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Lower Lakes Vegetation Condition Monitoring – 2010/2011.

Susan Gehrig, Jason Nicol and Kelly Marsland

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Executive Summary

The Condition Monitoring Plan for the Coorong, Lower Lakes and Murray Mouth Icon Site (Maunsell Australia Pty Ltd. 2009) identified that a monitoring program was required that focused on measuring key environmental parameters that were considered to be indicators of river and floodplain health in both the short and long term. This report presents the findings of the first three years of a monitoring program established to evaluate The Living Murray Target 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, lower Currency Creek and the mouths of the Angas and Bremer Rivers. Sites established in spring 2008 and spring 2009 (Goolwa channel monitoring sites) were re-surveyed. 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 every spring (October 2008, 2009 and November 2010) and autumn (March 2009, 2010 and 2011). The first two years of the monitoring program coincided with a period of record low water levels in the Lower Lakes. However, during this period, significant engineering interventions (construction of the Clayton regulator and Narrung bund and pumping of Narrung Wetland) also influenced vegetation communities and were considered as part of the monitoring program. In August 2010 water levels in Lake Alexandrina rapidly rose to historical levels and in September 2010 the Clayton regulator and Narrung bund were breached, reconnecting these areas with Lake Alexandrina.

Over the three year period (spring 2008 to autumn 2011), a total of 143 taxa (including 74 exotics and one species listed as rare in South Australia) were recorded at wetland sites and 114 taxa (including 57 exotics and one species listed as rare in South Australia) at lakeshore sites. 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 terrestrial species had colonised lower elevations than previously recorded in 2008-09. When water levels were reinstated aquatic species generally recolonised the inundated areas. Waltowa wetland remained dominated by salt tolerant and terrestrial taxa because the flow control structure on the inlet remained shut to prevent salt from entering Lake Albert.

Similar to wetlands, low water levels resulted in colonisation of terrestrial species around the shorelines of Lakes Alexandrina and Albert (lower elevations were colonised in 2009-10 compared with 2008-09). In contrast, by March 2010, an amphibious, emergent and submergent plant community developed in areas inundated by the Clayton regulator (which in 2008-09 were dominated by terrestrial taxa and bare soil). Water level management in Lake Albert did not result in colonisation of aquatic species or reconnect fringing vegetation. When water levels were reinstated, terrestrial taxa were extirpated in lakes Alexandrina and Albert. Furthermore, there was an increase in the abundance of emergent and amphibious species in Lake Alexandrina but not in Lake Albert. Breaching of the Clayton regulator resulted in lower salinity in Goolwa Channel, which resulted in further change to the plant community. *Potamogeton pectinatus* dominated large areas of Goolwa Channel from autumn 2010 to spring 2010 but was replaced by *Myriophyllum salsugineum* by autumn 2011. The emergent plant community in Goolwa Channel also changed significantly over the same period with *Schoenoplectus validus* abundance increasing between spring 2010 and autumn 2011.

Results showed that the plant community is resilient and is recovering but, the submergent plant community is different from the community present before water levels were drawn down. Large areas that were historically dominated by diverse submergent plant communities (e.g. Clayton Bay, Dunns Lagoon, Narrung) are yet to fully recover. The emergent plant community in Lake Albert also has not changed significantly since water levels were reinstated.

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 and lower Currency Creek. However there was a significant increase in aquatic species after water levels increased, which are capable of rapidly colonising large areas by asexual reproduction providing the current hydrological and salinity regime is maintained. Therefore, TLM target V3 may be attained for the Lower Lakes icon site in the near future.

1 Introduction

The Coorong, Lower Lakes and Murray Mouth region has been listed as one of six icon sites under the Murray-Darling Basin Authority's "The Living Murray" (TLM) program and has been identified as an indicator site under the proposed Basin Plan. 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 three 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; Gehrig *et al.* 2010).

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 Environmental Management Plan 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 and built upon existing monitoring programs (SAMDBNRM Board community wetland monitoring) 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). In 2009, eight extra sites in Goolwa Channel were added to assess the impact of the Goolwa Channel Water Level Management Project, and data from this project was included in the TLM Condition Monitoring Program (Gehrig and Nicol 2010a; Gehrig *et al.* 2010; Gehrig *et al.* 2011).

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 assemblage would be monitored with a separate technique used for *Melaleuca 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 2010-11. Information regarding *Melaleuca halmaturorum* stand condition is presented in Marsland and Nicol (2009).

From 1996 to 2010, the Murray-Darling Basin was subjected to the most severe drought in recorded history (Bond *et al.* 2008). Below average stream flows coupled with upstream extraction and river regulation resulted in reduced inflows into South Australia (Timbal and Jones 2008), which between January 2007 and August 2010 were insufficient to maintain pool level downstream of Lock and Weir number 1. Subsequently water levels in Lakes Alexandrina and Albert dropped to unprecedented lows (<-0.75 m AHD), fringing wetlands became disconnected, and extensive areas of acid sulfate soils were exposed; particularly in Lake Albert and the lower reaches of the Finniss River and Currency Creek (Merry *et al.* 2003; Fitzpatrick *et al.* 2009a; Fitzpatrick *et al.* 2009b).

Prior to 2007, fringing wetlands in the Lower Lakes region contained diverse communities of emergent, amphibiuous and submergent species (Renfrey *et al.* 1989; Holt *et al.* 2005; Nicol *et al.* 2006). By spring 2008 submergent species had been extirpated (except for a small number of *Ruppia tuberosa* plants in Hunters Creek, in Lake Alexandrina near Raukkun and Loveday Bay Wetland and *Lamprothamnium macropogon* in Loveday Bay Wetland), amphibious species had declined in abundance and diversity, stands of emergent species were diconnected from the lakes and fringing habitats were dominated by terrestrial species and bare soil (Marsland and Nicol 2009). Furthermore, submergent species had not colonised the remaining open water areas (Marsland and Nicol 2009).

The loss of submergent vegetation, decline in abundance and diversity of amphibious taxa and disconnection of fringing emegent macrophytes had serious implications for ecosystem dynamics of the Lower Lakes. Aquatic vegetation provides important ecosystem services in the Lower Lakes; plants are major primary producers (e.g. dos Santos and Esteves 2002; Camargo *et al.* 2006; Noges *et al.* 2010), improve water quality (e.g. Webster *et al.* 2001; James *et al.* 2004) provide habitat for invertebrates (e.g. Declerck *et al.* 2005; Cronin *et al.* 2006; Pinto *et al.* 2006; Papas 2007), birds (e.g. Brandle *et al.* 2002; Phillips and Muller 2006) and threatened fish (Wedderburn *et al.* 2007; Bice *et al.* 2008) and stabilise shorelines (Abernethy and Rutherfurd 1998; PIRSA Spatial Information Sevices 2009).

To mitigate acid sulfate soils three regulators were constructed in the Lower Lakes: the Narrung bund, the Clayton regulator and the Currency Creek regulator (Figure 1). However, only the impacts of the Narrung bund and Clayton regulator will be discussed in this report because the Currency Creek regulator spillway was inundated for the duration of the survey period. The regulators disconnected Goolwa Channel and Lake Albert from Lake Alexandrina, which enabled each site to be managed independently. 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*).

In August 2010, flows into South Australia increased, water levels in Lake Alexandrina were reinstated to historical levels (~+0.75 m AHD) and there was significant flow through the Murray Barrages for the first time since spring 2005 (although there was a small release in 2006-07 to operate fishways). Furthermore, the Clayton regulator and Narrung bund were breached in September 2010, and Lake Alexandrina was reconnected with Goolwa Channel and Lake Albert. The impacts of the regulators, pumping and unregulated River Murray flows on salinity and water levels are outlined in section 2.1

The recent period of low flow, regulator construction, pumping, unregulated River Murray flows and regulator breaching have caused large changes to the hydrological and salinity regime of the Lower Lakes since 2007. Salinity (e.g. Hart *et al.* 2003; James *et al.* 2003; Nielsen *et al.* 2003; Nielsen and Brock 2009) and water regime (determined by lake levels) (e.g. Brownlow 1997; Blanch *et al.* 1999; Brock *et al.* 1999; Blanch *et al.* 2000; Nicol *et al.* 2003) are two of the primary drivers of plant community composition in freshwater ecosystems. Historically, the systems were connected with relatively stable water levels ranging from +0.4 to +0.8 m AHD and surface water electrical conductivity lower than 2,000 $\mu S.cm^{-1}$ (Kingsford *et al.* 2009; Kingsford *et al.* 2011). Between 2007 and August 2010 surface water salinity, water regime and connectivity of the study area varied dramatically from historical patterns; however, since September 2010 the aforementioned factors have reflected historical patterns, except in Lake Albert where salinities have remained elevated.

The monitoring undertaken in 2010-11 builds on data collected from 2008 to 2010 and provides information regarding the change in plant communities since spring 2008. The survey period includes a period of record low water levels in Lake Alexandrina, several engineering interventions and an unregulated River Murray flow. Therefore, this monitoring program collected information regarding the change in wetland plant communities in response to drawdown, desiccation and increased water levels due to regulated inundation and natural flooding and provided an insight into recovery of the system under hydrological restoration. 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.
- Monitor the early stages of recovery of the aquatic plant community after hydrological restoration following extended drought, drawdown, fragmentation and desiccation of aquatic habitats.

2 Methods

2.1 Study site

Vegetation surveys were undertaken in Goolwa Channel, the lower Finniss River, Lower Currency Creek (herein referred to collectively as the Goolwa Channel), Lake Alexandrina and Lake Albert (Figure 1). Since early 2008, a range of interventions have been undertaken in the Lower Lakes to regulate water levels and mitigate acid sulfate soils; primarily construction of the Narrung bund and Clayton regulator (Figure 1). Construction of the Narrung bund was completed in early 2008 and disconnected Lake Albert from Lake Alexandrina (Figure 1). Water was then pumped from Lake Alexandrina into Lake Albert to maintain water levels above -0.5 m AHD. Construction of the Clayton regulator was finished in August 2009 and impounded water from the Finniss River and Currency and Tookayerta creeks (Figure 1). In addition, water was pumped from Lake Alexandrina to raise water levels to +0.7 m AHD in spring 2009.

Construction of the Narrung bund and Clayton regulator enabled independent management of Lake Alexandrina, Lake Albert and Goolwa Channel, which is reflected in water levels (Figure 2) and surface water salinity (measured as electrical conductivity (EC, $\mu S.cm^{-1}$) (Figure 3). Water levels in Lake Alexandrina were dependent on River Murray inflows and, to a much lesser extent, pumping into Lake Albert and Goolwa Channel. Due to low flows into South Australia, the water level in Lake Alexandrina remained below sea level for much of this previous survey period (Figure 2). River Murray flows into Lake Alexandrina increased in April 2010, and the lake was restored to historical water levels in August 2010 and fluctuated between +0.6 and +0.8 m AHD for the remainder of the survey period (Figure 2). Whilst River Murray inflows were below average, surface water EC in Lake Alexandrina remained relatively constant and ranged from 4,000 to 7,000 $\mu S.cm^{-1}$ (Figure 3). When inflows increased, EC decreased and by December 2010 had fallen to around 500 $\mu S.cm^{-1}$ where it remained for the remainder of the study period (Figure 3).

From August 2008 to August 2010 water levels in Lake Albert were dependent on pumping from Lake Alexandrina, local rainfall and evaporation. Between August 2008 and March 2009 water level decreased from -0.1 to -0.55 m AHD then increased to approximately -0.1 m AHD by September 2009 (Figure 2) as a result of pumping from Lake Alexandrina. Pumping ceased in September 2009 and water levels decreased to -0.7 m AHD in January 2010 (Figure 2). Pumping recommenced between April and June 2010 and water levels increased to -0.4 m AHD (Figure 2). In September 2010 the Narrung bund was breached, Lake Albert was reconnected with Lake Alexandrina, the water level increased rapidly to +0.8 m AHD and was dependent on water level in Lake Alexandrina for the remainder of the study period (Figure 2). Surface water EC increased from 5,000 to 12,000 $\mu S.cm^{-1}$ from August 2008 to March 2009, then (as a result of pumping from Lake Alexandrina) decreased to around 9,500 $\mu S.cm^{-1}$ by May 2009 and then remained relatively constant until October 2009 (Figure 3). When pumping ceased, surface water EC increased and exceeded 20,000 $\mu S.cm^{-1}$ by February 2010 (Figure 3). When pumping recommenced EC decreased to approximately 14,000 $\mu S.cm^{-1}$ until September 2010 when the bund was breached (Figure 3). After the bund was breached, EC decreased rapidly to 8,000 $\mu S.cm^{-1}$ and then slowly decreased to 6,000 $\mu S.cm^{-1}$ by the end of the study period (Figure 3).

Water levels in Goolwa Channel from August 2008 to August 2009 were dependent on River Murray inflows (Figure 2). Following completion of the Clayton Regulator, from August 2009 to August 2010, water level was dependent upon pumping from Lake Alexandrina, inflows from the Finniss River and Currency and Tookayerta creeks, local rainfall and evaporation and reached +0.75 m AHD (Figure 2). Pumping ceased in November 2009 and water levels decreased to -0.1 m AHD in April/May2010 (Figure 2). Water levels increased to +0.2 m AHD in response to tributary inflows in July 2010, and the regulator was breached in September 2010, which resulted in water levels rising to +0.8 m AHD (Figure 2). For the remainder of the survey period water levels were dependent on Lake Alexandrina water levels (Figure 2). Surface water EC at the beginning of the study period was approximately 21,000 $\mu S.cm^{-1}$, which decreased to around 14,000 $\mu S.cm^{-1}$ in September 2008, and then increased over spring and summer reaching a maximum of 33,000 $\mu S.cm^{-1}$ in February/March 2009 (Figure 3). The elevated EC was due to a combination of low River Murray inflows and seawater leaking through Goolwa Barrage into Goolwa Channel. From March 2009 to August 2009 EC decreased to around 20,000 $\mu S.cm^{-1}$ (Figure 3) due to higher water levels in Lake Alexandrina and engineering works that reduced seawater leakage through Goolwa Barrage. Construction of the Clayton regulator was completed and pumping from Lake Alexandrina commenced in August 2009, which reduced EC in Goolwa Channel to 10,000 $\mu S.cm^{-1}$ until pumping ceased in November 2009 (Figure 3). Surface water EC increased to around 20,000 $\mu S.cm^{-1}$ by April 2010 and fluctuated between 20,000 and 22,000 $\mu S.cm^{-1}$ until the regulator was breached in September 2010 (Figure 3). Post August 2010, EC decreased rapidly to approximately 500 $\mu S.cm^{-1}$ for the remainder of the survey period (Figure 3).

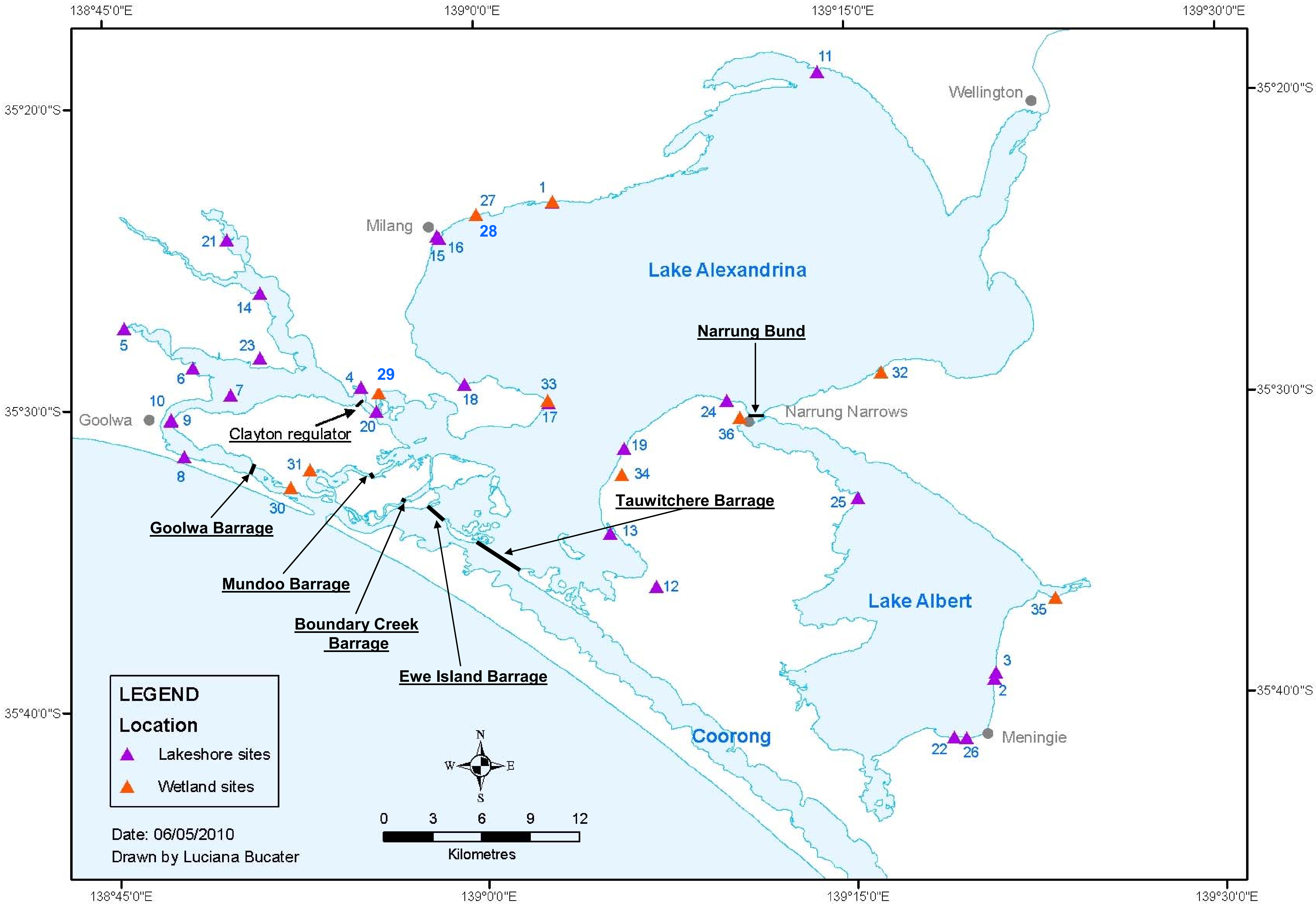

Figure 1: Map of Lakes Alexandrina and Albert and Goolwa Channel showing the location of lakeshore and wetland vegetation monitoring sites (site numbers correspond to Table 1) and major flow control structures.

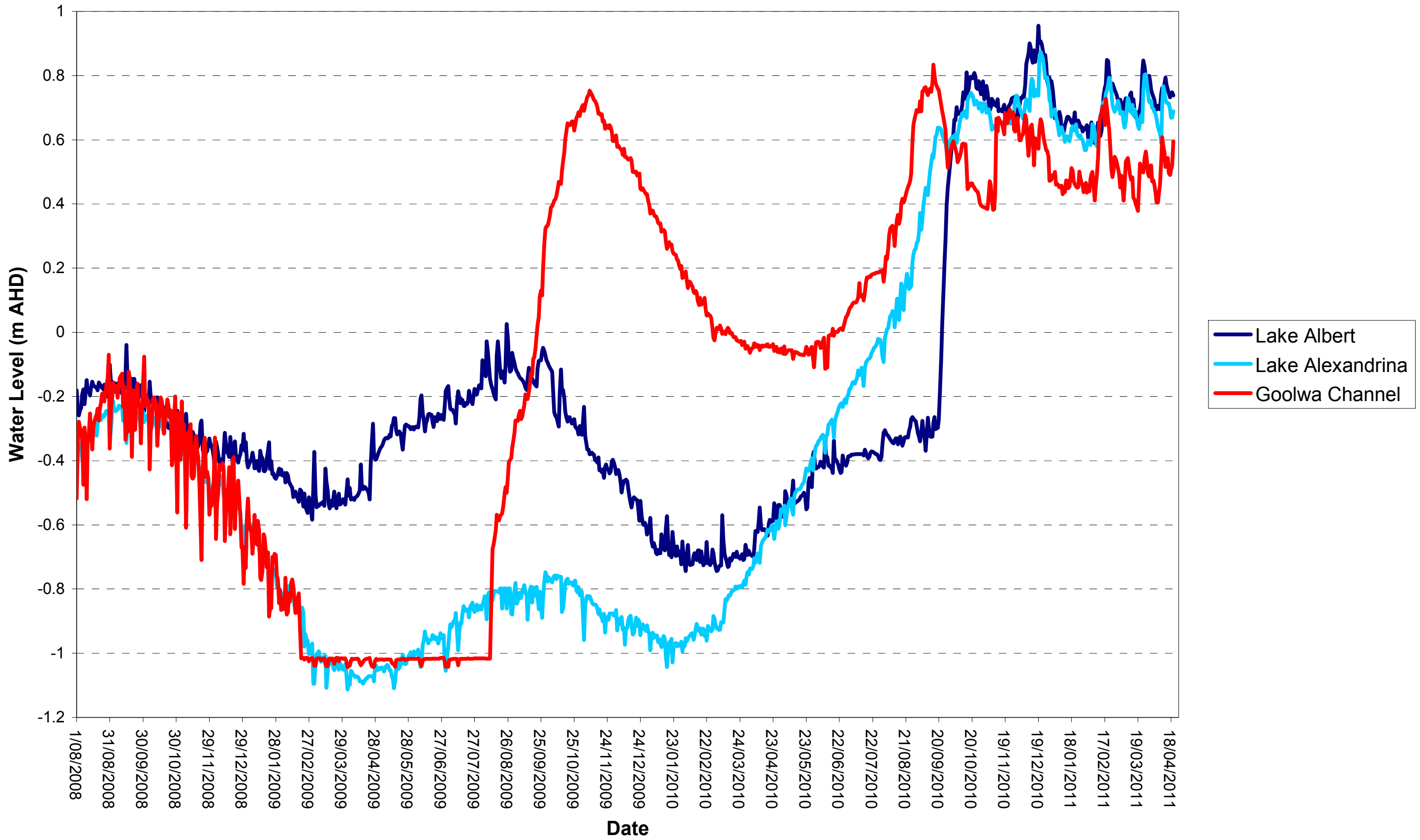

Figure 2: Water levels in Goolwa Channel (Signal Point), Lake Alexandrina (Milang) and Lake Albert (Meningie) from August 2008 to April 2011 (Department for Water 2011b).

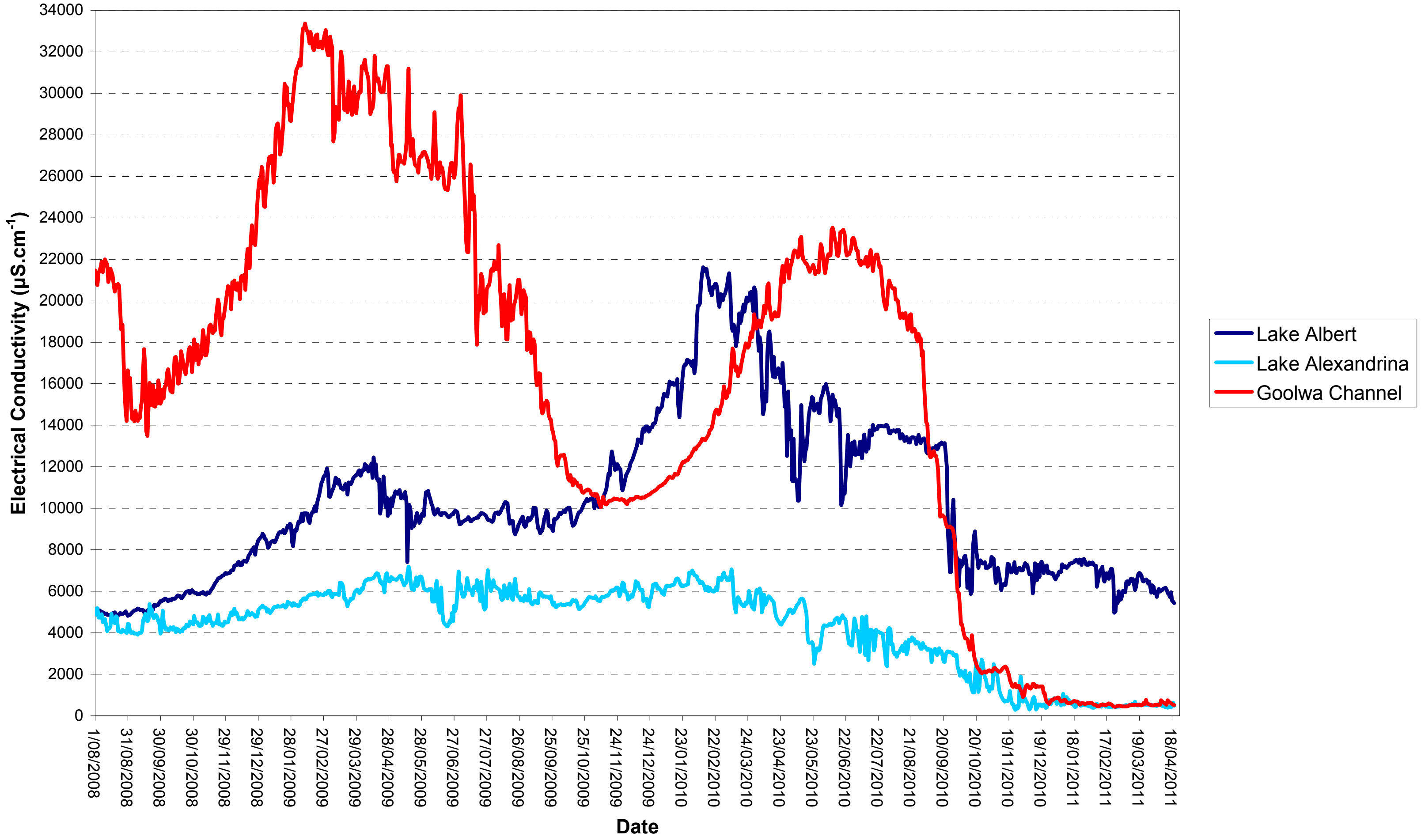

Figure 3: Surface water electrical conductivity (EC) in Goolwa Channel (Signal Point), Lake Alexandrina (Milang) and Lake Albert (Meningie) from August 2008 to April 2011 (Department for Water 2011a).

2.2 Vegetation surveying protocol

Monitoring of understorey vegetation was conducted at 11 wetland and 25 lakeshore sites in October 2008, March 2009, October 2009, March 2010, November 2010 and March 2011 (for sites established in 2008 or earlier) and October 2009, March 2010, November 2010 and March 2011 for sites established in 2009 (Table 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

Site #	Site Name	Location	Habitat	Year Established
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

2.2.1 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 established (Figure 4) at regular elevation intervals that represented the dominant plant communities (A. Frears pers. comm.). In wetlands with an established 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 plant community present during the spring 2008 survey. A minimum of one additional transect (but usually two or more transects were established in each wetland) was established, and quadrats were placed at the same elevations (determined using a laser level) 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 and T 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

2.2.2 Lakeshores

At each site, a transect running perpendicular to the shoreline was established and three, 1 x 3 m quadrats, separated by 1 m, were established at elevation intervals of +0.8, +0.6, +0.4, +0.2, 0 and -0.5 m AHD (Figure 4) (*sensu* Marsland and Nicol 2009; Gehrig and Nicol 2010a; Gehrig *et al.* 2010; Nicol and Marsland 2010).

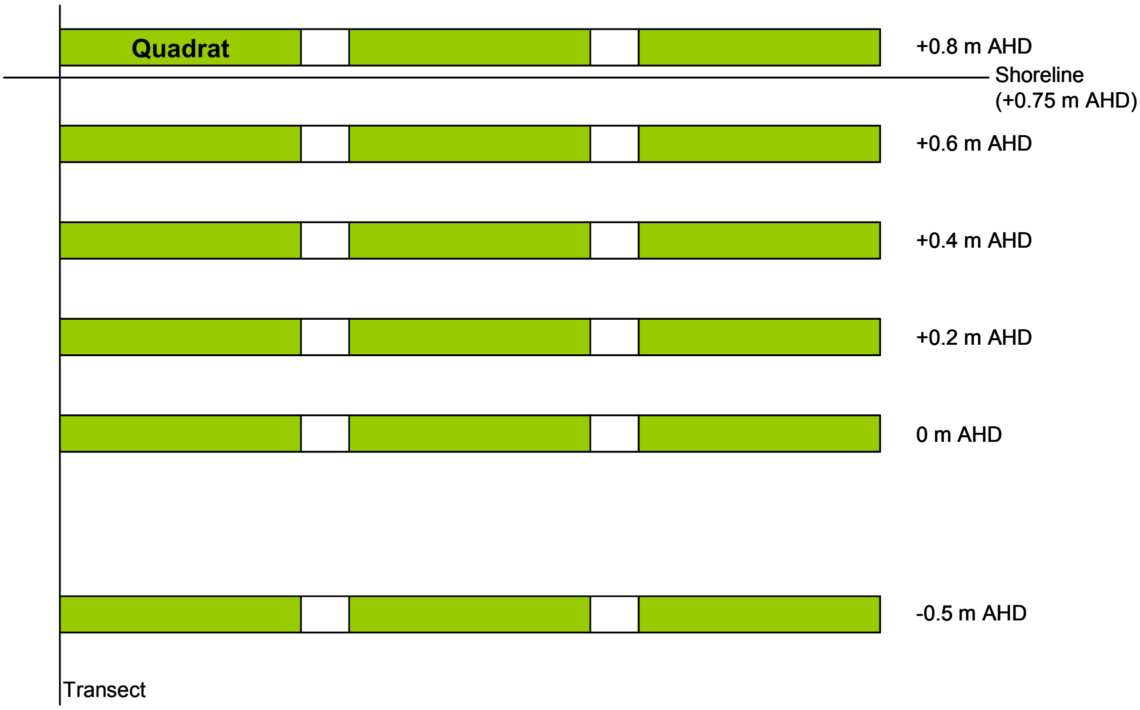

Figure 4: Vegetation surveying protocol for lakeshore sites: plan view showing placement of quadrats relative to the shoreline.

2.2.3 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 (1988) 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 species present, species were classified into functional groups (based on water regime preferences) outlined in Table 3 (see also Appendix 2). The position each group occupies in relation to flooding depth and duration is outlined in Figure 4. The 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 (2010b) to suit the Lower Lakes.

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 regime 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 and does not require prior biological knowledge of the system,
- it 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 to 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 and between locations and elevations, and TLM targets will be assessed using the species approach and discussed using both species and functional approaches.

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

Functional Group	Water Regime Preference	Examples
Terrestrial dry	Will not tolerate inundation and tolerates low soil moisture for extended periods.	*Medicago* spp.* *Brassica rapa** *Bromus* spp.*
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.	*Isolepis producta* *Isolepis platycarpa*
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* *Ludwigia peploides* *Cotula coronopifolia* *Hydrocotyle verticillata*
Floating	Static or fluctuating water levels, plants respond 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*
Emergent	Static shallow water <1 m or permanently saturated soil.	*Typha* spp. *Phragmites australis* *Schoenoplectus validus*
Submergent k-selected	Permanent water.	*Myriophyllum salsugineum* *Vallisneria australis* *Ruppia megacarpa* *Potamogeton pectinatus*

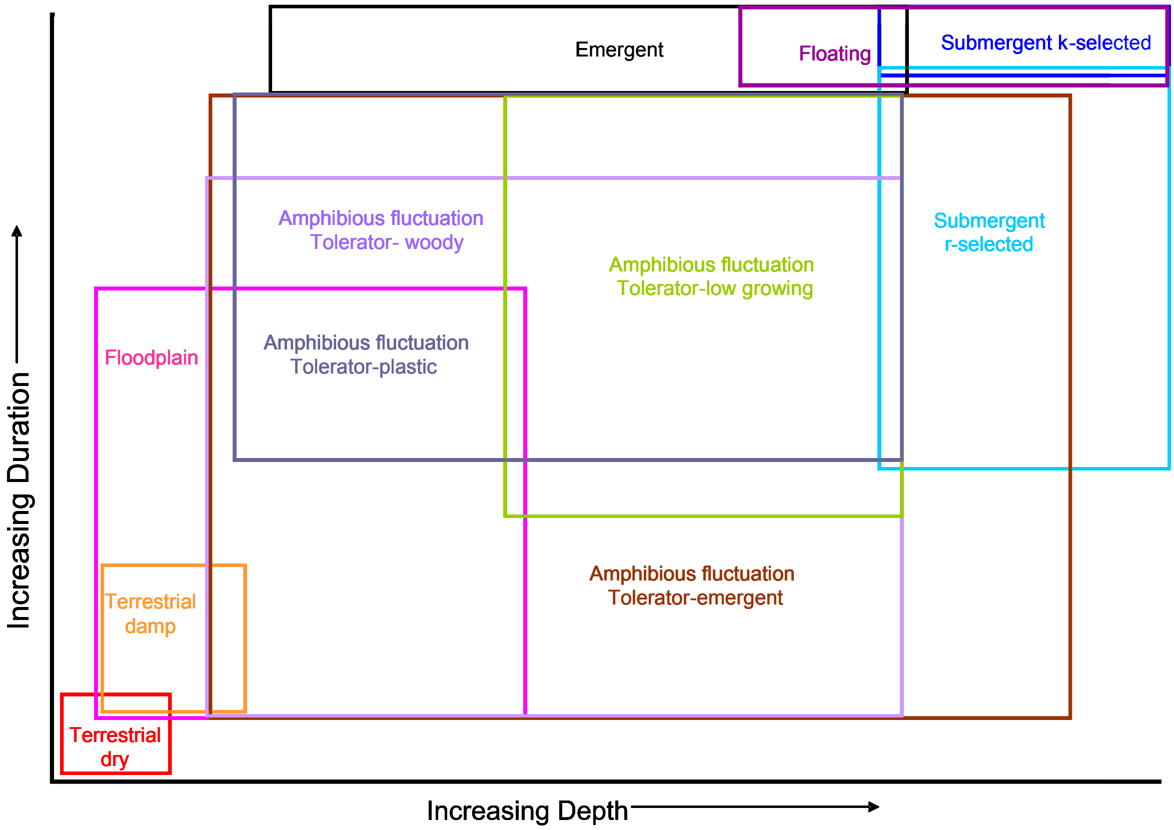

Figure 5: Plant functional groups in relation to depth and duration of flooding.

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 5) and consist of woody perennial species (Table 3) (Brock and Casanova 1997). 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 groups (Figure 5); 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 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 (Table 3).

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 5).

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 have 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 dependent 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 combined and treated as one wetland) using two-factor PERMANOVA (Anderson 2001; Anderson and Ter Braak 2003) and Indicator Species Analysis (Dufrene and Legendre 1997) using the packages PRIMER version 6.1.12 (Clarke and Gorley 2006) and PCOrd version 5.12 (McCune and Mefford 2006).

2.4.2 Lakeshores

Lakeshore sites were analysed separately to the wetlands. Changes in floristic composition through time and between elevations for each location (Goolwa Channel, Lake Alexandrina and Lake Albert) were analysed independently using two-factor PERMANOVA (Anderson 2001; Anderson and Ter Braak 2003) and Indicator Species Analysis (Dufrene and Legendre 1997) using the packages PRIMER version 6.1.12 (Clarke and Gorley 2006) and PCOrd version 5.12 (McCune and Mefford 2006).

Data were pooled across sites (each transect was a replicate) and Bray-Curtis (1957) similarities were used to calculate the similarity matrices for all multivariate analyses. α=0.05 for all statistical analyses.

2.4.3 Indicator Species Analysis

Dufrene and Legendre's (1997) indicator species analysis combines information on the concentration of species abundance in a particular group and the faithfulness of occurrence of a species in a particular group (McCune *et al.* 2002). A perfect indicator of a particular group should be faithful to that group (always present) and exclusive to that group (never occurring in other groups) (McCune *et al.* 2002). This test produces indicator values for each species in each group based on the standards of the perfect indicator. Statistical significance of each indicator value is tested by using a Monte Carlo (randomisation) technique, where the real data is compared against 5000 runs of randomised data (Dufrene and Legendre 1997). For this study, groups were assigned according to survey date and elevation for wetlands and survey date and elevation within a location for lakeshores. A species that is deemed not to be a significant indicator of a particular group is either found in one group but in low numbers (uncommon) or found in more than one group in similar numbers (widespread) (Dufrene and Legendre 1997).

In this study indicator species analysis was used to explain what was driving differences in floristic composition detected by PERMANOVA; however, widespread and uncommon species are not necessarily ecologically insignificant. Uncommon species may be of conservation significance and widespread species may be the dominant species throughout the survey period (e.g. hardy perennial taxa) or present in similar numbers seasonally (e.g. winter/spring annuals). Hence, raw data were examined for each wetland and lakeshore site to provide a description of the plant community.

3 Results

3.1 Wetlands

A total of 143 taxa (including 74 exotics and one species listed as rare in South Australia) were recorded for all wetland sites between spring 2008 and autumn 2011 (Appendix 3). Functional groups for the recorded taxa are listed in Appendix 2. In all wetlands (except Narrung), changes in floristic composition through time were not consistent between elevations, as indicated by a significant interaction between elevation and time.

Table 4: PERMANOVA results comparing the plant community through time and between elevations for each wetland.

Wetland	Factor	*df*	*Pseudo-F*	*P*
Angas and Bremer River Mouths	Time	5	2.90	<0.001
	Elevation	1	28.37	<0.001
	Time × Elevation	5	3.145	<0.001
Dunn's Lagoon	Time	5	7.77	<0.001
	Elevation	4	51.37	<0.001
	Time × Elevation	20	4.24	<0.001
Goolwa Channel Drive	Time	5	7.46	<0.001
	Elevation	2	45.24	<0.001
	Time × Elevation	10	3.54	<0.001
Hunter's Creek	Time	5	14.75	<0.001
	Elevation	1	124.82	<0.001
	Time × Elevation	5	9.72	<0.001
Loveday Bay	Time	5	9.64	<0.001
	Elevation	4	8.39	<0.001
	Time × Elevation	20	2.42	<0.001
Milang	Time	5	3.48	<0.001
	Elevation	3	14.81	<0.001
	Time × Elevation	15	15.56	<0.001
Narrung	Time	5	2.09	0.024
	Elevation	3	49.14	<0.001
	Time × Elevation	15	1.14	0.281
Poltalloch	Time	5	15.08	<0.001
	Elevation	3	12.52	<0.001
	Time × Elevation	15	4.31	<0.001
Point Sturt	Time	5	14.35	<0.001
	Elevation	2	9.54	<0.001
	Time × Elevation	10	3.12	<0.001
Teringie	Time	5	5.34	<0.001
	Elevation	3	28.03	<0.001
	Time × Elevation	15	5.20	<0.001
Waltowa	Time	5	3.90	<0.001
	Elevation	3	30.79	<0.001
	Time × Elevation	15	2.65	<0.001

3.1.1 Angas and Bremer River Mouths

A total of 35 taxa (including 18 exotics) were recorded at the mouths of the Angas and Bremer Rivers (Appendix 3). On the edges of the streams, there were significantly higher abundances of taxa from floodplain and emergent functional groups in spring 2008, but no significant indicator species were detected for the remainder of the survey period (Table 6). The edges of both streams were dominated by *Pennisetum clandestinum* (terrestrial dry) throughout the survey period.

The changes in floristic composition were more dynamic in the channel, where differences were reflected in higher abundances of terrestrial damp and floodplain taxa in autumn 2009; followed by an increase in abundance of *Vallisneria australis* (submergent k-selected) in spring 2009 and *Chenopodium album** (terrestrial damp) in autumn 2010 (Table 6). Following inundation with lake water in winter 2010, *Triglochin procerum* (emergent) was a significant indicator in spring 2010, while *Azolla filiculoides* (floating) and *Ceratophyllum demersum* (submergent k-selected) were significant indicators in autumn 2011 (Table 6).

3.1.2 Dunn's Lagoon

A total of 65 taxa (including 31 exotics) were recorded in Dunn's Lagoon (Appendix 3). From spring 2008 until autumn 2010, the most abundant taxa were generally from floodplain and terrestrial dry and terrestrial damp functional groups, but by spring 2010 (when all but the highest elevation were inundated) there was a strong shift towards aquatic taxa (amphibious, emergent and submergent functional groups) (Table 7). The highest elevation was dominated by *Paspalum distichum** (terrestrial damp) throughout the survey period; although there was a significant increase in abundance between spring 2010 and autumn 2011 (Table 7).

3.1.3 Goolwa Channel Drive

A total of 29 taxa (including 11 exotics) were recorded at Goolwa Channel Drive Wetland (Appendix 3). Throughout the survey period, the highest (3) and middle (2) elevations vegetation was predominantly a native salt marsh community. *Suaeda australis* (amphibious fluctuation tolerator-emergent), *Sarcocornia quinqueflora* (amphibious fluctuation tolerator-emergent), *Juncus kraussii* (amphibious fluctuation tolerator-emergent), *Frankenia pauciflora* (terrestrial dry), *Samolus repens* (terrestrial damp), *Distichlis distichophylla* (terrestrial damp), *Triglochin striatum* (amphibious fluctuation tolerator-emergent) and *Schoenoplectus pungens* (amphibious fluctuation tolerator-emergent) were present throughout the survey period; nevertheless, abundances did change through time. *Distichlis distichophylla* (terrestrial damp) and *Lachnagrostis filiformis* (floodplain) were more abundant at elevation 2 in spring 2008 and *Distichlis distichophylla* (terrestrial damp) at elevation 1 in autumn 2009 (Table 8). *Sarcocornia quinqueflora* and *Schoenoplectus pungens* (both amphibious fluctuation tolerator-emergent species) were significant indicators of the autumn 2009 survey at elevation 2 and *Samolus repens* (terrestrial damp) and *Triglochin striatum* (amphibious fluctuation tolerator-emergent) of the spring 2010 survey at the same elevation (Table 8). *Samolus repens* (terrestrial damp) was also more abundant at elevation 1 in spring 2010 (Table 8). In autumn 2011, there was a significant increase in *Phragmites australis* (emergent), *Paspalum distichum** (terrestrial damp), *Sarcocornia quinqueflora* (amphibious fluctuation tolerator-emergent) and *Wilsonia rotundifolia* (terrestrial damp) at elevation 1 (Table 8).

At the lowest elevation (1), *Phragmites australis* (emergent) was abundant throughout the study period. Prior to inundation with lake water terrestrial damp taxa were abundant also (although, *Bolboschoenus caldwellii* (emergent) was a significant indicator of the autumn 2009 survey) (Table 8). After inundation with lake water there was a significant increase in the abundance of submergent taxa (Table 8).

3.1.4 Hunter's Creek

A total of 26 taxa (including 8 exotics and one species listed as rare in South Australia) were recorded in Hunter's Creek (Appendix 3). The plant community along the edges was dominated by *Paspalum distichum* (terrestrial damp) throughout the study period (although this species was significantly more abundant in spring 2010), with *Distichlis distichophylla* and *Sonchus oleraceus** (both terrestrial damp species) significant indicators for the spring 2008 and spring 2009 surveys respectively (Table 9). After the creek was inundated with lake water there was an increase in the abundance of emergent and submergent species growing in the shallowly flooded margins (Table 9).

The channel was devoid of vegetation until autumn 2010 when the amphibious, halophytes: *Suaeda australis* and *Sarcocornia quinqueflora* (both amphibious fluctuation tolerator-emergent species) had colonised the dry creek bed (Table 9). After the creek was inundated, there was a significant increase in submergent species and *Paspalum distichum** (terrestrial damp) in spring 2010 (Table 9). The submergent species declined in abundance between spring 2010 and autumn 2011 and *Paspalum distichum** was absent (Table 9).

3.1.5 Loveday Bay

At total of 47 taxa (including 27 exotics) were recorded in Loveday Bay (Appendix 3). Loveday Bay Wetland was not inundated by lake water in winter 2010 and was dominated by taxa that are adapted to elevated salinities (e.g. *Sarcocornia quinqueflora, Suaeda australis* (both amphibious fluctuation tolerator-emergent species) *Ruppia tuberosa, Lamprothamnium macropogon* (both submergent r-selected species)) except in areas closest to Lake Alexandrina where freshwater emergent species (e.g. *Typha domingensis, Phragmites australis*) were present (Appendix 3). The plant community changed seasonally (not well detected by indicator species analysis) with terrestrial winter annuals present at elevations 2 to 5 in the spring surveys and generally absent in the autumn surveys. However, some winter annuals were present in higher abundances in some surveys (e.g. *Trifolium* spp. (terrestrial dry) at elevations 2 and 3 in spring 2010, *Hordeum vulgare** (terrestrial dry) at elevation 1 in spring 2009) (Table 10). *Distichlis distichophylla* (terrestrial damp) was a significant indicator of the spring 2008 survey at elevations 2 to 5 but present throughout the survey period in lower numbers (Table 10). Elevation 1 was inundated each spring and dominated by the submergent r-selected species *Ruppia tuberosa* and *Lamprothamnium macropogon* at these times; albeit in significantly higher abundances in spring 2008 (Table 10). *Typha domingensis* (emergent) was also a significant indicator of the spring 2008 survey at elevation 1 (Table 10) but was only present in the inlet channel. Several terrestrial damp species, *Lactuca serriola* (terrestrial dry) and *Bolboschoenus caldwellii* (emergent) were more abundant in autumn 2011, which corresponded with a period of above average summer rainfall (Bureau of Meteorology 2011b).

3.1.6 Milang

A total of 63 taxa (including 37 exotics, the largest number recorded of the wetlands surveyed) were recorded in Milang Wetland (Appendix 3). Similar to Loveday Bay the plant community in Milang wetland changed seasonally with winter annuals present during the spring surveys at all elevations. In addition, an area that was inundated seasonally with local runoff contained *Myriophyllum* sp. (submergent k-selected) in spring 2008 and *Ruppia polycarpa* (submergent r-selected) every spring during the survey period (abundance peaked in spring 2009) (Table 11). There were several perennial taxa (*Phragmites australis* (emergent), *Pennisetum clandestinum** (terrestrial dry), *Muehlenbeckia florulenta* (amphibious fluctuation tolerator-woody) and *Paspalum distichum** (terrestrial damp)) that that did not change significantly in abundance throughout the survey period (except *Pennisetum clandestinum** (terrestrial dry), which was a significant indicator of the autumn 2011 survey at elevation 4) (Table 11). Elevations 3 and 4 were flooded with lake water in winter 2010; however, there was only limited recruitment of amphibious species post-inundation (Table 11).

3.1.7 Narrung

A total of 21 taxa (including 10 exotics) were recorded in Narrung Wetland (Appendix 3). The plant community between elevations 2 and 4 (inclusive) was predominantly a native salt marsh composed of *Sarcocornia quinqueflora* (amphibious fluctuation tolerator-emergent), *Suaeda australis* (amphibious fluctuation tolerator-emergent) and *Frankenia pauciflora* (terrestrial dry) and elevation 1 was bare soil (Table 12). Winter annuals were present in spring throughout the survey period at elevations 2 to 4, which were generally not detected as significant indicators except *Eragrostis curvula** (terrestrial damp) at elevation 4 in spring 2008 and *Puccinellia* spp. (terrestrial damp), *Spergularia marina** (terrestrial damp) (elevation 4), *Sonchus oleraceus* (terrestrial damp) (elevations 3 and 4) and *Eragrostis curvula** (elevation 3) in spring 2009 (Table 12).

Water was pumped into Narrung Wetland from Lake Alexandrina in spring 2009 and inundated elevations 2 and 1; however, the wetland had dried before the autumn 2010 survey. No live plants were present at elevation1; however, there was evidence of charophytes and *Ruppia tuberosa* (submergent r-selected) on the wetland bed. Narrung was inundated with lake water in summer 2010-11 but there was no recruitment of aquatic species in the inundated areas by autumn 2011.

3.1.8 Point Sturt

A total of 39 taxa (including 24 exotics) were recorded in Point Sturt Wetland (Appendix 3). Similar to Dunns Lagoon, the wetland was dominated by terrestrial taxa for the first two years of the survey period

(Table 13). After the wetland was inundated in winter 2010 the plant community was dominated by exotic amphibious species but by autumn 2011 the community consisted of native floating and submergent taxa (Table 13).

3.1.9 Poltalloch

At total of 25 taxa (including 15 exotics) were recorded in Poltalloch (Appendix 3). Prior to inundation with lake water, Poltalloch Wetland was dominated by salt tolerant taxa, with winter annuals present in the spring surveys (Table 14). After the wetland was inundated there was an increase in the abundance of amphibious species (*Polypogon monspeliensis** and *Sarcocornia quinqueflora* (both amphibious fluctuation tolerator-emergent species)), which were replaced by submergent taxa by autumn 2011 (Table 14).

3.1.10 Teringie

At total of 42 taxa (including 22 exotics) were recorded in Teringie (Appendix 3). The plant community prior to inundation was dominated by salt tolerant taxa (*Sarcocornia quinqueflora* (amphibious fluctuation tolerator-emergent), *Suaeda australis* (amphibious fluctuation tolerator-emergent), *Distichlis distichophylla* (terrestrial damp)) with winter annuals present in the spring surveys (Table 15). Elevation 1 was inundated during spring 2010 from local runoff and the submergent r-selected species *Lamprothamnium macropogon* and *Ruppia tuberosa* and terrestrial damp species *Spergularia marina** had recruited (Table 15). Elevation 1 was inundated with lake water in summer 2010-11; however, there was no recruitment of aquatic species by autumn 2011 (Table 15). Elevations 2 to 4 remained dominated by salt tolerant taxa for the corresponding period with winter annuals present in spring 2010.

3.1.11 Waltowa

A total of 15 taxa (including 10 exotics) were recorded in Waltowa (Appendix 3). The flow control structure on the inlet channel of Waltowa Wetland remained shut for the survey period, even after lake levels returned to historical levels. Therefore, Waltowa remained dry for the survey period. The plant community at Waltowa was dominated by salt tolerant taxa (*Sarcocornia quinqueflora* and *Suaeda australis* (both amphibious fluctuation tolerator-emergent species)) at elevations 2 to 4 and bare soil at elevation 1 (elevation 1 was completely devoid of live plants for the survey period). Winter annuals were also present at elevations 2 to 4 during the spring surveys (Table 16). *Senecio runcinifolius* (floodplain) was present at significantly higher abundances at elevations 3 and 4 in spring 2008 and *Glyceria australis* (amphibious fluctuation tolerator-emergent) at elevations 2 and 3 in spring 2009.

Table 5: Colour codes for vegetation functional groups.

Functional Group (colour codes)
Terrestrial dry
Terrestrial damp
Floodplain
Amphibious fluctuation tolerators-emergent
Amphibious fluctuation tolerators-woody
Amphibious fluctuation tolerators-low growing
Amphibious fluctuation responders-plastic
Floating
Emergent
Submergent r-selected
Submergent k-selected

Table 6: Significant indicator species (Dufrene and Legendre 1997) for Angas and Bremer River Mouths between elevations, from spring 2008 to autumn 2011. Functional groups are also shown (colour codes provided in Table 5).

Elevation	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
Edge	*Aster subulatus** *Berula erecta** *Typha domingensis*					
Channel		*Aster subulatus** *Atriplex prostrata**	*Vallisneria australis*	*Chenopodium album**	*Triglochin procerum*	*Azolla filiculoides* *Ceratophyllum demersum*

Table 7: Significant indicator species (Dufrene and Legendre 1997) for Dunn's Lagoon between elevations, from spring 2008 to autumn 2011. Functional groups are also shown (colour codes provided in Table 5).

Elevation		Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
Highest → Lowest elevation	5	Distichlis distichophylla Samolus repens		Eragrostis curvula* Eragrostis sp. Medicago sp.* Melilotus indica* Plantago coronopus* Sonchus oleraceus*		Bromus diandrus* Bromus mollis* Hordeum vulgare*	Hypochoeris glabra* Paspalum distichum* Wilsonia rotundifolia
	4		Paspalum distichum*		Atriplex prostrata* Calystegia sepium Spergularia marina*		Azolla filiculoides Cotula coronopifolia* Myriophyllum salsugineum Triglochin procerum Typha domingensis
	3	Eragrostis sp. Hydrocotyle verticillata Persicaria lapathifolia Urtica urens*	Chenopodium glaucum*	Atriplex prostrata* Cotula coronopifolia* Pseudognaphalium luteo-album Reichardia tingitana* Senecio pterophorus* Sonchus oleraceus*	Ficinia nodosa		Azolla filiculoides Myriophyllum salsugineum Vallisneria australis
	2		Aster subulatus* Chenopodium glaucum*	Lachnagrostis filiformis Cotula coronopifolia* Eragrostis sp. Samolus repens Senecio pterophorus* Sonchus oleraceus* Spergularia marina*	Atriplex prostrata* Paspalum distichum*		Myriophyllum salsugineum Triglochin procerum
	1		Chenopodium glaucum*	Cotula coronopifolia* Senecio pterophorus* Sonchus oleraceus* Spergularia marina*			Myriophyllum salsugineum

Table 8: Significant indicator species (Dufrene and Legendre 1997) for Goolwa Channel Drive between elevations, from spring 2008 to autumn 2011. Functional groups are also shown (colour codes provided in Table 5).

Elevation (Highest → Lowest elevation)	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
3		*Distichlis distichophylla*			*Samolus repens* *Sonchus oleraceus**	*Paspalum distichum** *Phragmites australis* *Sarcocornia quinqueflora* *Wilsonia rotundifolia*
2	*Lachnagrostis filiformis* *Distichlis distichophylla*	*Sarcocornia quinqueflora* *Schoenoplectus pungens*		*Paspalum distichum**	*Samolus repens* *Triglochin striatum*	
1	*Sonchus oleraceus**	*Bolboschoenus caldwellii* *Paspalum distichum**		*Atriplex prostrata**	*Distichlis distichophylla* *Ruppia polycarpa* *Sarcocornia quinqueflora* *Suaeda australis*	*Potamogeton crispus*

Table 9: Significant indicator species (Dufrene and Legendre 1997) for Hunter's Creek between elevations, from spring 2008 to autumn 2011. Functional groups are also shown (colour codes provided in Table 5).

Elevation	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
Edge	*Distichlis distichophylla*		*Sonchus oleraceus**		*Eleocharis acuta* *Eragrostis curvula** *Paspalum distichum** *Plantago coronopus**	*Bolboschoenus caldwellii* *Ruppia megacarpa*
Channel				*Sarcocornia quinqueflora* *Suaeda australis*	*Paspalum distichum** *Potamogeton pectinatus* *Ruppia megacarpa* *Ruppia polycarpa*	

Table 10: Significant indicator species (Dufrene and Legendre 1997) for Loveday Bay between elevations, from spring 2008 to autumn 2011. Functional groups are also shown (colour codes provided in Table 5).

Elevation	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
Highest → Lowest elevation 5	_Distichlis distichophylla_		_Eragrostis curvula_* _Hordeum vulgare_*		_Lolium_ sp.* _Sonchus oleraceus_*	_Aster subulatus_* _Centaurea calcitrapa_* _Paspalum distichum_*
4	_Distichlis distichophylla_		_Eragrostis curvula_* _Sonchus oleraceus_*	_Suaeda australis_	_Centaurea calcitrapa_*	_Lactuca serriola_*
3	_Distichlis distichophylla_		_Schoenoplectus pungens_ _Sonchus oleraceus_*		_Trifolium_ sp.*	_Atriplex prostrata_* _Bolboschoenus caldwellii_
2	_Distichlis distichophylla_				_Lolium_ sp.* _Polypogon monspeliensis_* _Trifolium_ sp.*	_Bolboschoenus caldwellii_
1	_Lamprothamneum macropogon_ _Ruppia tuberosa_ _Typha domingensis_			_Atriplex prostrata_*		

Table 11: Significant indicator species (Dufrene and Legendre 1997) for Milang between elevations, from spring 2008 to autumn 2011. Functional groups are also shown (colour codes provided in Table 5).

Elevation	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
Highest → Lowest elevation 1	_Bromus diandrus_* _Medicago_ sp.*				_Lactuca serriola_* _Polypogon monspeliensis_*	
2	_Cotula coronopifolia_* _Medicago_ sp.*		_Lolium_ sp.* _Sonchus oleraceus_*		_Lactuca serriola_* _Polypogon monspeliensis_*	_Aster subulatus_* _Silybum marianum_*
3	_Lactuca saligna_* _Myriophyllum_ sp.		_Ruppia polycarpa_	_Cyperus gymnocaulos_ _Distichlis distichophylla_ _Enchylaena tomentosa_ _Lactuca serriola_* _Phragmites australis_ _Plantago coronopus_*	_Bromus mollis_* _Polypogon monspeliensis_*	
4	_Eragrostis_ sp.				_Bromus mollis_* _Conyza bonariensis_* _Triglochin striatum_	_Pennisetum clandestinum_*

Table 12: Significant indicator species (Dufrene and Legendre 1997) for Narrung Wetland between elevations, from spring 2008 to autumn 2011. Functional groups are also shown (colour codes provided in Table 5).

Elevation		Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
Highest elevation → Lowest	4	*Eragrostis curvula**		*Puccinellia* spp. *Sonchus oleraceus** *Spergularia marina**			
	3			*Eragrostis curvula** *Sonchus oleraceus**			
	2						
	1	Bare Soil					

Table 13: Significant indicator species (Dufrene and Legendre 1997) for Point Sturt between elevations, from spring 2008 to autumn 2011. Functional groups are also shown (colour codes provided in Table 5).

Elevation		Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
Highest elevation → Lowest	3	*Distichlis distichophylla*		*Reichardia tingitana**	*Atriplex suberecta* *Enchylaena tomentosa*	*Polypogon monspeliensis**	
	2	*Chenopodium glaucum** *Sonchus oleraceus**	*Enchylaena tomentosa*	*Reichardia tingitana** *Spergularia marina**		*Cotula coronopifolia** *Polypogon monspeliensis**	*Lemna* sp.
	1	*Chenopodium glaucum** *Distichlis distichophylla*	*Sarcocornia quinqueflora*	*Eragrostis curvula** *Reichardia tingitana** *Sonchus oleraceus** *Spergularia marina**	*Lycium ferocissimum**	*Polypogon monspeliensis**	*Lemna* sp. *Ruppia polycarpa*

Table 14: Significant indicator species (Dufrene and Legendre 1997) for Poltalloch between elevations, from spring 2008 to autumn 2011. Functional groups are also shown (colour codes provided in Table 5).

Elevation (Highest → Lowest elevation)	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
4	*Sarcocornia quinqueflora*		*Eragrostis curvula** *Hordeum vulgare** *Lolium* sp.* *Sonchus oleraceus**			*Paspalum distichum** *Suaeda australis*
3	*Distichlis distichophylla*		*Cotula coronopifolia** *Eragrostis curvula** *Polypogon monspeliensis** *Sonchus oleraceus**			
2	*Chenopodium glaucum**		*Distichlis distichophylla*		*Sarcocornia quinqueflora*	*Chara* spp. *Lamprothamnium macropogon*
1	*Chenopodium glaucum**		*Spergularia marina**	*Suaeda australis*	*Polypogon monspeliensis** *Sarcocornia quinqueflora*	*Chara* spp. *Lamprothamnium macropogon*

Table 15: Significant indicator species (Dufrene and Legendre 1997) for Teringie between elevations, from spring 2008 to autumn 2011. Functional groups are also shown (colour codes provided in Table 5).

Elevation (Highest → Lowest elevation)	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
4	*Eragrostis curvula** *Hordeum vulgare**		*Avena barbata** *Bromus diandrus** *Bromus hordeaceus** *Lolium* sp.*		*Lobelia alata* *Sonchus oleraceus**	
3	*Cotula coronopifolia** *Frankenia pauciflora* *Hordeum vulgare**		*Eragrostis curvula** *Lolium* sp.* *Polypogon monspeliensis**			
2	*Cotula coronopifolia** *Eragrostis curvula**					
1		*Distichlis distichophylla* *Sarcocornia quinqueflora*			*Lamprothamneum macropogon* *Ruppia tuberosa* *Spergularia marina**	

Table 16: Significant indicator species (Dufrene and Legendre 1997) for Waltowa between elevations, from spring 2008 to autumn 2011. Functional groups are also shown (colour codes provided in Table 5).

Elevation		Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
Highest Lowest elevation ↓	4	*Senecio runcinifolius*				*Lolium* sp.*	
	3	*Senecio runcinifolius*		*Glyceria australis* *Sonchus oleraceus**			
	2			*Glyceria australis* *Poa annua** *Sonchus oleraceus**			
	1	Bare Soil					

3.2 Lakeshores

A total of 114 taxa (including 57 exotics and one species listed as rare in South Australia) were recorded at shoreline sites in Lake Alexandrina, Lake Albert and Goolwa Channel. Lake Alexandrina had the highest species richness (98 taxa) followed by Goolwa Channel (56) with Lake Albert the least species rich (48) (Appendix 4). Lake Albert had the highest proportion of exotics (62.5%) compared to Lake Alexandrina (49%) and Goolwa Channel (46.4%) (Appendix 4).

In each location (Lake Alexandrina, Lake Albert and Goolwa Channel) the plant community changed through time and was different between elevations and there was a significant interaction between the two factors (Table 17). This indicates that the plant community changes through time were not consistent between elevations for each location; however, the species (and hydrological processes) that caused the changes differed between locations.

Table 17: PERMANOVA results comparing the plant community through time and between elevations for Lake Alexandrina, Lake Albert and Goolwa Channel shorelines.

Elevation	Factor	*df*	*F*	*P*
Lake Alexandrina	Elevation	5, 873	18.51	<0.001
	Time	5, 873	28.76	<0.001
	Elevation × Time	23, 873	6.64	<0.001
Lake Albert	Elevation	5, 419	14.95	<0.001
	Time	5, 419	24.53	<0.001
	Elevation × Time	23, 419	3.81	<0.001
Goolwa Channel	Elevation	5, 779	19.52	<0.001
	Time	5, 779	13.05	<0.001
	Elevation × Time	23, 779	2.97	<0.001

3.2.1 Lake Alexandrina

For the first two years of the survey period, the plant community in Lake Alexandrina was generally dominated by terrestrial taxa across all elevations (Table 18). However, there were some exceptions, *Salix babylonica* (emergent) was present at +0.8 m AHD, *Cyperus gymnocaulos* (amphibious fluctuation tolerator-emergent) and *Juncus acutus* (amphibious fluctuation tolerator-emergent) at +0.6 m AHD, *Polypogon monspeliensis** (amphibious fluctuation tolerator-emergent) at +0.4 m AHD, *Isolepis producta* (amphibious fluctuation tolerator-low growing) and *Ruppia tuberosa* (submergent r-selected) at -0.5 m AHD in spring 2008 (Table 18). *Salix babylonica** (emergent) and *Ruppia tuberosa* (submergent r-selected) were absent after spring 2008 and amphibious species recruited lower on the elevation gradient through time until spring 2010 (Table 18). When lake levels returned to historical levels in winter 2010 there was a significant increase in *Schoenoplectus validus* (emergent) at + 0.2 m AHD *Juncus usitatus* (amphibious fluctuation tolerator-emergent) at +0.4 m AHD by spring 2010 (Table 18). Furthermore, all of the terrestrial taxa had been extirpated from all elevations except +0.8 m AHD and the -0.5 m AHD elevation was devoid of plants. Between spring 2010 and autumn 2011 there was a significant increase in the abundance of floating, emergent and amphibious taxa from 0 to +0.8 m AHD (Table 18) but -0.5 m AHD remained bare.

3.2.2 Lake Albert

The plant community around the edge of Lake Albert, similar to Lake Alexandrina, was dominated by terrestrial species for the first two years of the survey period (Table 19). Several amphibious species were also present between +0.4 and +0.8 m AHD in spring 2008 but were subsequently replaced by terrestrial taxa with amphibious species recruiting lower on the elevation gradient through time until spring 2010 (Table 19). In contrast to Lake Alexandrina, when lake levels were restored there was no significant increase in abundance of emergent, amphibious (except *Cyperus gymnocaulos* (amphibious fluctuation tolerator-emergent)) or floating taxa (Table 19).

3.2.3 Goolwa Channel

In Goolwa Channel, terrestrial amphibious and emergent taxa dominated the plant community for the first year of the survey period (Table 20). Terrestrial species were extirpated when water levels rose in spring 2009 due to regulated flooding; however, there was limited recruitment of terrestrial taxa above 0 m AHD when water levels fell in summer and autumn 2009-10 (Table 20). In addition, by autumn 2010, *Potamogeton pectinatus* (submergent k-selected)) had recruited below 0 m AHD but was not a significant indicator (Table 20). By spring 2010, after water levels were reinstated, there was a significant increase in *Potamogeton pectinatus* (submergent k-selected) and *Triglochin procerum* (emergent); however, the *Potamogeton pectinatus* was replaced by *Myriophyllum salsugineum* (submergent k-selected) by autumn 2011. There was little change in the abundances of the emergent fringing species (e.g. *Phragmites australis*) over the survey period in Goolwa Channel.

Table 18: Significant indicator species (Dufrene and Legendre 1997) for Lake Alexandrina from spring 2008 to autumn 2011, at each elevation (*denotes exotic species). Functional groups are also shown (colour codes provided in Table 5).

Elevation (m AHD)	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
+0.8	*Brassica rapa** *Salix babylonica** *Vicia sativa**		*Avena barbata** *Bromus diandrus** *Hordeum vulgare** *Lactuca serriola** *Lolium* sp.* *Sonchus oleraceus**	*Pennisetum clandestinum**	*Atriplex prostrata**	*Azolla filiculoides* *Bolboschoenus caldwellii* *Persicaria lapathifolia* *Schoenoplectus pungens*
+0.6	*Aster subulatus** *Centaurea calcitrapa** *Cyperus gymnocaulos* *Eragrostis curvula** *Hordeum vulgare** *Hypochaeris glabra** *Juncus acutus** *Lachnagrostis filiformis* *Melilotus indica** *Onopordum acanthium** *Reichardia tingitana** *Trifolium* sp.*		*Bromus diandrus** *Hypochoeris radicata** *Lolium* sp.* *Lycopus australis* *Medicago* sp.*	*Pennisetum clandestinum**		*Azolla filiculoides* *Schoenoplectus pungens* *Schoenoplectus validus*
+0.4	*Cotula coronopifolia** *Distichlis distichophylla* *Eragrostis curvula** *Isolepis producta* *Lachnagrostis filiformis* *Lolium* sp.* *Medicago* sp.* *Melilotus indica** *Polypogon monspeliensis** *Pseudognaphalium luteo-album* *Reichardia tingitana** *Sonchus oleraceus**		*Avena* spp.* *Bromus diandrus** *Hordeum vulgare** *Persicaria lapathifolia* *Senecio pterophorus** *Sonchus asper**	*Ficinia nodosa* *Plantago coronopus**	*Juncus usitatus*	*Azolla filiculoides* *Lemna* sp. *Ludwigia peploides* *Schoenoplectus validus* *Typha domingensis*

Elevation (m AHD)	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
+0.2			*Avena* spp.* *Bromus diandrus** *Centaurea calcitrapa** *Conyza bonariensis** *Cyperus gymnocaulos* *Hordeum vulgare** *Lolium* sp.* *Medicago* sp.* *Pennisetum clandestinum** *Polypogon monspeliensis** *Sonchus oleraceus** *Trifolium* sp.*	*Aster subulatus** *Plantago coronopus**	*Schoenoplectus validus*	*Bolboschoenus caldwellii* *Typha domingensis*
0	*Eragrostis curvula** *Eragrostis* sp. *Isolepis producta* *Spergularia marina**	*Pennisetum clandestinum** *Picris hieracoides* *Polygonum aviculare** *Suaeda australis*	*Avena* spp.* *Bromus diandrus** *Centaurea calcitrapa** *Cotula coronopifolia** *Hordeum vulgare** *Lachnagrostis filiformis* *Lactuca serriola** *Lolium* sp.* *Medicago* sp.* *Plantago coronopus** *Polypogon monspeliensis** *Schoenoplectus pungens* *Senecio pterophorus** *Sonchus oleraceus** *Trifolium* sp.*	*Aster subulatus** *Juncus kraussii* *Paspalum distichum**		*Schoenoplectus validus*
-0.5	*Ruppia tuberosa*	*Conyza bonariensis** *Eragrostis* sp. *Picris hieracoides*	*Centaurium tenuiflorum** *Cotula coronopifolia** *Eragrostis curvula** *Hordeum vulgare** *Lachnagrostis filiformis* *Lobelia alata* *Lolium* sp.* *Plantago coronopus** *Polypogon monspeliensis** *Sonchus oleraceus**	*Chenopodium glaucum** *Paspalum distichum** *Suaeda australis*		

Table 19: Significant indicator species (Dufrene and Legendre 1997) for Lake Albert from spring 2008 to autumn 2011, at each elevation (*denotes exotic species). Functional groups are also shown (colour codes provided in Table 5).

Elevation (m AHD)	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
+0.8	*Distichlis distichophylla* *Polypogon monspeliensis** *Schoenoplectus pungens* *Sonchus oleraceus**		*Avena* spp.* *Bromus diandrus** *Lolium* sp.* *Pennisetum clandestinum**			
+0.6	*Medicago* sp. *Melilotus indica** *Polypogon monspeliensis** *Sonchus oleraceus**	*Schoenoplectus pungens*	*Avena* spp. *Bromus diandrus** *Lolium* sp.* *Pennisetum clandestinum**			*Paspalum distichum*
+0.4	*Distichlis distichophylla* *Lachnagrostis filiformis* *Polypogon monspeliensis** *Schoenoplectus validus*		*Bromus diandrus** *Lolium* sp.* *Pennisetum clandestinum** *Sonchus oleraceus*		*Cyperus gymnocaulos*	
+0.2			*Avena* spp.* *Bromus diandrus** *Lolium* sp.* *Paspalum distichum** *Pennisetum clandestinum** *Polypogon monspeliensis** *Sonchus oleraceus**	*Reichardia tingitana** *Sarcocornia quinqueflora*		
0			*Avena* spp.* *Bromus diandrus** *Cotula coronopifolia** *Lolium* sp.* *Pennisetum clandestinum** *Phragmites australis* *Polypogon monspeliensis** *Sonchus oleraceus**	*Paspalum distichum**		
-0.5		*Ficinia nodosa* *Lachnagrostis filiformis* *Paspalum distichum**	*Cotula coronopifolia** *Polypogon monspeliensis**			

Table 20: Significant indicator species (Dufrene and Legendre 1997) for Goolwa Channel from spring 2008 to autumn 2011, at each elevation (*denotes exotic species). Functional groups are also shown (colour codes provided in Table 5).

Elevation (m AHD)	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
+0.8	*Calystegia sepium* *Cyperus gymnocaulos* *Typha domingensis*	*Paspalum distichum**	*Sonchus oleraceus**			
+0.6	*Calystegia sepium* *Juncus kraussii*	*Lycopus australis* *Paspalum distichum**				
+0.4	*Aster subulatus** *Epilobium pallidiflorum* *Juncus kraussii* *Lachnagrostis filiformis* *Sonchus oleraceus**	*Atriplex* sp. *Chenopodium glaucum**			*Triglochin procerum*	
+0.2				*Atriplex prostrata**	*Potamogeton pectinatus* *Triglochin procerum*	
0	*Cotula coronopifolia**	*Atriplex prostrata** *Chenopodium glaucum** *Lachnagrostis filiformis*			*Potamogeton pectinatus*	*Myriophyllum salsugineum*
-0.5					*Potamogeton pectinatus*	

4 Discussion and management implications

4.1 Wetlands

Prior to 2007, the historical plant community in Lower Lakes wetlands was a diverse assemblage of submergent, amphibious, floating and emergent taxa (Renfrey *et al.* 1989; Holt *et al.* 2005; Nicol *et al.* 2006). From early 2007 to August 2010, wetlands were generally dominated by terrestrial taxa (Gehrig *et al.* 2010), which is typical of wetlands subjected to prolonged drawdown (e.g. Nicol 2010). Furthermore, 46 submergent, emergent and amphibious taxa that were recorded in the 2004 (Holt *et al.* 2005) and 2005 (Nicol *et al.* 2006) baseline surveys were not recorded between October 2008 and March 2010 (Gehrig *et al.* 2010). The only wetlands that supported wetland plant communities during this period were ones that contained areas that received local runoff. Theses areas supported submergent (usually submergent r-selected species), amphibious and emergent communities (Marsland and Nicol 2009; Gehrig *et al.* 2010). For example, Goolwa Channel Drive was dominated by emergent and amphibious taxa from 2008 to 2010, particularily at the lowest elevation (Gehrig *et al.* 2010). At the lowest elevation in Loveday Bay Wetland, submergent r-selected species (*Ruppia tuberosa* and *Lamprothamnium macropogon*) were present in spring 2008 (Gehrig *et al.* 2010). In Milang Wetland, 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 present (Gehrig *et al.* 2010). In the Angas and Bremer River mouths, submergent species (*Ceratophyllum demersum* and *Vallisneria australis*) were also present in spring surveys prior to August 2010. However, the water present in the channels of the Anagas and Bremer mouths each spring was due to catchment inflows derived from rainfall in the eastern Mount Lofty Ranges and not local runoff. In addition, Narrung wetland was watered in spring 2009 and Paton and Bailey (2010) reported that the submergent species *Ruppia tuberosa, Ruppia polycarpa, Lepilaena cylindrocapa, Lepilaena preissii, Potamgoteon pectinatus, Lamprothamnium* sp. and *Nitella* sp. recruited in response to watering.

In August 2010, water levels in the Lower Lakes returned to historical levels; however, hydrological restoration of wetlands occurred at different times (and in the case of Waltowa has not yet occurred). Wetlands with good hydrological connections with the lakes (Dunns Lagoon, Angas River Mouth, Bremer River Mouth, Poltalloch, Hunters Creek, Point Sturt, Narrung and Goolwa Channel Drive) filled when water levels exceeded the sills on the inlets and were inundated from August 2010. Sandbars formed at the inlets of Loveday Bay (D. Chandler pers. comm.) and Teringie (D. Walker pers. comm.) wetlands, preventing the wetlands from filling until they were cleared in summer 2010-11. Significant areas of Milang Wetland are perched and primarily receive water from local runoff (A. Frears pers. comm.) although low lying areas were inundated with lake water. Finally, the inlet structure on Waltowa Wetland has been closed since 2006 and not re-opened. Therefore, the response of the plant community to the return of historical lake levels differed between wetlands with respect to species and functional groups.

In the inudated areas of Dunn's Lagoon, the Angas and Bremer River mouths, Poltalloch, Hunters Creek, Goolwa Channel Drive and Point Sturt, the plant community showed a change from a terrestrial taxa dominated community to an amphibious, submergent, floating and emergent taxa dominanted communities. Whilst not detected by indicator species analyis until autumn 2011 in some instances, this change had occurred by the spring 2010 survey in the aforementioned wetlands but species from the aquatic functional groups were in lower abundances compared with the autumn 2011 survey.

Milang wetland generally remained dominated by terrestrial taxa despite low lying areas being inundated with lake water (these areas were predominantly bare or sparsely vegetated by amphibious and emegent species). However in areas that were dominated by emergent and amphibious species throughout the study period, there appeared to be increased vigour and improved condition in spring 2010 and autumn 2011, which did not result in a significant increase in percentage cover (pers. obs.). It is unclear whether this observation was due to above average local rainfall during the last 12 months of the survey period (Bureau of Meteorology 2011a) or increased lake levels.

Narrung Wetland is predominantly a saltmarsh; however, Holt *et al.* (2005) and Paton and Bailey (2010) reported that a diverse submergent plant community was present when inundated. Therefore, it is unknown why submergent plants were absent from the lower elevations during the spring 2010 and autumn 2011 surveys after the wetland was inundated with lake water.

Loveday Bay and Teringie wetlands were not inundated with lake water until summer 2010-11. The submergent r-selected species, *Ruppia tuberosa* and *Lamprothamnium macropogon* present in spring 2010 at both sites were due to low elevations being inundated by local runoff.. Both wetlands dried over summer and submergent plants had not recruited by autumn 2011 despite inundation with lake water.

Waltowa Wetland remained dry for the survey period, despite water levels in Lake Albert rising to a level that allowed water to enter the wetland. The control structure on the inlet channel remained closed for the duration of the survey period at the wetland due to landholder concerns around rising groundwater levels affecting pasture productivity. The plant community was dominated by salt tolerant species and terrestrial species throughout the survey period and will probably remain dominated by these funcational groups unless inundation is allowed.

4.2 Lakeshores

The changes in the plant community observed in Goolwa Channel, Lake Alexandrina and Lake Albert over the survey period were due to changes in water levels and salinity brought about by different management regimes for each location and the unregulated River Murray flow from August 2010. At the beginning of the survey period all three areas were connected, exhibiting similar water levels (Figure 2) and salinities (Figure 3) and in spring 2008 and autumn 2009 all elevations at all locations were dominated by terrestrial species due to low water levels (*sensu* Nicol 2010). Construction of the Narrung bund and Clayton regulator (constructed to mitigate effects of acid sulfate soils), resulted in fragmentation and the ability to manage water levels in Lake Albert and Goolwa Channel independently of Lake Alexandrina. The Narrung bund was constructed to maintain water levels above -0.5 m AHD in Lake Albert by pumping water from Lake Alexandrina. The Clayton regulator was constructed to maintain elevated water levels in Goolwa Channel, the lower Finniss River and lower Currency Creek by impounding flows from the Finniss River and Currency and Tookayerta Creeks and pumping from Lake Alexandrina. In addition salinity in Goolwa Channel, whilst not a direct result of regulated flooding (salinity was elevated in Goolwa Channel prior to regulator construction), was also higher than Lake Alexandrina (Figure 3). The unregulated flow (and subsequent breaching of the Clayton regulator and Narrung bund) resulted in reconnection, an increase in water levels (Figure 2) and a reduction in salinity (Figure 3) from August 2010.

From spring 2009 to autumn 2010, water levels ranged from -0.8 to -1.0 m AHD in Lake Alexandrina and 0 to -0.7 m AHD in Lake Albert (Figure 2). Hence, the plant community in both locations was dominated by terrestrial species, although fringing emergent species (predominately *Phragmites australis*) were present but disconnected from the lakes.

In contrast, water levels in Goolwa Channel over the same period ranged from +0.75 m AHD in spring 2009, to -0.1 m AHD in autumn 2010 (Figure 2) due to the influence of the Clayton regulator and pumping from Lake Alexandrina. The plant community during this period showed zonation in relation to water depth (*sensu* Spence 1982). At high elevations (+0.4 to +0.8 m AHD) the plant community was dominated by emergent and amphibious species such as *Phragmites australis, Muehlenbeckia florulenta, Typha domingensis* and *Calystegia sepium*. At intermediate elevations (0 to+0.4 m AHD) emergent species such as T*ypha domingensis* and *Schoenoplectus validus,* that are adapted to deeper water, were common. At -0.5 m AHD only submergents (*Potamogeton pectinatus* and *Myriophyllum salsugineum*) were present in quadrats. In addition, *Vallisneria australis, Ruppia megacarpa, Ceratophyllum demersum* and *Ruppia polycarpa* (submergent species) were also observed in low numbers outside of monitoring 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 and Ward 2010a; Nicol and Ward 2010b).

In autumn 2010, prior to the breaching of the Clayton regulator, surface water electrical conductivity (EC) in some areas of Goolwa Channel exceeded 20,000 $\mu S.cm^{-1}$ (Figure 3); a level significantly higher than the reported tolerances of several of the emergent and submergent species present (Bailey *et al.* 2002). Extensive stands of *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 µS.cm^{-1}) and *Schoenoplectus validus* (maximum reported salinity tolerance of 700 µS.cm^{-1}) (Bailey *et al.* 2002) were present in Goolwa Channel despite the elevated salinity. However, plants in Goolwa Channel had clearly regenerated from rhizomes, which support evidence from the seed bank assessment where *Typha domingensis* and *Schoenoplectus validus* did not germinate in salinities in excess of 5,000 µS.cm^{-1} (Nicol and Ward 2010b). Nevertheless, seeds remained viable when subjected to salinities as high as 20,000 µS.cm^{-1} for at least six weeks. These results suggested that there are local salt tolerant ecotypes of the aforementioned species present in Goolwa Channel (and potentially throughout the Lower Lakes); however, little is known about the impacts of sub-lethal salinities except that under elevated salinities these species are restricted to colonising new areas asexually.

In August 2010 River Murray inflows into Lake Alexandrina increased, water levels rose rapidly (Figure 2) and the Clayton regulator and Narrung bund were breached in September 2010 reconnecting the three locations. This resulted in similar water levels throughout the Lower Lakes (Figure 2); however, surface water EC in Lake Albert was significantly higher than Goolwa Channel and Lake Alexandrina (Figure 3). The terrestrial taxa that had recruited on the exposed sediment in Lakes Alexandrina and Albert were extirpated. Emergent and amphibious species increased in abundance from +0.8 to 0 m AHD in Lake Alexandrina but not in Lake Albert. The -0.5 m AHD elevation was generally devoid of plants in lakes Alexandrina and Albert. In Goolwa Channel emergent species (especially *Schoenoplectus validus*) increased in abundance (probably due to lower surface water salinity) and there were significant changes to the submergent plant community between spring 2010 and autumn 2011. In spring 2010 the submergent plant community was dominated by *Potamogeton pectinatus*, which had colonised over 2,000 ha of Goolwa Channel, the lower Finniss River and lower Currency Creek at elevations between +0.4 m and -2.5 m AHD (Gehrig *et al.* 2011). By autumn 2011, *Potamogeton pectinatus* had dramatically decreased in distribution and abundance and areas previously dominated by this species were dominated by open water, *Myriophyllum salsugineum* and *Schoenoplectus validus* (Gehrig *et al.* 2011).

The changes to the plant community in Goolwa Channel over the survey period can be attributed to changes in water quality (salinity and turbidity) and flow. *Potamogeton pectinatus* grows well in clear, slow flowing, saline water (at least 5 ‰ TDS) (Sainty and Jacobs 2003); therefore, the conditions in Goolwa Channel between August 2009 and August 2010 were conducive for recruitment and spread of this species. Once established, *Potamogeton pectinatus* can colonise large areas rapidly by asexual reproduction (rhizomes and tubers) (Sainty and Jacobs 2003) and in Goolwa Channel large (almost monospecific) beds were present throughout the shallow water habitats (Gehrig *et al.* 2011). In August 2010 fresh, turbid water replaced clear saline water and initially there was an increase in the abundance of *Potamogeton pectinatus* as there was sufficient photosynthetic tissue in the euphotic zone. However, as flows increased, plants were flattened and pushed out of the euphotic zone (and subsequently died) or were uprooted and washed into the Coorong. This provided an opportunity for species adapted to fresh turbid conditions (e.g. *Myriophyllum salsugineum, Ceratophyllum demersum, Potamogeton crispus, Vallisneria australis*) to colonise these areas.

Emergent species also responded to lower salinities in Goolwa Channel after September 2010 (Gehrig *et al.* 2011). There was an increase in abundance and extent of freshwater emergent species (*Typha domingensis, Phragmites australis* and *Schoenoplectus validus*) since the regulator was breached, which suggests that elevated salinity (whilst not lethal) did reduce growth (Gehrig *et al.* 2011).

Colonisation of submergent species in Goolwa Channel in response to regulated inundation and natural flooding provided evidence that the system is resilient and the aquatic plant community had the capacity to recover from low water levels. All submergent species observed in Goolwa Channel in autumn 2011 (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. Nevertheless, prior to reconnection with Lake Alexandrina, *Potamogeton crispus* was absent and *Ceratophyllum demersum* was restricted to the uppermost surveyed reaches of the Finniss River (adjacent to Wally's Landing). Furthermore, *Myriophyllum caput-medusae* was present in the seed bank (Nicol and Ward 2010b) and historically present (J. Nicol pers. obs.) but absent from the extant vegetation since 2007. The absence of *Myriophyllum caput-medusae* was probably initially due to elevated salinity in Goolwa Channel, which exceeded the maximum reported salinity tolerance (Bailey *et al.* 2002) but presently is most likely due to lack of viable propagules and/or lack of dispersal.

Results from three years of monitoring show that allocation of sufficient water to maintain lake levels between +0.4 and +0.8 m AHD and provide periodic flushing to maintain low salinities produced the most desirable outcomes with respect to aquatic plants. Construction of the regulators and pumping to maintain water levels should only be regarded as an emergency management action to mitigate acid sulfate soils. Nevertheless, regulated flooding resulted in recruitment of *Potamogeton pectinatus, Vallisneria australis* and *Myriophyllum salsugineum* and maintained emergent taxa, but salinities remained elevated throughout Goolwa Channel (water levels were not sufficiently high to inundate fringing vegetation in Lake Albert prior to reconnection). Elevated salinities resulted in reduced growth of emergent species and prevented or delayed germination (but not necessarily reduced seed viability) of emergent and submergent taxa (Nicol and Ward 2010b). This was supported by the distribution and abundance of three historically common freshwater submergent species (*Potamogeton crispus, Myriophyllum caput-medusae* and *Ceratophyllum demersum*) over the study period and the significant increase in the abundance of emergent species in autumn 2011. Furthermore, the dominance of *Potamogeton pectinatus* from March to November 2010 was probably due to regulated flooding and elevated salinity.

4.3 The Living Murray Target V3

Whilst there has been a significant increase in the abundance of submergent, amphibious, floating and emergent species since water levels returned to historical levels, the abundances of species from these functional groups now is probably much lower than in 2004 (Holt *et al.* 2005) or 2005 (Nicol *et al.* 2006). For example, the diverse submergent plant communities that covered extensive areas in Clayton Bay, Dunn's Lagoon, Narrung, Milang (Holt *et al.* 2005), Loveday Bay, Hunters Creek Point Sturt and Poltalloch (Nicol *et al.* 2006) had not re-established by autumn 2011. In addition, extensive areas of *Myriophyllum salsugineum* were present upstream of the Hindmarsh Island Bridge in shallow areas of Goolwa Channel prior to the draw down of lake levels (pers. obs.) but were not present in autumn 2011. Furthermore, three species (*Myriophyllum caput-medusae, Lepilaena cylindrocarpa* and *Batrachium trichophyllum*) recorded in the 2004 (Holt *et al.* 2005) and 2005 (Nicol *et al.* 2006) baseline surveys were not present in wetlands or lakeshores. However, extensive beds (468 ha) of *Myriophyllum salsugineum* had established in the lower Finniss River and lower Currency Creek, and the emergent plant community throughout Lake Alexandrina and Goolwa Channel showed signs of improved condition after water levels were reinstated.

Therefore, TLM target V3 has not been met when compared to the plant community present prior to draw down. However, all but three (*Myriophyllum caput-medusae, Batrachium trichophyllum* and *Lepilaena cylindrocarpa*) of the 46 species recorded in 2004 and 2005 that were lost when water levels decreased were recoded in the spring 2010 or autumn 2011 survey and data showed that the plant community has shifted from being dominated by terrestrial taxa to submergent, emergent, floating and amphibious species. Finally, most aquatic species are capable of rapid colonisation by asexual reproduction once mature (Grace 1993); therefore, it is likely that aquatic taxa will continue to increase in abundance providing water levels remain at current levels.

4.4 Further studies

Suggested further studies to improve the understanding of the vegetation dynamics of the Lower Lakes and impact of water levels and salinity include:

- Continue condition monitoring program to gain an understanding of the medium to long-term vegetation dynamics of the system and monitor recovery post hydrological restoration.

- Continue to map large-scale plant communities in Goolwa Channel (Gehrig et al. 2011) to complement condition monitoring program and gain a better understanding of vegetation dynamics at the landscape scale.

- Investigate salinity tolerances of potential local ecotypes of key species.

- Investigate the effects of sub-lethal salinities on key species.

- Determine propagule longevity under different conditions (e.g. salinity, pH, soil moisture).
- Investigate current submergent plant propagule bank in key wetlands and Goolwa Channel.
- Investigate the relationships between plant communities and other biotic groups such as fish, birds and invertebrates.

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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 2010b), 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, # denotes listed as rare in South Australia).

Taxon	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 stipitata	Terrestrial dry	Perennial	Native
Atriplex suberecta	Floodplain	Perennial	Native
*Avena barbata**	Terrestrial dry	Annual	Exotic-*Avena* spp. is comprised of *Avena barbata* and *Avena fatua*
Azolla filiculoides	Floating	Perennial	Native
*Batrachium trichophyllum**	Submergent (r-selected)	Annual	Exotic
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 mollis**	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
Ceratophyllum demersum#	Submergent (k-selected)	Perennial	Native-Listed as Rare in South Australia
Chara spp.	Submergent (r-selected)	Annual	Native
*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

Taxon	Functional Group	Life history strategy	Status and Comments
*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
*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
Ficinia nodosa	Amphibious fluctuation tolerator-emergent	Perennial	Native
*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
Iris spp.	Terrestrial dry	Perennial	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 subsecundus	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
Lemna sp.	Floating	Perennial	Native
Lobelia alata	Terrestrial damp	Perennial	Native
Ludwigia peploides ssp. *montevidensis*	Amphibious fluctuation responder-plastic	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

Taxon	Functional Group	Life history strategy	Status and Comments
Lythrum hyssopifolia	Amphibious fluctuation tolerator-emergent	Perennial	Native
Lythrum salicaria	Amphibious fluctuation tolerator-emergent	Perennial	Native
*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
Myriophyllum sp.	Submergent k-selected	Perennial	Native
*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
*Phyla canescens**	Amphibious fluctuation tolerator-low growing	Perennial	Exotic
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*
*Ranunculus trilobus**	Amphibious fluctuation tolerator-emergent	Annual	Exotic
*Reichardia tingitana**	Terrestrial dry	Annual	Exotic
Rhagodia spinescens	Terrestrial dry	Perennial	Native
*Rorippa nasturtium-aquaticum**	Amphibious fluctuation responder-plastic	Annual	Exotic
*Rorippa palustris**	Floodplain	Annual	Exotic
Ruppia megacarpa	Submergent k-selected	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

Taxon	Functional Group	Life history strategy	Status and Comments
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
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: Taxa present (green shading) in each wetland from spring 2008 to autumn 2011 (*denotes exotic taxon; #denotes listed as rare in South Australia).

Taxon	Angas and Bremer River Mouths	Dunns Lagoon	Goolwa Channel Drive	Hunters Creek	Loveday Bay	Milang	Narrung	Poltalloch	Point Sturt	Teringie	Waltowa
*Agapanthus praecox**						■					
Lachnagrostis filiformis	■	■	■	■							
*Asparagus asparagoides**						■					
*Aster subulatus**	■	■			■	■			■		
*Atriplex prostrata**	■	■	■	■	■	■	■		■		
Atriplex semibaccata							■			■	
Atriplex sp.									■	■	
Atriplex stipitata					■						
Atriplex suberecta									■	■	
*Avena barbata**	■	■				■			■	■	
Azolla filiculoides	■	■									
*Batrachium trichophyllum**					■						
Berula erecta	■										
Bolboschoenus caldwellii			■	■	■	■	■	■	■		
*Brassica rapa**		■									
*Brassica tournifortii**										■	
*Bromus diandrus**		■			■	■			■	■	
*Bromus hordeaceus**		■				■			■	■	
*Bromus mollis**		■				■					
*Bromus uniloides**											■
Calystegia sepium		■									
*Centaurea calcitrapa**	■		■		■			■			
Ceratophyllum demersum#	■			■							
Chara spp.			■					■	■		
*Chenopodium album**	■	■				■			■	■	
*Chenopodium glaucum**		■			■			■	■		
*Conyza bonariensis**	■	■	■		■	■					
*Cotula coronopifolia**	■	■	■	■	■	■		■	■	■	
Crinum sp.*						■					
Cyperus exaltatus	■										
Cyperus gymnocaulos		■			■	■		■		■	
Distichlis distichophylla		■	■	■	■	■	■	■	■	■	
Disphyma crassifolium							■			■	■
*Ehrharta longiflora**						■					
Einadia nutans									■		
Eleocharis acuta				■	■	■					
Enchylaena tomentosa		■				■			■	■	

Taxon	Angas and Bremer River Mouths	Dunns Lagoon	Goolwa Channel Drive	Hunters Creek	Loveday Bay	Milang	Narrung	Poltalloch	Point Sturt	Teringie	Waltowa
Epilobium pallidiflorum											
*Eragrostis curvula**											
Eragrostis sp.											
Frankenia pauciflora											
*Fumaria bastardii**											
Gahnia filum											
Glyceria australis											
*Heliotropium europaeum**											
*Holcus lanatus**											
*Hordeum vulgare**											
Hydrocotyle verticillata											
*Hypochoeris glabra**											
*Hypochoeris radicata**											
Iris sp.*											
Ficinia nodosa											
Isolepis producta											
*Juncus acutus**											
Juncus kraussii											
Juncus subsecundus											
Juncus usitatus											
*Lactuca saligna**											
*Lactuca serriola**											
*Lagurus ovatus**											
Lamprothamnium macropogon											
Lemna sp.											
Lobelia alata											
Lolium spp.*											
Ludwigia peploides ssp. *montevidensis*											
*Lycium ferocissimum**											
*Malva parviflora**											
*Marrubium vulgare**											
Medicago spp.*											
*Melilotus indica**											
Melaleuca halmaturorum ssp. *halmaturorum*											
Mentha sp.*											
Mimulus repens											
Muehlenbeckia florulenta											
Myriophyllum salsugineum											

Taxon	Angas and Bremer River Mouths	Dunns Lagoon	Goolwa Channel Drive	Hunters Creek	Loveday Bay	Milang	Narrung	Poltalloch	Point Sturt	Teringie	Waltowa
Myriophyllum sp.						■					
*Oxalis pes-caprae**						■				■	
*Paspalum distichum**	■	■	■	■	■	■		■	■	■	
*Pennisetum clandestinum**	■					■					
Persicaria lapathifolia	■	■									
Phragmites australis	■	■	■			■	■				
*Phyla canescens**					■						
Picris hieracoides		■			■						
*Plantago coronopus**	■	■	■	■	■	■			■	■	
*Poa annua**											■
*Polypogon monspeliensis**	■			■	■	■	■	■	■	■	
*Polygonum aviculare**									■		
Potamogeton crispus		■									
Potamogeton pectinatus		■	■	■							
Psuedognaphalium luteo-album		■			■						
Puccinellia spp.							■				
*Ranunculus trilobus**					■						
*Reichardia tingitana**	■	■	■			■			■	■	■
*Rorippa nasturtium-aquaticum**	■										
*Rorippa palustris**							■				
Ruppia megacarpa				■							
Ruppia polycarpa			■	■		■			■		
Ruppia tuberosa				■	■			■		■	
Salsola kali										■	
Samolus repens		■	■		■	■			■	■	
Sarcocornia quinqueflora		■	■	■	■	■	■	■	■	■	■
*Scabiosa atropurpurea**		■				■					
Schoenoplectus pungens		■	■	■	■						
Schoenoplectus validus		■			■						
Senecio pterophorus*	■	■			■	■	■		■		
Senecio runcinifolius		■									■
*Sonchus asper**		■				■					
*Sonchus oleraceus**	■	■	■	■	■	■	■	■	■	■	■
*Spergularia marina**		■	■		■	■	■	■	■	■	■
*Suaeda australis**		■	■	■	■	■	■	■	■	■	■
*Silybum marianum**					■	■					
Trifolium spp.*	■	■			■	■			■	■	
Triglochin procerum	■	■									
Triglochin striatum	■	■	■	■		■			■	■	

Taxon	Angas and Bremer River Mouths	Dunns Lagoon	Goolwa Channel Drive	Hunters Creek	Loveday Bay	Milang	Narrung	Poltalloch	Point Sturt	Teringie	Waltowa
Typha domingensis											
*Urtica urens**											
Vallisneria australis											
*Vicia sativa**											
Wilsonia rotundifolia											
Species Richness	**35**	**65**	**29**	**26**	**47**	**63**	**21**	**25**	**39**	**42**	**15**
Number of Exotics	**18**	**31**	**11**	**8**	**27**	**37**	**10**	**15**	**24**	**22**	**10**
% Exotics	**51.43**	**47.69**	**37.93**	**30.77**	**57.45**	**58.73**	**47.62**	**60.00**	**61.54**	**52.38**	**66.67**

Appendix 4: Taxa present (green shading)at lakeshore sites from spring 2008 to autumn 2011 (* denotes exotic taxon; # denotes listed as rare in South Australia).

Taxon	Lake Albert	Lake Alexandrina	Goolwa Channel
Acacia myrtifolia	■		
Lachnagrostis filiformis	■	■	■
*Apium graveolens**		■	
*Arctotheca calendula**	■	■	
*Asparagus officinalis**			■
*Aster subulatus**	■	■	■
*Atriplex prostrata**		■	■
Atriplex sp.		■	■
Atriplex suberecta		■	
*Avena barbata**	■	■	
Azolla filiculoides		■	■
Berula erecta		■	■
Bolboschoenus caldwellii		■	■
*Brassica rapa**		■	
*Brassica tournifortii**		■	■
*Briza minor**		■	
*Bromus diandrus**	■	■	■
*Bromus hordeaceus**	■	■	■
*Bromus uniloides**		■	
Calystegia sepium		■	■
*Centaurium tenuiflorum**		■	
*Centaurea calcitrapa**	■	■	■
Ceratophyllum demersum#		■	■
*Chenopodium album**	■		
*Chenopodium glaucum**	■	■	■
Chenopodium nitrariaceum		■	
*Conyza bonariensis**	■	■	■
*Cotula coronopifolia**	■	■	■
Cyperus exaltatus			■
Cyperus gymnocaulos	■	■	■
Distichlis distichophylla	■	■	
*Ehrharta longiflora**	■	■	
Einadia nutans		■	
Eleocharis acuta			■
Enchylaena tomentosa	■	■	■
Epilobium pallidiflorum			■
Eragrostis australasica	■		
*Eragrostis curvula**	■	■	
Eragrostis sp.		■	
*Euphorbia terracina**	■		
*Foeniculum vulgare**		■	
Frankenia pauciflora		■	
*Fumaria bastardii**		■	
*Holcus lanatus**		■	
*Hordeum vulgare**	■	■	

Taxon	Lake Albert	Lake Alexandrina	Goolwa Channel
Hydrocotyle verticillata		x	
*Hypochoeris glabra**	x	x	
*Hypochoeris radicata**	x	x	
Ficinia nodosa	x	x	x
Isolepis producta	x	x	
*Juncus acutus**		x	
Juncus kraussii		x	x
Juncus usitatus		x	x
*Lactuca saligna**		x	
*Lactuca serriola**		x	
*Lagurus ovatus**	x	x	
Lemna sp.		x	x
Lobelia alata		x	
Lolium spp.*	x	x	x
Ludwigia peploides ssp. *montevidensis*		x	
*Lupinus cosentinii**			x
Lycopus australis		x	x
Medicago spp.*	x	x	
*Melilotus indica**	x	x	x
Melaleuca halmaturorum ssp. *halmaturorum*	x		
Mentha australis		x	
Mentha sp.*		x	x
Mimulus repens	x	x	x
Muehlenbeckia florulenta		x	x
Myriophyllum salsugineum			x
*Onopordum acanthium**		x	
*Paspalum distichum**	x	x	x
*Pennisetum clandestinum**	x	x	x
Persicaria lapathifolia		x	
Phragmites australis	x	x	x
Picris hieracoides		x	x
*Plantago coronopus**	x	x	x
*Plantago lanceolata**			x
*Polypogon monspeliensis**	x	x	x
*Polygonum aviculare**		x	x
Potamogeton crispus			x
Potamogeton pectinatus			x
Psuedognaphalium luteo-album		x	
Puccinellia spp.	x	x	
*Reichardia tingitana**	x	x	
*Rorippa palustris**		x	
Rumex bidens		x	x
Ruppia tuberosa		x	
*Salix babylonica**		x	x
Sarcocornia quinqueflora	x	x	
*Scabiosa atropurpurea**			x
Schoenoplectus pungens	x	x	x

Taxon	Lake Albert	Lake Alexandrina	Goolwa Channel
Schoenoplectus validus			
Sclerolaena blackiana			
Senecio cunninghamii			
*Senecio pterophorus**			
Senecio runcinifolius			
*Solanum nigrum**			
Solanum sp.			
*Sonchus asper**			
*Sonchus oleraceus**			
*Spergularia marina**			
*Suaeda australis**			
*Silybum marianum**			
*Tamarix aphylla**			
Trifolium spp.*			
Triglochin procerum			
Triglochin striatum			
Triticum spp.*			
Typha domingensis			
*Urtica urens**			
Vallisneria australis			
*Vicia sativa**			
Wilsonia rotundifolia			
Species Richness	**48**	**98**	**56**
Number of Exotics	**30**	**48**	**26**
% Exotics	**62.50**	**48.98**	**46.43**