Inland Waters & Catchment Ecology

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Lower Lakes Vegetation Condition Monitoring – 2011/2012

Susan Gehrig, Jason Nicol, Kate Frahn 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 four 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, November 2010 and October 2011) and autumn (March 2009, 2010, 2011 and 2012). 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. High water levels, and subsequent connectivity, continued throughout the remainder of the condition monitoring program to date.

Over the four year period (spring 2008 to autumn 2012), a total of 121 taxa (including 56 exotics and one species listed as rare in South Australia) were recorded at wetland sites with 123 taxa (including 57 exotics and one species listed as rare in South Australia) at lakeshore sites. From 2008 to 2010, 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 by terrestrial species. In 2009-10 more terrestrial species had colonised lower elevations than previously recorded in 2008-09. When water levels were reinstated, aquatic species generally recolonised the inundated areas albeit not to the extent recorded in 2004 (Holt *et al.* 2005) and 2005 (Nicol *et al.* 2006). Waltowa wetland remained

dominated by salt tolerant and terrestrial taxa despite active management of water levels from May 2011 to April 2012.

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 a further change to the plant community. The submergent species, *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. In 2011/12 the aquatic and emergent plant community recovered further, although the changes were less dramatic than observed in the previous 12 months.

Results showed that the plant community is resilient and 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 and 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, after water levels increased there was a significant increase in aquatic species, 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 four 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; Gehrig *et al.* 2011b).

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 (in lakes Alexandrina and Albert), 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.* 2011a).

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 understory vegetation assemblage would be monitored with a separate technique used for the dominant tree species *Melaleuca halmaturorum*. Hence, the monitoring program consists of two complementary components: the first component involves the monitoring of aquatic and littoral understory vegetation in spring (high lake levels) and autumn (low lake levels) to determine the current condition, seasonal changes and medium to long-term changes in floristic composition, and the second component monitors the mid to long-term population dynamics of *Melaleuca halmaturorum*. The *Melaleuca halmaturorum* component of the monitoring program is undertaken every three to five years; hence stand condition was not monitored in 2011-12. 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, amphibious and submergent taxa (Renfrey *et al.* 1989; Holt *et al.* 2005; Nicol *et al.* 2006). By spring 2008 submergent taxa 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 taxa had declined in abundance and diversity, stands of emergent taxa were diconnected from the lakes and fringing habitats were dominated by terrestrial taxa and bare soil (Marsland and Nicol 2009). Furthermore, submergent taxa 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 emergent 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 due to the Currency Creek Regulator spillway remaining 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, with 250 ML of environmental water from Lake Alexandrina being 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 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 resulted in 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 2011-12 builds on data collected between 2008 and 2011 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 provides 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 being the 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 completed in August 2009 and impounded water from the Finniss River and Currency and Tookayerta creeks (Figure 1). In addition, water was pumped into Goolwa Channel (Figure 2) 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, remaining 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 4,000 $\mu S.cm^{-1}$ by the end of the study period (Figure 3).

Water levels in Goolwa Channel from August 2008 to August 2009 were largely dependent on River Murray inflows (Figure 2). From August 2009 to August 2010, following completion of the Clayton Regulator, 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 in spring 2009 (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 approximately 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 in the Goolwa Channel decreased rapidly to around 500 $\mu S.cm^{-1}$ for the remainder of the survey period, except for several salinity spikes (maximum approximately 47, 000 $\mu S.cm^{-1}$) between May 2011 and May 2012 as a result of very high tides pushing seawater through open barrage gates (Figure 3).

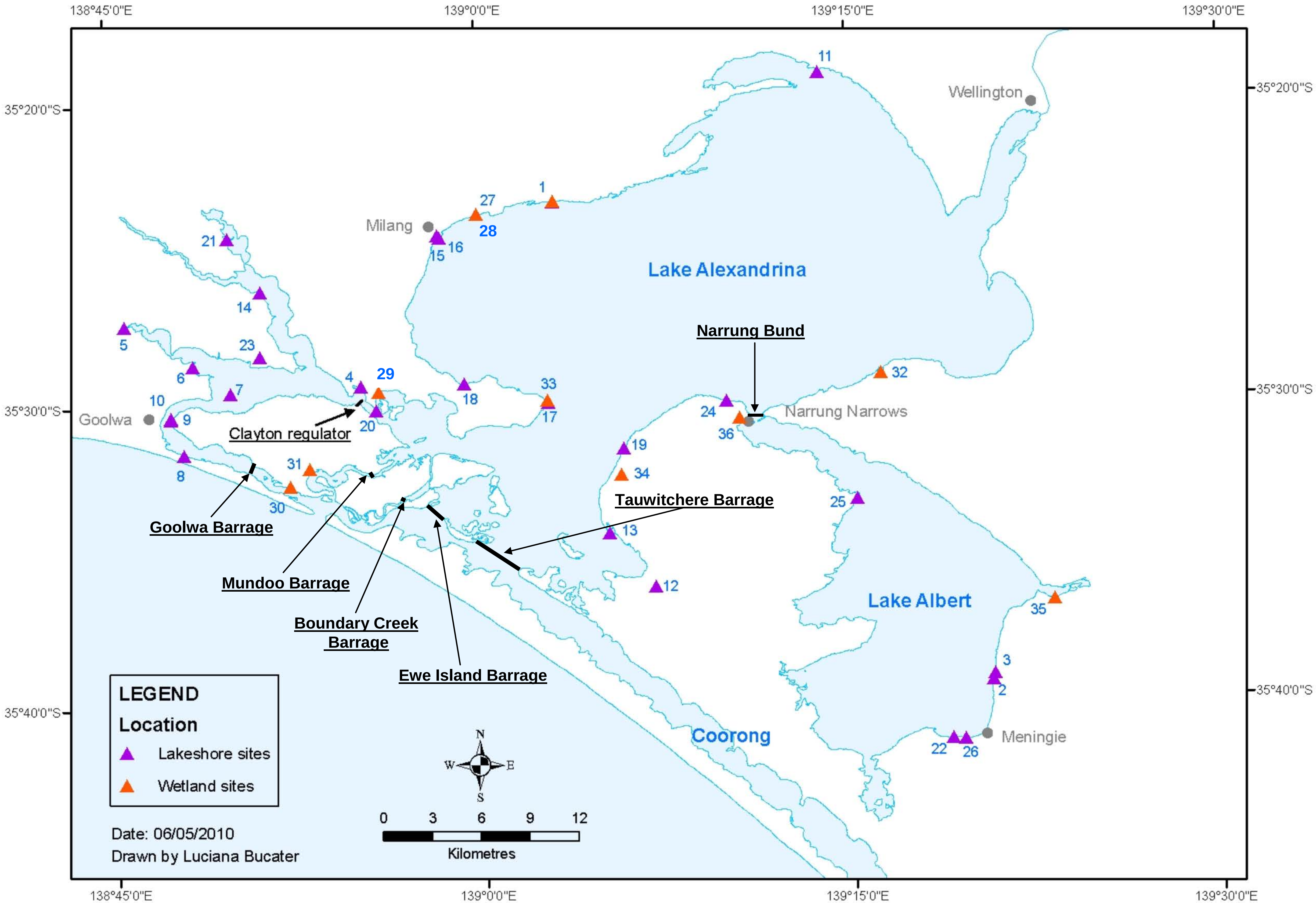


Figure 1: Map of Lakes Alexandrina and Albert and Goolwa Channel showing the location of lakeshore and wetland vegetation monitoring sites (site numbers correspond to Table 1) and major flow control structures (where sites are in close proximity they may not be visible on map).

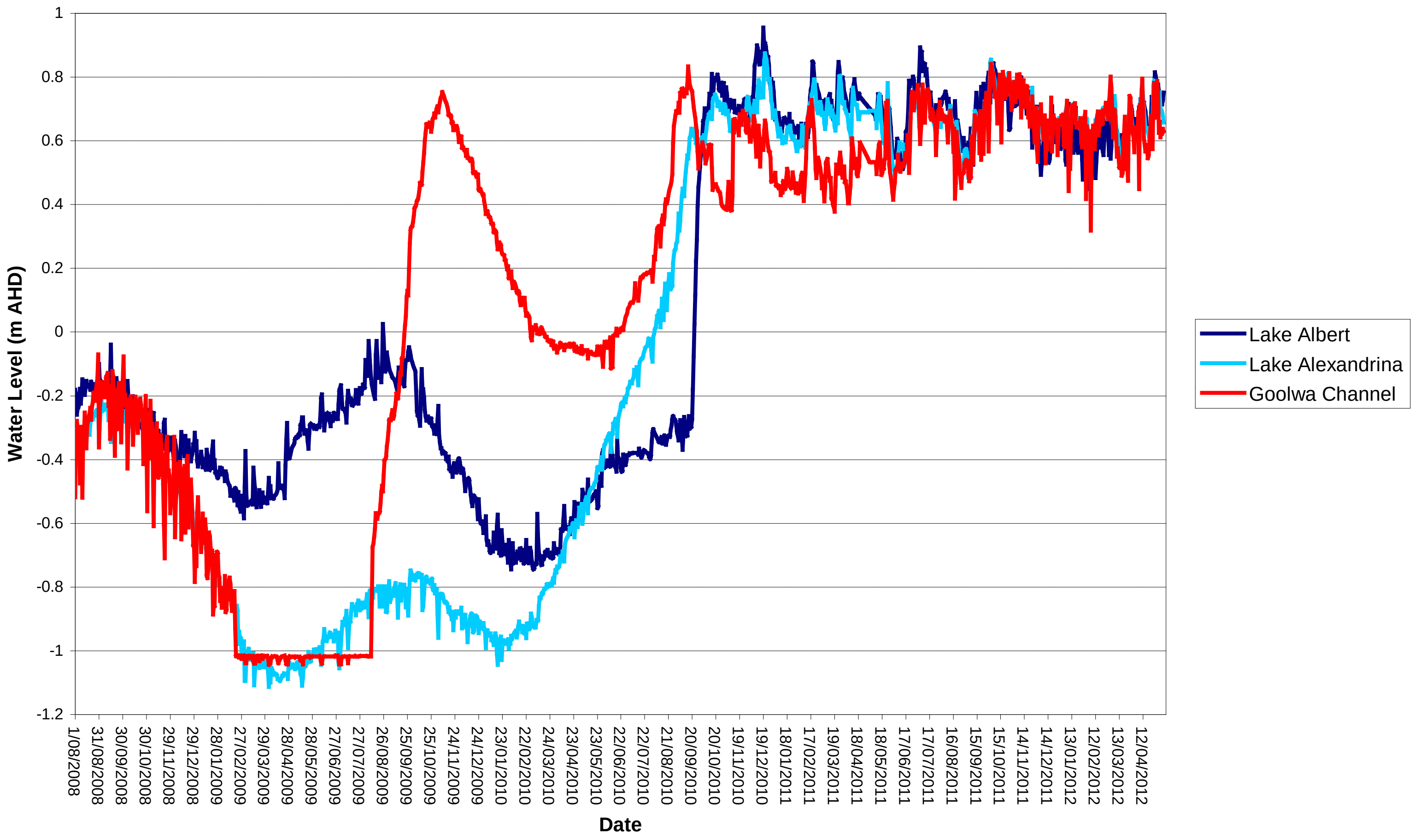


Figure 2: Daily mean water levels in Goolwa Channel (Signal Point), Lake Alexandrina (Milang) and Lake Albert (Meningie) from August 2008 to April 2011 (Department for Water 2011b).

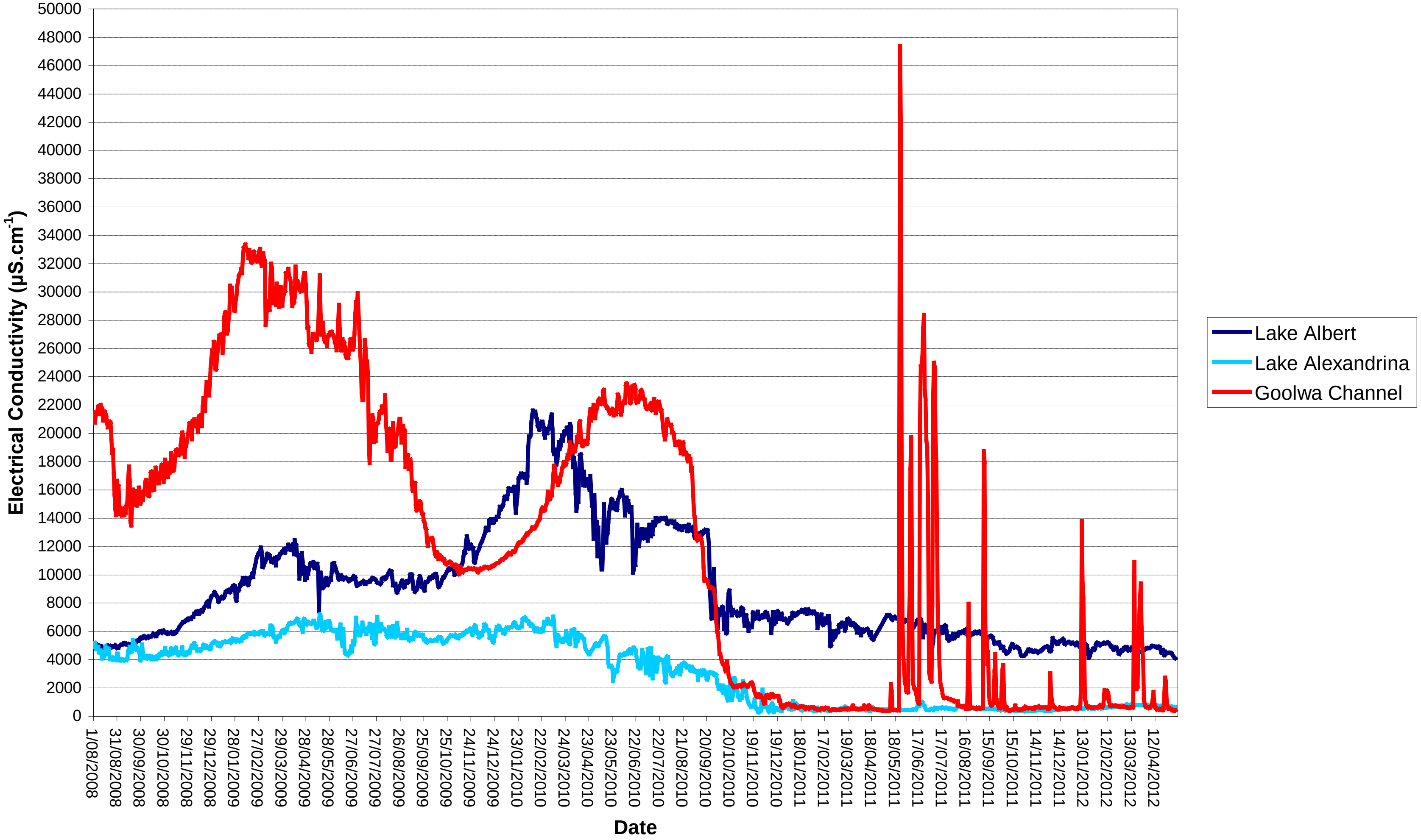


Figure 3: Daily mean surface water electrical conductivity (EC) in Goolwa Channel (Signal Point), Lake Alexandrina (Milang) and Lake Albert (Meningie) from August 2008 to April 2011 (Department for Water 2011a).

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, March 2011, October 2011 and March 2012 (for sites established in 2008 or earlier) and October 2009, March 2010, November 2010, March 2011, October 2011 and March 2012 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 (existing SAMDBNRM Board community monitoring site)	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

Site #	Site Name	Location	Habitat	Year Established
28	Bremer Mouth	Lake Alexandrina	wetland	2008
29	Dunns Lagoon	Lake Alexandrina	wetland	2008
30	Goolwa Channel Drive	Lake Alexandrina	wetland	2008
31	Hunters Creek	Lake Alexandrina	wetland	2008
32	Poltalloch	Lake Alexandrina	wetland	2008
33	Pt Sturt	Lake Alexandrina	wetland	2008
34	Teringie (existing SAMDBNRM Board community monitoring site)	Lake Alexandrina	wetland	pre-2008
35	Waltowa (existing SAMDBNRM Board community monitoring site)	Lake Albert	wetland	pre-2008
36	Narrung (existing SAMDBNRM Board community monitoring site)	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 in each wetland) was established, and quadrats were placed at the same elevations (determined using a laser level) as on the first transect. At sites where the elevation gradient was steep (e.g. Angas and Bremer River Mouth, Hunter's Creek) only edge and channel quadrats were surveyed. 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 three1 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).

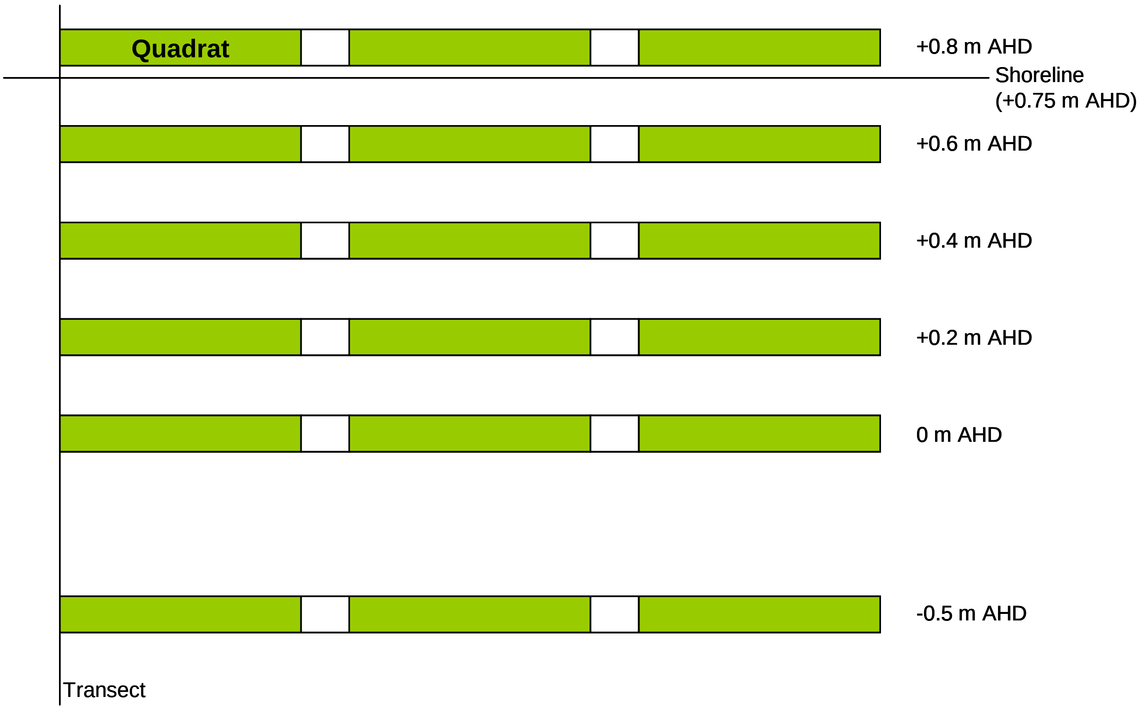


Figure 4: Vegetation surveying protocol for lakeshore sites: plan view showing placement of quadrats relative to the shoreline.

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 (also see 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 plant communities of 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 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 lapathifolia* *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 spiralis* var. *americana* *Ruppia megacarpa* *Potamogeton pectinatus*

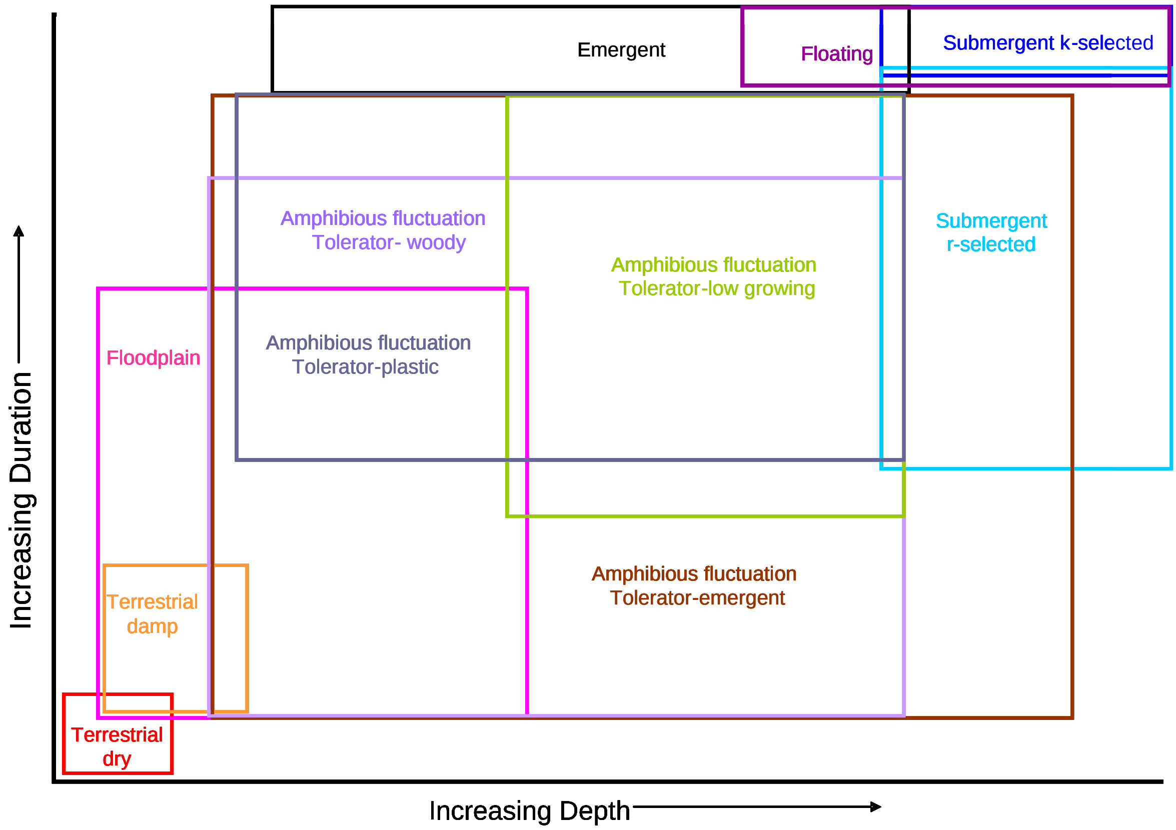


Figure 5: Plant functional groups in relation to depth and duration of flooding.

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.

Taxa 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). Taxa 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). Taxa 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 taxa 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).

Taxa 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" taxa 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 10 cm 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" taxa 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). Taxa in this group show many of the attributes of Grime's (1979) k-selected (competitor) taxa that are adapted to stable environments and are only found in permanent water bodies. The depth of colonisation of submergent k-selected taxa 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) using the package PRIMER version 6.1.12 (Clarke and Gorley 2006) and Indicator Species Analysis (Dufrene and Legendre 1997) using the package 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) using the package PRIMER version 6.1.12. (Clarke and Gorley 2006) and Indicator Species Analysis (Dufrene and Legendre 1997) using the package PCOrd version 5.12 (McCune and Mefford 2006). Bray-Curtis (1957) similarities were used to calculate the similarity matrices for all multivariate analyses. $\alpha=0.05$ for all statistical analyses.

3 Results

3.1 Wetlands

A total of 123 taxa (including 57 exotics and one species listed as rare in South Australia) were recorded for all wetland sites between spring 2008 and autumn 2012 (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	7, 95	3.24	<0.001
	Elevation	1, 95	42.30	<0.001
	Time × Elevation	7, 95	3.16	<0.001
Dunn's Lagoon	Time	7, 479	8.74	<0.001
	Elevation	4, 479	68.25	<0.001
	Time × Elevation	28, 479	4.40	<0.001
Goolwa Channel Drive	Time	7, 215	7.62	<0.001
	Elevation	2, 215	60.49	<0.001
	Time × Elevation	14, 215	3.47	<0.001
Hunter's Creek	Time	7, 275	8.64	<0.001
	Elevation	1, 275	219.13	<0.001
	Time × Elevation	7, 275	4.67	<0.001
Loveday Bay	Time	7, 455	7.86	<0.001
	Elevation	4, 455	11.64	<0.001
	Time × Elevation	28, 455	2.37	<0.001
Milang	Time	7, 359	3.26	<0.001
	Elevation	3, 359	21.45	<0.001
	Time × Elevation	21, 359	1.43	0.002
Narrung	Time	7, 263	7.21	0.024
	Elevation	3, 263	79.78	<0.001
	Time × Elevation	21, 263	3.23	0.281
Poltalloch	Time	7, 191	13.02	<0.001
	Elevation	3, 191	14.68	<0.001
	Time × Elevation	21, 191	4.17	<0.001
Point Sturt	Time	7, 143	12.04	<0.001
	Elevation	2, 143	11.37	<0.001
	Time × Elevation	14, 143	2.93	<0.001
Teringie	Time	7, 383	4.82	<0.001
	Elevation	3, 383	33.31	<0.001
	Time × Elevation	21, 383	4.26	<0.001
Waltowa	Time	7, 191	14.27	<0.001
	Elevation	3, 191	46.99	<0.001
	Time × Elevation	21, 191	2.75	<0.001

3.1.1 Angas and Bremer River Mouths

A total of 36 taxa (including 19 exotics) were recorded at the mouths of the Angas and Bremer Rivers (Appendix 3). On the edges of the streams, taxa from the terrestrial, amphibious and emergent functional groups were consistently present. In particular, the edges of both streams were dominated by *Pennisetum clandestinum* (terrestrial dry) throughout the survey period (Figure 6; Gehrig *et al.* 2011b). One exception was in autumn 2011 (nine months after inundation with lake water) when the submergent k-selected *Ceratophyllum demersum* was present. No significant indicator species were recorded for spring 2011 and autumn 2012 along the stream edges.

A greater functional diversity was recorded within channels throughout the survey period, where there was the general trend that in spring taxa from amphibious, emergent, floating and submergent k-selected functional groups were present as opposed to terrestrial, floodplain, amphibious and emergent functional groups recorded in autumn (Figure 6). However, there was the exception that following inundation with lake water in winter 2010 amphibious, emergent, submergent k-selected and floating taxa were recorded in autumn 2011 and only amphibious and emergent taxa present in autumn 2012 (Figure 6). Floating taxa *Azolla filiculoides* and *Lemna* spp. were significant indicators in spring 2011, but there were no significant indicators for autumn 2012.

3.1.2 Dunn's Lagoon

A total of 69 taxa (including 32 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 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), particularly at the lower elevations (3 to 1, inclusive) (Figure 7). Throughout the survey period the highest elevation (5) was dominated by exotic, perennial grass *Paspalum distichum* (Gehrig *et al.* 2011b), but in spring 2011 the exotic annual grasses, *Hordeum vulgare* and *Lolium* sp. significantly increased in abundance and the native perennial grass *Distichlis distichophylla* was more abundant in autumn 2012. At the next elevation (4), spring annuals *Lachnagrostis filiformis* and *Sonchus oleraceus* and emergent *Typha domingensis* were significantly more abundant in spring 2011, whereas in autumn 2012 *Plantago coronopus*, *Reichardia tingitana*, *Sarcocornia quinqueloflora* and *Juncus kraussii* were significant indicators. For elevation 3, *Myriophyllum salsugineum* and *Schoenoplectus validus* increased in abundance in spring 2011 and *Paspalum distichum* and *Triglochin procerum* in autumn 2012. At elevation 2 there was a further increase in the abundance of native species such as *Schoenoplectus validus* and *Vallisneria spiralis* var. *americana* in spring 2011 and *Myriophyllum salsugineum* in autumn 2012. There were no changes (i.e. no significant indicators) for the lowest elevation (1) in spring 2011 and autumn 2012.

3.1.3 Goolwa Channel Drive

A total of 31 taxa (including 14 exotics) were recorded at Goolwa Channel Drive Wetland (Appendix 3). Throughout the survey period, the plant communities at the highest (3) and middle (2) elevations were dominated by terrestrial, emergent and amphibious taxa (Figure 8); characterised by a native salt marsh community of dominant taxa such as, *Suaeda australis, Sarcocornia quinqueflora , Juncus kraussii, Frankenia pauciflora*, *Samolus repens, Distichlis distichophylla*, *Triglochin striatum* and *Schoenoplectus pungens* (Gehrig *et al.* 2011b). Native emergent taxa increased in abundance during the spring 2011 and autumn 2012 survey period. In particular, *Bolboschoenus caldwellii* was more abundant in spring 2011 and *Schoenoplectus pungens* in autumn 2012 at the highest elevation (3), although there were no significant indicators, and therefore no changes, for the middle elevation (2). At the lowest elevation there was an increase in abundance of *Typha domingensis* in autumn 2012.

3.1.4 Hunter's Creek

A total of 31 taxa (including 10 exotics and one species listed as rare in South Australia) were recorded in Hunter's Creek (Appendix 3). Across the survey period the plant community along the edges were predominantly amphibious, terrestrial and emergent taxa (Figure 9); although some submergent k-selected (spring 2010 and autumn 2011) taxa were also observed in the shallowly flooded margins (outside the surveyed quadrats) after the creek was inundated with lake water (winter 2010). In spring 2011, there was a significant increase in taxa, such as *Bolboschoenus caldwellii, Cotula coronopifolia*, *Lolium* sp. and *Polypogon monspeliensis*. The emergent *Schoenoplectus pungens* increased in abundance in autumn 2012.

Prior to autumn 2010, submergent r-selected *Ruppia tuberosa* was present in the creek channel in spring 2008 and spring 2009, until amphibious halophytes *Suaeda australis* and *Sarcocornia quinqueflora* colonised the bed after drying out (Figure 9). After the creek was inundated in winter 2010, there was a significant increase in the abundance of submergent k-selected, amphibious, floating and terrestrial taxa (Figure 9). In particular, there was a significant increase in *Potamogeton pectinatus* in spring 2011 and in *Azolla filiculoides*, *Bolboschoenus caldwellii* and *Myriophyllum salsugineum* in autumn 2011.

3.1.5 Loveday Bay

A total of 49 taxa (including 29 exotics) were recorded in Loveday Bay (Appendix 3). During the survey period terrestrial, amphibious, floodplain and emergent taxa were present at the higher elevations (5 to 2, inclusive) were dominated by (Figure 10) and the plant community (largely *Sarcocornia quinqueflora* and *Suaeda australis* dominated, adapted to elevated salinities) remained largely unchanged throughout that time; although *Aster subulatus* significantly increased in abundance in autumn 2012 at elevation 4.

When the lowest elevation (1) was inundated (e.g. in spring or following inundation with lake water in winter 2010) submergent r-selected taxa: *Ruppia tuberosa* and *Lamprothamnium macropogon* were often present; albeit in significantly higher abundances in spring 2008 (Gehrig *et al.* 2011b). Otherwise at this elevation emergent, amphibious and terrestrial taxa were present across the survey period (Figure 10) and there were no significant indicators for spring 2011 and autumn 2012.

3.1.6 Milang

A total of 65 taxa (including 36 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 was dominated by terrestrial, amphibious and some emergent taxa, across the entire survey (Figure 11), but changed seasonally with some winter annuals present during the spring surveys at all elevations. In addition, an area that was inundated seasonally with local runoff contained *Myriophyllum* sp. in spring 2008 and *Ruppia polycarpa* every spring during the survey period (abundance peaked in spring 2009) at some of the elevations (Figure 11; Gehrig *et al.* 2011b).

During the latest survey period (spring 2011 and autumn 2012) the plant community at the highest elevation (1) remained unchanged (i.e. no significant indicators), although at the next elevation (2) the annuals, *Hordeum vulgare* and *Lactuca serriola,* significantly increased in abundance in spring 2011. At elevation 3, the annual *Hordeum vulgare* also significantly increased in abundance in spring 2011 and *Suaeda australis* in autumn 2012. At the lowest elevation (4) *Muehlenbeckia florulenta* significantly increased in abundance in autumn 2012.

3.1.7 Narrung

A total of 31 taxa (including 12 exotics) were recorded in Narrung Wetland (Appendix 3). The plant communities at the highest elevations (4 to 2, inclusive) were a mix of terrestrial, amphibious and emergent taxa (Figure 12); in particular a native salt marsh composed of *Sarcocornia quinqueflora*, *Suaeda australis* and *Frankenia pauciflora*) (Gehrig *et al.* 2011b). The plant community remained unchanged across the survey period, with the exception of a significant increase in the annuals *Eragrostis curvula*, *Hordeum vulgare* and *Lolium* sp. in spring 2011 at the highest elevation (4). Up until spring 2011 the lowest elevation (1) was bare soil (Figure 12; Gehrig *et al.* 2011b), but in spring 2011 submergent (k and r-selected) taxa were present with *Chara* spp., P*otamogeton pectinatus* and *Ruppia polycarpa* significantly increasing in abundance. In autumn 2012, submergent r-selected, emergent and amphibious taxa were present with *Ruppia tuberosa* a significant indicator.

3.1.8 Point Sturt

A total of 40 taxa (including 23 exotics) were recorded in Point Sturt Wetland (Appendix 3). Similar to Dunns Lagoon, the wetland was generally dominated by terrestrial, amphibious and floodplain taxa for the first two years of the survey period (Figure 13); however, following inundation of the wetland (winter 2010), the plant community shifted and exotic amphibious taxa dominated (Figure 13). Furthermore, in autumn 2011 emergent, submergent r-selected (*Ruppia polycarpa*) and some native floating taxa were also present (Figure 13; Gehrig *et al.* 2011b). During the latest survey period (spring 2011 to autumn 2012), *Polypogon monspeliensis* significantly increased in abundance at the highest elevation (3) in spring 2011, there were no changes observed at elevation 2, and *Bolboschoenus caldwellii* significantly increased in abundance at the lowest elevation (1) in autumn 2012.

3.1.9 Poltalloch

A total of 26 taxa (including 16 exotics) were recorded in Poltalloch Wetland (Appendix 3). Prior to inundation with lake water (winter 2010) Poltalloch was dominated by terrestrial and amphibious taxa (Figure 14); largely salt tolerant taxa, with winter annuals present in the spring surveys. After inundation there was an increase in the abundance of amphibious taxa (especially at the higher elevations) that were later replaced by submergent r-selected taxa (e.g. *Ruppia tuberosa*) by autumn 2011. In the latest survey, *Ruppia polycarpa* significantly increased in abundance at elevation 3 in spring 2011 and both *Chara* sp. and *Ruppia polycarpa* were significantly abundant at elevation 2. The lowest elevation (1) saw a significant increase in *Chara* sp., *Ruppia polycarpa, Eragrostis curvula*, *Lolium* sp. and *Hordeum vulgare* in spring 2011, but there were no significant indicators recorded for autumn 2012.

3.1.10 Teringie

At total of 49 taxa (including 23 exotics) were recorded in Teringie (Appendix 3). Prior to inundation (winter 2010), terrestrial, amphibious and floodplain salt tolerant taxa (*Sarcocornia quinqueflora*, *Suaeda australis*, *Distichlis distichophylla*) with winter annuals were present in the spring surveys (Figure 15; Gehrig *et al.* 2011b). Elevation 1 was inundated during spring 2010 from local runoff and the submergent r-selected species *Lamprothamnium macropogon, Ruppia tuberosa* and *Spergularia marina* had recruited (Figure 15; Gehrig *et al.* 2011b). Elevations 2 to 4 (inclusive) remained dominated by salt tolerant taxa for the corresponding period with winter annuals present in spring 2010. In spring 2011, *Azolla filiculoides* significantly increased in abundance at both elevations 2 and 3. Perennial grasses (*Distichlis distichophylla, Paspalum distichum*) also significantly increased in abundance at elevation 3 in autumn 2012 and similarly *Erodium cicutarium* increased in abundance at the highest elevation (4) in autumn 2012. The lowest elevation (1) was inundated with lake water in summer 2010-11; however, there was no recruitment of aquatic species by autumn 2011 (Figure 15; Gehrig *et al.* 2011b) and no significant changes to the plant community during the latest survey period (spring 2011 and autumn 2012).

3.1.11 Waltowa

A total of 17 taxa (including 10 exotics) were recorded in Waltowa (Appendix 3). The flow control structure on the inlet channel of Waltowa Wetland was opened in May 2011 until April 2012. During that time the regulator was intermittently closed for short durations (days) to maintain water levels but between October 2011 and March 2012 there were difficulties in maintaining water levels into the wetland to compensate for the evaporative losses in the wetland due to choking of the inlet by *Phragmites australis* (although this area was cleared in autumn 2012). As a result the wetland was often dry during this period because sufficient water could not be delivered consistently. The higher elevations (4 to 2, inclusive) were largely dominated by terrestrial, floodplain and amphibious taxa (Figure 16), which was primarily salt tolerant taxa such as, *Sarcocornia quinqueflora* and *Suaeda australis*. The lowest elevation (1) was predominantly bare soil throughout the entire survey period, with some exceptions (e.g. spring 2011) when some terrestrial and/or amphibious taxa were present (Figure 16); however there were no significant indicator species for Waltowa during the latest surveys (spring 2011 and autumn 2012), suggesting the plant community remained largely unchanged.

3.2 Lakeshores

A total of 121 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 (101 taxa) followed by Goolwa Channel (71 taxa) with Lake Albert the least species rich (51 taxa) (Appendix 4). Lake Albert had the highest proportion of exotics (58.5%) compared to Lake Alexandrina (50.5%) and Goolwa Channel (43.66%) (Appendix 4).

In each location (Lake Alexandrina, Lake Albert and Goolwa Channel) the plant community changed through time, was different between elevations and there was a significant interaction between the two factors (Table 5). 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 5: 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, 1253	33.19	<0.001
	Time	7, 1253	15.19	<0.001
	Elevation × Time	33, 1253	2.56	<0.001
Lake Albert	Elevation	5, 599	21.79	<0.001
	Time	7, 599	23.87	<0.001
	Elevation × Time	33, 599	3.51	<0.001
Goolwa Channel	Elevation	5, 1136	30.48	<0.001
	Time	7, 1136	14.75	<0.001
	Elevation × Time	33, 1136	2.88	<0.001

3.2.1 Lake Alexandrina

Between spring 2008 and autumn 2010, the plant community in Lake Alexandrina was generally dominated by terrestrial taxa across all elevations (Figure 17); and for the following two years there was generally a concomitant decrease in terrestrial taxa and a marked increase in emergents, across all elevations (Figure 17). At the highest elevation (+0.8 m AHD) there was a significant increase in *Cotula coronopifolia*, *Holcus lanatus*, *Polypogon monspeliensis, Rumex bidens* and *Typha domingensis* in spring 2011. In autumn 2012, there were significant increases in the abundances of *Aster subulatus*, *Calystegia sepium*, *Limosella australis*, *Persicaria lapathifolia* and *Schoenoplectus pungens*. At the next elevation (+0.6 m AHD) significant indicators for spring 2011 were *Azolla filiculoides* and the state listed rare *Ceratophyllum demersum*. In autumn 2012, *Limosella australis* and emergents *Schoenoplectus pungens* and *Typha domingensis* also significantly increased in abundance. At +0.4 m AHD, *Azolla filiculoides*, *Bolboschoenus caldwellii* and *Lycopus australis* significantly increased in abundance in spring 2011 and *Berula erecta*, *Hydrocotyle verticillata* and *Typha domingensis* were more abundant in autumn 2012. At +0.2 m AHD, there was a significant increase in *Azolla filiculoides*, *Eleocharis acuta* and *Typha domingensis* in spring 2011, but there were no significant indicators for autumn 2012Although there was an increase in the proportions of emergent and submergent k-selected taxa present and a decrease in floating taxa (Figure 17). At the 0 m AHD elevation *Ceratophyllum demersum* significantly increased in abundance in autumn 2012, but there were no significant indicators and therefore no changes at the lowest elevation (-0.5 m AHD) across the latest survey period (spring 2011 to autumn 2012).

3.2.2 Lake Albert

The plant community around the edge of Lake Albert, similar to Lake Alexandrina, was generally dominated by terrestrial taxa between spring 2008 and autumn 2010, with some floodplain and amphibious taxa also present (Figure 18). From spring 2010, amphibious and emergent taxa replaced the terrestrial taxa, particularly between elevations +0.4 and +0.6 m AHD (Figure 18). At elevation +0.2 AHD there was a marked increase in emergent taxa (Figure 18). The lower elevations (0 and -0.5 m AHD) remained bare following inundation in winter 2010. Apart from significant increases in the abundance of *Aster subulatus* and *Cotula coronopifolia* in autumn 2012, there were no significant indicators for all remaining elevations, suggesting that the plant communities remained unchanged for the latest surveys (spring 2011 to autumn 2012).

3.2.3 Goolwa Channel

In Goolwa Channel, terrestrial, floodplain, amphibious and emergent taxa dominated the plant community at the higher elevations (0 to +0.8 m AHD, inclusive) between spring 2008 and autumn 2009, in contrast to the lowest elevation (-0.5 m AHD), which remained bare (Figure 19). When water levels rose in spring 2009, due to regulated flooding, some of the terrestrial taxa at these higher elevations were extirpated, although there was limited recruitment of terrestrial taxa above 0 m AHD when water levels fell in summer and autumn 2009-10 (Figure 19). There was little change in the abundances of the emergent fringing species (e.g. *Phragmites australis*) over the survey period in Goolwa Channel (Gehrig *et al.* 2011b). By autumn 2010, there was an increase in submergent k-selected taxa, namely *Potamogeton pectinatus* which recruited below 0 m AHD, but this was not a significant indicator (Gehrig *et al.* 2011b). By spring 2010, after water levels were reinstated, there was a significant increase in *Potamogeton pectinatus* as well as *Triglochin procerum* (emergent); however, the *Potamogeton pectinatus* was later replaced by *Myriophyllum salsugineum* by autumn 2011 (Gehrig *et al.* 2011b) .

During the latest survey, at +0.8 m AHD, *Juncus kraussii* and *Ficinia nodosa* significantly increased in abundance in spring 2011 as did the emergents *Typha domingensis* and *Berula erecta* in autumn 2012. At the next elevations (+0.4 and +0.6 m AHD) the emergent *Typha domingensis* significantly increased in abundance, whereas at +0.2 m AHD the emergent exotic *Salix babylonica* significantly increased in abundance in autumn 2012. There were no significant indicator species for the lower elevations (0 and -0.5 m AHD) suggesting there were no changes in the plant community across the latest survey period (spring 2011 and autumn 2012).

Table 6: Colour codes for vegetation functional groups.

Functional Group (colour codes)
Terrestrial
Floodplain
Amphibious
Floating
Emergent
Submergent r-selected
Submergent k-selected

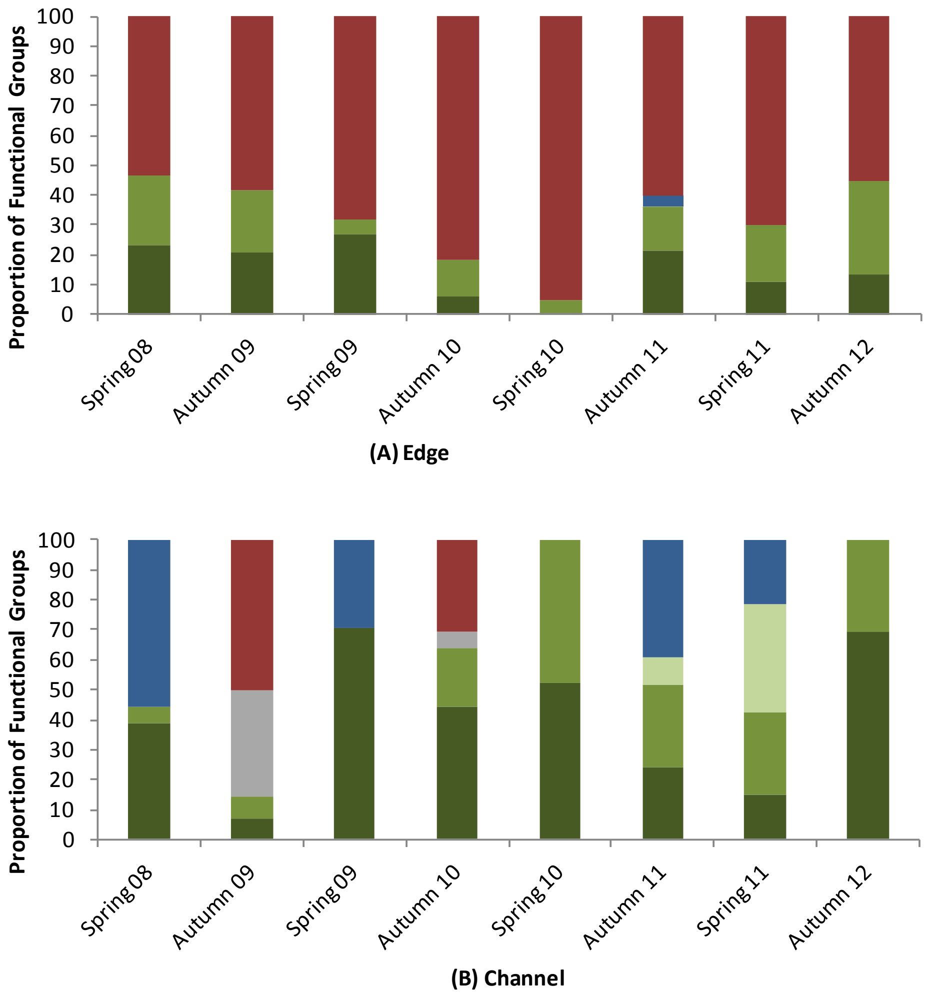


Figure 6: Proportion of plant functional groups for edge (A) and channel (B) elevations of Angas and Bremer River Mouths from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

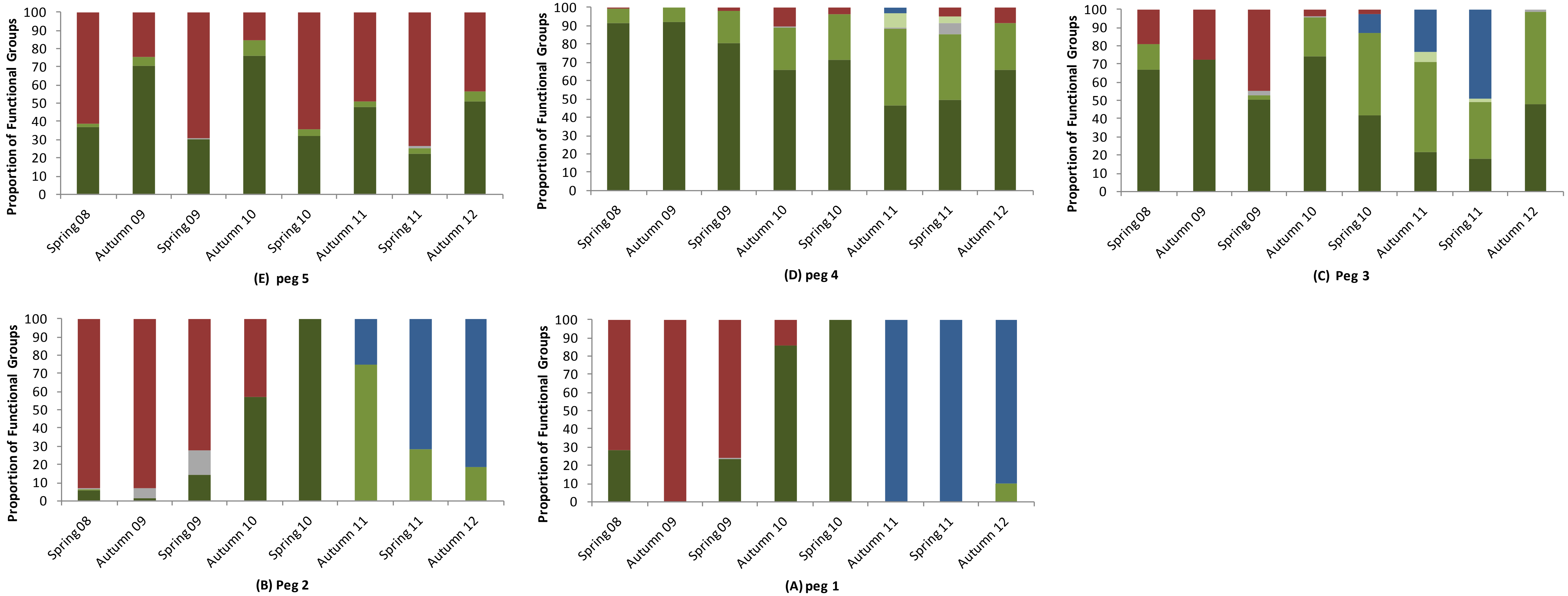


Figure 7: Proportion of plant functional groups from highest (E: peg 5) to lowest elevation (A: peg 1) in Dunn's Lagoon from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

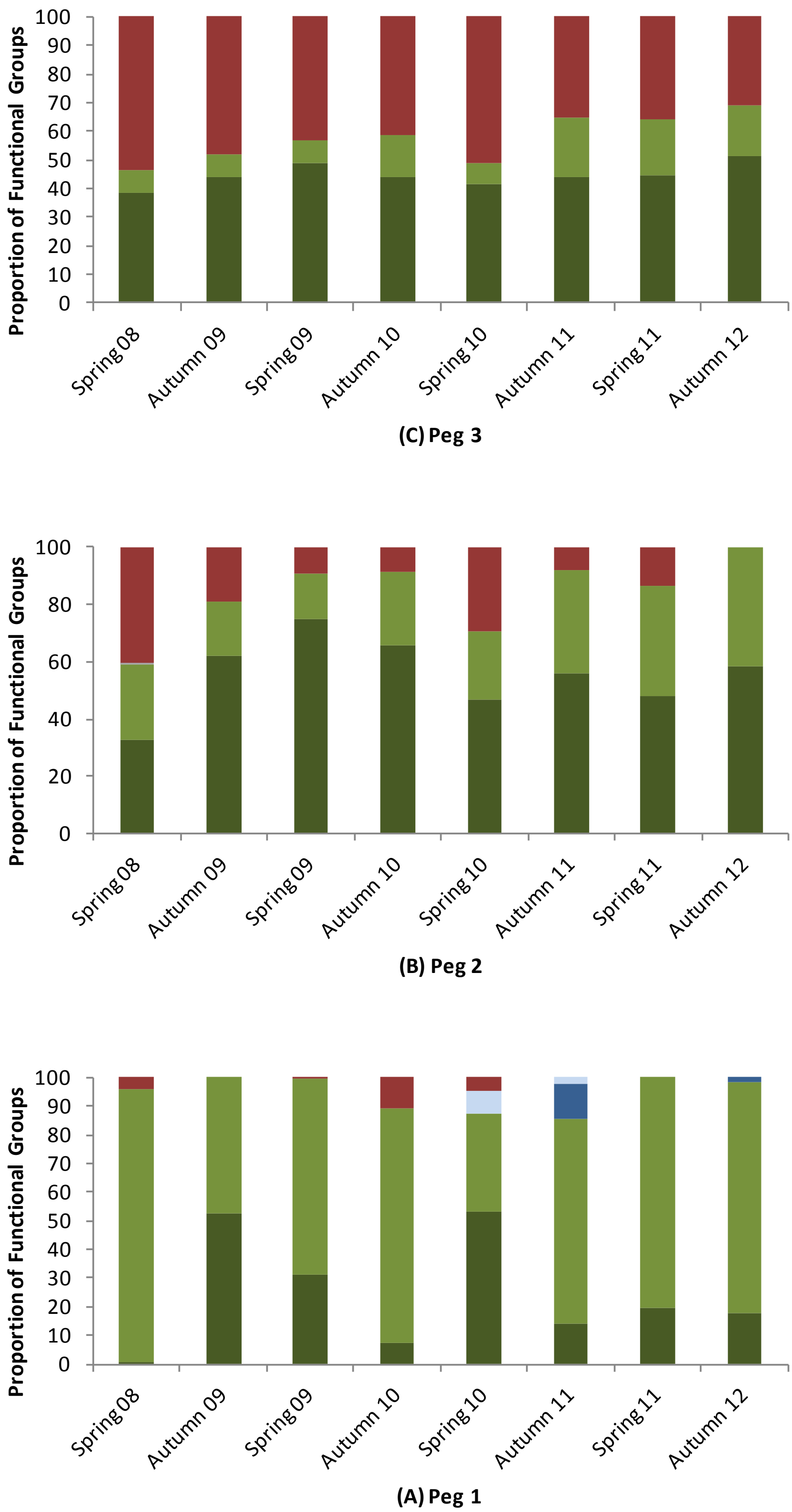
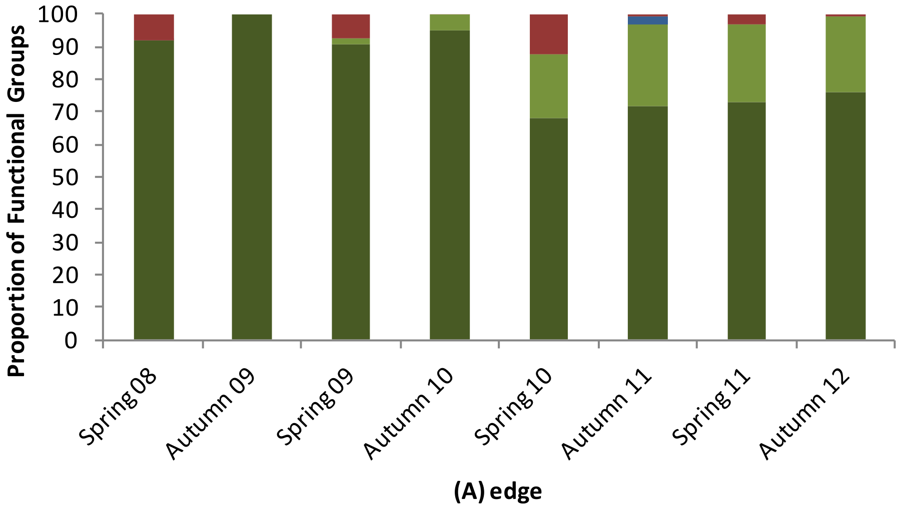


Figure 8: Proportion of plant functional groups from highest (C: peg 3) to lowest elevation (A: peg 1) in Goolwa Channel Drive from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).



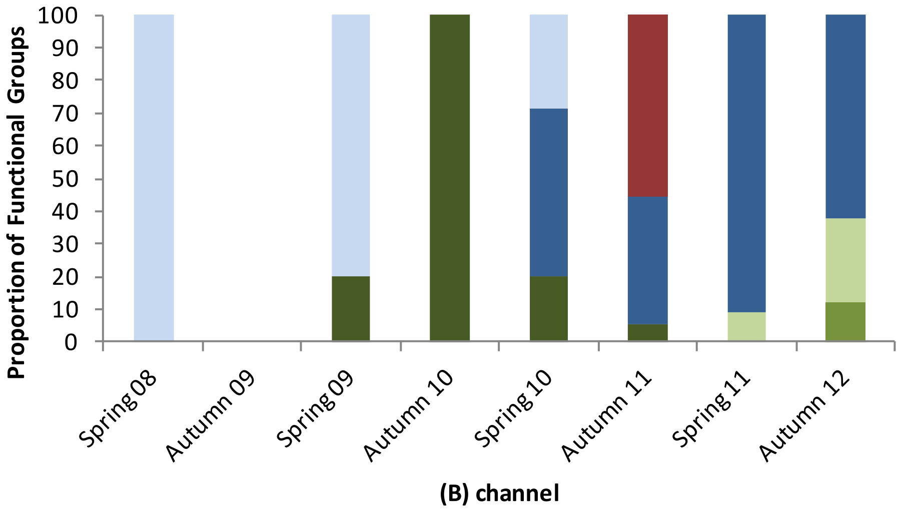


Figure 9: Proportion of plant functional groups for edge (A) and channel (B) elevations of Hunter's Creek from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

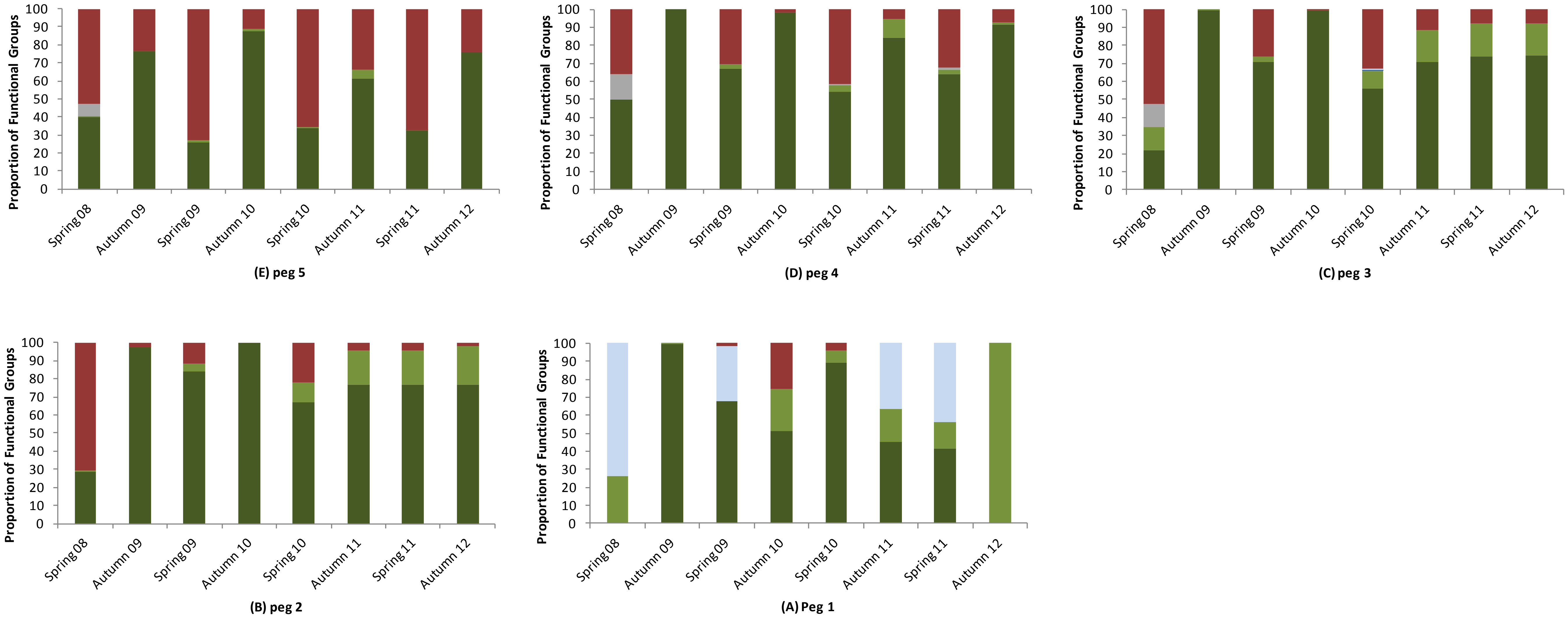


Figure 10: Proportion of plant functional groups across highest elevation (D: peg 4) to lowest elevation (A: peg 1) in Loveday Bay wetland from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

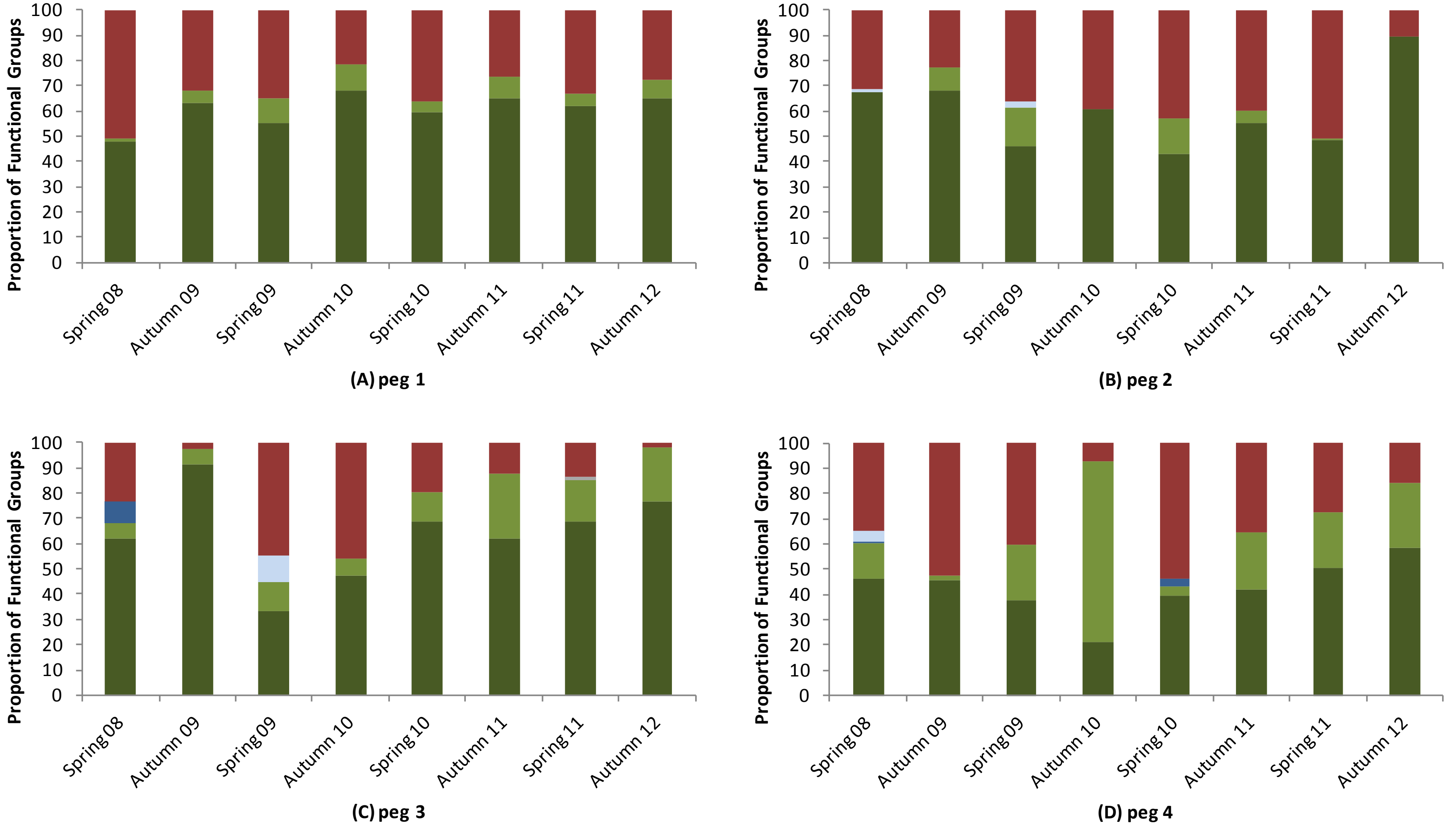


Figure 11: Proportion of plant functional groups across highest (A: peg 1) to lowest elevation (D: peg 4) in Milang Wetland from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

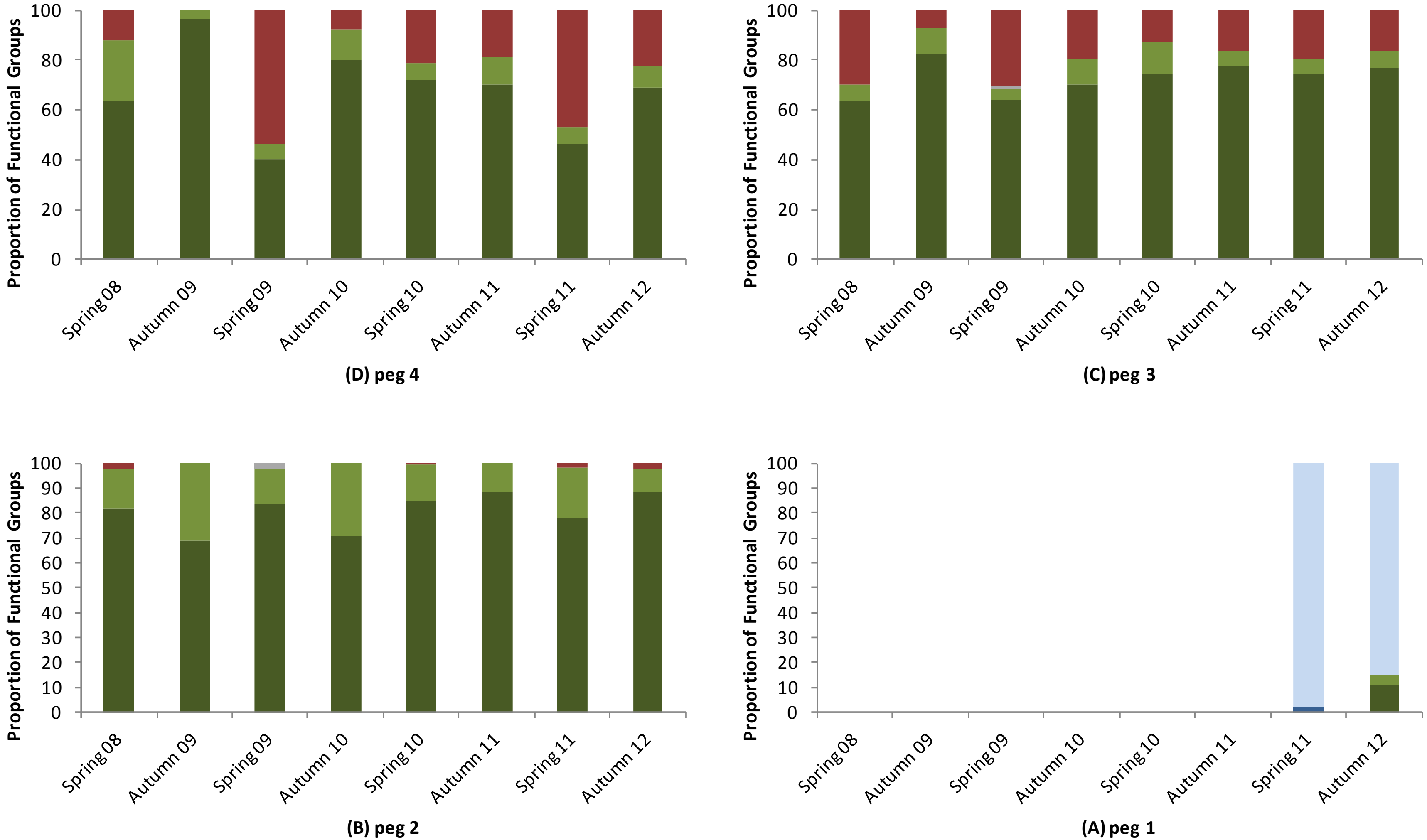


Figure 12: Proportion of plant functional groups across highest elevation (D: peg 4) to lowest elevation (A: peg 1) in Narrung wetland from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

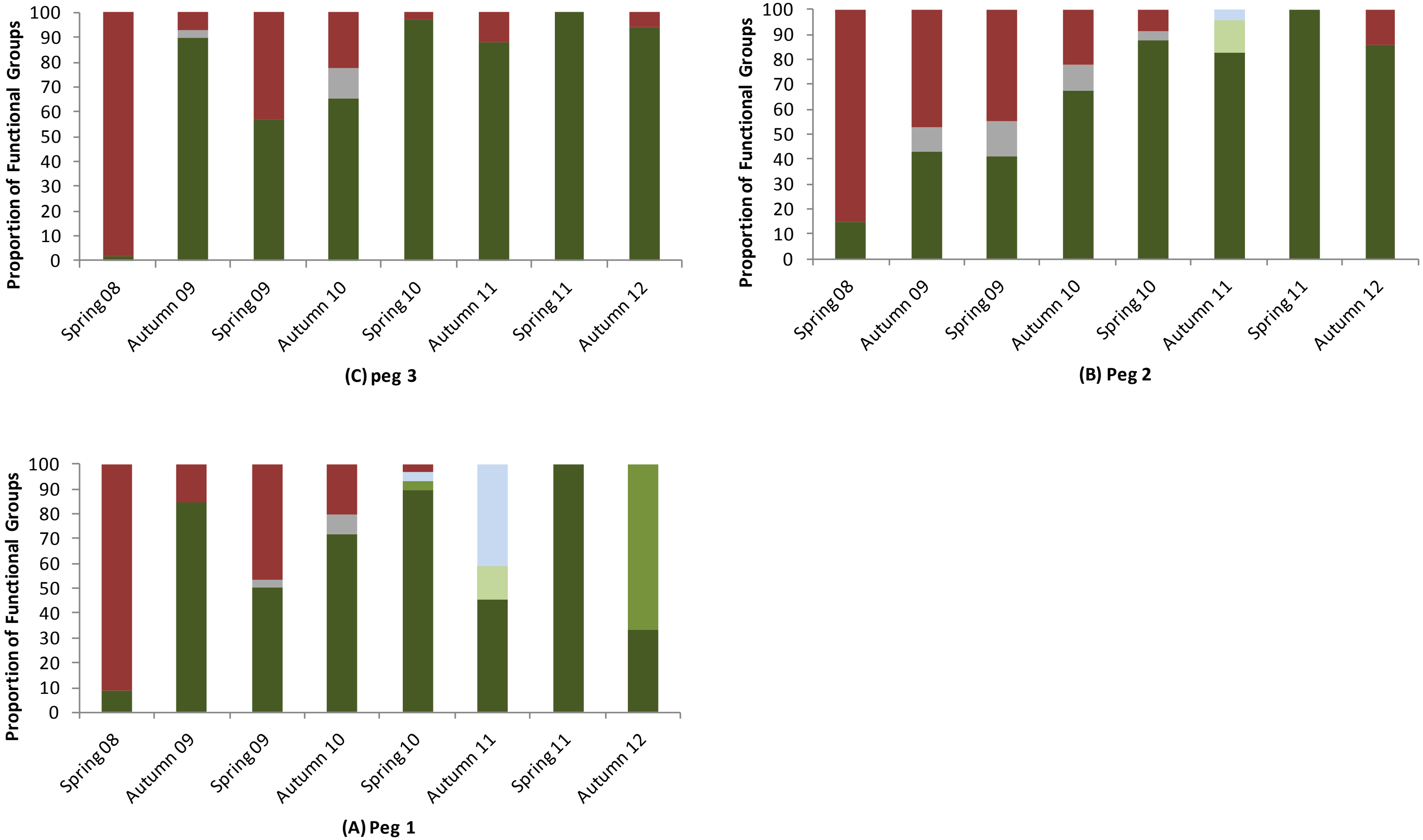


Figure 13: Proportion of plant functional groups across highest (C: peg 3) to lowest elevation (A: peg 1) in Point Sturt wetland from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

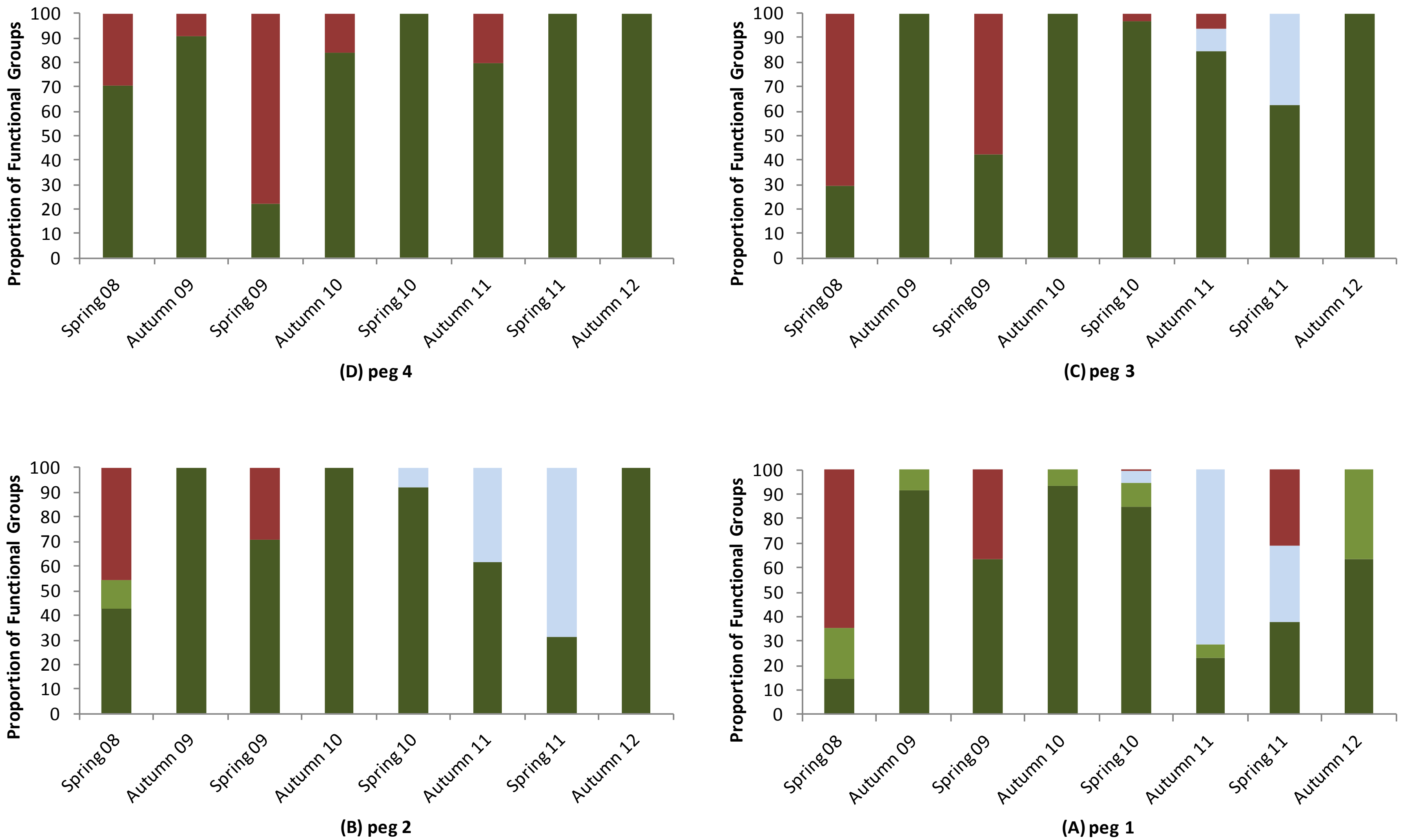


Figure 14: Proportion of plant functional groups across highest (D: peg 4) to lowest elevation (A: peg 1) in Poltalloch wetland from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

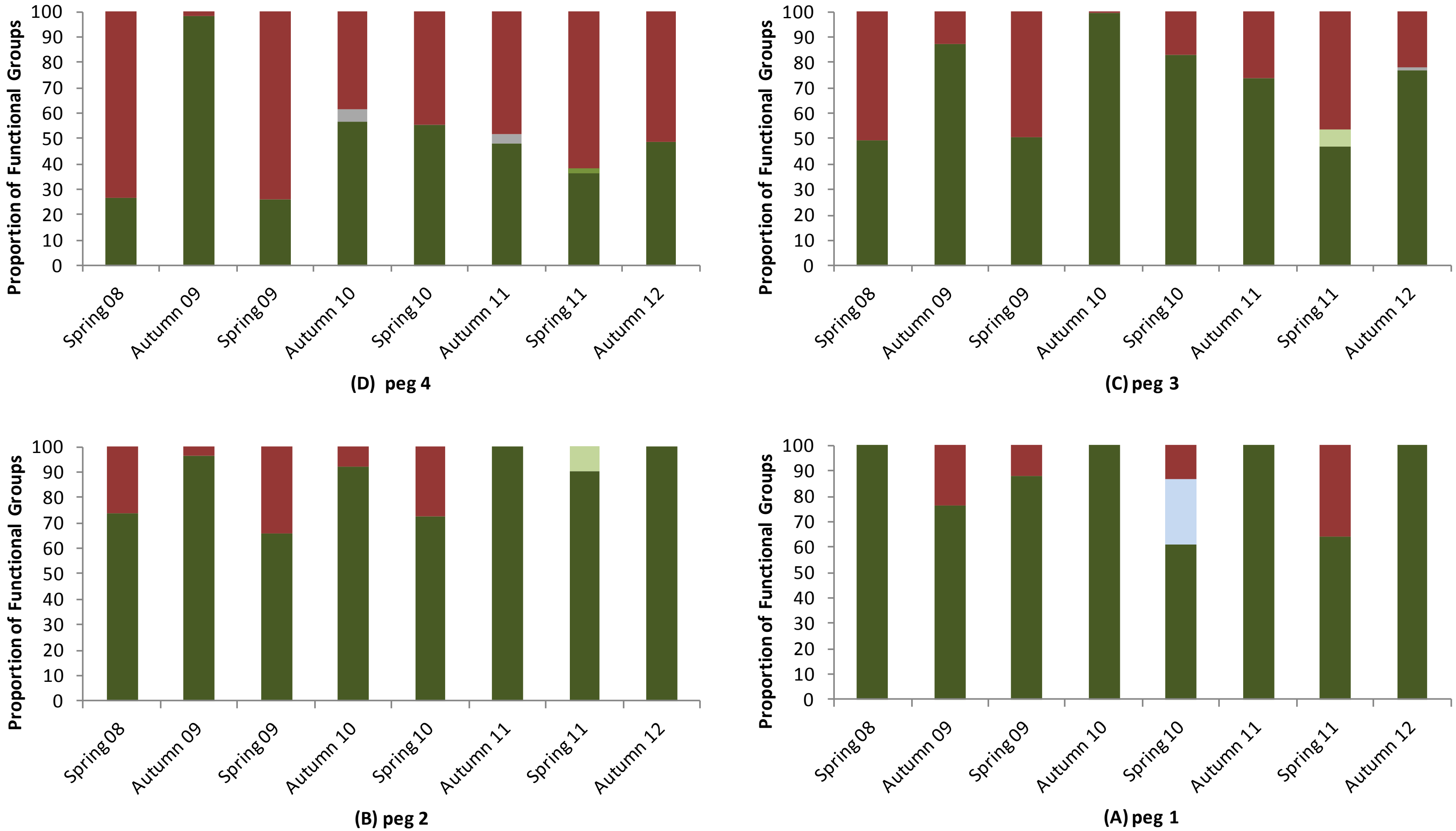


Figure 15: Proportion of plant functional groups across highest (D: peg 4) to lowest elevation (A: peg 1) in Teringie from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

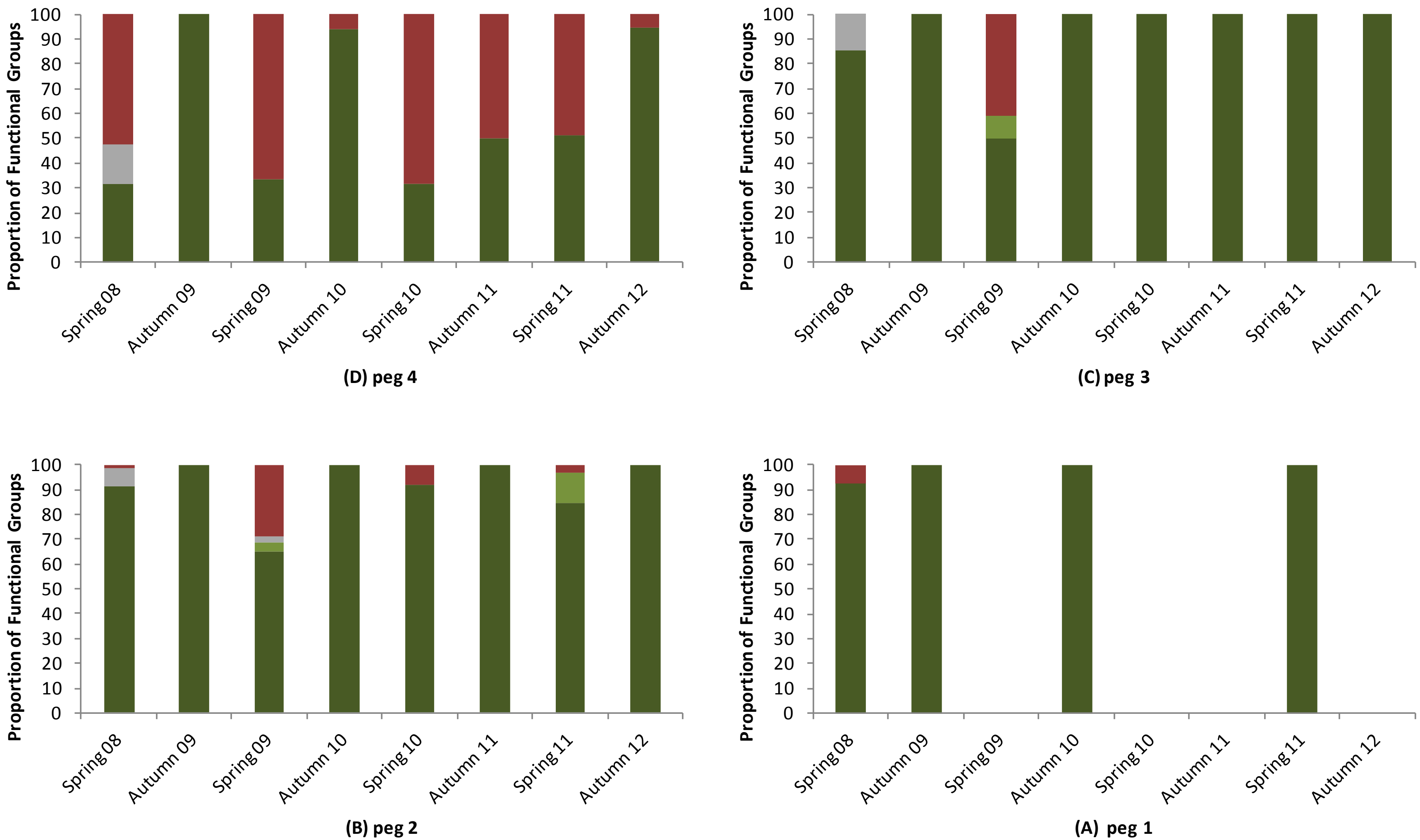


Figure 16: Proportion of plant functional groups across highest elevation (D: peg 4) to lowest elevation (A: peg 1) in Waltowa from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

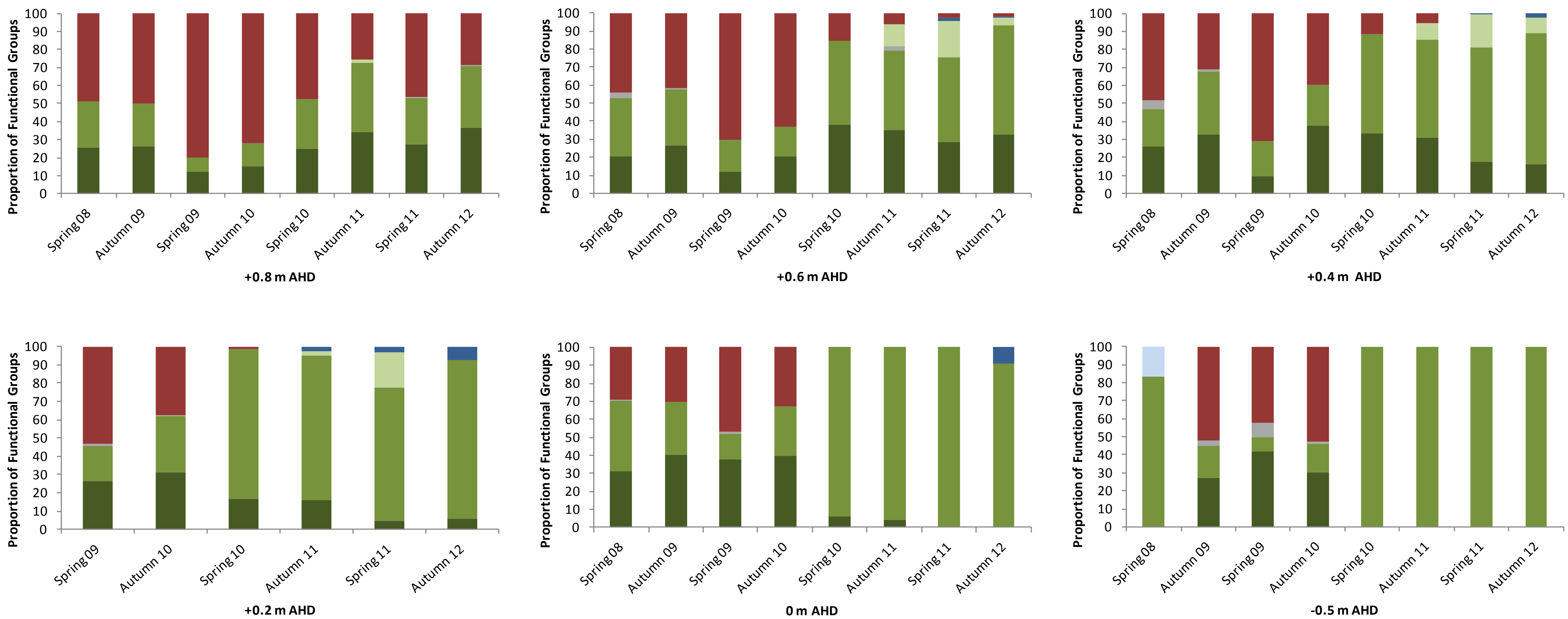


Figure 17: Proportion of plant functional groups from highest elevation (+0.8 m AHD) to lowest elevation (-0.5 m AHD) in Lake Alexandrina from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

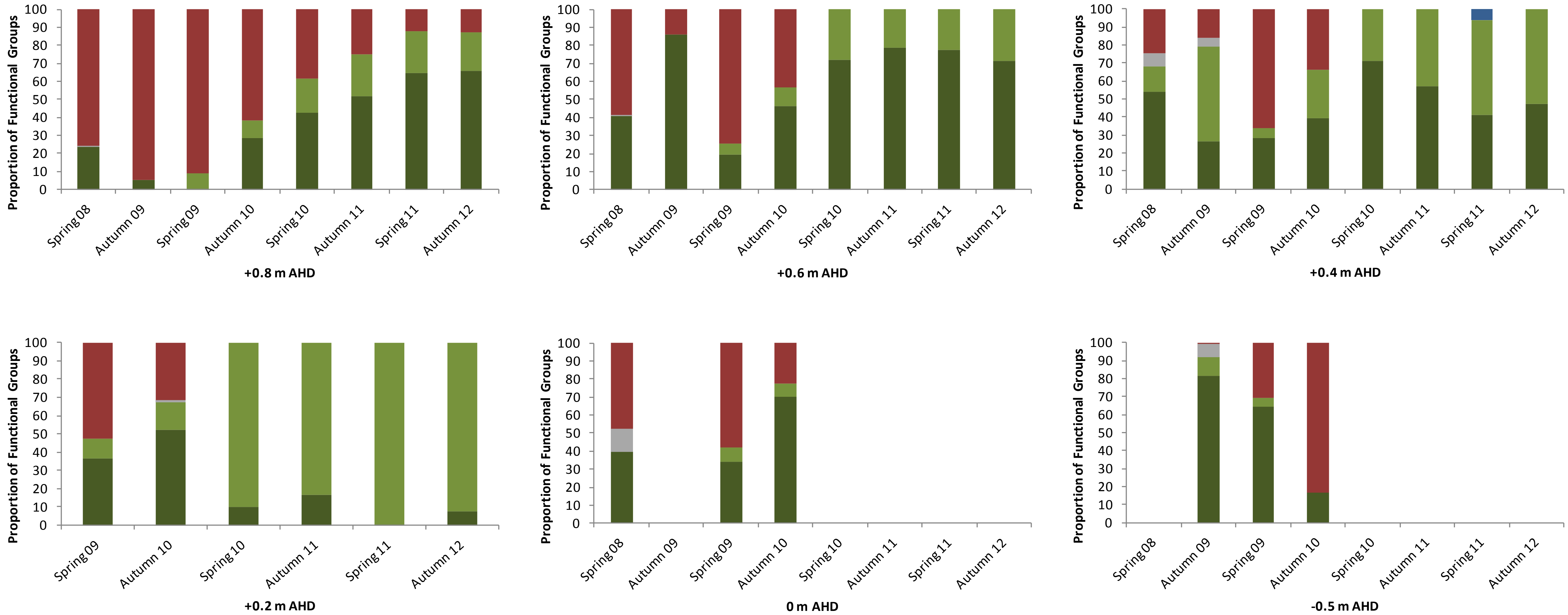


Figure 18: Proportion of plant functional groups from highest elevation (+0.8 m AHD) to lowest elevation (-0.5 m AHD) in Lake Albert from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

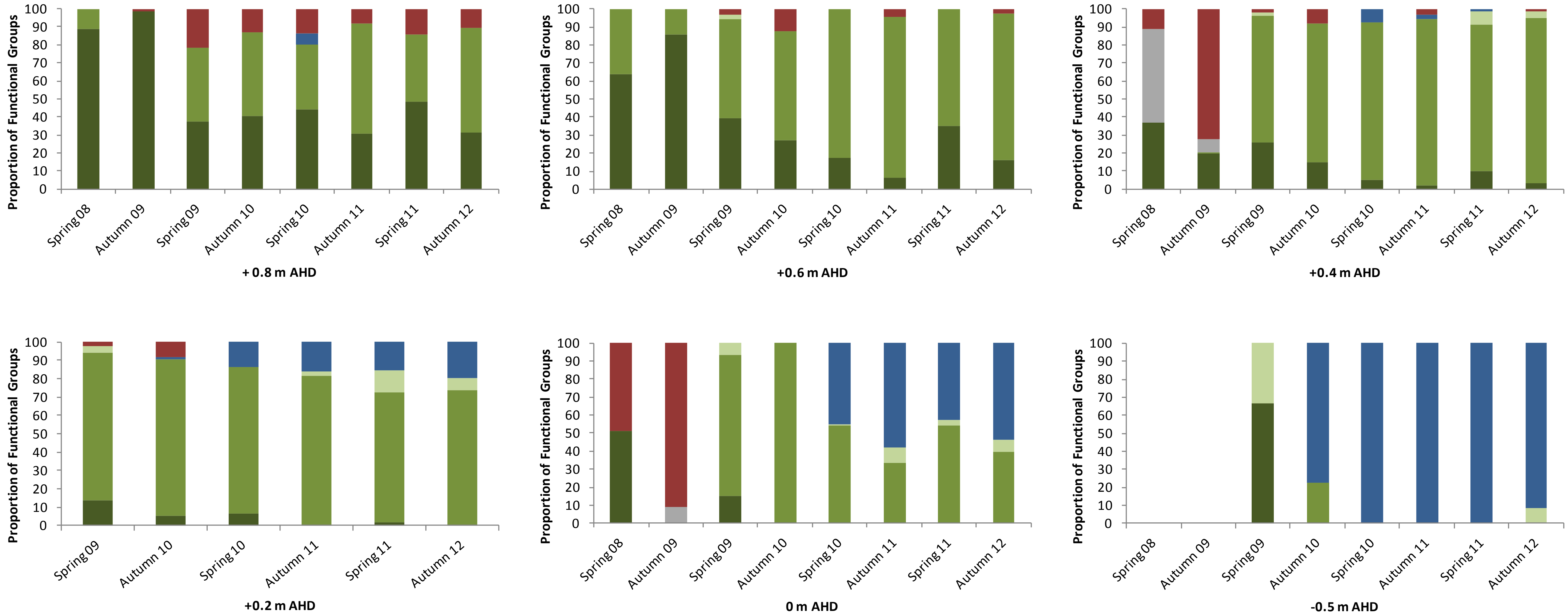


Figure 19: Proportion of plant functional groups from highest elevation (+0.8 m AHD) to lowest elevation (-0.5 m AHD) in Goolwa Channel from spring 2008 to autumn 2012 (Functional group key is provided in Table 6).

4 Discussion and management implications

4.1 Wetlands

Prior to 2007, the historical plant community in the 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) River Murray wetland baseline surveys for the Lower Lakes wetlands 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 those that contained areas that received local runoff. These areas supported submergent (usually submergent r-selected), amphibious and emergent taxa 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 striatum, 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 k-selected species (*Ceratophyllum demersum* and *Vallisneria spiralis* var. *americana*) were also present in spring surveys prior to August 2010. However, the water present in the channels of the Angas 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 received environmental water via pumping, in spring 2009 and Paton and Bailey (2010) reported that the submergent species *Ruppia tuberosa, Ruppia polycarpa, Lepilaena cylindrocapa, Lepilaena preissii, Potamogeton 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 only just occurred following the latest survey in autumn 2012). 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 some low lying areas were inundated with lake water.

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 predominantly terrestrial taxa to amphibious, submergent, floating and emergent taxa. Whilst this change was not detected by indicator species analysis until autumn 2011, in some instances changes had occurred by the spring 2010 survey in the aforementioned wetlands but taxa from the aquatic functional groups were in lower abundances compared with the autumn 2011 survey. The abundance of aquatic taxa either increased or remained similar to levels recorded in the 2010/11 surveys except in Poltalloch where abundances decreased. The reason for the decrease in submergent species in Poltalloch is unknown; however, this wetland was historically seasonal with inundation in spring and drying in autumn and summer. Most taxa were submergent r-selected species and the extended inudation may be unfavourable for this particular functional group.

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 emergent species). However in areas that were dominated by emergent and amphibious taxa 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 (J. Nicol pers. obs.). It is unclear whether this observation was due to above average local rainfall during the last 24 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. However, *Ruppia tuberosa* and charophytes had colonised the wetland bed at the lower elevations by spring 2011, and were still present in autumn 2012.

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* were present in spring 2010 at both sites 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. Low elevtions close to Lake Alexandrina in Teringie Wetland remianed inundated throughout 2011/12 but were dominated by amphibious taxa and the diverse submergent plant community recorded in spring 2004 (Holt *et al.* 2005) had not re-established. Loveday Bay Wetland only fills when lake levels are very high and there are strong westerly winds and lake water only just reached the causeway in 2011/12, which was probably why submergent species had not recolonised the wetland.

Sites in 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 and the inlet structure being open from May 2011 to April 2012. The plant community was dominated by salt tolerant species and terrestrial species throughout the survey period and will probably remain dominated by these functional groups (unless inundation occurs).

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 taxa 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 taxa, 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, inflows from the tributaries 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, Vallisneria spiralis* var. *americana, Ceratophyllum demersum* and *Myriophyllum salsugineum*) were present in quadrats. In addition, *Ruppia megacarpa* and *Ruppia polycarpa* (submergent species) were observed in low numbers outside of monitoring quadrats. Submergent taxa were not observed until autumn 2010, which was not unexpected as the spring 2009 survey was undertaken four weeks after pumping ceased and the majority of submergent taxa 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 $\mu S.cm^{-1}$) and *Schoenoplectus validus* (maximum reported salinity tolerance of 700 $\mu S.cm^{-1}$) (Bailey *et al.* 2002) were present in Goolwa Channel despite the elevated salinity. 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 $\mu S.cm^{-1}$ (Nicol and Ward 2010b). Nevertheless, seeds remained viable when subjected to salinities as high as 20,000 $\mu S.cm^{-1}$ for at least six weeks (Nicol and Ward 2010b). 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 taxa increased in abundance from +0.8 to 0 m AHD in Lake Alexandrina but not in Lake Albert. In addition, species richness was lower in Lake Albert compared to Lake Alexandrina and Goolwa Channel. It is unlikely that the elevated surface water EC in Lake Albert is the cause of lower species richness, since levels have not exceeded thresholds for most species present throughout the system since reconnection (Bailey *et al.* 2002; Nicol and Ward 2010a; Nicol and Ward 2010b) The lower overall species richness is probably due to the dominance of high energy shoreline in Lake Albert compared to Goolwa Channel and Lake Alexandrina where there is greater shoreline complexity and greater areas of protected shorelines.

The -0.5 m AHD elevation was generally devoid of plants in lakes Alexandrina and Albert. In Goolwa Channel emergent taxa (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.* 2011a). 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.* 2011a).

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, approximately 7,500 $\mu S.cm^{-1}$) (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.* 2011a). 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 spiralis* var. *americana*) to colonise these areas.

Emergent taxa also responded to lower salinities in Goolwa Channel after September 2010 (Gehrig *et al.* 2011a). 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.* 2011a).

Colonisation of submergent taxa 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 taxa. 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). *Potamogeton crispus* and *Ceratophyllum demersum* are now widespread throughout Goolwa Channel (although not highly abundant) and are also present in Dunns Lagoon. 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 four 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 spiralis* var. *americana* 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.

The salinity spikes in Goolwa Channel observed during the latest survey period appeared to have little impact on the plant community. The salinity spikes were of short duration followed by flushing of freshwater and the maximum salinities were generally lower than the salinity experienced during autumn 2010.

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 is now 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 2012. In addition, extensive areas of *Myriophyllum salsugineum* were present upstream of the Hindmarsh Island Bridge in shallow areas of Goolwa Channel prior to the drawdown of lake levels (J. Nicol pers. obs.) but were not present in autumn 2012. 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. These plant communities were present throughout 2011/12 and whilst not measured directly probably increased in extent but still not to the extent observed before the drought.

Therefore, TLM target V3 has not been met when compared to the plant community present prior to drawdown. 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 recorded in the spring 2010 or autumn 2011 survey and were present in 2011/12. Results showed that the plant community shifted from being dominated by terrestrial taxa to submergent, emergent, floating and amphibious taxa. 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 the condition monitoring program to gain an understanding of the medium to long-term vegetation dynamics of the system and monitor recovery post hydrological restoration.
- Map large-scale plant communities in Goolwa Channel (*sensu* Gehrig *et al.* 2011a), expanding to key wetlands and lakeshore areas to complement condition monitoring program and gain a better understanding of vegetation dynamics at the landscape scale.
- Undertake the *Melaleuca halmaturorum* component of the condition monitoring program in 2012/13 or 2013/14.
- 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 spp.*	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
*Ehrharta longiflora**	Terrestrial damp	Annual	Exotic
Einadia nutans	Terrestrial dry	Perennial	Native
Eleocharis acuta	Emergent	Perennial	Native
Enchylaena tomentosa	Terrestrial dry	Perennial	Native

Taxon	Functional Group	Life history strategy	Status and Comments
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
Helichrysum luteo-album	Floodplain	Annual	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
Ficinia 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
Lythrum hyssopifolia	Amphibious fluctuation tolerator-emergent	Perennial	Native
Lythrum salicaria	Amphibious fluctuation tolerator-emergent	Perennial	Native

Taxon	Functional Group	Life history strategy	Status and Comments
*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
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
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	Perennial	Native-Listed as Rare in the

Taxon	Functional Group	Life history strategy	Status and Comments
	tolerator-emergent		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 spiralis var. *americana*	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 2012 (*denotes exotic taxon; #denotes listed as rare in South Australia).

Species	Angas and Bremer Mouths	Dunns Lagoon	Goolwa Channel Drive	Hunters Creek	Loveday Bay	Milang	Narrung	Point Sturt	Poltalloch	Teringie	Waltowa
Agapanthus sp.											
*Asparagus asparagoides**											
Asphodelus fistulosus											
*Aster subulatus**											
*Atriplex prostrata**											
Atriplex semibaccata											
Atriplex sp.											
Atriplex stipitata											
Atriplex suberecta											
Avena spp.											
Azolla filiculoides											
*Batrachium trichophyllum**											
Berula erecta											
Bolboschoenus caldwellii											
*Brassica rapa**											
*Brassica tournifortii**											
*Bromus diandrus**											
Bromus hordeaceus											
*Bromus mollis**											
Calystegia sepium											
Carpobrotus rossii											
*Centaurea calcitrapa**											
Ceratophyllum demersum#											

Species	Angas and Bremer Mouths	Dunns Lagoon	Goolwa Channel Drive	Hunters Creek	Loveday Bay	Milang	Narrung	Point Sturt	Poltalloch	Teringie	Waltowa
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											
*Eragrostis curvula**											
Eragrostis sp.											
Erodium cicutarium											
Frankenia pauciflora											
Ficinia nodosa											
*Fumaria bastardii**											
Gahnia filum											
Glyceria australis											
Halosarcia pergranulata											
Helichrysum luteo-album											
*Heliotropium europaeum**											
*Holcus lanatus**											

Species	**Angas and Bremer Mouths**	**Dunns Lagoon**	**Goolwa Channel Drive**	**Hunters Creek**	**Loveday Bay**	**Milang**	**Narrung**	**Point Sturt**	**Poltalloch**	**Teringie**	**Waltowa**
*Hordeum vulgare**		■			■	■	■	■	■	■	■
Hydrocotyle verticillata		■									
*Hypochaeris glabra**		■			■						
*Hypochaeris radicata**	■	■									
Iris sp.*	■										
Isolepis platycarpa		■				■					
Isolepis producta				■		■					
*Juncus acutus**		■									
Juncus kraussii		■	■	■	■	■					
Juncus subsecundus		■		■	■	■					
Juncus usitatus						■					
Lachnagrostis filiformis	■	■	■	■	■	■	■	■		■	
*Lactuca saligna**		■			■	■					
*Lactuca serriola**	■	■			■	■			■	■	
*Lagurus ovatus**			■			■		■		■	
Lamprothamnium macropogon					■				■	■	
Lemna sp.	■							■			
Lobelia alata										■	
Lolium sp.*	■	■	■	■	■	■	■	■	■	■	■
Ludwigia peploides	■	■									
*Lycium ferocissimum**						■		■	■	■	
*Malva parviflora**						■			■		
*Marrubium vulgare**					■						
Medicago sp.*		■		■	■	■	■	■	■	■	■
*Melilotus indica**		■			■			■	■		
Melaleuca halmaturorum		■								■	

Species	Angas and Bremer Mouths	Dunns Lagoon	Goolwa Channel Drive	Hunters Creek	Loveday Bay	Milang	Narrung	Point Sturt	Poltalloch	Teringie	Waltowa
Mentha spp.*											
Mimulus repens											
Muehlenbeckia florulenta											
Myriophyllum salsugineum											
*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											
Puccinellia spp.											
*Ranunculus trilobus**											
*Reichardia tingitana**											
*Rorippa nasturtium-aquaticum**											
*Rorippa palustris**											
Rumex bidens											
Ruppia megacarpa											
Ruppia polycarpa											
Ruppia tuberosa											

Species	Angas and Bremer Mouths	Dunns Lagoon	Goolwa Channel Drive	Hunters Creek	Loveday Bay	Milang	Narrung	Point Sturt	Poltalloch	Teringie	Waltowa
Salsola kali											
Samolus repens											
Sarcocornia quinqueloflora											
*Scabiosa atropurpurea**											
Schoenoplectus pungens											
Schoenoplectus validus											
*Senecio pterophorus**											
Senecio runcinifolius											
Senecio sp.											
*Sonchus asper**											
*Sonchus oleraceus**											
*Spergularia marina**											
*Suaeda australis**											
*Silybum marianum**											
Trifolium sp.*											
Triglochin procerum											
Triglochin striatum											
Typha domingensis											
*Urtica urens**											
Vallisneria spiralis var. *americana*											
*Vicia sativa**											
Wilsonia rotundifolia											
Species Total	**36**	**69**	**31**	**31**	**50**	**65**	**31**	**40**	**26**	**49**	**17**
Exotics Total	**19**	**32**	**14**	**10**	**29**	**35**	**12**	**23**	**16**	**23**	**10**
% Exotics	**52.78**	**46.38**	**45.16**	**32.26**	**58.00**	**53.85**	**38.71**	**57.50**	**61.54**	**46.94**	**58.82**

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).

Species	Lake Albert	Lake Alexandrina	Goolwa Channel
Acacia myrtifolia	✓		
*Apium graveolens**		✓	
*Arctotheca calendula**	✓	✓	
*Asparagus officinalis**			✓
*Aster subulatus**	✓	✓	✓
*Atriplex prostrata**		✓	✓
Atriplex sp.		✓	✓
Atriplex suberecta		✓	✓
Avena spp.	✓	✓	
Azolla filiculoides		✓	✓
Berula erecta		✓	✓
Bolboschoenus caldwellii		✓	✓
*Brassica rapa**		✓	
*Brassica tournifortii**		✓	✓
*Briza minor**		✓	
*Bromus diandrus**	✓	✓	✓
*Bromus hordeaceus**	✓	✓	✓
Bromus mollis			✓
*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**	✓		
Ficinia nodosa	✓	✓	✓
*Foeniculum vulgare**		✓	

Species	Lake Albert	Lake Alexandrina	Goolwa Channel
*Fumaria bastardii**			
Glyceria australis			
Helichrysum luteo-album			
*Holcus lanatus**			
*Hordeum vulgare**			
Hydrocotyle verticillata			
*Hypochaeris glabra**			
*Hypochaeris radicata**			
Isolepis platycarpa			
Isolepis sp.			
*Juncus acutus**			
Juncus kraussii			
Juncus subsecundus			
Juncus usitatus			
Lachnagrostis filiformis			
*Lactuca saligna**			
*Lactuca serriola**			
*Lagurus ovatus**			
Lemna sp.			
Limosella australis			
Lobelia alata			
Lolium sp.*			
Ludwigia peploides			
*Lupinus cosentinii**			
Lycopus australis			
Lythrum salicaria			
Medicago sp.*			
*Melilotus indica**			
Melaleuca halmaturorum			
Mentha australis			
Mentha spp.*			
Mimulus repens			
Muehlenbeckia florulenta			
Myriophyllum salsugineum			
*Onopordum acanthium**			
*Paspalum distichum**			
*Pennisetum clandestinum**			
Persicaria lapathifolia			
Phragmites australis			
Picris hieracoides			
*Plantago coronopus**			
*Plantago lanceolata**			
Plantago major			
*Polypogon monspeliensis**			

Species	**Lake Albert**	**Lake Alexandrina**	**Goolwa Channel**
*Polygonum aviculare**			
Potamogeton crispus			
Potamogeton pectinatus			
Puccinellia spp.			
Ranunculus trilobus			
*Reichardia tingitana**			
Rorippa islandica			
Rumex bidens			
Ruppia tuberosa			
*Salix babylonica**			
Sarcocornia quinqueloflora			
*Scabiosa atropurpurea**			
Scaevola			
Schoenoplectus pungens			
Schoenoplectus validus			
Sclerolaena blackiana			
Senecio cunninghamii			
*Senecio pterophorus**			
Senecio runcinifolius			
Senecio sp.			
*Solanum nigrum**			
Solanum spp.			
*Sonchus asper**			
*Sonchus oleraceus**			
*Spergularia marina**			
*Suaeda australis**			
*Silybum marianum**			
Trifolium sp.*			
Triglochin procerum			
Triglochin striatum			
Triticum spp.*			
Typha domingensis			
*Urtica urens**			
Vallisneria spiralis var. *americana*			
*Vicia sativa**			
Species total	**51**	**101**	**71**
Exotic Total	**30**	**51**	**31**
% Exotics	**58.82**	**50.50**	**43.66**