii*), and Sudell's frog (*Neobatrachus sudelli*) both of which generally breed following heavy rainfall or outside of the target survey period as part of this project (Tyler and Walker 2011).

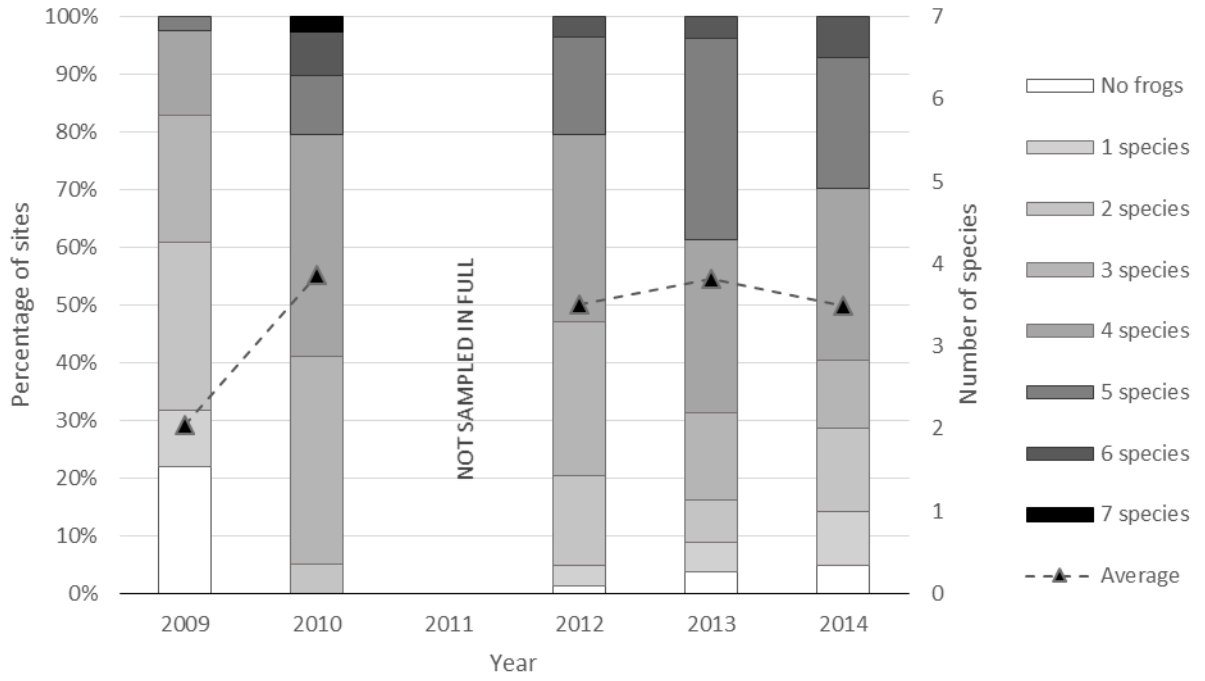


Figure 6: Percentage of sites per year associated with the number of species recorded per site and the average number of species per site. The total number of sites were 40 in 2009, 41 in 2010, 76 in 2012, 81 in 2013 and 84 in 2014.

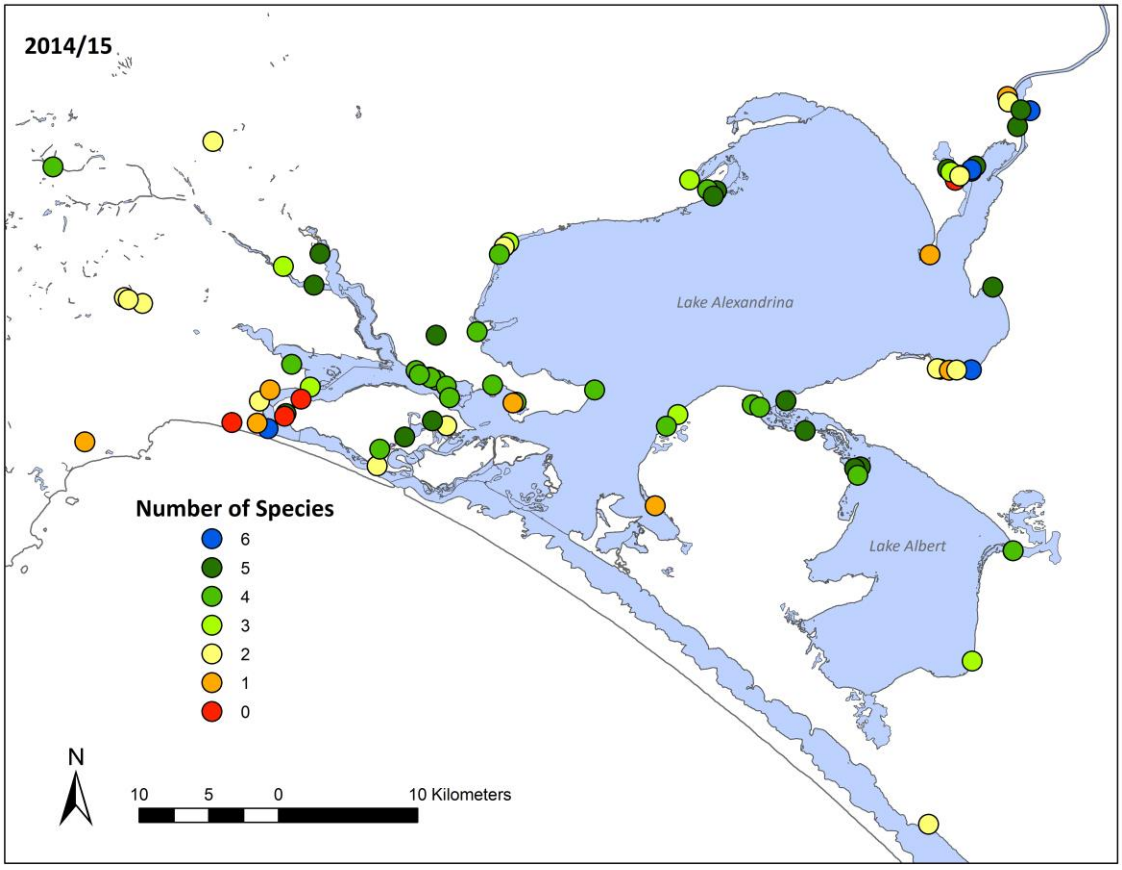


Figure 7: Species diversity including *L. raniformis* observed across all monitored locations in 2014/15

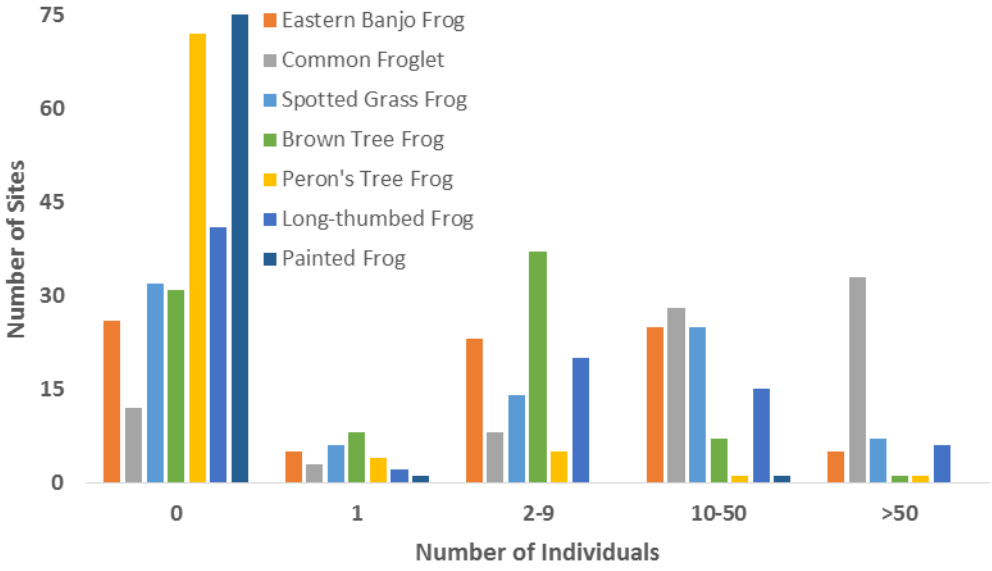
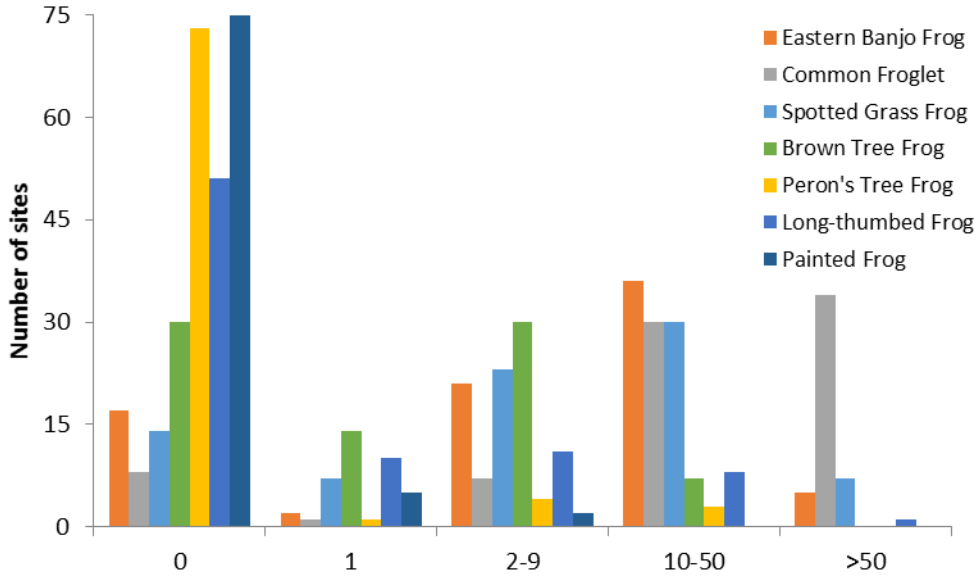


Figure 8: Distribution of abundance scores per species in 2014/15 across 84 sites.

a)



b)

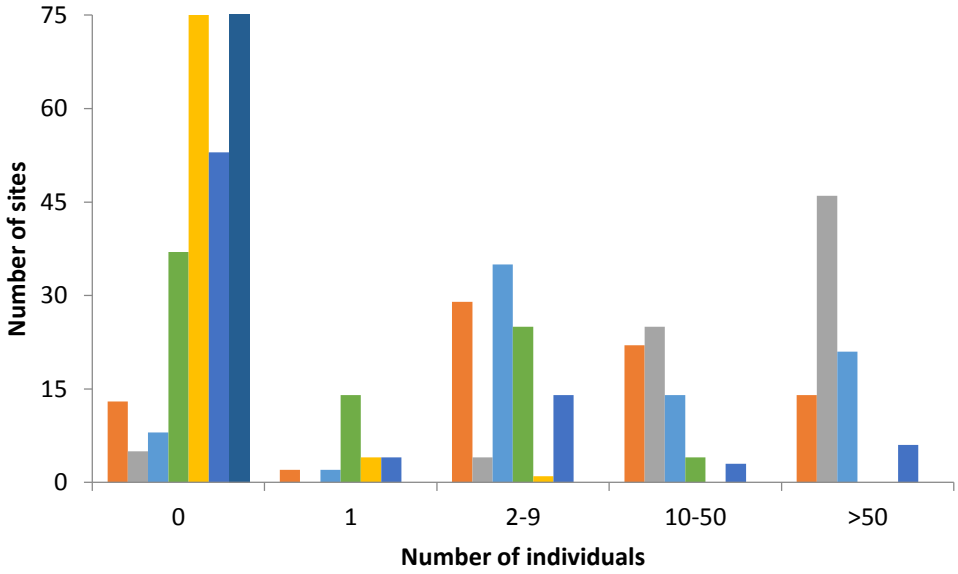
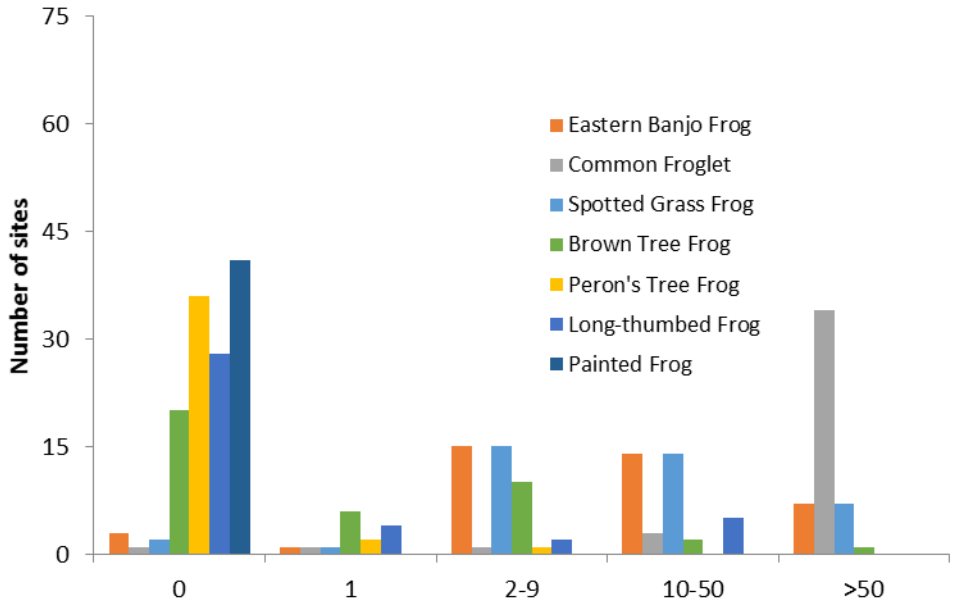


Figure 9: Distribution of abundance scores per species in a) 2013/14 across 81 sites and b) 2012/13 across 76 sites

a)



b)

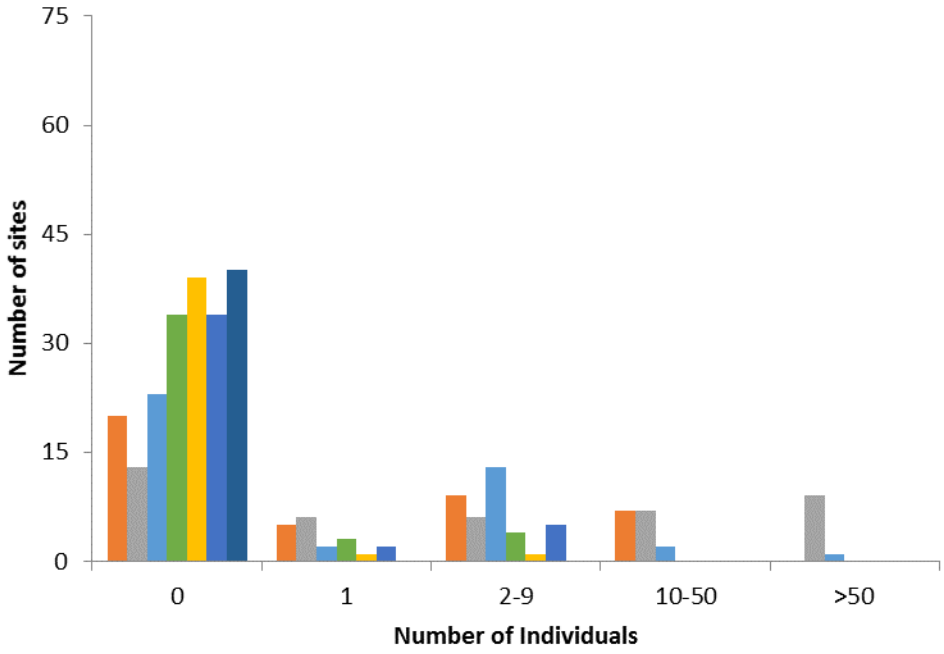


Figure 10: Distribution of abundance scores per species in a) 2010 across 41 sites and b) 2009 across 40 sites.

3.3 *L. raniformis* results

3.3.1 Nocturnal survey results

Nocturnal surveys were conducted in conjunction with tadpole surveys as part of targeted monitoring at four sites on four occasions between October 2014 and January 2015. Surveys were undertaken during early nightfall (between 8pm and 11pm). A total of 78 sites were surveyed by community volunteers on one to three occasions between June 2013 and January 2014. A total of 250 survey events were undertaken between project staff and volunteers.

L. raniformis was detected at only one location, Goolwa Channel 'Knappsteins 2' (Table 9, Figure 11). This location was known, to be inhabited by the species from recent or historical records (Holt et. al 2004, Mason 2010, Mason & Hillyard 2011, Walker 2000), the most recent record of one individual in September 2013 and January 2014 (Mason 2014). Abundance of calling *L. raniformis* was considered extremely low across the study region as only one individual male was observed calling on each of the two occasions.

Male *L. raniformis* were observed calling between 7.50 and 8.50pm. Weather and atmospheric conditions recorded at Goolwa Channel 'Knappstein's 2" on each survey event during 2013/14 are presented in Table 9 and show little trend in detection rates in relation to moon phase, rain presence, wind speed, cloud cover, temperature and relative humidity.

Calling individuals utilised sparse emergent common reed (*Phragmites australis*) and sea rush (*Juncus krausii*) intermingled with patches of moderate to dense submerged aquatic plants including red milfoil (*Myriophyllum verrucosum*) and water milfoil (*Myriophyllum salsugineum*). In close proximity to calling individuals were stands of river clubrush (*Schoenoplectus validus*), common rush (*Eleocharis acuta*) and water couch (*Paspalum* sp.) on the wetland fringes.

Table 9: Abundance of *L. raniformis* per method and weather and atmospheric scores and results per survey event where *L. raniformis* were detected.

	Call Recognition	Playback Response	Active Searching	Moon (0-4)	Rain (0-4)	Wind (0-4)	Cloud (0-5)	Temperature (°C)	Relative Humidity (%)
21/10/2014	1	0	0	0	0	1	3	26	33.8
18/11/2014	1	1	0	0	0	2	2	15.8	70.1
17/12/2014	0	0	0	0	0	0	1	13.2	82.1
3/02/2015	0	0	0	4	0	3	4	16.7	75.7

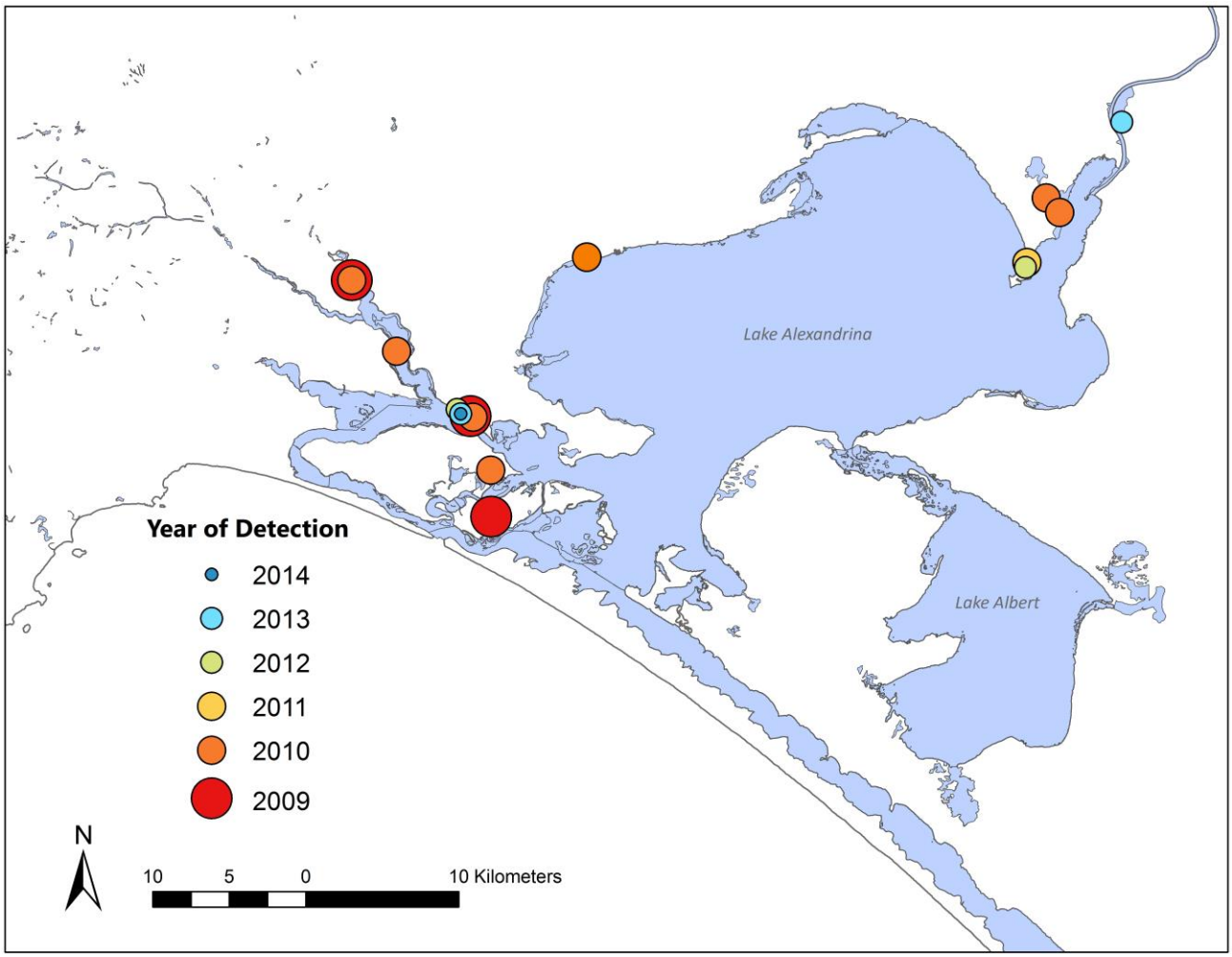


Figure 11: Sites occupied by *L. raniformis* between September 2009 and March 2015.

3.3.2 Tadpole surveys

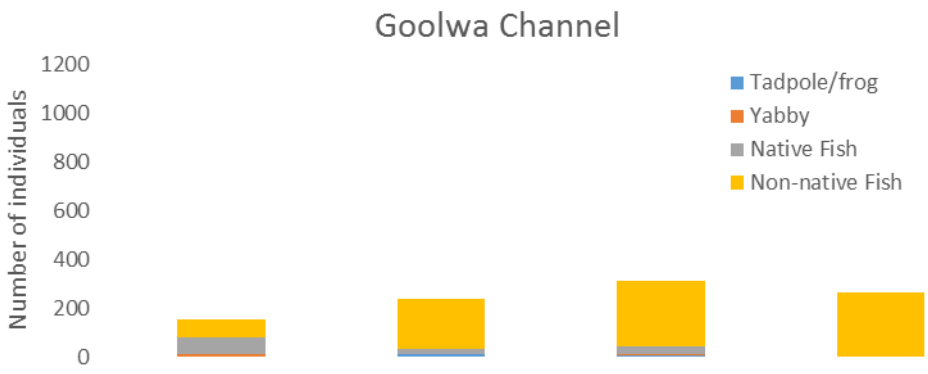
Tadpole surveys were conducted on a monthly basis between October 2014 and February 2015. These were undertaken at three sites where *L. raniformis* have been detected in recent years, Wellington East Wetland, Pelican Lagoon and Goolwa Channel 'Knappstein's 2'near Clayton Bay. Additional opportunistic surveys were conducted at Goolwa Channel 'Knappstein's 1' and Pomanda Point. No *L. raniformis* tadpoles were captured throughout the duration of the survey. See **Error! Reference source not found.** for detailed results of total captures.

A total of 674 tadpoles from three genus (*Litoria, Limnodynastes* and *Crinia*) were captured, 90 percent (n = 607) of which were captured at Wellington East Wetland. Of these, 89.6 percent were from the genus *Limnodynastes* which includes three species local to the CLLMM region; The Eastern banjo frog, spotted grass frog and long-thumbed frog.

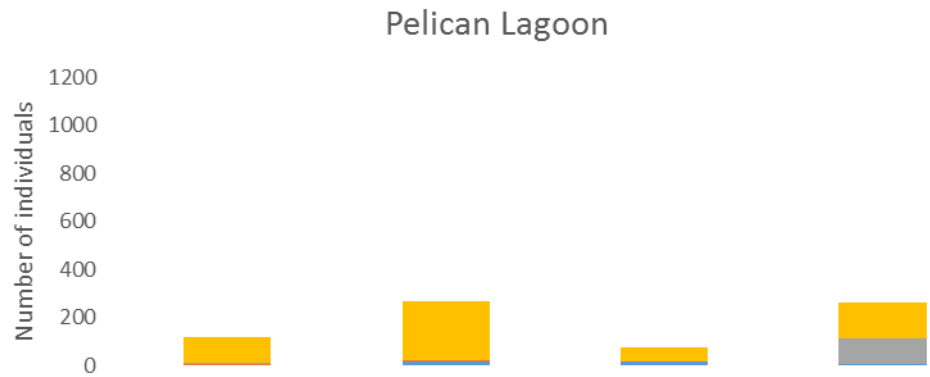
In total, eight native and three introduced fish species were captured. The most abundant fish species captured was the Eastern gambusia (*Gambusia holbrookii*) which constituted 61.5 percent of the total catch. The highest abundance of Eastern gambusia was captured at Wellington East Wetland which accounted for 78.9 percent of the total Eastern gambusia captured. The most abundant native fish species captured were from the carp gudgeon complex (*Hypseleotris* species) which constituted 10.2 percent of the total catch, of which 88 percent were captured at Wellington East Wetland.

Common carp (*Cyprinus carpio*) represented 7.8percent of the total catch, predominantly captured at Goolwa Channel 'Knappstein's 2' and Pelican Lagoon North. Large adult common carp were observed feeding in shallow water at each sampling event at Goolwa Channel 'Knappstein's 2'. The common carp captured where predominantly juvenile due to the 50mm mesh grills installed within the opening of the fyke nets (see section 2.2.2 for methodology) to prevent the capture of large fish and turtles which could impact the condition and survival of *L. raniformis* tadpoles.

a)



b)



c)

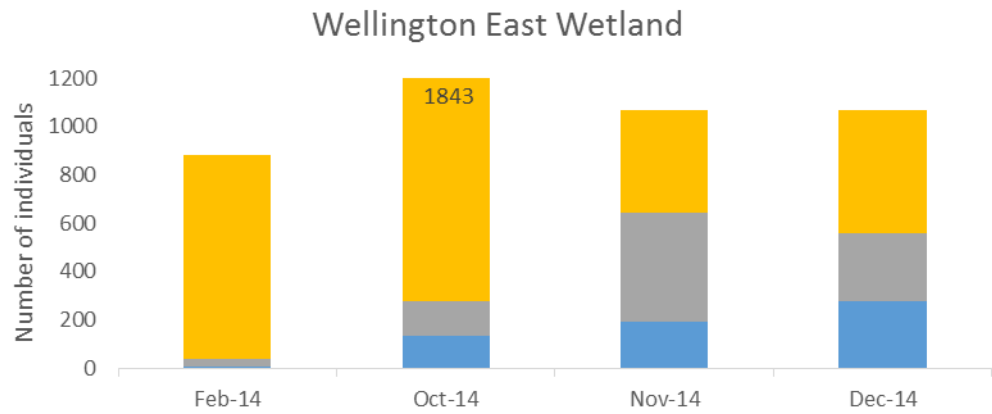


Figure 12: Total captures per survey event at a) Goolwa Channel 'Knappstein's 2' b) Wellington East Wetland and c) Pelican Lagoon 'Wellington Dairies' between October 2014 and February 2015 according to species type.

3.3.3 Description of area occupied by *L. raniformis*

Although all sites are considered wetland environments, in this assessment the term wetland was used to describe well-defined lagoons/water bodies in comparison to sites that directly fringe a lake or river/creek which can be less easily defined. Wind seiching (wind tides) is a significant feature of the River Murray reach below Lock 1. The movement of water by wind can be significant, raising or lowering water levels on a regular basis by ±10-60 cm, occasionally more. In this assessment, wind seiching was not incorporated into the definition of flow, but it is important to note that it was present at all sites connected to Lake Alexandrina and Lake Albert.

The only site where *L. raniformis* was found to be present in 2014/15 was Goolwa Channel 'Knappstein's 2'. A summary of the observational characteristics of the site is provided in Table 10. This site is a modified fringing wetland, approximately 10 hectares in size, on the north side of the Goolwa Channel, west of Clayton Bay Township. The survey site lies within the sheltered, semi-open highland side of the wetland. The north-western portion of the wetland contains remnant features from the period when the area was reclaimed for irrigated Lucerne (pers. comm. C. Knappstein) where *L. raniformis* was first detected in 2012. The south-eastern section is natural wetland with past modifications to the north and west side for mooring purposes. The wetland is moderate in depth (0.5-1.5 metres) and contains fringing and emergent reed beds predominantly common reed, river clubrush (*Schoenoplectus validus*) and common spike-rush (*Eleocharis acuta*) intermingled by couch grass (*Paspalum sp.*), spiky club-rush (*Schoenoplectus pungens*) on the fringes. Beyond the immediate two-metre band of fringing vegetation the area is mown for maintenance purposes by the landholder. Beyond the densely vegetated fringe the wetland contains scattered emergent reeds and submerged plant and algae communities including milfoil (*Myriophyllum* sp.) and hornwort (*Ceratophyllum demersum*) (Figure 13). Goolwa Channel 'Knappstein's 2' contained generally gradually sloping edges in addition to areas of man-made (or altered) steep-sloping banks. *L. raniformis* were not observed calling directly within these edges but from the open/semi-open water habitat. The site was predominantly surrounded by grasslands including pastures.

Table 10: Observational site description and attributes of Goolwa Channel 'Knappsteins' 2, occupied by *L. raniformis* from results of habitat assessment.

SITE	HABITAT TYPE	SITE MODIFICATION	FLOW ENVIRONMENT	FLOW	BANK SLOPE	LANDUSE	SUBSTRATE
Knappstein's 2	Wetland	Modified	Permanent	None	Steep/ Gradual incline	Recreation/ Restoration	Mud

a)

b)

c)

d)

e)

f)

Figure 13: a) Goolwa Channel 'Knappstein's 2' November 2014; b) Extensive submerged aquatic plants at Goolwa Channel 'Knappstein's 2' October 2014; c) Wellington East Wetland November 2014; d) Extensive submerged aquatic plants at Wellington East Wetland October 2014; e) Pelican Lagoon 'Wellington Dairies 1' October 2014 and f) Pelican Lagoon 'Wellington Dairies 2' December 2014.

3.3.4 Assessment of habitat values of sites occupied by *L. raniformis*

Description of the of vegetation communities at each site was divided into submerged, floating, emergent, and fringing vegetation, and an estimation of cover abundance (%) was given to each of these categories.

The single site occupied by *L. raniformis* in 2014/15, Goolwa Channel 'Knappsteins 2' contained a diverse assemblage of submerged, emergent and fringing vegetation of varying density. The site contained moderate to good cover abundance of submerged aquatic vegetation of between 5-25 percent (Table 11) with moderate diversity and included hornwort and red milfoil (Myriophyllum verrucosum), water milfoil (Myriophyllum salsugineum), eea tassel (Ruppia megacarpa) and filamentous green algae (Figure 13).

Scores assigned to floating vegetation incorporate both non-living organic debris and living plants (e.g. duckweed). Goolwa Channel 'Knappsteins 2' contained cover abundance of the water's surface of azolla sp. in 2014/15 of approximately 5 percent which was then absent at the time of the last targeted monitoring event in February 2015. In 2009, floating vegetation was incorporated within the emergent vegetation score which needs to be taken into consideration when comparing to results in successive years. (Table 11).

Common reed, rver clubrush, common rush, sea rush and water couch were the dominant emergent species within the 50-metre survey area of the Goolwa Channel 'Knappsteins 2' site. The cover abundance of emergent vegetation was consistent throughout the study period. Moderate to large stands of common reed were observed in the vicinity of the survey area.

The results showed little trend in the abundance of *L. raniformis* in relation to cover abundance of each vegetation type due to the low number of sites in which they have been found (Table 11). However, calling males were observed to be utilising similar habitats with similar vegetation scores in 2009, 2010, 2011, 2012 and 2013. In all years, the highest abundance of calling males was found amongst semi-open emergent vegetation of 5-50 percent cover and 1-25 percent cover of submerged or floating vegetation/debris. Although dense stands of tall reeds, predominantly common reed have often been in close vicinity of areas occupied by *L. raniformis*, males have not been detected utilising these areas for calling.

Table 11: Assessment of vegetative cover at sites occupied by *L. raniformis* per survey year 2009 – 2014 (0=0% cover, 1=<5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=>75%) displayed as averages taken across three assessments.

	Occupied Site	Submerged (0-5)	Floating Aquatic (0-5)	Emergent (0-5)	Fringing (0-5)	Maximum *L. raniformis* abundance recorded
2014/15	Goolwa Channel 'Knappsteins 2'	2	1	2.5	5	1
2013/14	Goolwa Channel 'Knappsteins 2'	0.75	1	2.5	5	1
	Wellington East	2	1	3	5	2-9
2012/13	Goolwa Channel 'Knappsteins 1'	1	0	2	4	1
	Nalpa Station 'Pomanda Point Causeway'	1	1	3	2	10-50
2011/12	Nalpa Station 'Pomanda Point Causeway'	1.5	0.5	2.5	1.5	3
2010/11	Clayton Bay 'Community Boardwalk	3	1	4	5	1
	Hindmarsh Island 'Boggy Creek'	1	1	3	5	1
	Hunters Creek 'Wyndgate Crossing'	1	1	3	5	1
	Finniss 'Sterling Downs'	2	0	3	5	2-9
	Finniss 'Wally's Landing'	2	1	2	5	2-9
	Pelican Lagoon 'Site 1'	1	1	2	4	>50
	Pelican Lagoon 'Site 2'	1	0	2	5	>50
2009/10	Clayton Bay 'Red-top Bay'	2		*5 (3 – emergent, 2 – floating)	5	10-50
	Finniss 'Wally's Landing'	2		*4	3	2-9
	Mundoo Island	5		*2	3	1

*this score incorporated floating vegetation in 2009/10, a breakdown of the score used field notes where possible

3.4 Water quality, water levels and rainfall

3.4.1 Water quality at targeted monitoring sites

Water quality was monitored on four occasions during each targeted monitoring round in October, November and December 2014 and January 2015. Water quality was monitored in the evening prior to or during nocturnal surveys between 6.30 and 10.55pm.

Where *L. raniformis* were detected calling at Goolwa Channel 'Knappsteins 2' in October and November 2014, water quality results were generally recorded within the preferred ranges for wetland productivity for low lying wetlands in South-Central Australia including; salinity, measured as Electrical conductivity (EC), below 5,000 µS/cm, pH between 5 and 9, dissolved oxygen (DO) above 5 parts per million (ppm) and turbidity generally less than 100 NTU (ANZECC 2000, Baldwin et al. 2005, Tucker 2003). However, DO cycles diurnally is generally at its lowest in the early morning as aquatic plants and algae respire (Tucker 2003). As water quality was sampled near the peak of the diurnal cycle it should be expected that DO levels in the morning would be lower than what was observed in the evening.

Across the targeted monitoring sites salinity ranged between 651 µS/cm and 2,403 µS/cm (Table 12). Both the highest and lowest EC results were recorded at Pelican Lagoon 'Wellington Dairies 2', demonstrating the variability at this site over the survey period. This site is located at the junction of the River Murray and Lake Alexandrina, receiving freshwater inflows from upstream (via the narrow main inlet to Pelican Lagoon downstream) and the effects of wind movement between the two basins that constitutes Pelican Lagoon, the furthest of which experiences elevated salinities. The highest salinity result of 2,403 µS/cm was recorded when water levels had decreased, reducing connectivity between the lagoon and the River Murray. Salinity at the remaining sites were less variable throughout the survey period. EC ranged between 1202 and 1398 µS/cm at Goolwa Channel 'Knappstein's 2', the highest result recorded in February 2015 when water levels had decreased. Salinities at Wellington East Wetland, the site at which *L. raniformis* was observed in low-moderate numbers in 2013/14, maintained marginally elevated salinity levels throughout the duration of the survey period ranging between 1,925 and 2,365 µS/cm. Wellington East Wetland does not have a known open connection to the adjacent River Murray but water passes through a degraded bank and willow (*Salix* sp.) root mass. The low turbidity results (between 6.6 and 26.4 NTU), low fish diversity and lack of large-bodied species captured in the tadpole surveys suggests that connectivity and fish movement between the wetland and the river is limited. The highest DO results across all sites were recorded at this site, ranging between 8.38 and 8.8 and were likely influenced by the extensive aquatic plant and algae communities present throughout the duration of the survey period. The substrate at Pelican Lagoon 'Wellington Dairies 1' and 'Wellington Dairies 2' contained a high proportion of organic matter predominantly decomposing root mass of reeds and leaf matter (from bulrush) and likely contributed to the low DO results.

Salinity at targeted monitoring sites were generally more than that of Lake Alexandrina or the Goolwa Channel recorded at the closest telemetry water quality station (Figure 14). An increase in salinity was observed throughout the survey period within both the targeted monitoring sites and Lake Alexandrina/Goolwa Channel. It is important to note at targeted monitoring sites salinity is measured close to the wetland fringes at approximately 40cm of depth where salinity is expected to be higher than in deeper water due to mobilisation of salts from soils, increased evapo-concentration and reduced mixing.

Table 12: Water quality results at targeted monitoring sites during each of the four monitoring rounds between October 2014 and February 2015 and the corresponding *L. raniformis* abundance observed during each survey event.

Site	Date	Time	Temperature (°C)	Electrical Conductivity (µS/cm)	pH	DO (ppm)	Turbidity (NTU)	Highest abundance of L. raniformis recorded
Goolwa Channel 'Knappsteins' 2	21/10/2014	6:30:00 PM	22.5	1202	7.3	5.87	225	1
	18/11/2014	7:26:00 PM	19.4	864	7.3	7.69	82.5	1
	17/12/2014	10:42:00 PM	20.5	1308	7.7	6.75	107	0
	3/02/2015	10:55:00 PM	25.1	1398	7.6	5.89	42.7	0
Pelican Lagoon 'Wellington Dairies' 1	30/10/2014	8:00:00 PM	17.8	808	7.3	2.5	63.6	0
Pelican Lagoon 'Wellington Dairies' 2	26/11/2014	8:00:00 PM	22.5	651	7.3	4.49	37.3	0
	17/12/2014	8:00:00 PM	23.1	734	6.8	1.3	32	0
	5/02/2015	8:30:00 PM	20.2	2403	7.4	6.7	44.5	0
Wellington East Wetland	30/10/2014	10:00:00 PM	13	2020	7.9	8.38	6.6	0
	26/11/2014	9:15:00 PM	17.5	1925	7.9	8.45	7.1	0
	17/12/2014	9:35:00 PM	22.9	2010	7.1	8.8	10.3	0
	4/02/2015	9:25:00 PM	20.6	2365	7.4	8.42	26.4	0

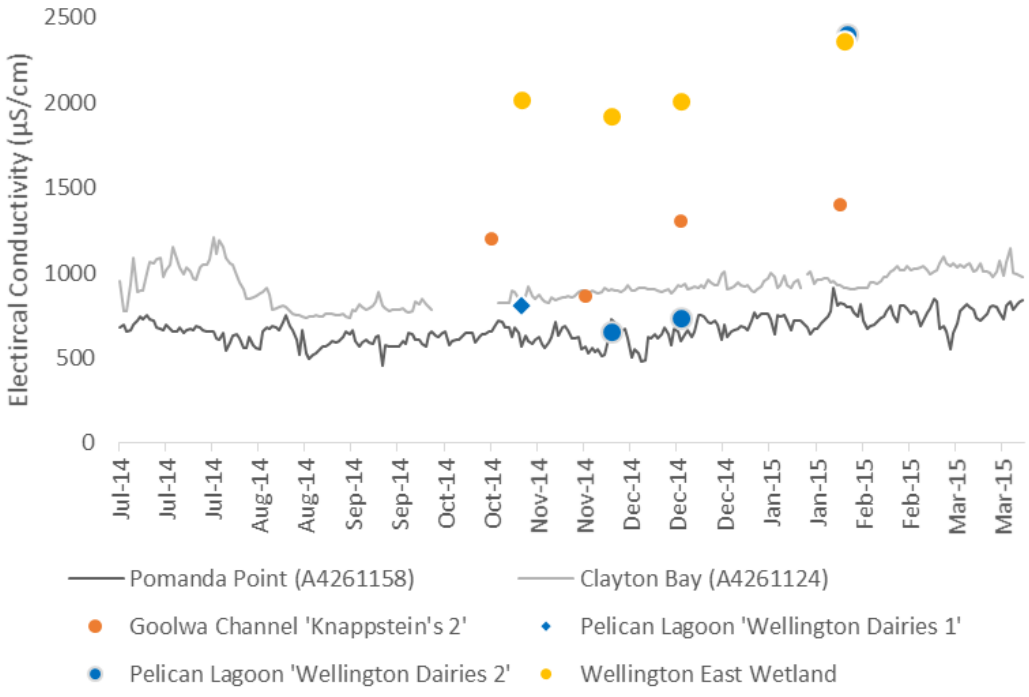


Figure 14: Salinity recorded at targeted monitoring sites and salinity levels from telemetry water quality stations in Lake Alexandrina (Pomanda Point – A4261158) and Goolwa Channel (2km West of Clayton Bay - A4261124) between July 2014 and March 2015 (Lake and Goolwa Channel salinity data source www.waterconnect.sa.gov.au).

3.4.2 Water Levels

Average daily water level data was sourced from two telemetry water quality monitoring stations located closest to targeted monitoring sites located in the Goolwa Channel near Clayton Bay and within Lake Alexandrina near Pomanda Point.

In 2014/15, water levels peaked in August 2014 at 0.858 mAHD, just prior to the survey period, however, continued to fall as low as approximately 0.344 mAHD near Clayton Bay in May 2015 (Figure 15). Throughout monitoring efforts between 2009 and 2014, *L. raniformis* have generally been observed in higher abundances when water levels have exceeded 0.7-0.75 mAHD (Mason 2014, Mason 2013, Mason & Hillyard 2012, Mason 2010) (Figure 16). Between July 2014 and May 2015, water levels were maintained above 0.7 mAHD for approximately 27 percent of the time and above 0.75 mAHD for approximately 14 percent of the time, predominantly between July and September. Water levels exceeded 0.8 mAHD for approximately 5 percent of the water year in July and August 2014 for a total of 17 days (non-consecutively).

On the two occasions where a single *L. raniformis* was detected at Goolwa Channel 'Knappstein's 2' in October and November 2014, water levels at the closest telemetry water quality station (Goolwa Channel 2km West Clayton Bay, A426114) were 0.722 and 0.68 mAHD respectively.

In the years where *L. raniformis* has been most abundant (2009 within the Goolwa Water Level Management Area and 2010 upon the return of flows), water levels prior to survey events had recently increased resulting in the inundation of large areas of previously dry sediments.

3.4.3 Rainfall

Daily mean rainfall data from the Bureau of Meteorology (BOM) was obtained from weather stations at Brinkley South (west of the township of Wellington) and Hindmarsh Island to gain an understanding of the climatic conditions characteristic of 2014 across the study region (Figure 17).

The total annual rainfall recorded for 2014 was 27.4 percent less at Hindmarsh Island and 18.8 percent less at Brinkley South than the respective means (BOM 2015). This follows five years of near or above-average rainfall, however, below average rainfall in the September to December period (the targeted survey period) in 2011, 2012 and 2014. Combined monthly rainfall for the period between September and December 2014 was 58.5 percent lower than the mean monthly rainfall at Brinkley South and 40.5 percent lower at Hindmarsh Island.

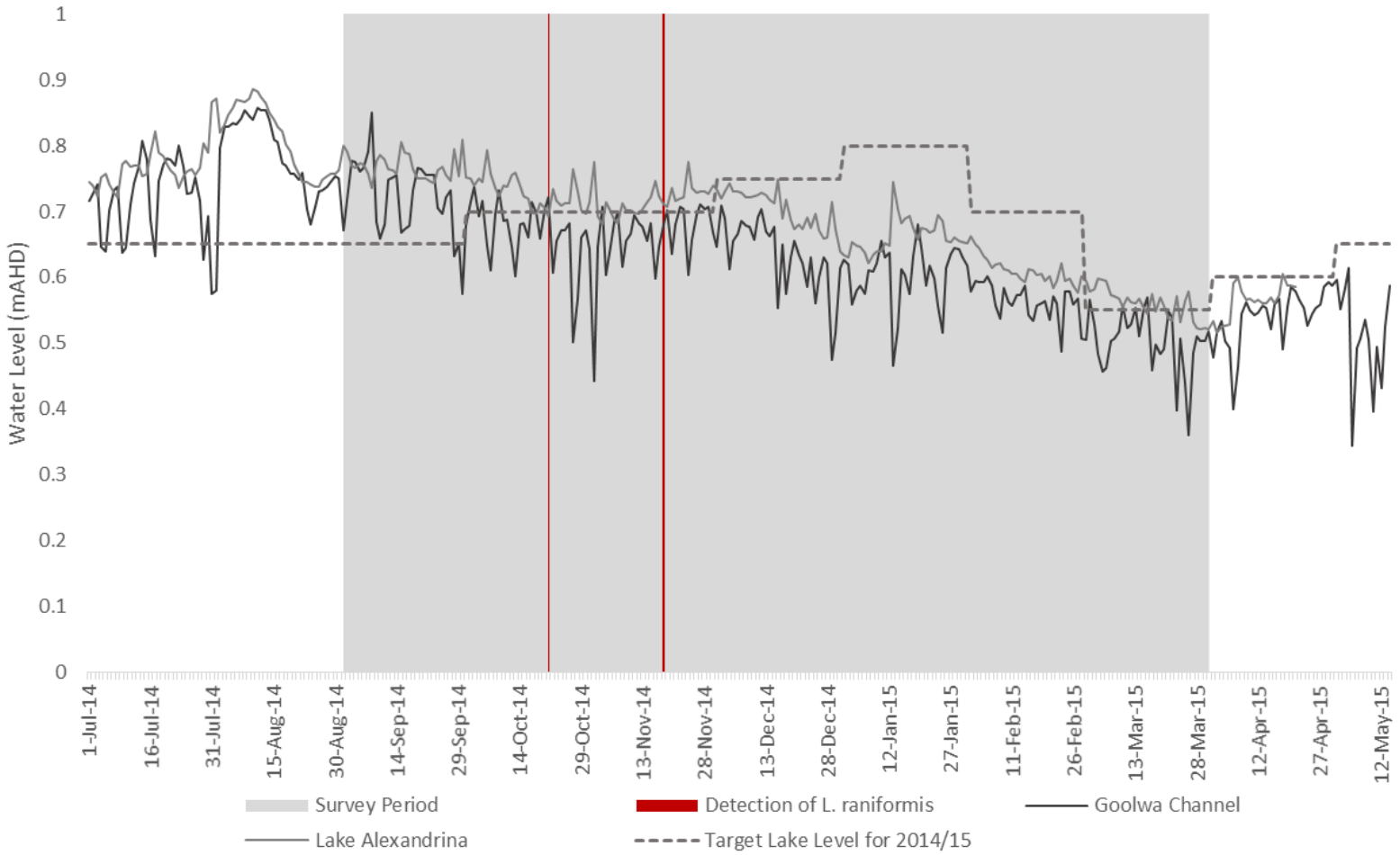


Figure 15: Timing of detection of *L. raniformis* against targeted water levels for the 2014/15 water year (source: The Living Murray 2015) and the average daily water levels (in metres Australian Height Datum) obtained from telemetry stations Goolwa Channel 2km West Clayton Bay (station A426114) and Lake Alexandrina 4km West Pomanda Point (station A4261158) during the 2014/15 survey period between September 2014 and March 2015 (water level data source www.waterconnect.sa.gov.au).

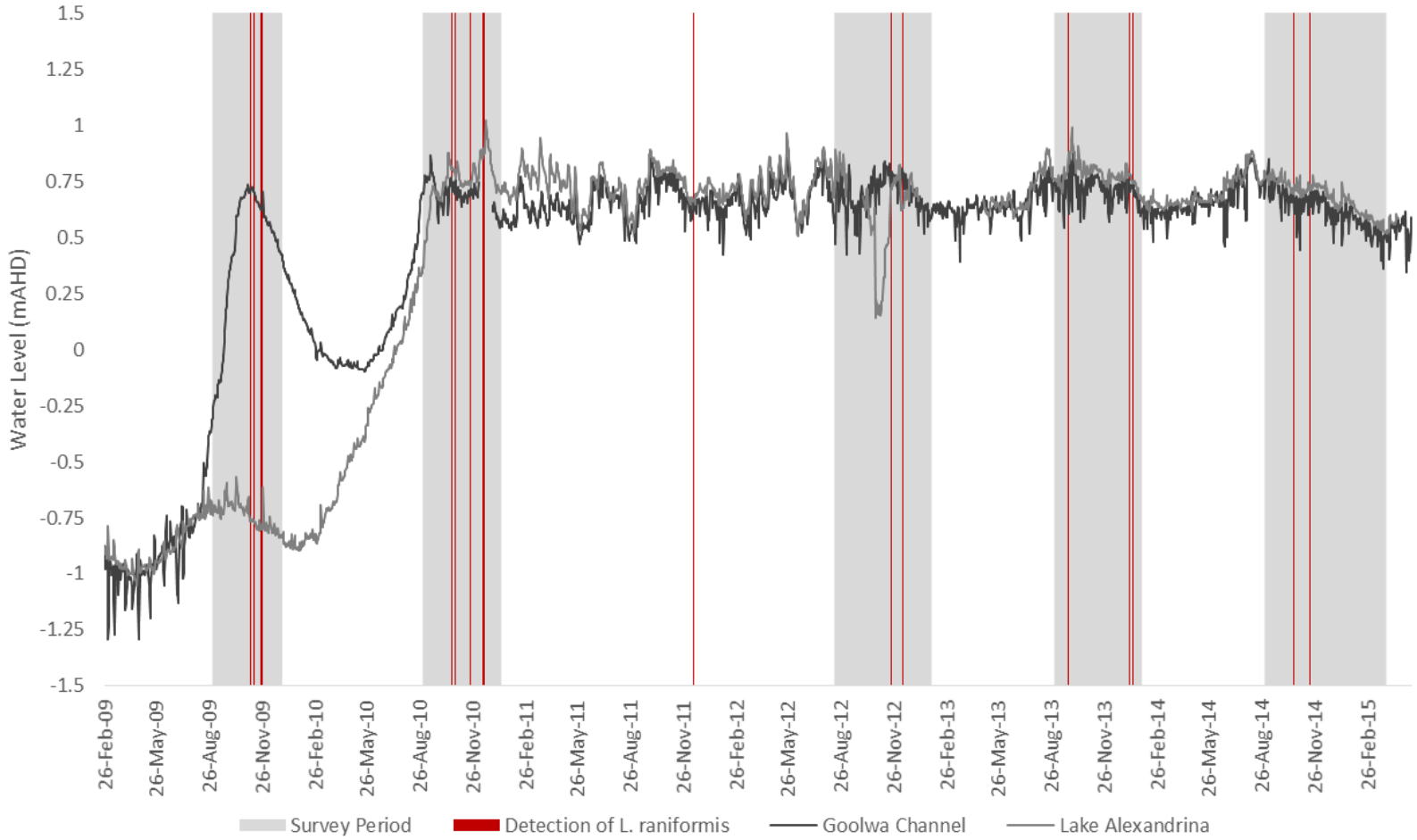
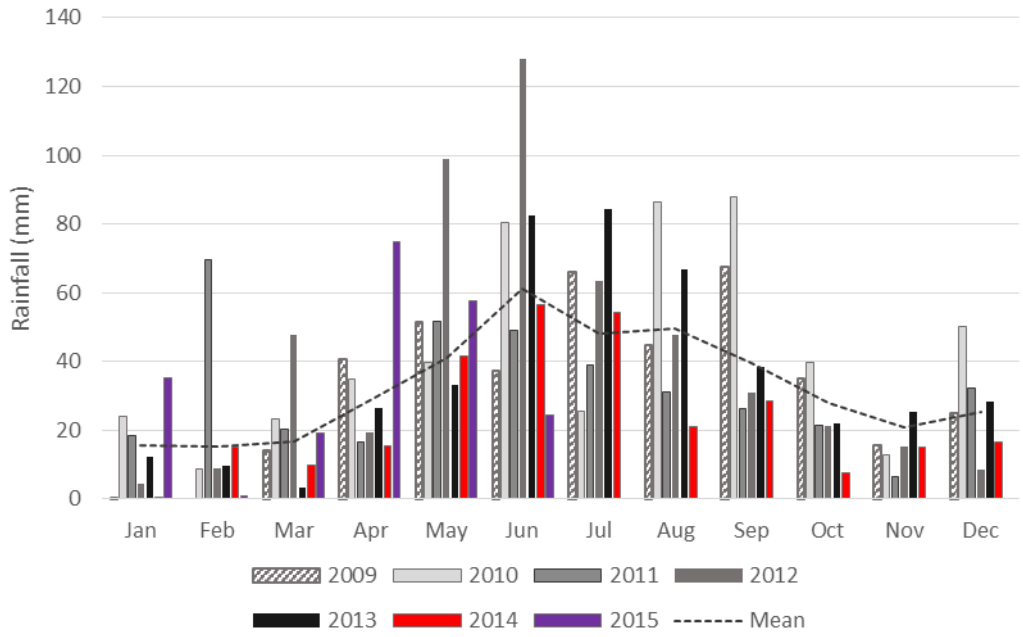


Figure 16: Timing of detection of *L. raniformis* against survey periods and average daily water level readings (in metres Australian Height Datum) from telemetry stations Goolwa Channel 2km West Clayton Bay (station A426114) and Lake Alexandrina 4km West Pomanda Point (station A4261158) between 2009 and 2015 (water level data source www.waterconnect.sa.gov.au

a)



b)

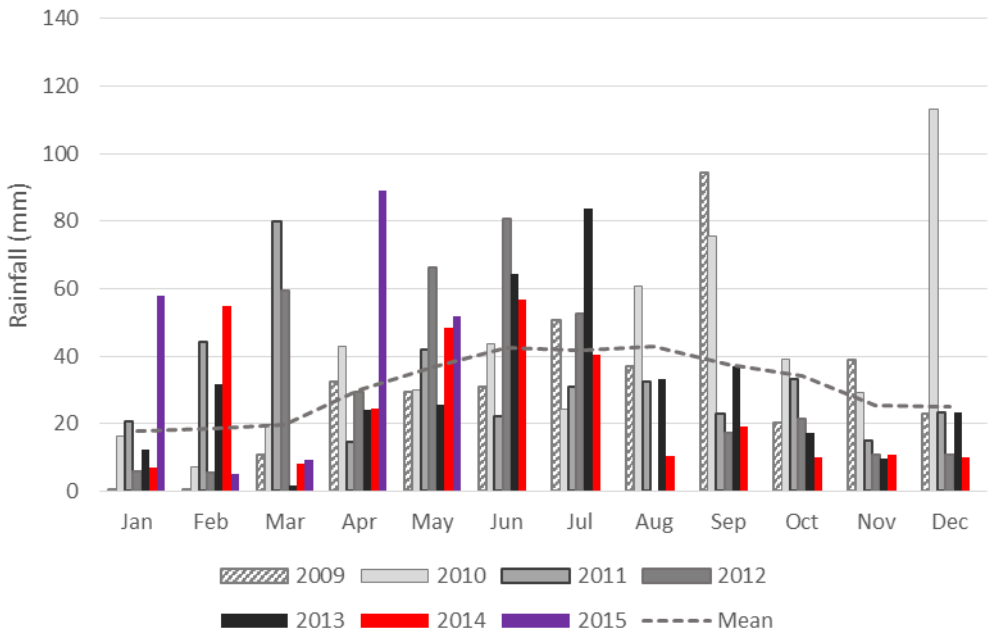


Figure 17: Monthly and median rainfall between January 2009 and May 2015 at a) Hindmarsh Island (station 23894) and Brinkley South (station 24572) (Data source: BOM 2015).

4.0 Discussion

4.1 Volunteer-based frog monitoring

Overall the monitoring conducted by volunteers was of a high quality and was effective in capturing a greater spatial area. It is considered that this is largely due to the existing knowledge and skills within communities in the CLLMM region, the face-to-face support provided by project and the relatively simple methodology and equipment provided. However, ongoing support is required in order to achieve the level of data required to assess trends. The existing relationships and networks that have been built with volunteers and community groups over recent years in the CLLMM region provide the foundation to detect how frog communities respond to their ever changing environment, provided there is consistency in the support available to those networks. The progression to the numerous online tools and applications that are now available currently do not meet the needs of community frog monitors in South Australia that was once met by past programs such as the EPA Frog Census, a platform that engaged with hundreds of people across the state.

Besides the reportable, quantitative results that volunteers contribute, it is also acknowledged that indirect outcomes have arisen from this community driven monitoring project. Outcomes observed as part of this project include increased skills and knowledge, greater awareness raising on environmental issues, particularly conservation of water-dependent biota.

4.2 Frog Abundance and Distribution

The locations of the 82 survey sites around Lake Alexandrina, Lake Albert and the tributaries were well distributed and are considered to meet the project objective to increase the number and spatial distribution of survey efforts. The distribution and abundance of frog species in CLLMM region during 2014/15 was generally to be expected and was comparable to 2013/14. The differences observed was the lower abundance of two of the most common species, the Eastern banjo frog and the spotted grass frog. Although fewer survey events were conducted in November, December and January, both of these species have been observed calling more frequently in months of August to October in past years and it is unlikely that the survey effort later in the survey period is due to the observed decrease in abundance. Lake Levels were highest prior to the commencement of community frog surveys and it is likely that higher abundances would have been observed during this period. The time required for tadpoles of these species to complete metamorphosis indicates that suitable habitat was inundated long enough for recruitment to be successful. Tadpoles from the *Limnodynastes* genus, which includes both the Eastern banjo frog and spotted grass frog (and long-thumbed frog), were detected at all targeted monitoring sites supporting this.

4.3 *L. raniformis* in the CLLMM region

4.3.1 Abundance and distribution

Out of 84 sites surveyed only one site was found to be occupied by *L. raniformis* in 2014/15. Goolwa Channel 'Knappsteins 2' is located near the township of Clayton Bay in the south-west of the region and was previously occupied in 2013, 2012 and in close vicinity to a site occupied in 2009 suggesting the species has persisted in this area for over six years. The observation of only one individual frog displaying breeding behaviour (calling) on two occasions suggests the species is present in extremely low abundance in the CLLMM region. The continued recovery of wetland habitats within the fringes of Lake Alexandrina, Lake Albert and the tributaries of Currency Creek and Finniss River since the return of water levels in 2010 have resulted in increased habitat complexity and amount of available habitat. It was anticipated that, in areas, these habitats would be conducive for *L. raniformis* breeding events.

The decline in water levels that occurred throughout the duration of the survey period resulted in the drying of fringing areas above 0.5-0.6 mAHD, including some areas previously occupied by *L. raniformis*. However, the expansion and diversification of submerged and emergent plant communities in the region provided areas of similar vegetative structure to that of previously occupied sites. The response by *L. raniformis* to water level management during past years (2009-2013) and the knowledge of the species readiness to favour newly inundated areas (Pyke 2002, Wassens 2011) suggests that water levels were the primary driver in *L. raniformis* occupancy in 2014/15. Calling activity may also have occurred in the two months directly prior to the survey period when higher lake levels prevailed. The highest abundances of *L. raniformis* across all survey events between 2009 and 2014 have been within recently inundated areas suggesting greater variation in water levels will promote an increase in breeding behaviour (calling).

Rainfall is known to influence movement and subsequent breeding behaviour of many frog species in Australia (Hamer at al 2008). Reduced rainfall was observed in the CLLMM region during what is considered a peak period for *L raniformis* breeding (October to January) in 2014. Although in some circumstances climatic conditions have not been found to contribute greatly to the movement of *L raniformis* individuals (Wassens et al 2008), the reduced rainfall was coupled with a decline in lake levels, however as suitable wetland habitat was still present during this period, it is worthy of further investigation.

Other threats which have not been assessed include the presence of Chytridriomycosis disease (Chytrid fungus) in frog species in the CLLMM region and predation from fox and cat populations and introduced fish, particularly Eastern gambusia (*Gambusia holbrookii*) and redfin (*Perca fluviatilis*).

4.3.2 Habitat use

The vegetative structural composition at the one location in which *L. raniformis* was detected calling was similar to that of previous years. The low level of detection across sites enables little opportunity for further analysis of habitat requirements of the species in the CLLMM region. Where *L. raniformis* were detected, adult males were recorded calling from within semi-open water with sparse coverage of emergent reeds and/or rushes, floating debris and moderate abundance of submerged aquatic plants. In all years assessed it was observed that sites entirely dominated by dense vegetation (particularly reeds) did not yield successful detection of *L. raniformis* (Mason 2010, Mason & Hillyard 2011).

Maintenance of more complex habitats in the region is likely to be an important element in promoting successful breeding events. *L. raniformis* is a species highly responsive to flooding, and inundation of suitable breeding habitat is one of the known cues for calling (Schultz 2007). The lower water levels observed during late 2014/early 2015 provided an opportunity for terrestrial and sub-aquatic plants to become established at lower elevations. This potentially provides a cue for *L. raniformis* as lake levels rise and re-inundate these areas which will comprise substantial vegetative structure suitable for breeding. Incorporating periods of lower water levels when planning lake level management during each water year will likely result in more dynamic wetland habitats and increase the likelihood of successful recruitment in *L. raniformis*.

5.0 Recommendations

- Continue to provide support to community-based frog monitoring by providing volunteers with assistance, face-to-face technical support, training opportunities and feedback. A publicly accessible platform to store and view monitoring results is needed to improve how results can be disseminated, increase the level of ownership of the data and therefore instill a longer-term investment by community members in wetland and frog conservation. Campaign for greater consistency in multiple sampling rounds to increase monitoring efforts across the desired sampling period and enable greater assessment of trends.

- Increase seasonal variability of water levels in the Lower Murray to cue breeding events and to increase the breadth of the littoral zone, increasing areas of suitable breeding habitat for *L. raniformis*. Incorporating an early spring increase in water level above 0.7 mAHD and a slow decline in water level in summer into a future water regime for the region is anticipated to generate large areas of suitable habitat for spawning. Based on the known timing of tadpole presence, inundation of these shallow fringing habitats for a minimum of three months would increase the probability of hatching and survival of tadpoles. Acknowledging the species is considered to be relatively long-lived (DEC 2005), these proposed fluctuations in water levels may not be an annual requirement. Acknowledging the magnitude of constraints that exist in the management of water levels, opportunities to manage suitable wetlands in isolation to the lake should be investigated.

- Monitor *L. raniformis* populations in the CLLMM region in response to continued water level management and changes in habitat condition. Collection of more detailed data relating to *L. raniformis* response to changes in water levels will assist in providing recommendations for lake level management.

- Assess impediments to flow and loss of habitat complexity from colonisation of reeds (particularly common reed and bulrush) in wetlands in the CLLMM region. Investigate options to improve connectivity and increase emergent plant diversity. For example; sensitive reed control methods to reinstate natural flow paths to wetlands, delivery of environmental water to above pool fringing wetlands and trial interactions between land management practices and plant diversity.

- Investigate means to assess habitat use and requirements of *L. raniformis* outside of the breeding season to determine impacts of changes in terrestrial habitat to survival.

- Undertake an assessment of the presence of Chytridiomycosis disease in frogs in the CLLMM region.

References

ABS. 2015. *Data by region.* Australian Bureau of Statistics, Australian Government. http://stat.abs.gov.au/itt/r.jsp?databyregion accessed 20th May 2015.

Anstis, M. 2013. Tadpoles and Frogs of Australia. New Holland Publishers. Sydney.

Baldwin, D. S., Nielsen, D. L., Bower, P. M. & Williams, J., 2005. *Recommended Methods for Monitoring Floodplains and Wetlands.* Canberra: Murray-Darling Basin Commission and the Murray-Darling Freshwater Research Centre.

Bice, C. M and Zampatti, B. P. 2014. *Fish assemblage structure, movement and recruitment in the Coorong and Lower Lakes in 2013/14*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2011/000186-4. SARDI Research Report Series No. 800. 61 pp.

BOM. 2015. *Climate Data Online*, Bureau of Meterology. Australian Government. http://www.bom.gov.au/climate/data/ accessed 1st June 2015.

Bjornsson, K. T. 2006. *Narrung Wetland Management Plan*. Coorong District Local Action Plan Committee, Tintinara.

Christy, M.T. and Dickman, C.R. 2002. *Effects of salinity on tadpoles of the green and golden bell frog* (*Litoria aurea*). Amphibia-Reptilia 23: 1–11.

Clemann, N. and Gillespie, G.R. 2010. *National Recovery Plan for the Growling Grass Frog* Litoria raniformis. Department of Sustainability and Environment, Melbourne.

Cree, A. 1984. *Breeding biology, respiration, and larval development of two introduced frogs* (Litoria raniformis and L. ewingii), New Zealand Journal of Zoology, 11:2, 179-187.

DEH, 2006. *Threatened species of the South Australian Murray-Darling Basin: Golden Bell Frog* Litoria raniformis*, Vulnerable*. Department for Environment and Heritage Murraylands Region, Fact Sheet 2542.06/Golden Bell Frog 7/06.

DfW 2010a. *River Murray Flow Update – 3rd December 2010*. www.waterforgood.sa.gov.au/news-info/publications/river-murray-flow-advice, Department for Water, Adelaide.

Frahn, K., Gehrig, S., Nicol, J. and Marsland, K. 2014. *Lower Lakes Vegetation Condition Monitoring – 2013/14*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2009/000370-6. SARDI Research Report Series No. 795. 83 pp.

Hocking, D. J. and Babbitt, K. J. 2014. *Amphibian contributions to ecosystem services*. Herpetological Conservation and Biology 9(1) 1−17.

Komak, S. and Crossland, M. 2000. *An assessment of the introduced mosquitofish (Gambusia affinis holbrooki) as a predator of eggs, hatchlings and tadpoles of native and non-native anurans.* Wildlife Research, 27, 185–189

Gonzalez, D., Scott, A. & Miles, M. 2011. *Amphibian, reptile & mammal vulnerability assessments-Attachment (3) to 'Assessing the vulnerability of native vertebrate fauna under climate change to inform wetland and floodplain management of the River Murray in South Australia*'. Report prepared for the South Australian Murray-Darling Basin Natural Resources Management Board.

Hammer, M. 2005. *Fish Survey Manual*. Draft. Native Fish Australia, South Australian Branch, Adelaide SA.

Heard, G.W. Robertson, P. Scroggiec, P. 2006. *Assessing detection probabilities for the endangered growling grass frog (*Litoria raniformis*) in southern Victoria*. Wildlife Research 33(7) 557–564.

Holt, M., Swingler, K., O'Donnell, E., Shriley, M., Malke, M., Conallin, A., Meredith, S., Ho, S., Prider, J., Poulson, D., Richardson, S., and Cooling, M. 2004. *River Murray Wetlands Baseline Survey: Volume 1 Data Report 2, 2004*. Sinclair Knight Merz, Melbourne, for the SA Murray Darling Basin Natural Resources Management Board, Adelaide.

Mason, K. 2010. *Southern Bell Frog (*Litoria raniformis*) Inventory of Lake Alexandrina, Lake Albert and Tributaries*. SA Murray Darling Basin Natural Resources Management Board, Murray Bridge, South Australia.

Mason, K., Hillyard, K. 2011. *Southern Bell Frog (*L. raniformis*) monitoring in the Lower Lakes. Goolwa River Murray Channel, tributaries of Currency Creek and Finniss River and Lakes Alexandrina and Albert*. Report to Department for Environment and Natural Resources. The South Australian Murray Darling Basin Natural Resources Management Board, Murray Bridge. South Australia.

Mason, K. 2014, *Frog Monitoring in the Coorong, Lower Lakes and Murray Mouth Region 2013/14*. Department of Environment Water and Natural Resources, Murray Bridge, South Australia.

Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, D.C., USA.

Morgan, L.A. and Buttemer, W. A. 1996. *Predation by the non-native fish* Gambusia holbrooki *on small* Litoria aurea *and* L. dentata *tadpoles*. Australian Zoologist 30 (2).

Simpson, D., Holt, M., Champion, T., Horan, A and Shirley, M. (Eds.). 2006. *River Murray Wetlands Baseline Survey-2005*. Sinclair Knight Merz, Melbourne, for the SA Murray Darling Basin Natural Resources Management Board, Adelaide.

Paton, D and Bailey, C. 2010. *Responses of aquatic vegetation to environmental watering of the Narrung wetland 2009-10*. Draft report. School of Earth and Environmental Sciences University of Adelaide, SA.

Robertson, P., Heard, G & Croggie, M. 2002. *The ecology and conservation status of the growling Grass Frog (*Litoria raniformis*) within the Merri Creek Corridor, Interim report: distribution, abundance and habitat requirements*. Report to the Department of Natural Resources and Environment, East Melbourne, Victoria. Wildlife Profiles Pty Ltd and the Arthur Rylah Institute for Environmental Research.

Robinson, M. 2000. *A field guide to frogs of Australia: From Port Augusta to Fraser Island, Including Tasmania*. Reed New Holland, French's Forest.

Schultz, M. 2007. *Distribution and detectability of the Southern Bell Frog Litoria raniformis in the South Australian River Murray Floodplain*. SA Murray Darling Basin Natural Resources Management Board, Berri.

Seaman, R. L. 2003. *Coorong and Lower Lakes habitat-mapping program.* Conservation Programs, Department for Environment and Heritage, South Australia.

Smith M.J, Schreiber S.G, Scroggie M.P, Kohout M, Ough K, Potts J, Lennie R, Turnbill D, Jin C & Clancy T. 2006. *Associations between anuran tadpoles and salinity in a landscape mosaic of wetlands impacted by secondary salinisation*. Arthur Rylah Institute, Heidelberg, Victoria, Department of Sustainability and Environment,

Environmental Water Reserve and River Health Division, East Melbourne, Victoria, Department of Agriculture, Fisheries and Forestry Bureau of Rural Sciences, Canberra, Australia.

Stratman, B. 2007. *A survey for the Southern Bell Frog (*Litoria raniformis*) in the Mosquito Creek Catchment, south-eastern Australia.* Department for Environment and Heritage.

Tucker, P. et al., 2003. *Your Wetland; Supporting Information*. Renmark: Australian Landscape Trust.

Tucker, P. 2004. *Your Wetland: Monitoring Manual – Data Collection*. River Murray Catchment Water Management Board, Berri and Australian Landscape Trust, Renmark.

Tyler, M. J. & Walker, S. J. 2011. *Frogs of South Australia.* Third Edition. Belair SA.

Walker, S. & P. M. Goonan. 2000. Frog Census 2000: *Community monitoring of water quality and habitat condition in South Australia using frogs as indicators*. Environmental Protection Agency, Adelaide.

Walker, S. 2002. Frog Census 2002: *Community monitoring of water quality and habitat condition in South Australia using frogs as indicators*. Environmental Protection Agency, Adelaide.

Wassens, S., Arnaiz, O., Healy, S., Watts, R. and Maguire, J. 2008 *Hydrological and habitat requirements to maintain viable Southern Bell Frog (*Litoria raniformis*) populations on the Lowbidgee floodplain- Phase 1*. Final Report DECC. Queanbeyan.

Wassens, S., Watts, R. J., Jansen, A. & Roshier, D. 2008. *Movement patterns of southern bell frogs (*Litoria raniformis*) in response to flooding*. Institute for Land, Water and Society, School of Environmental Sciences, Charles Sturt University, Wagga Wagga. Wildlife Research 35(1) 50–58.

Wassens S. 2005. *The use of space by the endangered Southern Bell Frog (*Litoria raniformis*) in the semi-arid region of New South Wales*, Australia. PhD Thesis Charles Sturt University.

Wedderburn, S. 2014. *An assessment of threatened fish populations in Lake Alexandrina and Lake Albert, South Australia*. The University of Adelaide, Adelaide, 30.

Wedderburn, S. and Hillyard, K. 2010. *Condition Monitoring of Threatened Fish Species at Lake Alexandrina and Lake Albert (2009-2010)*. Page 42. The University of Adelaide, Adelaide.

Appendices

Appendix 1: Field data sheet for community frog monitoring loan kits

Field Datasheet

Date of Recording *(eg 23/09/2007)*	**Starting Time** *(eg 21:30)*
Your name:	**Frog Kit Number:**
Your contact number:	**Recording Number:**

Site Name

Details of New Site – *Collect at location data at site with GPS or Map references or ask one of the staff to find the location data for you*

Map / GPS Reference Northing (7 digits) or Latitude:	Easting (6 digits) or Longitude:
Map Zone (52,53 or 54):	
Site description:	

WEATHER *(please circle)*

Rain: No Rain / Drizzle / Showers / Moderate Rain / Heavy Rain **Rain within last 2 days:** Yes / No

Moon-phase: No Moon / Quarter Moon / Half Moon / Three-quarter Moon / Full Moon / Hidden

Wind Speed: No Wind / Slight Breeze / Strong Breeze / Moderate Wind / Strong Wind

Cloud cover: 0% / <5% / 5-25% / 25-50% / 50-75% / >75%

Temperature:

Cold / cool / mild / warm / hot

HABITAT *Please select **one** habitat type that best reflects the major habitat at the site.*

☐ Dam	☐ Pond	☐ Wetland	☐ Swamp or Flooded Paddock or Marshland
☐ Drain/Channel	☐ River or Floodplain	☐ Stream/Creek	☐ Garden (eg Fernery or Grassy Area)
☐ Lakeshore	☐ Reservoir or Lake		☐ Other_____

WATER QUALITY *If you can see the water, please indicate the condition of the site. Please select all categories that apply.*

Water Appearance: ☐ Clear ☐ Polluted ☐ Foamy ☐ Oily ☐ Stained ☐ Muddy ☐ Other

Describe water appearance:

Could you hear frogs calling? *(please circle)* **Yes** **No**

COMMENTS or OBSERVATIONS *(such as; site is grazed by stock, water is flowing, water has pungent smell etc.)*

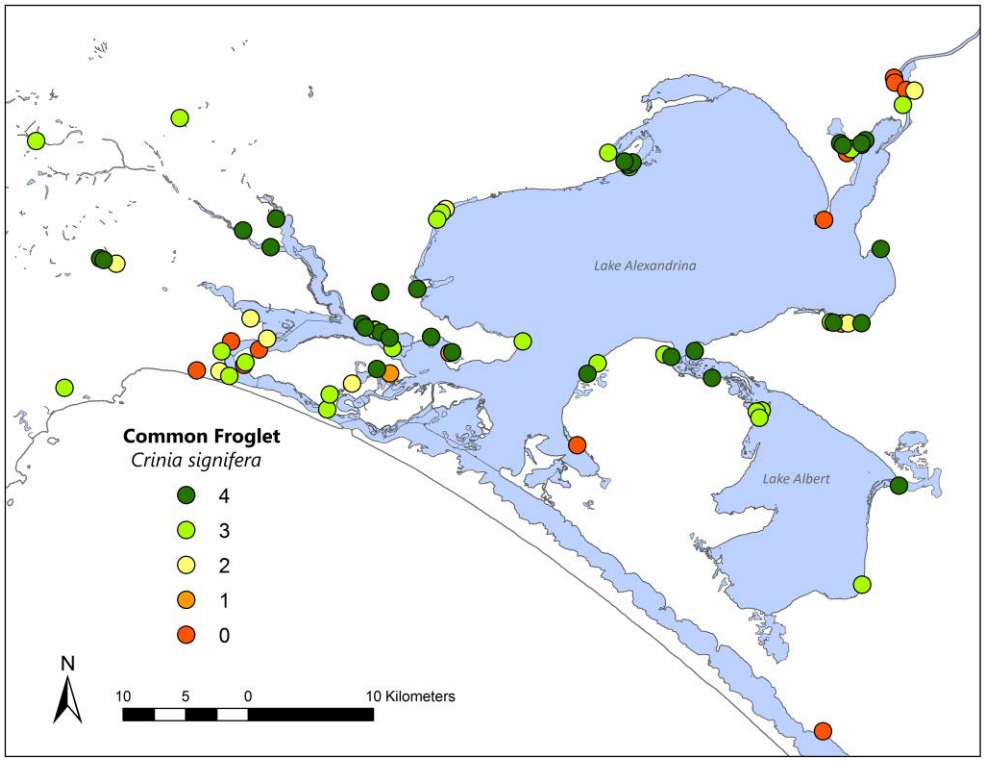
Thank you for being involved; we hope you had fun.

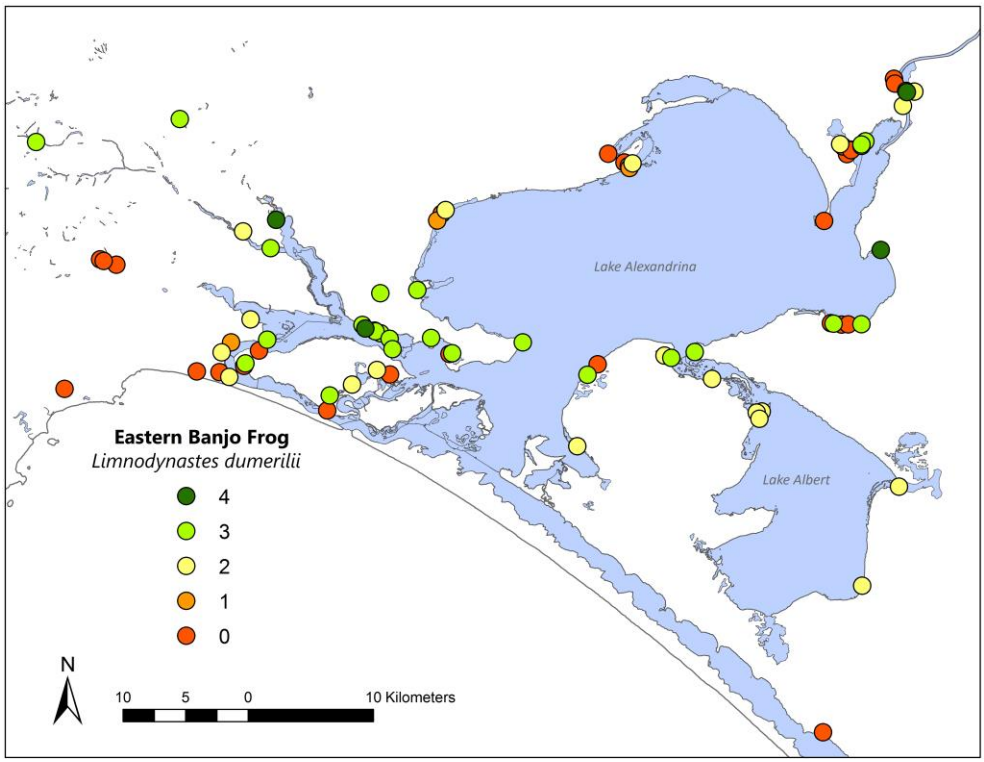
Appendix 2: Results of nocturnal surveys at all sites **(**including *L. raniformis*), abundance scores assigned to each species (1 = 1; 2 = 2-9; 3 = 10-50; 4 = >50)

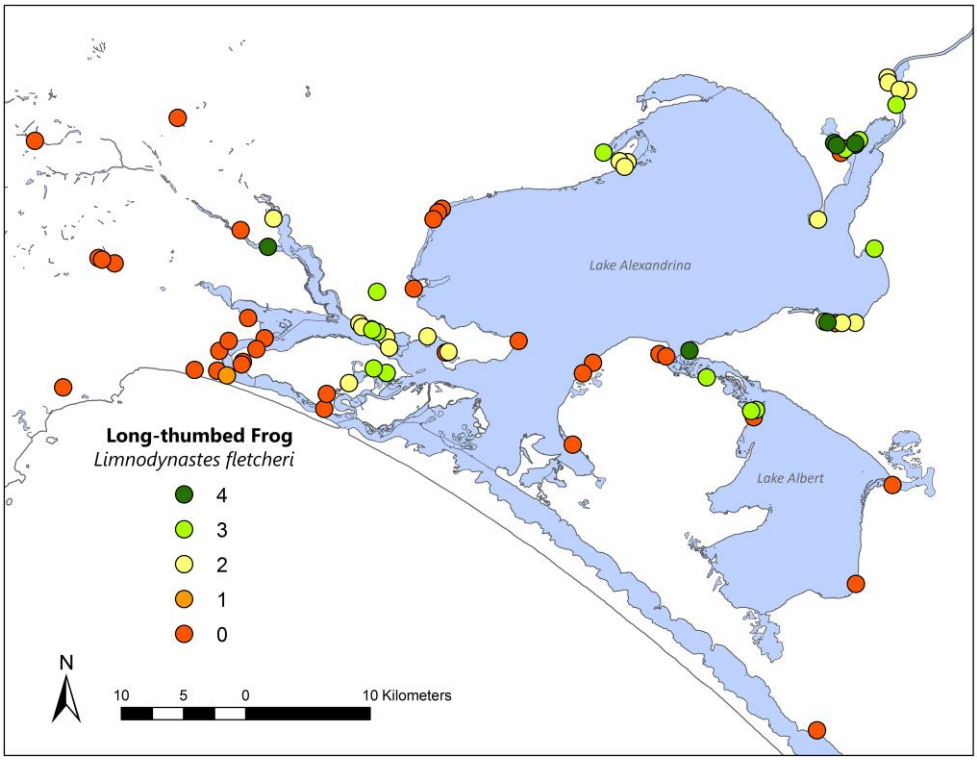
Site	Southern Bell Frog	Eastern Banjo Frog	Common Froglet	Spotted Grass Frog	Brown Tree Frog	Peron's Tree Frog	Long-thumbed Frog	Painted Frog	Total Species Recorded
Goolwa South 'Bird Viewing Hut'	0	2	3	3	1	1	1	0	**6**
Low Point	0	4	4	3	2	0	3	1	**6**
Masondrina	0	3	4	4	4	2	2	0	**6**
Pelican Lagoon North Site 2	0	2	3	2	2	1	3	0	**6**
Pelican Lagoon North Site 4	0	3	4	1	2	2	4	0	**6**
Wellington East stormwater pond	0	2	2	3	1	2	2	0	**6**
Hindmarsh Island Effluent Ponds	0	3	3	2	2	1	0	3	**6**
Alexandrina Station	0	3	4	4	2	0	4	0	**5**
Clayton Bay 'Ken and Sally's Swamp'	0	3	3	3	1	0	2	0	**5**
Clayton Bay 'Wetlands Beach'	0	3	4	1	1	0	3	0	**5**
Finniss River 'Wally's Landing'	0	4	4	3	2	0	2	0	**5**
Goolwa Channel 'Knappsteins Site 2'	0	4	4	3	2	0	1	0	**5**
Hindmarsh Island 'Denver Rd'	0	2	2	2	2	0	2	0	**5**
Hindmarsh Island 'Shadows Lagoon'	0	3	4	2	2	0	3	0	**5**
Narrung Narrows	0	2	3	3	3	0	3	0	**5**
Narrung Narrows Lot 3 Narrung Stud Rd	0	2	3	3	2	0	3	0	**5**
Narrung Narrows 'Warneke'	0	2	4	3	2	0	3	0	**5**
Pelican Lagoon North Site 1	0	2	4	2	1	0	4	0	**5**
Pelican Lagoon North Site 3	0	3	4	2	2	0	3	0	**5**
Point Malcolm Lighthouse	0	3	4	4	3	0	4	0	**5**
Tolderol Bay 6	0	2	4	3	2	0	2	0	**5**
Tolderol Main Channel	0	1	3	3	3	0	2	0	**5**
Tookayerta 'Watkins'	0	3	4	3	3	0	4	0	**5**
Wellington 'Tolmer Rd'	0	2	3	0	2	2	3	0	**5**
Wellington East Wetland	0	1	0	1	2	4	2	0	**5**
Goolwa North 'Alison Avenue'	0	3	3	0	2	3	0	2	**5**
Point Sturt 'Huczko Wetland'	0	3	3	3	2	0	0	1	**5**
Clayton Bay Boardwalk	0	3	4	0	2	0	3	0	**4**
Clayton Bay 'Red Top Bay'	0	3	3	0	2	0	3	0	**4**
Dunn's Lagoon 'Ducks Hospital'	0	3	4	0	2	0	2	0	**4**
Dunns Lagoon 'Snug Cove'	0	3	3	0	2	0	2	0	**4**
Goolwa North 'Currency Creek Rd'	0	2	2	2	2	0	0	0	**4**
Hindmarsh Island 'Murray Mouth Rd'	0	3	3	4	2	0	0	0	**4**
Milang S.W. Wetland	0	1	3	2	2	0	0	0	**4**
Mount Compass Stormwater ponds new	0	3	3	3	2	0	0	0	**4**
Narrung Wetland Pump Shed	0	2	3	4	2	0	0	0	**4**
Narrung Wetland Structure	0	3	4	3	2	0	0	0	**4**
Nurra Nurra Point	0	2	3	2	3	0	0	0	**4**
Pelican Lagoon North Site 5	0	0	3	2	2	0	3	0	**4**
Point Sturt 'Griffin'	0	3	4	3	0	0	2	0	**4**
Point Sturt 'Salty's'	0	3	4	3	0	0	2	0	**4**

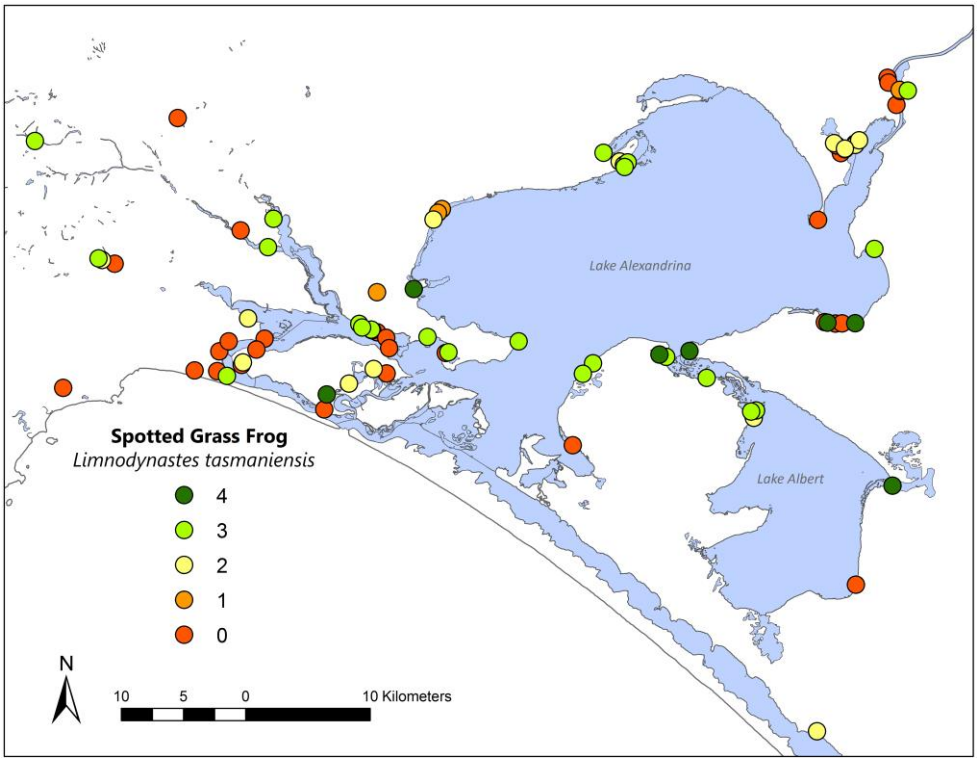
Site	Southern Bell Frog	Eastern Banjo Frog	Common Froglet	Spotted Grass Frog	Brown Tree Frog	Peron's Tree Frog	Long-thumbed Frog	Painted Frog	Total Species Recorded
Reedy Point Kindaruar	0	3	4	4	2	0	0	0	**4**
Teringie Site 2	0	3	4	3	2	0	0	0	**4**
Tolderol Bay 5	0	1	4	3	2	0	0	0	**4**
Tolderol Bay 7	0	0	4	2	2	0	2	0	**4**
Waltowa Structure Lake side	0	2	4	3	2	0	0	0	**4**
Waltowa Structure Wetland side	0	2	4	4	2	0	0	0	**4**
Goolwa Channel 'Knappsteins 1'	0	2	4	2	0	0	2	0	**4**
Goolwa Channel 'Knappsteins 2'	1	2	4	0	0	0	2	0	**4**
Goolwa 'Kessell Rd Effluent Ponds'	4	4	4	3	0	0	0	0	**4**
Goolwa Channel 'Knappsteins Site 1'	0	3	4	3	0	0	0	0	**3**
Goolwa North 'Daniel Avenue'	0	3	2	0	3	0	0	0	**3**
Meningie 'Hyde Avenue'	0	2	3	0	2	0	0	0	**3**
Milang Bay Wetland	0	2	2	1	0	0	0	0	**3**
Murrundi Wetland South	0	2	0	0	0	1	2	0	**3**
Teringie Site 1	0	0	3	3	2	0	0	0	**3**
Tookayerta Creek 'Winery Road'	0	2	4	0	3	0	0	0	**3**
Wellington East 'Lake'	0	4	0	1	1	0	0	0	**3**
Wetland near Tolderol entrance gate	0	0	3	3	0	0	3	0	**3**
Pelican Lagoon 'Wellington Dairies' 1	0	0	4	0	0	2	4	0	**3**
442 Seven Mile Road	0	0	0	2	1	0	0	0	**2**
Alexandrina Station near pump shed	0	0	3	0	0	0	2	0	**2**
Boggy Creek	0	0	1	0	0	0	3	0	**2**
Cox Scrub Swamp	0	3	3	0	0	0	0	0	**2**
Goolwa 'Murray Smith Reserve'	0	2	3	0	0	0	0	0	**2**
Hindmarsh Island 'Grey Paddock'	0	0	3	0	1	0	0	0	**2**
Masondrina 'Lady Jude Windmill'	0	0	2	0	0	0	2	0	**2**
Milang N.E. Wetland	0	0	3	1	0	0	0	0	**2**
Mt Jagged 'Back Dam'	0	0	4	3	0	0	0	0	**2**
Mt Jagged 'Currency and Crayfish Creek'	0	0	2	0	2	0	0	0	**2**
Mt Jagged 'Front Dam'	0	0	4	2	0	0	0	0	**2**
Pelican Lagoon 'Wellington Dairies' 2	0	0	3	0	0	0	3	0	**2**
Goolwa North 'Mark Lane West'	0	1	0	0	0	0	0	0	**1**
Goolwa South 'Golf Club'	0	0	2	0	0	0	0	0	**1**
Masondrina 'Lady Jude paddock'	0	0	1	0	0	0	0	0	**1**
Murrundi Wetland North	0	0	0	0	0	0	2	0	**1**
Point Sturt 'Salty's 2'	0	0	2	0	0	0	0	0	**1**
Tokuremoar Eastern side	0	0	0	0	0	0	0	3	**1**
Victor Harbour 'Stan Farquar Wetland'	0	0	3	0	0	0	0	0	**1**
Pomanda Point 'Causeway Gate'	0	0	0	0	0	0	2	0	**1**
Hindmarsh Island 'Captain Sturt Reserve'	0	0	0	0	0	0	0	0	**0**
Hindmarsh Island Marina	0	0	0	0	0	0	0	0	**0**
Loveday Bay	0	0	0	0	0	0	0	0	**0**
Pelican Lagoon - B (Lignum site)	0	0	0	0	0	0	0	0	**0**

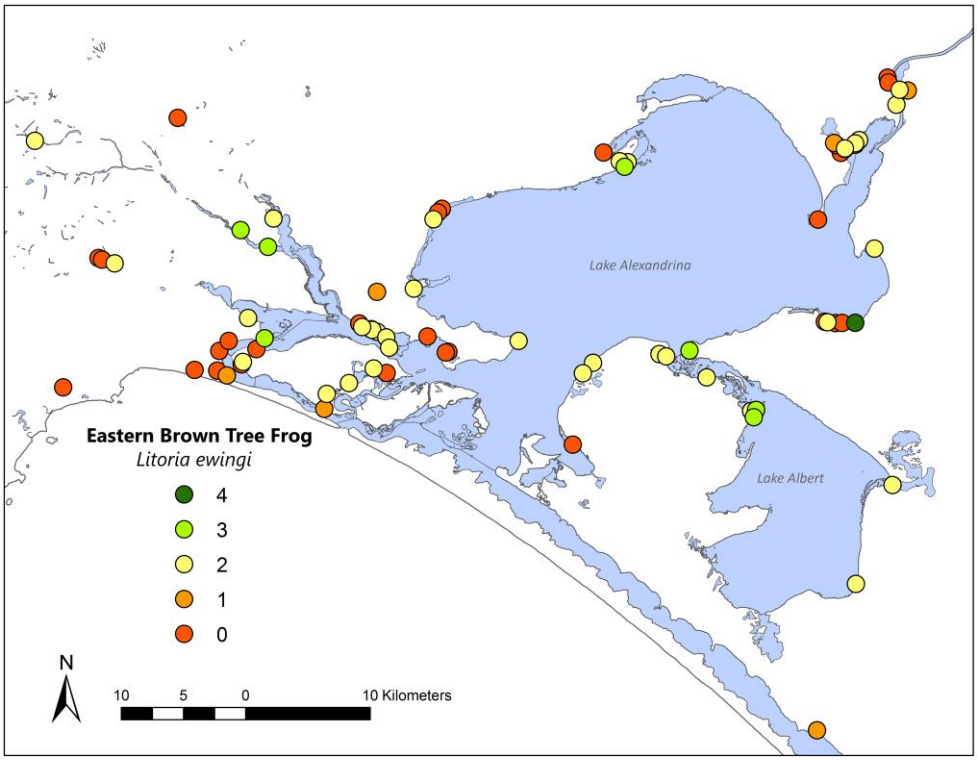
Appendix 3: Abundance of each frog species per monitoring site 2014/15

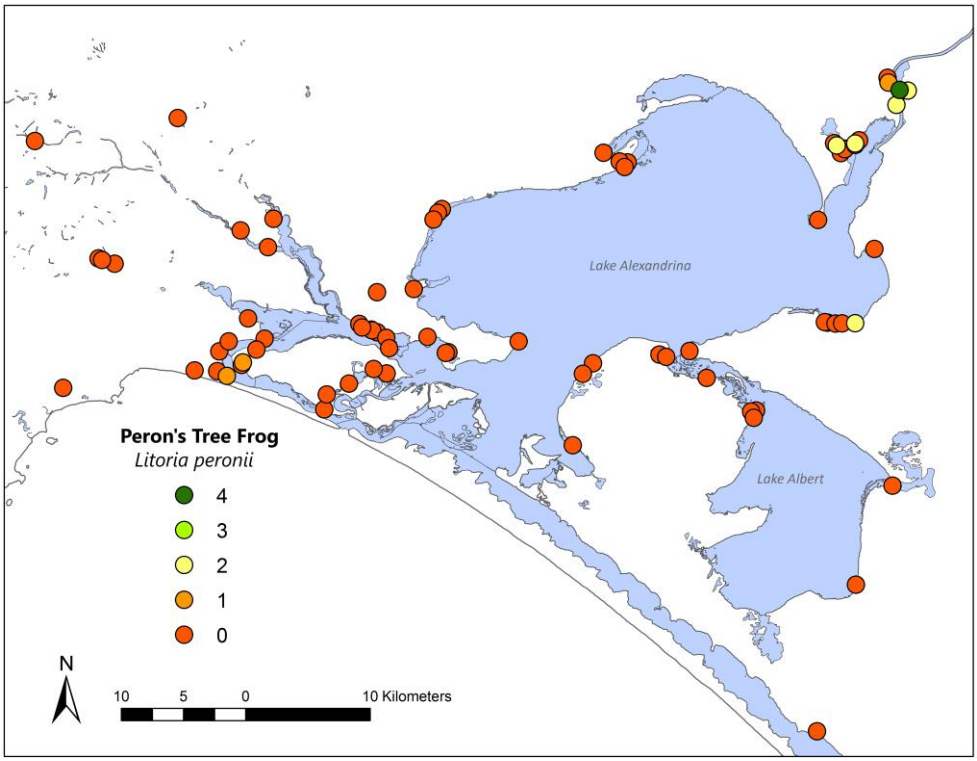


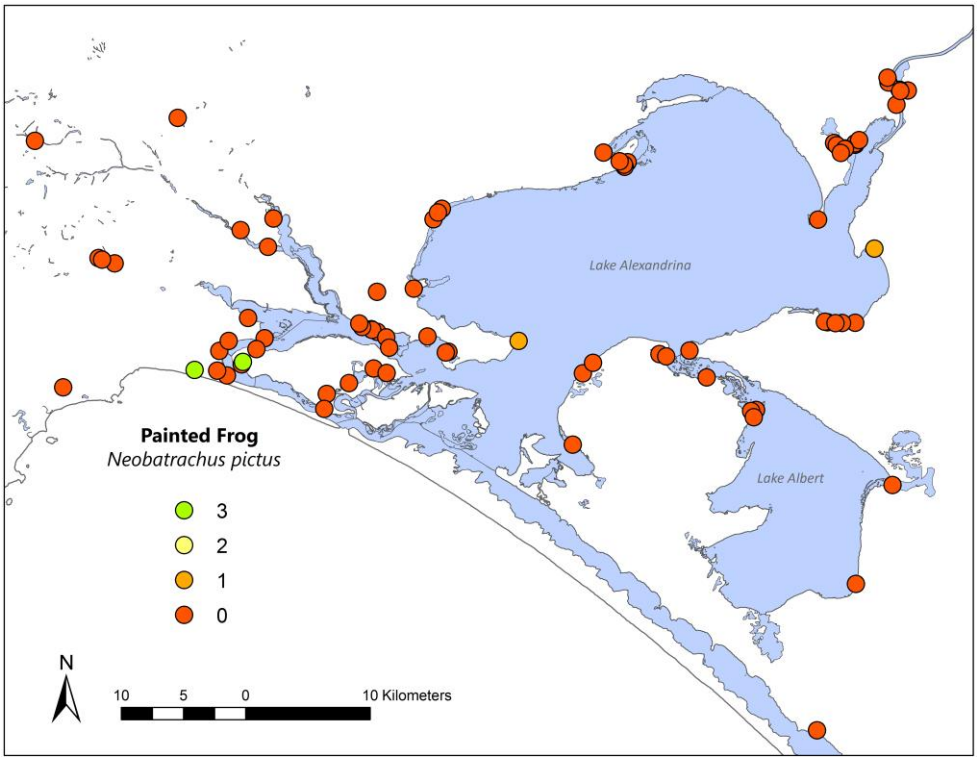



Lake Alexandrina
Lake Albert
Long-thumbed Frog
Limnodynastes fletcheri
4
3
2
1
0
N
10 5 0 10 Kilometers


Lake Alexandrina
Lake Albert
Spotted Grass Frog
Limnodynastes tasmaniensis
4
3
2
1
0
N
10 5 0 10 Kilometers


Lake Alexandrina
Lake Albert
Eastern Brown Tree Frog
Litoria ewingi
4
3
2
1
0
N
10 5 0 10 Kilometers


Lake Alexandrina
Lake Albert
Peron's Tree Frog
Litoria peronii
4
3
2
1
0
N
10 5 0 10 Kilometers


Lake Alexandrina
Lake Albert
Painted Frog
Neobatrachus pictus
3
2
1
0
N
10 5 0 10 Kilometers

Appendix 4: Combined total captures per site as part of tadpole surveys between October 2014 and February 2015

SPECIES NAME	COMMON NAME	Goolwa Channel 'Knappsteins' 2	Pelican Lagoon 'Wellington Dairies' 1	Pelican Lagoon 'Wellington Dairies' 2	Pomanda Point 'Causeway Gate'	Wellington East	Total
Gambusia holbrooki	Eastern gambusia	580	24	153	163	3449	4369
Hypseleotris spp.	Carp gudgeon complex	40	1	42	1	640	724
Limnodynastes sp.	Tadpole	19		36		549	604
Cyprinus carpio	Common carp	220	83	239		14	556
Philypnodon grandiceps	Flat-headed gudgeon	5	1	7	7	251	271
Carassius auratus	Goldfish	12		53		159	224
Galaxias maculatus	Common galaxias	7	2	60	85		154
Litoria sp.	Tadpole			2		58	60
Pseudogobius olorum	Western blue-spot goby	53			1		54
Philypnodon macrostomus	Dwarf Flat-headed gudgeon	15				24	39
Cherax destructor	Yabby	16	5	4	3		28
Crinia sp.	Tadpole	1	2	7			10
Crinia signifera	Common froglet	3					3
Chelodina longicollis	Eastern long-necked tortoise		2				2
Limnodynastes fletcheri	Long-thumbed frog			1		1	2
Retropinna semoni	Australian smelt	1			1		2
Limnodynastes tasmaniensis	Spotted marsh frog					1	1
Nematalosa erebi	Bony herring	1					1
Pseudaphritis urvillii	Congolli		1				1
	Total	973	121	604	261	5146	7105