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SA Murray-Darling Basin

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

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Summary

Forming part of the internationally recognised Ramsar Coorong, Lower Lakes and Murray Mouth (CLLMM) Icon Site, Lake Alexandrina, Lake Albert and the Eastern Mount Lofty Ranges tributaries have undergone significant changes in the past five years as a result of a prolonged period of reduced freshwater flows and low water levels. Water-dependant species suffered marked declines in the region, with many species lost from former sites or retracting to remnant pools. Over the past three years the region has experienced stages of recovery to a functioning freshwater and estuary system, following increased freshwater flows into the system. With the continued return of water to fringing wetland habitats and waterways, the recovery of many once-common species, including the EPBC vulnerable-listed Southern bell frog (*Litoria raniformis*) has not been of the magnitude expected. 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. Southern bellfFrog populations in the study region have declined, likely as a result of changes in natural water regimes and a decline in availability of key habitat.

Between September 2013 and January 2014, a monitoring project was undertaken to observe the biotic response of *L. raniformis* to changes in environmental conditions within Lake Alexandrina, Lake Albert and the mouths of the Eastern Mount Lofty Ranges tributaries. Assessing the response of frog species to the continued water availability following drought and changes in habitat condition were the two key objectives of the project. Monitoring methods included a combination of call identification and active searching. With the combined help from volunteers, nocturnal frog surveys were undertaken at 81 locations across the region (43 project sites, 38 volunteer sites). A total of 214 survey events were completed. *L. raniformis* was detected at only two sites in the north and western areas of the study region at Wellington East Wetland and near Clayton Bay Township. Overall detected abundance across the study region was low to extremely low.

In 2013/14, calling of male *L. raniformis* occurred during January 2014 and one individual was spotlighted in September. Adult *L. raniformis* were observed calling within semi-open, vegetated, sheltered waterbodies comprising of emergent and submerged vegetation. An analysis of data from all years shows the highest abundance of calling males was found amongst semi-open emergent vegetation of 5-50% cover and 1-25% cover of submerged or floating vegetation/debris. No *L. raniformis* calls were captured by automated call recording units installed at sites occupied by *L. raniformis* in recent years.

Overall, there was considered to be an increase in availability of suitable *L. raniformis* breeding habitat in 2013/14. With inclusion of the late August/early September period prior to the first round of nocturnal surveys, inundation of suitable wetland habitats were maintained for approximately a 3 month period. Peak water levels were observed in late September and early October. It is likely increased habitat availability will influence the detectability of the species due to dispersal and occupancy of new areas. Increased predation over the past two years on adult frogs, eggs and tadpoles by introduced species (Eastern gambusia, redfin, cats and foxes) is likely influencing survival rates of *L. raniformis*.

An increase in emergent and fringing vegetation was observed at a number of sites previously occupied by *L. raniformis* in past years. The extent and density of bulrush (*Typha sp*.) and common reed (*Phragmites sp*.) in some areas in the CLLMM region now restrict flow between wetland habitats and the River Murray or have outcompeted other plant species, reducing overall habitat complexity. The maintenance of more complex habitats in the region is considered to be an important element in promoting successful breeding events.

Trial use of motion-sensor cameras were used non-amphibious species, specifically the presence of water rats *(Hydromys chrysogaster*) and swamp rats (*Rattus lutreolus*) at four locations.The detection rate of water rats in the camera traps exceeded expectations and detection occurred relatively rapidly. Water rats were identified at all four camera trapping sites and swamp rats at one, and within days of camera installation. The outcomes of this trial show that this approach to assessing the distribution of water rats in the CLLMM region is highly effective.

Results of this study outline the need to promote habitat complexity through the appropriate management of wetlands and waterways and the vegetation communities associated with *L. raniformis* breeding habitat by building upon current land management practices and implementing a variable hydrological regime.

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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	Kilometers
LAP	Local Action Planning Association
m	Meters
mg	milligrams
NR 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
SA MDB NRM Board	South Australian Murray-Darling Basin Natural Resources Management Board
µS	Micro Siemens

1.0 Introduction

Of the 225 frog species that have been taxonomically identified in Australia, 27 of these occur in South Australia and only 11 within the SA Murray-Darling Basin (SAMDB) (Tyler and Walker 2011). Yet 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).

The Southern bell frog (*Litoria 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 and is now listed as nationally 'vulnerable' under the *Environment Protection and Biodiversity Conservation Act 1999* (Clemann & Gillespie 2010, Stratman 2007). At a State and Territory level the species is considered 'vulnerable' in South Australia and Tasmania and 'endangered' in Victoria, New South Wales and the Australian Capital Territory.

This project addresses 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

This project is primarily being undertaken to determine the effects of changes in habitat features and the management of water levels through targeted surveys of frog (particularly *L. raniformis*) populations and habitat condition assessment within the Lower Lakes and Murray Mouth region. The results from monitoring conducted aims to address the key questions and test the hypothesis outlined in Table 1.

The broad services of the project are to:

- Conduct targeted broad-scale surveys for *L. raniformis* in habitat considered suitable for the species within the Lower Lakes and tributaries
- Identify key extant *L. raniformis* populations
- Assess the habitat conditions at identified populations particularly in relation to water level and habitat structure with comparisons to past years (i.e drought, recovery and post-drought) where possible.
- Compare data obtained from current frog monitoring technique (field-based call recognition) to automatic sound recording devices.
- Trial motion-sensor camera traps at existing nocturnal frog survey sites to determine use by non-amphibious species (e.g. swamp and water rats)

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 response of: Frog Species to: A) the continued water availability following the recent drought (years), and; B) changes in habitat condition in comparison to drought conditions (comparison of past monitoring data)	1. What has been the response of frog species to continued water availability and re-inundation of suitable habitats? Has species distribution and abundance changed since re-inundation of these habitats? 2. Has there been any evidence of successful recruitment at three *L. raniformis* populations and how were these events likely influenced by water levels? 3. How have extended returned water levels influenced habitat structure and how has this influenced use by *L. raniformis*? 4. How does the data compare between the two methods of detecting frog populations (automatic sound recording vs. in-situ field monitoring). 5. Are other non-amphibious species (i.e. water and swamp Rats) utilizing monitored sites?	1. Frog assemblages in the study area will have increased in abundance since re-inundation of wetland habitats. 2. Water levels above 0.8 m AHD will result in an increase in available habitat for *L. raniformis* and therefore an increase in the number of sites where *L. raniformis* is detected. 3. Successful *L. raniformis* recruitment will occur where preferred habitat is inundated for three or more months. 4. Automatic sound recording devices will detect greater species diversity than in-situ field monitoring.

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 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 lead to several significant impacts upon the Lower Lakes including unprecedented low lake levels, with Lake Alexandrina dropping 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 at relatively 'normal' levels and provided flows through the barrages and the Murray Mouth.

1.3 Species description

The Southern bell frog, 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).

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). Males call while floating or rafting amongst aquatic vegetation such as grasses, reeds, emergent parts of submerged vegetation and inundated terrestrial vegetation (Anstis 2013, Mason 2010, Stratman 2007). Females lay jelly-like masses of eggs typically after a local rain or flooding in the South-east of South Australia (Schultz 2006) and after inundation of ephemeral areas in the SA Murray-Darling Basin which are predominantly influenced by river flows (Overton *et al.* 2006). Egg laying occurs within days of flooding and tadpoles hatch 2-4 days later (DEH 2005). Egg masses can contain up to approximately 4000 eggs (Anstis 2013).

Tadpoles of *L. raniformis* are cylindrical to rotund in shape with a well arched tapered tail and can reach up to 110 mm in length. They are generally dark coloured in the early stages often gradually becoming translucent with yellow with darker and green pigmentation a copper sheen over the body and a dense copper-gold colouring of the iris. Colouring can vary depending on local conditions (Anstis 2013, Stratman 2007).

The larval period is highly variable for *L. raniformis* across its distribution, with shorter tadpole phases generally exhibited in temporary wetlands (Clemann & Gillespie 2010). Metamorphosis has been known to take up to 12-15 months (Anstis 2013) but can be as short as 2-3 months when conditions are ideal (Mann *et al.* 2010, Clemann and Gillespie 2010, Cree 1984). Development times are likely to be driven more by water temperature and food availability (S. Wassens pers. comm. 2011 cited in Gonzalez *et al.* 2011). In a recent 2010 study at a wetland within the CLLMM region, tadpoles 35-61 mm in length were captured approximately four months after the site was inundated due to increased flows following the drought (Mason 2010). By contrast, hundreds of larger tadpoles (>80 mm) that were close to the completion of metamorphosis, were captured four months after the delivery of environmental water via pumping in two ephemeral wetlands of the Riverland in 2009 (Nickolai pers. comm). The group of closely-related species within the *Litoria aurea* complex (which includes *L. raniformis*) are known to grow rapidly within the first year following metamorphosis after which growth rates slow (Mann et. al 2010). There is evidence to suggest males reach sexual maturity before females (Hamer & Mahony 2007).

Although the Southern bell frog almost always occurs in freshwater, there have been occurrences of breeding males inhabiting waterbodies of higher salinities in the South-east and CLLMM region of South Australia. 10,730 – 15,230 mS/cm, although no indication of successful recruitment was found (Mason 2010, Stratman 2007).

1.4 Threats

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).

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 SA Murray-Darling Basin 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).

Climate change is forecast to have substantial impacts on regional weather patterns in Australia, with a reduction of up to 30% of annual discharge into the Murray-Darling Basin expected. The major impacts are predicted to be reduced frequency and duration of flooding events and longer dry periods between floods; increased evaporation rates (resulting in decreased periods of wetland inundation and more frequent drying of semi-permanent and permanent wetlands), reduced flow in River channel and associated anabranches and low rainfall coming into summer and less moisture (CSIRO 2008). An assessment of the vulnerability of vertebrate fauna to the effects of climate change indicated *L. raniformis* as being of high risk (Gonzalez *et al.* 2011). The major limitations of *L. raniformis* to tolerate the effects of climate change were identified as; strong habitat preference shown by *L. raniformis* and its reliance on flooding for strong recruitment; sensitivity to predation/competition, particularly during larval stages by alien fish species (such as Eastern gambusia and common carp); and population ability to survive during extended dry periods.

An emerging potential threat to South Australian *L. raniformis* populations is the spread of a closely-related frog species within the *Litoria aurea* species-group (commonly known as the bell frogs), the spotted-thigh frog (*Litoria cyclorhyncha*). Native to the southwest and arid zones of Western Australia *L. cyclorhyncha* is a large frog, up to 108mm in size (Anstis 2013), which has become established on the Eyre Peninsula in South Australia through anthropogenic means within the last decade. The species is predatory (as is *L. raniformis*), has shown tolerances to exposure of high salinity as both adult and tadpole and is considered to have a high dispersal capacity (Kerr 2013). Predation, displacement and possible hybridization are the key threats to *L. raniformis*.

1.5 Distribution within the Lower Lakes region

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 Goolwa Water Level Management Project (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.

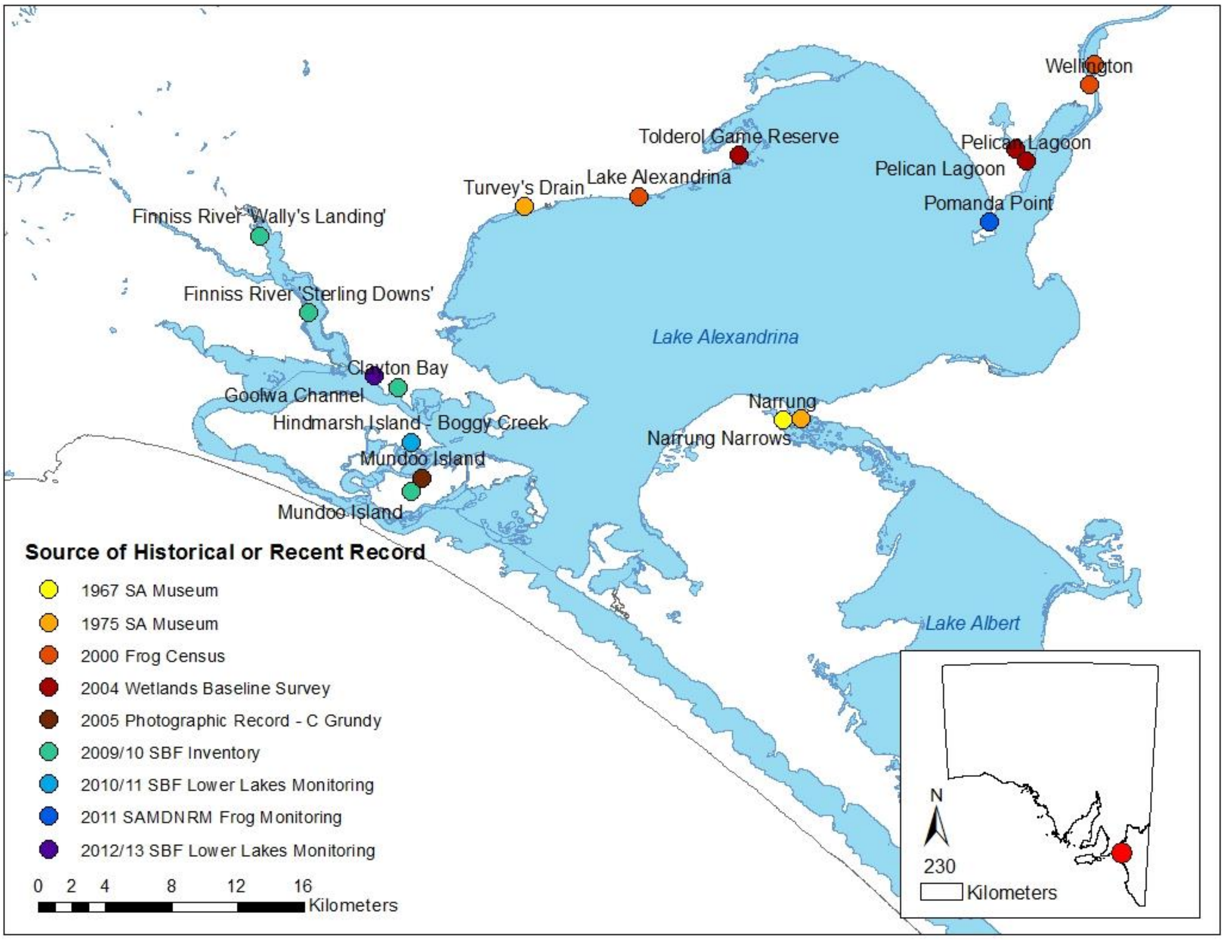


Figure 1: Known distribution of the Southern bell frog (*Litoria raniformis*) in the CLLMM region.

1.6 Habitat characteristics at historical sites

Litoria raniformis is known to occupy a range of natural and artificial habitat 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.

Historical sites known to support extant populations are broadly characterised by permanently or temporarily inundated water bodies with emergent and submergent aquatic vegetation. Individuals detected within the Finniss River near Wally's Landing in 2009 occupied an area dominated by lignum shrublands with an understorey of saltwater couch (*Paspalum vaginatum*), sea rush (*Juncus kraussii*) and scattered but not dense common reed (*Phragmites australis*) and Bulrush (*Typha domingensis*).

Clayton Bay contained extensive stands of emergent river club-rush (*Schoenoplectus validus*) with large mats of filamentous algae caught between. These stands of *S. validus* and algae were recently inundated, standing in approximately 1.4m of water. The wetland fringes were dominated by *P. vaginatum*. Submerged aquatic plants such as milfoil (*Myriophyllum sp.*), widgeon grass (*Ruppia sp.*) and hornwort (*Ceratophyllum demersum*) were also present in low to moderate abundance.

Individuals heard calling at Tolderol Game Reserve occupied common spike-rush (*Eleocharis acuta*) dominated sedgelands comprising an understory of *P. vaginatum*, aquatic herbs and scattered clumps of salt club-rush (*Bolboschoenus caldwellii*) (Holt *et al.* 2004). Tolderol Game Reserve fringes Lake Alexandrina and before the drought, consisted of a series of regulated artificial bays, which were temporarily inundated via a regulated pumping system. Dense, tall reed beds and water channels dominated by bulrush. and common reed were also characteristic of the site (Holt *et al*. 2004).

Pelican Lagoon, a site known to support *L. raniformis* pre 2006, consists of three distinct permanent lagoons/billabongs connected by broad shallow channels. The site fringes the north-eastern shore of Lake Alexandrina and is characterised by a number of vegetation types. *L. raniformis* were heard calling within stands of common rush (*Juncus usitatus*) and spiny flat-sedge (*Cyperus gymnocaulos*). The site also contains lignum shrublands which are flooded intermittently.

In September 2000, between 10-50 male *L. raniformis* were heard calling in marshland and flooded paddocks near Langhorne Creek. Several males were also heard during the same month in riverine habitat at the Wellington ferry.

While habitat descriptions found to support *L. raniformis* were not recorded in the SA Museum database, most sites are characterised by permanent water and plentiful vegetative structure.

1.7 Impact of drought on *L. raniformis* populations

Following the decline in water levels in the River Murray reach below Lock 1 (at Blanchetown) during 2006/07, the fringing wetlands of Lake Alexandrina, Lake Albert, the lower Finniss River and Currency Creek and the Goolwa Channel dried. The exception to this was the provision of environmental water to three isolated wetlands or drains for the purpose of maintaining threatened fish populations or protecting viability of significant submerged aquatic plant seed-banks (K. Hillyard pers. comm.). Flooding and drying (or partial drying) is a recognised technique in wetland rehabilitation as it attempts to mimic pre-regulation water regimes (Tucker *et. al*. 2003). A number of the benefits that can be gained from fluctuating water regimes were observed during the 12 months following drying of fringing Lower Lakes wetlands such as the colonisation of terrestrial vegetation on exposed wetland and lakebed. However, prolonged drying of wetlands in the region occurred (up to four years) resulting in, but not limited to, loss of aquatic plant communities (from dry conditions and smothering from sand and sediment drift), increase in weed species, degradation of wetland sediments from wind and access by stock and exposure of sulfidic sediments.

As limited information on the abundance and distribution of *L. raniformis* in the region was available prior to the drying of their known habitats, it is difficult to accurately assess the impact drought and reduced freshwater flows had on populations in the study region. During 2009, inundation of wetlands and riparian zones within the GWLMA provoked a positive response in local frog communities, including *L. raniformis* (Mason 2010). However outside of this region, the majority of known *L. raniformis* locations remained dry. As *L. raniformis* is a species known to respond rapidly to increases in water levels, opportunities arose within the GWLMA for breeding events to occur providing water levels were maintained high enough to keep their preferred habitat inundated until metamorphosis of tadpoles could be completed.

2.0 Methodology

2.1 Site selection

Sites selected for inclusion in the 2013/14 survey (Figure 2 and Table 2), fit one or more of the following criteria:

- were the location of a historic or recent record of the species and was inundated, and/or;
- contained similar attributes to sites that were occupied in 2009/10 or 2010/11 or suitable vegetation associations.
- Have been monitored in previous years with the same methodology;

As part of this project, community groups/organisations, landholders and volunteers were encouraged to undertake frog monitoring at sites of their own choosing to enable greater spatial coverage of sites within the region. The locations of these sites surveyed as part of this project are included in Figure 2 and Table 3. A total of 38 sites were monitored by volunteers. In addition to the 25 sites formally selected, data from an additional 18 sites were included in the results in-kind. Monitoring at these sites were undertaken as part of the SA MDBNRM Board's Aquatic Biodiversity Wetland Monitoring and Management Program.

Habitat assessments aided the final selection of sites and were undertaken at each location 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 4). Table 5 shows cover abundance scores used to assess habitat features including submerged, floating, emergent, fringing and surrounding habitat.

Table 2: GPS locations of NRM project survey sites (map datum GDA94)

Site #	Site Name	Record of *L.raniformis* occupancy	Easting	Northing
1	Angas Mouth		318405	6081201
2	Bremer Mouth		323062	6082057
3	Dunn's Lagoon - Duck Hospital		312161	6070048
4	Dunn's Lagoon - Snug Cove		312396	6069224
5	Finniss River - Allnutts		304875	6077573
6	Finniss River - Sterling Downs 1	F	306038	6074965
7	Finniss River - Sterling Downs 2		306023	6074882
8	Finniss River - Wally's Landing	F	303099	6079610
9	Hindmarsh Island - Boggy Creek	G	312194	6067197
10	Hindmarsh Island - Boggy Creek Culvert	G	311008	6065778
11	Hindmarsh Island - Hunters Creek Denver Rd		309173	6066386
12	Hindmarsh Island - Shadows Lagoon		311160	6067547
13	Hunters Creek - Hunter's Creek Fishway		308282	6065505
14	Jenny's Lagoon - FR01		328953	6058906
15	Jenny's Lagoon - FR02		329302	6058652
16	Knappstein's 1	H	309991	6071160
17	Knappstein's 2	H	310220	6070872
18	Lake Albert - Kennedy Bay		343260	6044090
19	Lake Albert - Tobin Lodge		340406	6061715
20	Lake Albert - Waltowa Bay		352768	6058760
21	Lake Albert - Waltowa Structure		353209	6058224
22	Lake Alexandrina - Loveday Bay		326752	6061647
23	Lake Alexandrina - Low Point		351405	6077178
24	Milang Snipe Sanctuary - North Basin MILFR05		315878	6079731
25	Milang Snipe Sanctuary - North Shack side		315951	6079747
26	Milang Snipe Sanctuary - Pobbybonk Point MILFR07		315720	6079402
27	Mundoo Island - Pig Island/Fishtrap Creek	E	312863	6065019
28	Mundoo Island - Stockyard Swamp		312280	6064559
29	Nalpa Station - Pomanda Point	G	347197	6080490
30	Narrung - NARFRO3	B	334295	6069631
31	Narrung - Wetland Structure (NARFR01)	A	334692	6068522
32	Narrung Narrows - Lakehouse / Jacobs		337928	6066842
33	Narrung Narrows - Nurra Nurra		341958	6064014
34	Pelican Laggon - C (Windmill site)	D	349370	6084099
35	Pelican Lagoon - B (Lignum site)	D	348715	6084862
36	Teringie - TERFR01		328783	6068008
37	Teringie - TERFR02		327971	6067163
38	Tolderol - Channel 6 (TOLFRO3)	D	332024	6084482
39	Tolderol - Lakeshore Picnic area (TOLFRO2)	D	331828	6083772
40	Tolderol - Main Channel Lake end (TOLFRO1)	D	331081	6084044
41	Tolderol - Pump shed (TOLFR043)	D	330854	6084234
42	Waltowa Bay		352768	6058760
43	*Wellington East	C	353434	6089933

*Opportunistic

Table 3: Location of community monitored survey sites (map datum GDA94)

Site #	Site Name	Record of *L.raniformis* occupancy	Easting	Northing
44	442 Seven Mile Road 15km south of Meningie		348845	6038812
45	81 McLeay Rd, Hindmarsh Island		305512	6067636
46	Alison Avenue, Goolwa North		301877	6070094
47	Angas River near park, Strathalbyn		308298	6096288
48	Bird Viewing Hut, Goolwa South		299358	6066990
49	Boggy Lake fringing wetland		335446	6090936
50	Borrett's Swamp, Sheoak Lane Mosquito Creek		323832	6089542
51	Byrnes Road stormwater pond, Goolwa North		299990	6070389
52	Clayton Bay Boardwalk	F	311433	6070489
53	Currency Creek Rd, Goolwa North Site A		300964	6071849
54	Currency Creek Rd, Goolwa North Site B		301051	3071605
55	Fiebig - near Waltowa		352750	6058779
56	Golfview Road - Goolwa		296903	6068086
57	Gollan's Waterhole, Mosquito Creek		326663	6090137
58	Grey Paddock Hindmarsh Island behind shacks		307186	6064311
59	Hayter, Finniss		306883	6075491
60	Hindmarsh Island Effluent Ponds		300649	6068078
61	Hindmarsh Island Marina		300536	6067883
62	Huczko Wetland, Point Sturt		322809	6069768
63	Kessell Road effluent ponds Goolwa		297697	6069572
64	Meningie stormwater culvert		349528	6049451
65	Milang Bay Wetland		316639	6080378
66	Milang Swan Sanctuary		316318	6080069
67	Murray Mouth Rd, Hindmarsh Island		307388	6065514
68	N.E. Wetland, Milang		316318	6080069
69	Narrung Wetland		334103	6069357
70	Nurra Nurra Point		341706	6063639
71	Nurra Nurra Reserve		341751	6064222
72	S.W. Wetland, Milang		315995	6079513
73	Samphire wetlands opp, side road Chappell Rd Hindmarsh Island		305411	6067663
74	Samphire wetlands opp. 81 McLeay Rd, Hindmarsh Island		305436	6067603
75	Swamp on Barnhill Rd, Finniss		302823	6081311
76	Tolmer st, Wellington	C	353177	6088730
77	Tookayerta creek, south of Currency Creek Winery		300443	6078656
78	Waltowa Structure		353209	6058224
79	Watkins, Tookayerta		302650	6077320
80	Wellington East	C	353434	6089933
81	Wetland Beach, Clayton Bay	F	311420	6073708

Record Key

A	1967 SA Museum
B	1975 SA Museum
C	2000 Frog Census
D	2004 Wetlands Baseline Survey
E	2005 Photograph - C Grundy
F	2009/10 SBF Inventory
G	2010/11 SBF Lower Lakes Monitoring
H	2012/13 SBF Lower Lakes Monitoring

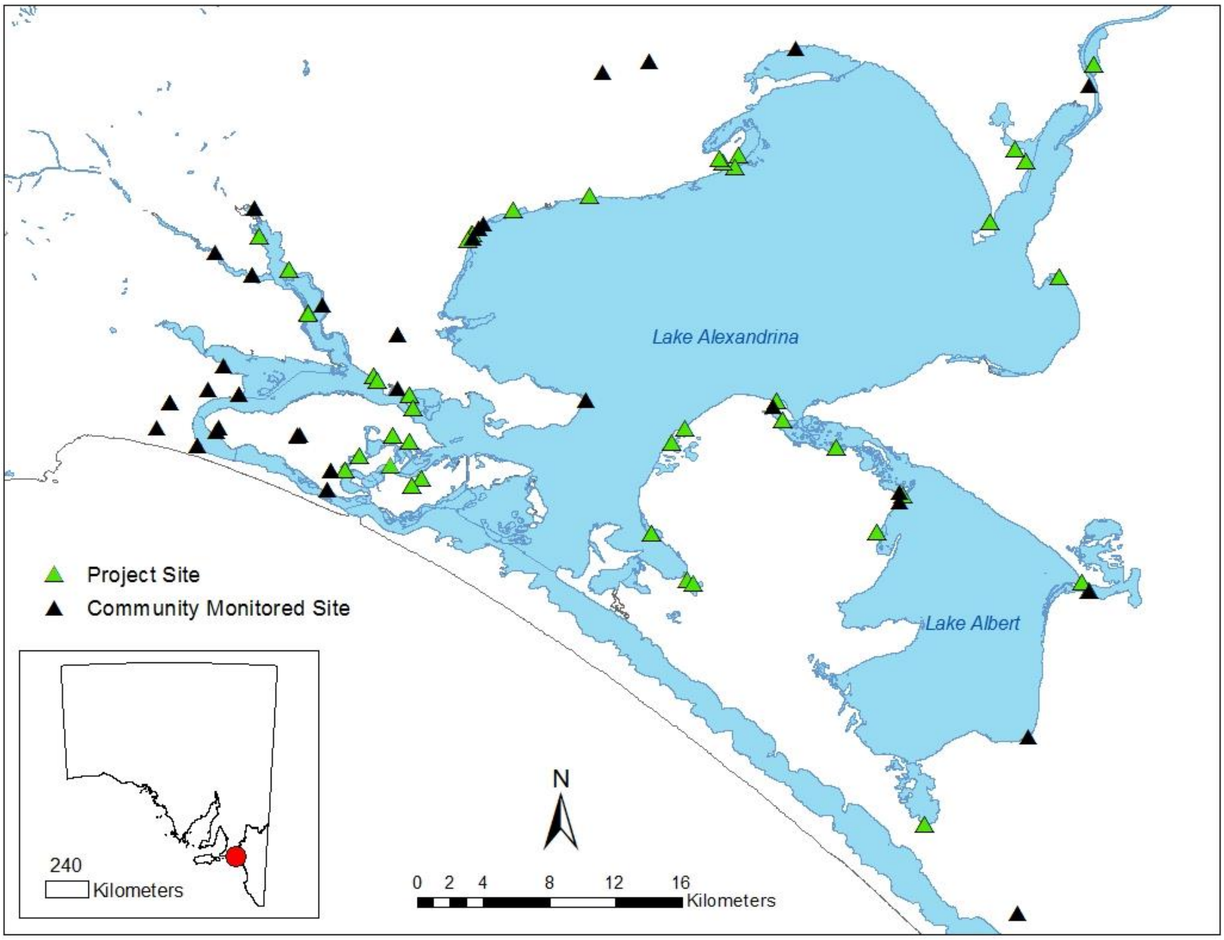


Figure 2: Map location of monitoring sites including community monitored sites and those associated to a recent or historical *L. raniformis* location.

Table 4: Habitat variables recorded at each frog 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 5: 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

2.2 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: methodology outlined by Tucker (2004) and adjusted with increased recording time from three minutes to five minutes (start and finish times were recorded). Humidity and air temperature were recorded and scores were given to amount of moon, wind, rain and cloud present at the time of each survey (Table 6).

- Active searching: scanning fringes of water body with small spotlight over a standard area.

- 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 7). As frogs become difficult to count in higher abundances, scoring is an effective way to estimate numbers.

Equipment used included a Sony digital voice recorder (Model ICD-P620), Yoga shotgun uni-directional microphone (Model EM-2700), combination hygrometer and thermometer (Model LM-81HT) and a spotlight head-torch.

Automated call recording units were deployed at six locations for one week periods between December 2013 and February 2014. The units were programmed to record frogs on an hourly basis for half-hour periods commencing at 8pm, 9pm, 10pm and 11pm. The units were constructed by SoundID Professional and fitted with SonyLS-10 digital recorders and dual microphones. The units were secured to two steel droppers, 50cm above the ground.

2.2 Nocturnal surveys - community collected data

In addition to targeted surveys, frog monitoring loan kits were available for landholders, volunteers and groups/organisations. The same methodology and equipment types as the targeted surveys were used but with a narrowed focus on the five-minute recording and descriptive atmospheric and habitat conditions. Identification of frog species from sound files was undertaken by project staff. The loan kit field datasheet (Appendix 1) was adapted from the Zoos SA Frog Atlas (formally the EPA Frog Census) datasheet.

Over 20 volunteers contributed approximately 150 hours to the project undertaking frog monitoring at 38 sites (75 survey events).

Table 6: 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 7: Abundance scores for nocturnal frog surveys.

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

2.3 Trial use of motion-sensor cameras to detect non-amphibious species

Motion-sensor cameras were installed as a trial at four locations (Figure 3) in the CLLMM region over a continuous four week period to detect the presence of non-amphibious species, specifically targeting swamp rats (*Rattus lutreolus*) and water rats (*Hydromys chyrsogaster*). Sites were chosen as they were secure (low risk of theft/vandalism), had restricted stock access, contained suitable vegetation communities for the target species and are sites that are included in other monitoring programs. Two of the sites were chosen as they were known to be occupied by one of the target species; Nurra Nurra (swamp rats) and Teringie (water rats).

The methodology used was adapted from Bondi *et. al.* (2010) which targeted terrestrial small-mammal communities in Victoria. Six cameras (model Moultrie M-900i) were installed at each site, three targeting swamp rats on terrestrial areas adjacent the water bodies and three targeting water rats within the waterbody fringe within the vicinity of reedbeds. Cameras were mounted horizontally 130 centimetres off the ground facing downwards onto a lure. The lure was a small plastic specimen jar with three holes drilled into the top containing rolled oats and peanut butter for swamp rats and dry cat food for water rats and were secured to the base of the dropper with wire. Lures were 58mm by 42mm in size and allowed accurate estimates of head/body/tail lengths to aid in identification. Loose debris and obstructive plant stems/leaves were cleared from the photo area to prevent the motion sensor to be triggered by movement from wind and to assist identification.

To increase the likelihood of capturing a clear photo, a series of three photographs were taken over a six second period each time the motion sensor was triggered. Each series of three photos was recorded as one 'event'. As species abundance cannot be determined using this method (as individuals can repetitively trigger the sensors), the number of events per species are used in the analysis as a general indication of activity level. A 'site' refers to the location of one collective group of cameras (i.e. Teringie). Where data is analysed at a camera level it is referred to as a 'camera site' (i.e. TER-SR-01).

Habitat variables recorded at each camera location include dominant vegetation associations, vegetation height, soil substrate, camera aspect, canopy cover, water depth and depth of the littoral zone. Other variables recorded by the camera units were temperature, moon phase, time and date.

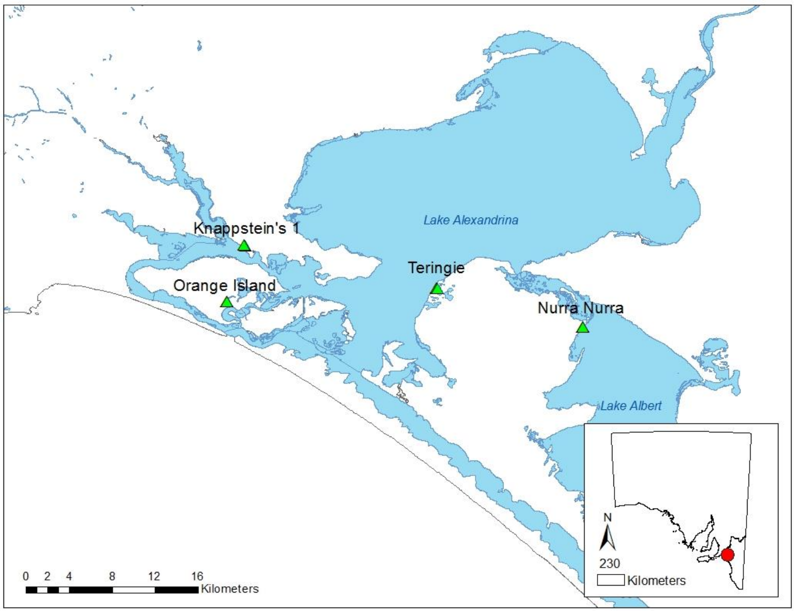


Figure 3: Map location of camera-trapping sites

Table 8: GPS locations of cameras at each site (map datum GDA94)

ID	Wetland Complex	Site	Camera ID	Target Species	Easting	Northing
1	Goolwa Channel	Knappstein's 1	KNA-SR-01	swamp rat	310187	6071132
2	Goolwa Channel	Knappstein's 1	KNA-SR-02	swamp rat	310145	6071199
3	Goolwa Channel	Knappstein's 1	KNA-SR-03	swamp rat	310103	6071253
4	Goolwa Channel	Knappstein's 1	KNA-WR-01	water rat	310146	6071154
5	Goolwa Channel	Knappstein's 1	KNA-WR-02	water rat	310119	6071195
6	Goolwa Channel	Knappstein's 1	KNA-WR-03	water rat	310076	6071151
7	Hindmarsh Island	Orange Island	ORA-SR-01	swamp rat	308460	6065953
8	Hindmarsh Island	Orange Island	ORA-SR-02	swamp rat	308472	6065935
9	Hindmarsh Island	Orange Island	ORA-SR-03	swamp rat	308511	6065971
10	Hindmarsh Island	Orange Island	ORA-WR-01	water rat	308439	6065913
11	Hindmarsh Island	Orange Island	ORA-WR-02	water rat	308467	6065915
12	Hindmarsh Island	Orange Island	ORA-WR-03	water rat	308498	6065912
13	Narrung Narrows	Nurra Nurra	NUR-SR-01	swamp rat	341643	6063569
14	Narrung Narrows	Nurra Nurra	NUR-SR-02	swamp rat	341631	6063564
15	Narrung Narrows	Nurra Nurra	NUR-SR-03	swamp rat	341616	6063558
16	Narrung Narrows	Nurra Nurra	NUR-WR-01	water rat	341654	6063607
17	Narrung Narrows	Nurra Nurra	NUR-WR-02	water rat	341643	6063592
18	Narrung Narrows	Nurra Nurra	NUR-WR-03	water rat	341645	6063580
19	Teringie	Teringie	TER-SR-01	swamp rat	328036	6067191
20	Teringie	Teringie	TER-SR-02	swamp rat	328005	6067191
21	Teringie	Teringie	TER-SR-03	swamp rat	327984	6067174
22	Teringie	Teringie	TER-WR-01	water rat	328075	6067179
23	Teringie	Teringie	TER-WR-02	water rat	328101	6067180
24	Teringie	Teringie	TER-WR-03	water rat	328118	6067177

3.0 Results

3.1 *L. raniformis* results

3.1.1 Nocturnal survey results

Nocturnal surveys were conducted at 43 sites on four occasions between September and December 2012. Surveys were undertaken during early nightfall (between 8pm and 1am). An additional 38 sites were surveyed by community volunteers on one to three occasions between June 2013 and January 2014 (75 survey events). A total of 214 survey events were undertaken between project staff and volunteers.

L. raniformis was detected at only two of the 81 locations surveyed, Wellington East and Goolwa Channel 'Knappsteins 2' (Table 9, Figure 5). Both of these sites are known, or near areas known, to be inhabited by the species from recent or historical records (Holt et. al 2004, Mason 2010, Mason & Hillyard 2011, Walker 2000). Detection of *L. raniformis* was more successful by call recognition. One individual at' Knappstein's 2' was visually identified by active searching (spotlighting). No *L.* raniformis were observed calling when this single individual was identified in September 2013.

Abundance of calling *L. raniformis* was considered to be extremely low across the study region with a maximum of 2-9 individual males calling at Wellington East (in January 2014) and only one individual calling on one occasion (December 2012) at Goolwa Channel 'Knappsteins 2'.

At Wellington East, male *L. raniformis* were observed rafting amongst floating and emergent plants and organic debris amongst scattered emergent common reed (*Phragmites australis*). Rafting material included hornwort (*Ceratophyllum demersum*), and azolla (*Azolla* sp.). The single male observed at Goolwa Channel 'Knappsteins 2' in September 2013 was spotlighted on mown terrestrial grasses adjacent the waterbody fringe which contained emergent river clubrush (*Schoenoplectus validus*), patchy common reed, couch grass (*Paspalum sp.*), common spike-rush (*Eleocharis acuta*) and spiky club-rush (*Schoenoplectus pungens*) with submerged filamentous algae and milfoil (*Myriophyllum* sp.). The single individual observed calling at this same site in December 2013 was utilising this floating and emergent plant material close the wetland fringe.

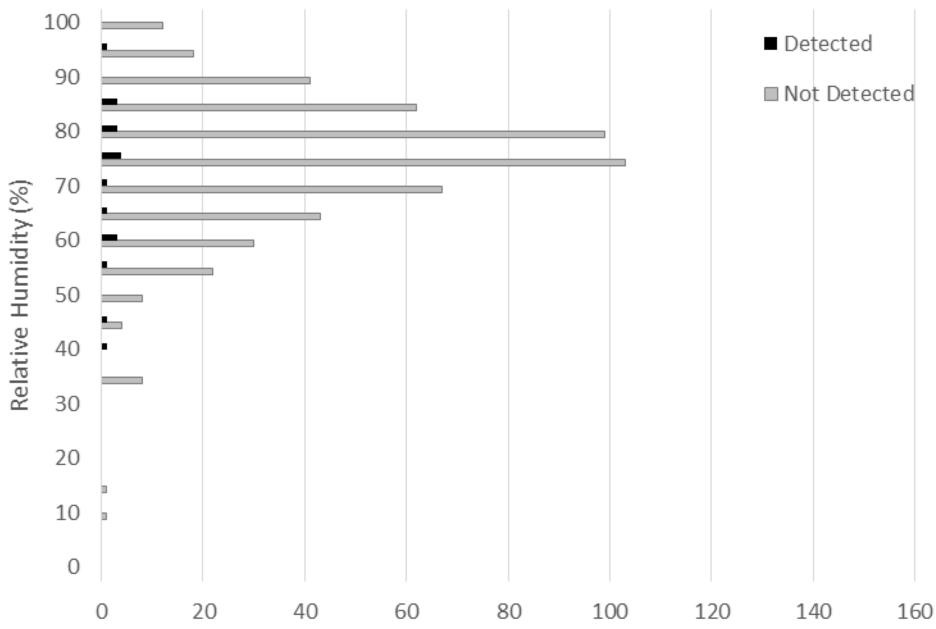
L. raniformis were observed calling between 8.30pm and 11:30pm, and nocturnal surveys were generally undertaken inside this period at the two occupied sites. No *L. raniformis* calls were captured by automated call recording units installed at sites occupied by *L. raniformis* in recent years, Goolwa Channel 'Knappstein's 1', Hindmarsh Island 'Boggy Creek', Nalpa Station 'Pomanda Point' and Nalpa Station 'Pelican Lagoon'. Automated call recording units were also installed at sites without past records of *L. raniformis* occupancy but contained suitable habitat; Narrung Narrows 'The Lake House'. No *L. raniformis* calls were captured. Automated recording units were not installed at Wellington East after *L. raniformis* due to the likelihood of theft or vandalism at the site.

Weather and atmospheric conditions recorded at each survey event during 2013/14, presented in Table 9, show little trend in detection rates in relation to moon phase, rain presence, wind speed, cloud cover, temperature and relative humidity. Little trend was observed with inclusion of data from all years (2009 – 2014) in temperature and relative humidity (Figure 4). Only a small percentage of survey events detected *L. raniformis* during 2013/14 (1.4 percent (%) of all survey events, 3 events) and during all years of combined data between 2009 and 2014 (2.3% of all survey events, 15 events) limiting analysis of trends in weather and atmospheric conditions. The individual *L. raniformis* visually identified at Goolwa Channel 'Knappsteins 2' was sighted in rainy conditions.

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

	L. raniformis abundance		Weather Observation Scores				Atmospheric Conditions	
Site and Date	**Call Recognition**	**Active Searching**	**Moon (0-4)**	**Rain (0-4)**	**Wind (0-4)**	**Cloud (0-5)**	**Temperature (°C)**	**Relative Humidity (%)**
Knappstein's 2								
25/09/2013	0	1	0	1	2	5	14.4	82.7
29/10/2013	0	0	0	0	2	5	14.3	69.5
4/12/2013	0	0	0	3	2	4	11.8	92.1
15/01/2014	1	0	4	0	0	0	22.5	76.7
Wellington East								
5/12/2013	0	0	0	1	1	5		
9/01/2014	2-9	0	2	0	2	0	18.7	80.6
20/01/2014	0	0	4	0	2	0	16	75.1

a)



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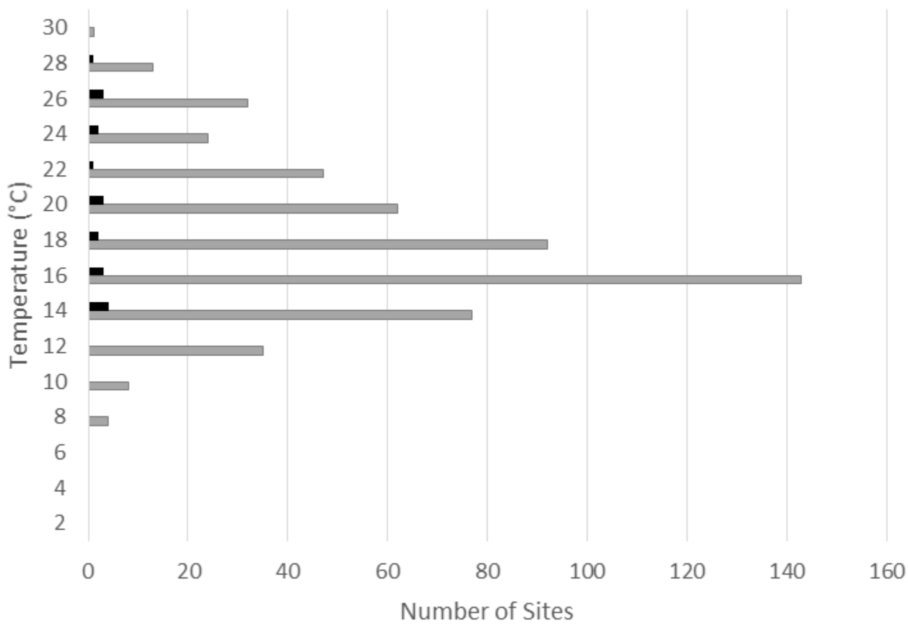
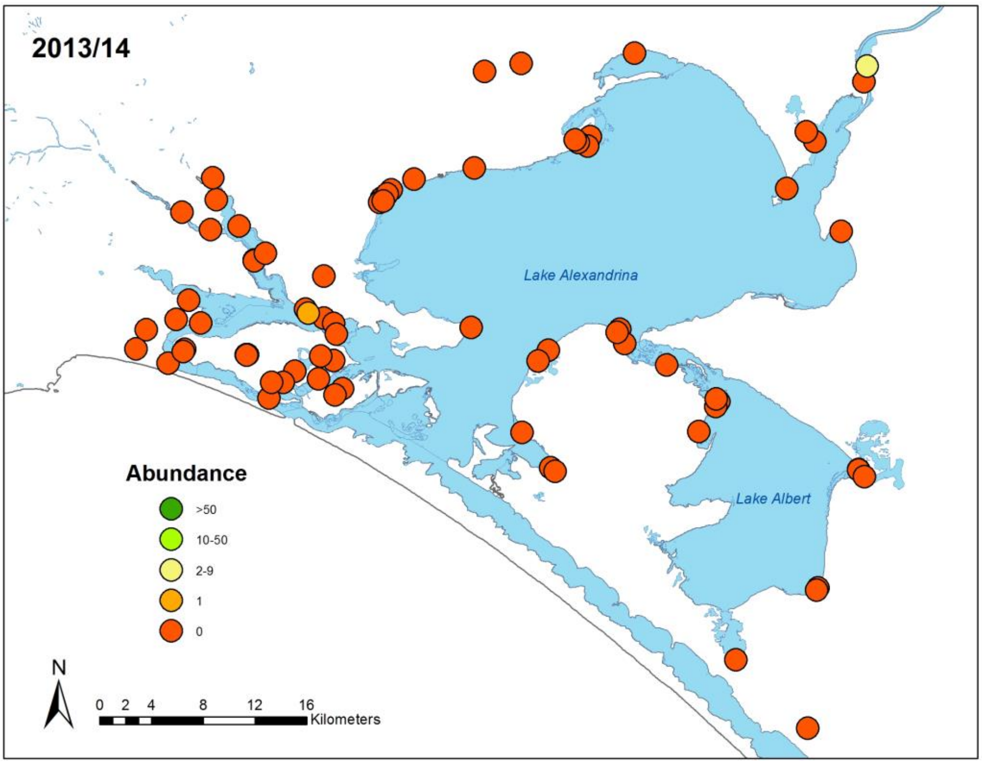


Figure 4: Distribution of detection of *L. raniformis* in relation to a) percentage relative humidity and b) air temperature at all combined survey events between 2009 and 2014 (664 survey events).

a)



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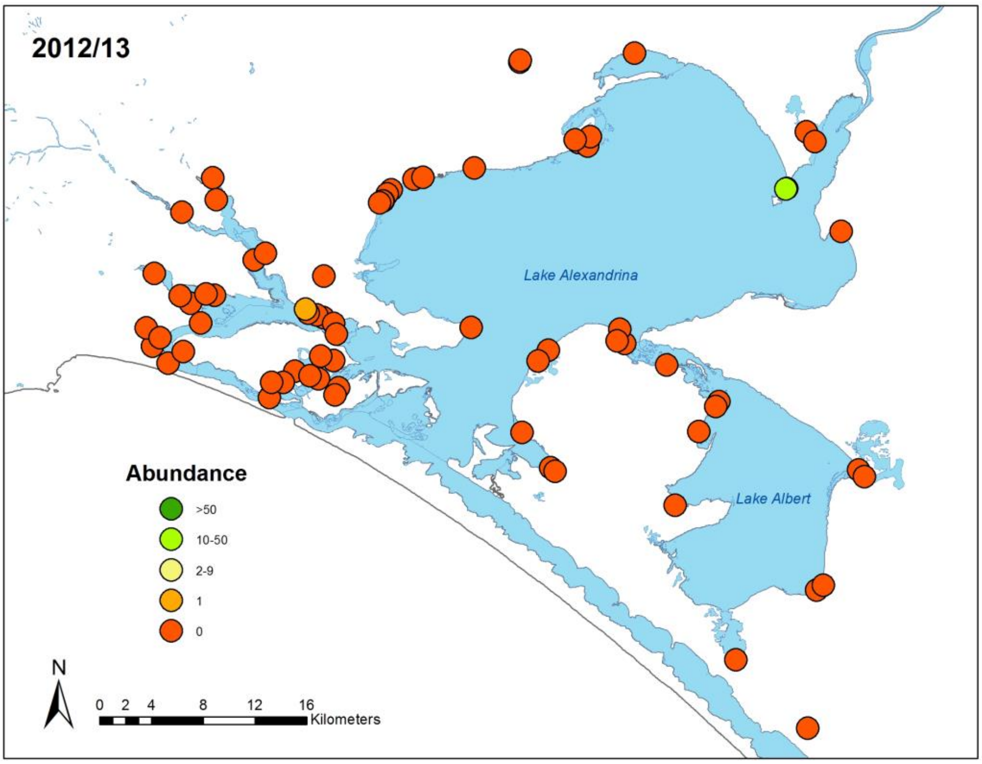
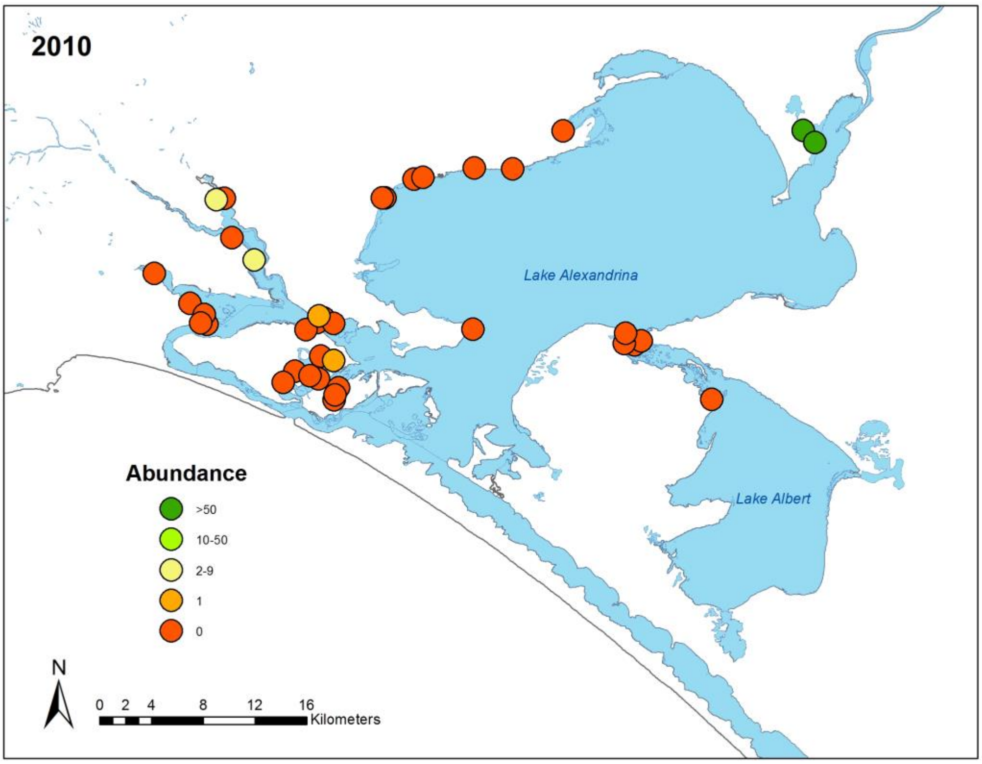


Figure 5: a) Maximum *L. raniformis* abundance recorded across 81 sites between September 2013 and January 2014 b) Maximum *L. raniformis* abundance recorded across 76 sites between September and December 2012

a)



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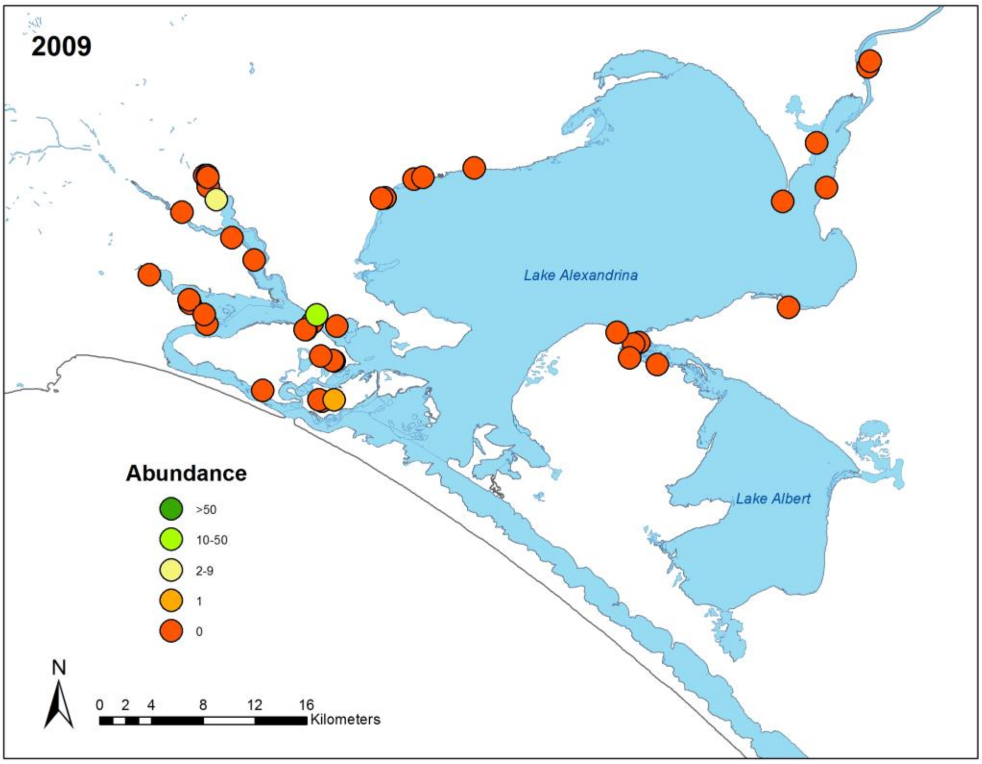


Figure 6: a) Maximum *L. raniformis* abundance recorded across 36 sites between October and December 2010 b) Maximum *L. raniformis* abundance recorded across 37 sites between October and December 2009.

3.1.2 Description of sites occupied by *L. raniformis*

Sites occupied by *L. raniformis* in 2013/14 were characterised by permanent or connected wetlands (at the time of assessment) and with little to no flow bordered partially or entirely by roads and/or man-made levees.

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 highest abundance of *L. raniformis* was observed at Wellington East, on the opposite site of the River Murray from the Township of Wellington. The wetland is approximately 11.5 hectares in size and is bordered by man-made roads or levees and a divide of weeping willow (*Salix x babilonica*) trees that separates the wetland from the River Murray. There is no open flow path that connects the Wetland to the River, instead water seeps through the dense bank of Willows. The wetland is generally shallow, 0.5-0.7 mAHD when River levels at are 'pool' (0.75 mAHD) but contain shallow areas, due to sedimentation, less than 0.3 m in depth. The majority of the wetland is colonised by Common Reed.

Goolwa Channel 'Knappstein's 2' 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 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*).

Both sites contain generally steep sloping edges (Table 9) which were, in both cases, man-made (or altered) banks for access purposes. *L. raniformis* were not observed calling directly within these edges but from the open/semi-open water habitats. Goolwa Channel 'Knappstein's 2' was predominantly surrounded by grasslands including pastures. Wellington East is bordered by man-made roads across which lie Samphire shrublands alongside reclaimed irrigation pasture and a housing estate of the Wellington Marina.

Table 10: Observational site description and attributes of each site 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
Wellington East	Wetland	Modified	Permanent	None	Steep	Roadside	Mud/ organic matter

3.1.3 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.

Both sites occupied by *L. raniformis* in 2013/14 contained submerged aquatic vegetation of between 1-25 percent (%) cover (Table 11). Goolwa Channel 'Knappsteins 2' contained a relatively diverse assemblage of submerged plants including filamentous algae, hornwort and milfoil. Wellington East was dominated by green filamentous algae amongst semi open common reed stems (Figure 8).

Scores assigned to floating vegetation incorporate both living (i.e., duckweed) and non-living organic debris but was dominated at both occupied sites by azolla (*Azolla* sp.) and duckweed (*Lemna* sp). In 2009, floating vegetation was incorporated within the emergent vegetation score which needs to be taken into consideration when comparing 2010 and 2012 results with that of 2009. In 2010 floating vegetation was separated out into a separate category following the analysis of 2009 data and field observations of how *L. raniformis* were utilising floating plants and debris for rafting.

In 2013/14, *L. raniformis* were observed calling within areas of 5-50% cover of emergent vegetation, consistent with observations in previous years (Table 11). At both occupied sites this comprised of semi-open reedbeds of common reed, river clubrush and common spikerush at Goolwa Channel 'Knappsteins 2' and predominantly common reed at Wellington East. Field observations noted that semi-open stands of reeds harboured higher cover abundance of submerged vegetative cover (milfoil, algae) that areas of open water or dense reedbeds.

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 (Figure 7, Table 11). However, calling males were observed to be utilising similar habitats with similar vegetation scores in 2009, 2010, 2011 and 2012. In all years, the highest abundance of calling males was found amongst semi-open emergent vegetation of 5-50% cover and 1-25% cover of submerged or floating vegetation/debris (Figure 7).

An increase in emergent and fringing vegetation was observed at a number of sites previously occupied by *L. raniformis* in past years, particularly at Pelican Lagoon and Finniss River 'Sterling Downs' and Hindmarsh Island 'Boggy Creek'. Pelican Lagoon, which has been occupied by *L. raniformis* in high abundances in past years (most notably in 2010) still contains much of the habitat values and vegetation communities assessed in previous years however with a marked increase in cover abundance of fringing vegetation increasing from 5-25% cover to 50-75% cover. This is presented in Figure 9 which is representative of the similar changes in vegetative structure at Finniss River 'Sterling Downs' and Hindmarsh Island 'Boggy Creek'. The site contains a diverse herbland and sedgeland community amongst the lignum (*Duma florulenta*) shrublands with encroaching common reed (Figure 10). Monoculture stands of bulrush (*Typha domingensis*) have responded well to the reinundation of Pelican Lagoon, its sheltered aspect and relatively stable water levels. The extent and density of bulrush at Pelican Lagoon now restrict flow between the wetland and the River Murray. Changes in land management practices (such as timing of grazing) have also been noted in field observations at the three previously occupied sites.

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
2013/14	Knappsteins 2	0.75	1	2.5	3.25	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

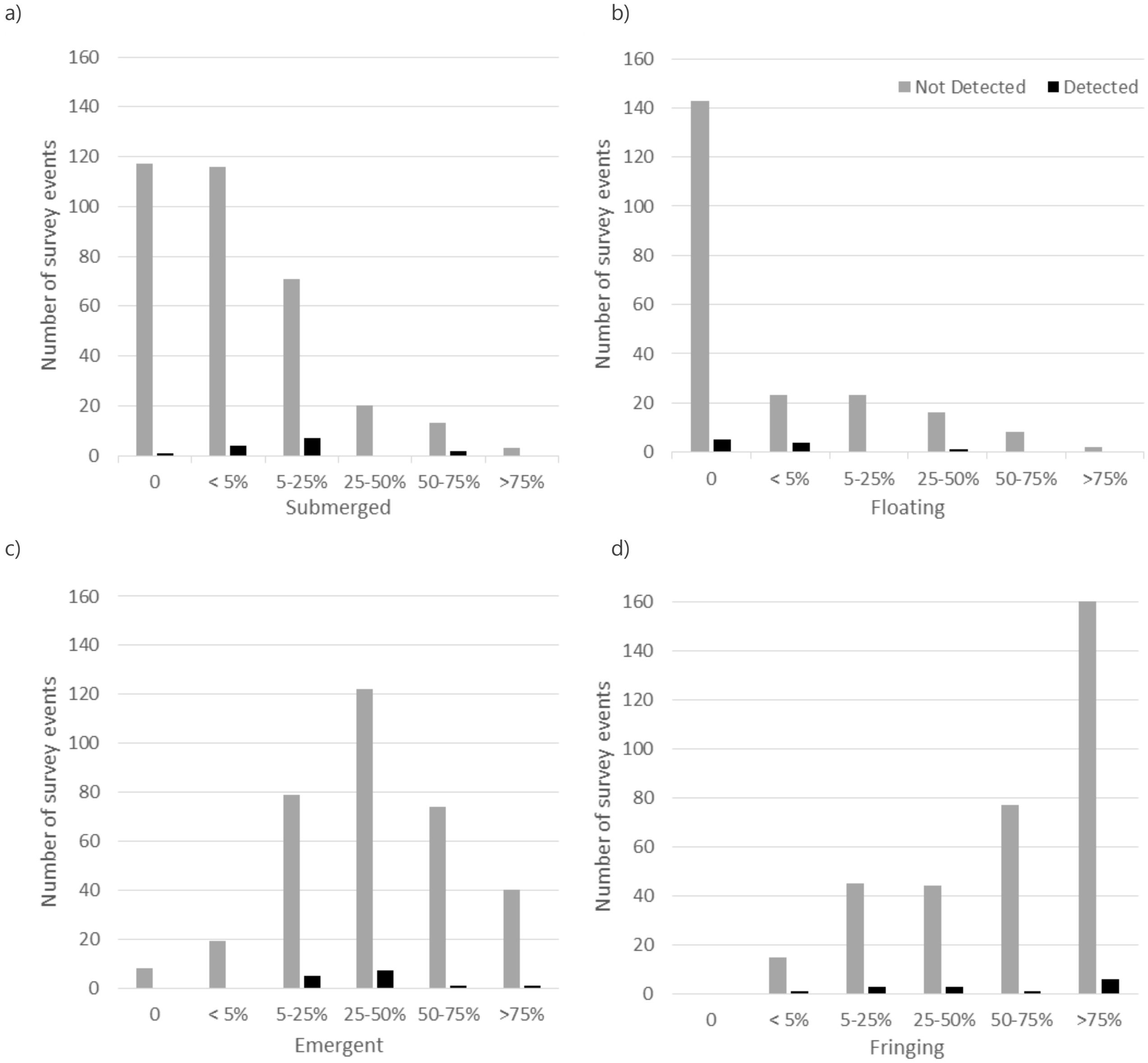


Figure 7: Distribution of detection of *L. raniformis* in relation to a) submerged; b) floating; c) emergent and d) fringing vegetative cover at all survey events between 2009 and 2014 (0=0% cover, 1=<5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=>75%).

a)

b)

c)

Figure 8: a) An adult *L. raniformis* spotlighted at Goolwa Channel 'Knappsteins 2' in September 2013 (photo: Regina Durbridge); b) microhabitat from where *L. raniformis* were observed calling at Wellington East and c) Wellington East Wetland.

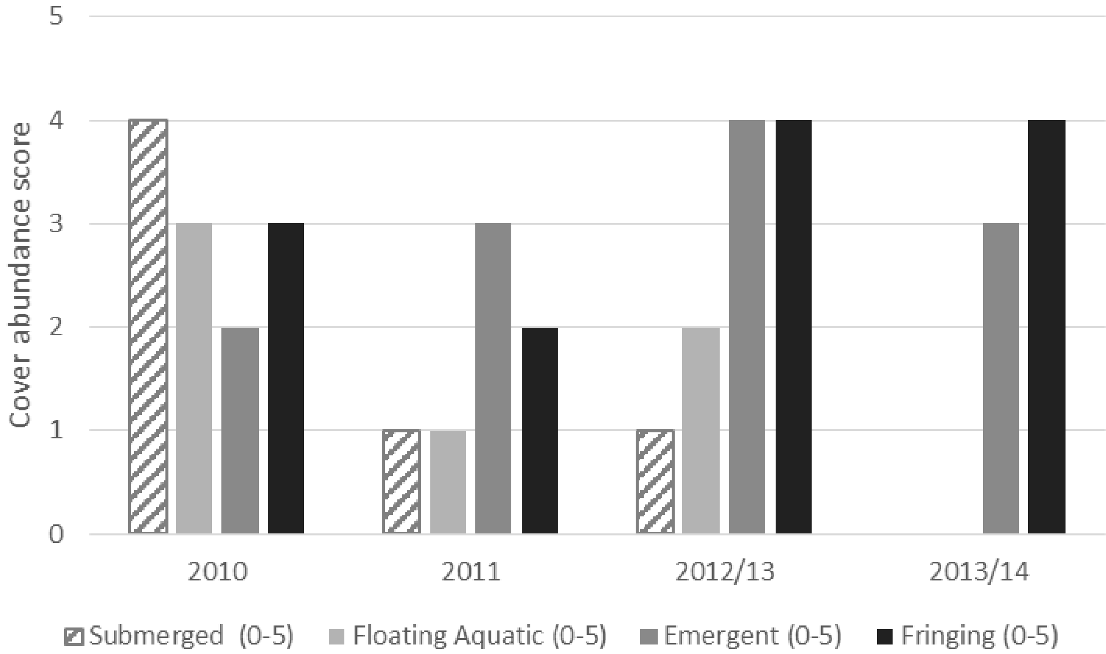


Figure 9: Cover abundance of submerged, floating, emergent and fringing vegetation at Pelican Lagoon 2010-2014 (0=0% cover, 1=<5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=>75%)

a)

b)

Figure 10: Pelican Lagoon 'Site 1' in a) December 2010 and b) November 2013

3.1.4 Water quality and water levels

Of all the project sites, the majority have been continuously inundated since the return of lake levels in late 2010, although varying in extent. Table 12 presents water quality results from sites occupied by *L. raniformis*. See Appendix 2 for water quality results at all project sites.

Surface water salinities (measured as electrical conductivity) ranged between 1498 and 2810 µs/cm at survey locations occupied by *L. raniformis* (Table 13). Salinity levels were marginally lower at Goolwa Channel 'Knappsteins 2' (1253-1498 µs/cm) which receives incoming freshwater flows from upstream as it lies within the area where the River Murray enters Lake Alexandrina. Salinities at 'Wellington East' were recorded on one occasion in January 2014 2810 µs/cm, 11 days after *L. raniformis* were detected during opportunistic surveys. The higher salinity result at 'Wellington East' is likely influenced by the restricted connectivity between the wetland and the River Murray channel caused by degraded earthen banks which are densely colonised by Willows. No clear opening or inlet was observed.

No trend was observed between pH or turbidity of surface water and abundance of *L. raniformis.* Surface water was alkaline ranging between 8.13 and 9.03 at sites occupied by *L. raniformis* and turbidity ranged between 109 and 181 NTU at Goolwa Channel 'Knappsteins 2' which decreased throughout the survey period. Turbidity at Wellington East was 2.7 NTU due to the sheltered aspect of emergent vegetation and the restricted connection to the more turbid waters in the River Channel.

Dissolved oxygen (DO) shows a diurnal cycle where lowest DO is generally recorded in the early morning and increases during the day as a result of the photosynthetic activities of aquatic plants and algae (Tucker, 2003). DO was highly variable across all sites ranging between 1.64 and 9.7 ppm at occupied sites (Table 12) and between 0.32 and 18.51 ppm at remaining sites (Appendix 2), indicating a high level of primary production (photosynthesis during daylight, respiration at night).

Average daily water level data was obtained from four telemetered water quality monitoring stations that contained the most continuous data and were closest to sites occupied by *L. raniformis.* Throughout the duration of the survey period between September 2013 and January 2014, average daily water levels exceeded 0.75 mAHD (approximate 'pool' level) for approximately 60% of the time (Figure 11 and Figure 12). With inclusion of the late August/early September period prior to the first round of nocturnal surveys, inundation of suitable wetland habitats were maintained for approximately a 3 month period. Peak water levels were observed in late September and early October. The maximum level observed at West Clayton (closest to occupied site Knappstein's 2) was 0.876 mAHD on the 5th October 2013 and downstream of the Wellington Ferry (closest to the occupied site Wellington East) was 1.002 mAHD on the 2nd October 2013.

Table 12: Water quality results at sites occupied by *L. raniformis* using a TPS multimeter

Date/Site	Time	Temperature (°C)	Electrical Conductivity (µS/cm)	pH	Dissolved Oxygen (ppm)	Turbidity (NTU)	*L. raniformis* abundance recorded	Water level (mAHD) at nearest telemetry station
Knappstein's 2								
25/09/2013	8:30 PM	19.9	1498	9.03	6.69	181	1	0.717
29/10/2013	9:25 PM	18.7	1254	8.84	8.74	166.5	0	0.665
4/12/2013	10:35 PM	17	1258	8.5	9.7	146.9	0	0.692
15/01/2014	10:59 PM	25.4	1253	8.13	1.64	109.2	1	0.719
Wellington East								
*29/08/2013							0	
*2/10/2013							0	
*11/11/2013	12:00AM						0	
*5/12/2013	11:45 PM						0	0.858
*9/01/2014	11:00 PM						2-9 (~5)	0.786
20/01/2014	10:56 PM	21.8	2810	8.96	3.71	2.7	0	0.762

*Opportunistic survey

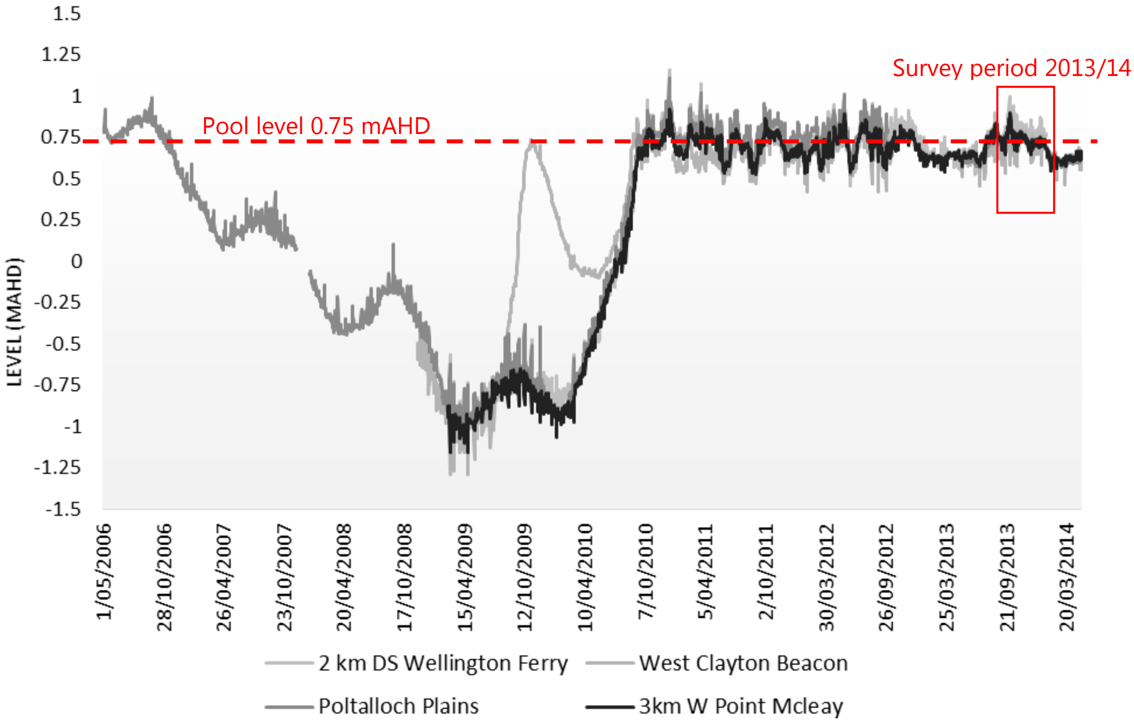


Figure 11: Average daily water level readings from telemetry stations Downstream of the Wellington Ferry, Poltalloch Plains, West Clayton Beacon and 3km West of Point Mcleay between 2006 and 2014 (water level data source www.waterconnect.sa.gov.au).

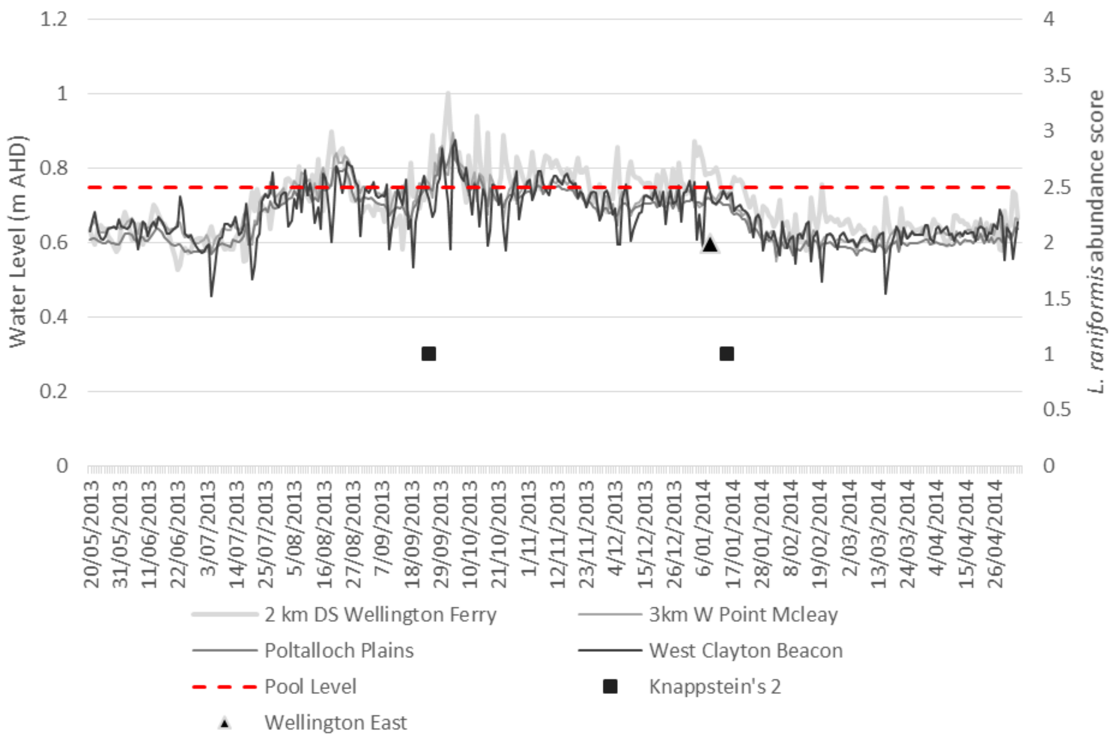


Figure 12: Timing and abundance of *L. raniformis* per monitoring round against average daily water levels (in metres Australian Height Datum) measured at telemetry stations closest to sites occupied by *L. raniformis* between May 2013 and May 2014 (water level data source www.waterconnect.sa.gov.au) (1 = 1; 2 = 2-9; 3 = 10-50 and 4 = >50 individuals)

2.4 Other frog species results

A total of eight frog species (including *L. raniformis*) were recorded in the study region in 2013/14. The most widespread and abundant species was the common froglet (*Crinia signifera*) which was detected at 89% of sites and in abundances of greater than 50 individuals at 47% of occupied sites (Figure 13). The spotted grass frog and Eastern banjo frog were also abundant, detected at 82.7% and 72% of sites respectively. A table of the full results for each species per monitoring site can be found in Appendix 3. Individual species abundance maps are presented in Appendix 4.

Long-thumbed/barking marsh frogs (*Limnodynastes fletcheri*) were detected at a similar number of sites to 2012 (37% in 2013 compared to 35.5% 2012). Prior to 2012 the species was detected at 27% of sites in 2010 and 17.5% 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 eight locations and greater than 50 individuals (score of 4) at only one location. The abundance score per site on average was less in 2013 than that observed in 2012 when the species was recorded in abundances greater than 50 at six locations.

The brown tree frog (*Litoria ewingii*) was relatively well distributed within the region, more common in the Wellington and Clayton Bay/Hindmarsh Island districts. It was detected at 63% of sites in 2013 compared to 57% of sites in 2012, 46% in 2010 and 17.5% in 2009. Abundances per site were generally low (<10) with, an abundance score of 2 recorded at 86% of sites occupied by *L. ewingii*. Juvenile frogs or frogs nearing completion of metamorphosis were often spotlighted indicating the peak breeding would likely have been earlier than the survey period.

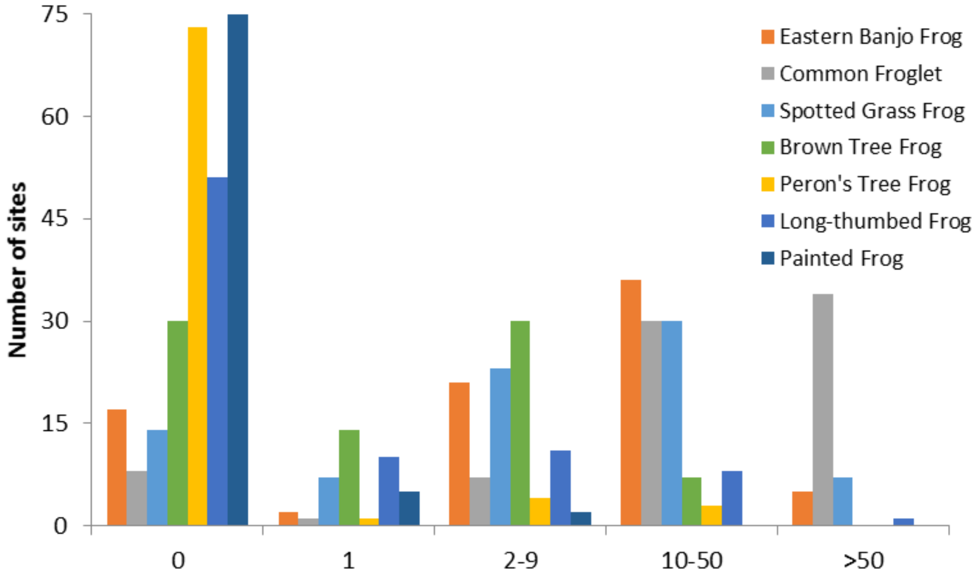
The Peron's tree frog (*Litoria peronii*) was observed at a marginally greater number of sites in 2013 (9.9%) and more often in higher abundances than previous years. An abundance score of 3 (10-50 individuals) were recorded at three of the eight sites occupied by the *L. peronii*. The species was detected at 6.6% of sites in 2012, 7.3% in 2010 and 5% in 2009.

One species identified in 2013 which had not been detected in previous years was the painted frog (*Neobatrachus pictus*). Individuals were not calling, however adult frogs were spotlighted at seven locations in the CLLMM region between September and December 2013. Three of these sites were close to the township of Milang, the remainder at Point Sturt, Goolwa, Hindmarsh Island and Teringie Wetlands (near the township of Raukkan). *N. pictus* is a burrowing species and is known to call in autumn and winter (Tyler and Walker 2011), particularly after heavy rain.

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).

The highest diversity observed was six species (Figure 15) at three sites (Clayton Bay and Goolwa townships and at Pelican Lagoon on Nalpa Station), see Appendix 3 for table of results. The average number of species recorded per site is relatively comparable to 2012 (2.82 species). The highest average number of species per site was observed in 2010 following the widespread reinundation of fringing wetlands on the return of lake levels. In 2009 the low species diversity (averaging 1.44 species) and abundance of frogs was the result of habitat loss due to low water levels. The artificial water level management within the Goolwa Water Level Management Area (GWLMA) was the primary available habitat for frogs during this time, including *L. raniformis*. Since in 2010, species diversity has continued to be dominated by the common froglet, spotted grass frog and Eastern banjo frog.

a)



b)

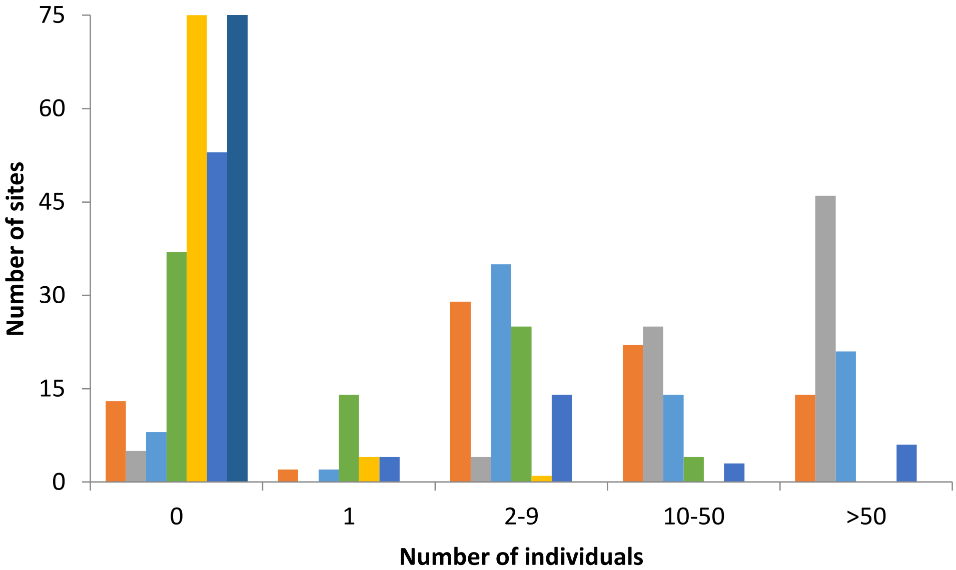
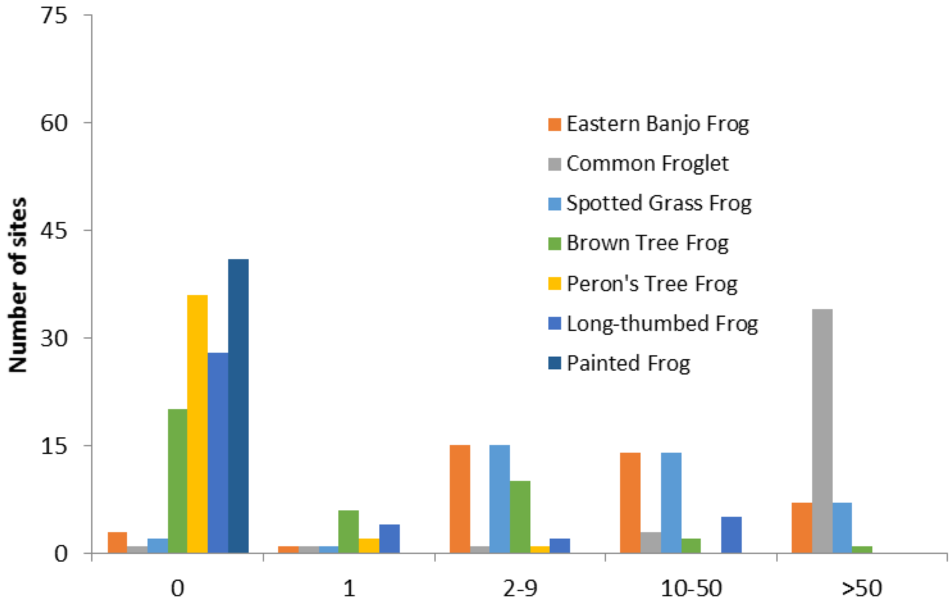


Figure 13: Distribution of abundance scores per species in a) 2013/14 across 81 sites and b) 2012/13 across 76 sites

a)



b)

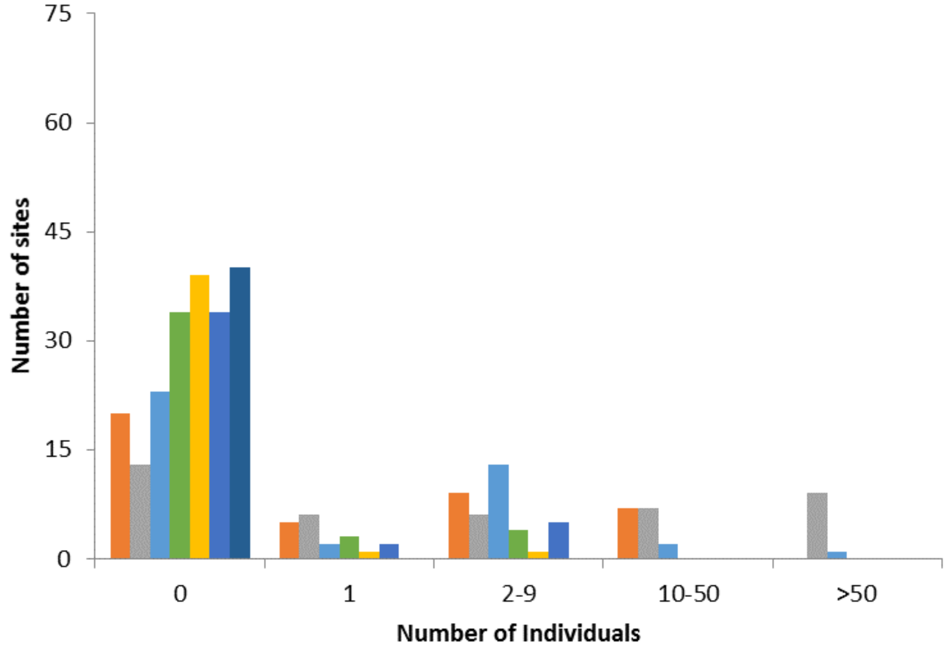
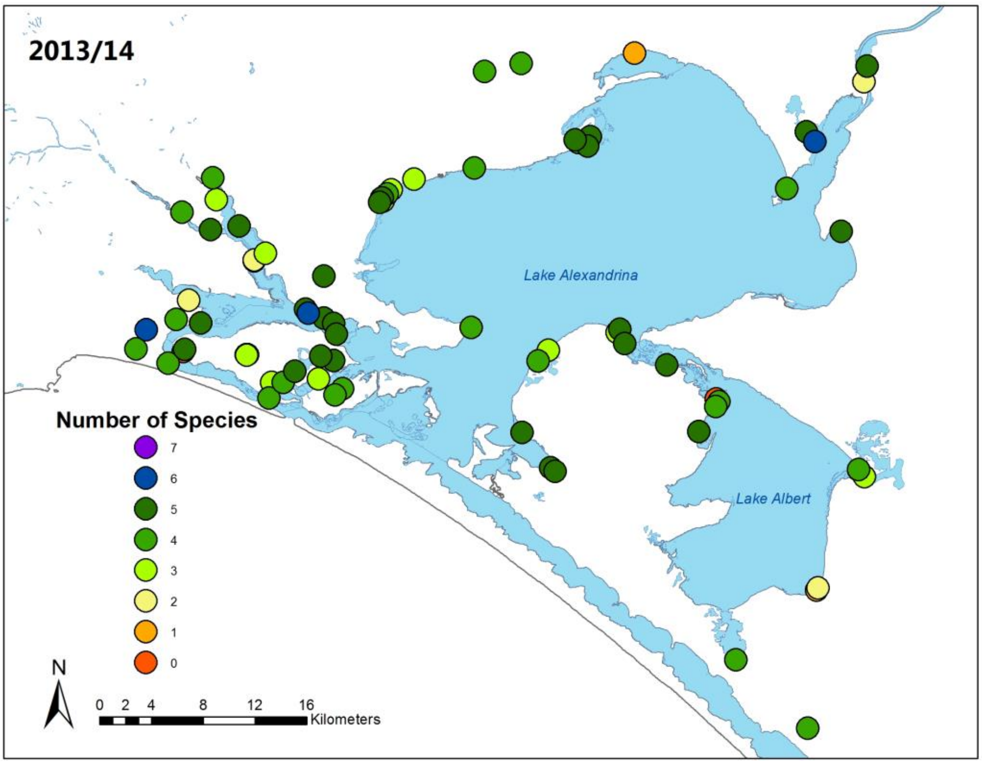


Figure 14: Distribution of abundance scores per species in a) 2010 across 41 sites and b) 2009 across 40 sites.

a)



b)

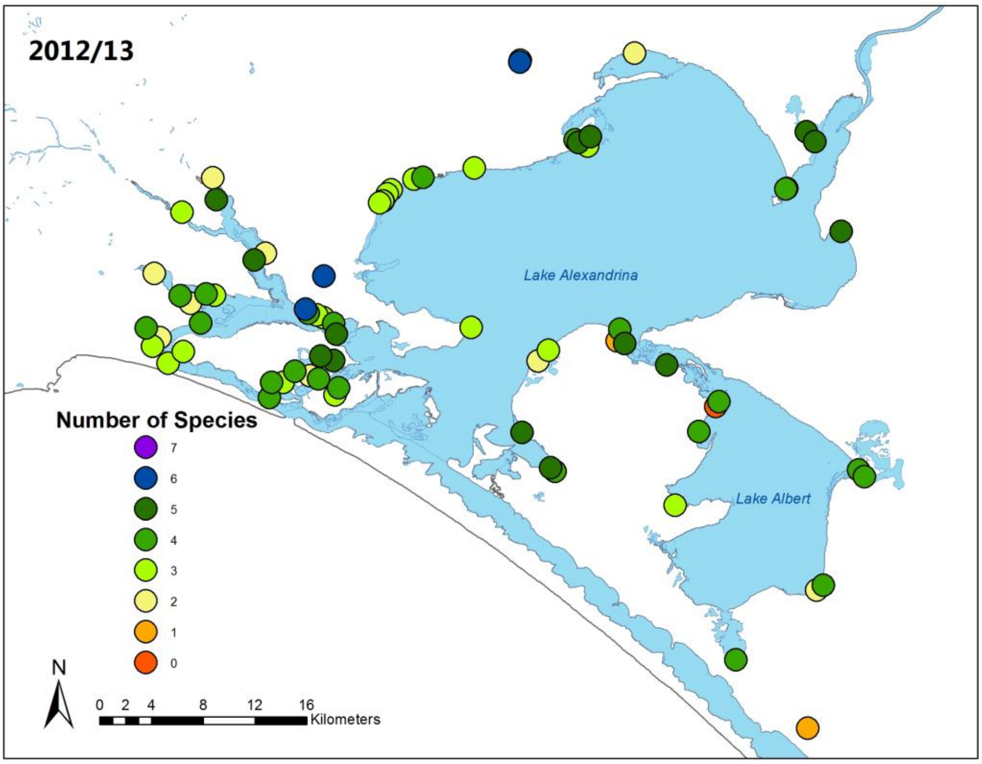
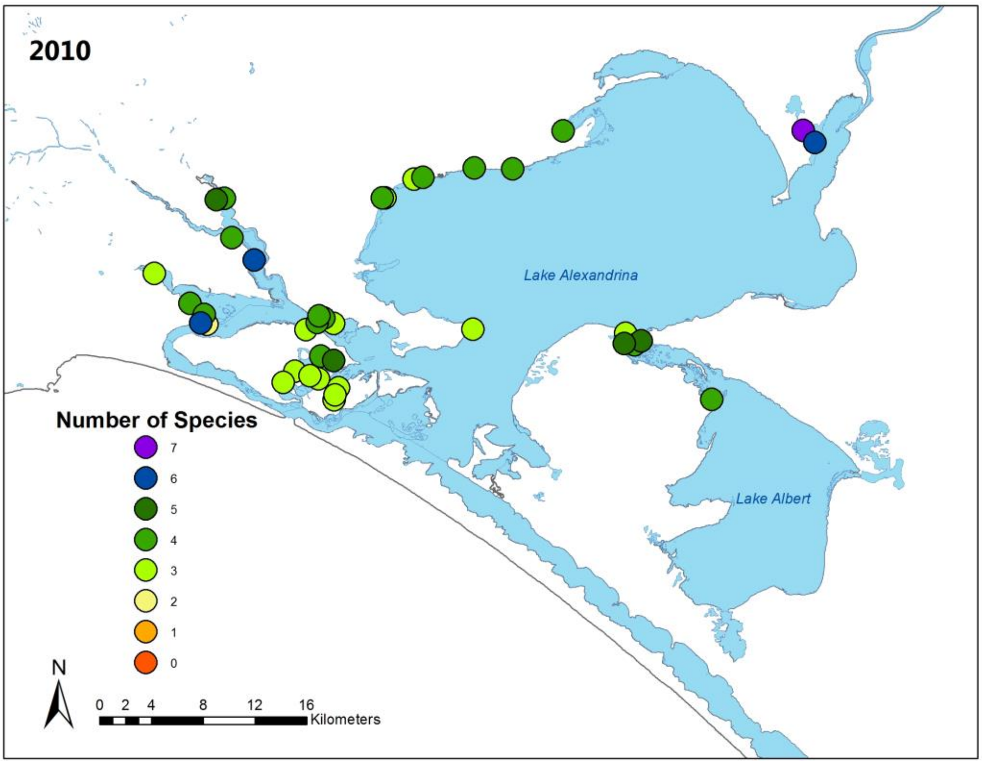


Figure 15: Species diversity including *L. raniformis* observed across all monitored locations in a) 2013/14 and b) 2012/13

a)



b)

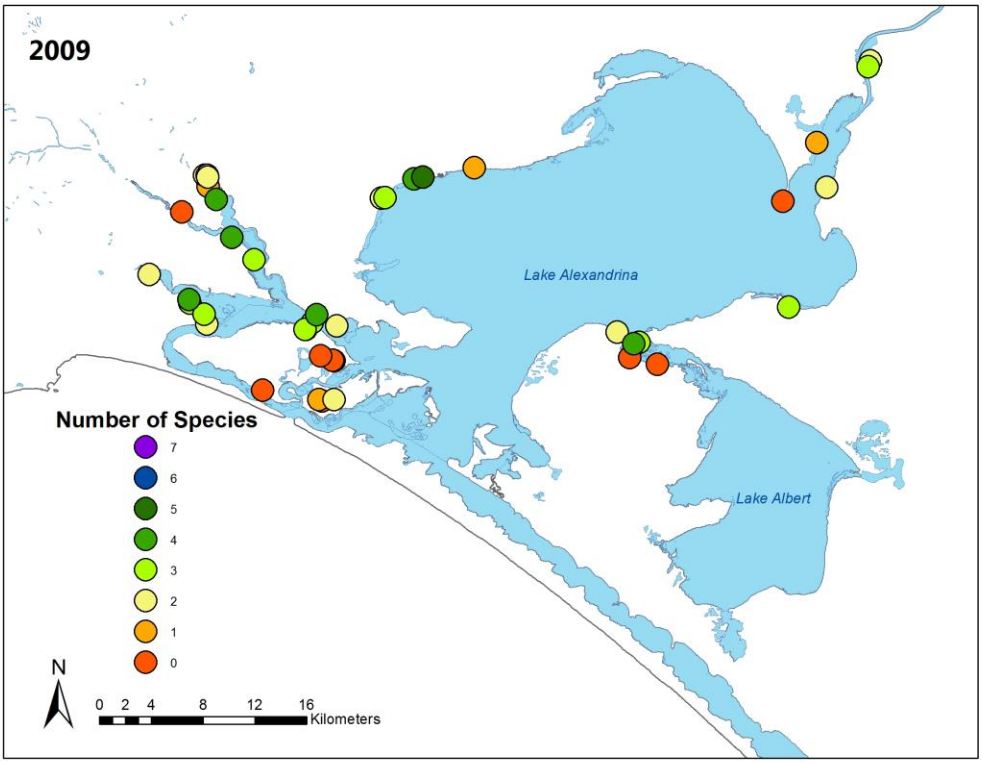


Figure 16: Species diversity including *L. raniformis* observed across all monitored locations in a) 2010 and b) 2009

2.5 Utilisation of sites by non-amphibious species

A total of 17 native and five introduced species were captured by motion-sensor cameras during April and May 2014 across four sites. A total of 3058 photographic events were captured, dominated by the house mouse (*Mus musculus*) which constituted 76.9%. House mice were present at all sites and observed on all cameras targeted at swamp rats. A total of 92 % of the events captured non-target species including 13 native bird species (both terrestrial and water birds), two non-target mammal species and four introduced mammal species. One introduced large-bodied fish species, the common carp (*Cyprinus carpio*) was also captured at Teringie Wetland (Figure 17 and Figure 18).

Water rats were captured within 4.02% of events and were identified at all sites, and within days of camera installation. The species was known to occur at one of the sites prior to surveying (Teringie) where an adult water rat was captured during small-bodied fish surveys 2012. No trend in preference of time of day was observed (Figure 19). Site characteristics were variable. All site has existing reed beds in close proximity to the camera locations but the shorelines were not uncomplex. Grasslands (of predominantly introduced grasses *Paspalum* sp., *Pennisetum clandestium* and/or the native grass *Distichlis distichlophylla*), sedgelands (*Bolboschoenus cardwellii, Juncus kraussii* and *Eleocharis actua*) and herblands (*Ludwigia peploides*, *Aster subulatus* and *Myriophyllum* sp.) constituted much of the area at each site contributing to the complexity of habitat. Due to the small sample size, detailed analysis of the influence of habitat characteristics on capture rates will be undertaken following an increase in sampling effort.

Swamp rats were only detected at one site, Nurra Nurra on the fringe of Lake Albert at the eastern end of the Narrung Narrows. The species constituted 3.98% of the total photographic events from all sites and 18% of events at Nurra Nurra (122 events). 58% of the swamp rat events were captured between 6.00pm and 9.00pm (Figure 19). The site contains deep sands, which have eroded in areas. There was clear evidence of swamp rat occupancy at the site (burrows, scratchings and runs) (Figure 20). Revegetation efforts cover much of the site incorporating common over-storey species such as native pine (*Callitris* sp.), drooping sheoak (*Allocasuarina verticillata*) and *Eucalyptus* species throughout the existing veldt grass (*Erharta* sp.) grasslands. Soursobs (*Oxalis pes-capre*) were abundant and possibly constitute a portion of the swamp rat diet. Many of the scratchings by Swamp rats contained the empty fibrous outer-layers of the soursob bulb (the underground reproductive part of the plant). Predation on house mice (and likely swamp rats) by cats, foxes and birds was captured on six occasions, two of these by cats at Nurra Nurra during night hours (Figure 21).

Table 13: Total number of photographic events captured per species at each monitoring location during April/May 2014.

		Site				
Common Name	**Species Name**	**Knappstein's 1**	**Nurra Nurra**	**Orange Island**	**Teringie**	**Total**
Native mammal species						
Echidna	*Tachyglossus aculeatus*	3				**3**
Swamp rat	*Rattus lutreolus*		122			**122**
Water rat	*Hydromys chyrsogaster*	4	63	4	52	**123**
Western grey kangaroo	*Macropus fuliginosus*				18	**18**
Native bird species						
Black kite	*Milvus migrans*		1			**1**
Duck sp.				1	1	**2**
Eastern barn owl	*Tyto delicatula*			1		**1**
Egret sp.		1		1		**2**
Eurasian coot	*Fulica atra*	22		4		**26**
Magpie	*Cracticus tibicen*	12		4		**16**
Pacific black duck	*Anas superciliosa*			195		**195**
Pelican	*Pelecanus conspicillatus*			4		**4**
Pied cormorant	*Phalacrocorax varius*			1		**1**
Quail	*Turnix sp.*				1	**1**
Splendid fairy-wren	*Malurus splendens*		7			**7**
White-faced heron	*Egretta novaehollandiae*	30			3	**33**
Willie wagtail	*Rhipidura leucophrys*	4				**4**
Introduced species						
Cat	*Felis catus*		1			**1**
Common carp	*Cyprinus carpio*				25	**25**
Cow	*Bos primigenius*			62	58	**120**
House mouse	*Mus musculus*	771	483	681	417	**2352**
Rabbit	*Lepus curpaeums*			1		**1**
	Total	**847**	**677**	**959**	**575**	**3058**

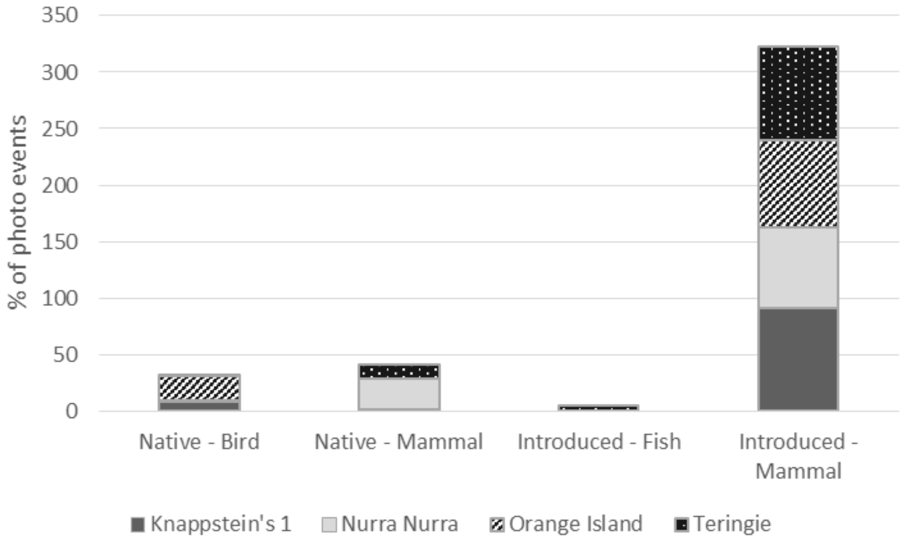


Figure 17: Percentage of total photo events for all sites captured per species type over a four-week period in April/May 2014

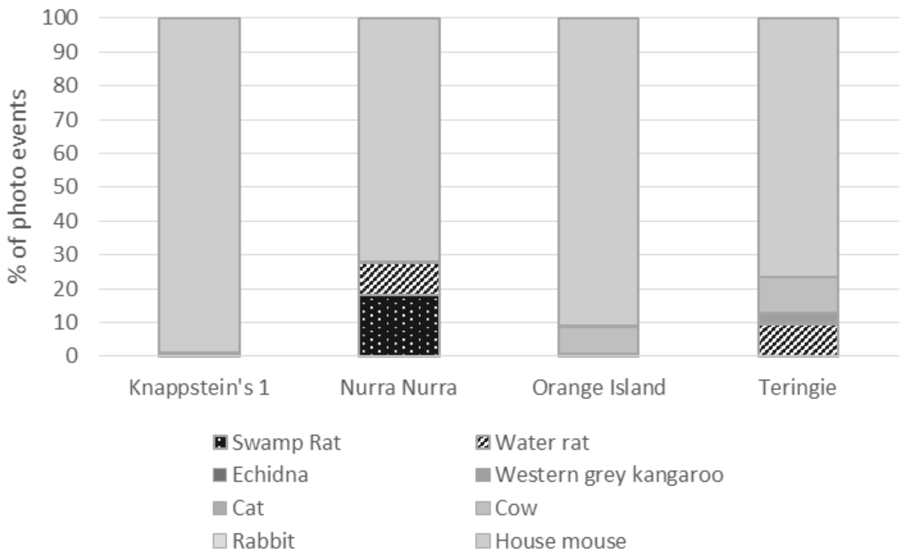


Figure 18: Percentage of total photo event of mammals captured per site over a four-week period in April/May 2014

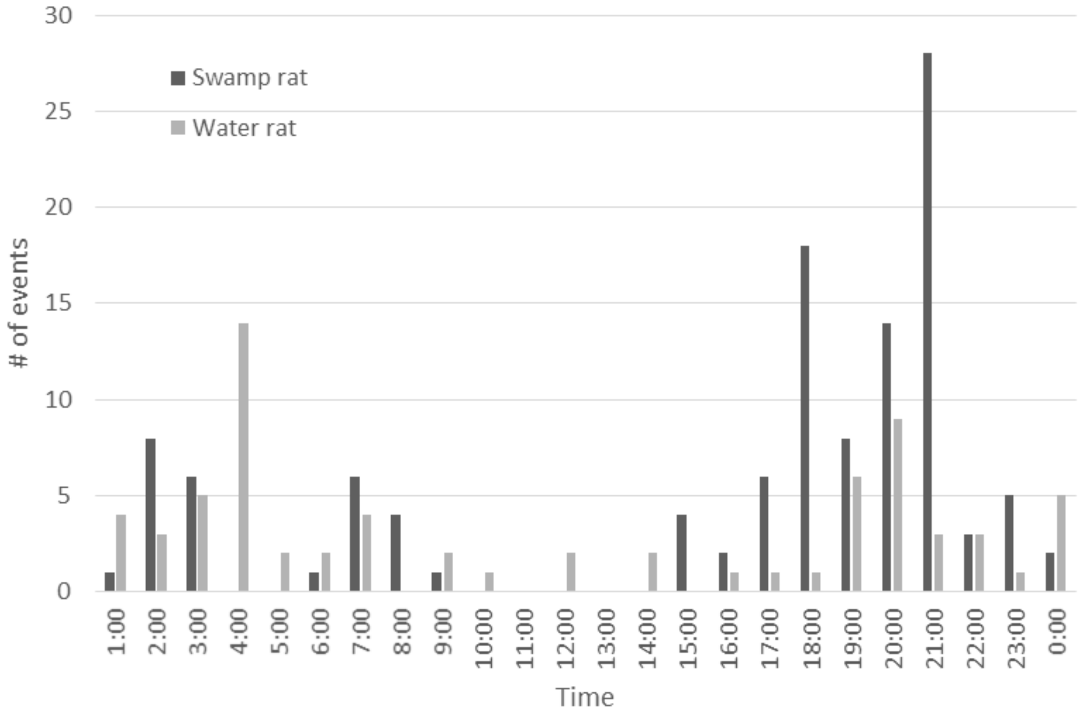


Figure 19: Distribution of photographic events over time of day for swamp rats and water rats April/May 2014

a) b)

Figure 20: a) example of water rat camera setup and b) swamp rat scratchings at Nurra Nurra

a)

b)

c)

d)

e)

f)

Figure 21: a) swamp rat (Nurra Nurra); b) water rat (Teringie); c) swamp rat (Nurra Nurra); d) feral Cat (Nurra Nurra); e) echidna (Knappstein's 1) and f) barn owl (Orange Island)

4.0 Discussion

4.1 Abundance and Distribution

Since the return of water levels in 2010, Lake Alexandrina and Lake Albert has experienced relatively stable water levels (within the band of 0.5-1.0m AHD) resulting in comparatively continuous inundation of wetland habitats for three years (with the exception of some ephemeral sites). Together with data provided by volunteers, this project has provided good spatial coverage of *L. raniformis* monitoring sites in the Lake Alexandrina, Lake Albert and the lower connected areas of the tributaries of Currency Creek and Finniss River. Amount of available habitat and habitat complexity has improved since 2010 and water levels were maintained at a level which inundated these habitats over a period that would be considered to be conducive for *L. raniformis* breeding events. The response by *L. raniformis* to habitat condition and water level management during 2013/14 has been assessed over four consecutive surveys incorporating historic locations, recent observations and suitable *L. raniformis* habitat.

Out of 43 project sites and an additional 38 community monitored sites, only two sites were found to be occupied by *L. raniformis* in 2013/14. Wellington East Wetland in the north-east of the study region where the River Murray begins to meet Lake Alexandrina and Goolwa Channel 'Knappsteins 2' near the township of Clayton Bay in the south-west of the region. The increase in available habitat for *L. raniformis* by the continued recovery of wetland habitats in many areas of the CLLMM region may influence the detectability of the species due to dispersal and occupancy of new areas. *L. raniformis* is a species known to readily occupy new areas (Wassens *et al.* 2008) with the ability to travel up to a kilometre in 24-hour period (Robertson *et al*. 2002). To cue strong breeding responses *L. raniformis* is considered to be reliant on flooding of temporary of ephemeral areas for breeding (Wassens 2008, Gonzalez et.al, 2011). Despite the increase in habitat and the period of elevated water levels by approximately 0.4 metres during August to October, calling of *L. raniformis* was not detected until January just prior to water levels receding. This suggest that the timing of inundation may have influenced *L. raniformis* abundance in 2013/14. Algae and submerged aquatic plant growth were generally observed to increase during the warmer months from which *L. raniformis* were rafting from.

Only one individual was visually identified at 'Knappsteins 2' during one survey event and one individual detected calling during the final survey event. This site is, however, located within 300 metres of what was an occupied site in 2012 and one kilometre of what was an occupied site in 2009 at Clayton Bay following the artificial blocking and inundation of the Goolwa Water Level Management Area. The *L. raniformis* observed at Wellington East (approximately five individuals on one occasion) were also within a relatively short distance of a previously occupied site, Pelican Lagoon, 7 km downstream and a Frog Census record near the Wellington township in 2000. Pelican Lagoon has been considered the 'stronghold' population of the CLLMM region, having been occupied in moderate to high abundances by *L. raniformis* in 2005 (Simpson *et al*. 2006) and 2010 (Mason & Hillyard 2011) (no surveys were conducted in between these periods). The changes observed in the distribution of *L. raniformis* in 2013/14 in comparison to past years continue to demonstrate their responsiveness to changes in habitat as a result of water level and land management and/or changing habitat condition.

No *L. raniformis* were detected using automated call recording units and similar species composition of other species were recording when comparing four rounds of manual nocturnal surveys with four weeks of automated recordings. Limitations currently exist around using call recognition software to identify frog species particularly regarding the development of suitable reference call files and filtering of unwanted noise matter. Wind and reed beds are characteristics of the study region. Manual identification of frogs from standardised portions of the recordings do provide a useful tool to sample areas that are inaccessible at night and to achieve more fine-scale sampling, particularly in response to rapidly changing water levels.

No *L. raniformis* have been detected within in the eastern side of the study area, encompassing Lake Albert, during all monitoring events conducted between 2009 and 2014. This may simply be due to the low number of sites sampled in this area. Previously, the elevated salinity in Lake Albert has influenced site suitability as part of the selection process. In the past six months, salinity levels have now decreased in Lake Albert to a level comparable to sites occupied by *L. raniformis* in January 2014, suggesting the need for a greater sampling effort in this area in the future.

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*). A significant increase in Eastern gambusia abundance in the CLLMM region in the past two years have been observed (Wedderburn & Barnes 2014). The species is a major threat to the survival of frog eggs and tadpoles, (Komak & Crossland 2000). Mortality of tadpoles due to Gambusia predation was found to be as high as 40% in laboratory experiments of the green and golden bell frog (*Litoria aurea*), a closely related species to *L. raniformis* (Morgan & Buttemer 1996).

The key changes observed in the distribution and abundance of remaining frog species was the detection of the painted frog. Average species diversity per site was comparable to 2012. Species diversity was highest in 2010 following re-inundation of wetland habitats, which also coincided with the highest abundance of *L. raniformis* recorded as part of this monitoring program. 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).

4.2 Habitat Use and Management

Sites occupied by *L. raniformis* in 2013/14 were of similar vegetative structural composition to those of previous years. Where *L. raniformis* were detected, adult males were typically recorded calling from within semi-open water with moderate coverage of emergent reeds and/or rushes, floating debris and some 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). Although the species was identified at only two locations in 2013, both of these sites contained dense reed monocultures within the close vicinity of the site, however were not utilised by calling males. The increase in plant growth at sites previously occupied in past years, particularly key sites such as Pelican Lagoon, combined with (or possibly as a result of) decreased connectivity due to colonisation of reeds are likely contributing factors to the lack of detection of *L. raniformis* at these sites and their dispersal to other areas. The maintenance of more complex habitats in the region is considered 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), dense vegetation may however provide habitat for the species outside the peak breeding period when frogs disperse from the breeding area. Little is known of their habitat requirements in the CLLMM region outside of the breeding period.

The reduced connectivity and reduced flows due to colonisation by reeds, particularly Common reed and Bulrush was apparent in a number of areas in the CLLMM region in 2013/14, notably at sites previously occupied by *L. raniformis* (i.e. Pelican Lagoon, Finniss River and Hindmarsh Island). Although reeds shelter areas making favourable conditions for many other plant species (and potentially *L. raniformis*), their ability to impede flow and increase sedimentation increases the risk of wetland habitats becoming disconnected and impacting water quality (a critical factor influencing wetland biota).

4.3 Non-amphibious species monitoring

The detection rate of water rats in the camera traps exceeded expectations and detection occurred relatively rapidly. This approach to assessing the distribution of Water rats in the CLLMM region is considered to be highly effective. The results of this project suggest this methodology may be less effective for assessing Swamp rat distribution in the CLLMM region, however a greater number of sites would need to be assessed.

Camera trap monitoring offers opportunities for the community to be a part of research and investigation activities in the region. The setup used in this project, which was refined over a longer period, is easy to maintain. Photos are a visual, easily shared way of increasing people's connection to the environmental changes occurring in the region. Careful setup and management through existing monitoring programs and networks would be needed to support volunteers and maintain consistency.

Recommendations

- 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.

- Increased engagement of volunteer input into monitoring events to promote better spatial coverage of monitoring locations. Provision of volunteer support, training, equipment and promotion are key elements for successful ongoing participation. Campaign for multiple sampling rounds to increase monitoring efforts across the desired sampling period.

- Assess impediments to flow and loss of habitat complexity from colonization 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.

- Monitor *L. raniformis* populations in the CLLMM region in response to continued water level management and changes in habitat condition. Target the use of automated call recording at sites inaccessible during night hours and to collect fine-scale information regarding changes in water levels. As salinity levels decrease in Lake Albert, increase sampling effort in this area of the CLLMM region, particularly in wetland areas that have shown good recovery in regards to submerged and emergent plant diversity.

- Define potential threatening processes affecting egg and larval stages of recruitment particularly by the exotic fish species, redfin and Eastern gambusia. Eastern gambusia favour shallow, vegetated wetland habitats where eggs settle and tadpole reside. Where possible/appropriate, control/removal of introduced fish would likely not only benefit *L. raniformis* tadpole survival, but tadpoles of other frog species and small-bodied fish.

- 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.

- Determine the distribution of water rats using camera trap methodology to help develop a baseline assessment of the population in the CLLMM region. Photo captures can be stored on publically accessible locations (i.e. web-based databases).

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

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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

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: minimum and maximum water quality results from all project sites

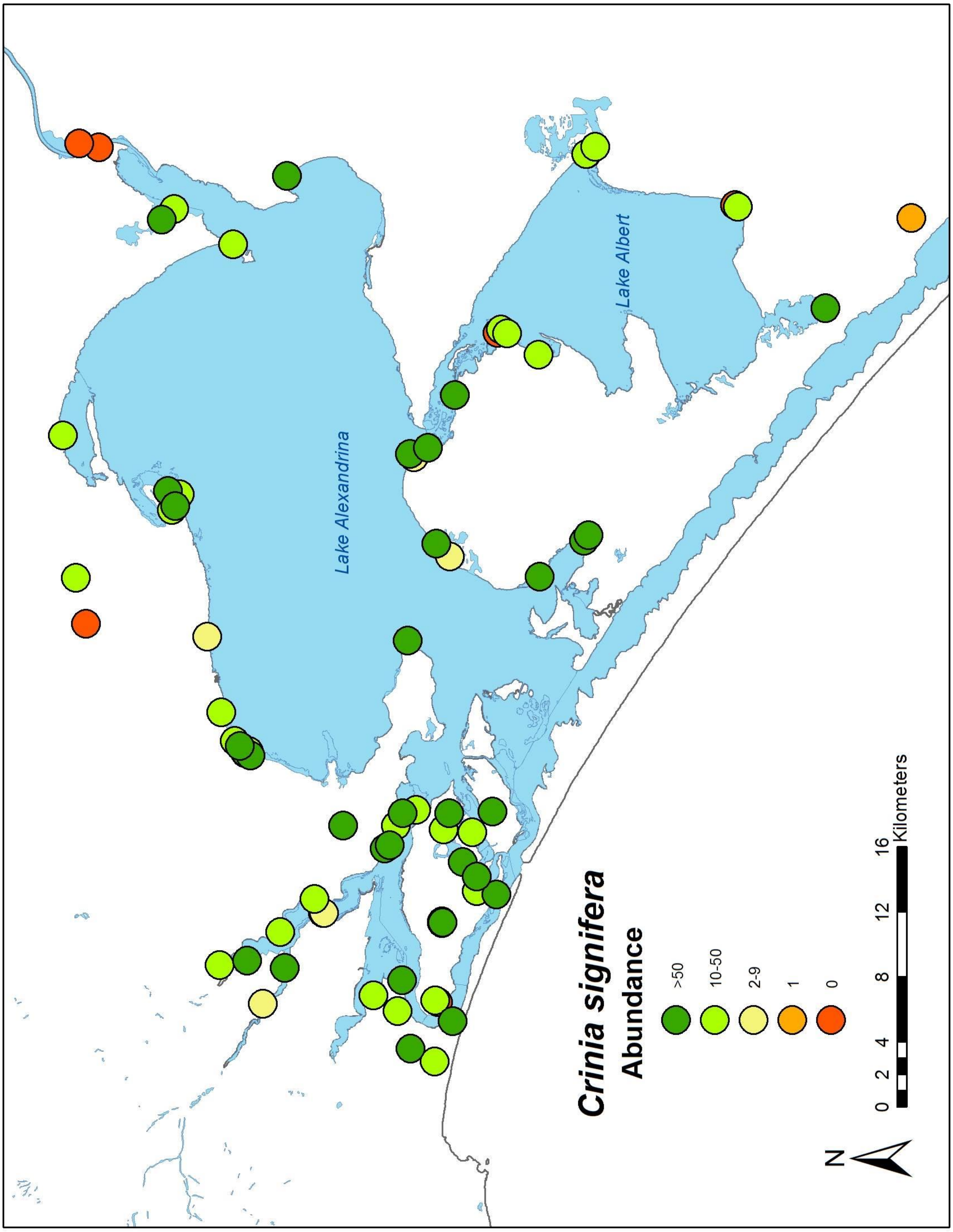
Site	Minimum temperature (°C)	Maximum temperature (°C)	Minimum Electrical Conductivity (µS/cm)	Maximum Electrical Conductivity (µS/cm)	Minimum pH	Maximum pH	Minimum Dissolved Oxygen (ppm)	Maximum Dissolved Oxygen (ppm)	Minimum Turbidity (NTU)	Maximum Turbidity (NTU)
Angas Mouth	19.4	25.1	1535	1757	7.69	8.6	4.66	8.51	8.33	32.5
Bremer Mouth	18.7	25.9	692	1794	7.98	8.17	5.7	9.08	46.9	116.3
Dunn's Lagoon - Duck Hospital	17.3	24.9	895	1167	7.97	9.66	5.08	9.11	33	44.8
Dunn's Lagoon - Snug Cove	18.4	25.4	769	929	7.22	8.88	5.55	8.95	22.6	44.6
Finniss River - Allnutts	18.4	28.9	1150	1996	7.72	8.79	2.7	7.26	7.4	24.6
Finniss River - Sterling Downs 1	22.2	26.4	1604	1706	8.26	8.88	3.17	8.62	9.7	28.2
Finniss River - Wally's Landing	17.9	29.6	1070	2440	7.73	7.97	4.52	8.01	29.2	47.1
Hindmarsh Island - Boggy Creek	16.5	27.8	1303	2213	8.02	8.94	4.69	10.18	8.1	45
Hindmarsh Island - Boggy Creek Culvert	16.9	16.9	1321	1321	8.36	8.36	9.15	9.15	40.2	40.2
Hindmarsh Island - Hunters Creek Denver Rd	16.8	29.9	1119	2090	7.69	9.97	5.49	7.56	7.9	31.1
Hindmarsh Island - Shadows Lagoon	16.1	20.6	1397	2300	8.11	8.61	5.78	8.23	34.2	96
Hunters Creek - Hunter's Creek Fishway	16.4	31.2	1234	2650	7.99	9.31	8	9.17	24.3	49.5
Jenny's Lagoon - FR01	15.8	22.1	1106	2043	8.35	8.81	3.05	6.95	32.5	38.2
Jenny's Lagoon - FR02	15.2	17	4.5	2018	9.69	9013	7.26	7.85	3.3	42.3
Knappstein's 1	16.6	24.9	1316	1387	7.95	8.72	5.53	8.73	82.1	130.2
Knappstein's 2	17	25.4	1253	1498	8.13	9.03	1.64	9.7	109.2	181
Lake Albert - Kennedy Bay	16.5	21.6	1118	13560	8.47	9.28	6.57	8.42	31	110.4
Lake Albert - Tobin Lodge	15.4	23.1	2.92	2580	7.86	8.23	4.48	6.98	15.7	209
Lake Albert - Waltowa Bay	20.5	20.5	3850	3850	8.46	8.46	3.26	3.26	101.8	101.8
Lake Albert - Waltowa Structure	17.2	22.2	1183	3010	8.44	8.53	5.3	5.55	139.4	148.6
Lake Alexandrina - Loveday Bay	15.1	22	599	1310	7.75	8.37	1.83	2.99	15	49
Lake Alexandrina - Low Point	15.2	21.8	591	837	8.24	10.4	3.53	9.89	28.8	229
Milang Snipe Sanctuary - North Basin MILFR05	14.7	24	3930	24200	7.42	7.73	1.44	5.87	3.5	9.8
Milang Snipe Sanctuary - North Shack side	15.3	18.7	7180	7530	7.3	7.9	2.48	4.55	1	3.7
Milang Snipe Sanctuary - Pobbybonk Point MILFR07	13.9	13.9	4230	4230	8.36	8.36	4.41	4.41	4.8	4.8
Milang Snipe Sanctuary - Southern end	13.1	15.2	235	8380	7.92	8.54	2.68	8.06	1.4	1.4
Mundoo Island - Pig Island/Fishtrap Creek	18.4	18.4	1570	3670	7.64	8.41	3.18	4.97	1	37.4
Mundoo Island - Stockyard Swamp	17.4	31.1	773	2194	6.88	8.24	4.43	8.26	25.7	86.8
Nalpa Station - Pomanda Point	19.2	22	404	777	7.41	7.9	5.77	9.45	86.8	96.9
Narrung - NARFRO3	17.2	23.5	650	5260	7.58	8.52	7.85	9.81	3.1	79.2
Narrung - Wetland Structure (NARFR01)	16.5	23.9	4.08	5300	7.45	8.73	7.87	9.01	33.3	60
Narrung Narrows - Lakehouse / Jacobs	17.8	22.4	1109	1807	7.67	9.05	6.64	8.07	18.2	130.2
Narrung Narrows - Nurra Nurra	17.8	22.1	2310	2760	7.65	8.29	1.69	6.03	20.8	46.2
Pelican Laggon - C (Windmill site)	18.5	23.7	241	596	7.73	8.55	4.2	7.69	110.7	246
Pelican Lagoon - B (Lignum site)	18.7	23.1	660	937	6.8	7.89	0.32	6.54	5.81	218
Teringie - TERFR01	14.9	16.9	3.33	3630	8.66	9.28	4.34	6.19	36.3	342
Teringie - TERFR02	15.2	15.2	43400	43400	8.91	8.91	5.7	5.7	68.1	68.1
Tolderol - Channel 6 (TOLFRO3)	16.4	25.1	779	846	8.08	8.48	3.3	12.26	3.7	27.8
Tolderol - Lakeshore Picnic area (TOLFRO2)	15.9	26.6	567	756	8.29	8.67	5.01	10.16	57	126
Tolderol - Main Channel Lake end (TOLFRO1)	17.9	25.4	28.7	729	7.56	8.55	7.51	18.4	1.4	87.6
Tolderol - Pump shed (TOLFR043)	15.5	25.6	2.18	2.89	7.64	7.85	4.03	5	0.3	3
Wellington East	21.8	24.2	2690	2810	8.04	8.96	3.71	4.31	2.7	5.8

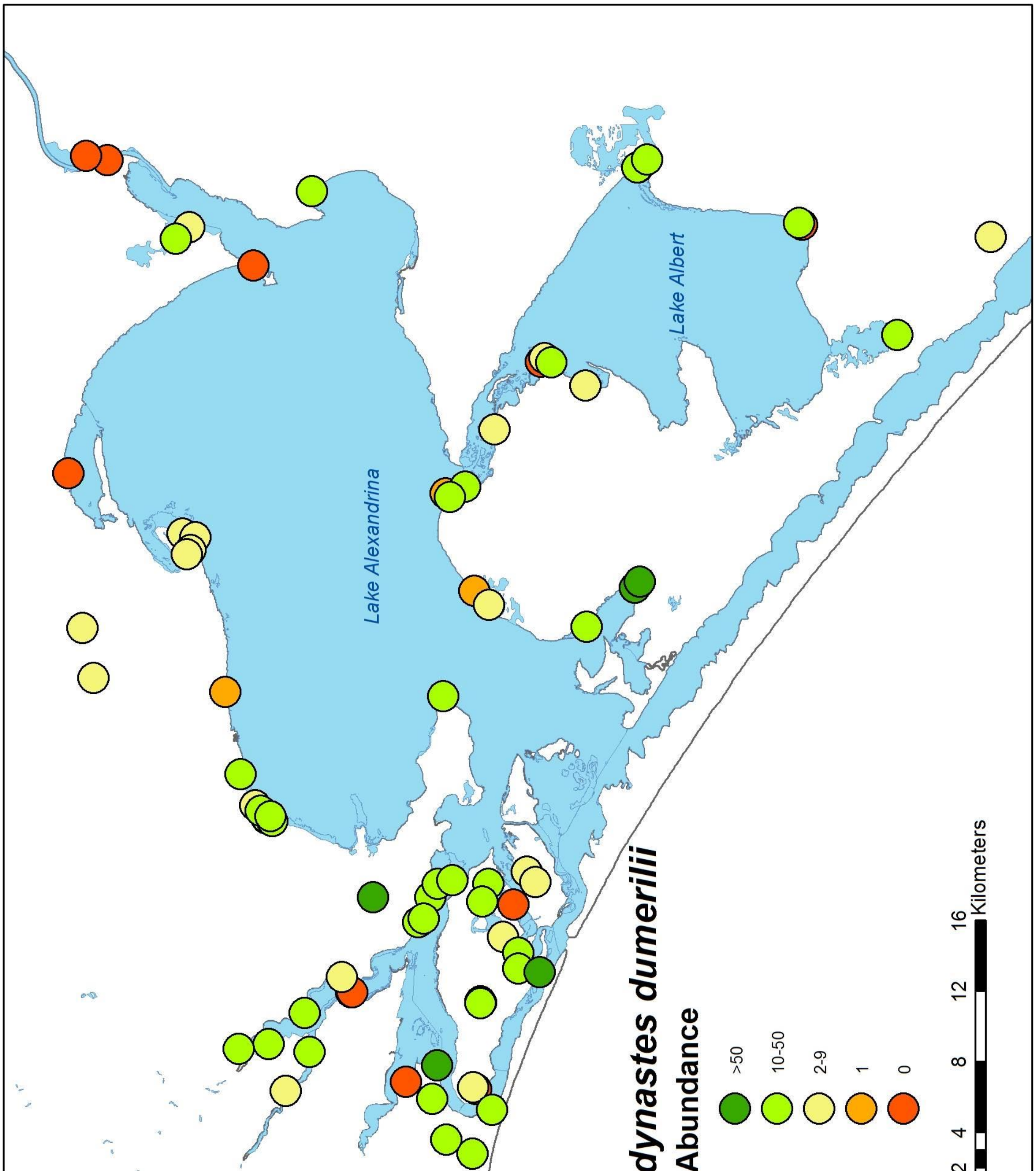
Appendix 3: Results of nocturnal surveys at all sites **(**including *L. raniformis*), abundance scores assigned to each species (1 = 1; 2 = 2-9; 3 = 10-50; 4 = >50)

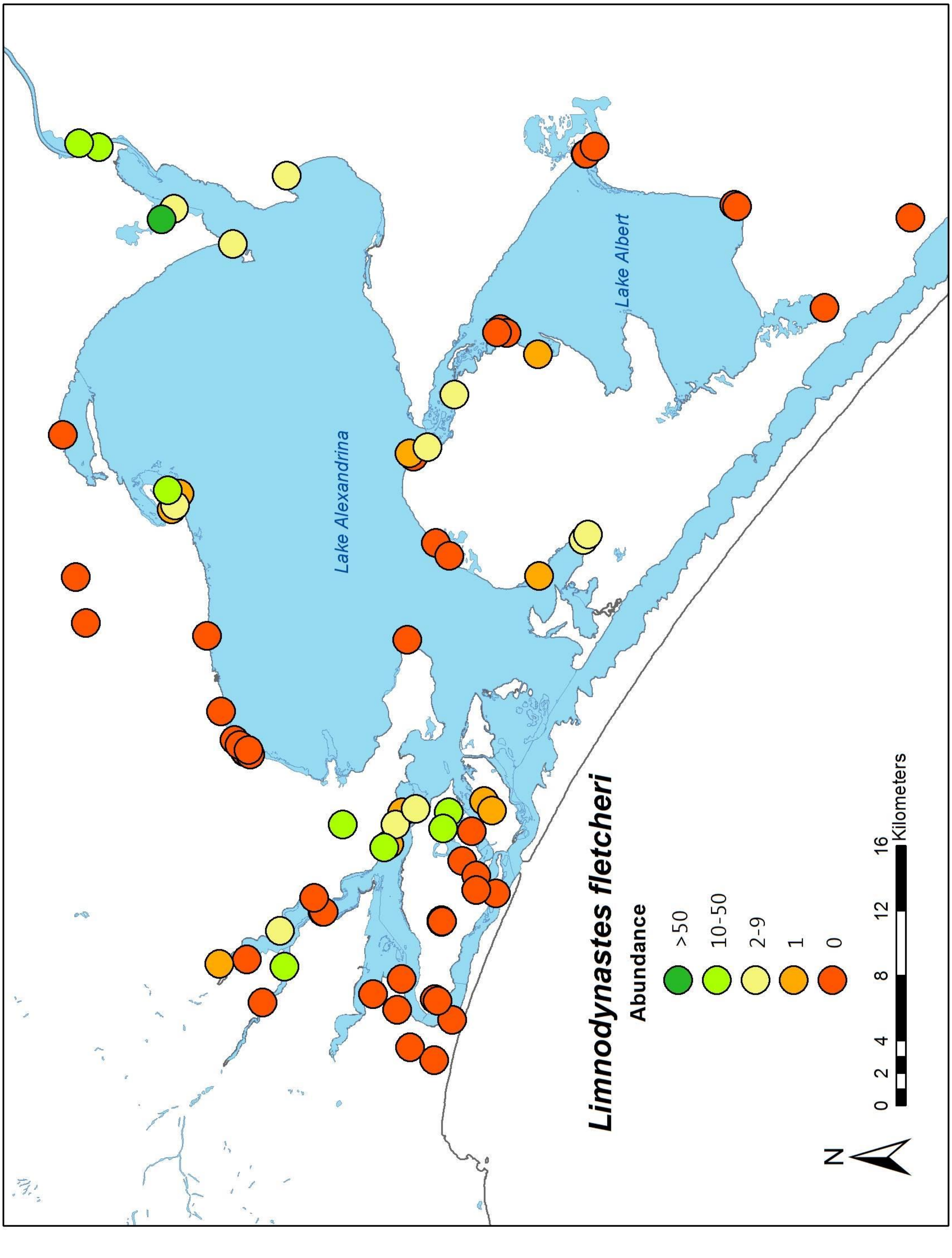
SITE	Southern Bell Frog	Eastern Banjo Frog	Common Froglet	Spotted Grass Frog	Brown Tree Frog	Peron's Tree Frog	Long-thumbed Frog	Painted Frog	Total Species Recorded
Kessell Road effluent ponds Goolwa	0	3	4	3	3	2	0	2	6
Knappstein's 2	1	3	4	3	2	0	1	0	6
Pelican Laggon - C (Windmill site)	0	2	3	1	2	1	2	0	6
Alison Avenue, Goolwa North	0	4	4	1	2	3	0	0	5
Clayton Bay Boardwalk	0	3	3	2	2	0	2	0	5
Dunn's Lagoon - Duck Hospital	0	3	4	2	2	0	1	0	5
Dunn's Lagoon - Snug Cove	0	3	3	2	2	0	2	0	5
Finniss River - Allnutts	0	3	3	1	2	0	2	0	5
Hindmarsh Island - Boggy Creek	0	3	4	3	3	0	3	0	5
Hindmarsh Island - Hunters Creek Denver Rd	0	2	4	3	3	0	0	1	5
Hindmarsh Island - Shadows Lagoon	0	3	3	3	3	0	3	0	5
Hindmarsh Island Effluent Ponds	0	2	3	2	2	2	0	0	5
Jenny's Lagoon - FR01	0	4	4	3	1	0	2	0	5
Jenny's Lagoon - FR02	0	4	4	3	1	0	2	0	5
Knappstein's 1	0	3	4	3	1	0	3	0	5
Lake Albert - Tobin Lodge	0	2	3	3	3	0	1	0	5
Lake Alexandrina - Loveday Bay	0	3	4	4	1	0	1	0	5
Lake Alexandrina - Low Point	0	3	4	3	2	0	2	0	5
Milang Snipe Sanctuary - North Basin MILFR05	0	3	4	3	1	0	0	1	5
Milang Snipe Sanctuary - North Shack side	0	3	4	4	2	0	0	1	5
Milang Snipe Sanctuary - Pobbybonk Point MILFR07	0	3	4	3	1	0	0	1	5
Narrung - NARFRO3	0	1	4	4	3	0	1	0	5
Narrung - Wetland Structure (NARFR01)	0	3	4	3	2	0	2	0	5
Narrung Narrows - Lakehouse / Jacobs	0	2	4	3	2	0	3	0	5
Pelican Lagoon - B (Lignum site)	0	3	4	3	2	0	4	0	5
Tolderol - Channel 6 (TOLFRO3)	0	2	4	3	2	0	3	0	5
Tolderol - Lakeshore Picnic area (TOLFRO2)	0	2	3	2	2	0	1	0	5
Tolderol - Pump shed (TOLFR043)	0	2	3	2	2	0	1	0	5
Watkins, Tookayerta	0	3	4	3	2	0	3	0	5
Wellington East	2	0	0	3	2	3	3	0	5
Wetland Beach, Clayton Bay	0	4	4	4	2	0	3	0	5
442 Seven Mile Road 15km south of Meningie	0	2	1	1	1	0	0	0	4
Bird Viewing Hut, Goolwa South	0	3	4	4	1	0	0	0	4
Borrett's Swamp, Sheoak Lane Mosquito Creek	0	2	0	2	2	3	0	0	4
Bremer Mouth	0	1	2	2	2	0	0	0	4
Byrnes Road stormwater pond, Goolwa North	0	3	3	3	0	0	0	2	4
Currency Creek Rd, Goolwa North Site B	0	2	3	2	2	0	0	0	4
Fiebig - near Waltowa	0	3	3	3	1	0	0	0	4
Golfview Road - Goolwa	0	3	3	2	3	0	0	0	4

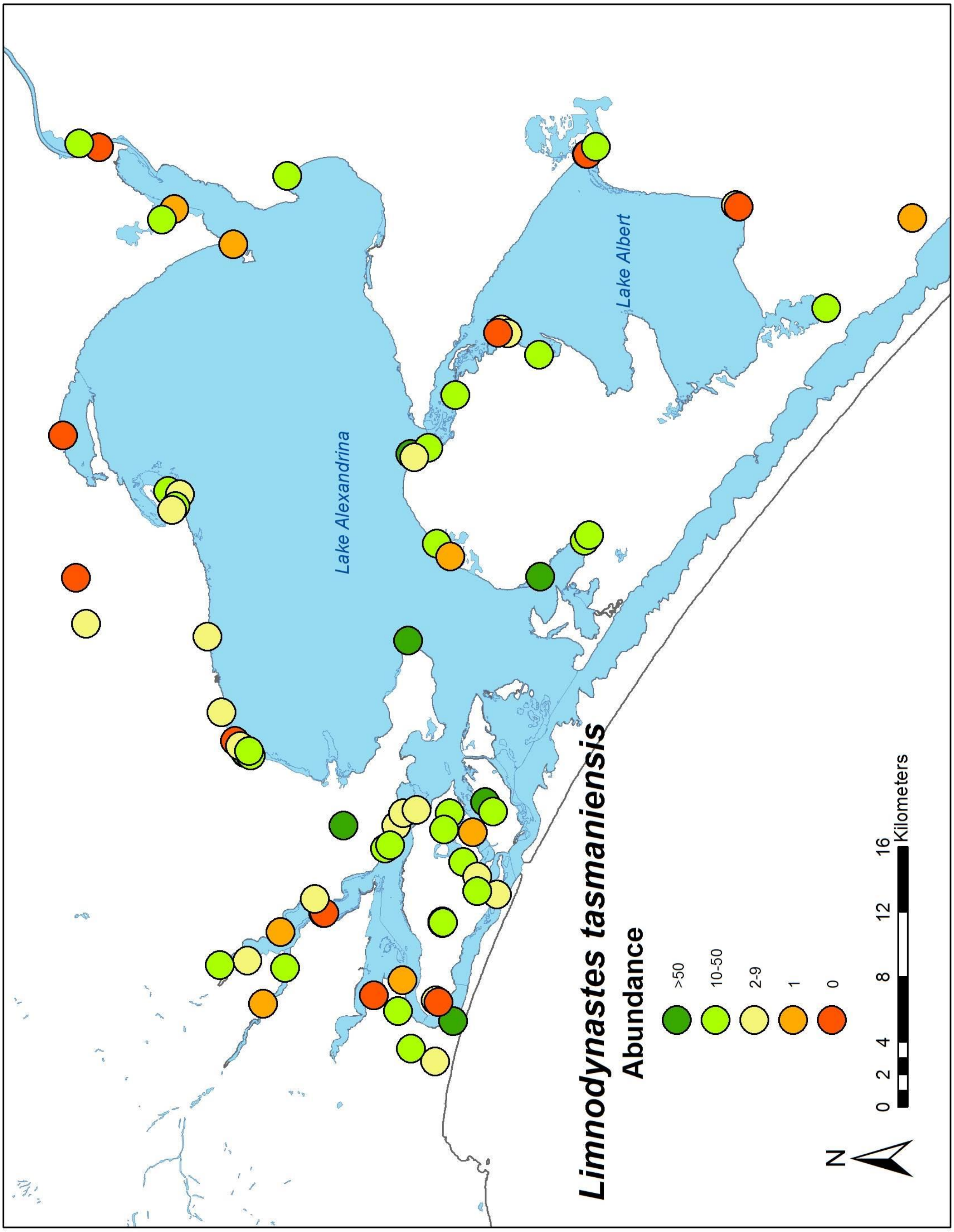
SITE	Southern Bell Frog	Eastern Banjo Frog	Common Froglet	Spotted Grass Frog	Brown Tree Frog	Peron's Tree Frog	Long-thumbed Frog	Painted Frog	Total Species Recorded
Gollan's Waterhole, Mosquito Creek	0	2	3	0	2	2	0	0	4
Grey Paddock Hindmarsh Island behind shacks	0	4	4	2	2	0	0	0	4
Huczko Wetland, Point Sturt	0	3	4	4	0	0	0	2	4
Hunters Creek - Hunter's Creek Fishway	0	3	4	2	1	0	0	0	4
Lake Albert - Kennedy Bay	0	3	4	3	1	0	0	0	4
Milang Swan Sanctuary	0	3	3	2	2	0	0	0	4
Mundoo Island - Pig Island/Fishtrap Creek	0	2	5	4	0	0	1	0	4
Mundoo Island - Stockyard Swamp	0	2	4	3	0	0	1	0	4
N.E. Wetland, Milang	0	3	4	2	2	0	0	0	4
Nalpa Station - Pomanda Point	0	0	3	1	2	0	2	0	4
Narrung Narrows - Nurra Nurra	0	2	3	2	2	0	0	0	4
Nurra Nurra Point	0	3	3	2	2	0	0	0	4
Swamp on Barnhill Rd, Finniss	0	3	3	3	0	0	1	0	4
Teringie - TERFR02	0	2	2	1	0	0	0	1	4
Tolderol - Main Channel Lake end (TOLFRO1)	0	2	4	3	0	0	2	0	4
Tookayerta creek, south of Currency Creek Winery	0	2	2	1	2	0	0	0	4
Angas Mouth	0	3	3	2	0	0	0	0	3
Finniss River - Wally's Landing	0	3	4	2	0	0	0	0	3
Hayter, Finniss	0	2	3	2	0	0	0	0	3
Hindmarsh Island - Boggy Creek Culvert	0	0	3	1	1	0	0	0	3
Milang Bay Wetland	0	2	3	0	1	0	0	0	3
Murray Mouth Rd, Hindmarsh Island	0	3	3	3	0	0	0	0	3
Narrung Wetland	0	3	2	2	0	0	0	0	3
S.W. Wetland, Milang	0	3	3	3	0	0	0	0	3
Samphire wetlands opp, side road Chappell Rd Hindmarsh Island	0	3	4	3	0	0	0	0	3
Samphire wetlands opp. 81 McLeay Rd, Hindmarsh Island	0	2	4	3	0	0	0	0	3
Teringie - TERFR01	0	1	4	3	0	0	0	0	3
Waltowa Structure	0	3	3	3	0	0	0	0	3
81 McLeay Rd, Hindmarsh Island	0	0	4	2	0	0	0	0	2
Currency Creek Rd, Goolwa North Site A	0	0	3	0	1	0	0	0	2
Finniss River - Sterling Downs 1	0	0	2	2	0	0	0	0	2
Lake Albert - Waltowa Structure	0	0	3	0	1	0	0	0	2
Meningie Foreshore	0	3	0	2	0	0	0	0	2
Tolmer st, Wellington	0	0	0	0	0	2	3	0	2
Angas River near park, Strathalbyn	0	0	2	0	0	0	0	0	1
Boggy Lake fringing wetland	0	0	3	0	0	0	0	0	1
Finniss River - Sterling Downs 2	0	0	2	0	0	0	0	0	1
Meningie stormwater culvert	0	0	3	0	0	0	0	0	1
Hindmarsh Island Marina	0	0	0	0	0	0	0	0	0
Lake Albert - Waltowa Bay	0	0	0	0	0	0	0	0	0
Nurra Nurra Reserve	0	0	0	0	0	0	0	0	0

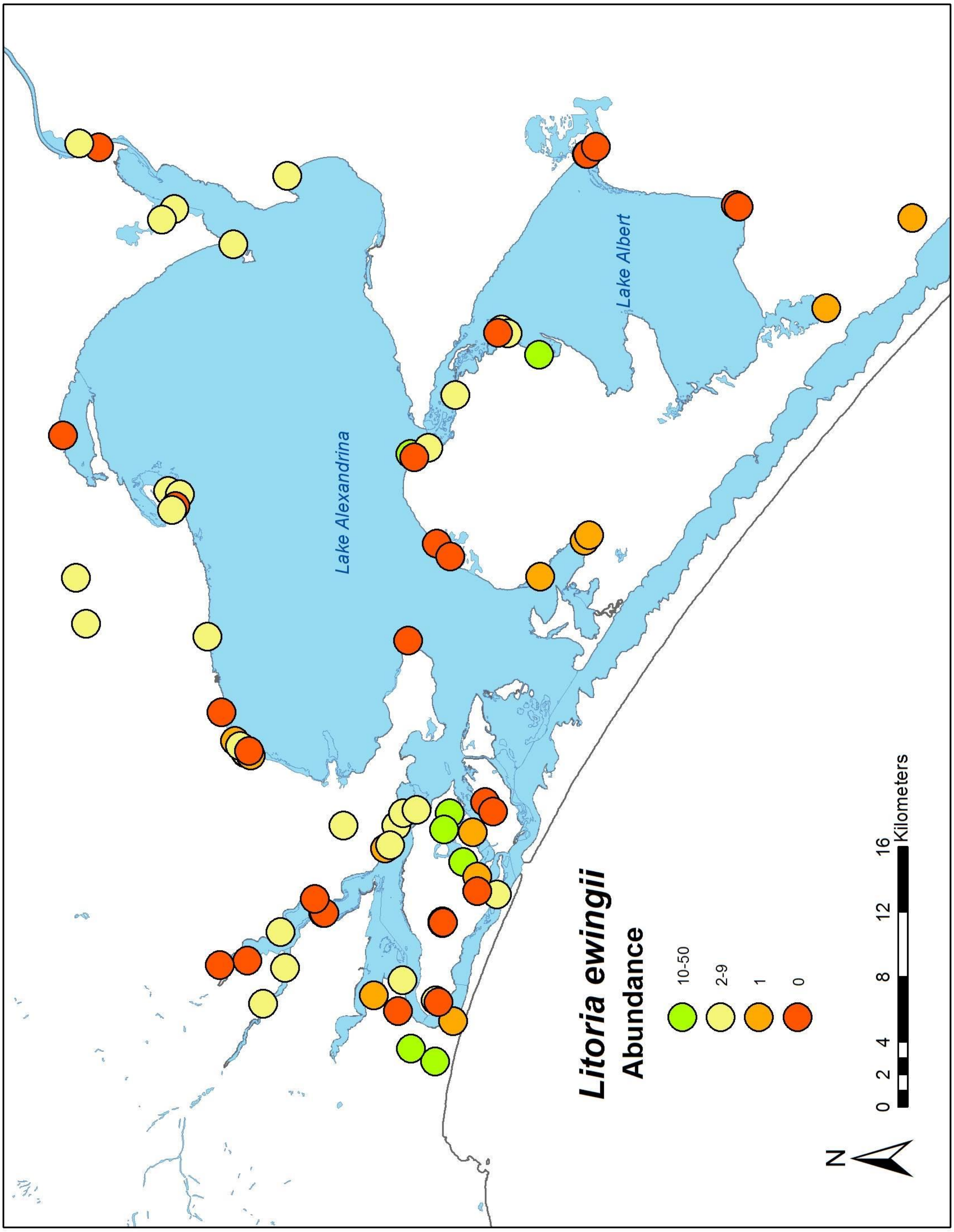
Appendix 4: Abundance of each frog species per monitoring site 2013

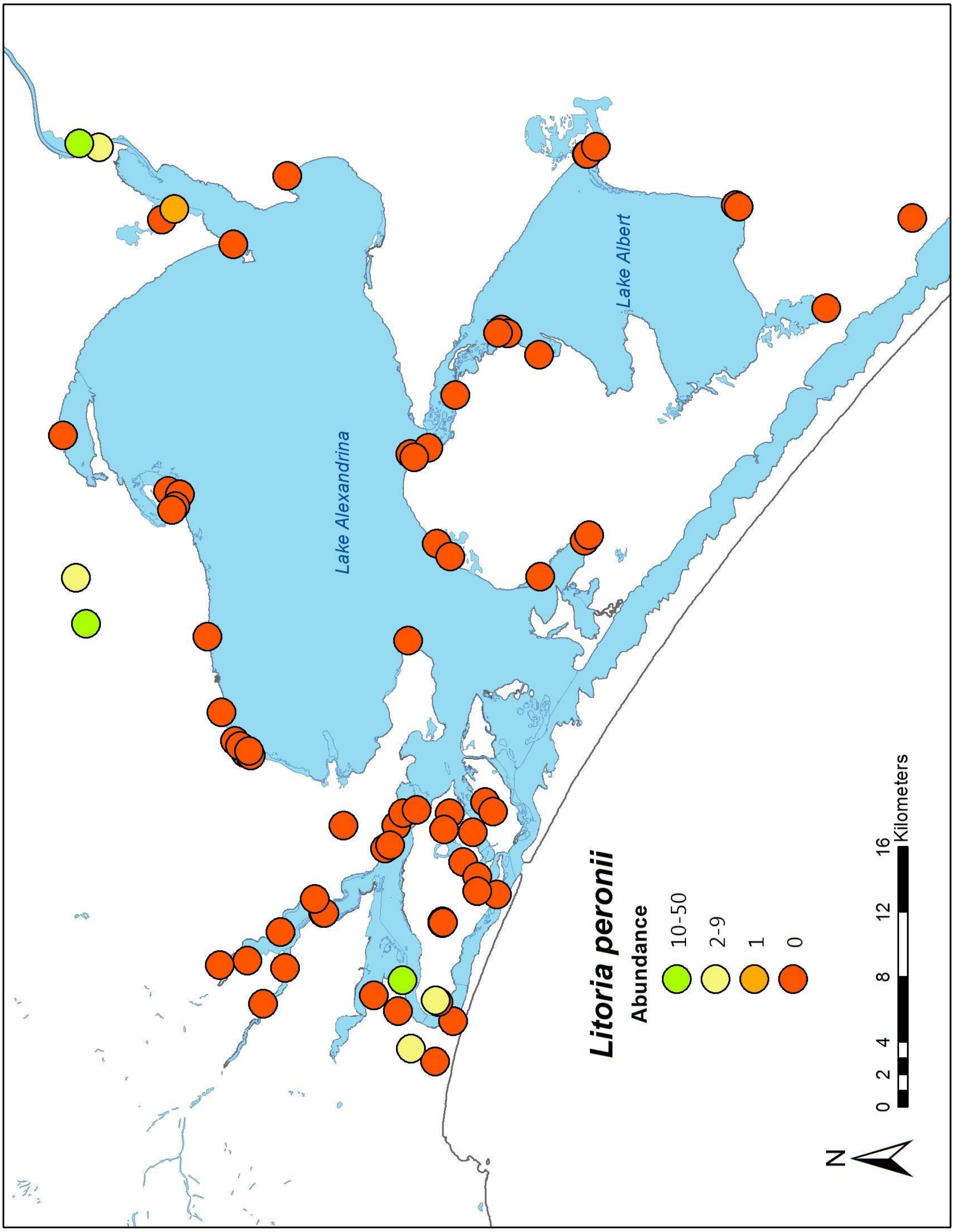


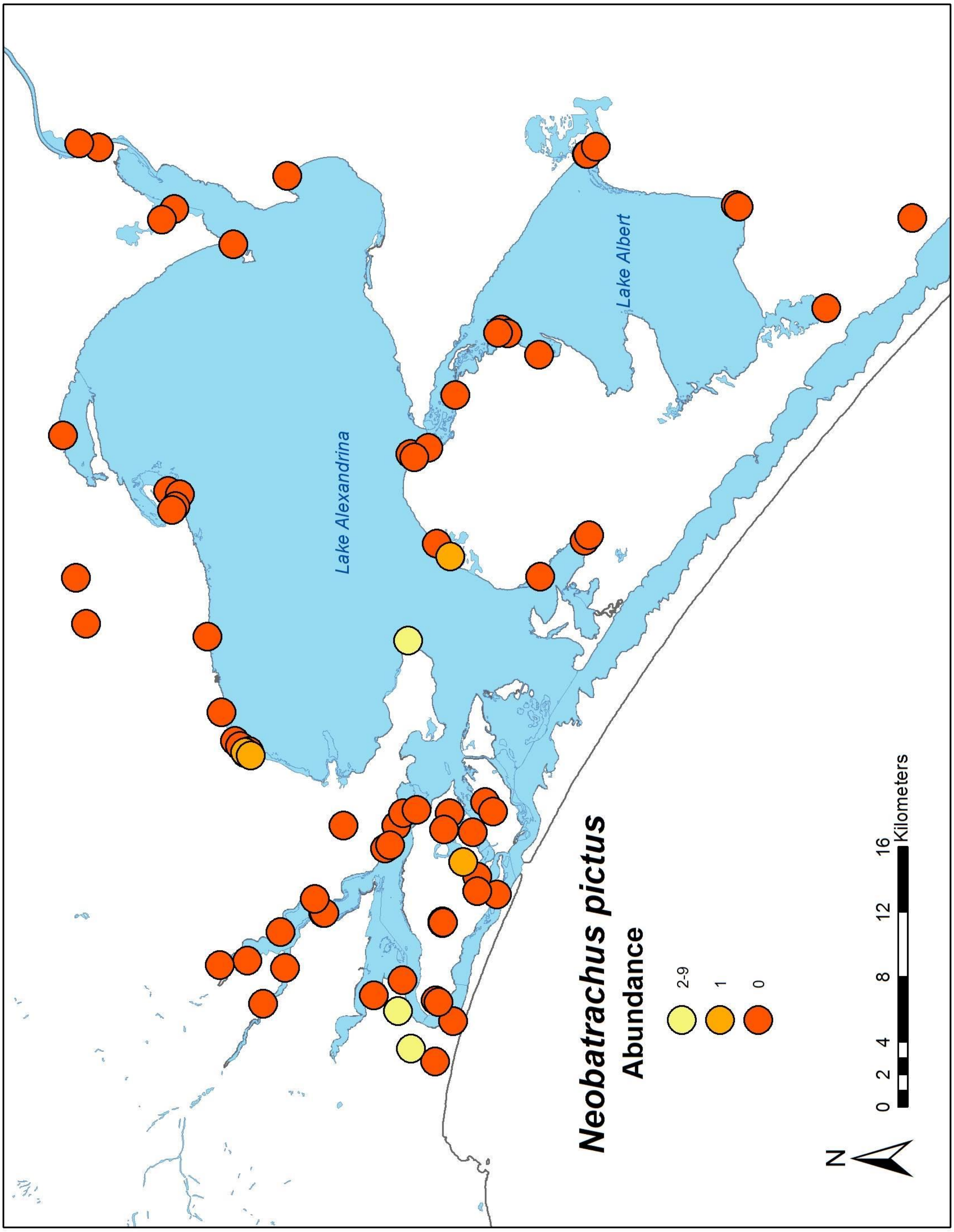

Lake Alexandrina
Lake Albert
Limnodynastes dumerilii
Abundance
>50
10-50
2-9
1
0
0 2 4 8 12 16
Kilometers
N


Limnodynastes fletcheri
Abundance
>50
10-50
2-9
1
0
Lake Alexandrina
Lake Albert
0 2 4 8 12 16
Kilometers
N


Lake Alexandrina
Lake Albert
Limnodynastes tasmaniensis
Abundance
>50
10-50
2-9
1
0
0 2 4 8 12 16
Kilometers
N


Lake Alexandrina
Lake Albert
Litoria ewingii
Abundance
10-50
2-9
1
0
0 2 4 8 12 16
Kilometers
N


Lake Alexandrina
Lake Albert
Litoria peronii
Abundance
10-50
2-9
1
0
0 2 4 8 12 16
Kilometers
N


Lake Alexandrina
Lake Albert
Neobatrachus pictus
Abundance
2-9
1
0
0 2 4 8 12 16
Kilometers
N