Lower Lakes Aquatic and Littoral Vegetation Condition Monitoring 2009-10

Susan Gehrig, Jason Nicol and Kelly Marsland

SARDI Publication No. F2010/000370-2
SARDI Research Report Series No. 495

SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

September 2010

Government of South Australia

South Australian Murray-Darling Basin Natural Resources Management Board

Department of Environment and Natural Resources

Australian Government

Murray–Darling Basin Authority

Lower Lakes Aquatic and Littoral Vegetation Condition Monitoring 2009-10

Susan Gehrig, Jason Nicol and Kelly Marsland

SARDI Publication No. F2010/000370-2
SARDI Research Report Series No. 495

September 2010

This Publication may be cited as:
Gehrig, S.L., Nicol, J.M. and Marsland, K.B (2010). Lower Lakes Aquatic and Littoral Vegetation Condition Monitoring 2009-10. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2010/000370-2. SARDI Research Report Series No. 495. 54pp.

South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024

Telephone: (08) 8207 2400
Facsimile: (08) 8207 5406
http://www.sardi.sa.gov.au

This project was funded by The Living Murray initiative of the Murray-Darling Basin Commission, which has now transitioned to become the Murray-Darling Basin Authority.

Printed in Adelaide: September 2010

SARDI Publication No. F2010/000370-2
SARDI Research Report Series No. 435

Author(s): Susan Gehrig, Jason Nicol and Kelly Marsland

Reviewer(s): Rod Ward and Brenton Zampatti

Approved by: Dr Qifeng Ye
Program Leader – Inland Waters & Catchment Ecology

Signed:

Date: 10 September 2010

Distribution: SAMDBNRM Board, Murray-Darling Basin Authority, DENR, DFW, SAASC Library and University of Adelaide Library

Circulation: Public Domain

Table of Contents

List of Figures

List of Tables

List of Appendices

Acknowledgements

The authors would like to thank Arron Strawbridge, Rod Ward, Kate Mason, Pip Taylor, Geoff Braddock, Robert Mrongovius, Margaret Mrongovius, Charles Andre, Jo Andre, John Rowe, Lorraine Rowe, Bev Stone, Alex Stone, Dennis Chandler, the Raukkan Natural Resources Management Team, Colleen Bakker and Belinda Gunn for field assistance. Adrienne Frears, Pip Taylor, Rod Ward, Brenton Zampatti and Justin Brookes for comments on early drafts of this report. Geoff and Libby Braddock, Dennis Chandler, Chris and Beth Cowan, the Raukkan Natural Resources Management Team, Charles and Jo Andre and David and Cathy Harvey for access to their properties. Geoff and Libby Braddock, Charles and Jo Andre, Alex and Bev Stone for lunches, tea, coffee and scones. This project was funded by the Murray-Darling Basin Authority's Living Murray program through the South Australian Murray-Darling Basin Natural Resources Management Board and the Department for Environment and Natural Resources through the Murray Futures (Lower Lakes) Program.

Executive Summary

Condition Monitoring Plan for the Coorong, Lower Lakes and Murray Mouth Icon Site (Maunsell Australia Pty Ltd. 2009) identifies that a monitoring program is required that focuses on measuring the key environmental parameters that are indicators of river and floodplain health in both the short and longer terms. This report presents the findings of the first two years of a monitoring program established to evaluate V3 in the aforementioned plan: maintain or improve aquatic and littoral vegetation in the Lower Lakes.

Vegetation surveys were conducted at selected wetlands and lakeshore sites across Lakes Alexandrina and Albert, Goolwa Channel, the lower Finniss River and lower Currency Creek and the mouths of the Angas and Bremer Rivers. Sites established in spring 2008 were resurveyed and additional sites were set up in spring 2009 in Goolwa Channel, the lower Finniss River and lower Currency Creek to assess the impact of the Clayton regulator. At each site, transects were established perpendicular to the shoreline and three 1 x 3 m quadrats separated by 1 m were located at regular elevation intervals (defined by plant community) for wetlands or elevations (+0.8, +0.6, +0.4, +0.2, 0 and -0.5 m AHD) for lakeshores. The cover and abundance of each species present in quadrats was estimated using a modified Braun-Blanquet (1932) cover abundance score. Vegetation surveys were undertaken in October 2008, March 2009, October 2009 and March 2010 during a period of record low water levels in the Lower Lakes. However, significant engineering interventions (construction of the Clayton regulator and pumping of Narrung Wetland) also occurred during the study period and were assessed as part of the monitoring program.

Between spring 2008 and autumn 2010, a total of 127 taxa (including 67 exotics) were recorded. Disconnection and subsequent desiccation of wetlands generally resulted in the loss of submergent taxa (except from wetlands that received rainfall runoff or were filled by pumping i.e. Narrung) and colonisation of terrestrial species. In 2009-10 more terrestrial species colonised lower elevations than in 2008-09. Low water levels resulted in colonisation of terrestrial species (lower elevations were colonised in 2009-10 compared with 2008-09) around the shorelines of Lakes Alexandrina and Albert, similar to wetlands. The majority of the terrestrial taxa that colonised wetlands and lakeshores were exotic agricultural weeds (generally pasture grasses and legumes), which is probably due to surrounding land use. In contrast, a diverse amphibious, emergent and submergent plant community had developed by March 2010 in areas inundated by the Clayton regulator, which in 2008-09 were dominated by terrestrial taxa and bare soil.

Comparison between monitoring results and the River Murray Wetlands baseline surveys undertaken in 2004 and 2005 show that target V3 has not been met for understorey vegetation, except in Goolwa Channel, the lower Finniss River, lower Currency Creek and Narrung

Wetland. Results from Narrung Wetland and areas inundated by the Clayton regulator provide insight into the recovery of the system when water levels are restored to historical levels and show that the system is resilient and can recover from the current degraded state.

1 Introduction

The Coorong, Lower Lakes and Murray Mouth region has been listed as one of six icon sites under Murray-Darling Basin Authority's "The Living Murray" (TLM) program. The Condition Monitoring Plan for the Coorong, Lower Lakes and Murray Mouth Icon Site outlined a series of 17 condition targets for the Icon Site (Maunsell Australia Pty Ltd. 2009). This report presents the findings from the first two years of the understorey component of a condition monitoring program designed to evaluate target V3: maintain or improve aquatic and littoral vegetation in the Lower Lakes (Marsland and Nicol 2009).

Scientifically defensible and statistically robust monitoring programs need to be established to assist in meeting the ecological targets in the Coorong, Lower Lakes and Murray Mouth Icon Site and the Ramsar Management Plan. Marsland and Nicol (2006) identified that existing monitoring programs (in 2006) would not adequately assess target V3; therefore, a monitoring program that expanded upon existing monitoring programs (SAMDBNRM Board community wetland monitoring) and builds upon this program was established in 2008 (Marsland and Nicol 2009). The understorey vegetation monitoring program described in this report uses the same methods and sites as the SAMDBNRM Board community wetland monitoring program but includes additional sites in lakeshore habitats, the lower reaches of the Finniss River, Currency Creek and Goolwa Channel and wetlands that were not part of the original community wetland monitoring program (Marsland and Nicol 2009).

The Condition Monitoring Plan for the Icon Site proposed 'indicators for monitoring' that comprised of individual taxa and discrete communities: *Melaleuca halmaturorum*, *Myriophyllum* spp. *Gahnia filum*, *Schoenoplectus* spp., *Typha domingensis*, *Phragmites australis* and samphire communities (Maunsell Australia Pty Ltd. 2009). However, further discussions concluded that the entire understorey vegetation would be monitored with a separate technique used for *M. halmaturorum*. Hence, the monitoring program consists of two complementary components: the first component involves the monitoring of aquatic and littoral understorey vegetation in spring (high lake levels) and autumn (low lake levels) to determine the current condition and seasonal changes in floristic composition and the second component monitors the mid to long-term population dynamics of the dominant tree species *Melaleuca halmaturorum*. The *Melaleuca halmaturorum* component of the monitoring program is undertaken every three to five years and stand condition was not monitored in 2009-10. Information regarding *Melaleuca halmaturorum* stand condition is presented in Marsland and Nicol (2009).

Aquatic and littoral plants play important roles in the ecosystem dynamics of the Lower Lakes. Plants are major primary producers (e.g. Noges *et al.* 2010), provide habitat for fish (e.g. Wedderburn *et al.* 2007), birds (e.g. Mondon *et al.* 2009) and invertebrates (e.g. Cronin *et al.*

2006), stabilise sediments (e.g. Abernethy and Rutherfurd 1998) and improve water quality (Rodriguez-Gallego *et al.* 2010). Historically (post barrage construction (1940) to2007) the Lower Lakes fringing wetlands were permanently inundated and contained diverse submergent, emergent and amphibious plant communities (Renfrey *et al.* 1989; Holt *et al.* 2005; Nicol *et al.* 2006). Lakeshore habitats were dominated by large stands of emergent macrophytes that had recruited along the shoreline with submergent and amphibious species restricted to sheltered areas with low wave intensity (e.g. Milang, Goolwa Channel, the lower Finniss River and lower Currency Creek) (J. Nicol pers. obs.).

Water levels in Lakes Alexandrina and Albert have fallen to unprecedented lows (<-0.75 m AHD) since 2007, disconnecting fringing wetlands and exposing extensive areas of acid sulfate soils (Merry *et al.* 2003; Fitzpatrick *et al.* 2009a; Fitzpatrick *et al.* 2009b). The threat of acid sulfate soil development due to low water levels prompted two large-scale engineering interventions: the construction of a bund at Narrung (completed in May 2008) and a regulator at Clayton (completed in August 2009). The bund at Narrung was constructed to prevent water levels in Lake Albert falling below -0.5 m AHD (water was pumped from Lake Alexandrina to maintain Lake Albert water levels). The regulator at Clayton was constructed to impound flows from the Finniss River and Currency Creek between the regulator and Goolwa Barrage; in addition water was pumped from Lake Alexandrina to raise water levels to +0.7 m AHD in Goolwa Channel. Construction of the Narrung and Clayton regulators has hydrologically disconnected Lake Albert and Goolwa Channel (and the lower Currency Creek and Finniss River) from Lake Alexandrina allowing these water bodies to be operated independently. Therefore, differences in water levels now exist between Lake Alexandrina, Lake Albert and Goolwa Channel in a system where these waterbodies were historically connected. This may have particular consequences for plant communities (e.g. Rea and Ganf 1994; Brock and Casanova 1997; Nicol *et al.* 2003). An additional hydrological intervention was undertaken at Narrung Wetland, 250 ML of environmental water from Lake Alexandrina was pumped into the wetland in October 2009 to provide suitable conditions for the growth of submergent taxa (particularly *Ruppia tuberosa*).

Results from 2008-09 showed that disconnection and subsequent desiccation of fringing wetlands changed the plant community from a diverse amphibious, emergent and submergent community (Renfrey *et al.* 1989; Holt *et al.* 2005; Nicol *et al.* 2006) to one dominated by terrestrial taxa or bare soil (Marsland and Nicol 2009). Terrestrial species also dominated lakeshore habitats in Lake Alexandrina and Goolwa Channel; however, large stands beds of emergent species were still present along the historical shoreline and the lowest elevation surveyed (-0.5 m AHD) was generally bare (Marsland and Nicol 2009). Despite the stable water levels, results were similar for Lake Albert with no recruitment of shoreline vegetation at -0.5 m AHD (Marsland and Nicol 2009).

The monitoring undertaken in 2009-10 builds on data collected in 2008-09 and provides information regarding the change in plant communities since spring 2008. The study period includes a period of record low water levels in Lake Alexandrina but also includes an engineering intervention that has resulted in elevated water levels in Goolwa Channel. Therefore, this monitoring program will simultaneously collect information regarding the change in wetland plant communities in response to drawdown, desiccation and increasing water levels. Consequently it will provide an insight into recovery of the system when water levels are restored to historical levels. The aims of this project were to:

- continue the statistically robust, quantitative understorey aquatic and littoral vegetation monitoring program in the Lower Lakes to assess TLM target V3
- expand monitoring program (in conjunction with a complementary project funded by DENR) to investigate the impact of increased water levels in Goolwa Channel, the lower Finniss River and lower Currency Creek

2 Methods

Monitoring of understorey vegetation was conducted at 11 wetland and 25 lakeshore sites in October 2008, March 2009, October 2009 and March 2010 (for sites established in 2008 or earlier) and October 2009 and March 2010 for sites established in 2009 (Table 1, Figure 1). Sites were grouped on the basis of habitat (lakeshore or wetland) and location (Lake Alexandrina, Lake Albert or Goolwa Channel). GPS coordinates for each site are listed in Appendix 1.

Table 1: List of understorey vegetation site numbers (relative to map provided in Figure 1), site name, location, habitat type (wetland or lakeshore) and the year sites were established.

Site #	Site Name	Location	Habitat	Year Established
1	Bremer Mouth Lakeshore	Lake Alexandrina	lakeshore	2008
2	Brown Beach 1	Lake Albert	lakeshore	2008
3	Brown Beach 2	Lake Albert	lakeshore	2008
4	Clayton Bay	Goolwa Channel	lakeshore	2009
5	Currency Creek 3	Goolwa Channel	lakeshore	2008
6	Currency Creek 4	Goolwa Channel	lakeshore	2008
7	Goolwa North	Goolwa Channel	lakeshore	2009
8	Goolwa South	Goolwa Channel	lakeshore	2009
9	Hindmarsh Island Bridge 01	Goolwa Channel	lakeshore	2009
10	Hindmarsh Island Bridge 02	Goolwa Channel	lakeshore	2009
11	Lake Reserve Rd	Lake Alexandrina	lakeshore	2008
12	Loveday Bay	Lake Alexandrina	lakeshore	2009
13	Loveday Bay Lakeshore	Lake Alexandrina	lakeshore	2009
14	Lower Finniss 02	Goolwa Channel	lakeshore	2009
15	Milang	Lake Alexandrina	wetland	pre-2008
16	Milang Lakeshore	Lake Alexandrina	lakeshore	2009
17	Pt Sturt Lakeshore	Lake Alexandrina	lakeshore	2008
18	Pt Sturt Water Reserve	Lake Alexandrina	lakeshore	2008
19	Teringie Lakeshore	Lake Alexandrina	lakeshore	2008
20	Upstream of Clayton Regulator	Lake Alexandrina	lakeshore	2009
21	Wally's Landing	Goolwa Channel	lakeshore	2009
22	Warrengie 1	Lake Albert	lakeshore	2009
23	Lower Finniss 03	Goolwa Channel	lakeshore	2009
24	Narrung Lakeshore	Lake Alexandrina	lakeshore	2008
25	Nurra Nurra	Lake Albert	lakeshore	2008
26	Warrengie 2	Lake Albert	lakeshore	2009
27	Angas Mouth	Lake Alexandrina	wetland	2008
28	Bremer Mouth	Lake Alexandrina	wetland	2008
29	Dunns Lagoon	Lake Alexandrina	wetland	2008
30	Goolwa Channel Drive	Lake Alexandrina	wetland	2008
31	Hunters Creek	Lake Alexandrina	wetland	2008
32	Poltalloch	Lake Alexandrina	wetland	2008
33	Pt Sturt	Lake Alexandrina	wetland	2008
34	Teringie	Lake Alexandrina	wetland	pre-2008
35	Waltowa	Lake Albert	wetland	pre-2008
36	Narrung	Lake Alexandrina	wetland	pre-2008

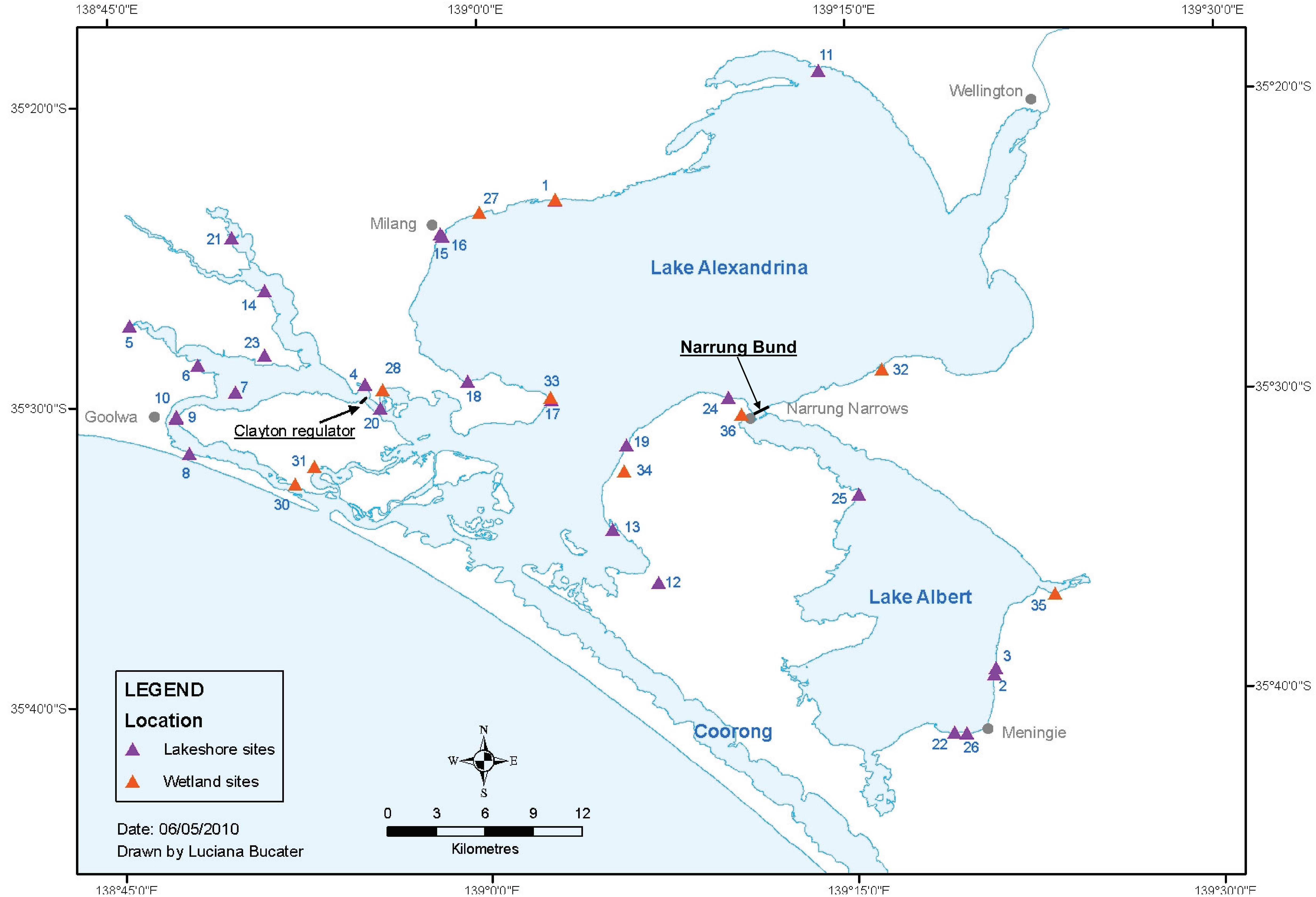

Figure 1: Map of Lakes Alexandrina and Albert and Goolwa Channel showing the location of lakeshore and wetland monitoring sites.

2.1 Vegetation surveying protocol

2.1.1 Wetlands

At each site a transect running perpendicular to the shoreline was established and three 1 x 3 m quadrats separated by 1 m were positioned at regular elevation intervals (A. Frears pers. comm.). In wetlands with an existing monitoring program (Milang, Waltowa, Teringie and Narrung) existing sites were re-surveyed. For the remaining wetlands (Dunns Lagoon, Pt Sturt, Hunters Creek, Goolwa Channel Drive, Bremer River Mouth, Angas River Mouth and Loveday Bay) a transect was established and quadrats placed in each vegetation community present during the spring 2008 survey. A minimum of one additional transect (but usually three or more transects were set up in each wetland) was established and quadrats were placed at the same elevations as on the first transect.

Cover and abundance of each species present in the quadrat were estimated using the method outlined in Heard and Channon (1997) except that N (not many, 1-10 individuals) and T (sparsely or very sparsely present) were replaced by 0.1 and 0.5 to enable statistical analyses (Table 2).

Table 2: Modified Braun-Blanquet (1932) scale estimating cover/abundance as per Heard and Channon (1997).

Score	Modified Score	Description
N	0.1	Not many, 1-10 individuals
T	0.5	Sparsely or very sparsely present; cover very small (less than 5%)
1	1	Plentiful but of small cover (less than 5%)
2	2	Any number of individuals covering 5-25% of the area
3	3	Any number of individuals covering 25-50% of the area
4	4	Any number of individuals covering 50-75% of the area
5	5	Covering more than 75% of the area

2.1.2 Lakeshores

The vegetation surveying protocol used to survey wetlands (see section 2.1.1, Table 2), was also used for lakeshores. However, quadrats were positioned at +0.8, +0.6, +0.4, +0.2, 0 and -0.5 m AHD on transects running perpendicular to the shore.

2.2 Plant identification and nomenclature

Plants were identified using keys in Cunningham *et al.* (1981), Jessop and Toelken (1986), Dashorst and Jessop (1998), Romanowski (1998), Sainty and Jacobs (1981; 2003), Prescott

(1998) and Jessop *et al.* (2006). In some cases due to immature individuals or lack of floral structures plants were identified to genus only. Nomenclature used follows Barker *et al.* (2005).

2.3 Functional Groups

Due to the large number of taxa present, species were classified into functional groups (based on water regime preferences) outlined in Table 3. Functional classification was based on the classification framework devised by Brock and Casanova (1997), which was based on species from wetlands in the New England Tablelands region of New South Wales and modified by Gehrig and Nicol (2010) to suit the Lower Lakes. The position each group occupies in relation to flooding depth and duration is outlined in Figure 2.

The use of a functional group approach to assess change through time and potential impacts of management strategies has several advantages compared to a species or community based approach:

- species with similar water regimes preferences are grouped together, which simplifies systems with high species richness (especially where there are large numbers of species with similar water regime preferences),
- predictions about the response of the plant community are made based on processes; therefore, does not require prior biological knowledge of the system,
- is transferrable between systems,
- robust and testable models that predict the response of a system to an intervention or natural event can be constructed, which can in turn be used as hypotheses for monitoring programs.

However there are limitations of the approach, which include:

- loss of information on species or communities (especially if there are species or communities of conservation significance or there is a pest plant problem),
- uncertainty regarding which species should be classified into which functional group,
- important factors (e.g. salinity) are often not taken into consideration (additional factors can be included. However, this can often complicate the functional classification and in systems where there is low species richness the number of groups may be greater than the number of species).

In this report, changes through time between locations and elevations and TLM targets will be assessed using species and functional approaches.

Table 3: Functional classification of plant species based on water regime preferences, modified from Brock and Casanova (1997).

Functional Group	Water Regime Preference	Examples
Terrestrial dry	Will not tolerate inundation and tolerates low soil moisture for extended periods.	*Rhagodia spinescens, Enchylaena tomentosa*
Terrestrial damp	Will tolerate inundation for short periods (<2 weeks) but require high soil moisture throughout their life cycle.	*Centaurea calcitrapa, Chenopodium album, Fumaria bastardii*
Floodplain	Temporary inundation, plants germinate on newly exposed soil after flooding but not in response to rainfall.	*Lachnagrostis filiformis*
Amphibious fluctuation tolerator-emergent	Fluctuating water levels, plants do not respond morphologically to flooding and drying and will tolerate short-term complete submergence (<2 weeks).	*Cyperus gymnocaulos, Juncus kraussii, Schoenoplectus pungens*
Amphibious fluctuation tolerator-woody	Fluctuating water levels, plants do not respond morphologically to flooding and drying and are large perennial woody species.	*Melaleuca halmaturorum, Muehlenbeckia florulenta*
Amphibious fluctuation tolerator-low growing	Fluctuating water levels, plants do not respond morphologically to flooding and drying and are generally small herbaceous species.	*Limosella australis, Crassula helmsii, Brachycome basaltica*
Amphibious fluctuation responder-plastic	Fluctuating water levels, plants respond morphologically to flooding and drying (e.g. increasing above to below ground biomass ratios when flooded).	*Persicaria lapathifolium*
Floating	Static or fluctuating water levels, responds to fluctuating water levels by having some or all organs floating on the water surface. Most species require permanent water to survive.	*Azolla* spp., *Lemna* spp.,
Submergent r-selected	Temporary wetlands that hold water for longer than 4 months.	*Ruppia tuberosa, Ruppia polycarpa, Lamprothamnium papulosum*
Emergent	Static shallow water <1 m or permanently saturated soil.	*Typha* spp., *Phragmites australis, Schoenoplectus validus*
Submergent k-selected	Permanent water.	*Myriophyllum* spp. *Vallisneria australis, Ruppia megacarpa Potamogeton pectinatus*

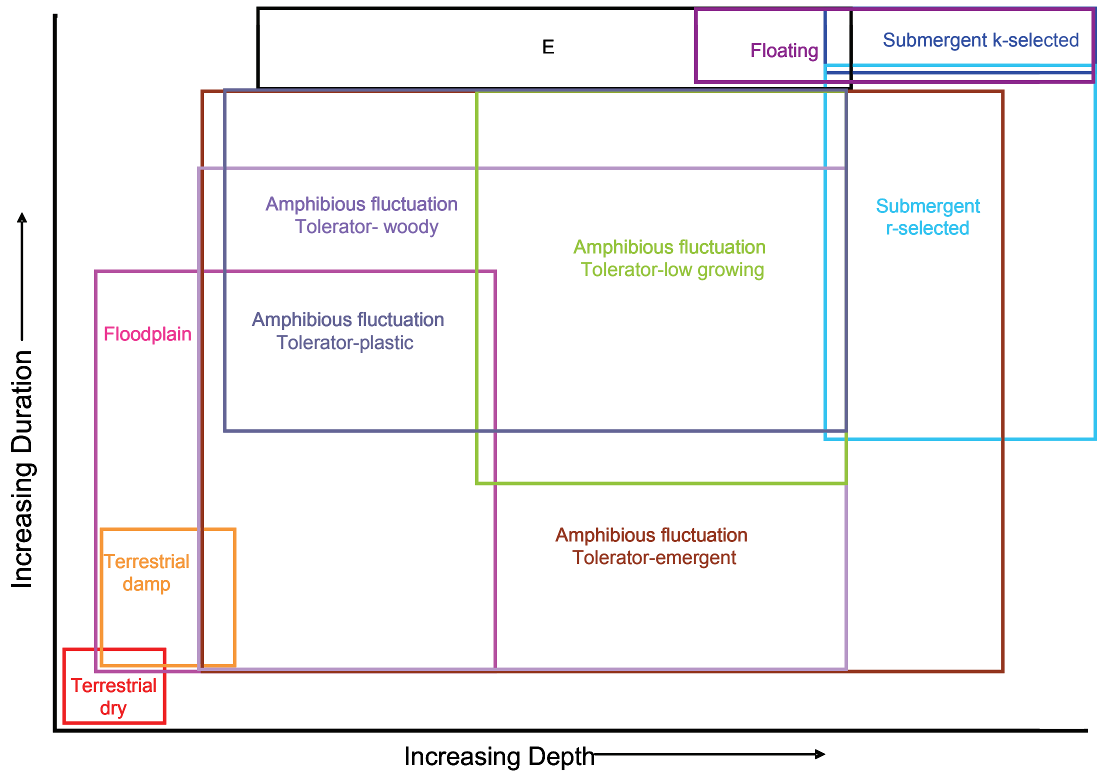

Figure 2: Plant functional groups in relation to depth and duration of flooding.

The "terrestrial dry" functional group is intolerant of flooding and taxa will persist in environments with low soil moisture (Table 3) (Brock and Casanova 1997). Taxa from this functional group often invade wetlands that have been drawn down for an extended period or floodplains where there has been a lack of flooding but are generally restricted to highlands that never flood (Brock and Casanova 1997).

Taxa in the "terrestrial damp" group will tolerate inundation for short periods and require high soil moisture to complete their life cycle (Table 3) (Brock and Casanova 1997). Taxa from this functional group are often winter annuals, perennial species that grow around the edges of permanent water bodies where there is high soil moisture or species that colonise wetlands shortly after they are drawn down and riparian zones and floodplains shortly after flood waters recede (Brock and Casanova 1997).

Taxa in the "floodplain" functional group exhibit most of the traits of terrestrial species; they are generally intolerant of long-term inundation but are restricted to areas that flood periodically (they are absent from the highlands) because they only germinate after flood waters recede or wetlands are drawn down, not in response to rainfall (Table 3) (Nicol 2004). Taxa from this functional group colonise floodplains and riparian zones after flood waters have receded and when wetlands are drawn down (Nicol 2004). Floodplain species often have flexible life history strategies, they grow whilst soil moisture is high and flower and set seed (after which most species die) in response to low soil moisture (Nicol 2004).

The "amphibious fluctuation tolerator-emergent" group consists mainly of emergent sedges and rushes that prefer high soil moisture or shallow water but require their photosynthetic parts to be emergent, although many will often tolerate short-term submergence (Table 3) (Brock and Casanova 1997). Taxa from this group are often found on the edges of permanent water bodies, in seasonal and temporary wetlands, in riparian zones and areas that frequently wet and dry.

Species in the "amphibious fluctuation tolerator-woody" group have similar water regime preferences to the amphibious fluctuation tolerator-emergent group (Figure 2) and consist of woody perennial species (Table 3) (Brock and Casanova 1997). These plants generally require high soil moisture in the root zone but there are several species that are tolerant of desiccation for extended periods (Roberts and Marston 2000). Species in this functional group are generally found on the edges of permanent water bodies, in seasonal and temporary wetlands, in riparian zones and areas that frequently wet and dry.

The "amphibious fluctuation tolerator-low growing" group have similar water regime preferences to the amphibious fluctuation tolerator-emergent and amphibious fluctuation tolerator-woody group (Figure 2); however, some species can grow totally submerged except during flowering (when there is a requirement for a dry phase) (Table 3) (Brock and Casanova 1997). Species in the this functional group are generally found on the edges of permanent water bodies, in seasonal and temporary wetlands, in riparian zones and areas that frequently wet and dry but species are usually less desiccation tolerant than species in the other amphibious tolerator groups (Figure 2).

The "amphibious fluctuation responder-plastic" group occupies a similar zone to the amphibious fluctuation tolerator-low growing group; except that they have a physical response to water level changes such as rapid shoot elongation or a change in leaf type (Brock and Casanova 1997). They can persist on damp and drying ground because of their morphological flexibility but can flower even if the site does not dry out. They occupy a slightly deeper/wet for longer area than the amphibious fluctuation tolerator-low growing group (Figure 2).

Species in the "floating" functional group float on the top of the water (often unattached to the sediment) with the majority of species requiring the presence of free water of some depth year round; although, some species can survive and complete their life cycle stranded on mud (Table 3) (Brock and Casanova 1997). Taxa in this group are usually found in permanent waterbodies, often forming large floating mats upstream of barriers (e.g. weirs), in lentic water bodies and slackwaters.

"Submergent r-selected" species colonise recently flooded areas (Table 3) and show many of the attributes of Grime's (1979) r-selected (ruderal) species, which are adapted to periodic disturbances. Many require drying to stimulate germination; they frequently complete their life cycle quickly and die off naturally. They persist via a dormant, long-lived bank of seeds, spores or asexual propagules (e.g. *Ruppia tuberosa* and *Ruppia polycarpa* turions in the sediment) (Brock 1982). They prefer habitats that are annually flooded to a depth of more than 10cm but can persist as dormant propagules for a number of years (temporary or ephemeral wetlands).

The "emergent" group consists of taxa that require permanent shallow water or a permanently saturated root zone, but require emergent leaves or stems (Table 3). They are often found on the edges of permanent waterbodies and in permanent water up to 2 m deep (depending on species) or in areas where there are shallow water tables (Roberts and Marston 2000).

"Submergent k-selected" species require permanent water greater than 10 cm deep for more than a year to either germinate or reach sufficient biomass to start reproducing (Table 3) (Roberts and Marston 2000). Species in this group show many of the attributes of Grime's (1979) k-selected (competitor) species that are adapted to stable environments and are only found in permanent water bodies. The depth of colonisation of submergent k-selected species is dependant on photosynthetic efficiency and water clarity (*sensu* Spence 1982).

2.4 Data Analysis

2.4.1 Wetlands

The changes in floristic composition through time and between elevations were analysed for each wetland (except Angas and Bremer Mouths, which were pooled) using two-factor PERMANOVA (Anderson 2001; Anderson and Ter Braak 2003), NMS ordination, Group Average Clustering (McCune *et al.* 2002) and Indicator Species Analysis (Dufrene and Legendre 1997) using the packages PCOrd version 5.12 (McCune and Mefford 2006) and PRIMER version 6.1.12 (Clarke and Gorley 2006). For Hunter's Creek, the middle of the wetland was devoid of vegetation, so changes through time were only compared at the edge elevation using single-factor PERMANOVA, (Anderson 2001; Anderson and Ter Braak 2003) and Indicator Species Analysis (Dufrene and Legendre 1997).

2.4.2 Lakeshores

Lakeshore sites were analysed separately to the wetlands. The changes in floristic composition through time and between elevations for each location (Goolwa Channel, Lake Alexandrina and Lake Albert at sites where two year's of data were available) were analysed using two-factor PERMANOVA (Anderson 2001; Anderson and Ter Braak 2003) and Indicator Species Analysis

(Dufrene and Legendre 1997) using the packages PCOrd version 5.12 (McCune and Mefford 2006) and PRIMER version 6.1.12 (Clarke and Gorley 2006).

Changes in the plant community from spring 2009 and autumn 2010 for each elevation (+0.8, +0.6, +0.4, +0.2, 0 and -0.5 m) were compared between locations (Goolwa Channel, Lake Alexandrina and Lake Albert) using two-factor PERMANOVA (Anderson 2001; Anderson and Ter Braak 2003) and Indicator Species Analysis (Dufrene and Legendre 1997) using the packages PCOrd version 5.12 (McCune and Mefford 2006) and PRIMER version 6.1.12 (Clarke and Gorley 2006). Bray-Curtis (1957) similarities were used to calculate the similarity matrices for all multivariate analyses and $\alpha=0.05$ for statistical analyses.

3 Results

A total of 127 taxa (including 67 exotics) were recorded for all sites between spring 2008 and autumn 2010 (Appendix 2). Functional groups, life history strategies and state and regional conservation significance for the recorded taxa are also listed in Appendix 2.

3.1 Wetlands

3.1.1 Hunter's Creek

A total of 11 taxa (including three exotics) were recorded in Hunter's Creek (Appendix 3). Despite Hunter's Creek having the lowest number of species, it also had the lowest percentage of exotics for all wetlands (Appendix 3). The middle of the creek was devoid of vegetation (except for the section between the fishway and bank, which was inundated with seawater and contained *Ruppia tuberosa*), but for the fringing plant community there were significant changes through time (Table 4). In particular there were significantly higher abundances of taxa from the terrestrial damp functional group in spring 2008, autumn 2009 and spring 2009 (Appendix 2; Appendix 4; Table 5).

3.1.2 Angas and Bremer River Mouths

A total of 28 taxa (including 15 exotics) were recorded at the mouths of the Angas and Bremer Rivers (Appendix 3). PERMANOVA (comparing the change in plant community through time and between elevations) detected significant differences in species assemblages were detected through time and between elevations and there was a significant interaction, which indicates that the changes through time were not consistent between elevations (Table 4). In the middle of the channel, the differences were predominantly due to significantly higher abundances of taxa from terrestrial damp and amphibious fluctuation responder-plastic functional groups in autumn (2009 and 2010). At the edges of the channels, differences were largely driven by significantly higher abundances of emergent and terrestrial damp taxa in spring 2008 (Appendix 2; Appendix 4; Table 6).

3.1.3 Dunn's Lagoon

A total of 57 taxa (including 30 exotics) were recorded in Dunn's Lagoon, which made this site the most species rich (total number and number of native species) wetland surveyed (Appendix 3). PERMANOVA (comparing the change in plant community through time and between elevations) detected significant differences in the floristic composition were between elevations and through time and there was a significant interaction (Table 4). General trends were taxa from the terrestrial damp functional group tended to be in significantly higher abundances during autumn surveys, especially at the lower elevations (Appendix 2; Appendix 4; Table 7). In spring 2009, the significant indicator taxa were found from a wide range of functional groups (terrestrial dry, terrestrial damp, floodplain and amphibious fluctuation responder-plastic group) (Appendix 2; Appendix 4; Table 7). At the lowest elevation (1), differences are reflected in a greater abundance of *Chenopodium glaucum* in autumn 2009, and higher abundances of *Cotula coronopifolia* and *Senecio pterophorus* in spring 2009. At elevation 2, there were greater relative abundances of taxa from terrestrial damp functional groups in autumn 2009, and in spring 2009 grasses: *Lachnagrostis filiformis* and *Eragrostis* sp. and winter annuals: *Senecio pterophorus* and *Sonchus oleraceus* and the amphibious *Cotula coronopifolia* were present in spring 2009. In autumn 2010 taxa from the terrestrial damp functional group were in significantly higher abundances (Appendix 4; Table 7). Differences at elevation 3 reflected greater abundances of *Persicaria lapathifolia* in spring 2008 compared to greater abundances of winter annuals from terrestrial dry, terrestrial damp and amphibious functional groups in spring 2009. The plant community at elevation 4 remained relatively unchanged across time, although there were significantly higher abundances of taxa from the terrestrial damp functional group in autumn 2009. At the highest elevation (5), there were greater abundances of *Distichlis distichophylla* and *Samolus repens* in spring 2008, and winter annuals such as, *Eragrostis curvula*, *Eragrostis* sp. *Plantago coronopu*s, *Reichardia tingitana* and *Sonchus oleraceus* in spring 2009.

3.1.4 Waltowa

A total of 23 taxa (including 14 exotics) were recorded in Waltowa (Appendix 3). Significant differences in floristic composition through time and between elevations were detected, and there was a significant interaction (Table 4). General trends across all elevations were that in spring 2008 significant indicator taxa were from amphibious fluctuation tolerator-emergent or floodplain functional groups, whereas in spring 2009 the significant indicator taxa were from emergent, terrestrial dry and terrestrial damp functional groups (Appendix 2; Appendix 4; Table 8). At the lowest elevation (1), there were relatively few changes through time; although there was a significantly high abundance of *Halosarcia pergranulata* in spring 2008. Similarly, for elevation 2, there were high abundances *Halosarcia pergranulata* in spring 2008; however by spring 2009 *Glyceria australis, Poa annua* and *Sonchus oleraceus* were significant indicators. At elevation 3, *Halosarcia pergranulata* and *Senecio runcinifolius* had higher abundances in spring 2008, but in spring 2009 Glyceria australis and Sonchus oleraceus significantly more abundant, and by autumn 2010, *Sarcocornia quinqueloflora* was the most abundant species. At the highest elevation (4), *Halosarcia pergranulata* and *Senecio runcinifolius* were in high abundance in spring 2008, whereas *Lolium* spp. had a significantly greater abundance by spring 2009 (Table 8).

3.1.5 Narrung

A total of 18 taxa (including nine exotics) were recorded in Narrung Wetland (Appendix 3). There were significant differences in the plant community between elevations; however, there was no significant change through time or a significant interaction, despite the wetland being watered in spring 2009 (Table 4). At the lowest elevation (1) there were no significant indicators because this particular elevation was devoid of plants; however, there was evidence of *Ruppia* spp. (or *Lepilaena* spp.) and charophytes in March 2010 that had recruited whilst the wetland was inundated but no living plants present at the time of the survey (Appendix 4). For the remaining elevations, *Paspalum distichum* was in greater abundance at elevation 2, the salt tolerant taxa *Distichlis distichophylla*, *Frankenia pauciflora* and *Sarcocornia quinqueloflora* had significantly higher abundances at elevation 3, and at the highest elevation (4), *Spergularia marina* was significantly more abundant (Table 9).

3.1.6 Goolwa Channel Drive

A total of 22 taxa (including 10 exotics) were recorded at Goolwa Channel Drive Wetland (Appendix 3). Significant changes in floristic composition were detected through time and between elevations, and there was a significant interaction (Table 4). General trends showed that in spring 2008 most of the taxa present were from the floodplain, terrestrial dry and terrestrial damp functional groups, but by autumn 2010 most taxa were present from terrestrial damp, amphibious fluctuation tolerator-emergent and emergent functional groups (Appendix 2; Appendix 4; Table 10). At the highest elevation (3) the differences were due to significantly higher abundances of *Suaeda australis* in autumn 2009 whereas, *Phragmites australis*, *Samolus repens* and *Sarcocornia quinqueloflora* had greater abundances in autumn 2010 (Table 10). At elevation 2, *Lachnagrostis filiformi*s, *Distichlis distichophylla*, *Plantago coronopus* and *Sonchus oleraceus* were abundant in spring 2008 and *Sarcocornia quinqueloflora* and *Schoenoplectus pungens* had significantly higher abundances in autumn 2009. There were no significant indicators for spring 2009 at elevation 2, but by autumn 2010 *Paspalum distichum* and *Plantago coronopus* dominated. At the lowest elevation (1) there were significantly higher abundances of *Sonchus oleraceus* in spring 2008. In autumn 2009 there were greater abundances of the grass *Paspalum distichum,* the emergent *Bolboschoenus caldwellii* and amphibious *Schoenoplectus pungens*. In spring 2009 *Suaeda australis*, *Typha domingensis* were the most abundant species, and by autumn 2010 the most dominant species was *Atriplex prostrata* (Table 10).

3.1.7 Loveday Bay

A total of 30 taxa (including 16 exotics) were recorded in Loveday Bay (Appendix 3). The floristic composition changed significantly through time and between elevations and there was a significant interaction (Table 4). At the lowest elevation, submergent r-selected taxa such as *Lamprothamnium macropogon* and *Ruppia tuberosa* had significantly higher abundances in spring 2008. There were no significant indicators for the intervening surveys, but by autumn 2010 taxa such as *Aster subulatus*; *Atriplex prostrata* and *Bolboschoenus caldwellii* from terrestrial damp, emergent and amphibious fluctuation tolerator-emergent functional groups, were significantly more abundant (Appendix 2; Appendix 4; Table 11). At elevation 2, *Distichlis distichophylla* had a significantly higher abundance in spring 2008, but from then on the plant community did not change significantly. At elevation (3), *Lachnagrostis filiformis, Bolboschoenus caldwellii* and *Distichlis distichophylla* were significantly more abundant in spring 2008, but *Schoenoplectus pungens* and *Sonchus oleraceus* were more abundant in spring 2009. At elevation 4, *Paspalum distichum* and *Sarcocornia quinqueloflora* were significantly more abundant in autumn 2009, but in spring 2009, *Sonchus oleraceus* dominated, and by autumn 2010 *Suaeda australis* was more abundant. At the highest elevation (elevation 5), *Lachnagrostis filiformis* was significantly more abundant in spring 2008, but in autumn 2009, *Sarcocornia quinqueloflora* dominated. In spring 2009, *Eragrostis curvula, Hordeum vulgare* and *Lolium* spp. were significantly more abundant and in autumn 2010 *Sonchus oleraceus* and *Paspalum distichum* had significantly higher abundances (Table 11).

3.1.8 Milang

A total of 53 taxa (including 33 exotics, the largest number in any of the wetlands surveyed) were recorded in Milang Wetland (Appendix 3). The floristic composition changed through time and between elevations, and there was a significant interaction (Table 4). Taxa within the Milang wetland were generally from terrestrial dry, terrestrial damp, amphibious fluctuation responder-plastic and amphibious fluctuation tolerator emergent functional groups (Appendix 2; Appendix 4; Table 12). At the highest elevation (1), exotic terrestrial taxa such as *Avena* spp., *Bromus diandrus* and *Medicago* spp. were dominant in spring 2008, and *Asparagus asparagoides* in spring 2009. At elevation (2), *Bromus diandrus* and *Cotula coronopifolia* were significantly more abundant in spring 2008, and in autumn 2009 the emergent species *Bolboschoenus caldwellii*, had a significantly higher abundance. By spring 2009, exotic terrestrials such as *Hordeum vulgare*, *Lolium* sp. and *Sonchus oleraceus* had a higher abundance and by autumn 2010 *Distichlis distichophylla*, *Plantago coronopus* and *Samolus repens* dominated. At elevation (3), *Lactuca saligna* and *Polypogon monspeliensis* were abundant in spring 2008, whereas *Bromus diandrus*, *Cotula coronopifolia*, *Lolium* sp. and *Sonchus oleraceus* were more abundant by spring 2009, In autumn 2010, *Cyperus gymnocaulos*, *Distichlis distichophylla*, *Enchylaena tomentosa*, *Lactuca serriola* and *Plantago coronopus* were present in greater abundances. At elevation (4), *Eragrostis* sp., *Lolium* sp. and *Polypogon monspeliensis* were more abundant in spring 2008, in autumn 2009 *Wilsonia rotundifolia* was the most abundant species and there were no significant indicators for spring 2009 and autumn 2010 (Appendix 4).

3.1.9 Poltalloch

At total of 18 taxa (including 11 exotics) were recorded in Poltalloch (Appendix 3). The floristic composition changed through time and between elevations, and there was a significant interaction (Table 4). Taxa were generally from terrestrial dry, terrestrial damp and amphibious fluctuation responder-plastic and amphibious fluctuation tolerator-emergent functional groups (Appendix 2; Appendix 4; Table 13). At elevation 1, *Chenopodium glaucum* was more abundant in spring 2008, in spring 2009 *Polypogon monspeliensis* and *Spergularia marina* were dominant and in autumn 2010, *Paspalum distichum* and *Suaeda australis* were significantly more abundant. At elevation 2, *Suaeda australis* had a significantly higher abundance in spring 2009 and *Paspalum distichum* in autumn 2010. At elevation 3, *Sarcocornia quinqueloflora* were present in higher abundance in 2008, but *Distichlis distichophylla* was dominant in autumn 2009 and *Hordeum vulgare* and *Sonchus oleraceus* in spring 2009.

3.1.10 Point Sturt

A total of 34 taxa (including 23 exotics, the largest proportion of exotic taxa from the wetlands surveyed) were recorded in Point Sturt Wetland (Appendix 3). The floristic composition changed through time and between elevations and there was a significant interaction (Table 4). Taxa from this wetland were from terrestrial dry, terrestrial damp, amphibious fluctuation responder-plastic and amphibious fluctuation tolerator-emergent functional groups (Appendix 2; Appendix 4; Table 14). At elevation (1) *Chenopodium glaucum* and *Distichlis distichophylla* were present in significantly greater abundances during spring 2008, but in spring 2009 *Cotula coronopifolia, Eragrostis curvula, Reichardia tingitana, Sonchus oleraceus* and *Spergularia marina* were more abundant. At elevation (2), *Chenopodium album* and *Cotula coronopifolia* were more abundant in spring 2008, but by autumn 2009, *Paspalum distichum* was more abundant and in spring 2009, *Cotula coronopifolia* and *Reichardia tingitana* were in significantly higher abundances. At elevation 3, *Distichlis distichophylla* had a significantly higher abundance in spring 2008, and in autumn 2009 *Paspalum distichum* was significantly more abundant. By spring 2009 *Reichardia tingitana* was more abundant and in autumn 2010, *Aster subulatus, Enchylaena tomentosa* and *Sarcocornia quinqueloflora* were more abundant (Table 14).

3.1.11 Teringie

At total of 30 taxa (including 18 exotics) were recorded in Teringie (Appendix 3). The floristic composition changed through time and between elevations, and there was a significant interaction (Table 4). Taxa from the terrestrial dry functional group were in significantly higher abundances in spring 2009, but in the following surveys taxa in high abundances were from a wider range of functional groups (terrestrial dry, terrestrial damp, amphibious fluctuation tolerator-emergent) (Appendix 2; Appendix 4; Table 15). At the highest elevation (elevation 1), *Distichlis distichophylla* and *Sarcocornia quinqueloflora* had significantly higher abundances in autumn 2009; otherwise there were minimal changes in floristic composition through time. For elevation 2, *Senecio* sp. was more abundant in spring 2008; otherwise there were no significant changes in floristic composition through time. For the lowest elevation (3), *Frankenia pauciflora* and *Senecio* sp. had significantly higher abundances in spring 2008, but by the following spring (2009), *Eragrostis curvula* and *Polypogon monspeliensis* were the most abundant. For elevation 4, *Hordeum vulgare* was the most abundant species in spring 2008, but by *Avena* spp., *Lolium* spp. and *Medicago* spp. were most abundant in spring 2009 and in autumn 2010, *Enchylaena tomentosa* was the most abundant species (Table 15).

Table 4: PERMANOVA *Pseudo F*-statistic results comparing time and elevation for each wetland.

Wetland	Factor	*df*	*F*	*P*
Hunter's Creek	Time	3, 48	8.78	<0.001
Angas and Bremer River Mouths	Elevation	1,48	9.88	<0.001
	Time	3, 48	1.92	0.018
	Elevation × Time	3, 48	2.24	0.003
Dunn's Lagoon	Elevation	4, 239	40.54	<0.001
	Time	3, 239	7.01	0.11
	Elevation × Time	12, 239	3.82	0.12
Waltowa	Elevation	3, 96	10.83	<0.001
	Time	3, 96	22.59	<0.001
	Elevation × Time	9, 96	2.89	<0.001
Narrung	Elevation	3, 144	30.57	<0.001
	Time	3, 144	1.1	0.34
	Elevation × Time	9, 144	0.89	0.591
Goolwa Channel Drive	Elevation	2, 108	37.71	<0.001
	Time	3, 108	5.85	<0.001
	Elevation × Time	6, 108	4.19	<0.001
Loveday Bay	Elevation	4, 180	5.68	<0.001
	Time	3, 180	8.09	<0.001
	Elevation × Time	12, 180	2.43	<0.001
Milang	Elevation	3, 144	9.14	<0.001
	Time	3, 144	4.09	<0.001
	Elevation × Time	9, 144	2.20	<0.001
Poltalloch	Elevation	2, 72	9.30	<0.001
	Time	3, 72	9.51	<0.001
	Elevation × Time	6, 72	2.83	<0.001
Point Sturt	Elevation	2, 72	7.89	<0.001
	Time	3, 72	15.98	<0.001
	Elevation × Time	6, 72	3.62	<0.001
Teringie	Elevation	3, 192	21.58	<0.001
	Time	3, 192	7.36	<0.001
	Elevation × Time	9, 192	7.40	<0.001

Table 5: List of significant indicator species (Dufrene and Legendre 1997) for Hunter's Creek between elevations from spring 2008 to autumn 2010.

Elevation	Time			
	Spring 2008	**Autumn 2009**	**Spring 2009**	**Autumn 2010**
Edge	*Sonchus oleraceus**	*Paspalum distichum**	*Distichlis distichophylla*	
Middle	bare	bare	bare	bare

Table 6: List of significant indicator species (Dufrene and Legendre 1997) for Angus and Bremer River Mouths between elevations from spring 2008 to autumn 2010.

Elevation	Time			
	Spring 2008	**Autumn 2009**	**Spring 2009**	**Autumn 2010**
Edge	*Berula erecta*, *Sonchus oleraceus**, *Typha domingensis*			
Middle		*Aster subulatus**, *Atriplex prostrata**		*Chenopodium album**, *Paspalum distichum**, *Persicaria lapathifolia*

Table 7: List of significant indicator species (Dufrene and Legendre 1997) for Dunn's Lagoon between elevations from spring 2008 to autumn 2010.

Elevation		Time			
		Spring 2008	**Autumn 2009**	**Spring 2009**	**Autumn 2010**
Lowest	1		*Chenopodium glaucum**	*Cotula coronopifolia**, *Senecio pterophorus**	
	2		*Aster subulatus**, *Chenopodium glaucum**	*Lachnagrostis filiformis*, *Eragrostis* sp., *Senecio pterophorus**, *Sonchus oleraceus**, *Cotula coronopifolia**	*Atriplex prostrata**, *Paspalum distichum**
	3	*Persicaria lapathifolia*		*Reichardia tingitana**, *Sonchus oleraceus**, *Cotula coronopifolia**	
	4		*Paspalum distichum**		
Highest	5	*Distichlis distichophylla*, *Samolus repens*		*Eragrostis curvula**, *Eragrostis* sp., *Plantago coronopus**, *Reichardia tingitana**, *Sonchus oleraceus**	

Table 8: List of significant indicator species (Dufrene and Legendre 1997) for Angus and Bremer River Mouths Wetlands between elevations from spring 2008 to autumn 2010.

Elevation		Time			
		Spring 2008	Autumn 2009	Spring 2009	Autumn 2010
Highest → Lowest	1	*Halosarcia pergranulata*			
	2	*Halosarcia pergranulata*		*Glyceria australis*, *Poa annua**, *Sonchus oleraceus**	
	3	*Halosarcia pergranulata*, *Senecio runcinifolius**		*Glyceria australis*, *Sonchus oleraceus**	*Sarcocornia quinqueloflora*
	4	*Halosarcia pergranulata*, *Senecio runcinifolius**		*Lolium* spp.*	

Table 9: List of significant indicator species (Dufrene and Legendre 1997) for Narrung Wetland between elevations.

Elevation		
Highest → Lowest	1	
	2	*Paspalum distichum**,
	3	*Distichlis distichophylla*, *Frankenia pauciflora*, *Sarcocornia quinqueloflora*
	4	*Spergularia marina*
	5	bare

Table 10: List of significant indicator species (Dufrene and Legendre 1997) for Goolwa Channel Drive Wetland between elevations from spring 2008 to autumn 2010.

Elevation		Time			
		Spring 2008	Autumn 2009	Spring 2009	Autumn 2010
Highest → Lowest	1	*Sonchus oleraceus**	*Paspalum distichum**, *Bolboschoenus caldwellii*, *Schoenoplectus pungens*	*Suaeda australis*, *Typha domingensis*	*Atriplex prostrata**
	2	*Lachnagrostis filiformis*, *Distichlis distichophylla*, *Plantago coronopus**, *Sonchus oleraceus**	*Sarcocornia quinqueloflora*, *Schoenoplectus pungens*		*Paspalum distichum**, *Plantago coronopus**
	3		*Suaeda australis*		*Phragmites australis*, *Samolus repens*, *Sarcocornia quinqueloflora*

Table 11: List of significant indicator species (Dufrene and Legendre 1997) for Loveday Bay Wetland between elevations from spring 2008 to autumn 2010.

Elevation		Time			
		Spring 2008	Autumn 2009	Spring 2009	Autumn 2010
Lowest	1	*Lamprothamnium macropogon*, *Ruppia tuberosa*			*Aster subulatus**, *Atriplex prostrata**, *Bolboschoenus caldwellii*
	2	*Distichlis distichophylla*			
	3	*Lachnagrostis filiformis*, *Bolboschoenus caldwellii*, *Distichlis distichophylla*		*Schoenoplectus pungens*, *Sonchus oleraceus**	
	4		*Paspalum distichum**, *Sarcocornia quinqueloflora*	*Sonchus oleraceus**	*Suaeda australis*
Highest	5	*Lachnagrostis filiformis*	*Sarcocornia quinqueloflora*	*Eragrostis curvula**, *Hordeum vulgare**, *Lolium* spp.*	*Sonchus oleraceus** , *Paspalum distichum**

Table 12: List of significant indicator species (Dufrene and Legendre 1997) for Milang Wetland between elevations from spring 2008 to autumn 2010.

Elevation		Time			
		Spring 2008	Autumn 2009	Spring 2009	Autumn 2010
Highest	1	*Avena* spp.*, *Bromus diandrus**, *Medicago* spp.*		*Asparagus asparagoides**	
	2	*Bromus diandrus** , *Cotula coronopifolia**	*Bolboschoenus caldwellii*	*Hordeum vulgare**, *Lolium* spp.*, *Sonchus oleraceus**	*Distichlis distichophylla*, *Plantago coronopus**, *Samolus repens*
	3	*Lactuca saligna**, *Polypogon monspeliensis**		*Bromus diandrus**, *Cotula coronopifolia**, *Lolium* spp.*, *Sonchus oleraceus**	*Cyperus gymnocaulos*, *Distichlis distichophylla*, *Enchylaena tomentosa*, *Lactuca serriola**, *Plantago coronopus**
Lowest	4	*Eragrostis* sp., *Lolium* spp.*, *Polypogon monspeliensis**	*Wilsonia rotundifolia*		

Table 13: List of significant indicator species (Dufrene and Legendre 1997) for Poltalloch Wetland between elevations from spring 2008 to autumn 2010.

Elevation		Time			
		Spring 2008	Autumn 2009	Spring 2009	Autumn 2010
Lowest	1	*Chenopodium glaucum**		*Polypogon monspeliensis**, *Spergularia marina**	*Paspalum distichum**, *Suaeda australis*
	2			*Suaeda australis*	*Paspalum distichum**
Highest	3	*Sarcocornia quinqueloflora*	*Distichlis distichophylla*	*Hordeum vulgare**, *Sonchus oleraceus**	

Table 14: List of significant indicator species (Dufrene and Legendre 1997) for Point Sturt Wetland between elevations from spring 2008 to autumn 2010 (*denotes exotic taxon)

Elevation		Time			
		Spring 2008	Autumn 2009	Spring 2009	Autumn 2010
Lowest	1	*Chenopodium glaucum** *Distichlis distichophylla*		*Cotula coronopifolia**, *Eragrostis curvula**, *Reichardia tingitana**, *Sonchus oleraceus**, *Spergularia marina**	
↑	2	*Chenopodium album** *Cotula coronopifolia**	*Paspalum distichum**	*Cotula coronopifolia**, *Reichardia tingitana**	
Highest	3	*Distichlis distichophylla*	*Paspalum distichum**	*Reichardia tingitana**	*Aster subulatus*, *Enchylaena tomentosa*, *Sarcocornia quinqueloflora*

Table 15: List of significant indicator species (Dufrene and Legendre 1997) for Teringie Wetland between elevations from spring 2008 to autumn 2010 (*denotes exotic taxon)

Elevation		Time			
		Spring 2008	Autumn 2009	Spring 2009	Autumn 2010
Lowest	1		*Distichlis distichophylla* *Sarcocornia quinqueloflora*		
↑	2	*Senecio* sp.			
	3	*Frankenia pauciflora*, *Senecio* sp.		*Eragrostis curvula** *Polypogon monspeliensis**	
Highest	4	*Hordeum vulgare**	*Avena* spp*, *Lolium* spp.* *Medicago* spp.*		*Enchylaena tomentosa*

3.2 Lakeshores

3.2.1 Changes between locations (Lake Alexandrina, Lake Albert and Goolwa Channel) from spring 2009 to autumn 2010 at each elevation

3.2.1.1 +0.8 m AHD

The floristic composition changed through time and between locations, and there was a significant interaction (Table 16). At the highest elevation (+0.8 m AHD) there were significantly higher abundances of species form the terrestrial dry and terrestrial damp functional groups in Lake Alexandrina in spring 2009, but no significant indicator species in autumn 2010 (Appendix 2; Appendix 4; Table 17). Similarly for Lake Albert, taxa from the terrestrial dry functional group were significantly abundant during spring 2009, but no significant indicator species for autumn 2010 (Appendix 2; Appendix 4; Table 17). In Goolwa Channel, taxa from a wider range of functional groups (amphibious fluctuation tolerant emergent, amphibious fluctuation tolerator woody and emergent) were significantly more abundant in spring 2009, whereas the emergent *Phragmites australis* dominated in autumn 2010 (Appendix 2; Appendix 4; Table 17).

3.2.1.2 +0.6 m AHD

There were significant differences in floristic composition between location and time, but there was no significant interaction (Table 16). In spring 2009, *Hypochoeris radicata* (terrestrial dry functional group) was significantly more abundant in Lake Alexandrina, but there were no significant indicators in autumn 2010 (Appendix 2; Appendix 4; Table 17). Similarly in Lake Albert, taxa from the terrestrial dry and terrestrial damp functional groups were significantly more abundant in spring 2009. In autumn 2010, taxa from the terrestrial dry, terrestrial damp, amphibious fluctuation tolerator woody functional groups were significantly more abundant (Appendix 2; Appendix 4; Table 17). In the Goolwa Channel, *Muehlenbeckia florulenta* (amphibious fluctuation tolerator woody) and *Phragmites australis* (emergent) were significant indicators in spring 2009, whereas *Bolboschoenus caldwellii* (emergent) were significantly abundant during autumn 2010 (Appendix 2; Appendix 4; Table 17).

3.2.1.3 +0.4 m AHD

There were significant differences in floristic composition between location and time and a significant interaction (Table 16). In Lake Alexandrina taxa from terrestrial dry, terrestrial damp and amphibious fluctuation responder-plastic functional groups were significantly more abundant in Spring 2009 while in autumn 2010 taxa from the same terrestrial dry, terrestrial damp and amphibious fluctuation tolerant emergent functional groups were significant indicators (Appendix 2; Appendix 4; Table 17). For Lake Albert, similar trends were observed with the significant indicators present from the terrestrial dry, terrestrial damp and amphibious fluctuation tolerator emergent functional groups in spring 2009 and autumn 2010. In Goolwa Channel, *Muehlenbeckia florulenta* was significantly more abundant in spring 2009 and in autumn 2010 *Juncus usitatus* (amphibious fluctuation tolerator-emergent) and *Typha domingensis* (emergent) were significant indicators (Appendix 2; Appendix 4; Table 17).

3.2.1.4 +0.2 m AHD

There were significant differences in floristic composition between location and time and there was also a significant interaction (Table 16). In Lake Alexandrina taxa from terrestrial dry, terrestrial damp and amphibious fluctuation tolerator emergent functional groups were significantly more abundant in spring 2009 and autumn 2010 (Appendix 2; Appendix 4; Table 17). The same trends were evident in Lake Albert (Appendix 2; Appendix 4; Table 17). In Goolwa Channel there were no significant indicators at this elevation in spring 2009, but in autumn 2010 *Atriplex prostrata* (terrestrial damp) and the emergent species *Schoenoplectus validus* and *Typha domingensis* were significantly more abundant (Table 17).

3.2.1.5 0 m AHD

There were significant differences in floristic composition between location and time and there was also a significant interaction (Table 16). In Lake Alexandrina taxa from a wide range of functional groups (terrestrial dry, terrestrial damp, floodplain and amphibious fluctuation tolerator emergent) were significantly more abundant in spring 2009, while in autumn 2010 the sedges *Juncus kraussii* and *Juncus usitatus* (amphibious fluctuation tolerator emergent) were significantly indicators (Appendix 2; Appendix 4; Table 17). Similarly there were significant indicators in Lake Albert, from a wide range of functional groups (terrestrial dry, terrestrial damp, amphibious fluctuation responder-plastic and amphibious fluctuation tolerator emergent) in spring 2009, only *Paspalum distichum* was significantly more abundant in autumn 2010 (Appendix 2; Appendix 4; Table 17). There were no significant indicator species for Goolwa Channel in spring 2009, although the emergent species *Schoenoplectus validus* was significantly more abundant in autumn 2010 (Table 17).

3.2.1.6 -0.5 m AHD

Significant differences in floristic composition were detected between location and time and there was also a significant interaction (Table 16). In Lake Alexandrina a large number of taxa from a wide range of functional groups (floodplain, terrestrial dry, terrestrial damp, amphibious floodplain responder plastic, amphibious fluctuation tolerator low-growing and amphibious fluctuation tolerator emergent) were significantly more abundant in spring 2009. In autumn 2010 there were fewer significant indicators, from fewer functional groups (terrestrial dry, terrestrial damp, amphibious fluctuation tolerator emergent) (Appendix 2; Appendix 4; Table 17). In Lake Albert the significant indicators in spring 2009 were from the terrestrial damp, amphibious fluctuation tolerator emergent and amphibious fluctuation tolerator woody (*Melaleuca halmaturorum*) groups. In autumn the terrestrial damp species, *Chenopodium album* was significantly more abundant (Appendix 2; Appendix 4; Table 17). In Goolwa Channel there were no significant indicators in spring 2009, but *Myriophyllum salsugineum* and *Potamogeton pectinatus* (submergent k-selected) were significantly more abundant in autumn 2010 (Table 17).

Table 16: PERMANOVA Pseudo-F-statistic results through time and location (Lake Alexandrina, Lake Albert and Goolwa channel region) per elevation.

Elevation	Factor	*df*	*F*	*P*
+0.8 m AHD	Location	2, 143	20.56	<0.001
	Time	1, 143	5.06	<0.001
	Location × Time	2, 143	1.92	0.041
+0.6 m AHD	Location	2, 143	14.77	<0.001
	Time	1, 143	2.72	0.022
	Location × Time	2, 143	1.38	0.178
+0.4 m AHD	Location	2, 143	9.48	<0.001
	Time	1, 143	3.62	0.005
	Location × Time	2, 143	2.65	0.004
+0.2 m AHD	Location	2, 143	10.45	<0.001
	Time	1, 143	3.71	0.003
	Location × Time	2, 143	2.32	0.009
0 m AHD	Location	2, 143	12.54	<0.001
	Time	1, 143	9.23	<0.001
	Location × Time	2, 143	3.89	<0.001
-0.5 m AHD	Location	2, 143	6.11	<0.001
	Time	1, 143	6.26	<0.001
	Location × Time	2, 143	4.77	<0.001

Table 17: Significant indicator species (Dufrene and Legendre 1997) for locations (Lake Alexandrina, Lake Albert and Goolwa Channel) from spring 2009 to autumn 2010, at each elevation (*denotes exotic taxon).

Location	Elevation											
	+0.8 m AHD		*+0.6 m AHD*		*+0.4 m AHD*		*+0.2 m AHD*		*0 m AHD*		*-0.5 m AHD*	
	Spring 2009	**Autumn 2010**	**Spring 2009**	**Autumn 2010**	**Spring 2009**	**Autumn 2010**	**Spring 2009**	**Autumn 2010**	**Spring 2009**	**Autumn 2010**	**Spring 2009**	**Autumn 2010**
Lake Alexandrina	*Hordeum vulgare**, *Lactuca serriola**, *Sonchus oleraceus**		*Hypochoeris radicata**		*Hordeum vulgare**, *Persicaria lapathifolia*, *Senecio pterophorus**, *Sonchus asper**,	*Isolepis nodosa*, *Paspalum distichum**, *Plantago coronopus**	*Conyza bonariensis**, *Cyperus gymnocaulos*, *Hordeum vulgare**	*Aster subulatus**, *Juncus kraussii*, *Plantago coronopus**	*Centaurea calcitrapa**, *Eragrostis curvula**, *Hordeum vulgare**, *Hypochoeris radicata**, *Lachnagrostis filiformis*, *Lactuca serriola**, *Polypogon monspeliensis**, *Senecio pterophorus**, *Trifolium* spp.*	*Juncus kraussii*, *Juncus usitatus*	*Lachnagrostis filiformis*, *Aster subulatus**, *Centaurium tenuiflorum**, *Cotula coronopifolia**, *Eragrostis curvula**, *Hordeum vulgare**, *Isolepis platycarpa*, *Lobelia alata*, *Lolium spp**, *Plantago coronopus** *Polypogon monspeliensis** *Sonchus oleraceus**	*Centaurea calcitrapa** *Chenopodium glaucum** *Paspalum distichum** *Senecio pterophorus** *Suaeda australis*
Lake Albert	*Avena* spp.*, *Bromus diandrus**, *Pennisetum clandestinum**, *Trifolium* spp.*, *Vicia sativa**		*Avena* spp.*, *Bromus diandrus**, *Lolium* spp.*, *Pennisetum clandestinum**, *Sonchus oleraceus**	*Paspalum distichum**, *Reichardia tingitana**, *Suaeda australis*	*Bromus diandrus**, *Lolium* spp.*, *Medicago* spp.*, *Pennisetum clandestinum**, *Polypogon monspeliensis**, *Sonchus oleraceus**, *Suaeda australis*,	*Reichardia tingitana**, *Sarcocornia quinqueloflora*, *Scabiosa atropurpurea**, *Spergularia marina*,	*Avena* spp.*, *Bromus diandrus**, *Lolium* spp.*, *Paspalum distichum**, *Pennisetum clandestinum**, *Polypogon monspeliensis**, *Sonchus oleraceus**	*Eragrostis australasica*, *Reichardia tingitana**, *Sarcocornia quinqueloflora*,	*Avena* spp.*, *Bromus diandrus**, *Cotula coronopifolia**, *Euphorbia terracina**, *Lolium* spp.*, *Medicago* spp.*, *Sarcocornia quinqueloflora*, *Sonchus oleraceus**,	*Paspalum distichum**,	*Cyperus gymnocaulos*, *Isolepis nodosa*, *Melaleuca halmaturorum*, *Puccinellia* spp.	*Chenopodium album**
Goolwa Channel	*Calystegia sepium*, *Muehlenbeckia florulenta*, *Typha domingensis*	*Phragmites australis*	*Muehlenbeckia florulenta*, *Phragmites australis*	*Bolboschoenus caldwellii*	*Muehlenbeckia florulenta*,	*Juncus usitatus*, *Typha domingensis*		*Atriplex prostrata**, *Schoenoplectus validus*, *Typha domingensis*		*Schoenoplectus validus*,		*Myriophyllum salsugineum*, *Potamogeton pectinatus*

3.2.2 Changes within locations (Lake Alexandrina, Lake Albert and Goolwa Channel) between elevations from spring 2008 to autumn 2010

3.2.2.1 Lake Alexandrina

Significant differences in the plant community in Lake Alexandrina were detected through time and between elevations and there was a significant interaction (Table 18). At the highest elevation (+0.8 m AHD) terrestrial dry annuals and *Salix babylonica* (emergent) were significantly more abundant in spring 2008 but there were no significant indicators in the following autumn and spring 2009. By autumn 2010 *Pennisetum clandestinum* was significantly more abundant (Appendix 2; Appendix 4; Table 19). At +0.6 m AHD *Melilotus indica* was significantly more abundant in spring 2008 and *Bromus diandrus* in spring 2009; however, there were no significant indicators in autumn 2009 and 2010 (Table 19). At +0.4 m AHD, there were significant indicators from a range of functional groups (floodplain, terrestrial damp, amphibious fluctuation responder-plastic and amphibious fluctuation tolerator emergent) in spring 2008, but no further significant indicators until autumn 2010 when Isolepis nodosa was significantly abundant (Appendix 2; Appendix 4; Table 19). At 0 m AHD exotic terrestrial dry taxa, exotic terrestrial damp taxa, *Isolepis* sp. (amphibious fluctuation tolerator–low growing) and *Schoenoplectus validus* (emergent) were significantly more abundant in spring 2008 (Appendix 4). In autumn 2009 *Polygonum aviculare* was significantly more abundant, and terrestrial damp taxa were significant indicators in spring 2009. In autumn 2010 Juncus usitatus and Paspalum distichum were significantly more abundant (Appendix 2; Appendix 4; Table 19). At the lowest elevation (-0.5 m AHD) the submergent r-selected *Ruppia tuberosa* was a significant indicator in spring 2008, but by autumn 2009 *Eragrostis* sp. was significantly more abundant (Appendix 4). In the following spring (2009), exotics from a wide range of functional groups (floodplain, terrestrial damp, terrestrial dry, amphibious fluctuation tolerator-low growing) were significantly more abundant. In autumn 2010 taxa from emergent, amphibious fluctuation tolerator-low growing, terrestrial damp and amphibious fluctuation tolerator emergent groups were significant indicators (Appendix 2; Appendix 4; Table 19).

3.2.2.2 Lake Albert

Significant differences in the plant community in Lake Albert were detected through time and between elevations, and there was a significant interaction (Table 18). At the highest elevation (+0.8 m AHD) *Distichlis distichophylla* was significantly more abundant in spring 2008, and terrestrial dry taxa were significant indicators in the following spring (2009). In autumn 2010 *Pennisetum clandestinum* was significantly more abundant (Appendix 2; Appendix 4; Table 19). At +0.6 m AHD *Melilotus indica* was significantly more abundant in spring 2008, and *Bromus diandrus* in spring 2009 (Appendix 2; Appendix 4; Table 19). There were minimal changes through time at

+0.4 m AHD, although *Polypogon monspeliensis* and *Schoenoplectus validus* were significantly more abundant in spring 2008 (Table 19). At 0 m AHD there were no significant indicators in spring 2008 and autumn 2009. By spring 2009, *Sonchus oleraceus* was significantly more abundant and by autumn 2010 *Aster subulatus* and *Paspalum distichum* were significant indicators (Table 19). At the lowest elevation (-0.5 m AHD) there were no significant indicators in spring 2008 or autumn 2009 but by spring 2009 *Cotula coronopifolia, Isolepis nodosa, Puccinellia* spp. and *Melaleuca halmaturorum* seedlings were significantly more abundant. In autumn 2010, *Chenopodium album* (terrestrial damp) was a significant indicator (Appendix 2; Appendix 4; Table 19).

3.2.2.3 Goolwa Channel

Significant differences in the floristic composition of Goolwa Channel were detected through time and between elevations, and there was also a significant interaction (Table 18). At the highest elevation (+0.8 m AHD) *Calystegia sepium* (amphibious fluctuation tolerator-emergent species) was significantly more abundant in spring 2008, and there were no significant indicators in autumn 2009 and spring 2009. By autumn 2010, however, *Paspalum distichum* was significantly more abundant. At +0.6 m AHD, there were no significant indicator species in the first year, but by spring 2009 *Cyperus gymnocaulos* and *Isolepis nodosa* (amphibious fluctuation tolerator emergent species) were significantly more abundant and the emergent species *Bolboschoenus caldwellii* was significantly more abundant in autumn 2010 (Appendix 2; Appendix 4; Table 19). In spring 2008 floodplain, terrestrial damp, amphibious fluctuation tolerator emergent taxa were significantly more abundant at +0.4 m AHD. In autumn 2009, *Chenopodium glaucum* was significantly more abundant and there were no significant indicators in spring 2009. In autumn 2010 *Juncus usitatus* (amphibious fluctuation tolerator-emergent) and *Typha domingensis* (emergent) were significantly more abundant (Appendix 2; Appendix 4; Table 19). At 0 m AHD *Cotula coronopifolia* had a significantly higher abundance in spring 2008, but there were no significant indicators in the subsequent surveys. At the lowest elevation (-0.5 m AHD) there were no significant indicators until autumn 2010, when the submergent k-selected species: *Myriophyllum salsugineum* was significantly more abundant (Appendix 4; Table 19).

Table 18: PERMANOVA Pseudo-F-statistic results comparing time (spring 2008, autumn 2009, spring 2009 and autumn 2010) and location (Lake Alexandrina, Lake Albert and Goolwa channel region) for each elevation.

Location	**Factor**	***df***	***F***	***P***
Lake Alexandrina	Elevation	4, 359	13.22	<0.001
	Time	3, 359	7.56	<0.001
	elevation × Time	12, 359	2.06	<0.001
Lake Albert	Location	4, 119	10.75	<0.001
	Time	3, 119	22.97	<0.001
	Location × Time	12, 119	4.15	<0.001
Goolwa Channel	Elevation	4, 119	21.81	<0.001
	Time	3, 119	4.4	<0.001
	elevation × Time	12, 119	3.5	<0.001

Table 19: Significant indicator species (Dufrene and Legendre 1997) within locations (Lake Alexandrina, Lake Albert and Goolwa Channel) and between elevations from spring 2008 to autumn 2010 (*denotes exotic taxon).

Elevation	Location											
	Lake Alexandrina				Lake Albert				Goolwa Channel			
	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010
+0.8 m AHD	*Brassica rapa**, *Senecio* sp., *Vicia sativa**, *Salix babylonica**			*Pennisetum clandestinum**	*Distichlis distichophylla*		*Avena* spp.*, *Lolium* spp.*, *Trifolium* spp.*, *Vicia sativa**	*Pennisetum clandestinum**	*Calystegia sepium,*			*Paspalum distichum**
+0.6 m AHD	*Melilotus indica**		*Bromus diandrus**		*Melilotus indica**		*Bromus diandrus**				*Cyperus gymnocaulos, Isolepis nodosa*	*Bolboschoenus caldwellii*
+0.4 m AHD	*Cotula coronopifolia**, *Cyperus gymnocaulos, Holcus lanatus**, *Psuedognaphalium luteo-album*			*Isolepis nodosa*	*Polypogon monspeliensis**, *Schoenoplectus validus*				*Lachnagrostis filiformis, Aster subulatus**, *Juncus kraussii.*, *Epilobium pallidiflorum, Sonchus oleraceus**	*Chenopodium glaucum**	*Juncus usitatus, Typha domingensis*	
0 m AHD	*Aster subulatus**, *Eragrostis curvula**, *Polypogon monspeliensis**, *Isolepis* sp., *Schoenoplectus validus,*	*Polygonum aviculare**	*Centaurea calcitrapa**, *Sonchus oleraceus**	*Juncus usitatus, Paspalum distichum**			*Sonchus oleraceus**	*Aster subulatus**, *Paspalum distichum**	*Cotula coronopifolia**			
-0.5 m AHD	*Ruppia tuberosa*	*Eragrostis* sp.	*Lachnagrostis filiformis, Centaurium tenuiflorum**, *Hordeum vulgare**, *Isolepis platycarpa, Lobelia alata, Lolium* spp.*, *Plantago coronopus**	*Bolboschoenus caldwellii, Triglochin striatum, Spergularia marina**, *Suaeda australis*			*Cotula coronopifolia**, *Isolepis nodosa, Puccinellia* spp., *Melaleuca halmaturorum*	*Chenopodium album**				*Myriophyllum salsugineum*

4 Discussion and management implications

4.1 Wetlands

The sustained decline in water levels downstream of Lock 1 between 2007 and 2010 has resulted in permanent wetlands that were historically connected to Lakes Alexandrina and Albert becoming disconnected and drying. Prior to 2007 the plant community in the Lower Lakes wetlands was a diverse assemblage of submergent, amphibious and emergent taxa (Holt *et al.* 2005; Nicol *et al.* 2006). By spring 2008, all submergent species except *Lamprothamnium macropogon* (Loveday Bay)*, Ruppia tuberosa* (Loveday Bay and Hunters Creek) and *Ruppia polycarpa* (Milang) had been lost from the system (Marsland and Nicol 2009). In addition to submergent species, a total of 33 species of emergent, floating and amphibious taxa were lost from wetlands between 2005 and 2008 (Holt *et al.* 2005; Nicol *et al.* 2006; Marsland and Nicol 2009). Whilst there have been no further species losses in 2009-10, wetlands have remained dry and there has been a trend of terrestrial species that were historically confined to high elevations colonising lower elevations (*sensu* Brock and Casanova 1997; Nicol *et al.* 2003).

Similar to 2008-09 the changes in floristic composition through time were generally due to changes in abundance of winter annuals; however, terrestrial taxa have colonised lower elevations than in 2008-09 (Marsland and Nicol 2009). Wetlands subjected to prolonged drawdown are generally invaded by terrestrial taxa because conditions for the growth and survial of wetland taxa are unsuitable (Nicol *et al.* 2003, Nicol 2010). The majority of terrestrial taxa that have colonised the Lower Lakes wetlands are agricultural weeds, typically pasture grasses and legumes (Cunningham *et al.* 1981; Jessop and Tolken 1986; Dashorst and Jessop 1998; Jessop *et al.* 2006). Invasion of agricultural weeds is probably due to the surrounding land use (predominantly agricultural and urban); furthermore, Nicol and Ward (2010 b) reported that the sediment seed bank of Goolwa Channel was dominated by agricultural weeds.

Despite the dominance of terrestrial taxa; submergent, amphibious and emergent taxa were present in some wetlands, particularly those that receive runoff from winter rainfall. Goolwa Channel Drive was dominated by emergent and amphibious taxa from 2008 to 2010, particularily at the lowest elevation (the changes in the plant community were generally changes in the abundances of winter annuals at the high elevations). Submergent r-selected species (*Ruppia tuberosa* and *Lamprothamnium macropogon*) were present at the lowest elevation in Loveday Bay Wetland in spring in both years. Submergent k-selected (*Myriophyllum salsugineum*), amphibious *Triglochin sriatum, Cyperus gymnocaulos, Juncus kraussii, Juncus usitatus*) submergent r-selected (*Ruppia polycarpa*) and emergent (*Bolboschoenus caldwellii, Eleocharis acuta, Phragmites australis, Triglochin procerum*) taxa were also present in Milang Wetland in an area that receives stormwater runoff.

Furthermore, wetlands that received rainfall runoff had higher species richness of wetland species and these sites may be important for the persistence of wetland taxa whilst water levels are low.

Despite the current poor condition of lower lakes wetlands there is evidence that there is potential for wetland vegetation to recover if water levels are reinstated to historical levels. Nicol and Ward (2010b) reported that 11 submergent and emergent native taxa were present in the seed banks of Dunn's and Shadow's Lagoons. In addition, the Raukkun Natural Resources Management Team undertook submergent plant seed bank assessments of Narrung, Loveday Bay, Waltowa and Teringie wetlands that showed that all of the aforementioned wetlands had a sediment seed bank (Narrung had the largest and most diverse seed bank). Results from this trial led to Narrung Wetland being watered in spring 2009 and when surveyed in autumn 2010 (whilst the wetland was dry when surveyed) there was evidnece that *Ruppia* spp. and charophytes had colonised the wetland and replenished the propagule bank. Monitoring undertaken by Paton and Bailey (2010) in Narrung Wetland confirmed these observations with at least seven species of submergent plants (*Ruppia tuberosa, Ruppia polycarpa, Lepilaena cylindrocapa, Lepilaena preissii, Potamgoteon pectinatus, Lamprothamnium* sp. and *Nitella* sp.) recruiting in response to watering. Furthermore, the plant community that recruited in response to watering was similar to the community described by Holt *et al.* (2005) in spring 2004 (Paton and Bailey 2010). Finally, there was a significant increase in propagule density after the wetland was watered compared to pre-watering densities (Paton and Bailey 2010).

Water levels are currently increasing downstream of Lock 1 due to floods in the northern Murray-Darling Basin but the maximum water level is unclear; therefore, it is unknown which wetlands will reconnect with Lake Alexandrina. However, water levels are expectecd to decrease over summer; hence, reconnection may only be temporary and wetlands may dry. Reflooding of wetlands will result in mortality of terrestrial taxa (Brock and Casanova 1997; Nicol 2004) and provide suitable conditions for germination of submergent species (Nicol and Ward 2010a; Nicol and Ward 2010b). Nevertheless, if wetlands dry before plants have the opportunity to complete their life cycle the seed bank may become depleted, which may compromise long-term recovery.

4.2 Lakeshores

Sustained low water levels have also resulted in large areas of lake bed, which were historically inundated, becoming exposed In contrast to wetlands, historical (pre 2007) information regarding the vegetation of lakeshores is not available (except for DEH Biological Survey data (Stewart *et al.* 2009), which generally does not include aquatic habitats). Therefore, comparisons between current and historical conditions cannot be made; however, there is anecdotal evidence that suggests that lakeshores were dominated by emergent taxa and submergent species were generally absent, except between Clayton and Goolwa and the lower Finniss River and lower Currency Creek (J. Nicol pers. obs.). Similar to wetlands, terrestrial taxa have colonised large areas of lake bed that were historically restricted to elevations above +0.8 m AHD; nevertheless extensive reed beds (generally *Phragmites australis* monocultures) are still present between +0.8 and +0.4 m AHD (Marsland and Nicol 2009).

Similar to 2008-09 the changes in floristic composition through time in Lakes Alexandrina and Albert were generally due changes in abundance of winter annuals but terrestrial taxa have colonised lower elevations than in 2008-09 (Marsland and Nicol 2009). Construction of the Clayton regulator and pumping from Lake Alexandrina has resulted in higher water levels in Goolwa Channel, the lower Finniss River and lower Currency Creek compared with Lakes Alexandrina and Albert. Higher water levels in Goolwa Channel have resulted in different plant communities developing between -0.5 m and +0.8 m AHD in Goolwa Channel compared with Lakes Alexandrina and Albert in 2009-10.

In 2009-10 in Goolwa Channel, the lower Finniss River and lower Currency Creek zonation of the plant community in relation to water depth has occurred (*sensu* Spence 1982), whereas in 2008-09 the fringing reed beds were present between +0.4 and +0.8 m AHD but the lower elevations were dominated by terrestrial taxa and bare soil (Marsland and Nicol 2009). In 2009-10 at high elevations (+0.4 to +0.8 m AHD) in Goolwa Channel the plant community was dominated by emergent and amphibious species such as *Phragmites australis, Muehlenbeckia florulenta, Typha domingensis* and *Calystegia sepium.* The corresponding elevations in Lakes Alexandrina and Albert were dominated by *Phragmites australis* and terrestrial taxa. At intermediate elevations (0 to+0.4 m AHD) in 2009-10 emergent species that are adapted to deeper water such as T*ypha domingensis* and *Schoenoplectus validus* were common in Goolwa Channel but in Lakes Alexandrina and Albert terrestrial species were the dominant functional group.

At -0.5 m AHD in 2009-10 only submergent and amphibious species (*Potamogeton pectinatus* and *Myriophyllum salsugineum*) were present in Goolwa Channel. In addition, *Vallisneria australis, Ruppia megacarpa, Ceratophyllum demersum* and *Ruppia polycarpa* were also observed in inundated areas of Goolwa Channel but not present in any quadrats. Submergent species were not observed until autumn 2010, which was not unexpected because the spring 2009 survey was undertaken four weeks after pumping ceased and the majority of submergent species require longer than four weeks of inundation to germinate (Nicol 2004; Nicol and Ward 2010a; Nicol and Ward 2010b). The colonisation of submergent species in Goolwa Channel in response to regulated inundation provides further evidence that the system is resilient and the aquatic plant community has the capacity to recover from low water levels. All submergent species observed in Goolwa Channel (except *Ceratophyllum demersum*) were present in the sediment seed bank (Nicol and Ward 2010b), which suggests that the seed bank is an important source of propagules for recolonisation of submergent species. In Lakes Alexandrina and Albert bare soil and terrestrial species were dominant at -0.5 m AHD.

Furthermore, the majority of the terrestrial taxa that have colonised the dry lakebed in Lakes Alexandrina and Albert were exotics and there was also an increase in the number of exotics compared to 2008-09 (Marsland and Nicol 2009). The dominance of exotic species is probably due to adjacent land use (agricultural and urban), which is dominated by exotic species.

Surface water salinity in Goolwa Channel (which was in excess of 19,000 $\mu S.cm^{-1}$ adjacent to the Hindmarsh Island Bridge in March 2010) was higher than the reported tolerances for several of the emergent and submergent species present (Bailey *et al.* 2002). Extensive stands of healthy *Typha domingensis* (maximum reported salinity tolerance of 8,000 $\mu S.cm^{-1}$), *Phragmites australis* (reported to show signs of severe stress at 15,000 $\mu S.cm^{-1}$) and *Schoenoplectus validus* (maximum reported salinity tolerance of 700 $\mu S.cm^{-1}$) (Bailey *et al.* 2002) were present in Goolwa Channel despite the elevated salinity. These results provide evidence that there are local salt tolerant ecotypes of the aforementioned species present in Goolwa Channel and potentially more broadly in the Lower Lakes.

Similar to wetlands, the impact of the current rise in water levels on lakeshores will depend on the maximum height and duration of inundation, and will only affect Lake Alexandrina (although water levels in Lake Albert may rise due to pumping). Submergent species may recruit in sheltered areas where these species were present historically (i.e. near Milang Jetty J. Nicol pers. obs.); however, hydroperiods need to be sufficient for species to complete their life cycle or the seed bank may become depleted. Results from Goolwa Channel showed that diverse fringing communities developed in response to high water levels in areas that were almost *Phragmites australis* monocultures (Marsland and Nicol 2009; Gehrig and Nicol 2010). The rise in water level may provide conditions suitable for regeneration of fringing emergent and amphibious species and increase diversity of the fringing plant community.

4.3 TLM Targets

Continued low water levels have meant that TLM target V3 has not been met for Lakes Alexandrina or Albert (except Narrung Wetland) due to the dominance of terrestrial species. However, the construction of the Clayton regulator and resultant high water levels has meant that aquatic and floodplain vegetation has recolonised areas between Goolwa and Clayton and the lower Finniss River and Currency Creek. Goolwa Channel monitoring (Gehrig and Nicol 2010), seed bank assessment (Nicol and Ward 2010a; Nicol and Ward 2010b) results and observations at Narrung Wetland have shown that there is capacity for wetland vegetation to recolonise areas that have been dry for up to 3 years. Increased water levels in spring 2010 may also result in recolonisation of aquatic, amphibious and emergent taxa; however, the maximum water level and in turn the potential for wetland plant recolonisation is unclear at this stage. If water is available, the potential changes in the fringing plant community in Lake Alexandrina may occur in Lake Albert if water levels can be maintained at a similar level by pumping.

4.4 Further Studies

- TLM and Goolwa Channel vegetation monitoring for 2010-11 have been funded, which will provide information regarding the impact of increased water levels in wetlands and lakeshores. In addition, this monitoring will provide information on succession of plant communities in Goolwa Channel under managed inundation.

- An honours research project investigating the impacts of acid sulfate soil and remediation measures (e.g. liming and mulching) on the performance of emergent species will be undertaken by Rod Ward and supervised by Molly Whelan, Duncan McKay and Jason Nicol at Flinders University in 2010-11.

- Results from targeted seed bank studies, Goolwa Channel monitoring and observation in Narrung Wetland have shown that there is the capacity for submergent plant communities to recover if water levels are restored to historical levels. Nevertheless, the spatial extent of these studies is limited and the capacity of vegetation to recover in other areas of the Lower Lakes is unknown. In addition, there is no information regarding seed longevity under different physico-chemical conditions (e.g. salinity and pH).

- The seed bank is only one mechanism of recovery of plant communities, there is no information regarding other mechanisms of recovery such as dispersal of plant propagules into wetlands by water (hydrochory) or animals (zoochory).

- Surface water salinity in Goolwa Channel exceeded 19,000 $\mu S.cm^{-1}$ in March 2010, which is higher than the reported tolerances of many of the species that were present and appeared to be in very good condition (Bailey *et al.* 2002). Therefore, published salinity tolerances probably do not apply to many species in the Lower Lakes region and the tolerances of local ecotypes are unknown.

5 References

Abernethy, B. and Rutherfurd, I.D. (1998). Where along a river's length will vegetation most effectively stabilise stream banks? *Geomorphology* **23**: 55-75.

Anderson, M.J. (2001). A new method for non-parametric analysis of variance. *Austral Ecology* **26**: 32-46.

Anderson, M.J. and Ter Braak, C.J.F. (2003). Permutation tests for multi-factorial analysis of variance. *Journal of Statistical Computation and Simulation* **73**: 85-113.

Bailey, P., Boon, P. and Morris, K. (2002). Salt sensitivity database. Land and Water Australia.

Barker, W.R., Barker, R.M., Jessop, J.P. and Vonow, H.P. (2005). Census of South Australian Vascular Plants (5.00 edn). (Botanic Gardens of Adelaide & State Herbarium: Adelaide).

Braun-Blanquet, J. (1932). Plant Sociology. (McGraw-Hill: New York).

Bray, J.R. and Curtis, J.T. (1957). An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs* **27**: 325-349.

Brock, M.A. and Casanova, M.T. (1997). Plant life at the edge of wetlands: ecological responses to wetting and drying patterns. In 'Frontiers in Ecology: Building the Links'. (Eds Klomp, N. and Lunt, I.) pp. 181-192. (Elsevier Science: Oxford).

Cronin, G., Lewis, W.M. and Schiehser, M.A. (2006). Influence of freshwater macrophytes on the littoral ecosystem structure and function of a young Colorado reservoir. *Aquatic Botany* **85**: 37-43.

Cunningham, G.M., Mulham, W.E., Milthorpe, P.L. and Leigh, J.H. (1981). Plants of Western New South Wales. (New South Wales Government Printing Office: Sydney).

Dashorst, G.R.M. and Jessop, J.P. (1998). Plants of the Adelaide Plains and Hills. (The Botanic Gardens of Adelaide and State Herbarium: Adelaide).

Dufrene, M. and Legendre, P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs* **67**: 345-366.

Fitzpatrick, R., Grealish, G., Shand, P., Marvanek, S., Thomas, B., Creeper, N., Merry, R. and Raven, M. (2009a). Preliminary assessment of acid sulfate soil materials in Currency Creek, Finniss River, Tookayerta Creek and Black Swamp region, South Australia. CSIRO Land and Water, Adelaide.

Fitzpatrick, R.W., Grealish, G., Shand, P., Simpson, S.L., Merry, R.H. and Raven, M.D. (2009b). Acid sulfate soil assessment in Finniss River, Currency Creek, Black Swamp and Goolwa Channel, South Australia. CSIRO Land and Water, 26/09, Adelaide.

Gehrig, S.L. and Nicol, J.M. (2010). Aquatic and littoral vegetation monitoring of Goolwa Channel 2009-10. South Australian Research and Development Institute (Aquatic Sciences), SARDI Publication Number F2010/000383-1, Adelaide.

Heard, L. and Channon, B. (1997). Guide to a native vegetation survey using the biological survey of South Australia. South Australian Department of Environment and Natural Resources, Adelaide.

Holt. M., Swingler, K., O'Donnell, E., Shirley, M., Lake, M., Conallin, A., Meredith, S., Ho, S., Prider, J., Poulsen, D., Richardson, S. and Cooling, M. (2005). River Murray Wetlands Baseline Survey. River Murray Catchment Water Management Board, Berri.

Jessop, J., Dashorst, G.R.M. and James, F.R. (2006). Grasses of South Australia. An illustrated guide to the native and naturalised species. (Wakefield Press: Adelaide).

Jessop, J.P. and Tolken, H.R. (1986). The Flora of South Australia. (Government of South Australia Printer: Adelaide).

Marsland, K. and Nicol, J. (2006). Current and proposed monitoring activities in relation to The Living Murray Lower Lakes, Coorong and Murray Mouth Icon Site Environmental Management Plan. SARDI Aquatic Sciences, SARDI Publication Number F2006/000081 P01, Adelaide.

Marsland, K.B. and Nicol, J.M. (2009). Lower Lakes vegetation condition monitoring-2008/09. South Australian Research and Development Institute (Aquatic Sciences), SARDI Publication Number F2009/000370-1, Adelaide.

Maunsell Australia Pty Ltd. (2009). Lower Lakes, Coorong and Murray Mouth Icon Site condition monitoring plan. South Australian Murray-Darling Basin Natural Resources Management Board, Adelaide.

McCune, B. and Mefford, M.J. (2006). PC-ORD. Multivariate Analysis of Ecological Data, Version 5.12. (MjM Software Design: Glenden Beach, Oregon, USA).

McCune, B., Grace, J.B. and Urban, D.L. (2002). Analysis of Ecological Communities. (MjM Software Design: Gleneden Beach, Oregon).

Merry, R.H., Fitzpatrick, R.W., Barnett , E.J., Davies, P.J., Fotheringham, D.G., Thomas, B.P. and Hicks, W.S. (2003). South Australian inventory of acid sulfate soil risk (atlas). CSIRO Land and Water, Adelaide.

Mondon, J., Morrison, K. and Wallis, R. (2009). Impact of saltmarsh disturbance on seed quality of Sarcocornia (*Sarcocornia quinqueflora*), a food plant of an endangered Australian parrot. *Ecological Management and Restoration* **10**: 58-60.

Murray-Darling Basin Commission (2005). The Lower Lakes, Coorong and Murray Mouth Asset Environmental Management Plan 2005/2006. Murray-Darling Basin Commission, Canberra.

Nicol, J.M. (2010). Vegetation monitoring of River Murray Wetlands downstream of Lock 1. South Australian Research and Development Institute (Aquatic Sciences), SARDI Publication Number F2009/000416-1, Adelaide.

Nicol, J.M., Ganf, G.G. and Pelton, G.A. (2003). Seed banks of a southern Australian wetland: the influence of water regime on final species composition. *Plant Ecology* **168**: 191-205.

Nicol, J. and Ward, R. (2010a). Seed bank assessment of Dunn's and Shadow's Lagoons. South Australian Research and Development Institute (Aquatic Sciences), SARDI Publication Number F2010/000594-1, Adelaide.

Nicol, J. and Ward, R. (2010b). Seed bank assessment of Goolwa Channel, Lower Finniss River and Lower Currency Creek. South Australian Research and Development Institute (Aquatic Sciences), SARDI Publication Number F2010/000303-1, Adelaide.

Nicol, J.M., Weedon, J.T. and Doonan, A. (2006). Vegetation Surveys. In 'River Murray Wetlands Baseline Survey – 2005'. (Eds D Simpson, M Holt, T Champion, A Horan and M Shirley). (South Australian Murray-Darling Basin Natural Resources Management Board: Berri).

Noges, T., Luup, H. and Feldmann, T. (2010). Primary production of aquatic macrophytes and their epiphytes in two shallow lakes (Peipsi and Vortsjarv) in Estonia. *Aquatic Ecology* **44**: 83-92.

Paton, D.C. and Bailey, C.P. (2010). 'Responses of aquatic vegetation to environmental watering of the Narrung wetland 2009-10.' The University of Adelaide, Adelaide.

Prescott, A. (1988). It's blue with five petals. Wild flowers of the Adelaide region. (Ann Prescott: Prospect, South Australia).

Rea, N. and Ganf, G.G. (1994). The influence of water regime on the performance of aquatic plants. *Water Science and Technology* **29**: 127-132.

Renfrey, A.P.C., Rea, N. and Ganf, G.G. (1989). The aquatic flora of Hindmarsh Island, South Australia. Department of Environment and Planning, Adelaide.

Rodriguez-Gallego, L., Meerhoff, E., Clemente, J. and Conde, D. (2010). Can ephemeral proliferations of submerged macrophytes influence zoobenthos and water quality in coastal lagoons? *Hydrobiologia* **646**: 253-269.

Romanowski, N. (1998). Aquatic and wetland plants. A field guide for non-tropical Australia. (University of New South Wales Press: Sydney).

Sainty, G.R. and Jacobs, S.W.L. (1981). Water plants of New South Wales. (Water Resources Commission New South Wales: Sydney).

Sainty, G.R. and Jacobs, S.W.L. (2003). Waterplants in Australia. (Sainty and Associates: Darlinghurst, N.S.W., Australia).

Spence, D.H.N. (1982). The zonation of plants in freshwater lakes. *Advances in Ecological Research* **12:** 37-125.

Stewart, H. (2000). Baseline monitoring of the flora and fauna of Deep Swamp. Department for Environment, Heritage and Aboriginal Affairs, Adelaide.

Wedderburn, S.D., Walker, K.F. and Zampatti, B.P. (2007). Habitat separation of *Craterocephalus* (Atherinidae) species and populations in off-channel areas of the lower River Murray, Australia. *Ecology of Freshwater Fish* **16**: 442–449.

6 Appendices

Appendix 1: GPS coordinates (UTM format, map datum WGS84) for lakeshore and wetland understorey vegetation monitoring sites.

Site	Easting	Northing	Site type
Bremer Mouth Lakeshore	323061	6081991	lakeshore
Brown Beach 1	350172	6052777	lakeshore
Brown Beach 2	350287	6053158	lakeshore
Clayton Bay	311301	6070626	lakeshore
Currency Creek 3	296772	6074222	lakeshore
Currency Creek 4	301013	6071800	lakeshore
Goolwa North	303330	6070156	lakeshore
Goolwa South	300490	6066366	lakeshore
Hindmarsh Island Bridge 01	299670	6068521	lakeshore
Hindmarsh Island Bridge 02	299695	6068616	lakeshore
Lake Reserve Rd	339298	6089987	lakeshore
Loveday Bay	329431	6058407	lakeshore
Loveday Bay Lakeshore	326621	6061647	lakeshore
Lower Finniss 02	305131	6076401	lakeshore
Milang	315964	6079870	lakeshore
Milang Lakeshore	316081	6079746	lakeshore
Pt Sturt Lakeshore	322811	6069643	lakeshore
Pt Sturt Water Reserve	317673	6070784	lakeshore
Teringie Lakeshore	327461	6066887	lakeshore
Upstream of Clayton Regulator	312281	6069151	lakeshore
Wally's Landing	303066	6079631	lakeshore
Warrengie 1	347722	6049163	lakeshore
Lower Finniss 03	305131	6072406	lakeshore
Narrung Lakeshore	333762	6069807	lakeshore
Nurra Nurra	341786	6063837	lakeshore
Warrengie 2	348487	6049133	lakeshore
Angas Mouth	318391	6081206	wetland
Bremer Mouth	323056	6082019	wetland
Dunns Lagoon	312417	6070300	wetland
Goolwa Channel Drive	307024	6064437	wetland
Hunters Creek	308219	6065526	wetland
Poltalloch	343248	6071554	wetland
Pt Sturt	322778	6069794	wetland
Teringie	327334	6065286	wetland
Waltowa	353908	6057756	wetland
Narrung	334542	6068744	wetland

Appendix 2: Species list, functional classification (Gehrig and Nicol 2010), life history strategy and conservation status (state conservation status from listings in Barker *et al.* (2005) and regional conservation status from listings in Lang and Kraehenuehl (2001)) from all sites and survey dates (*denotes exotic taxon).

Taxa	Functional Group	Life history strategy	Status and Comments
Acacia myrtifolia	Terrestrial dry	Perennial	Native
*Agapanthus praecox**	Terrestrial dry	Perennial	Exotic
*Apium graveolens**	Terrestrial damp	Annual	Exotic
*Arctotheca calendula**	Terrestrial dry	Annual	Exotic
*Asparagus asparagoides**	Terrestrial dry	Perennial	Exotic
*Asparagus officinalis**	Terrestrial dry	Perennial	Exotic
*Aster subulatus**	Terrestrial damp	Annual	Exotic
*Atriplex prostrata**	Terrestrial damp	Perennial	Exotic
Atriplex semibaccata	Terrestrial dry	Perennial	Native-Listed as Uncommon in the Murray Region
Atriplex suberecta	Floodplain	Perennial	Native
Avena spp.*	Terrestrial dry	Annual	Exotic-*Avena* spp. is comprised of *Avena barbata* and *Avena fatua*
Berula erecta	Emergent	Perennial	Native
Bolboschoenus caldwellii	Emergent	Perennial	Native
*Brassica rapa**	Terrestrial dry	Annual	Exotic
*Brassica tournifortii**	Terrestrial dry	Annual	Exotic
*Briza minor**	Terrestrial dry	Annual	Exotic
*Bromus diandrus**	Terrestrial dry	Annual	Exotic
*Bromus hordeaceus**	Terrestrial dry	Annual	Exotic
*Bromus uniloides**	Terrestrial dry	Annual	Exotic
Calystegia sepium	Amphibious fluctuation tolerator-emergent	Perennial	Native-Listed as Uncommon in the Murray and Southern Lofty Regions
Carpobrotus rossii	Terrestrial dry	Perennial	Native
*Centaurium tenuiflorum**	Terrestrial damp	Annual	Exotic
*Centaurea calcitrapa**	Terrestrial damp	Annual	Exotic
*Chenopodium album**	Terrestrial damp	Annual	Exotic
*Chenopodium glaucum**	Terrestrial damp	Annual	Exotic
Chenopodium nitrariaceum	Terrestrial dry	Perennial	Native
*Conyza bonariensis**	Terrestrial damp	Annual	Exotic
*Cotula coronopifolia**	Amphibious fluctuation responder-plastic	Perennial	Exotic
Crinum sp.*	Terrestrial dry	Perennial	Exotic-garden escapee not in any of the identification keys and could not be identified to species
Cyperus exaltatus	Amphibious fluctuation tolerator-emergent	Perennial	Native
Cyperus gymnocaulos	Amphibious fluctuation tolerator-emergent	Perennial	Native
Distichlis distichophylla	Terrestrial damp	Perennial	Native-Listed as Uncommon in the Murray Region
Disphyma crassifolium	Terrestrial dry	Perennial	Native
*Ehrharta longiflora**	Terrestrial damp	Annual	Exotic
Einadia nutans	Terrestrial dry	Perennial	Native
Eleocharis acuta	Emergent	Perennial	Native
Enchylaena tomentosa	Terrestrial dry	Perennial	Native
Epilobium pallidiflorum	Terrestrial damp	Perennial	Native-Listed as Uncertain in the Murray Region and uncommon in the Southern Lofty Region
Eragrostis australasica	Floodplain	Perennial	Native

Taxa	Functional Group	Life history strategy	Status and Comments
*Eragrostis curvula**	Terrestrial damp	Annual	Exotic-Proclaimed pest plant in SA
Eragrostis sp.	Terrestrial damp	Annual	Native-could not identify to species
*Euphorbia terracina**	Terrestrial dry	Annual	Exotic-Proclaimed pest plant in SA
*Foeniculum vulgare**	Terrestrial damp	Annual	Exotic
Frankenia pauciflora	Terrestrial dry	Perennial	Native
*Fumaria bastardii**	Terrestrial damp	Annual	Exotic
Gahnia filum	Amphibious fluctuation tolerator-emergent	Perennial	Native-Listed as Rare in the Murray and Southern Lofty Regions
Glyceria australis	Emergent	Perennial	Native
Halosarcia pergranulata	Amphibious fluctuation tolerator-emergent	Perennial	Native
*Heliotropium europaeum**	Floodplain	Annual	Exotic
*Holcus lanatus**	Terrestrial damp	Annual	Exotic
*Hordeum vulgare**	Terrestrial dry	Annual	Exotic
Hydrocotyle verticillata	Amphibious fluctuation responder-plastic	Perennial	Native-Listed as Uncertain in the Southern Lofty Region
*Hypochoeris glabra**	Terrestrial dry	Annual	Exotic
*Hypochoeris radicata**	Terrestrial dry	Annual	Exotic
Isolepis nodosa	Amphibious fluctuation tolerator-emergent	Perennial	Native
Isolepis platycarpa	Amphibious fluctuation tolerator-low growing	Perennial	Native
Isolepis sp.	Amphibious fluctuation tolerator-low growing	Perennial	Native-could not identify to species
*Juncus acutus**	Amphibious fluctuation tolerator-emergent	Perennial	Exotic
Juncus kraussii	Amphibious fluctuation tolerator-emergent	Perennial	Native
Juncus usitatus	Amphibious fluctuation tolerator-emergent	Perennial	Native
Lachnagrostis filiformis	Floodplain	Annual	Native
*Lactuca saligna**	Terrestrial dry	Annual	Exotic
*Lactuca serriola**	Terrestrial dry	Annual	Exotic
*Lagurus ovatus**	Terrestrial dry	Annual	Exotic
Lamprothamnium macropogon	Submergent r-selected	Annual	Native
Lobelia alata	Terrestrial damp	Perennial	Native
Lolium spp.*	Terrestrial dry	Annual	Exotic-*Lolium* spp. comprises of *Lolium perenne* and *Lolium rigidum*
*Lupinus cosentinii**	Terrestrial dry	Annual	Exotic
*Lycium ferocissimum**	Terrestrial dry	Perennial	Exotic-Proclaimed pest plant in SA
Lycopus australis	Amphibious fluctuation tolerator-emergent	Perennial	Native-Listed as Rare in the Murray Region
*Malva parviflora**	Terrestrial dry	Annual	Exotic
Medicago spp.*	Terrestrial dry	Annual	Exotic-*Medicago* spp. comprises of *Medicago polymorpha, Medicago truncatula* and *Medicago minima*
Melaleuca halmaturorum	Amphibious fluctuation tolerator-woody	Perennial	Native
*Melilotus indica**	Terrestrial dry	Annual	Exotic
Mentha australis	Amphibious fluctuation tolerator-emergent	Perennial	Native
Mentha spp.*	Amphibious fluctuation tolerator-emergent	Perennial	Exotic-*Mentha* spp. comprises of *Mentha piperita, Mentha pulegium* and *Mentha spicata*
Mimulus repens	Amphibious fluctuation tolerator-low growing	Perennial	Native
Muehlenbeckia florulenta	Amphibious fluctuation tolerator-woody	Perennial	Native
Muehlenbeckia gunnii	Amphibious fluctuation tolerator-woody	Perennial	Native
Myriophyllum salsugineum	Submergent k-selected	Perennial	Native-Listed as Uncertain in the Southern Lofty Region

Taxa	Functional Group	Life history strategy	Status and Comments
*Onopordum acanthium**	Terrestrial damp	Annual	Exotic
*Oxalis pes-caprae**	Terrestrial dry	Annual	Exotic-Proclaimed pest plant in SA
*Paspalum distichum**	Terrestrial damp	Perennial	Exotic
*Pennisetum clandestinum**	Terrestrial dry	Perennial	Exotic
Persicaria lapathifolia	Amphibious fluctuation responder-plastic	Perennial	Native
*Phalaris arundinacea**	Amphibious fluctuation tolerator-emergent	Perennial	Exotic
Phragmites australis	Emergent	Perennial	Native
Picris hieracoides	Terrestrial dry	Annual	Native
*Plantago coronopus**	Terrestrial dry	Annual	Exotic
*Plantago lanceolata**	Terrestrial dry	Annual	Exotic
*Plantago major**	Terrestrial dry	Annual	Exotic
*Polypogon monspeliensis**	Amphibious fluctuation tolerator-emergent	Annual	Exotic
*Polygonum aviculare**	Terrestrial dry	Perennial	Exotic
Potamogeton pectinatus	Submergent k-selected	Perennial	Native
Pseudognaphalium luteoalbum	Floodplain	Annual	Native
Puccinellia sp.*	Terrestrial damp	Annual	Exotic-could not be identified to species but was not *Puccinellia stricta* or *Puccinellia perlaxa*
*Reichardia tingitana**	Terrestrial dry	Annual	Exotic
Rhagodia spinescens	Terrestrial dry	Perennial	Native
Ruppia polycarpa	Submergent r-selected	Annual	Native
Ruppia tuberosa	Submergent r-selected	Annual	Native
*Salix babylonica**	Emergent	Perennial	Exotic
Salsola kali	Terrestrial dry	Perennial	Native
Samolus repens	Terrestrial damp	Perennial	Native- Listed as Rare in the Murray Region and Uncommon the Southern Lofty Region
Sarcocornia quinqueloflora	Amphibious fluctuation tolerator-emergent	Perennial	Native
*Scabiosa atropurpurea**	Terrestrial dry	Annual	Exotic
Schoenoplectus pungens	Amphibious fluctuation tolerator-emergent	Perennial	Native-Listed as Rare in the Southern Lofty Region
Schoenoplectus validus	Emergent	Perennial	Native
Sclerolaena blackiana	Terrestrial dry	Perennial	Native-Listed as Rare in SA
Senecio cunninghamii	Floodplain	Perennial	Native
*Senecio pterophorus**	Terrestrial dry	Annual	Exotic
Senecio runcinifolius	Floodplain	Perennial	Native-Listed as Uncommon in the Murray Region
*Solanum nigrum**	Terrestrial damp	Annual	Exotic
*Sonchus asper**	Terrestrial damp	Annual	Exotic
*Sonchus oleraceus**	Terrestrial damp	Annual	Exotic
*Spergularia marina**	Terrestrial damp	Annual	Exotic
Suaeda australis	Amphibious fluctuation tolerator-emergent	Perennial	Native
*Silybum marianum**	Terrestrial damp	Annual	Exotic-Proclaimed pest plant in SA
*Tamarix aphylla**	Terrestrial dry	Perennial	Exotic
Trifolium spp.*	Terrestrial dry	Annual	Exotic-*Trifolium* spp. comprises of *Trifolium angustifolium, Trifolium arvense, Trifolium repens* and *Trifolium subterraneum*
Triglochin procerum	Emergent	Perennial	Native-Listed as Uncommon in the Southern Lofty Region
Triglochin striatum	Amphibious fluctuation tolerator-low growing	Perennial	Native
Triticum sp.*	Terrestrial dry	Annual	Exotic-could not be identified to species

Taxa	Functional Group	Life history strategy	Status and Comments
Typha domingensis	Emergent	Perennial	Native
*Urtica urens**	Terrestrial damp	Annual	Exotic
Vallisneria australis	Submergent k-selected	Perennial	Native-Listed as Uncommon in the Murray Region and Threatened in the Southern Lofty Region
*Vicia sativa**	Terrestrial dry	Annual	Exotic
Wilsonia rotundifolia	Terrestrial damp	Perennial	Native

Appendix 3: Species present in wetlands from spring 2008 to autumn 2010 (*denotes exotic species).

Species	Angas Mouth	Bremer Mouth	Dunn's Lagoon	Goolwa Channel Drive	Hunter's Creek	Loveday Bay	Milang	Narrung	Poltalloch	Point Sturt	Teringie	Waltowa
*Agapanthus praecox**							*					
*Asparagus asparagoides**							*					
*Aster subulatus**	*	*	*			*	*			*		
*Atriplex prostrata**	*		*	*	*	*	*			*		
Atriplex semibaccata								*		*	*	
Atriplex suberecta										*		
Avena spp.*			*				*			*	*	*
Berula erecta		*										
Bolboschoenus caldwellii				*	*	*	*		*			
*Brassica rapa**			*									
*Brassica tournifortii**											*	
*Bromus diandrus**			*				*			*	*	*
*Bromus hordeaceus**			*				*			*	*	
*Bromus uniloides**												*
Calystegia sepium			*									
Carpobrotus rossii												*
*Centaurea calcitrapa**		*		*		*						
*Chenopodium album**	*		*				*					
*Chenopodium glaucum**			*						*	*		
*Conyza bonariensis**			*	*								
*Cotula coronopifolia**		*	*	*		*	*		*	*	*	
Crinum sp.*							*					
Cyperus exaltatus	*											
Cyperus gymnocaulos			*			*	*		*		*	
Disphyma crassifolium												*
Distichlis distichophylla			*	*	*	*	*	*	*	*	*	
*Ehrharta longiflora**							*					
Einadia nutans										*		
Eleocharis acuta							*					
Enchylaena tomentosa			*				*			*	*	
*Eragrostis curvula**			*			*	*	*	*	*	*	*
Eragrostis sp.			*				*	*		*	*	
Frankenia pauciflora				*		*	*	*			*	

Species	Angas Mouth	Bremer Mouth	Dunn's Lagoon	Goolwa Channel Drive	Hunter's Creek	Loveday Bay	Milang	Narrung	Poltalloch	Point Sturt	Teringie	Waltowa
*Fumaria bastardii**							*					
Gahnia filum			*									
Glyceria australis												*
Halosarcia pergranulata												*
*Heliotropium europaeum**											*	
*Holcus lanatus**							*					
*Hordeum vulgare**			*			*	*	*	*	*	*	*
Hydrocotyle verticillata			*									
*Hypochoeris glabra**			*									
*Hypochoeris radicata**		*	*									
Isolepis nodosa			*	*					*			
Isolepis platycarpa			*									
*Juncus acutus**			*									
Juncus kraussii			*	*	*	*	*					
Juncus usitatus							*					
Lachnagrostis filiformis	*		*	*	*	*		*		*		
*Lactuca saligna**			*			*	*					
*Lactuca serriola**			*			*	*		*			
*Lagurus ovatus**							*			*	*	*
Lamprothamnium macropogon						*						
Lolium spp.*		*	*	*		*	*	*	*	*	*	*
*Lycium ferocissimum**							*			*	*	
*Malva parviflora**							*					
Medicago spp.*			*			*	*	*	*	*	*	*
Melaleuca halmaturorum			*									
*Melilotus indica**			*			*				*		
Mentha spp.*			*									
Mimulus repens			*						*	*		
Muehlenbeckia florulenta							*					
Muehlenbeckia gunnii			*									
Myriophyllum salsugineum							*					
*Oxalis pes-caprae**							*					
*Paspalum distichum**	*	*	*	*	*	*	*		*	*	*	*
*Pennisetum clandestinum**	*	*					*					*
Persicaria lapathifolia	*	*	*									

Species	Angas Mouth	Bremer Mouth	Dunn's Lagoon	Goolwa Channel Drive	Hunter's Creek	Loveday Bay	Milang	Narrung	Poltalloch	Point Sturt	Teringie	Waltowa
Phragmites australis		*	*	*			*	*				*
Picris hieracoides			*									
*Plantago coronopus**		*	*	*		*	*			*	*	*
*Polygonum aviculare**										*		
*Polypogon monspeliensis**	*	*					*	*	*	*	*	
Psuedognaphalium luteo-album			*									
Puccinellia sp.*								*				
*Reichardia tingitana**		*	*	*			*			*		*
Ruppia polycarpa							*					
Ruppia tuberosa					*	*						
Salsola kali											*	
Samolus repens			*	*		*	*			*	*	
Sarcocornia quinqueloflora			*	*	*	*	*	*	*	*	*	*
Schoenoplectus pungens			*	*	*	*						
Senecio cunninghamii		*					*	*			*	*
*Senecio pterophorus**		*	*			*	*	*		*		
Senecio runcinifolius			*									*
*Sonchus asper**			*									
*Sonchus oleraceus**	*	*	*	*	*	*	*	*	*	*	*	*
*Spergularia marina**			*	*			*	*	*	*	*	*
Suaeda australis			*	*	*	*	*	*	*	*	*	*
Trifolium spp.*		*	*			*	*			*	*	
Triglochin procerum		*	*									
Triglochin striatum	*	*	*				*				*	
Typha domingensis	*	*	*	*		*	*					
*Urtica urens**			*									
Vallisneria australis		*										
*Vicia sativa**							*					
Wilsonia rotundifolia			*			*	*					
Species Richness	**12**	**21**	**57**	**22**	**11**	**30**	**53**	**18**	**18**	**34**	**30**	**23**
No. Exotics	**7**	**13**	**30**	**10**	**3**	**16**	**33**	**9**	**11**	**23**	**18**	**14**
% Exotics	**58.33**	**61.90**	**52.63**	**45.45**	**27.27**	**53.33**	**62.26**	**50.00**	**61.11**	**67.65**	**60.00**	**60.87**

Appendix 4: Water regime functional groups present in each wetland and at each surveyed elevation in Lake Alexandrina, Lake Albert andsGoolwa Channel from spring 2008 to autumn 2010.

						Water Regime Functional Group						
Site/Elevation	**Survey Date**	**Terrestrial dry**	**Terrestrial damp**	**Floodplain**	**Amphibious fluctuation tolerator emergent**	**Amphibious fluctuation tolerator woody**	**Amphibious fluctuation tolerator low growing**	**Amphibious fluctuation responder-plastic**	**Floating**	**Submergent r-selected**	**Emergent**	**Submergent k-selected**
Hunters Creek	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Angus and Bremer Mouths	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Dunns Lagoon	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Waltowa	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Narrung	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Goolwa Channel Drive	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Loveday Bay	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Milang	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Poltalloch	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Point Sturt	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Teringie	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											

Site/Elevation	Survey Date	Terrestrial dry	Terrestrial damp	Floodplain	Amphibious fluctuation tolerator emergent	Water Regime Functional Group Amphibious fluctuation tolerator woody	Amphibious fluctuation tolerator low growing	Amphibious fluctuation responder-plastic	Floating	Submergent r-selected	Emergent	Submergent k-selected
Lake Alexandrina +0.8 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Lake Alexandrina +0.6 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Lake Alexandrina +0.4 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Lake Alexandrina +0.2 m AHD	Spring 2009											
	Autumn 2010											
Lake Alexandrina 0 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Lake Alexandrina -0.5 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Lake Albert +0.8 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Lake Albert +0.6 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Lake Albert +0.4 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Lake Albert +0.2 m AHD	Spring 2009											
	Autumn 2010											
Lake Albert 0 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Lake Albert -0.5 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											

						Water Regime Functional Group						
Site/Elevation	Survey Date	Terrestrial dry	Terrestrial damp	Floodplain	Amphibious fluctuation tolerator emergent	Amphibious fluctuation tolerator woody	Amphibious fluctuation tolerator low growing	Amphibious fluctuation responder-plastic	Floating	Submergent r-selected	Emergent	Submergent k-selected
Goolwa Channel +0.8 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Goolwa Channel +0.6 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Goolwa Channel +0.4 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Goolwa Channel +0.2 m AHD	Spring 2009											
	Autumn 2010											
Goolwa Channel 0 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											
Goolwa Channel -0.5 m AHD	Spring 2008											
	Autumn 2009											
	Spring 2009											
	Autumn 2010											