Government of South Australia
South Australian Murray-Darling Basin Natural Resources Management Board

June 2011

South Australian Murray-Darling Basin Natural Resources Management

Southern Bell Frog Monitoring (*Litoria raniformis*) in the Lower Lakes

Goolwa River Murray Channel, Tributaries of Currency Creek and Finniss River and Lakes Alexandrina and Albert

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The project was funded by Department for Environment and Natural Resources, Coorong, Lower Lakes and Murray Mouth Program

Government of South Australia

Cover Photo: Survey site 'Pelican Lagoon Site 1' February 2011.

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

Summary

Over the past five years, Lake Alexandrina, Lake Albert and the Eastern Mount Lofty Ranges tributaries experienced significant changes as a result of reduced freshwater flows and over-allocation of water resources and recently, the first stages of recovery to a functioning freshwater and estuary system, following increased freshwater flows into the system. Water-dependant species suffered marked declines in the region, with many species lost from former sites or retracting to remnant pools. With the return of water to fringing wetland habitats and waterways, attentions turn to the recovery of many of our once-common species, including the EPBC vulnerable-listed Southern Bell Frog (*Litoria raniformis*). The largest of the 12 frog species known in the Lower Murray, *L. raniformis* is responsive to flooding; readily occupying shallow, newly inundated vegetated areas to breed. Southern Bell Frog populations in the study region have declined, likely as a result of a lack of flooding, disconnection of key habitat and increased salinity.

Between October 2010 and February 2011, a monitoring project was undertaken to observe the biotic response of *L. raniformis* to changes in environmental conditions within the Goolwa Channel as part of year two of the Goolwa Channel Water Level Management Project. Identifying key extant populations and detecting successful recruitment were the two main objectives of the project. Monitoring methods included a combination of call identification, call play-back active searching, and tadpole trapping. Nocturnal surveys were undertaken at 36 sites across the region to detect adults and tadpole surveys were conducted at 17 of the 36 sites to detect larval stages. *L. raniformis* was detected at six sites in the north and western areas of the study region within Pelican Lagoon, south of Wellington, Finniss River, Hindmarsh Island and Clayton Bay. With the exception of the population observed at Pelican Lagoon, overall detected abundance across the study region was low. Adult *L. raniformis* were observed calling within recently inundated, vegetated and sheltered areas, comprising of inundated terrestrial, emergent and submerged vegetation. *L. raniformis* was not detected at sites which were dominated by the Common Reed (*Phragmites australis*) or Bulrush (*Typha domingensis*), a common feature of the region. This may be due to the current grazing regimes that were in place. Grazed areas generally contained more diverse plant assemblages than sites dominated by *P. australis*. However further studies are required to test any linkages between grazing of riparian areas and Southern Bell Frog distribution. Successful recruitment of *L. raniformis* was observed at only one location at Pelican Lagoon. Recruitment may not have occurred at remaining occupied sites due to only intermittent inundation of suitable breeding habitat.

Results of this investigation show that there is a need to conserve and appropriately manage wetlands and vegetation communities associated with *L. raniformis* breeding habitat by building upon current land management practices and implementing a variable hydrological regime.

Acknowledgments

The authors wish to thank the many people who assisted this project and offered their expertise, enthusiasm and local knowledge. Over 40 community members assisted throughout the project on a voluntary basis. Approximately 210 hours were provided to the project collectively from volunteers.

Thanks to Karl Hillyard for jointly coordinating and conducting field work, Pip Taylor and Irene Wegener who assisted in much of the field work and the Signal Point Riverine Environment Group (SPREG). All nocturnal surveys at the four sites within Currency Creek and Goolwa North Stormwater Wetland were coordinated and undertaken by SPREG who have also assisted the SA MDB NRM Board in frog monitoring activities since 2009. Thanks to Karl Hillyard and Kelly Marsland for assistance in reviewing and editing this document.

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Kym Lose (SPREG)

Robert and Margaret Mrongovius

John and Lorraine Rowe

Charles and Jo Andre

Colin and Sally Grundy

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1. Introduction

The Southern Bell Frog (*Litoria raniformis*) is a large ground-dwelling frog which was formerly common and widespread throughout much of south-eastern Australia and Tasmania, however over the past 20-25 years the species has suffered noticeable declines in distribution and abundance and is now listed as nationally 'vulnerable' under the *Environment Protection and Biodiversity Conservation Act 1999*. 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, Currency Creek and Tookayerta Creek and their responses to changing water levels as part of the second year of the Goolwa Channel Water Level Management Project Ecological Monitoring Program (GCWLMPEMP).

1.1 Project objectives

During 2009 *L. raniformis* responded to management of water levels in the Goolwa Channel Water Level Management Area (GCWLMA) and two main populations were found at Clayton Bay and the Finniss River 'Watchalunga' (Mason 2010). Since this time, water levels have increased outside of the GCWLMA in Lakes Alexandrina and Albert and their fringing wetlands. This project addresses part of monitoring objective three of the Goolwa Channel Water Level Management Plan (GCWLMP), which is to assess the biotic response of *L. raniformis* to the regulator construction and elevated Goolwa Channel water levels during year two of the GCWLMP. They key hypothesis and questions addressed in this project are:

Hypothesis 3.5

Extended high water levels in the Goolwa Channel will allow southern bell frogs to successfully breed and recruit within the project area.

Key Question 3.8

Are southern bell frogs present in the GCWLMP area and do water levels remain high enough over summer to allow successful recruitment?

This project focuses on detection of presence of adults and spawning of *L. raniformis* and project builds upon the Southern Bell Frog Inventory conducted in 2009/10 (year one of the GCWLMA project).

Project objectives:

- conduct targeted broad-scale surveys for *L. raniformis* in suitable habitat within GCWLMA, the Lower Lakes and tributaries;
- identify key extant populations;
- identify core breeding populations within (this will include surveys for *L. raniformis* tadpoles);
- assess the habitat conditions at core breeding populations in relation to water level and habitat structure; and
- identify populations that may require active management/habitat enhancement and conservation.

Litoria raniformis requires permanent water, at least over spring and much of summer, and dense vegetative structure for successful breeding and recruitment to occur. Thus knowledge of the influence of water levels on *L. raniformis* is essential for the long-term management of extant populations.

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 Lower Lakes Ramsar area (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 has experienced severe drought 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 and 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 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 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 Lower Lakes and re-inundated fringing wetland habitats that had been dry for up to four years. The blocking bank was partially removed in September 2010 reconnecting the Goolwa Channel to Lake Alexandrina.

1.3 Species Description

The Southern Bell Frog is also known as the Golden Bell Frog, Green and Golden Grass Frog, and the Growling Grass Frog due of their loud growling ‘crawaark’ calls. They are large compared to other frogs (up to 10 cm) and have warty green skin varying from dull olive-brown to bright emerald green, mottled with irregular brown to tan blotches depending on local conditions (Stratman 2007). These frogs reside in or near temporary ponds and wetlands, or near permanent water bodies along the River Murray (DEH 2006).

They are most active in spring and summer where 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. Feeding at night, *L. raniformis* eats small water bugs, beetles, termites and insect larvae. They can also be cannibalistic and eat other frogs (DEH 2006). They are opportunistic predators, sitting and waiting to ambush whatever prey comes within reach.

During spring and summer, the male *L. raniformis* calls with a repeated ‘crawark crawaaark crok crok’ to attract a mate, while floating in open water or under aquatic vegetation. Females lay jelly-like masses of eggs (up to 400) typically after a local rain or flooding (DEH 2006). Two days later, the tadpoles hatch, and hide in vegetation near the water’s edge where the water is shallower and warmer. The tadpoles metamorphose into frogs in summer and autumn.

1.4 Threats

Decline of the species has been thought to be due to introduction of alien predatory fish; habitat loss, degradation and fragmentation; infection by Chytriodiomycosis disease; 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). Consequently, for the conservation of viable populations of *L. raniformis*, it is imperative that studies are carried out to clarify their distribution and abundance across its range.

1.5 Distribution within the Lower Lakes region

Knowledge of the distribution and abundance of *L. raniformis* in the Lower Lakes 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 had been 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 water levels dropping and their wetland habitats drying.

Based on records obtained from the Southern Bell Frog Inventory, Biological Survey Database, Frog Census, SA Museum and River Murray Baseline Database, the species was known from a total of nine localities within the Lower Lakes District (Fig. 1). Many of these records pre-dated 1980, with *L. raniformis* recorded from six localities since 1976. *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 'Wally's Landing/Watchalunga' (2-9 individuals) and Mundoo Island (1 individual). Clayton Bay and Wally's Landing were located within recently inundated wetlands and shorelines following the implementation of the Goolwa Water Level Management Project (GWLMP).

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 (Fig. 1). Frog census data collected in September 2000 also resulted in the identification of *L. raniformis* at the Wellington ferry and Langhorne Creek. Historically, the species is also known from Point Malcolm, Narrung, Wellington and the Milang district (Fig. 1). Voucher specimens were collected at each of these sites, all of which are currently held in the SA Museum. Colin and Sally Grundy, landholders of Mundoo Island, provided photographs of an adult *L. raniformis* collected on the island in 2005.

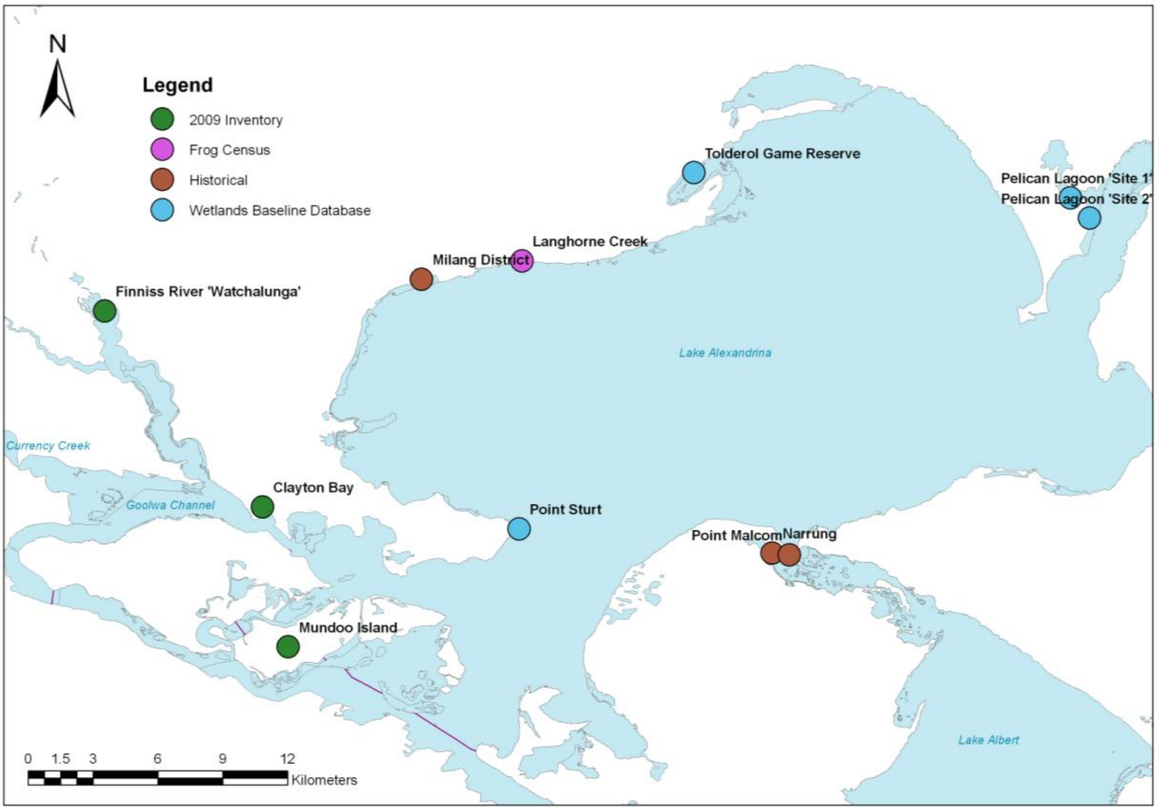


Figure 1: Recent and historical distribution of the Southern Bell Frog (*Litoria raniformis*)

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 (*Muehlenbeckia 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 (Fig. 1) 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 vallidus*) with large mats of filamentous algae caught between. These stands of *S. vallidus* 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 (*Ceratophyllulm 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 reedbeds 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) and 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 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 2009/10 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 rose 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 would be completed.

2. Methodology

2.1 Site Selection

Monitoring conducted in 2009 and early 2010 as part of an inventory of the species during drought conditions was largely based upon historic records of the species and was highly dependent on water availability (Mason 2010). Increased flow into South Australia during 2010 resulted in the re-inundation of fringing wetlands and allowed historic locations to be incorporated. The historic records were compiled from the Environmental Protection Agency's (EPA) Frog Census records and Wetland Baseline Survey data (Holt *et al.* 2004, Simpson *et al.* 2006).

Sites selected for inclusion in the 2010/2011 survey (Fig 2, Table 1), fit one or more of the following criteria:

- was occupied by *L. raniformis* during the 2009/10 inventory
- was the location of a historic record of the species and was inundated
- contained similar attributes to sites that were occupied in 2009/10 or suitable vegetation associations

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 2). Table 3 shows cover abundance scores used to assess habitat features including submerged, emergent, fringing and surrounding habitat.

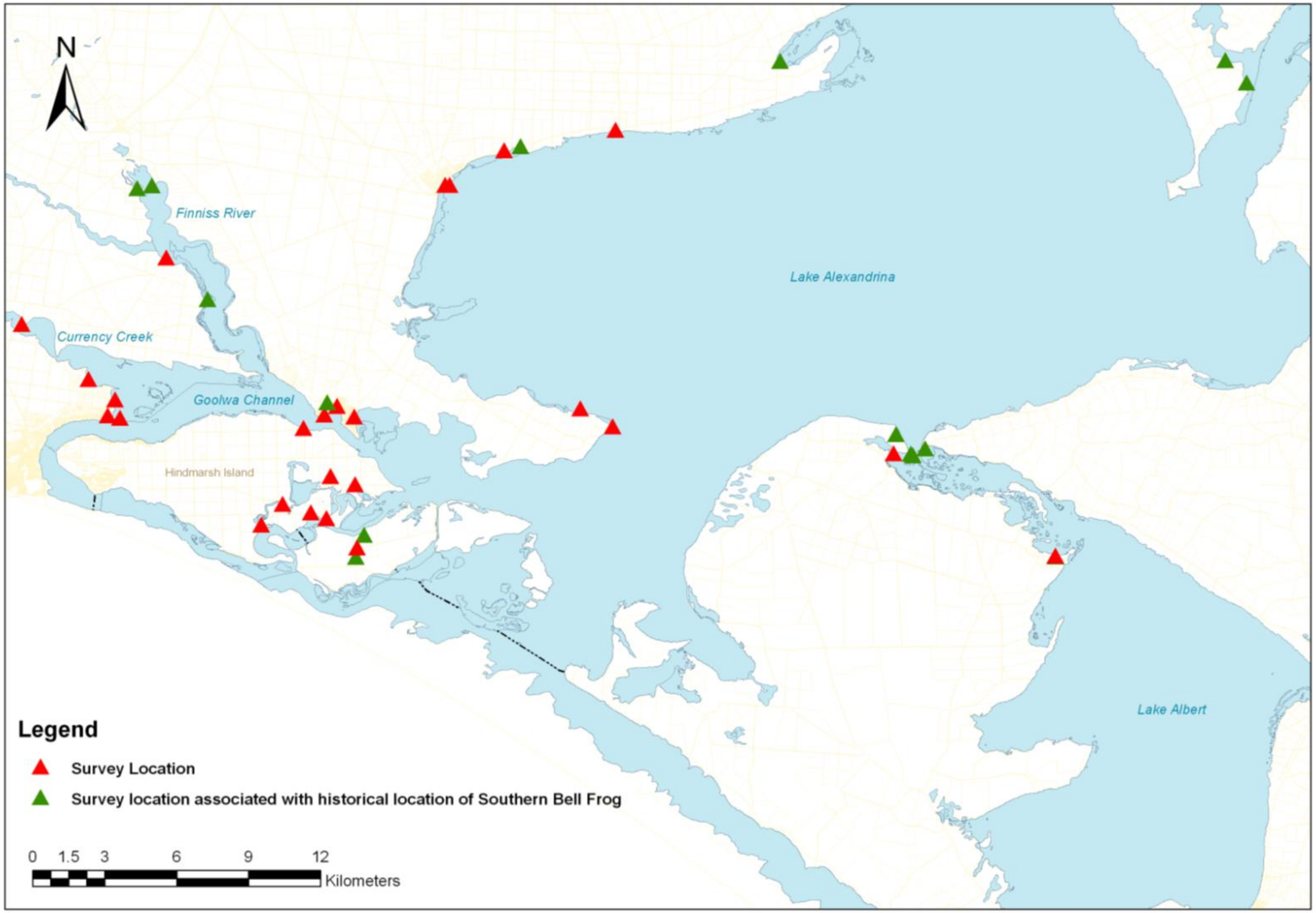


Figure 2: Survey site locations undertaken 2010/11 with reference to historical *L. raniformis* locations

Table 1: Location of survey sites (map datum GDA94).

No.	**SITE**	**EASTING**	**NORTHING**	**Containing or near historical record of *L. raniformis***
1	Angas Mouth	318405	6081201	
2	Bremer Mouth	323062	6082057	
3	Clayton Bay 'Community Boardwalk'**	311433	6070489	
4	Clayton Bay 'Gloria Jones Reserve'**	310905	6070128	
5	Clayton Bay 'Red Top Bay'	311035	6070646	*
6	Currency Creek 'Ballast Stone'	298289	6073926	
7	Currency Creek 'Currency Creek Road'	301079	6071618	
8	Currency Creek Daniel Ave	302385	6069981	
9	Currency Creek 'Fidock Road'	302179	6070750	
10	Dog Lake	329932	6084930	*
11	Dunn's Lagoon 'Ducks Hospital'	312161	6070048	
12	Finniss 'Finniss Park'	304311	6076696	
13	Finniss 'Sterling Downs'	306038	6074965	*
14	Finniss 'Wally's Landing'	303099	6079610	*
15	Finniss 'Watchalunga'	303726	6079733	*
16	Goolwa 'Alison Ave Stormwater Pond'**	301877	6070094	
17	Hindmarsh Island 'Boggy Creek'	312194	6067197	
18	Hindmarsh Island 'Boggy Creek Mouth'	311000	6065790	
19	Hindmarsh Island 'Hartills'	310037	6069568	
20	Hindmarsh Island 'Hunter's Creek Denver Rd'	309173	6066386	
21	Hindmarsh Island 'Hunter's Creek Fishway'	308282	6065505	
22	Hindmarsh Island 'Shadow's Lagoon'	311160	6067547	
23	Hindmarsh Island 'Steamer East'	310344	6066023	
24	Milang Shores	316135	6079747	
25	Lake Alexandrina North 'The Old Girl Block' **	326000	6081992	*
26	Milang Snipe Sanctuary	315951	6079747	
27	Mundoo Island 'Channel 1'	312218	6064159	*
28	Mundoo Island 'Pig Island'**	312569	6065085	*
29	Mundoo Island 'Stockyard Swamp'**	312280	6064559	
30	Narrung Narrows 'Near Ferry, North Side'**	335965	6068708	*
31	Narrung Narrows 'Nurra Nurra'**	341400	6064212	
32	Narrung Narrows 'Wetland Structure'	334659	6068507	
33	Pelican Lagoon 'Site 1'	348490	6084975	*
34	Pelican Lagoon 'Site 2'	349374	6084035	*
35	Point Sturt**	322934	6069625	*
36	Turvey's Drain	319095	6081360	*

**Site data provided to project by other projects

In addition to the 26 sites formally selected, data from an additional 10 sites were included in the results. Monitoring at these sites were undertaken as part of other projects such as the SA MDBNRM Board's Wetland Monitoring and Management Program and/or were a result of additional volunteer input.

Table 2: habitat variables recorded at each site.

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

Table 3: 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

Nocturnal surveys were conducted at 36 sites during October, November and December 2010 (Fig. 2, Table 1). Three rounds of nocturnal surveys were undertaken during this period conducted during early nightfall (between 8pm and 12am).

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:

1. 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 temperature were recorded and scores were given to amount of moon, wind, rain and cloud present at the time of each survey (Table 4).
2. Call response: pre-recorded calls of the male *L. raniformis* were played on site using a portable speaker and responses from present males observed.
3. Active searching: scanning fringes of water body with small spotlight over a standard area.

An abundance score was given to all species recorded at each site (Table 5). As frogs become difficult to count in higher abundances, scoring is an effective way to estimate numbers.

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

Variable	Measure
Air temperature	Degrees Celsius
Humidity	% relative humidity
Moon	0-4 scale
Wind	0-4 scale
Rain	0-4 scale
Cloud	0-5 scale

Table 5: abundance scores for nocturnal frog surveys.

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

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.

2.3 Tadpole Surveys

Tadpole surveys were conducted in December 2010 and February 2011. Representing a 1 month and 3 month interval from the peak calling recording during nocturnal surveys, during which time tadpoles would have grown to an easily identifiable size. Tadpole surveys were conducted at 17 sites (Fig. 3). Sites were selected using the following criteria:

1. *L. raniformis* were recorded during the nocturnal surveys OR
2. Were within vicinity or migratory range of a site with a *L. raniformis* survey (1-5km) OR
3. Habitat values matched that of a site with a *L. raniformis* recording.

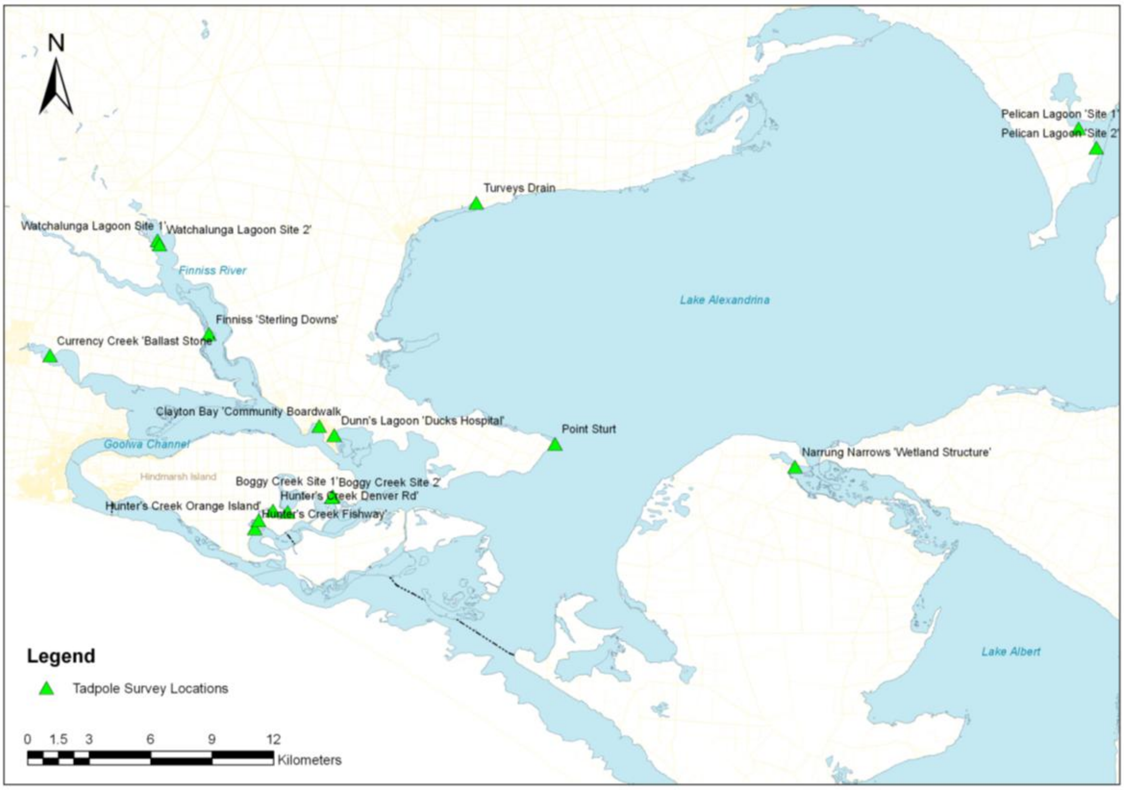
Fyke nets and bait traps (also called shrimp or box traps) were used to capture tadpoles and were set in or around fringing and emergent vegetation at each site. Two single-winged fyke nets and five bait traps were set at each survey location spread across a distance of approximately 50 metres of wetland fringe (depending on habitat type and water depth).

The traps were set pre-dusk and were left overnight for an average of 15 hours. All species caught, including frogs, fish, yabbies and crustaceans, were identified and abundances were recorded. Total length measurements of tadpoles are taken from mouth to tail tip. To avoid potentially transferring pathogens between sites, traps were cleaned in a diluted bleach solution before re-use.

In 2009, bait traps were used in preference to fyke nets to standardize methods with interstate projects for comparable data. Bait traps also allowed more sites to be included in the project within a short timeframe. However, fyke nets (fitted with 50mm plastic mesh in the trap mouth to exclude large fish) have the ability to catch greater numbers of tadpoles and were included in this project. All *L. raniformis* tadpoles caught during surveys were measured to the nearest millimetre (mouth to tail tip).

Water quality parameters monitored at each location during the tadpole surveys included electrical conductivity (a proxy for salinity) ($\mu S.cm^{-1}$), pH, turbidity (Nephelometric Turbidity Units: NTU) and temperature (degrees Celsius) using a TPS multi-parameter meter (model 90-FLT Field Lab Analyser).

a)



b)

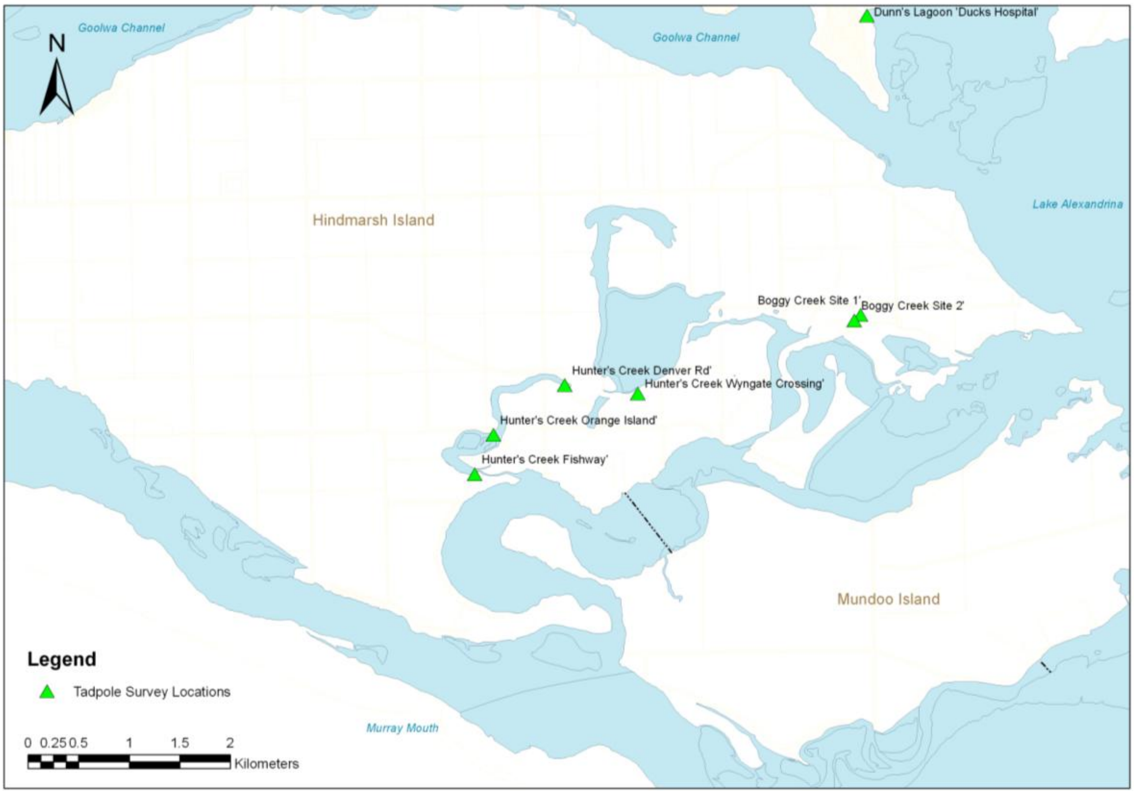


Figure 3: a) Sites where tadpole surveys were conducted during the 2010-2011 Lower Lakes Southern Bell Frog census, b) inset map of Hindmarsh Island and surrounding site locations

3. Results

3.1 Nocturnal Survey Results

L. raniformis was detected during nocturnal surveys at six of the 36 sites. A total of 108 surveys were conducted between the 21st October and 20th December 2010. Three of the six populations were located within the Goolwa Channel Water Level Management Area (GCWLMA) at Finniss 'Watchalunga', Finniss 'Sterling Downs' and Clayton Bay. The remaining three were located at Hindmarsh Island, 'Boggy Creek' and Pelican Lagoon (Pelican Lagoon Site 1, Pelican Lagoon Site 2). The highest abundance was recorded at Pelican Lagoon (Site 1) with the peak calling period in late October (Fig. 4). Pelican Lagoon had moderate to high abundances during the three consecutive survey events.

Abundance was predominantly determined by call recognition. Call playback did not achieve a response at any of the sites except where adult males were already calling. No increase in abundance of calling males was detected as a result of call playback (Table 6). The one individual detected calling at Clayton bay in October 2010 ceased calling after playback. Call playback was not undertaken if weather conditions did not permit (i.e. strong winds or rain). Spotlighting was useful to achieve a clearer estimation of population abundance. Spotlighting at Pelican Lagoon detected a higher number of individuals than those calling during round two of the nocturnal surveys. No individual *L. raniformis* were spotlighted outside of sites where calling males were present. Spotlighting was not undertaken at sites dominated by dense stands of Common Reed. Adults, first year adults and metamorphs of other frog species (*Limnodynastes* spp., *Litoria* spp. *and Crinia* spp.) were frequently spotlighted. Egg masses of *Limnodynastes* spp. were also observed during spotlighting during October and November.

Field observations during spotlighting at Pelican Lagoon noted *L. raniformis* inhabited a range of microhabitats within a site while calling. All individuals utilised vegetative structure, often calling from within Lignum bushes; floating amongst dense floating aquatic plants, such as Duckweed (*Lemna* sp.) and algae; and inundated grasses both floating and along wetland fringes containing grasses, sedges or both.

Time of recording at each occupied site varied from directly after sunset (21:00hrs) to close to midnight (23:15hrs), however the highest abundances were recorded between 21:55hrs and 23:15hrs.

Table 6: Highest detected abundance of *L. raniformis* at each occupied site (three nocturnal surveys collectively) per method used

Site/Date	*L. raniformis* abundance Call Recognition	Call Playback	Spotlighting
Clayton Bay 'Red Top Bay'			
26/10/2010	0	1	0
24/11/2010	0	0	0
14/12/2010	0	0	0
Finniss 'Sterling Downs'			
24/11/2010	0	0	0
26/11/2010	0	0	0
14/12/2010	2-9	2-9	0
***Finniss 'Watchalunga Lagoon'**			
26/10/2010	0	0	n/a
24/11/2010	0	0	n/a
14/12/2010	2-9	2-9	n/a
Hindmarsh Island 'Boggy Creek'			
4/11/2010	0	0	0
29/11/2010	0	0	0
13/12/2010	0	1	0
Pelican Lagoon 'Site 1'			
21/10/2010	>50	>50	0
22/11/2010	10-50	10-50	>50
15/12/2010	0	2-9	1
Pelican Lagoon 'Site 2'			
21/10/2010	4	4	3
22/11/2010	3	3	3
15/12/2010	0	1	0

*Recorded from sites Finniss 'Wally's Landing' and Finniss 'Watchalunga'.

Atmospheric conditions recorded at each survey event do not demonstrate clear trends in *L. raniformis* detection in relation to temperature and humidity (Fig. 5). High abundances of *L. raniformis* were detected in survey events with relatively low temperatures of 12-14°C and 14-16°C. Moderate abundances were detected at higher temperatures (22-28°C).

Weather conditions recorded at each survey event, presented in Figures 6 and 7, show little trend in detection rates in relation to moon phase, rain presence, wind speed and cloud cover. Only a small percentage of survey events detected *L. raniformis* (11.2% of all survey events) and detection only occurred at three sites after increases in water levels and subsequent inundation of suitable vegetation associations, limiting analysis of trends in weather conditions.

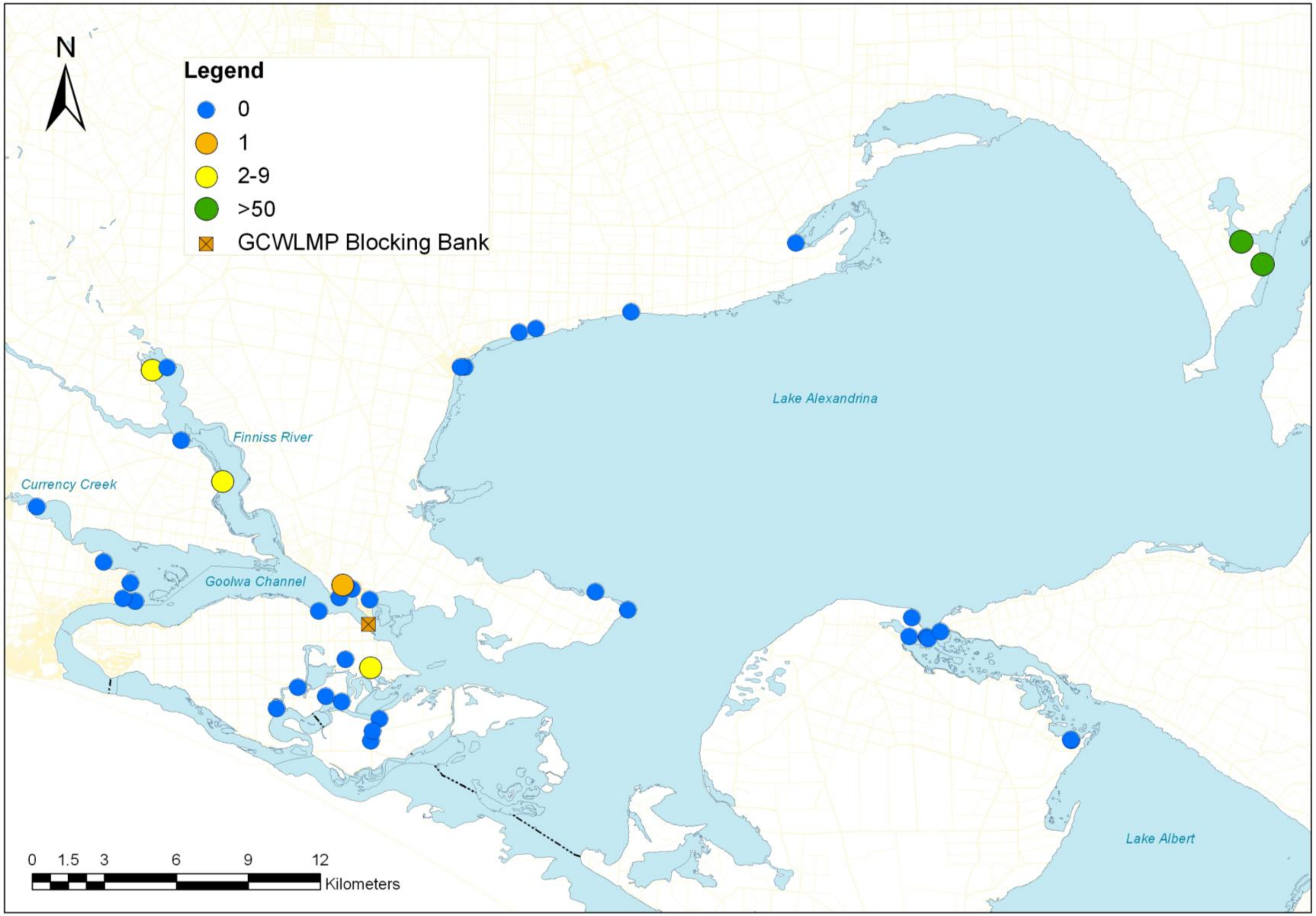
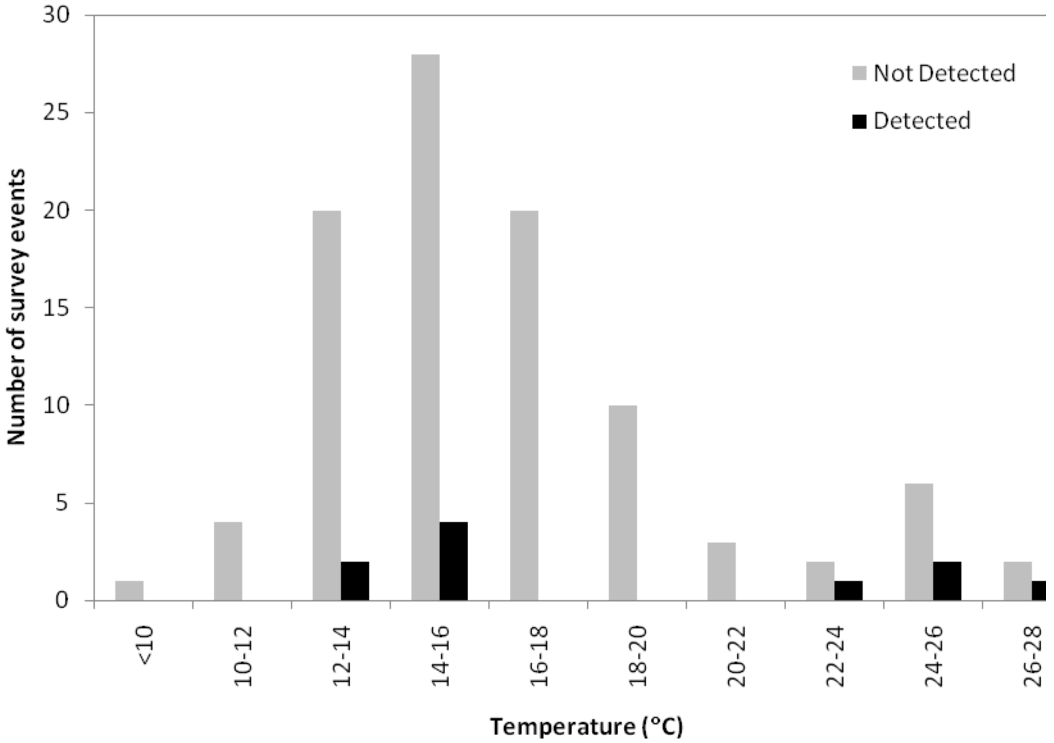


Figure 4: Highest occupancy of *L. raniformis* recorded in 2010 per site

a)



b)

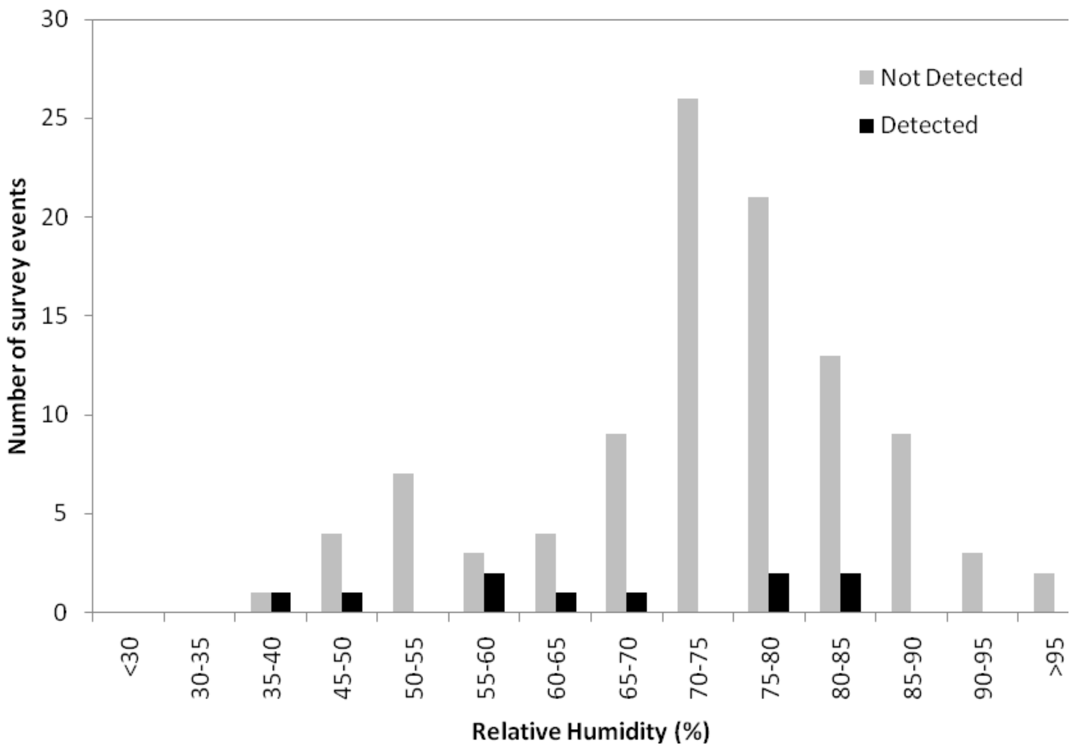
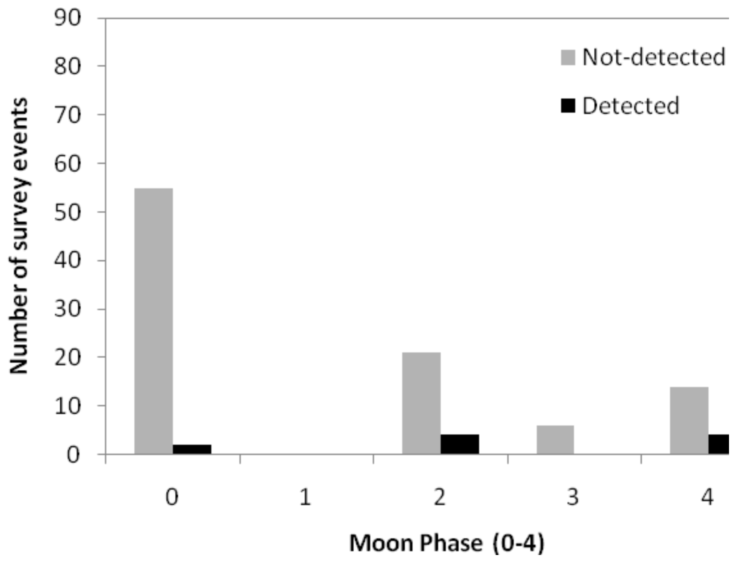


Figure 5: Distribution of a) temperatures and b) relative humidity in relation to detection of *L. raniformis* across all survey events

a)



b)

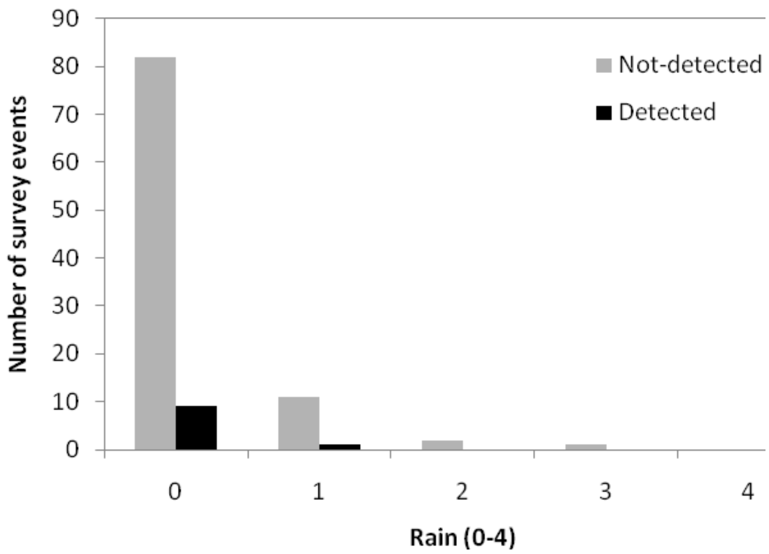
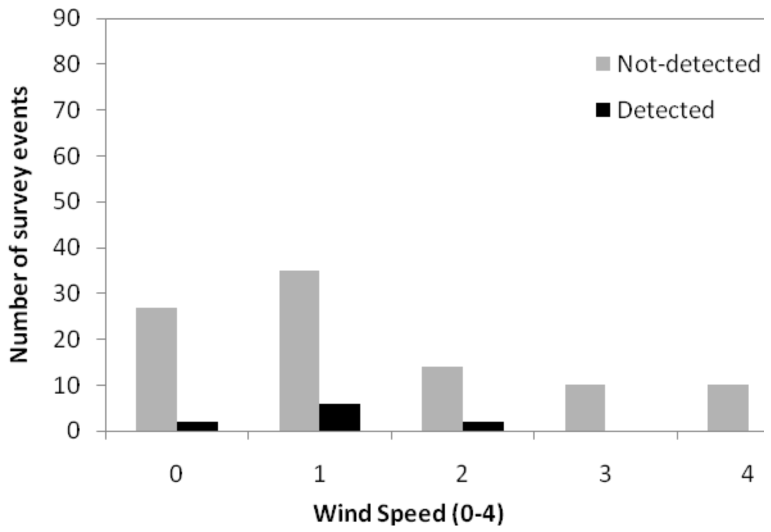


Figure 6: Distribution of detection of *L. raniformis* at all survey events in relation to a) moon phase and b) rain. Moon phase 0 = no moon (or not yet risen); 1 = quarter moon; 2 = half moon; 3 = three-quarter moon; 4 = full moon. Rain presence: 0 = no rain; 1 = drizzle; 2 = showers; 3 = moderate rain; 4 = heavy rain.

a)



b)

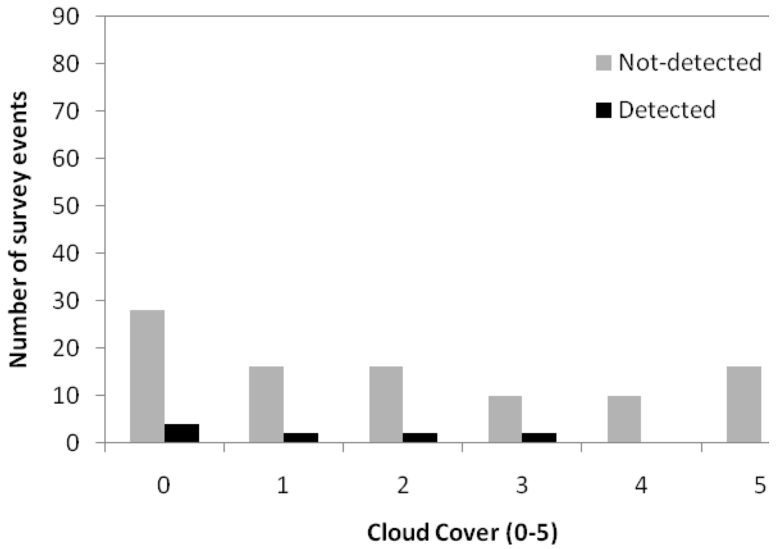


Figure 7: Distribution of detection of *L. raniformis* at all survey events in relation to a) wind speed and b) cloud cover. Wind speed 0 = no wind; 1 = slight breeze; 2 = strong breeze; 3 = moderate wind; 4 = strong wind. Cloud cover 0 = no cloud; 1 = <5% cover; 2 = 5-25% cover; 3 = 25-50% cover; 4 = 50-75% cover; 5 = >75% cover.

3.2 Other Frog Species

A further six frog species were observed additional to *L. raniformis* (Table 7, Fig. 8). The most commonly found species was the Eastern Banjo Frog (*Limnodynastes dumerili*) which was recorded at all sites. The Common Froglet (*Crinia signifera),* and the Spotted Grass Frog (*Limnodynastes tasmaniensis*) were recorded at all but one site. The Brown Tree Frog (*Litoria ewingi*) was recorded at 17 sites (46%) and the Long-thumbed Frog/Barking Marsh Frog (*Limnodynastes fletcheri*) was recorded at 10 sites (27%). The least recorded species was the Peron's Tree Frog (*Litoria peroni*) which was detected at only three sites (8.1%) at Pelican Lagoon (Site 1 and 2) and Goolwa 'Alison Ave Stormwater Pond'.

Where the highest abundance of *L. raniformis* was detected, the diversity of other frog species was also high (Fig. 8).

Metamorphs of *Limnodynastes* dumerili, *L. tasmaniensis* and *Litoria ewingi* were seen at many locations. The stage of metamorph varied indicating individuals caught were not the result of a singular breeding event.

Table 7: Presence of all other frog species at each site (collectively from three nocturnal survey rounds)

Site	Eastern Banjo Frog (*Limnodynasted dumerili*)	Common Froglet (*Crinia signifera*)	Spotted Grass Frog (*Limnodynastes tasmaniensis*)	Brown Tree Frog (*Litoria ewingi*)	Peron's Tree Frog (*Litoria peroni*)	Long-thumbed Frog (*Limnodynastes fletcheri*)	Total number of species excluding *L. raniformis*
Angas Mouth	*	*	*				3
Bremer Mouth	*	*	*	*			4
Clayton Bay 'Community Boardwalk	*	*	*	*			4
Clayton Bay 'Gloria Jones Reserve'	*	*	*	*			4
Clayton Bay 'Red Top Bay'	*	*	*				3
Currency Creek 'Ballast Stone'	*	*	*				3
Currency Creek 'Currency Creek Road'	*	*	*	*			4
Currency Creek 'Daniel Ave'	*	*					2
Currency Creek 'Fidock Road'	*	*	*	*			4
Dog Lake	*	*	*			*	4
Dunn's Lagoon 'Ducks Hospital'	*	*	*				3
Finniss 'Finniss Park'	*	*	*	*			4
Finniss 'Sterling Downs'	*	*	*	*		*	5
Finniss 'Wally's Landing'	*	*	*			*	4
Finniss 'Watchalunga'	*	*	*			*	4
Goolwa 'Alison Ave Stormwater Pond'	*	*	*	*	*	*	6
Hindmarsh Island 'Boggy Creek'	*	*	*			*	4
Hindmarsh Island 'Boggy Creek Mouth'	*	*	*				3
Hindmarsh Island 'Hartills'	*	*	*				3
Hindmarsh Island 'Hunter's Creek Denver Rd'	*	*	*				3
Hindmarsh Island 'Hunter's Creek Fishway'	*	*	*				3
Hindmarsh Island 'Shadow's Lagoon'	*	*	*	*			4
Hindmarsh Island 'Steamer East'	*	*	*				3
Lake Alexandrina North 'The Old Girl Block'	*	*	*	*			4
Milang Snipe Sanctuary	*	*	*	*			4
Mundoo Island 'Channel '	*	*	*				3
Mundoo Island 'Pig Island'	*	*	*				3
Mundoo Island 'Stockyard Swamp'	*	*	*				3
Narrung Narrows 'Near Ferry, North Side'	*	*	*	*		*	5
Narrung Narrows 'Nurra Nurra'	*	*	*	*			4
Narrung Narrows 'Wetland Stucture, Lake Albert Side'	*	*	*	*		*	5
Pelican Lagoon 'Site'	*	*	*		*	*	5
Pelican Lagoon 'Site'	*	*	*	*	*	*	6
Point Sturt	*	*	*				3
Turveys Drain	*	*	*	*			4

Figure 8: Number of all other frog species recorded at each site in relationship to abundance of *L. raniformis.* Abundance of *L. raniformis* represented as 0 = none; 1 = 1; 2 = 2-9; 3 = 10-50; 4= >50

3.3 Habitat

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

Sites occupied by *L. raniformis* were characterised by permanent or connected water-bodies (at time of assessment) of either lake edge, river/creek or wetland environments and with little to no flow (Table 8). The six sites occupied by *L. raniformis* were predominantly grazed (n=5, 83.3%). The extent of grazing was not captured within the habitat assessment however it was observed that grazing pressures were frequent but not constant. All sites contained gradually sloping edges with occasional areas of steep to vertical bank slopes (Finniss 'Wally's Landing', Finniss 'Watchalunga' and Hindmarsh Island 'Boggy Creek'), (Table 8). Pugging of fringing soils was present at grazed sites. All occupied sites had clayey and/or silty sediments. Pelican Lagoon Site 2 had exposed limestone bedrock substrate, which was the result of clearance for access to water when water levels dramatically declined during 2008/09. Sites were predominantly surrounded by grassland vegetation communities which were often pastures.

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. The only occupied 'lake edge' site, Finniss River 'Sterling Downs', could perhaps be considered more a river/creek site, however, it is located close to the confluence of the Goolwa Channel of the River Murray and the Finniss River where the width of the river at that point is nearly one kilometre. At the time of assessment, low to moderate flows in the tributaries (Finniss River, Currency Creek, Angas River, Bremer River) were observed as a result of rainfall in their catchments, but were not at their peak. Wind seiching (wind tides) is a significant feature of the River Murray reach below Lock 1. The movement of water by wind can be great, 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.

Table 8: Observational site description and attributes of each site occupied by *L. raniformis* from results of habitat assessment

Site	Waterbody	Site Modification	Flow Environment	Flow	Bank Slope	Observed Landuse	Surrounding Vegetation Association	Substrate
Clayton Bay 'Community Boardwalk	Wetland	Natural	Permanent connection	None	Gradual Incline	Recreation	Grassland	Clay/Silt
Finniss 'Sterling Downs'	Lake Edge	Natural	High connection	None	Gradual Incline	Grazing	Grassland	Clay/Silt
Finniss 'Wally's Landing'	River/Creek	Modified	Permanent connection	Low	Mixed	Recreation and Grazing	Sedgeland	Clay/Silt
Finniss 'Watchalunga'	Wetland	Natural	High connection	Low	Mixed	Grazing	Grassland and Sedgeland	Clay/Silt
Hindmarsh Island 'Boggy Creek'	Wetland	Modified	High connection	None	Mixed	Grazing	Grassland and Woodland	Clay/Silt
Pelican Lagoon 'Site 1'	Wetland	Modified	High connection	None	Gradual Incline	Grazing	Grassland	Clay/Silt
Pelican Lagoon 'Site 2'	Wetland	Modified	High connection	None	Gradual Incline	Grazing	Grassland	Clay/Silt and Bedrock

Vegetation

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.

All sites occupied by L. raniformis contained submerged aquatic vegetation. Between 1-25% cover was observed at the majority of occupied sites (n=5, 83.3%) (Table 9, Fig. 10). Clayton Bay 'Red Top Bay' contained approximately 40-50% cover by submerged aquatic plants. Green filamentous algae was present at the majority of sites (n=5, 83.3%), often constituting the majority of the submerged vegetative cover, as seen at Finniss 'Sterling Downs' in December 2010 (Fig. 9). The most common plants observed were Hornwort (Certaphyllum demersum) and Milfoil (Myriophyllum sp.) and Widegon Grass (Ruppia sp.). The data showed little trend in the abundance of L. raniformis in relation to cover abundance of submerged aquatic vegetation, as both detected and undetected sites had similar cover abundances in submerged vegetation.

Floating aquatic vegetation was observed in low abundances at the time of assessment (0-5%) at four sites occupied by L. raniformis. The three species identified include Ferny Azolla (Azolla filiculoides), Pacific Azolla (Azolla pinnata) and Duckweed (Lemna minor). Increases in cover abundance of these species were observed in sheltered shallow areas across the region over the study period. The data showed little trend in the abundance of L. raniformis in relation to floating aquatic vegetation (Fig. 10).

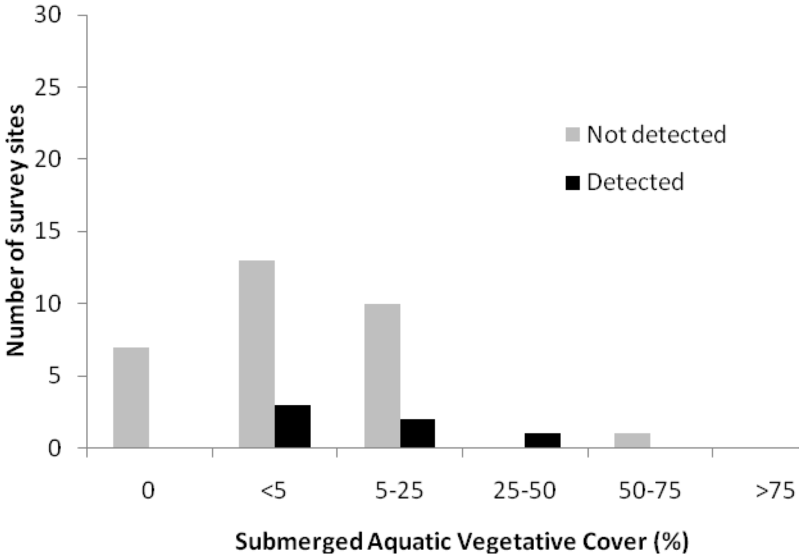
Emergent vegetation assessed the below water part of emergent plants, living or dead. It was observed in many instances that inundated terrestrial plants constituted a low to moderate percentage of emergent vegetation. At occupied sites, 5-75% emergent vegetative cover was observed. Sites that detected the highest abundance of L. raniformis had lesser coverage of emergent vegetation (5-25%), (Fig. 11). Although the data indicated a correlation between the percentage cover of emergent vegetation and number of calling adult males, the analysis was limited by the low number of L. raniformis detections. Lignum (Muehlenbeckia florulenta) was the dominant emergent vegetative cover at Pelican Lagoon Site 1 and Finniss 'Watchalunga Lagoon' but was also present, if only as scattered bushes, at all remaining sites. All sites surveyed, both occupied and unoccupied by L. raniformis, had high percentage coverage of fringing vegetation (Fig. 11).

Table 9: Assessment of vegetative cover at sites occupied by *L. raniformis* (0=0% cover, 1=<5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=>75%) displayed as averages taken across three assessments. *L. raniformis* abundance scored as 0=0, 1=1, 2=2-9, 3=10-50, 4=>50.

Occupied Site	SUBMERGED (0-5)	FLOATING AQUATIC (0-5)	EMERGENT (0-5)	FRINGING (0-5)	Highest *L. raniformis* abundance recorded (0-4)
Clayton Bay 'Red Top Bay'	3	1	4	5	**1**
Hindmarsh Island 'Boggy Creek'	1	1	3	5	**1**
Finniss 'Sterling Downs'	2	0	3	5	**2**
Finniss 'Watchalunga Lagoon'	2	1	2	5	**2**
Pelican Lagoon 'Site 1'	1	1	2	4	**4**
Pelican Lagoon 'Site 2'	1	0	2	5	**4**

Figure 9: Finniss 'Sterling Downs' with high percentage cover of green filamentous algae, low reeds and grasses and the scattered Lignum bushes from which *L. raniformis* were observed calling. December 2010.

a)



b)

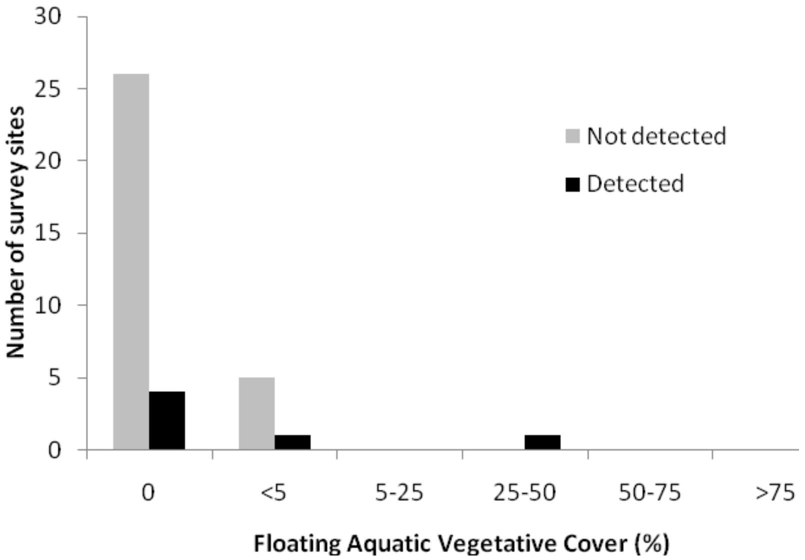
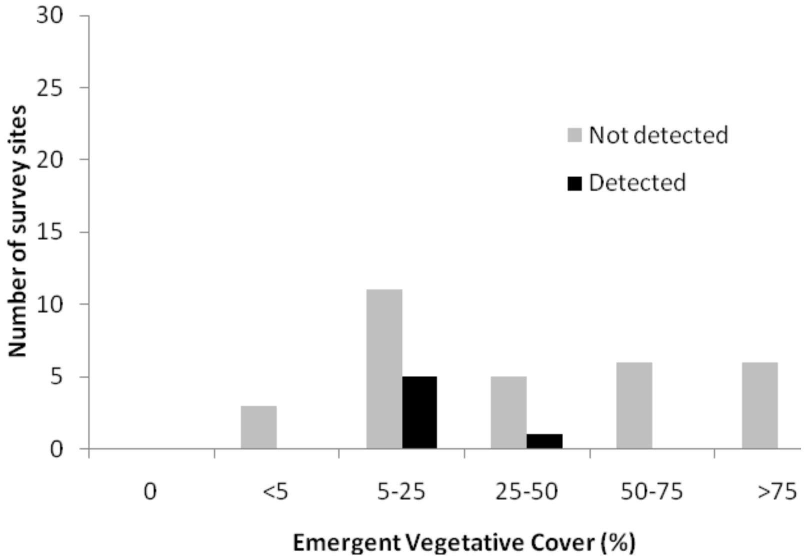


Figure 10: Abundance of detected *L. raniformis* (0=0, 1=1, 2=2-9, 3=10-50, 4=>50) in relation to submerged and floating aquatic vegetative cover (0=0% cover, 1=<5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=>75%)

a)



b)

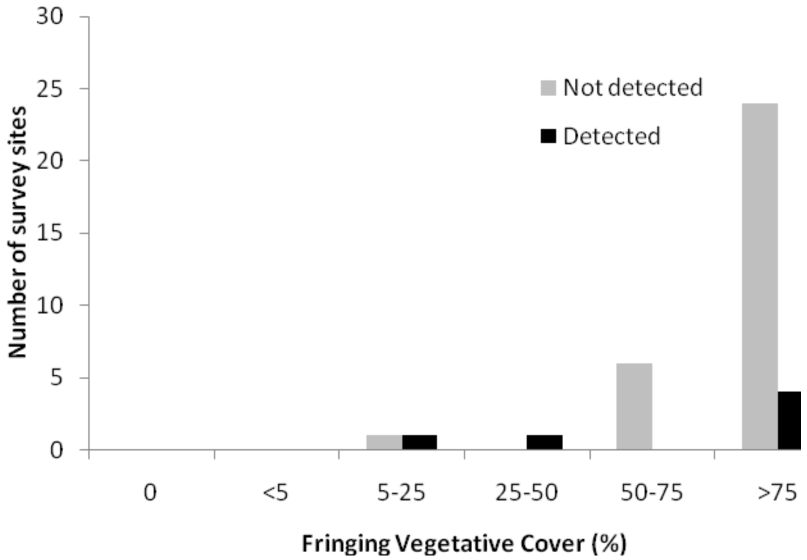


Figure 11: Abundance of detected *L. raniformis* (0=0, 1=1, 2=2-9, 3=10-50, 4=>50) in relation to emergent and fringing vegetative cover (0=0% cover, 1=<5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=>75%)

Water Levels and Habitat Availability

Throughout the duration of the survey period between October 2010 and February 2011, variations in water level had an influence on the availability of habitat for adult *L. raniformis*. Water levels exceeded 0.8 mAHD in four of the six sites where *L. raniformis* were recorded in December 2010 (Table 10, Fig.12). During this time, low-lying sheltered areas containing Lignum shrub-lands and low sedge and grasslands became shallowly inundated. Many of these plant communities were found in linear bands parallel to what was considered to be the shoreline of a previously managed pool level.

Figures 13 to 18 show areas of inundation at sites where *L. raniformis* were recorded under varying water levels.

Table 10: *L. raniformis* call abundance at occupied sites and the respective water levels at fixed telemetry sites at time of survey event (metres Australian Height Datum). Water level data source: River Murray Data, DfW 2010.

DATE	SITE	WATER LEVEL (mAHD)	*L. raniformis* Call Abundance
21/10/2010	Pelican Lagoon 'Site 1'	0.789	>50
21/10/2010	Pelican Lagoon 'Site 2'	0.789	>50
26/10/2010	Clayton Bay 'Red Top Bay'	0.741	1
22/11/2010	Pelican Lagoon 'Site 1'	0.745	10-50
22/11/2010	Pelican Lagoon 'Site 2'	0.745	10-50
13/12/2010	Hindmarsh Island 'Boggy Creek'	0.82	1
14/12/2010	Finniss 'Sterling Downs'	0.82	2-9
14/12/2010	Finniss 'Watchalunga Lagoon'	0.82	2-9
15/12/2010	Pelican Lagoon 'Site 1'	0.871	2-9
15/12/2010	Pelican Lagoon 'Site 2'	0.871	1

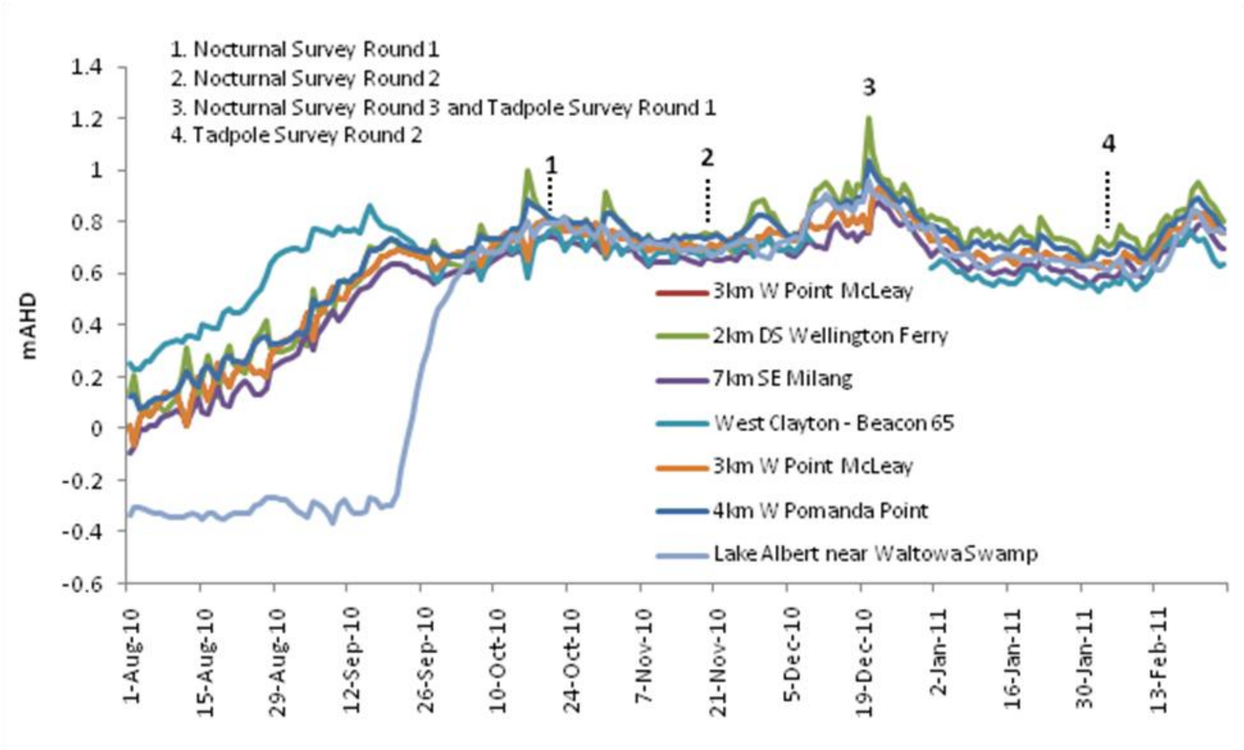


Figure 12: Water levels (mAHD) between August 2010 and February 2011and timing of field surveys (Source: River Murray Data, DfW).

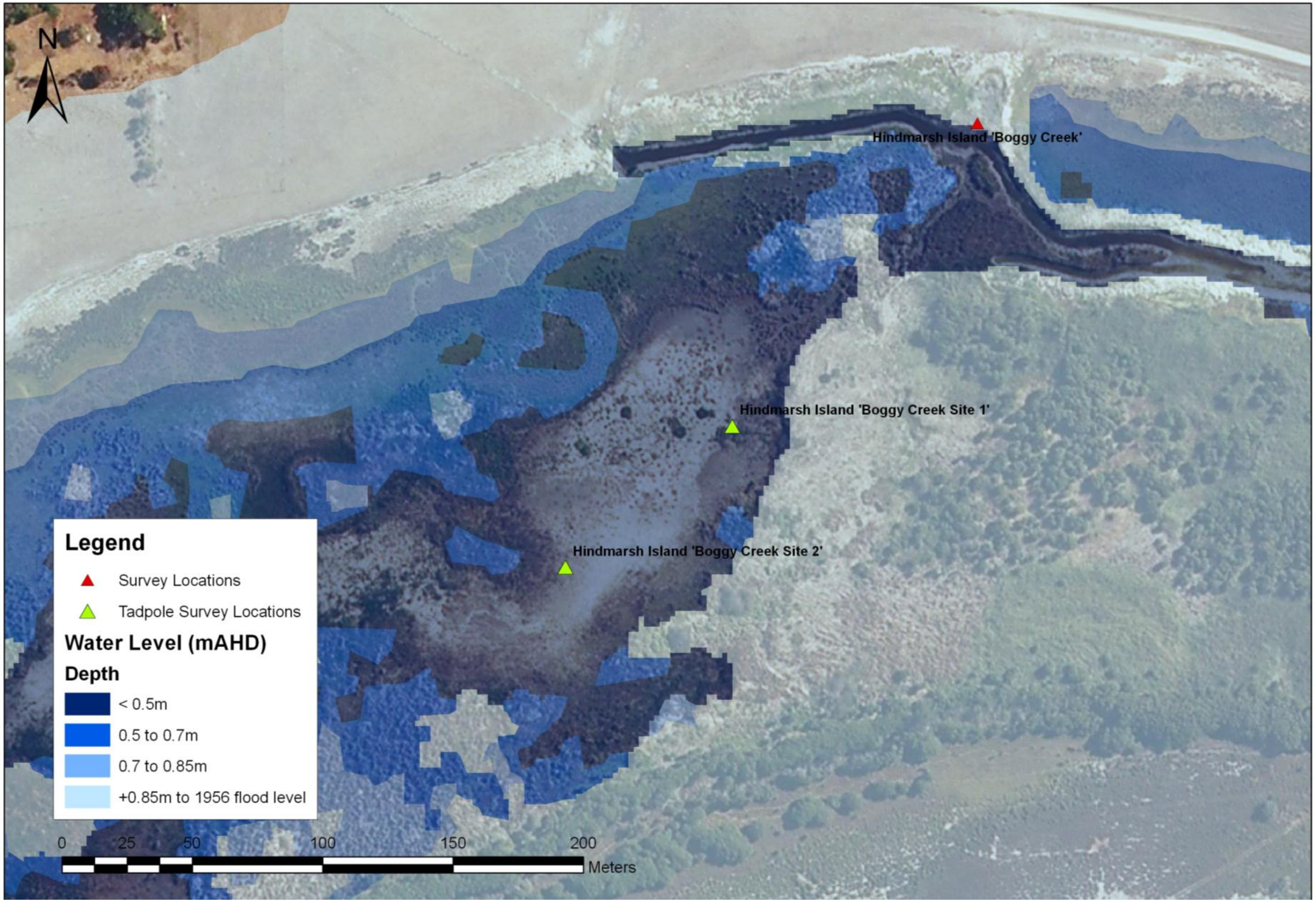


Figure 13: Map of Hindmarsh Island 'Boggy Creek' showing area of inundation at increasing water levels (Source: DENR 2010)

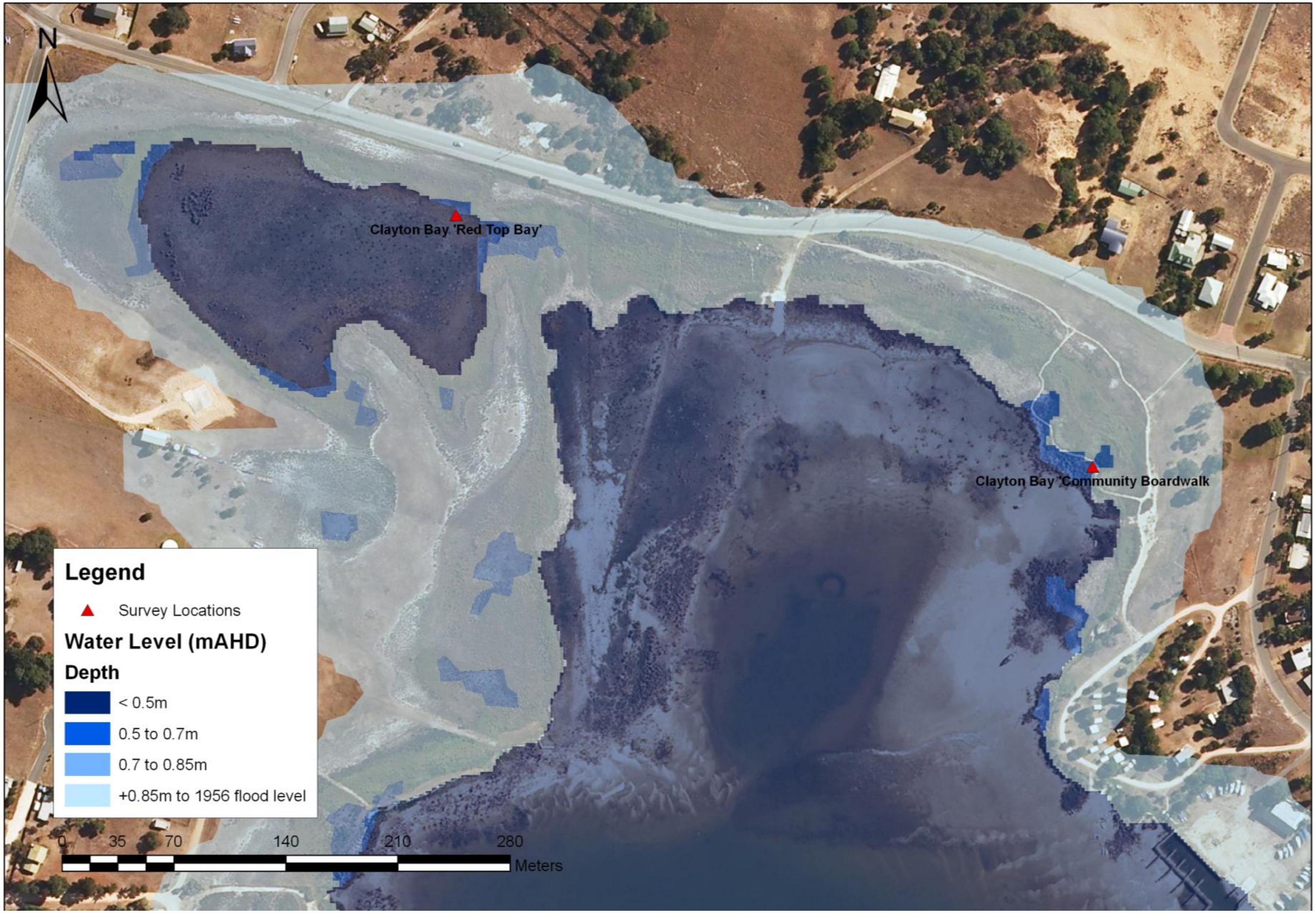


Figure 14: Map of Clayton Bay 'Community Boardwalk' and 'Red Top Bay' showing area of inundation at increasing water levels (Source: DENR 2010)

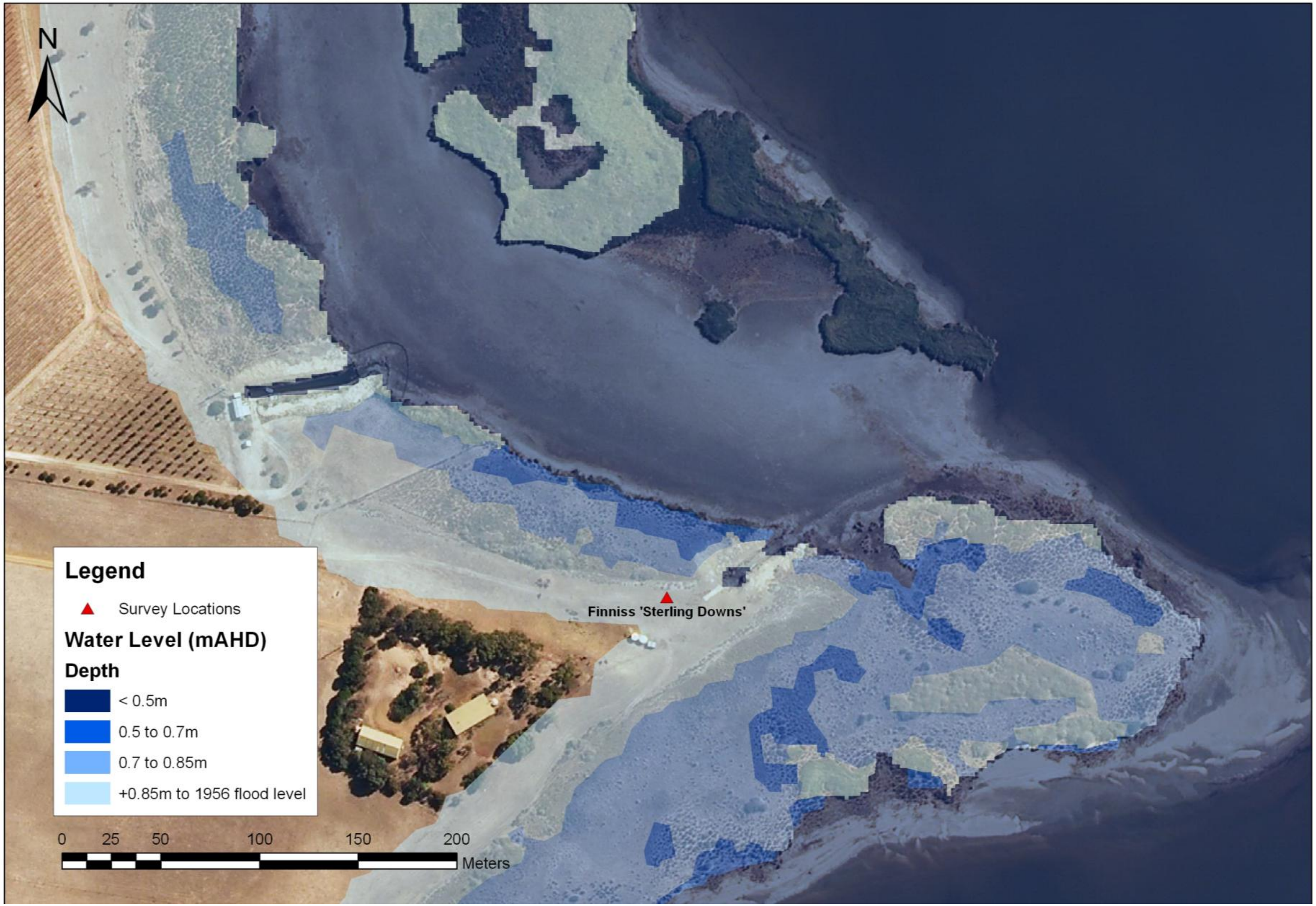


Figure 15: Map of Finniss 'Sterling Downs' showing area of inundation at increasing water levels (Source: DENR 2010)

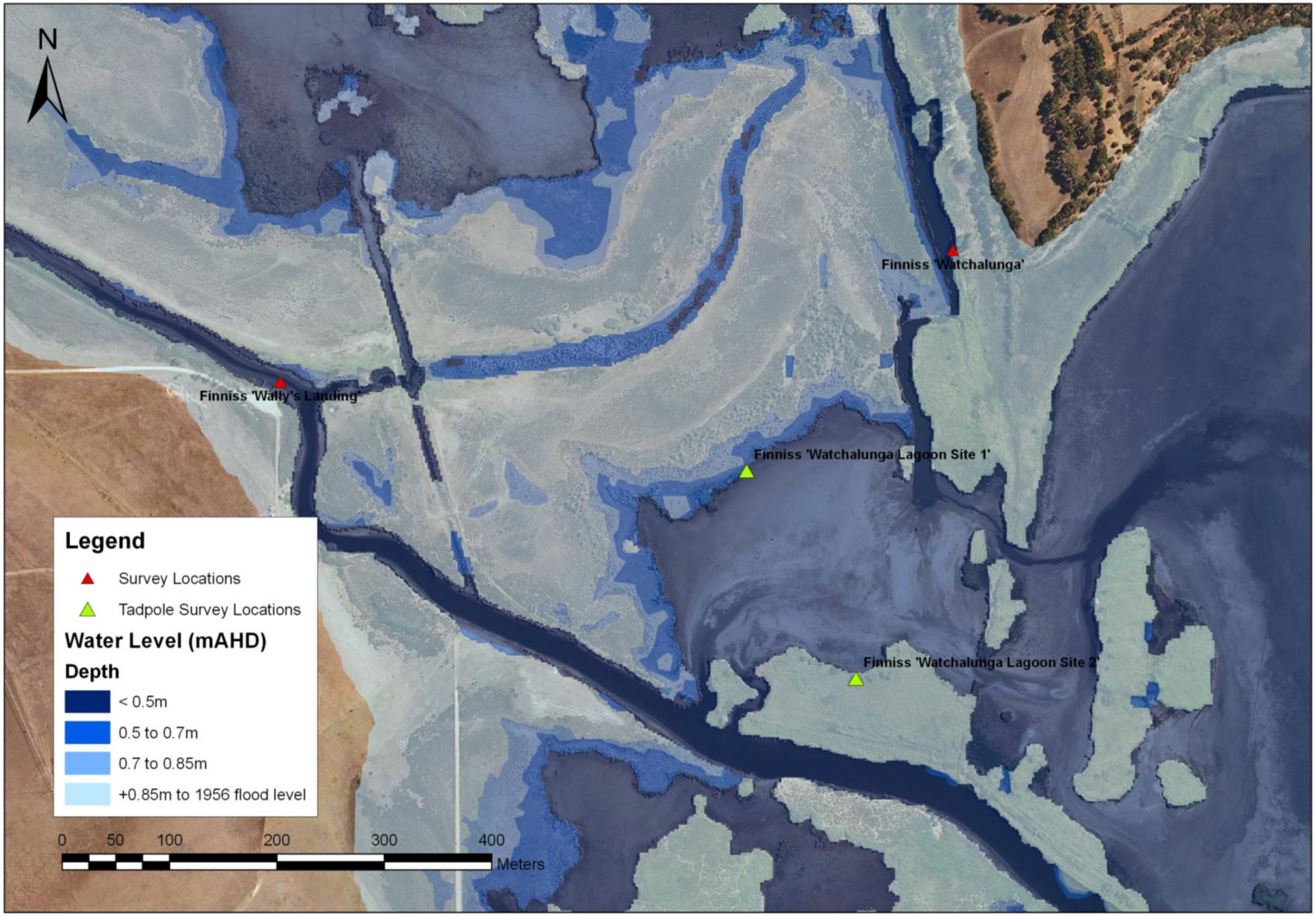


Figure 16: Map of Finniss 'Watchalunga' showing area of inundation at increasing water levels (Source: DENR 2010)

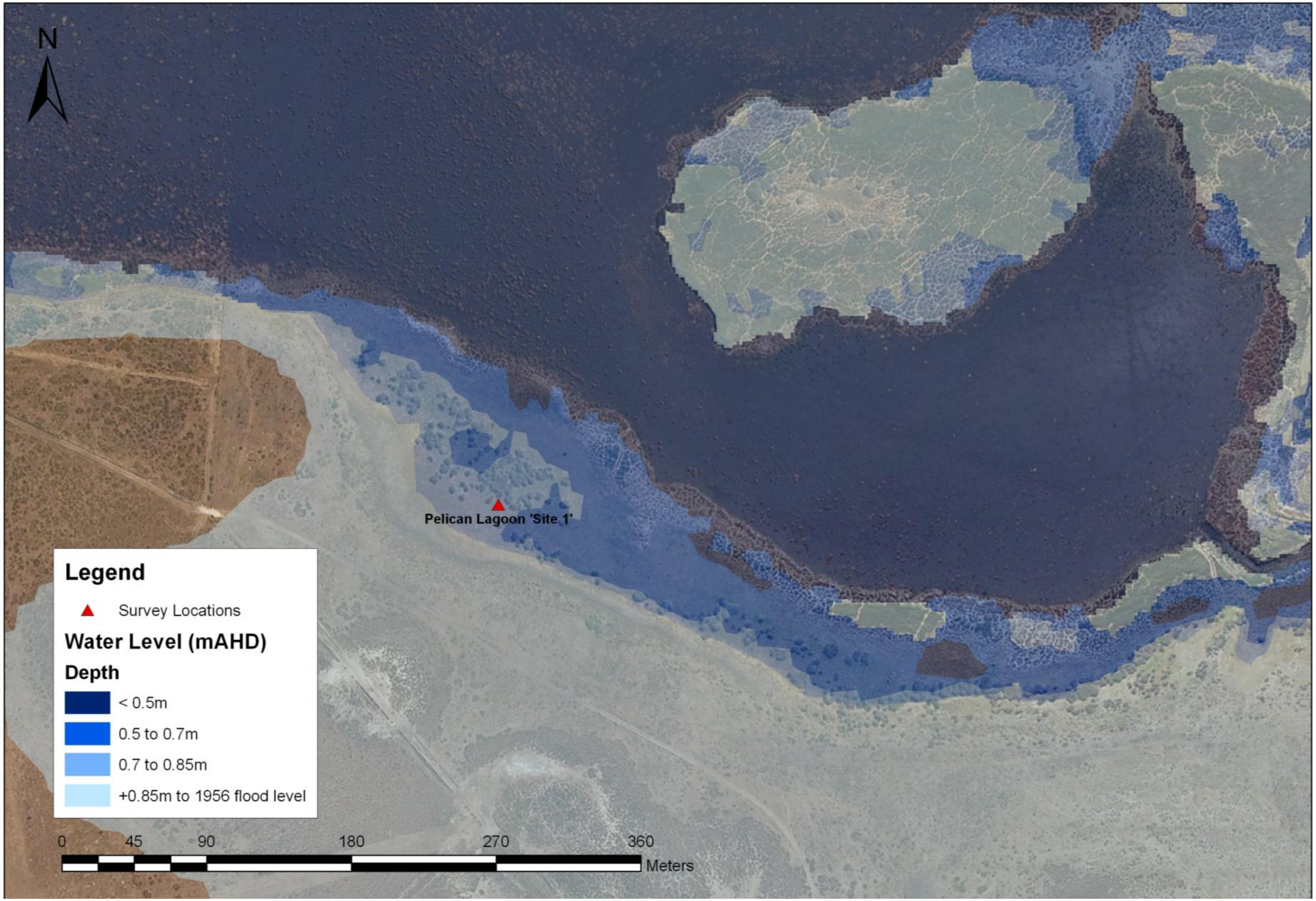


Figure 17: Map of Pelican Lagoon 'Site 1' showing area of inundation at increasing water levels (Source: DENR 2010)

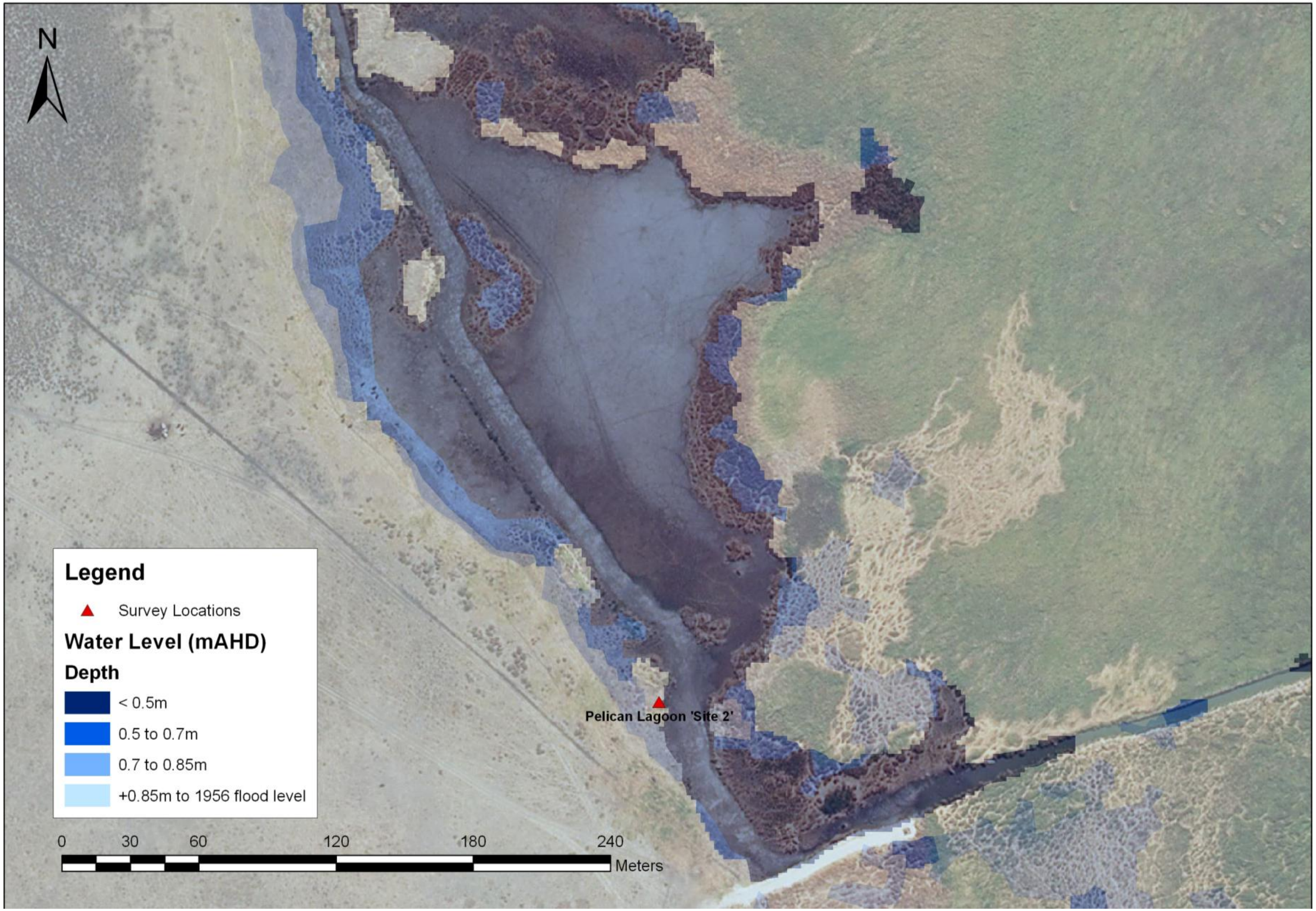


Figure 18: Map of Pelican Lagoon 'Site 2' showing area of inundation at increasing water levels (Source: DENR 2010)

Water Quality

Increased flow into the Lower Murray during August 2010 had substantial influence on water quality in the region. As water levels increased, salinity (electrical conductivity) in the Lower Murray, particularly Lake Alexandrina and the GCWLMA decreased (Fig. 19). Salinities in sites occupied by *L. raniformis* varied but were predominantly in the range of 320-2560 µs.cm^{1}, with the exception one observation of 19210 µs/cm^{1} at Clayton Bay ‘Red Top Bay’ in February 2011. At the time of detection, however, salinity was lower at 11890 µs.cm^{1}. Salinity fluctuated at this location (11890 µs.cm^{1}, 8810 µs.cm^{1} and 19210µs.cm^{1} consecutively) due to the poor connection to the Goolwa Channel due to the dense Saltwater Couch grasslands and Cumbungi/Bulrush reed beds that the water must feed through to inundate this shallow sheltered bay. Discussed in section 3.3, this site was dominated by tadpoles (not of *L. raniformis*) and had very few fish due to the vegetated connection described. On the opposite side of the Saltwater Couch barrier water quality was more representative of that of the Goolwa Channel with salinity decreasing from 2580 µs.cm^{1} in October 2010 to 703 µs.cm^{1} in February 2011. The data for both sites have been included in Table 11 as it demonstrates the variability in water quality across short distances.

The lowest salinity was recorded at Pelican Lagoon Site 2 (320 µs.cm^{1}) in December 2010. Little change in salinity was observed in February 2011 during fish surveys, when 382 µs.cm^{1} was recorded. Pelican Lagoon Site 1 is located further away from the lagoons’ connection to the River Murray. Salinity at this site was 456µs.cm^{1} in December 2010 and 626µs.cm^{1} in February 2011. Pelican Lagoon Site 1 recorded the highest consecutive abundance of *L. raniformis* across the survey period.

No trend was observed between pH of the surfacewater and abundance of *L. raniformis.* Values predominantly ranged between just below neutral, 6.48 (Pelican Lagoon Site 1) and alkaline, 8.49 (Clayton Bay ‘Community Boardwalk’).An unusually high pH of 10.51was recorded at Clayton Bay ‘Red Top Bay’ in February 2011. Low connectivity to the Goolwa Channel and a high algal content may have influenced this. Salinity and turbidity were also higher at this site. As pH can change over the course of a day due to the influence of variables such as presence of algae, organic matter and sediment type, the time of day in which pH was recorded is important. In general, pH values within the sites assessed were generally lower than that of Lake Alexandrina and the GCWLMA during October and November (Table 11, Fig. 20). During this time many of the fringing and off-channel wetlands had only recently been inundated, some for the first time in over three years. pH increased between sampling periods across nearly all sites where multiple sampling was undertaken (Table 11).

Turbidity at sites occupied by *L. raniformis* was recorded between 70.2 NTU and 228 NTU. Field observers noted that a higher content of breaking down organic matter was present at sites where high turbidity was recorded. Turbidity recorded at Finniss ‘Wally’s Landing’ in October 2010 of 18.2 NTU, was not representative of where *L. raniformis* adults were detected calling. Turbidity observed at Finniss ‘Watchalunga Lagoon’ is the most representative of the area occupied by *L. raniformis.*

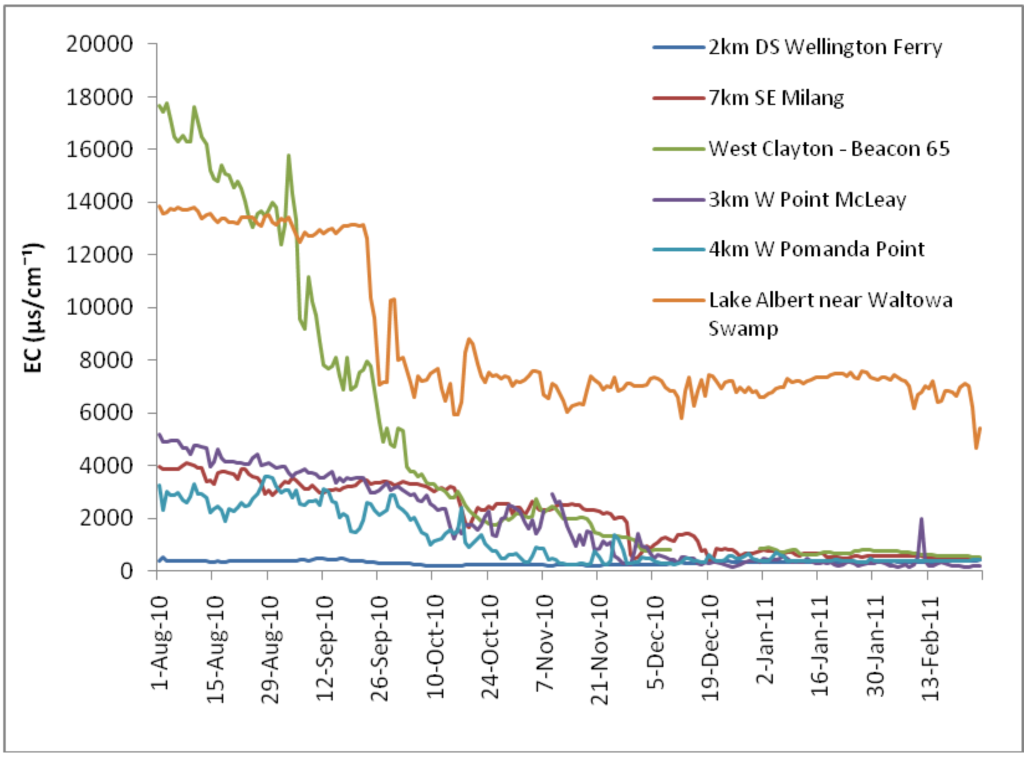


Figure 19: Salinity measured at telemetry stations (electrical conductivity) in Lake Alexandrina and the Goolwa Channel August 2010-February 2011 (Source: River Murray Data, DfW).

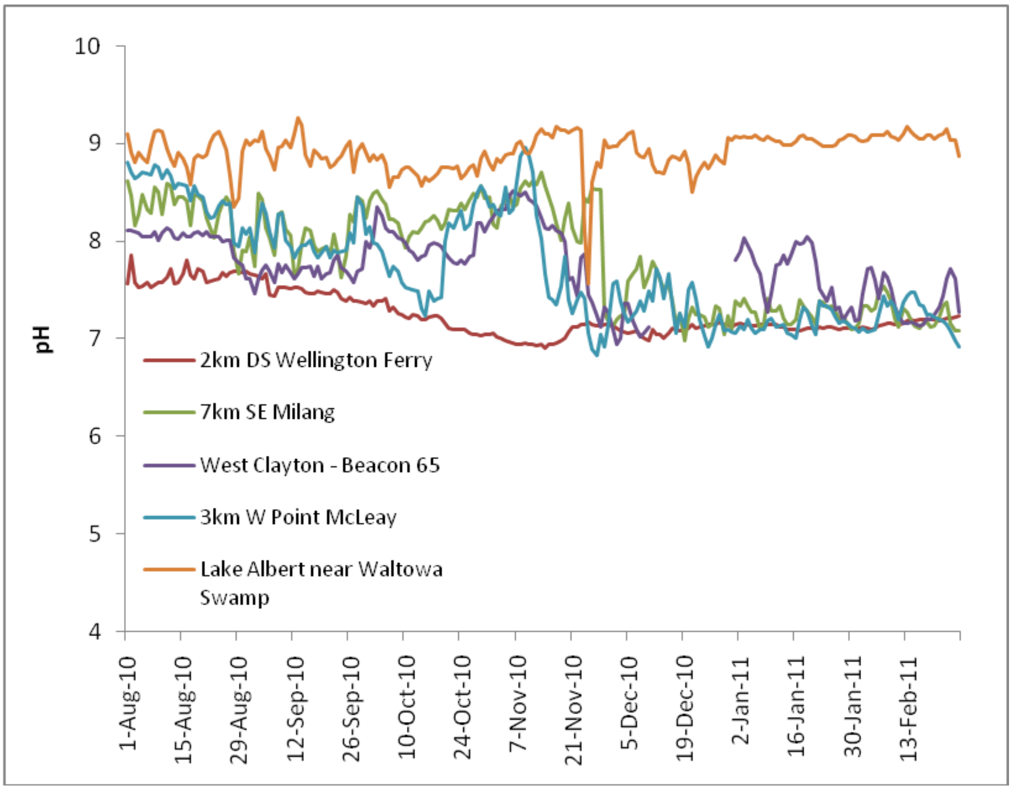


Figure 20: pH measured at telemetry stations in Lake Alexandrina and the Goolwa Channel August 2010-February 2011 (Source: River Murray Data, DfW).

Table 11: Water quality results at sites occupied by *L. raniformis* using handheld instruments

Site	Date	Time	Electrical Conductivity ($\mu s.cm^{-1}$)	Dissolved Oxygen (ppm)	Turbidity (NTU)	Temperature (°C)	pH
Clayton Bay 'Community Boardwalk'	26/10/2010	21:40	2580	7.43	11	19.5	8.97
Clayton Bay 'Community Boardwalk'	15/12/2010	7:00	1606	5.08	33.4	15.5	7.2
Clayton Bay 'Community Boardwalk'	9/02/2011	9:45	703	4.71	90	20.1	8.49
Clayton Bay 'Red Top Bay'	26/10/2010	17:30	11890	2.74	15	19.4	7.36
Clayton Bay 'Red Top Bay'	15/12/2010	10:00	8810	4.46	31.1	17.8	6.68
Clayton Bay 'Red Top Bay'	8/02/2011	15:20	19210	19.16	>400	24.3	10.51
Finniss 'Sterling Downs'	26/10/2010	23:00	2530	2.18	13	17.5	6.64
Finniss 'Sterling Downs'	22/12/2010	8:18	2560	373	84.8	9.4	7.23
Finniss 'Sterling Downs'	8/02/2011	9:00	2340	6.2	96.2	24.9	7.2
Finniss 'Wally's Landing'	26/10/2010	19:00	1825	7.55	18.2	23.7	7.16
Finniss 'Watchalunga'	26/10/2010	19:30	1791	3.08	8.6	20.2	6.83
Finniss 'Watchalunga Lagoon'	8/02/2011	8:00	2530	6.52	70.2	22.3	7.61
Hindmarsh Island 'Boggy Creek'	3/02/2011	9:50	803	2.97	52.8	24.6	7.14
Pelican Lagoon 'Site 1'	15/12/2010	7:45	456	3.55	110.4	13.2	6.48
Pelican Lagoon 'Site 1'	4/02/2011	13:12	626	3.18	228	27.2	7.58
Pelican Lagoon 'Site 2'	15/12/2010	7:20	320	6.5	126.1	13.7	6.56
Pelican Lagoon 'Site 2'	4/02/2011	9:40	382	5.1	73.6	28.7	7.57

3.3.2 Description of features, vegetation and grazing of sites occupied by L. raniformis

a) Pelican Lagoon

The highest abundance of *L. raniformis* was observed at Pelican Lagoon in 2010 and supported populations of *L. raniformis* during the River Murray Wetlands Baseline Survey in 2005 (Simpson *et al.* 2006) prior to water levels falling and the subsequent drying of the lagoons in 2007. The wetland complex consists of three distinct once permanent lagoons/billabongs connected by broad shallow channels located approximately 5 km south of the township of Wellington as the River Murray Channel converges with Lake Alexandrina. The entrance to the lagoon is broad (over 1.5 km); however it is choked by large expanses of Common Reed and Bulrush. A small inlet channel, previously dredged for water access, is currently the only open-water entry point to the lagoons. Wetland edges are flat to gently sloping at the survey sites within the southern and entrance lagoon, allowing over-bank flooding with only small increases in water level. Stands of Lignum are located at Site 1 along these low-lying fringes extending to the start of Site 2. Site 1 is dominated by shallowly inundated Lignum with an understorey of Samphire, Duckweed, pasture grasses and Sea Rush (Fig. 21). Site 2 is dominated by pasture grasses, pasture clovers, Samphire and low, grazed Lignum. Large stands of Bulrush and Common Reed are situated across the waterbody towards the river. The low-lying areas, including the Lignum shrublands, become intermittently inundated when water levels exceed 0.75 mAHD. Approximately 10-15% of the shrublands remain inundated at 0.6-0.7 mAHD (River Murray Data, DfW 2010). Wind seiching from Lake Alexandrina drive fluctuations in water level. The wetland is surrounded by land used predominantly for primary production. The wetland fringes are grazed and allow water access for stock.

Figure 21: Lignum shrublands at Pelican Lagoon Site 1 from where adult *L. raniformis* was observed calling, February 2011

b) Finniss River 'Wally's Landing' and 'Watchalunga'

Watchalunga is a grazing property on the Finniss River located directly south of the Winery Road Finniss River crossing. The area is a mosaic of permanent lagoons, channel habitats and low lying ephemeral floodplain containing open water habitats, sedgelands, reedbeds, pastures and Lignum shrublands. Nocturnal survey sites are located on opposite banks of the floodplain. In between these sites lie Lignum shrublands from which *L. raniformis* adult males were recorded calling in November 2009 (Mason 2010) and December 2010 (as part of this study). The Lignum shrublands contain understorey vegetation of Sea Rush, Saltwater Couch, Samphire (*Halosarcia, Sarcocornia* sp) and aquatic herbs. This association is located behind stands of Bulrush and Common Reed. Submerged aquatic plants were located in the open water lagoon habitats including Curly Pondweed (*Potamogeton* crispus) and Water Milfoil. The area is generally flat with low lying depressions and a gradual to steep bank slope at the bands of Bulrush and Common Reed. As observed during 2009 (following increases in water level in the GWLMA), the shrubland areas inundate when water levels exceed 0.70 mAHD. *L. raniformis* was heard calling at this site during the third nocturnal survey round in November 2010 when water levels were at approximately 0.82 mAHD (River Murray Data, DfW 2010). The site is grazed by cattle and provides access to drinking water for stock.

Figure 22: Aerial photo location of Watchalunga/Wally's Landing, Finniss River, January 2011 (Photo courtesy of Pip Taylor)

c) Finniss River 'Sterling Downs'

Sterling Downs is located on the Finniss River approximately 5 km north of the confluence with the Goolwa Channel/River Murray (Fig. 22). The survey site is located within an off-channel lagoon divided from the Finniss River by reedbeds. Although the wetland fringes are dominated by Common Reed (*Phragmites australis*), behind these reedbeds the gently sloping littoral zone contains a diverse plant assemblage. This consists of Sea Rush, Common Spike-rush (*Eleocharis acuta*) and Three-corner rush (*Bolboschoenus cardwellii*) sedgelands with Austral Seabite (*Suaeda australis*) and Samphire shrublands with scattered Lignum. The few scattered Lignum bushes were from where *L. raniformis* were observed calling. The site also contained inundated pasture grasses and a diversity of low-growing semi-aquatic plants such as Creeping Monkey Flower (*Mimulus repens*), Streaked Arrowgrass (*Triglochin striatum*) and Water Buttons (*Cotula coronopifolia**). Filamentous algae were present amongst the inundated vegetation and decomposing pasture grasses. Together they provided approximately 10% of submerged vegetative structure. This diverse community was inundated during the third nocturnal survey and first tadpole survey in December 2010 when water levels were at approximately 0.82 mAHD. In February 2011, during the second tadpole survey the water level had receded to approximately 0.57 mAHD (River Murray Data, DfW 2010) where only 15-20% of the target area was inundated (Fig 23). An increase in cover abundance of Common Reed was observed between the December and February survey rounds. The site is grazed and the lagoon provides access to water for stock.

a)

b)

Figure 23: a).Finniss 'Sterling Downs' in December with green filamentous algae and shallowly inundated Lignum 2010 b) Finniss 'Sterling Downs in February 2011following recession of water levels and increase in Common Reed.

d) Hindmarsh Island 'Boggy Creek'

Boggy Creek is located on eastern side of Hindmarsh Island. The survey site is located at a threatened fish management site (Wedderburn and Hillyard 2010) just upstream of the connection to Shadow's lagoon and approximately 1.7 km downstream from the junction of Boggy Creek and Mundoo Channel. Environmental water was provided to a remnant pool in Boggy Creek in 2009 to maintain a population of the threatened Murray Hardyhead (*Craterocephalus fluviatilis*). The site consists of channel habitat with gradual to steep bank slopes, shallow open water lagoons, ephemeral low-lying floodplain and pastures, all containing diverse plant communities (Fig. 24). Common Reed and Bulrush reedbeds are becoming the dominant vegetation layer within the shallow lagoons following reinundation of the entire Boggy Creek system in late 2010. The site also contains Three-corner Rush, Sea Rush and Common Spike-rush with Couch, Water Ribbons (*Triglochin procerum*), Water Buttons and submerged aquatic plants such as Water Milfoil and Widgeon Grass. A large stand of remnant Swamp Paperbark (*Melaleuca halmaturorum*) is located adjacent the site. The northern side of the site is grazed and the wetlands provide access to water for stock.

One adult male *L. raniformis* was observed calling in the third nocturnal survey in December 2010 from floating mats of organic matter amongst scattered reeds and inundated grasses. At this time water levels were at approximately 0.82 mAHD (River Murray Data, DfW 2010).

Figure 24: Hindmarsh Island 'Boggy Creek' facing east February 2011

e) Clayton Bay 'Red Top Bay'

Red Top Bay is a fringing wetland located before the Goolwa Channel converges with Lake Alexandrina, sheltered by the small peninsulas of the township of Clayton Bay. The site became inundated in November 2009 following the completion of the blocking bank at Clayton and implementation of the Goolwa Water Level Management Project (GWLMP). Red Top Bay contains sheltered open water with fringing and semi-submerged reedbeds and a shallow, densely vegetated lagoon that currently has no open-water connection to the remainder of Red Top Bay. This area is inundated as water feeds through dense reedbeds and grassland. The single adult *L. raniformis* detected at this site during the first nocturnal survey round in December 2010 utilised the dense inundated grasses (Predominantly Couch, as seen in Fig. 25a) however was not observed a second time. Dense submerged aquatic plant growth was present across 80% of the lagoon containing Water Milfoil. and Widgeon Grass. No grazing was observed during the project. The nearby survey site Clayton Bay 'Community Boardwalk' is predominantly fringed by Bulrush and Common Reed. Scattered stands of River Club Rush in the open water sit amongst dense swathes of submerged Hornwort, Water Milfoil and Ribbonweed (Fig. 25b).

a)

b)

Figure 25: a) Clayton Bay 'Red Top Bay' December 2010 b) Clayton Bay 'Community Boardwalk' February 2011.

3.4 Detection of Recruitment

3.4.1 Tadpoles

Surveys were undertaken at 14 sites in late December 2010 and 17 sites in early February 2011 to detect presence of *L. raniformis* tadpoles and therefore assess recruitment success (Fig. 26). Tadpoles were captured at only one location, Pelican Lagoon Site 1 during December 2010 (Fig. 27). No tadpoles were captured during February 2011. A total of 14 *L. raniformis* tadpoles were caught. Total length (TL) measurements ranged between 35 and 61 mm (Table 12, Fig. 28), though the majority of tadpoles were greater than 50 mm (n=9, 71.4%). Seven tadpoles were caught in Box Traps and seven were caught in Fyke nets. The data does not suggest any trend in total length measurements in relation to net type (Table 12).

Tadpole surveys were not conducted at Hindmarsh Island ‘Boggy Creek’ and Finniss River ‘Wally’s Landing/Watchalunga’ during December 2010 due to limited access despite *L. raniformis* being detected at these sites during the final round of nocturnal (call) surveys in December 2010.

Figure 26: Map location of fish surveys undertaken for detection of tadpoles.

Figure 27: *Litoria raniformis* tadpole captured at Pelican Lagoon, December 2010.

Table 12: *L. raniformis* tadpole length measurements taken during first round of tadpole surveys at Pelican Lagoon Site 1 in relationship to net type each individual was caught in.

Tadpole	Length (Total Length – Mouth to Tail Tip) mm	Net Type
1	55	Fyke
2	57	Fyke
3	50	Fyke
4	60	Fyke
5	45	Fyke
6	35	Fyke
7	61	Fyke
8	60	Box
9	46	Box
10	40	Box
11	61	Box
12	57	Box
13	60	Box
14	52	Box

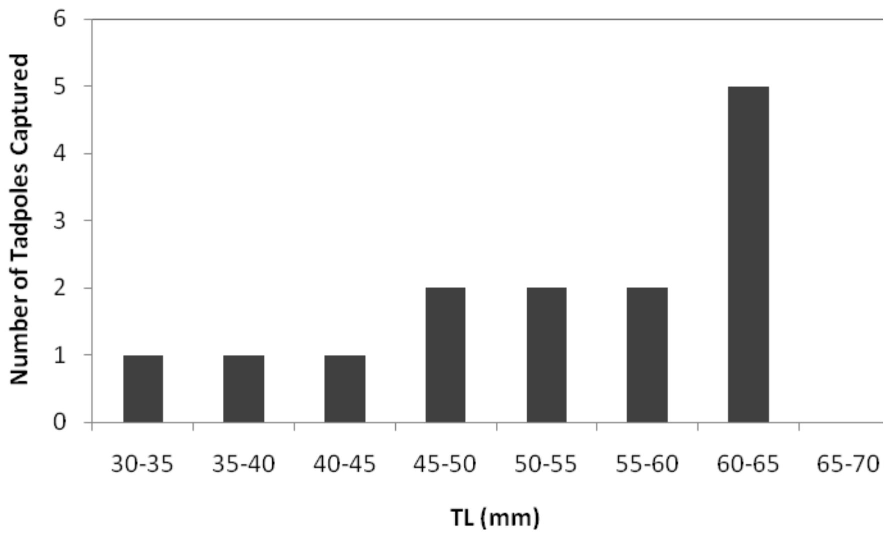


Figure 28: Distribution of total length (TL) measurements of all *L. raniformis* tadpoles captured at Pelican Lagoon February 2011.

3.4.2 Fish Abundance and Diversity

A total of 29,186 individuals were captured collectively from the two tadpole surveys undertaken in December 2010 and January/February 2011. Abundance was higher in December 2010 (n=21,461) but was dominated by introduced fish species (Fig. 29), predominantly juvenile alien Common Carp (*Cyprinus carpio*). Common Carp, one of four introduced species captured which constituted 62.5% (n=13,413) of the total combined catch (Table 13, Fig. 30). In January and February 2011, abundance of introduced fish had decreased, making up 51.4% (n=3973) of the total catch (Fig. 29), 82% of which was European Carp.

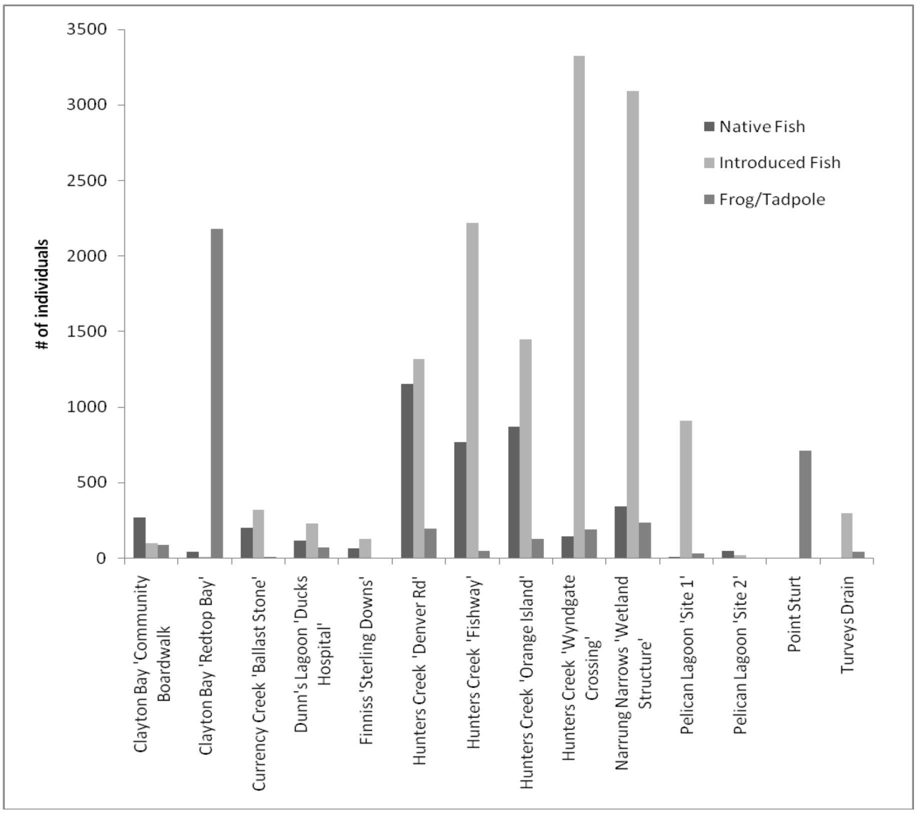
In December 2010 two sites, Clayton Bay 'Red Top Bay' and Point Sturt, were dominated by tadpoles of the *Limnodynastes* and *Crinia* genus. These two sites had poor connectivity to the Goolwa Channel and Lake Alexandrina that limited fish passage. They also contained high organic content in the water column and fluctuating water quality.

Sites where *L. raniformis* were detected in December 2010 generally had lower abundances in fish species, than other sites. The highest abundance of fish was captured at Hindmarsh Island in Hunters Creek 'Wyndgate Crossing' and Narrung 'Wetland Structure' in December 2010 (Table 13) and Hindmarsh Island 'Boggy Creek' and Point Sturt in February 2011 (Table 14).

Five species of conservation significance were captured between December 2010 and February 2011 (Fig. 31). See Tables 13 and 14 for abundances and site locations.

- Murray Hardyhead (*Craterocephalus fluviatilis*) – Nationally vulnerable (*EPBC Act 1999*), SA Endangered (Hammer *et al*. 2009)
- Southern Pygmy Perch (*Nannoperca australis*) – SA endangered (Hammer *et al*. 2009), Protected (*Fisheries Management Act 2007*)
- Juvenile Murray Cod (*Maccullochella peelii*) – SA endangered (Hammer *et al.* 2009)
- Freshwater Catfish (*Tandanus tandanus*) – SA Endangered (Hammer *et al*. 2009), Protected (*Fisheries Management Act 2007*)

a)



b)

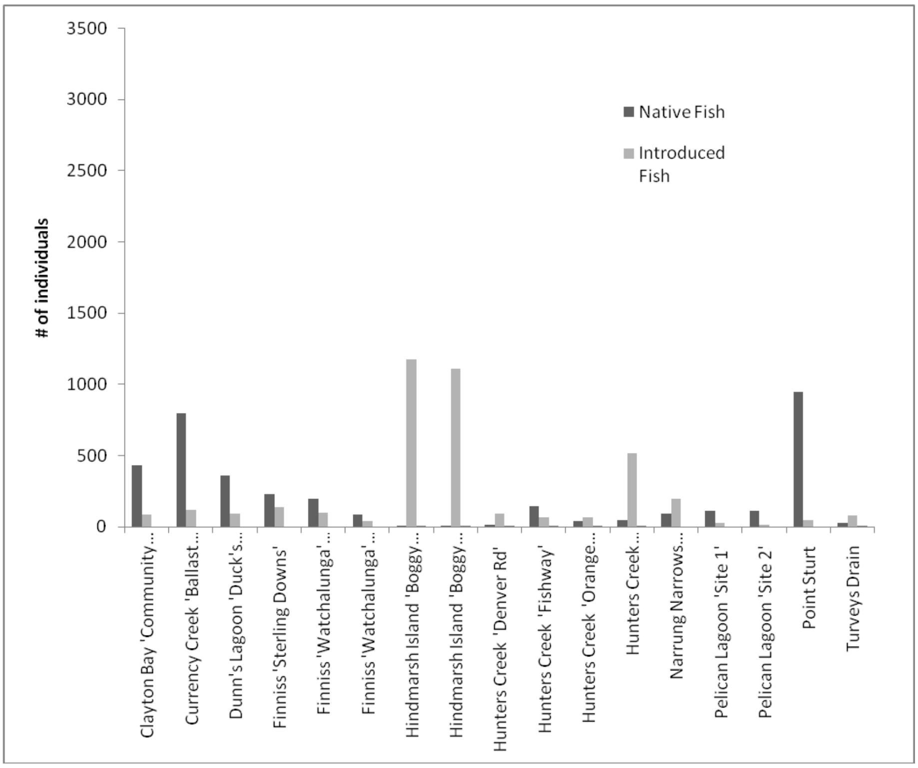
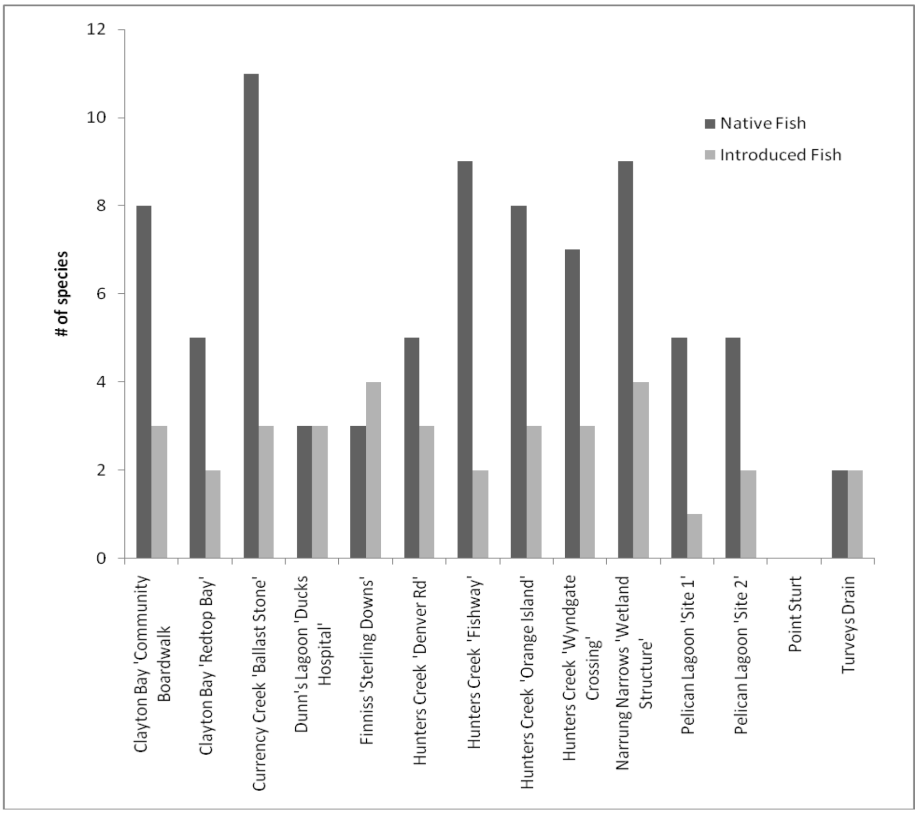


Figure 29: Species abundance of total captures from all sites during a) first tadpole survey round, December 2010 and b) second tadpole survey round, February 2011.

a)



b)

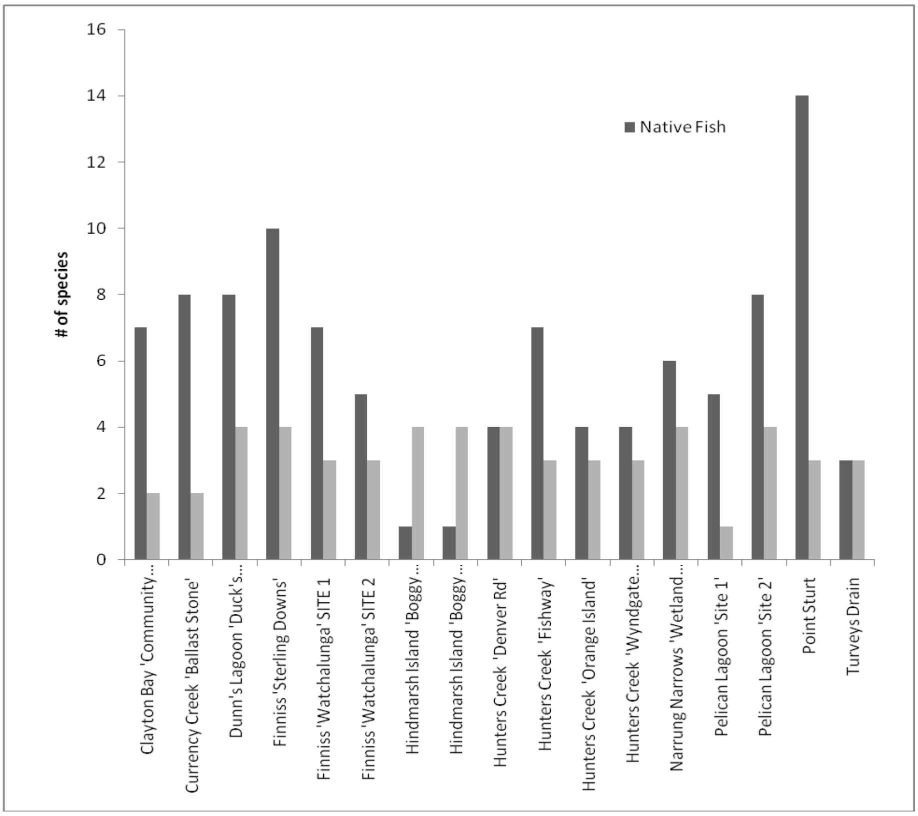


Figure 30: Species diversity of total captures from all sites during a) first tadpole survey round, December 2010 and b) second tadpole survey round, February 2011.

Table 13: Total captures and abundances December 2010

	Clayton Bay 'Community Boardwalk	Clayton Bay 'Redtop Bay'	Currency Creek 'Ballast Stone'	Dunn's Lagoon 'Ducks Hospital'	Finniss 'Sterling Downs'	Hunters Creek 'Denver Rd'	Hunters Creek 'Fishway'	Hunters Creek 'Orange Island'	Hunters Creek 'Wyndgate Crossing'	Narrung Narrows 'Wetland Structure'	Pelican Lagoon 'Site 1'	Pelican Lagoon 'Site 2'	Point Sturt	Turveys Drain	Total
Native Fish Species															
Australian Smelt (*Retropinna semoni*)			8		48		1		1	7		9			74
Bony Bream/Bony Herring (*Nematalosa erebi*)	33		6			6	41	21	14	22	3	6			152
Bridled Goby (*Arenigobius bifrenatus*)	11		10				1								22
Callop/Golden Perch (*Macquaria ambigua ambigua*)										1		2			3
Carp Gudgeon Complex (*Hypseleotris* spp.)	19	12		3			1	3		7	1	9			55
Common Froglet (*Crinia signifera*)		1													1
Common Galaxias (*Galaxias maculatus)*	5		1				2	7	3	16	1				35
Congolli (*Pseudaphritis urvillii)*	2		4			46	28	5		1					86
Eastern Banjo Frog (*Limnodynastes dumerili*)		2	1												3
Flat-headed Gudgeon (*Philypnodon grandiceps*)	169	1	133	100	12	1078	651	789	123	285	2	22		1	3366
Murray Hardyhead (*Craterocephalus fluviatilis*)			3					1							4
Small-mouthed Hardyhead (*Atherinosoma micros*	3	28	6			17	34	45	1	2					136
Southern Pygmy Perch (*Nannoperca australis*)														2	2
Tamar River Goby (*Afurcagobius tamarensis*)			12						1						13
Unspecked Hardyhead (*Craterocephalus stercusmuscarum fulvus*)											1				1
Western Blue-spot Goby (*Pseudogobius olorum*)	30		16	12	5	5	10	1	2	1					82
Total Abundance Native Fish	**272**	**44**	**200**	**115**	**65**	**1152**	**769**	**872**	**145**	**342**	**8**	**48**	**0**	**3**	**4035**
Number of Fish Species	**8**	**5**	**11**	**3**	**3**	**5**	**9**	**8**	**7**	**9**	**5**	**5**	**0**	**2**	**16**
Alien Fish Species															
Common Carp (**Cyprinus carpio*)	56	5	109	220	27	1171	1212	970	3274	3016	911	17		15	11003
Eastern Gambusia (*Gambusia holbrookii*)	17		178		95					1				284	575
Goldfish (*Carassius auratus*)		1		9	2	26		8	11	1					58
Redfin Perch (*Perca fluviatilis*)	26		36	2	3	119	1009	468	39	74		1			1777
Total Abundance Introduced Fish	**99**	**6**	**323**	**231**	**127**	**1316**	**2221**	**1446**	**3324**	**3092**	**911**	**18**	**0**	**299**	**13413**
Number of Introduced Fish Species	**3**	**2**	**3**	**3**	**4**	**3**	**2**	**3**	**3**	**4**	**1**	**2**	**0**	**2**	**4**
Total Number of Fish Species	**11**	**7**	**14**	**6**	**7**	**8**	**11**	**11**	**10**	**13**	**6**	**7**	**0**	**4**	**20**
Frog Species															
Southern Bell Frog Tadpole (*Litoria raniformis*)											14				14
Spotted Grass Frog (*Limnodynastes tasmaniensis*)		1													1
Tadpoles															0
Limnodynastes spp., *Crinia* spp.		1478											712		2190
Limnodynastes spp.	88	702	7	69	3	198	50	128	192	234	20			42	1733
Total Abundance Frogs	**88**	**2181**	**7**	**69**	**3**	**198**	**50**	**128**	**192**	**234**	**34**	**0**	**712**	**42**	**3938**
Other															
Long-necked Tortoise (*Chelondina longicollis*)				2											2
Yabby (*Cherax destructor*)														73	73
Total Adundance	**459**	**2231**	**530**	**417**	**195**	**2666**	**3040**	**2446**	**3661**	**3668**	**953**	**66**	**712**	**417**	**21461**

Table 14: Total captures and abundances February 2011

	Clayton Bay 'Community Boardwalk	Currency Creek 'Ballast Stone'	Dunn's Lagoon 'Duck's Hospital'	Finniss 'Sterling Downs'	Finniss 'Watchalunga' SITE 1	Finniss 'Watchalunga' SITE 2	Hindmarsh Island 'Boggy Creek' Site 1	Hindmarsh Island 'Boggy Creek' Site 2	Hunters Creek 'Denver Rd'	Hunters Creek 'Fishway'	Hunters Creek 'Orange Island'	Hunters Creek 'Wyndgate Crossing'	Narrung Narrows 'Wetland Structure'	Pelican Lagoon 'Site 1'	Pelican Lagoon 'Site 2'	Point Sturt	Turveys Drain	**Total**
Native Fish Species																		
Australian Smelt (*Retropinna semoni*)				7	11										10	31		**59**
Bony Bream/Bony Herring (*Nematalosa erebi*)	64	74	67	14	24	13			4	5	5	7	82	45	44	18		**466**
Bridled Goby (*Arenigobius bifrenatus*)	14	60	1	2		1				1						1		**80**
Callop/Golden Perch (*Macquaria ambigua ambigua*)	1																	**1**
Carp Gudgeon Complex (*Hypseleotris spp.*)	21		37	12	7	18				1			1	3	20	7		**127**
Common Galaxias (*Galaxias maculatus*)			2	3					1	2	3	3	1		4	43		**62**
Congolli (*Pseudaphritis urvillii*)	6	2	3	2	4				1	41	13	2	3			19	1	**97**
Dwarf Flat-headed Gudgeon (*Philypnodon macrostomus*)				1	1	1												**3**
Flat-headed Gudgeon (*Philypnodon grandiceps*)	318	99	233	183	58	55	8	2	6	91	22	38	6	63	29	60	26	**1297**
Freshwater Catfish (*Tandanus tandanus*)														2	2	3		**7**
Lagoon Goby (*Tasmanogobius lasti*)		1														661		**662**
Murray Cod (*Maccullochella peelii*)																2		**2**
Murray Rainbowfish (*Melanotaenia fluviatilis*)															2			**2**
Tamar River Goby (*Afurcagobius tamarensis*)		4														10		**14**
Unspecked Hardyhead (*Craterocephalus stercusmuscarum fulvus*)													2		3	4		**9**
Western Blue-spot Goby (*Pseudogobius olorum*)	6	558	19	8	94					7						86	2	**780**
Total abundance native fish	**430**	**798**	**362**	**232**	**199**	**88**	**8**	**2**	**12**	**148**	**43**	**50**	**95**	**113**	**114**	**945**	**29**	**3668**
Total number of native fish species	**7**	**7**	**7**	**9**	**7**	**5**	**1**	**1**	**4**	**7**	**4**	**4**	**6**	**4**	**8**	**13**	**3**	**16**
Introduced Fish Species																		
Common Carp (*Cyprinus carpio*)	80	99	69	62	35	23	1128	978	59	41	34	424	122	27	11	41	32	**3265**
Eastern Gambusia (*Gambusia holbrookii*)			1	64	39		8	49	2				59		1		49	**272**
Goldfish (*Carassius auratus*)			10	3		1	19	78	33	6	12	63	10		2	2	1	**240**
Redfin Perch (*Perca fluviatilis*)	8	18	14	7	26	19	21	5	2	17	18	30	9		1	1		**196**
Total abundance introduced fish	**88**	**117**	**94**	**136**	**100**	**43**	**1176**	**1110**	**96**	**64**	**64**	**517**	**200**	**27**	**15**	**44**	**82**	**3973**
Total number of introduced fish species	**2**	**2**	**4**	**4**	**3**	**3**	**4**	**4**	**4**	**3**	**3**	**3**	**4**	**1**	**4**	**3**	**3**	**4**
Total number of fish species	9	9	11	13	10	8	5	5	8	10	7	7	10	5	12	16	6	20
Frog Species																		
Spotted Grass Frog (*Limnodynastes tasmaniensis*)								1										**1**
Eastern Banjo Frog (*Limnodynastes dumerili*)								1										**1**
Tadpoles (*Limnodynastes spp.*)							1		5	1	1	11					7	**26**
Total abundance frogs	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**2**	**5**	**1**	**1**	**11**	**0**	**0**	**0**	**0**	**7**	**28**
Other																		
Long-necked Tortoise (*Chelondina longicollis*)													6					**6**
Yabby (*Cherax destructor*)		5		2	4	2	2	7			4						24	**50**
Total adundance	**518**	**920**	**456**	**370**	**303**	**133**	**1187**	**1121**	**113**	**213**	**112**	**578**	**301**	**140**	**129**	**989**	**142**	**7725**

a)

b)

c)

d)

e)

f)

Figure 31: a) Murray Hardyhead at Currency Creek 'Ballast Stone', December 2010; b) Southern Pygmy Perch at Turvey's Drain, December 2010; c) juvenile Callop/Golden Perch at Clayton Bay 'Community Boardwalk', December 2010; d) juvenile Congolli at Currency Creek 'Ballast Stone', December 2010; e) juvenile Freshwater Catfish at Pelican Lagoon Site 2, February 2011; f) juvenile Murray Cod at Point Sturt, February 2011.

4. Discussion

a) Abundance and Distribution

This monitoring project has provided good spatial coverage of Southern Bell Frog assessment sites in the Goolwa Channel Water Level Management Project Area and the greater Lower Lakes. The response by *L. raniformis* populations to elevated water levels in the GCWLMA as a result of a management actions and the return of flows to the CLLMM region has been assessed. Inclusion of historic locations of *L. raniformis*, recent observations and suitable *L. raniformis* habitat provided a diversity of fringing wetland habitats assessed over consecutive surveys. With the large scale of the study region in mind, a detailed description of the distribution of *L. raniformis* in the study region is difficult to compile due to the gaps of unsurveyed territory. In order to achieve this, a greater number of survey sites would be required to detect any additional populations.

Results from nocturnal surveys show that the distribution of *L. raniformis* populations was restricted to the north and western side of the study region, however fewer sites were undertaken on the eastern side. Although a greater number of occupied sites were located within the Finniss River, Goolwa Channel and Hindmarsh Island, in the south-west of the study region, the greatest abundance of calling males was observed within the northern point of Lake Alexandrina at Pelican Lagoon, a site previously containing *L. raniformis* prior to drying in 2007 (Holt *et al*. 2004). Abundance of calling males at the remaining sites was low to extremely low, with two sites having two to nine calling males and two sites detecting only one. These results partially answer key question 3.8 by the confirmed presence of calling adult *L. raniformis* within the GCWLMA.

Abundance of calling adult males peaked in October 2010 at Pelican Lagoon, but peaked at the remaining occupied sites in December 2010. This may be due to weather conditions during survey events, however it is more likely linked to water levels and inundation of suitable breeding habitat. The Lignum shrublands, a feature of the breeding habitat provided at Pelican Lagoon, become inundated (if only marginally) at water levels of approximately 0.5-0.6 mAHD unlike the shrublands of Finniss 'Watchalunga' and Finniss 'Sterling Downs which inundate above 0.7 mAHD. Water levels reached 0.7mAHD in September 2010 (Source: River Murray Data, DfW 2010) and coupled with suitable water quality and climatic conditions, it is feasible that *L. raniformis* began calling earlier than the first nocturnal survey in October 2010.

b) Habitat Requirements and Management

One of the distinguishing features of the occupied sites is the presence of Lignum shrublands. Five of six occupied sites contained Lignum, with adult males observed calling from within or near bushes that were inundated to depths ranging from approximately 0.1 m to 1.2 m of water. These shrublands were not dense, instead scattered with semi open areas in between. The greatest areas of Lignum were observed at Pelican Lagoon and Watchalunga. Inundated vegetative structure was present at all occupied sites. This often included terrestrial species, particularly grasses. An important observation was that sites entirely dominated by dense reedbeds of *P. australis* did not yield successful detection of *L. raniformis.* Where *L. raniformis* were detected, adult males were typically recorded calling from within semi-open water bodies and/or Lignum with a high density of organic matter, decomposing or providing structure, despite the dense reedbeds often in the vicinity.

Five of the six sites occupied by *L. raniformis*, were grazed, which possibly accounted for the absence of *P. australis* (Van Deursen and Drost 1990; Roberts 2000; Jansen and Robertson 2001). It is possible grazing, in the absence of frequent over-bank flooding, may benefit *L. raniformis* by preventing breeding habitats becoming dominated by *P. australis*. Although grazing has been shown to benefit some frogs (Bull and Hayes 2000; Burton et al. 2009), grazing impacts may actually harm from trampling *L. raniformis* (DEWHAA 2009a). However, caution is advised in altering a grazing regime at a known *L. raniformis* population (DEWHAA 2009b).

Water levels played a vital role in the provision of suitable breeding habitat. *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). An analysis undertaken of available *L. raniformis* call recognition data of the South Australian River Murray corridor showed 66% of all calling records over a 12-year period were from temporary wetlands or wetlands with significantly fluctuating water levels (Schultz 2008). When water levels reached their highest in the Lower Lakes in December 2010 during the study period (0.75-0.85 mAHD), coupled with good survey (i.e. climatic) conditions, calling males were detected at three additional sites, Finniss ‘Watchalunga’, Boggy Creek and Finniss ‘Sterling Downs’. The latter two sites had not detected *L. raniformis* before or during the 2009 inventory. The data shows that even small increases in water level may invoke responses in *L. raniformis* males. Seasonal fluctuations in water level may allow plant communities to colonise exposed sediments and which are then utilised by *L. raniformis* once re-inundated. This may, in part, help to explain the low abundance of *L.raniformis* detected at Clayton Bay ‘Red Top Bay’ which supported the largest population during the 2009/10 Southern Bell Frog Inventory (Mason 2010) when large swathes of green filamentous algae were present after the sites inundation following implementation of the GCWLMP.

c) Breeding Success

Tadpoles were present at only one of the 17 sites surveyed. 14 tadpoles were captured at Pelican Lagoon (site 1) during December 2010 amongst the Lignum shrublands from which more than 50 adult male *L. raniformis* were calling from in October and November 2010. Average lengths of tapdoles (52.8mm ± 8.44mm) were smaller than the known common average lengths for *L. raniformis* tadpoles (85-110 mm: Anstis 2002) suggesting the potential for further growth and development. This potential for further tadpole growth is consistent with the time at which the breeding habitats were inundated in August/September 2010. The low abundance of calling males detected at other occupied sites, absence of tadpoles and the short time in which the preferred breeding habitat was inundated suggests that spawning may not have occurred at these sites. This suggests that water levels did not remain sufficiently high for long enough within the GCWLMA to allow a successful breeding event, contrary to the hypothesis stated in section 1.6. Presence of relatively small tadpoles at Pelican Lagoon (Site 1) and the time in which the site was inundated suggest that inundation of prime breeding habitat for a minimum of three months would increase likelihood of successful egg production and hatching. This is supported by recommendations made by Schultz (2008) following environmental watering of dry wetlands in the Chowilla Floodplain in 2006/07 calling for a minimum inundation of identified *L. raniformis* breeding habitat of three months which was based upon peak calling periods and growth and development of captured tadpoles in relation to time since inundation.

Peak adult male calling did not occur at other occupied sites (Finniss 'Watchalunga', Finniss 'Sterling Downs' and Boggy Creek) until December 2010, thus it was expected that fully developed tadpoles would be detected, were they present, during the second round of tadpoles surveys in February 2011.

5. Recommendations

Based on the results of this project, the following recommendations are made which will assist the recovery of viable *L. raniformis* populations in the River Murray reach below Lock 1 and increase knowledge of their ecology in the region. They aim to better inform future management decisions that affect the future of *L. raniformis* populations, which in turn influence land and water management practices and the health and diversity of freshwater habitats in the Lower Lakes Icon Site.

- Promote a fluctuating water regime in the Lower Murray which will 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 into a future water regime for the region would 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.
- Define potential threatening processes affecting egg and larval stages of recruitment focussing on introduced fish species and the influence of grazing (trampling, nutrient loads). Where possible/appropriate, removal of introduced fish would likely not only benefit *L. raniformis* tadpole survival, but tadpoles of other frog species and small-bodied fish.
- Investigate of impact of Common Reed (*Phragmites australis*) dominance on suitable *L. raniformis* breeding habitat. The Common Reed has benefited from previously stable water levels, and has also extended into large areas of exposed wetland and lake bed in the past three years of lake levels. A correlation between grazing, low Common Reed cover and *L. raniformis* abundance was observed. Investigating the role of grazing and overbank flooding in maintaining *L. raniformis* breeding habitat is an important step to improve management practices to conserve *L. raniformis* populations in the Lower Lakes
- Retain status quo at Pelican Lagoon. Develop an on-going monitoring program to detect changes in population abundance and responses to variations in water level and habitat condition.
- Continue monitoring known populations and habitat similar to that of known populations to determine the effects of changes in habitat features and future management of water levels. Incorporate additional sites on the eastern side of the icon site (Lake Albert and eastern side of Lake Alexandrina), particularly following the completed re-connection of Lake Albert to Lake Alexandrina, to fill gaps in knowledge of spatial distribution.

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