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Lower Lakes Vegetation Condition Monitoring – 2013/2014

Kate Frahn, Susan Gehrig, Jason Nicol and Kelly Marsland

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Cover Photo: Shoreline of Lake Alexandrina at Raukkan showing *Phragmites australis*, *Typha domingensis, Ceratophyllum demersum* and *Schoenoplectus validus* (Regina Durbridge).

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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 six years of a monitoring program established to evaluate The Living Murray (TLM) Target V3 in the aforementioned plan: maintain or improve aquatic and littoral vegetation in the Lower Lakes.

The program consists of two complementary components: 1. Understorey vegetation surveys conducted during spring (high lake levels) and autumn (low lake levels); and 2. Monitoring of the mid to long-term population dynamics of the dominant tree species *Melaleuca halmaturorum*.

Vegetation surveys were conducted at selected wetlands and lakeshore sites across Lakes Alexandrina and Albert, Goolwa Channel, 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 were estimated using a modified Braun-Blanquet (1932) cover abundance score. Vegetation surveys were undertaken every spring (October 2008, 2009, November 2010, October 2011, 2012 and 2013) and autumn (March 2009, 2010, 2011, 2012, 2013 and 2014). 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 environmental water into 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 normal pool level and in September 2010, the Clayton Regulator and Narrung Bund were breached, reconnecting these areas with Lake Alexandrina. Water levels between +0.9 and +0.4 m AHD and connectivity throughout the system, continued throughout the remainder of the monitoring program.

In addition to understorey monitoring, *Melaleuca halmaturorum* age class structure was monitored in autumn 2014 for the first time since spring 2008. Four of the five sites established

in spring 2008 were resurveyed and age class structure determined using the technique outlined in Stewart (2000).

Over the six year period (spring 2008 to autumn 2014), a total of 155 taxa (including 79 exotics, three weeds of national significance, eight proclaimed pest plants in South Australia and one species listed as rare in South Australia) were recorded throughout the Lower Lakes. At wetland sites, 128 taxa were recorded (including 62 exotics) and at lakeshore sites 127 taxa were recorded (including 63 exotics). From 2008 to 2010, disconnection and subsequent desiccation of wetlands generally resulted in the loss of submergent taxa, except for wetlands that received rainfall runoff (Teringie and Loveday Bay) or were filled by pumping (Narrung) and colonisation by terrestrial species. In 2009/10, more terrestrial species had colonised lower elevations than was recorded in 2008/09. During this period a total of 46 submergent, emergent and amphibious taxa that were present in 2004 and 2005 were not recorded. When water levels were reinstated, aquatic species generally recolonised the inundated areas and increased in cover for the remainder of the survey period, albeit probably 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 2014.

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 due to lower water levels). 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, emergent, amphibious and submergent species colonised Lake Alexandrina and emergent and amphibious species colonised Lake Albert. The abundance of the aforementioned functional groups in lakes Alexandrina and Albert continued throughout the survey period. Breaching of the Clayton Regulator decreased 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 and a more diverse submergent plant community that also included *Vallisneria australis, Ceratophyllum demersum, Potamogeton crispus* and *Myriophyllum caput-medusae* was present in March 2013 and 2014. The emergent plant community in Goolwa Channel also changed significantly over the same period with *Schoenoplectus validus, Typha domingensis and Phragmites australis* abundance increasing between spring 2010 and autumn 2014.

Results showed that the plant community is resilient and recovering but the submergent plant community is different (cover and diversity) 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, Teringie and Narrung) are yet to fully recover. All but three (*Myriophyllum caput-medusae, Ranunculus trichophyllus* and *Lepilaena cylindrocarpa*) of the 46 species recorded in 2004 and 2005 that were not onbserved during the drought were present by 2011/12. *Myriophyllum caput-medusae* was recorded for the first time since 2005 in 2012/13 and *Ranunculus trichophyllus* in 2013/14; however, *Lepilaena cylindrocarpa* has not been recorded.

Melaleuca halmaturorum age class structure showed that recruitment occurred at two sites; at Goat Island recruitment was continuous but at Hunters Creek there was one recruitment event between 2008 and 2014. No recruitment was recorded at Hindmarsh Island and Kennedy Bay, which was probably due to dense, monospecific stands of *Phragmites australis* surrounding both sites. Furthermore, seedlings observed at Kennedy Bay in 2008 were inundated when water levels were reinstated and had not survived. The stand at Salt Lagoon was not able to be surveyed in 2014.

Comparison between monitoring results and the River Murray Wetlands baseline surveys undertaken in 2004 and 2005 show that target V3 has still not been met for understory vegetation. However, after water levels increased there was a significant and sustained increase in the abundance, extent and diversity of aquatic plant communities. In addition, all of the aquatic species that have recruited 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

1.1. Background

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 "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 six years of the understorey component and two rounds of the tree component of a condition monitoring program designed to evaluate target TLM V3: maintain or improve aquatic and littoral vegetation in the Lower Lakes (Marsland and Nicol 2009; Gehrig *et al.* 2010; 2011b; 2012; Frahn *et al.* 2013).

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 Ramsar Management Plan. Marsland and Nicol (2006) identified that existing monitoring programs (in 2006) would not adequately assess TLM target V3; therefore, a monitoring program that expanded and built upon existing monitoring programs 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 community wetland monitoring program established by the River Murray Catchment Water Management Board (now Natural Resources SA Murray-Darling Basin) but includes additional sites in lakeshore habitats (in Lakes Alexandrina and Albert), the lower reaches of the Finniss River, Currency Creek and Goolwa Channel (herein referred to as Goolwa Channel) and wetlands that were not part of the original 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 (Gehrig and Nicol 2010a; Gehrig *et al.* 2011a), and data from this project was included in the TLM Condition Monitoring Program (Gehrig *et al.* 2010; 2011b; 2012; Frahn *et al.* 2013).

The Condition Monitoring Plan for the Icon Site proposed 'indicators for monitoring' that comprised individual taxa and discrete communities: *Melaleuca halmaturorum, Myriophyllum* spp. *Gahnia filum, Schoenoplectus* spp., *Typha domingensis, Phragmites australis* and samphire communities (Maunsell Australia Pty Ltd 2009). However, further discussions concluded that the entire understorey vegetation assemblage would be monitored with a separate technique used for the dominant tree species *Melaleuca halmaturorum*. Hence, the monitoring program consists of two complementary components: (1) monitoring of aquatic and littoral understorey 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 (2) mid- to long-term population dynamics of *Melaleuca halmaturorum*. The *Melaleuca halmaturorum* component of the monitoring program first undertaken in 2008/09 and stand demographics were monitored again in autumn 2013/14.

From 1996 to 2010, the Murray-Darling Basin was subjected to the most severe drought in recorded history (van Dijk *et al.* 2013). Below average stream flows coupled with upstream extraction and river regulation resulted in reduced inflows into South Australia (van Dijk *et al.* 2013), 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 desiccated 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; 2009b; 2010; 2011).

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). For example, in 2004, *Ruppia polycarpa, Lepilaena* sp., *Nitella* sp. and *Myriophyllum* sp. were common in Narrung Wetland; *Myriophyllum* sp. and *Vallisneria australis* were common in Dunn's Lagoon; *Ruppia polycarpa, Ruppia tuberosa, Myriophyllum* sp. and *Potamogeton pectinatus* were common in Teringie Wetland and *Myriophyllum caput-medusae* was common in Shadows Lagoon and Boggy Creek (Holt *et al.* 2005). Furthermore, in 2005, *Ranunculus trichophyllus, Vallisneria australis* and *Myriophyllum caput medusae* were common in Pelican Lagoon; *Ruppia polycarpa* was common Point Strut Wetland; *Ruppia tuberosa* and *Myriophyllum caput-medusae* were common in Poltalloch; *Ranunculus trichophyllus* and *Ruppia polycarpa* were common in Loveday Bay Wetland; and *Myriophyllum caput-medusae, Myriophyllum salsugineum, Ruppia megacarpa, Ruppia tuberosa* and *Potamogeton pectinatus* were common in Hunters Creek (Nicol *et al.* 2006).

By spring 2008, submergent taxa had been extirpated (except for a small number of *Ruppia tuberosa* plants in Hunters Creek, 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 disconnected from remaining water 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 is a critical ecosystem component 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. Wright *et al.* 2002; Papas 2007; Bassett *et al.* 2012; Bell *et al.* 2013; Walker *et al.* 2013; Matuszak *et al.* 2014), 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 Services 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 after the Clayton regulator was constructed. The regulators disconnected Goolwa Channel and Lake Albert from Lake Alexandrina, which enabled water levels within 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 (five flow control structures located at Goolwa, Tauwitchere, Ewe Island, Boundary Creek and Mundoo) that prevent saltwater intrusion in the Lower Lakes (Figure 1) 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 period of low flow and subsequent low water levels, regulator construction, pumping, unregulated River Murray flows, regulator breaching and entitlement flows have resulted in large changes to the hydrological and salinity regime of the Lower Lakes since 2007. Salinity (e.g. Hart *et al.* 1991; Nielsen *et al.* 2003; Nielsen *et al.* 2007; Nielsen and Brock 2009) and water regime (determined by lake levels) (e.g. Brock and Casanova 1997; Blanch *et al.* 1999a; 1999b; 2000; Nicol *et al.* 2003) are two of the primary drivers of plant community composition in freshwater ecosystems. Historically, the various components of the system 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; 2011). Between January 2007 and August 2010, surface water salinity, water regime and connectivity of the study area varied dramatically from historical patterns; however, since September 2010 these factors have reflected historical patterns, except in Lake Albert where salinities have remained elevated.

1.2. Objectives

The monitoring undertaken in 2013/14 builds on data collected between 2008 and 2013 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, a large unregulated River Murray flow, two in-channel flow pulses and entitlement flows. 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 recovery of the aquatic plant community after hydrological restoration following extended drought, drawdown, fragmentation and desiccation of aquatic habitats.
- Compare the age class structure of *Melaleuca halmaturorum* stands between 2008 and 2014.

2. METHODS

2.1. Study site, hydrology and salinity

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). Between 2008 and 2010, a range of interventions were undertaken in the Lower Lakes to regulate water levels and mitigate acid sulfate soils; primarily 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. Both structures were breached in spring 2010 and from then on water levels were dependent on barrage operations. Water level and surface water electrical conductivity in the Lower Lakes from August 2008 to May 2014 are presented in Figure 2 and Figure 3, respectively. Details regarding interventions and their impacts on water level and salinity from 2008 to 2010 are outlined in Frahn *et al.* (2013).

Since the Clayton Regulator and Narrung Bund were breached in spring 2010 water levels in the Lower Lakes returned to historical levels and remained at these levels for the remainder of the survey period (Figure 2). Salinity in Lake Alexandrina and Goolwa Channel decreased rapidly after the Clayton Regulator and Narrung Bund were breached; however, salinity remains elevated (but slowly decreasing) in Lake Albert and there have been several short salinity spikes in Goolwa Channel during periods of reverse head (the water level in the Coorong is higher than Lake Alexandrina) (Figure 3).

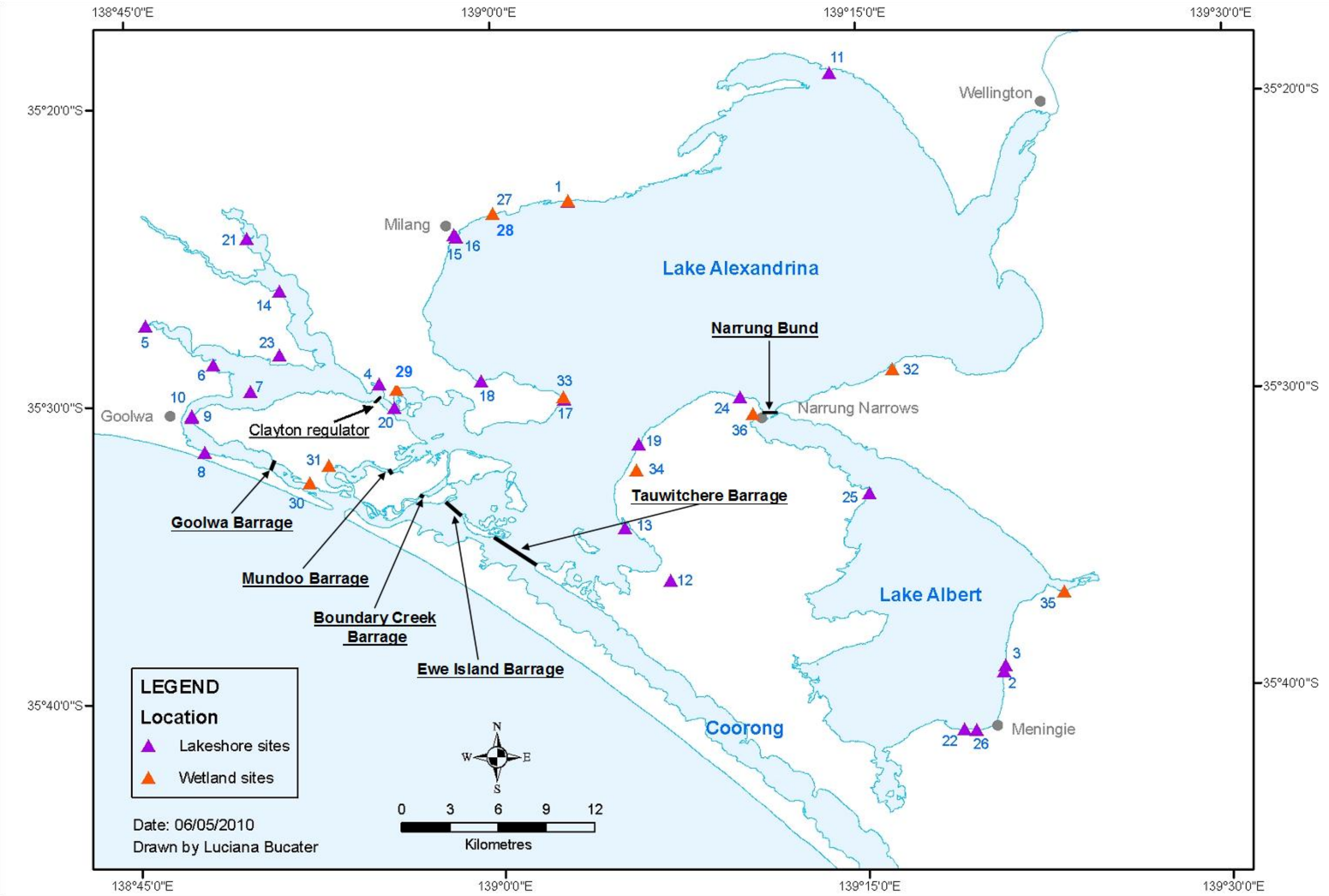

Figure 1: Map of Lakes Alexandrina and Albert and Goolwa Channel showing the location of lakeshore and wetland vegetation monitoring sites (site numbers correspond to Table 1) and major flow control structures present in winter 2010 (where sites are in close proximity they may not be visible on map).

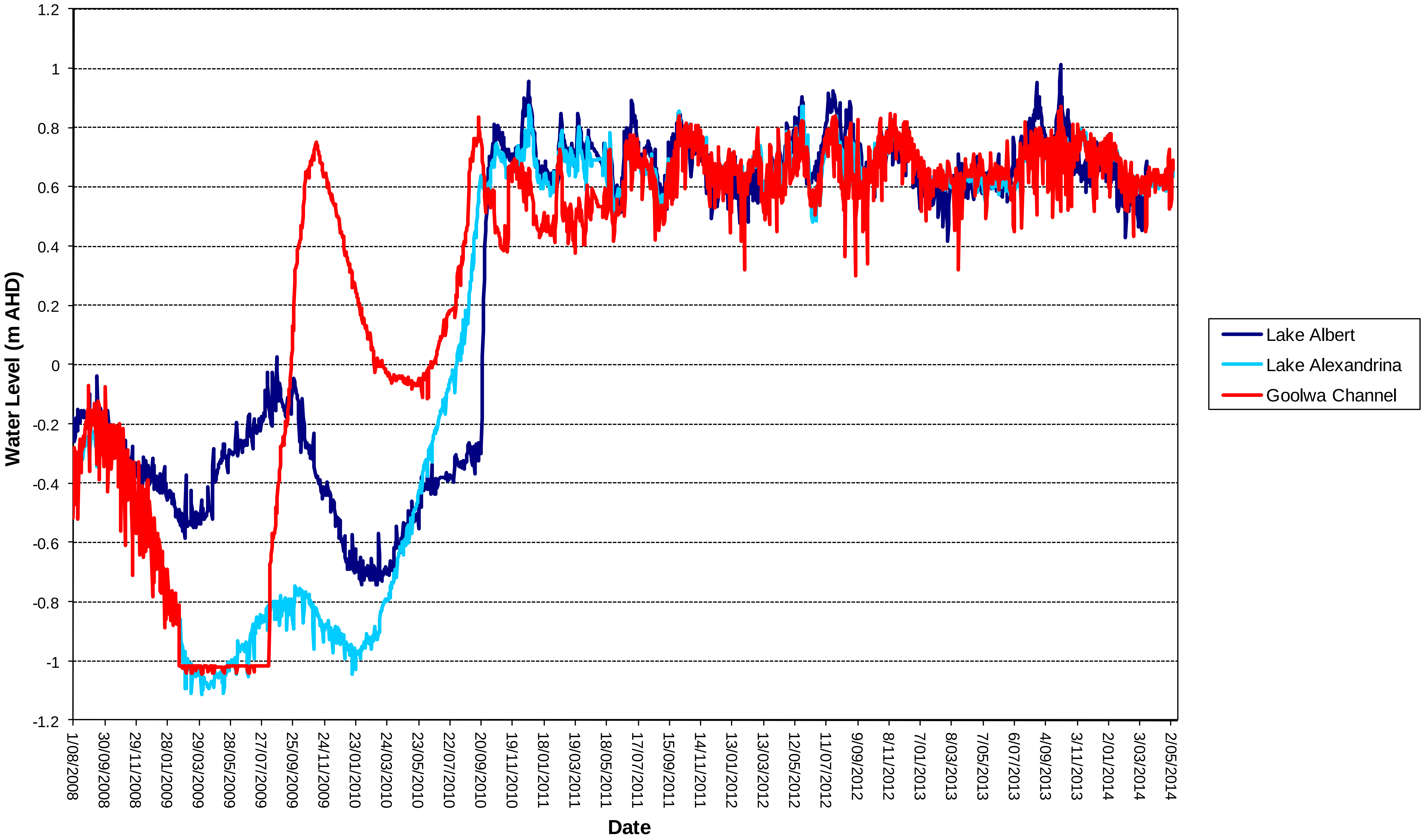

Figure 2: Daily mean water levels in Goolwa Channel (Signal Point), Lake Alexandrina (Milang) and Lake Albert (Meningie) from August 2008 to May 2014 (Department of Environment, Water and Natural Resources 2014b).

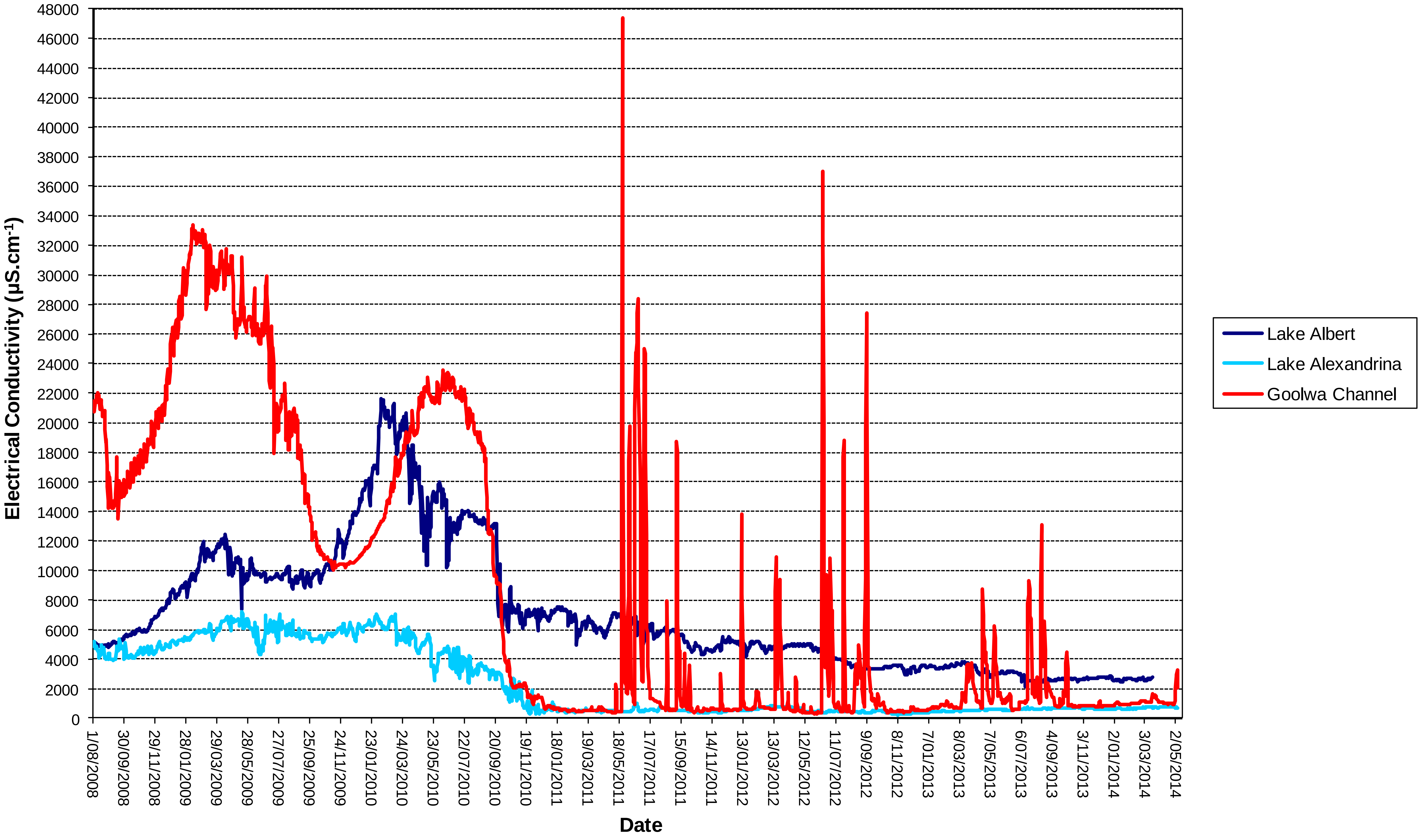

Figure 3: Daily mean surface water electrical conductivity (EC) in Goolwa Channel (Signal Point), Lake Alexandrina (Milang) and Lake Albert (Meningie) from August 2008 to May 2014 (Department of Environment, Water and Natural Resources 2014a).

2.2. Understorey vegetation surveying protocol

Monitoring of understorey vegetation was conducted at 11 wetland and 25 lakeshore sites in every spring and autumn from October 2008 to March 2014 (for sites established in 2008 or earlier) and every spring and autumn from October 2009 to March 2014 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), number of survey sites and the year sites were established.

Site #	Site Name	Location	Habitat	No. Survey Sites	Year Established
1	Bremer Mouth Lakeshore	Lake Alexandrina	lakeshore	1	2008
2	Brown Beach 1	Lake Albert	lakeshore	1	2008
3	Brown Beach 2	Lake Albert	lakeshore	1	2008
4	Clayton Bay	Goolwa Channel	lakeshore	1	2009
5	Currency Creek 3	Goolwa Channel	lakeshore	1	2008
6	Currency Creek 4	Goolwa Channel	lakeshore	1	2008
7	Goolwa North	Goolwa Channel	lakeshore	1	2009
8	Goolwa South	Goolwa Channel	lakeshore	1	2009
9	Hindmarsh Island Bridge 01	Goolwa Channel	lakeshore	1	2009
10	Hindmarsh Island Bridge 02	Goolwa Channel	lakeshore	1	2009
11	Lake Reserve Rd	Lake Alexandrina	lakeshore	1	2008
12	Loveday Bay	Lake Alexandrina	wetland	4	2009
13	Loveday Bay Lakeshore	Lake Alexandrina	lakeshore	1	2009
14	Lower Finniss 02	Goolwa Channel	lakeshore	1	2009
15	Milang (existing SAMDBNRM Board community monitoring site)	Lake Alexandrina	wetland	4	pre-2008
16	Milang Lakeshore	Lake Alexandrina	lakeshore	1	2009
17	Pt Sturt Lakeshore	Lake Alexandrina	lakeshore	1	2008
18	Pt Sturt Water Reserve	Lake Alexandrina	lakeshore	1	2008
19	Teringie Lakeshore	Lake Alexandrina	lakeshore	1	2008
20	Upstream of Clayton Regulator	Lake Alexandrina	lakeshore	1	2009
21	Wally's Landing	Goolwa Channel	lakeshore	1	2009
22	Warrengie 1	Lake Albert	lakeshore	1	2009
23	Lower Finniss 03	Goolwa Channel	lakeshore	1	2009
24	Narrung Lakeshore	Lake Alexandrina	lakeshore	1	2008
25	Nurra Nurra	Lake Albert	lakeshore	1	2008
26	Warrengie 2	Lake Albert	lakeshore	1	2009
27	Angas Mouth	Lake Alexandrina	wetland	1	2008
28	Bremer Mouth	Lake Alexandrina	wetland	1	2008
29	Dunns Lagoon	Lake Alexandrina	wetland	4	2008
30	Goolwa Channel Drive	Lake Alexandrina	wetland	3	2008
31	Hunters Creek	Lake Alexandrina	wetland	5	2008
32	Poltalloch	Lake Alexandrina	wetland	2	2008
33	Pt Sturt	Lake Alexandrina	wetland	2	2008
34	Teringie (existing SAMDBNRM Board community monitoring site)	Lake Alexandrina	wetland	4	pre-2008
35	Waltowa (existing SAMDBNRM Board community monitoring site)	Lake Albert	wetland	2	pre-2008
36	Narrung (existing SAMDBNRM Board community monitoring site)	Lake Alexandrina	wetland	3	pre-2008

Wetlands

At each survey site (Table 1), a transect running perpendicular to the shoreline 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, except the Angas and Bremer River mouths) 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

Lakeshores

With the exception of quadrat placement, lakeshores were surveyed using the same technique as 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 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).

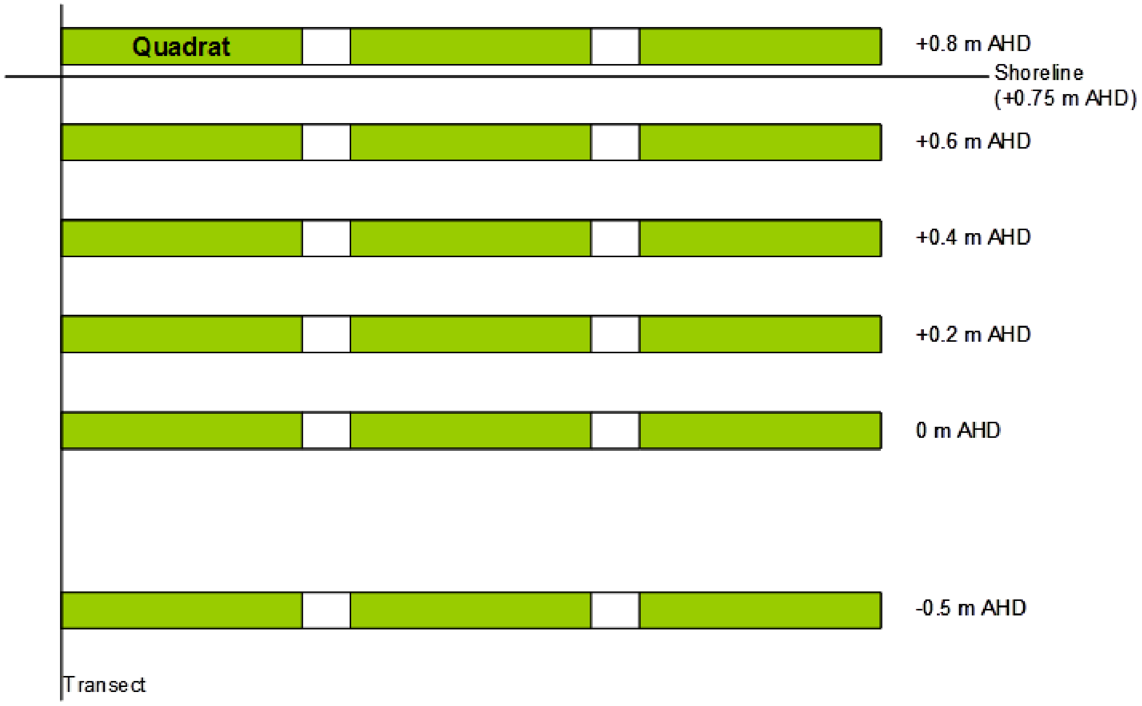

Figure 4: Vegetation surveying protocol for lakeshore sites: plan view showing placement of quadrats relative to the shoreline.

Plant identification and Nomenclature

Plants were identified using keys in Sainty and Jacobs (1981), Jessop and Tolken (1986), Prescott (1988), Cunningham *et al.* (1992), Dashorst and Jessop (1998), Romanowski (1998), Sainty and Jacobs (2003) and Jessop *et al.* (2006). In some cases due to immature individuals or lack of floral structures plants were identified to genus only. Nomenclature follows the Centre for Australian National Biodiversity Research and Council of Heads of Australasian Herbaria (2014) and changes to nomenclature since 2012 are presented in Appendix 2.

2.3. Plant 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 3). The position each group occupies in relation to flooding depth and duration is outlined in Figure 5. The functional classification was based on the classification framework devised by Brock and Casanova (1997) and Casanova (2011), which were based on species from wetlands in the New England Tablelands region of New South Wales and Mount Lofty Ranges, respectively. The aforementioned frameworks were 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) and Casanova (2011) (*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* *Duma 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*
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 australis* *Ruppia megacarpa* *Potamogeton pectinatus*

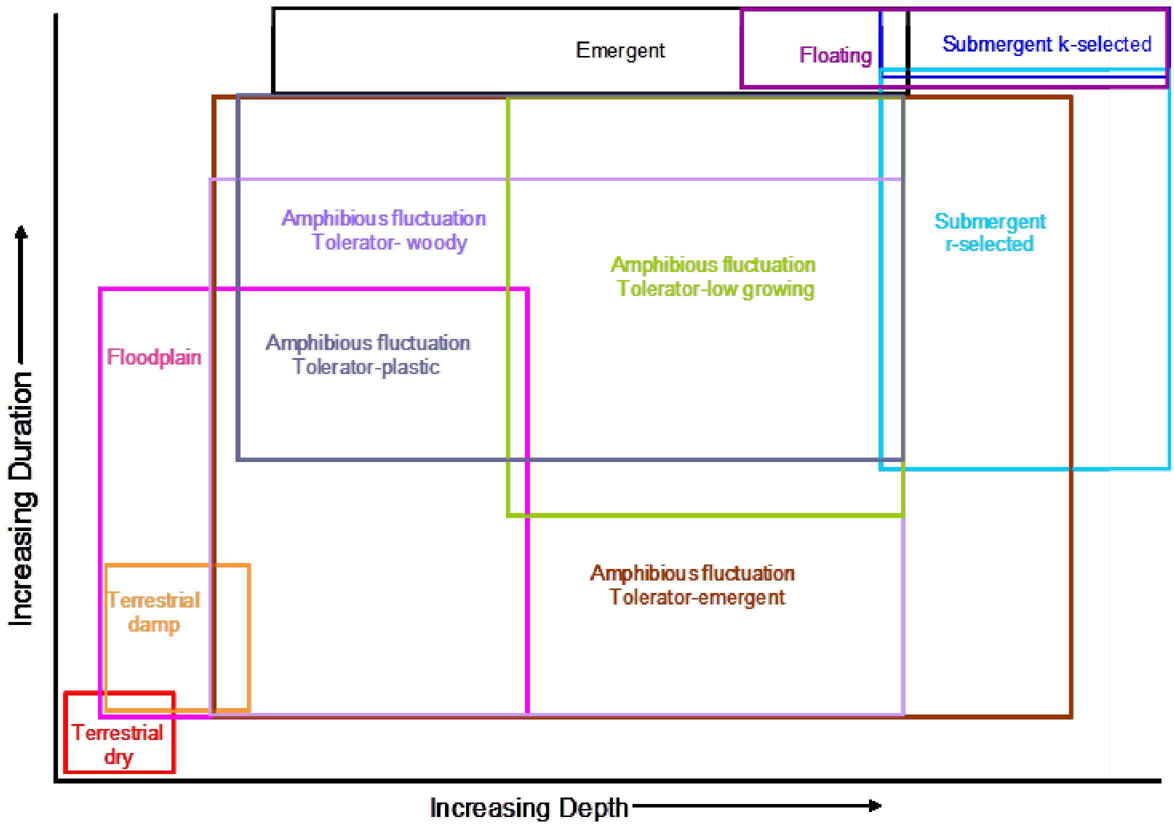

Figure 5: Plant functional groups in relation to depth and duration of flooding.

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

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

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

The “amphibious fluctuation tolerator-emergent” group consists mainly of emergent sedges and rushes that prefer high soil moisture or shallow water but require their photosynthetic parts to be emergent, although many will often tolerate short-term submergence (Table 3) (Nicol 2004). 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 2011). 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 2011).

"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 2011). 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

Wetlands

Changes in floristic composition through time and between elevations were analysed for each wetland (except Angas and Bremer Mouths, where data 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).

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. $\alpha=0.05$ was used for all statistical analyses.

2.5. *Melaleuca halmaturorum* age class structure

Age class structure and recruitment of *Melaleuca halmaturorum* was determined using the method developed for this species as part of the Deep Swamp (Stewart 2000) and Tilley Swamp (Telfer *et al.* 2000) vegetation monitoring programs (Table 4). Three transects running perpendicular to the lakeshore that spanned the entire stand (where possible and if it was not possible to walk through the stand extra transects were established on the edges of stands) were established at Salt Lagoon, Hunters Creek, Kennedy Bay, Goose Island and Boggy Creek in spring 2008. All trees within 5 m of the centre of each transect were assessed. Age class structure was assessed at all sites in spring 2008 and at all sites, except Salt Lagoon in autumn 2014.

Table 4: *Melaleuca halmaturorum* age class structure assessment (Stewart 2000).

Age Class	Description	Age (years)
1	Seedlings < 75 cm tall, single stem (sometimes damaged and multi-stemmed	1 to 2
2	Established juveniles, usually single stems <2 m tall, intact canopy	2 to 5
3	Multi or single stemmed, 2 to 3 m tall; evidence of recent flowering, no procumbent branches	5 to 7
4	Multi-stemmed >3 m tall, intact canopy, flowering, no procumbent branches	10 to 20
5	Main trunk intact (not procumbent), prolific leaf growth, flowering	28
6	Trees with one or more procumbent limbs all with evidence of recent flowering and terminal leaf growth, canopy intact on each limb with dense foliage	>28
7	Trees with majority (>50%) of procumbent limbs alive (alive=intact canopy, green leaves and flowering)	>28
8	Trees with minority (<50%) of procumbent limbs alive. Trees with procumbent limbs, but none dead, all with evidence of recent leaf growth and flowering. A minority with a sparse leaf cover, but the majority with intact canopies and good leaf cover.	>28
9	Major loss of canopy, no evidence of recent flowering, no leaf growth on the terminal branchlets, seeds/old fruits or absent in the aerial seed bank. All trees with a grey appearance, branchlets broken and major loss of bark. Tree split into a number of procumbent limbs, only of which one has green leaves.	Approx. 100
10	Mature, recently dead (i.e. not storm damage)	Dead

Figure 6: Map of the southern section of lakes Alexandrina and Albert showing the locations of *Melaleuca halmaturorum* monitoring sites.

3. RESULTS

3.1. Wetlands

A total of 128 taxa (64 exotics including two weeds of national significance, seven proclaimed pest plants in South Australia and one species listed as rare in South Australia) were recorded for all wetland sites between spring 2008 and autumn 2014 (Appendix 4). Functional groups for the recorded taxa are listed in Appendix 3. In all wetlands changes in floristic composition through time were not consistent between elevations, as indicated by a significant interaction between elevation and time (Table 5).

Table 5: 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	11, 143	4.06	<0.001
	Elevation	1, 143	75.10	<0.001
	Time × Elevation	11, 143	3.79	<0.001
Dunn's Lagoon	Time	11, 719	10.18	<0.001
	Elevation	4, 599	94.23	<0.001
	Time × Elevation	44, 719	4.20	<0.001
Goolwa Channel Drive	Time	11, 323	7.55	<0.001
	Elevation	2, 323	89.62	<0.001
	Time × Elevation	22, 323	2.96	<0.001
Hunter's Creek	Time	11, 413	16.83	<0.001
	Elevation	1, 413	299.87	<0.001
	Time × Elevation	9, 413	7.86	<0.001
Loveday Bay	Time	11, 678	7.62	<0.001
	Elevation	4, 678	19.24	<0.001
	Time × Elevation	44, 678	2.45	<0.001
Milang	Time	11, 558	2.52	<0.001
	Elevation	3, 558	37.97	<0.001
	Time × Elevation	33, 558	1.41	<0.001
Narrung	Time	11, 398	5.75	<0.001
	Elevation	3, 398	123.55	<0.001
	Time × Elevation	33, 398	2.77	<0.001
Poltalloch	Time	11, 281	15.76	<0.001
	Elevation	3, 281	34.17	<0.001
	Time × Elevation	33, 281	5.35	<0.001
Point Sturt	Time	11, 215	12.70	<0.001
	Elevation	2, 215	17.29	<0.001
	Time × Elevation	22, 215	3.20	<0.001
Teringie	Time	11, 572	5.92	<0.001
	Elevation	3, 572	49.89	<0.001
	Time × Elevation	27, 572	4.15	<0.001
Waltowa	Time	11, 287	11.29	<0.001
	Elevation	3, 287	64.52	<0.001
	Time × Elevation	33, 287	2.42	<0.001

Angas and Bremer River Mouths

A total of 36 taxa (including 25 exotics) were recorded at the mouths of the Angas and Bremer Rivers from spring 2008 to autumn 2014 (Appendix 4) with eight species (including two exotics) present in 2013/14. 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 7; Frahn *et al.* 2013). However, there has been a steady increase in the proportion of emergent species (*Typha domingensis* and *Phragmites australis*) since spring 2012 (Figure 7), with *Typha domingensis* being a significant indicator of the autumn 2014 survey. Furthermore, *Azolla filiculoides* was a significant indicator of the aforementioned survey; hence, the high proportion of floating species (Figure 7). The only other significant indicator for the survey period was in autumn 2011 (nine months after inundation with lake water) when the submergent k-selected *Ceratophyllum demersum* was abundant in the Angas River Mouth.

A greater functional diversity was recorded within channels throughout the survey period (Figure 7). Prior to inundation with lake water there was the general trend that in spring taxa from amphibious, emergent, floating and submergent k-selected functional groups were present when the channel was inundated with flows from the catchments (Figure 7). In autumn, when the channels were dry; terrestrial, floodplain, amphibious and emergent functional groups dominated (Figure 7). Following inundation with lake water in winter 2010, amphibious, emergent, submergent k-selected (*Ceratophyllum demersum* was a significant indicator) and floating taxa were recorded in autumn 2011, after which there was generally a decrease in the diversity of functional groups with only emergent species (*Typha domingensis* and *Phragmites australis*) being present in autumn 2014 (Figure 7).

Dunns Lagoon

A total of 75 taxa (including 33 exotics) were recorded from Dunn's Lagoon from spring 2008 to autumn 2014 (Appendix 4) with 28 species (including five exotics) present in 2013/14. 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 was inundated) there was a strong shift towards aquatic taxa (amphibious, emergent and submergent functional groups), at the lower elevations (pegs three to one, inclusive) (Figure 8). At pegs one and two only (the lowest elevations) emergent, submergent k-selected and floating species were present from autumn 2011 onwards, with only submergent species present at peg one from spring 2013 to autumn 2014 (Figure 8). The highest elevation (peg five) was dominated by terrestrial taxa throughout the survey period and peg four (which was located on the shoreline) was dominated by amphibious species from spring 2008 to spring 2010 after which there was an increase in the proportion of emergent and terrestrial species (primarily *Paspalum distichum*) (Figure 8).

The highest elevation (5) had a significant increase of the terrestrial species *Distichlis distichophylla* in autumn 2013. At the next elevation (4), terrestrial taxa *Distichlis distichophylla* and *Plantago coronopus* were significantly more abundant in spring 2012. For elevation 3, *Azolla filiculoides, Juncus acutus, Myriophyllum caput-medusae* and *Typha domingensis* increased in abundance in spring 2012. At elevation 2, there was a significant increase in abundance of the native species *Myriophyllum caput-medusae* in spring 2012 and *Schoenoplectus validus, Azolla filiculoides,* and *Myriophyllum salsugineum* in autumn 2013. The lowest elevation (1) had a significant increase in the submergent *Myriophyllum caput-medusae* in spring 2012 and similarly in autumn 2013, *Myriophyllum salsugineum* and *Schoenoplectus validus* significantly increased. No significant indicators were detected for spring 2013 or autumn 2014; however, all of the emergent and submergent species recorded in 2012/13 were present in 2013/14.

Goolwa Channel Drive

A total of 35 taxa (including 15 exotics) were recorded at Goolwa Channel Drive Wetland from spring 2008 to autumn 2014 (Appendix 4) with 17 species (including five exotics) present in 2013/14. Throughout the survey period, the plant communities at the highest (peg three) and middle (peg two) elevations were dominated by terrestrial, emergent and amphibious taxa and changes in the proportions of functional groups over this period was minimal (Figure 9). The plant community at these elevations was characterised by a native salt marsh community dominated by *Suaeda australis, Sarcocornia quinqueflora, Juncus kraussii, Frankenia pauciflora, Samolus repens, Distichlis distichophylla, Triglochin striatum* and *Schoenoplectus pungens* (Frahn *et al.* 2013). The lowest elevation was dominated by emergent species (primarily *Phragmites australis*) throughout the survey period and submergent species were absent in 2013/14 (Figure 9).

The highest elevation (3) had a significant increase in *Aster subulatus* in spring 2012, *Phragmites australis* and *Paspalum distichum* significantly increased in abundance in autumn 2013 and the terrestrial dry species *Plantago coronopus* and *Atriplex* spp. were significant indicators of the spring 2013 survey. At the middle elevation (peg two) *Lachnagrostis filiformis* and *Distichlis distichophylla* peaked in abundance in spring 2008, *Sarcocornia quinqueflora* in autumn 2009, *Suaeda australis* in spring 2009, *Plantago coronopus* in spring 2010 and *Phragmites australis* in autumn 2014. At the lowest elevation (peg one) there were no significant indicators after autumn 2013 when *Bolboschoenus caldwellii* was a significant indicator. Prior to autumn 2013 *Sonchus oleraceus* was a significant indicator of the spring 2008 survey, *Paspalum distichum* of the autumn 2009 survey, *Distichlis distichophylla, Ruppia polycarpa, Schoenoplectus pungens* and

Sarcocornia quinqueflora of the spring 2010 survey and *Potamogeton pectinatus* of the autumn 2011 survey.

Hunters Creek

A total of 39 taxa (including 12 exotics and one species listed as rare in South Australia) were recorded in Hunter's Creek from spring 2008 to autumn 2014 (Appendix 4) with 22 species (including four exotics) present in 2013/14. Across the survey period the plant community along the edges were predominantly amphibious and emergent taxa until spring 2012 when there was an increase in the proportion of terrestrial species (primarily *Paspalum distichum,* which peaked in abundance in spring 2013) (Figure 10). However, submergent and floating taxa were observed in the shallowly flooded margins after the creek was inundated with lake water in winter 2010 with *Myriophyllum caput-medusae, Potamogeton crispus* and *Potamogeton pectinatus* significant indicators of the spring 2011 survey and *Myriophyllum salsugineum, Ceratophyllum demersum* and *Azolla filiculoides* of the autumn 2012 survey. The native emergent *Bolboschoenus caldwellii* and exotic amphibious species *Aster subulatus* were significant indicators of the autumn 2014 survey. The aforementioned submergent and floating species were also common in 2013/14 (but not significant indicators).

In spring 2008 the submergent r-selected species *Ruppia tuberosa* was the only plant present in the channel and in autumn 2009 no plants were present (Figure 10). *Ruppia tuberosa* was also present in spring 2009 but by autumn 2010 the channel was dominated by the amphibious halophytes *Suaeda australis* and *Sarcocornia quinqueflora* (Figure 10). After the creek was inundated in winter 2010, there was an increase in the abundance of submergent k-selected, amphibious and floating taxa (floating stolons of *Paspalum distichum* had extended into the middle of the channel and were present in large numbers in autumn 2011) and from spring 2011 onwards only floating, submergent k-selected and emergent species were present (Figure 10). The abundance of submergent k-selected species peaked in 2013 with *Ceratophyllum demersum* and *Myriophyllum salsugineum* significant indicators of the spring survey and *Potamogeton crispus* and *Potamogeton pectinatus* of the autumn 2013 survey.

Loveday Bay

A total of 55 taxa (including 30 exotics) were recorded from Loveday Bay from spring 2008 to autumn 2014 (Appendix 4) with 29 species (including 12 exotics) present in 2013/14. At the highest elevations (pegs four and five) the plant community was dominated by terrestrial and amphibious species throughout the survey period; however, since spring 2012 the proportion of terrestrial species has increased (Figure 11). A similar pattern was observed at peg three but there were a higher proportion of emergent species compared to pegs four and five and submergent r-selected species were present in spring 2013 and 2013 (Figure 11). This was due to an increase in the abundance of *Paspalum distichum* since spring 2012, which occurred throughout the wetland but was most prevalent at the upper elevations. In spring 2008 the native terrestrial damp species *Distichlis distichophylla* was a significant indicator at all elevations (except peg one) and over the survey period it decreased in abundance, which corresponded with the increase in abundance of the exotic terrestrial damp species *Paspalum distichum*.

Species from the amphibious functional group dominated the plant community at peg two (except in spring 2008 when *Distichlis distichophylla* abundant). In spring 2010 there was an increase in the abundance of emergent species; however, amphibious species were still the dominant group until spring 2012 (Figure 11). In spring 2012 there was an increase in the abundance of *Ruppia tuberosa* and *Lamprothamnium macropogon* (submergent r-selected species) (Figure 11), which were significant indicators of this survey. These species were also present in spring 2013 (along with the floating species *Azolla filiculoides*) but absent in autumn 2013 and 2014 when the wetland was dry and dominated by amphibious and emergent (Figure 11).

The lowest elevation (peg one) was inundated due to local runoff in spring 2008 and 2009 and the plant community was dominated by *Ruppia tuberosa*, which peaked in abundance in spring 2008 (Figure 11). Whilst the wetland was not inundated (all autumn surveys except 2011) the plant community was generally dominated by amphibious and terrestrial taxa (Figure 11). *Lamprothamnium macropogon* was present in autumn 2011 and a significant indicator in spring 2011 (Figure 11). Amphibious halophytes dominated in autumn 2012 and 2013 but were only present in low numbers in spring 2012 when submergent r-selected species (*Ruppia tuberosa* and *Lamprothamnium macropogon*) were abundant (Figure 11). Terrestrial (predominantly *Paspalum distichum*) and emergent species were the dominant groups in spring 2013 and autumn 2014 (Figure 11).

Milang

A total of 67 taxa (including 40 exotics; the largest number recorded of the wetlands surveyed) were recorded from Milang Wetland from spring 2008 to autumn 2014 (Appendix 4) with 23 species (including eight exotics) present in 2013/14. At the highest elevation (peg one) the plant community in Milang wetland was dominated by terrestrial, amphibious (generally halophytes) and some emergent taxa, across the entire survey period with a higher proportion of terrestrial taxa in the spring surveys due to the presence of winter annuals (Figure 12). A similar pattern was observed for peg two; although the changes in proportions of the functional groups was more variable through time and submergent r-selected species were present in spring 2008 and 2009 in areas that received local runoff (Figure 12). In 2013/14 terrestrial species (primarily *Paspalum distichum*) were dominant; however emergent species (*Phragmites australis*) and amphibious halophytes were also present (Figure 12). A higher proportion of emergent species (usually *Phragmites australis;* however*, Bolboschoenus caldwellii* was also abundant at some sites) was present at the lower elevations (pegs three and four) in Milang wetland throughout the survey period (Figure 12). *Myriophyllum salsugineum* was a significant indicator for the spring 2008 survey but absent for the remainder of the survey period (Figure 12). Submergent r-selected taxa (*Ruppia polycarpa* and charophytes) were present in some of the spring surveys but their occurrence was irregular (Figure 12). The terrestrial species present at the low elevations throughout the survey period was *Paspalum distichum* (Figure 12).

Narrung

A total of 31 taxa (including 14 exotics) were recorded from Narrung Wetland from spring 2008 to autumn 2014 (Appendix 4) with 14 species (including five exotics) present in 2013/14. The plant communities at the highest elevations (pegs three and four) were a mix of terrestrial, amphibious and emergent taxa throughout the survey period (Figure 13); in particular a native samphire community of *Sarcocornia quinqueflora, Suaeda australis* and *Frankenia pauciflora*. The higher proportion of emergent species at peg three in spring 2013 (Figure 13) was due to a significantly greater abundance of *Bolboschoenus caldwellii*.

A higher proportion of emergent species (predominantly *Phragmites australis*) and lower proportion of terrestrial species were present at peg two compared to pegs three and four (Figure 13). However, there has been an increase in the proportion of terrestrial taxa at this elevation since spring 2011 (Figure 13), which was due to an increase in the abundance of *Paspalum distichum*.

The lowest elevation was generally devoid of plants except in spring 2011 and autumn 2012 (Figure 13). The plant community was dominated by submergent r-selected species with abundances of *Ruppia tuberosa, Ruppia polycarpa* and *Chara fibrosa* peaking in spring 2011.

Point Sturt

A total of 40 taxa (including 26 exotics) were recorded from Point Sturt Wetland from spring 2008 to autumn 2014 (Appendix 4) with nine species (including three exotics) present in 2013/14. At the highest elevation the plant community was dominated by terrestrial taxa (predominantly *Distichlis distichophylla*) in spring 2008 but between this survey and following survey in autumn 2009 there was a large decrease in terrestrial species and a corresponding increase in the proportion of amphibious species (generally halophytes) (Figure 14). The plant community remained dominated by amphibious species for the remainder of the survey period but there was an increase in the proportion of terrestrial species (predominantly *Paspalum distichum*) from spring 2012 (Figure 14). A similar pattern was observed for the plant community at peg two; although there was a higher proportion of terrestrial species and corresponding lower proportion of amphibious species from spring 2012 onwards compared to peg three (Figure 14). In addition, the exotic terrestrial damp species *Atriplex prostrata* was a significant indicator for the autumn 2014 survey.

Terrestrial species dominated the plant community at the lowest elevation (peg one) for Point Sturt wetland in spring 2008 and, similar to the higher elevations, this was replaced by amphibious species by autumn 2009 (Figure 14). The proportion of amphibious species remained high until autumn 2012; however, submergent r-selected and emergent species were also present except in spring 2011 when only amphibious taxa were recorded (Figure 14). Emergent species dominated the plant community in autumn 2012 (although amphibious species were present) but by spring 2012 no plants were recorded (Figure 14). Emergent (*Bolboschoenus caldwellii*) and amphibious species has colonised the wetland by autumn 2013 but by spring no plants were recorded (Figure 14). Only terrestrial species (*Paspalum distichum*) were present in autumn 2014.

Poltalloch

A total of 30 taxa (including 17 exotics) were recorded from Poltalloch wetland from spring 2008 to autumn 2014 (Appendix 4) with 14 species (including four exotics) present in 2013/14. The highest elevation in Poltalloch wetland (peg four) was generally dominated by amphibious taxa (predominantly the halophytes *Sarcocornia quinqueflora* and *Suaeda australis*) throughout the survey period, except in spring 2009 when there was a high proportion of terrestrial species (Figure 15). The high proportion of terrestrial species in spring 2009 was due to high abundances of the annual terrestrial weeds *Eragrostis curvula, Hordeum vulgare, Lolium* spp. and *Sonchus oleraceus*.

The plant community at peg three prior to inundation with lake water in winter 2010) was dominated by terrestrial species in spring (exotic winter annuals) and amphibious species (halophytes) in autumn (Figure 15). From spring 2010 to autumn 2012 the plant community was generally dominated by amphibious taxa (halophytes) except in autumn and spring 2011 when the submergent r-selected species *Ruppia tuberosa* was present (abundance peaked in spring 2011) (Figure 15). After spring 2011 amphibious species (halophytes) dominated autumn surveys, except autumn 2014 when *Paspalum distichum* was highly abundant and exotic terrestrial winter annuals and amphibious halophytes in spring (Figure 15).

The two lowest elevations (pegs one and two), showed similar patterns, prior to inundation with lake water a similar pattern observed at the two higher elevations with exotic winter annuals present in the spring surveys and amphibious halophytes dominating the plant community in autumn; however, emergent species were sometimes present (Figure 15). After inundation with lake water there was a decrease in amphibious species and an increase in submergent r-selected species (predominantly *Ruppia tuberosa*) but the wetland had dried by autumn 2012 and was dominated by amphibious halophytes (Figure 15). The wetland was inundated in spring 2012 and dominated by submergent r-selected (Figure 15) species but at this time the dominant species were *Ruppia tuberosa* and *Chara fibrosa*. The wetland dried again by autumn 2013 and was dominated by amphibious halophytes at peg two and amphibious halophytes and *Bolboschoenus caldwellii* (an emergent species) at peg one (Figure 15). The wetland was inundated in spring 2013 and the lower elevations were dominated (nearly 100% cover in the inundated areas of the wetland) by the charophyte *Lamprothamnium macropogon* (a submergent r-selected species) (Figure 15). The wetland had dried by autumn 2014 and peg two was dominated by *Paspalum distichum* (a terrestrial damp species) and peg one by amphibious halophytes and *Bolboschoenus caldwellii* (Figure 15).

Teringie

At total of 51 taxa (including 27 exotics) were recorded from Teringie Wetland from spring 2008 to autumn 2014 (Appendix 4) with 11 species (including four exotics) present in 2013/14. The two highest elevations in Teringie wetland were dominated by amphibious halophytes (*Suaeda australis* and *Sarcocornia quinqueflora*) and terrestrial species (Figure 16). From spring 2008 to autumn 2010 the pattern observed at high elevations in Poltalloch, Milang and Loveday Bay of higher proportions of terrestrial species in spring compared to autumn was also observed in Teringie and driven by higher abundances of exotic winter annuals in spring. After autumn 2010 there was a general decrease in the proportion of amphibious taxa and increase in terrestrial species (Figure 16), which was driven primarily by an increase in the abundance of *Paspalum distichum*.

The pattern observed at pegs three and four between spring 2008 and autumn 2010 was observed at peg two from spring 2008 to autumn 2011 also driven by higher abundances of exotic winter annuals in spring compared to autumn (Figure 16). Some wetland basins were inundated by lake water in spring 2011 (a bar that formed at the inlet during the period of low water levels, which prevented inundation of some wetland basins in winter 2010 was dredged in winter 2011) and there was an increase in the proportion of amphibious species and terrestrial species were extirpated (Figure 16). However, from spring 2012, the pattern of higher proportions of terrestrial species in spring compared to autumn returned and remained for the duration of the survey period (Figure 16).

The lowest elevation (peg one) was generally dominated by amphibious species throughout the survey period; however, in spring 2010 several basins were inundated due to local runoff and *Ruppia tuberosa* was present (Figure 16). Two of the wetland basins surveyed in Teringie do not fill with lake water. On basin is highly saline and has been devoid of vegetation throughout the survey period and the other terrestrial species (usually exotic winter annuals) are present at this elevation in spring with amphibious halophytes dominating during summer (Figure 16).

Waltowa

A total of 15 taxa (including 8 exotics) were recorded from Waltowa from spring 2008 to autumn 2014 (Appendix 4) with three species (including one exotics) present in 2013/14. The highest elevation (peg four) was dominated by amphibious halophytes and terrestrial species (generally exotic winter annuals in spring surveys but the native *Disphyma crassifolium*, was also present) (Figure 17). The lower elevations were dominated by amphibious halophytes throughout the survey period with the lowest elevation (peg one) often completely devoid of vegetation (Figure 17).

3.2. Lakeshores

A total of 127 taxa (63 exotics including one weed of national significance (*Tamarix aphylla*), four proclaimed pest plants in South Australia and one species listed as rare in South Australia) were recorded at shoreline sites in Lake Alexandrina, Lake Albert and Goolwa Channel from spring 2008 to autumn 2014. Lake Alexandrina had the highest species richness (105 taxa across 10 sites) followed by Lake Albert (77 taxa across 5 sites) with Goolwa Channel exhibiting the lowest species richness (69 taxa across 10 sites) (Appendix

5). Lake Alexandrina had the highest proportion of exotics (53.33%) compared to Lake Albert (49.35%) and Goolwa Channel (44.93%) (Appendix 5). In 2013/14 Lake Alexandrina was the most species rich with 36 species (including 11 exotics) followed by Goolwa Channel with 34 species (including 10 exotics) with Lake Albert having the lowest number of species with 28 (including 10 exotics).

In each location (Lake Alexandrina, Lake Albert and Goolwa Channel) the plant community changed through time, was different between elevations but there was no significant interaction between the two factors (Table 6). This indicates that the plant community changes through time were consistent between elevations for each location.

Table 6: PERMANOVA results comparing the plant community through time and between elevations for Lake Alexandrina, Lake Albert and Goolwa Channel shorelines.

Elevation	Factor	*df*	*Pseudo-F*	*P*
Lake Alexandrina	Elevation	4, 587	15.59	<0.001
	Time	11, 587	3.80	<0.001
	Elevation × Time	53, 587	0.734	0.891
Lake Albert	Elevation	5, 319	24.60	<0.001
	Time	11, 319	5.57	<0.001
	Elevation × Time	53, 319	0.97	0.601
Goolwa Channel	Elevation	5, 618	4.74	<0.001
	Time	11, 618	45.59	<0.001
	Elevation × Time	53, 618	0.849	<0.835

Lake Alexandrina

The plant community at +0.8 m AHD from spring 2008 to autumn 2010 (whilst water levels were low) was dominated by terrestrial taxa; although, amphibious and emergent species were present over this period (Figure 18). After water levels were reinstated there was a decrease in the proportion of terrestrial species and an increase in emergent and amphibious taxa (Figure 18). Terrestrial species were present after water levels were reinstated and were more abundant in spring surveys compared to autumn surveys (Figure 18) which was due to exotic winter annuals. Between spring 2013 and autumn 2014 there was an increase in the proportion of emergent and amphibious species (terrestrial taxa were still present but their proportion of the plant community was very low) (Figure 18) with *Calystegia sepium, Berula erecta, Mentha australis,* and *Typha domingensis* significant indicators of the autumn 2014 survey.

A similar pattern to +0.8 m AHD was observed at +0.6 m AHD with terrestrial species dominating the plant community from spring 2008 to autumn 2010 (Figure 18). Similarly there was a decrease in the proportion of terrestrial species and corresponding increase in amphibious and emergent species when water levels were reinstated (Figure 18). In addition, floating species were present, which were absent from +0.8 m AHD (Figure 18). Submergent k-selected species recruited in spring 2013 and there was a small increase in their abundance in autumn 2014 (Figure 18). *Berula erecta* was a significant indicator of the spring 2013 survey and *Typha domingensis, Calystegia sepium* and *Mentha australis* of the autumn 2014 survey.

The change in proportion of functional groups over the survey period at +0.4, +0.2 and 0 m AHD was similar to +0.6 m AHD with the exception of submergent k-selected species recruiting earlier (Figure 18). Species in the aforementioned functional group were first observed in spring 2011 at +0.4 m AHD and in autumn 2011 at +0.2 and 0 m AHD and increased in abundance over the remainder of the survey period (Figure 18). *Ceratophyllum demersum* was a significant indicator of the autumn 2014 survey at +0.4, +0.2 and 0 m AHD.

In spring 2008, the water level had not fallen below -0.5 m AHD (Figure 2) and the plant community was dominated by emergent species (Figure 18). Terrestrial species recruited by autumn 2009 and were dominant until water levels were reinstated in winter 2010 (Figure 18). After water levels were reinstated, species from the emergent functional group were only present until spring 2013, after which no plants were observed (Figure 18).

Lake Albert

The plant community at +0.8 m AHD from spring 2008 to autumn 2010 (whilst water levels were low) was dominated by terrestrial taxa (Figure 19). After water levels were reinstated the proportion of terrestrial species declined and amphibious and emergent species increased until spring 2012 (Figure 19). After spring 2012 there was an increase in the proportion of terrestrial species (Figure 19), which was due to an increase in the abundance of *Paspalum distichum*. Despite the dominance of *Paspalum distichum* from autumn 2013; *Typha domingensis* was a significant indicator of the spring 2013 survey.

At +0.6 m AHD whist water levels were low the plant community was dominated by terrestrial species except for the autumn 2009 survey, which had a high proportion of amphibious species (Figure 19). Terrestrial species were extirpated and replaced by amphibious and emergent species after water levels were reinstated until spring 2012 (Figure 19). From spring 2012 terrestrial species recruited (primarily *Paspalum distichum*) and persisted for the remainder of the survey period (Figure 19). Despite being present in very low numbers, *Myriophyllum salsugineum* was a significant indicator of the autumn 2014 survey. *Typha domingensis* was also significantly more abundant in autumn 2014.

The changes in the proportions of functional groups over the survey period at +0.4 m AHD was similar to +0.6 m AHD but the proportion of terrestrial species was lower from spring 2012 onwards (Figure 19). *Typha domingensis* and *Myriophyllum salsugineum* were also significant indicators of the autumn 2014 survey.

At +0.2 m AHD there was a mix of terrestrial, emergent and amphibious species present whilst water levels were low (Figure 19). After water levels were reinstated the plant community predominantly consisted of emergent species (Figure 19).

At 0 and -0.5 m AHD there were a wide range of functional groups present whilst water levels were low (Figure 19). After water levels were reinstated all plants were extirpated and plants were absent for the remainder of the survey period (Figure 19).

Goolwa Channel

The plant community in Goolwa Channel at +0.8 m AHD was generally dominated by amphibious and emergent species throughout the study period (Figure 20). The sudden appearance of emergent and terrestrial taxa in spring 2010 was due to the extra sites from the Goolwa Channel monitoring project (Gehrig and Nicol 2010a; Gehrig *et al.* 2011a) being established and included in the TLM monitoring program. Similarly there was little change in the proportions of functional groups at +0.6 m AHD during the survey period after spring 2009; however, emergent species were the dominant group at this elevation (Figure 20). In addition, submergent k-selected species were present from spring 2012 onwards (Figure 20) and *Berula erecta* and *Hydrocotyle verticillata* were significant indicators of the autumn 2014 survey.

The change in proportion of functional groups at +0.4 m AHD was also similar to the top two elevations, with very little change after spring 2009; however, emergent species accounted for nearly 100% of the plant community over this period (Figure 20). Submergent k-selected species were first recorded in spring 2010 and were present in low numbers for the remainder of the survey period (Figure 20).

The plant community at +0.2 m AHD was also dominated by emergent species throughout the survey period (Figure 20). Submergent k-selected species were first recorded in autumn 2010 (primarily *Potamogeton pectinatus*, which recruited due to regulated inundation) and persisted for the remainder of the survey period although the floristic composition differed during the period and became more species rich through time (Figure 20). Furthermore, *Ceratophyllum demersum* was a significant indicator of the autumn 2014 survey.

At 0 m AHD amphibious and terrestrial taxa dominant in spring 2008 and by autumn 2009 the plant community was almost entirely terrestrial (Figure 20). After the Clayton regulator was constructed, the plant community was dominated by emergent species and after water levels were reinstated submergent and emergent species were the dominant groups (Figure 20).

Prior to construction of the Clayton regulator no plants were present at -0.5 m AHD (Figure 20). Emergent and amphibious species dominated in spring 2009, after which submergent species (*Potamogeton pectinatus, Myriophyllum salsugineum, Ceratophyllum demersum Vallisneria australis* and *Potamogeton crispus*) were the dominant group and the only group present since spring 2013 (Figure 20).

Table 7: Colour codes for vegetation functional groups.

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

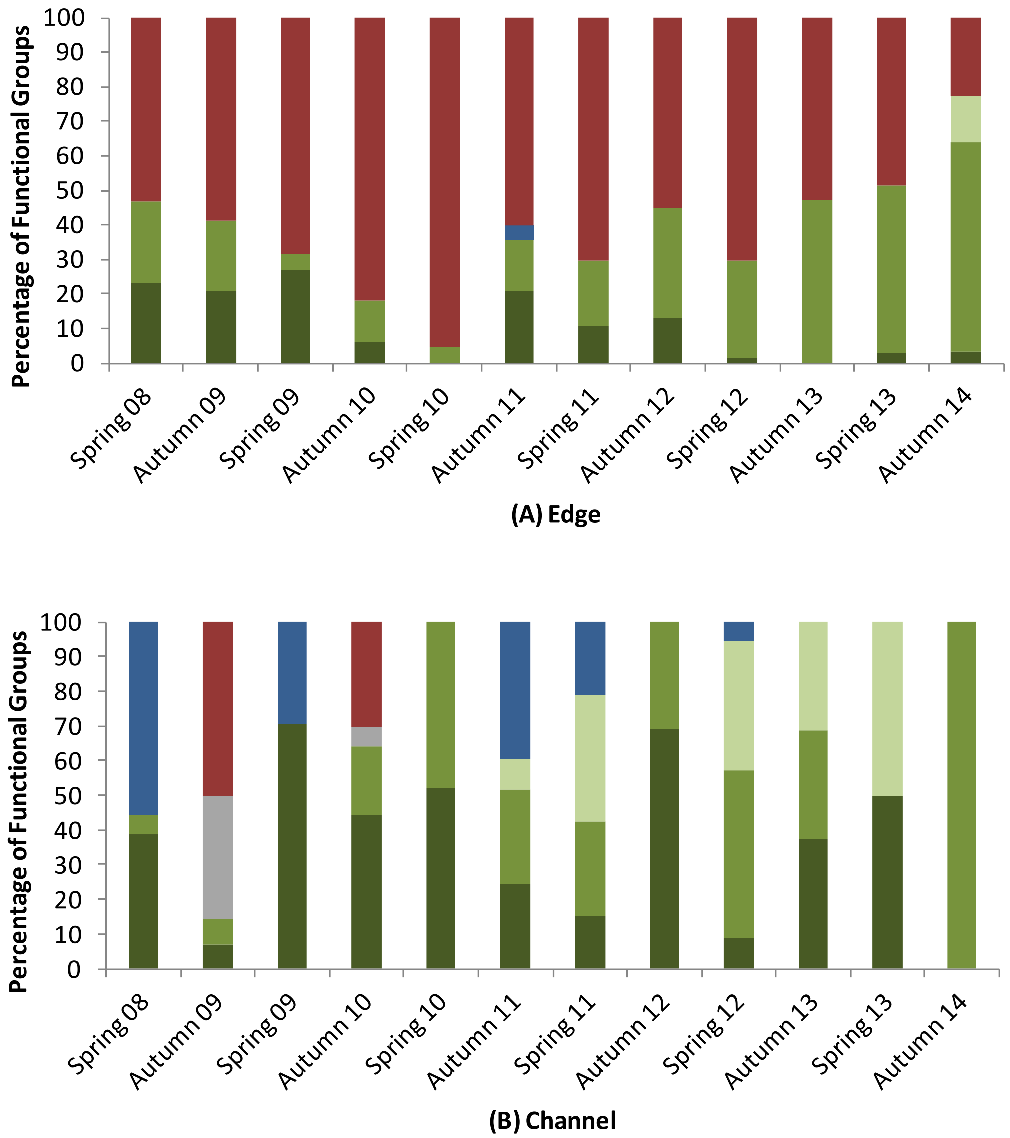

Figure 7: Percentage of plant functional groups for the edge (A) and channel (B) elevations of Angas and Bremer River Mouths from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

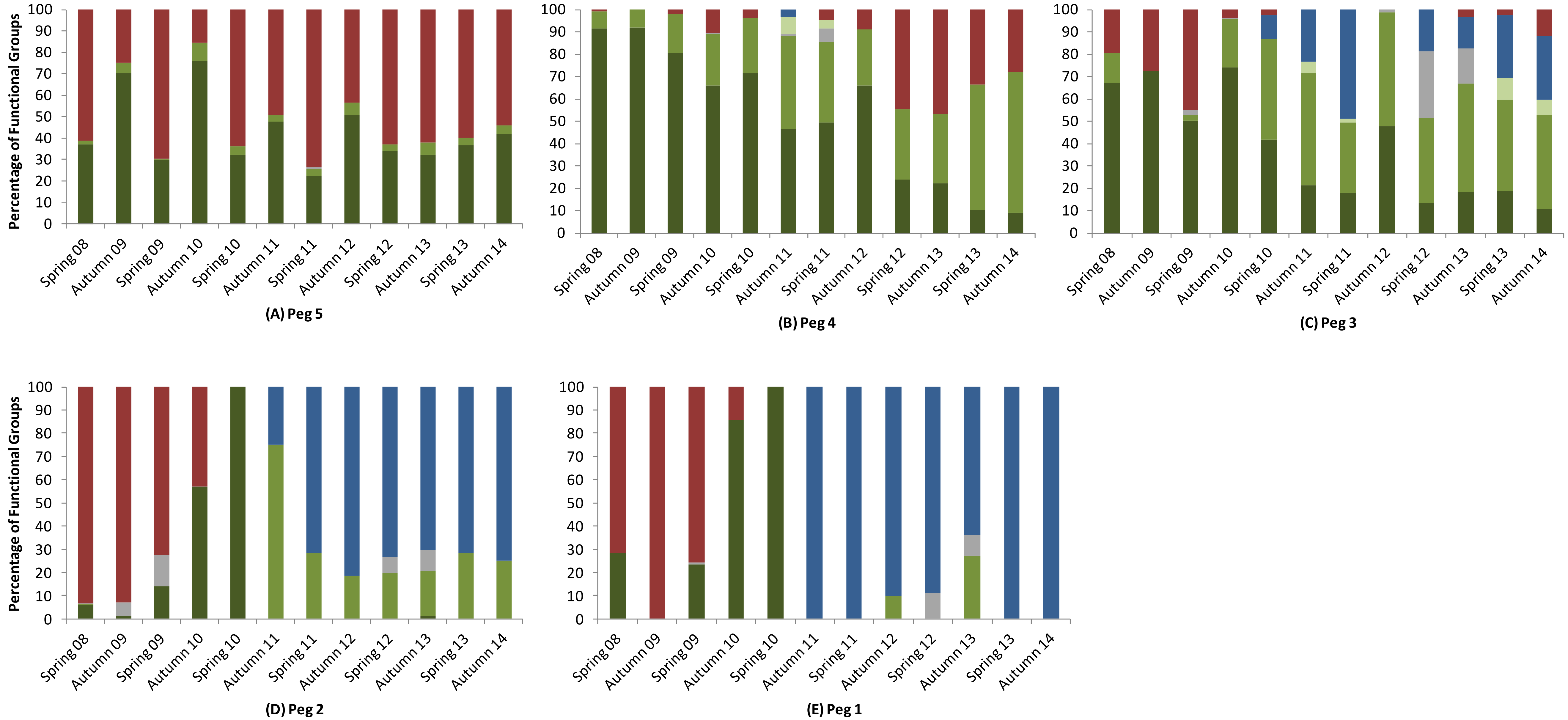

Figure 8: Percentage of plant functional groups from highest (A: peg 5) to lowest elevation (E: peg 1) in Dunn's Lagoon from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

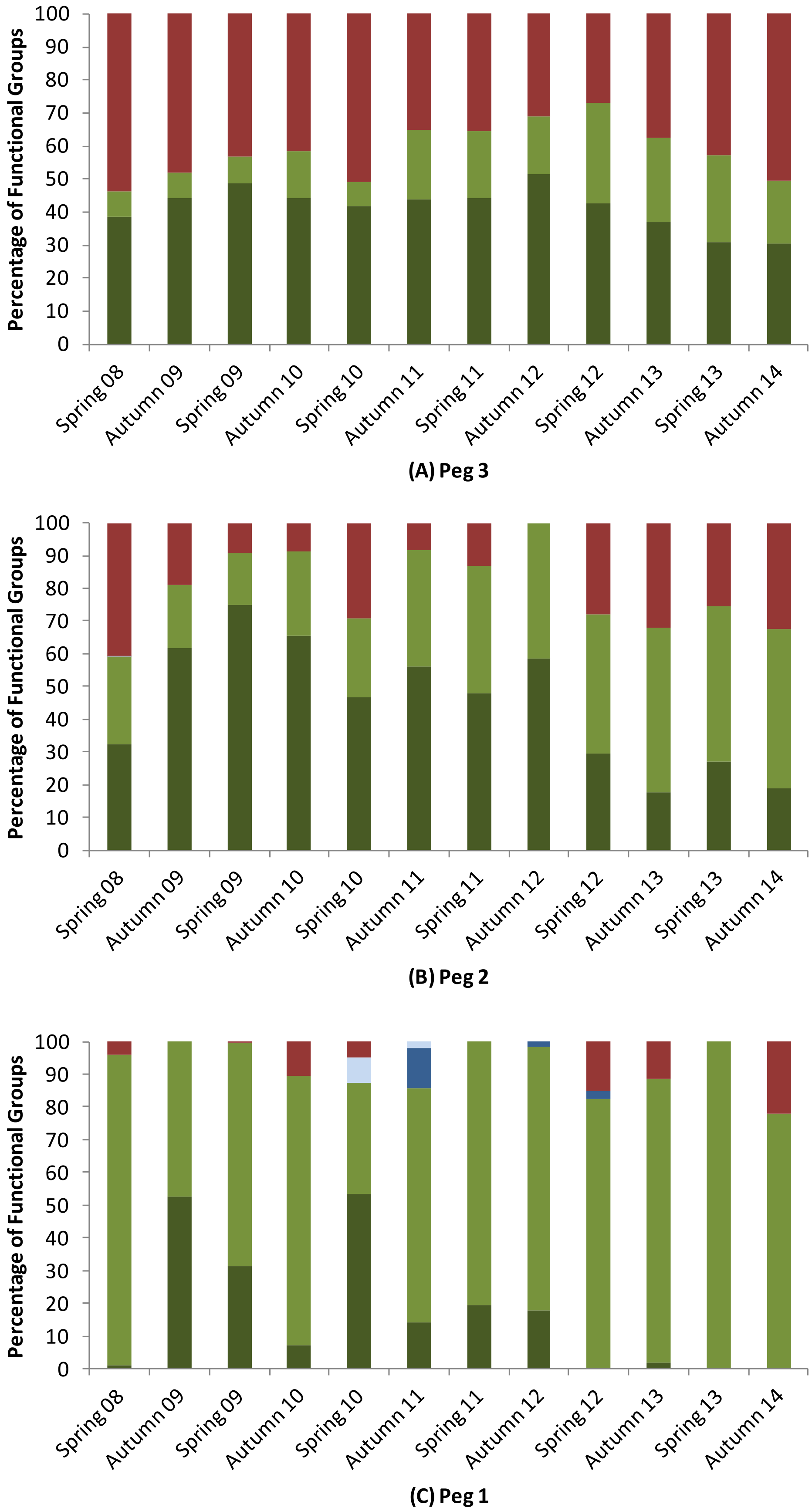

Figure 9: Percentage of plant functional groups from highest (A: peg 3) to lowest elevation (C: peg 1) in Goolwa Channel Drive from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

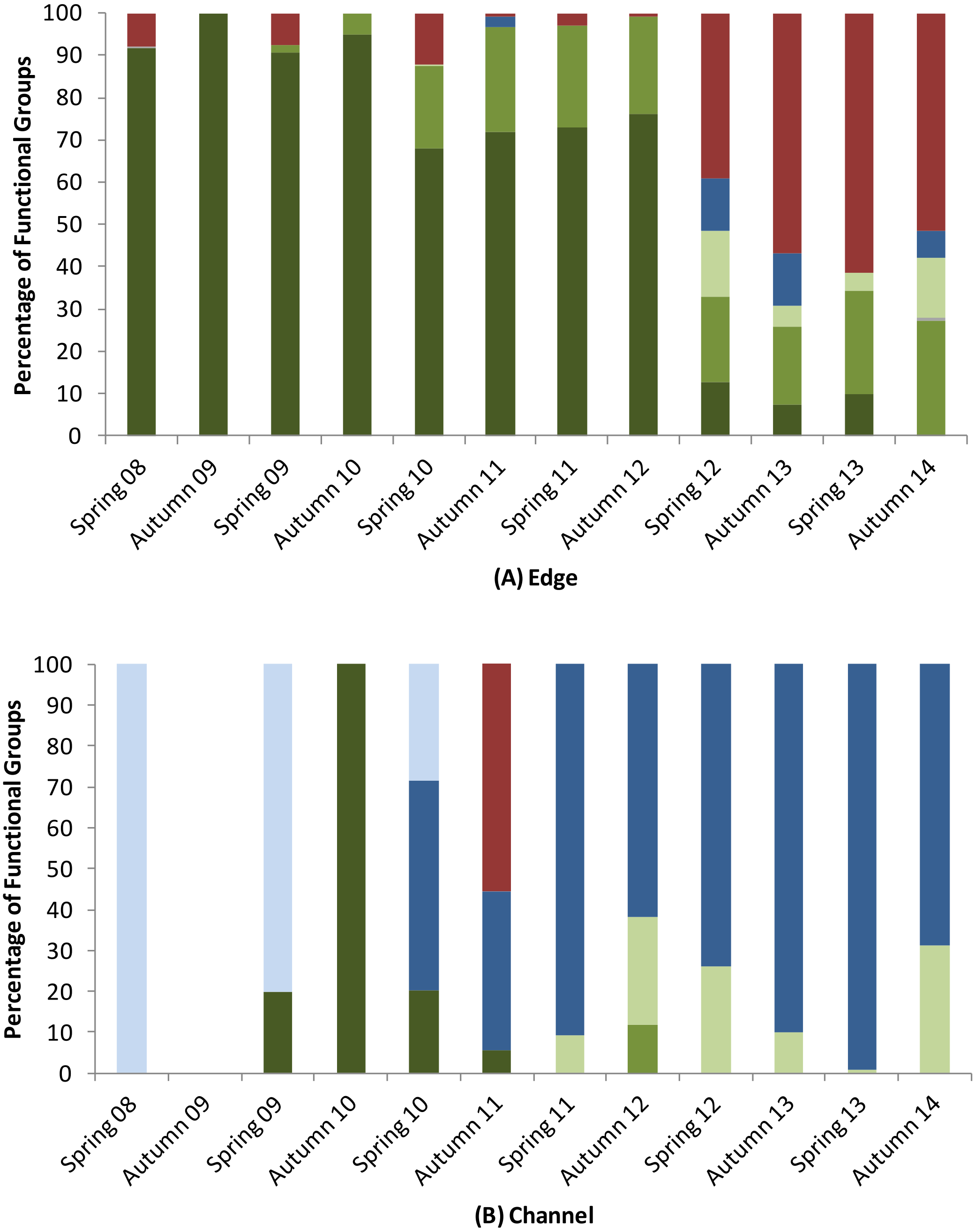

Figure 10: Percentage of plant functional groups for the edge (A) and channel (B) elevations in Hunters Creek from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

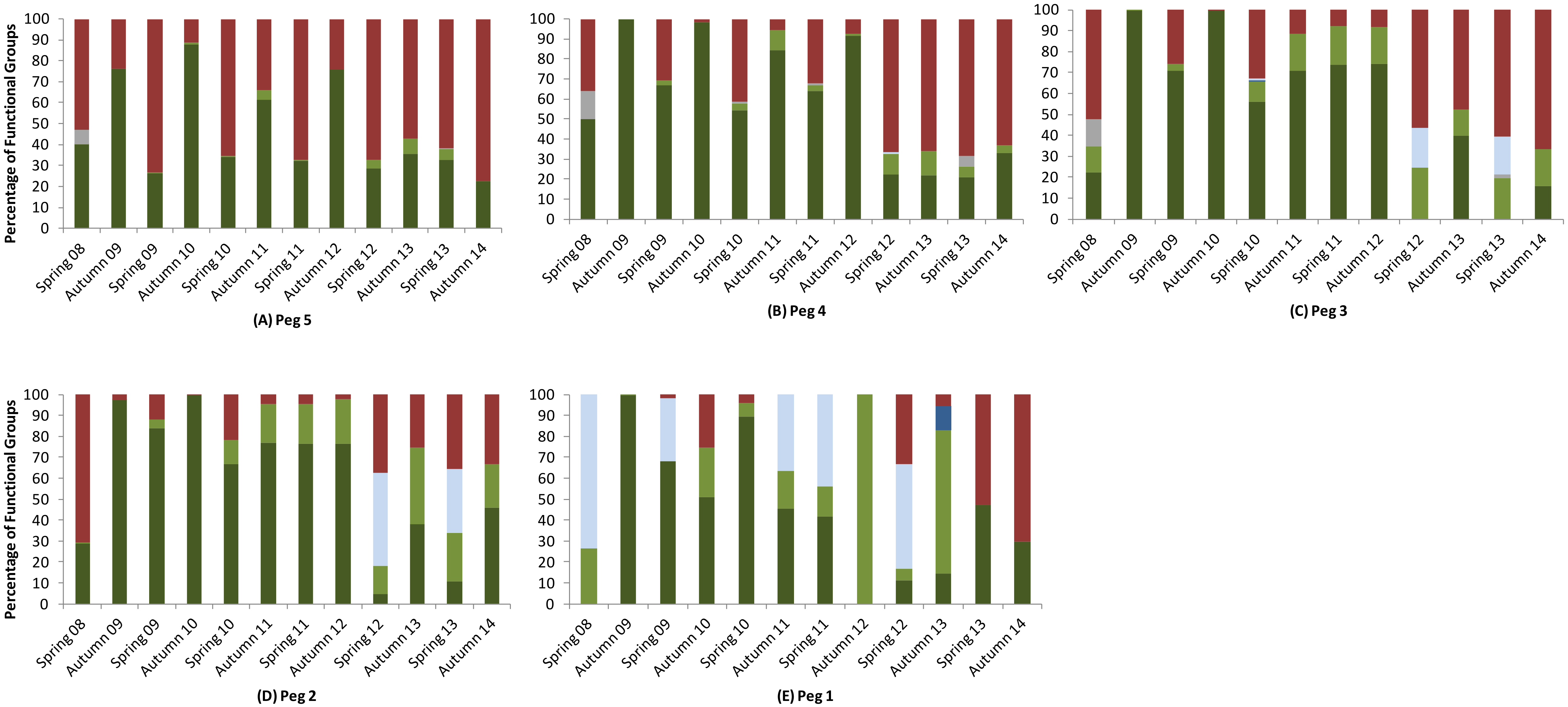

Figure 11: Percentage of plant functional groups across highest elevation (A: peg 5) to lowest elevation (E: peg 1) in Loveday Bay wetland from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

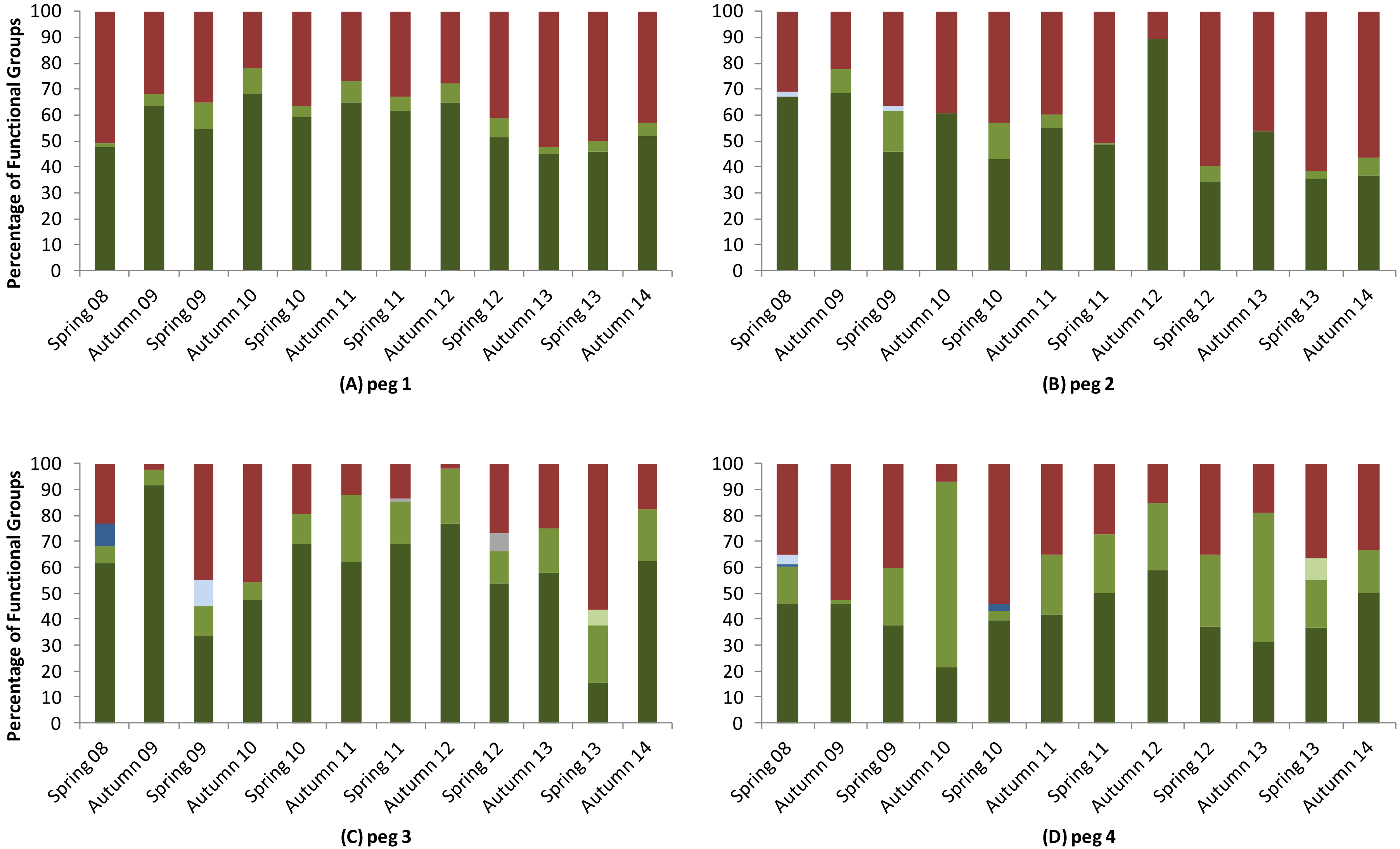

Figure 12: Percentage of plant functional groups across highest elevation (A: peg 4) to lowest elevation (D: peg 1) in Milang wetland from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

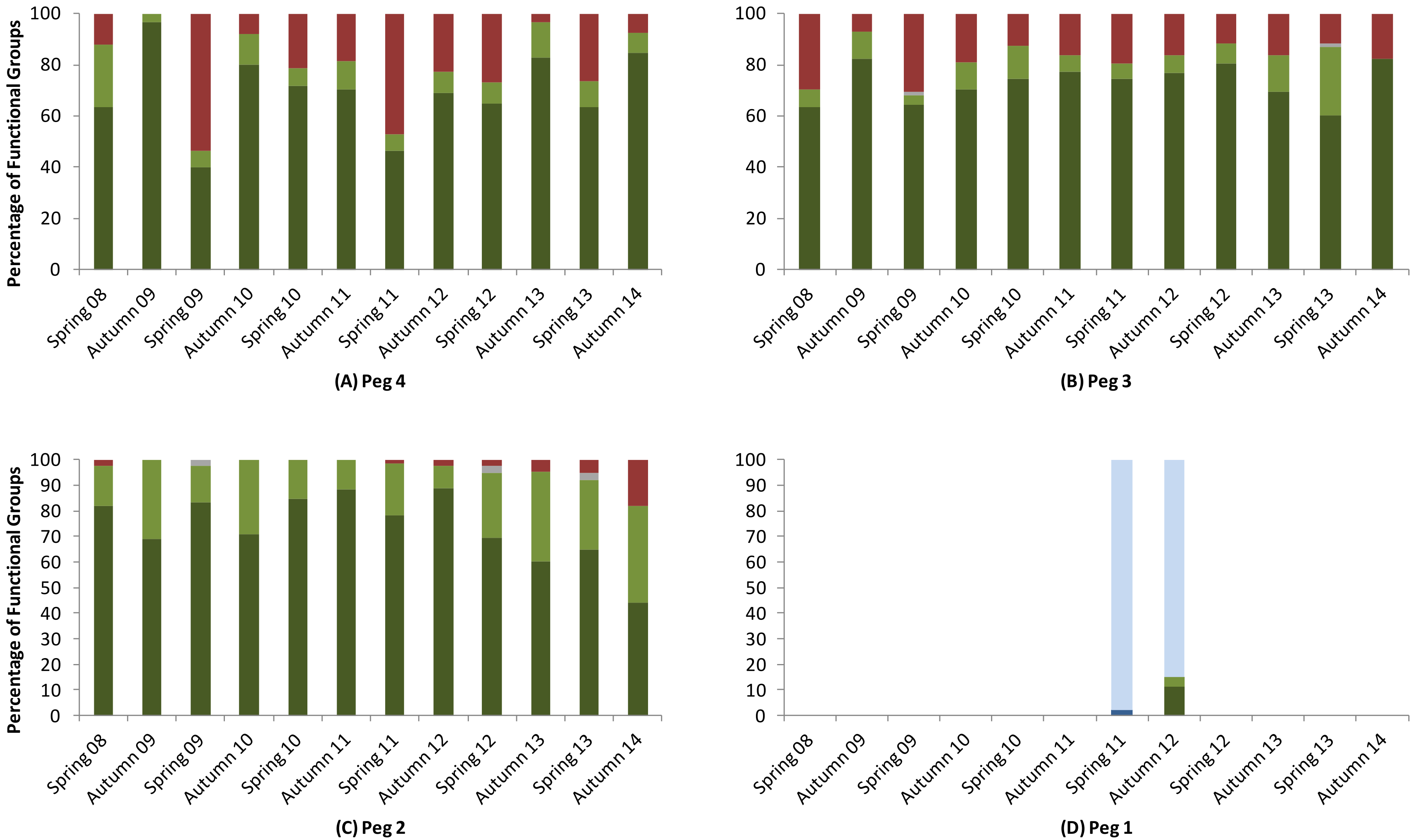

Figure 13: Percentage of plant functional groups across highest elevation (A: peg 4) to lowest elevation (D: peg 1) in Narrung wetland from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

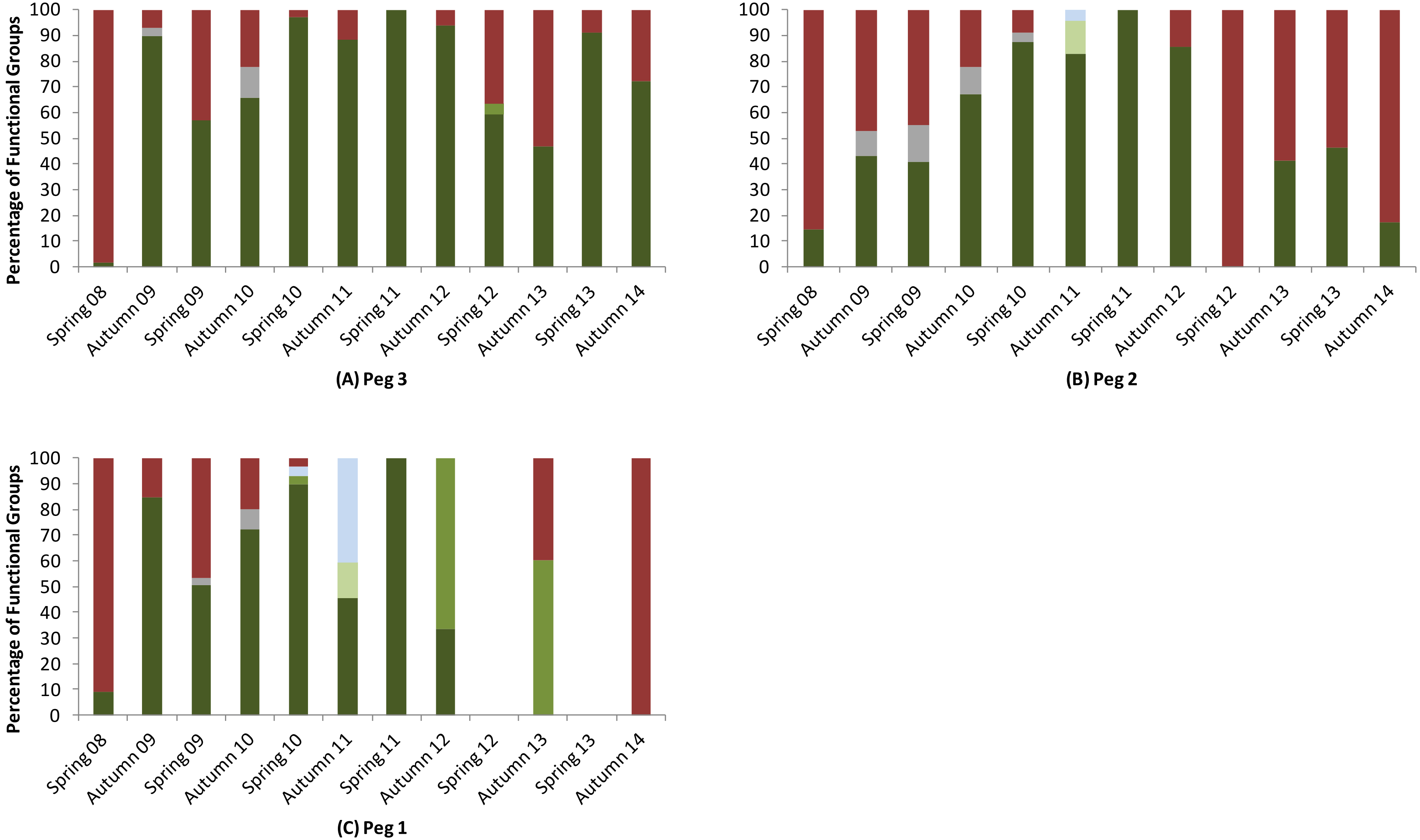

Figure 14: Percentage of plant functional groups across highest elevation (A: peg 3) to lowest elevation (C: peg 1) in Point Sturt wetland from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

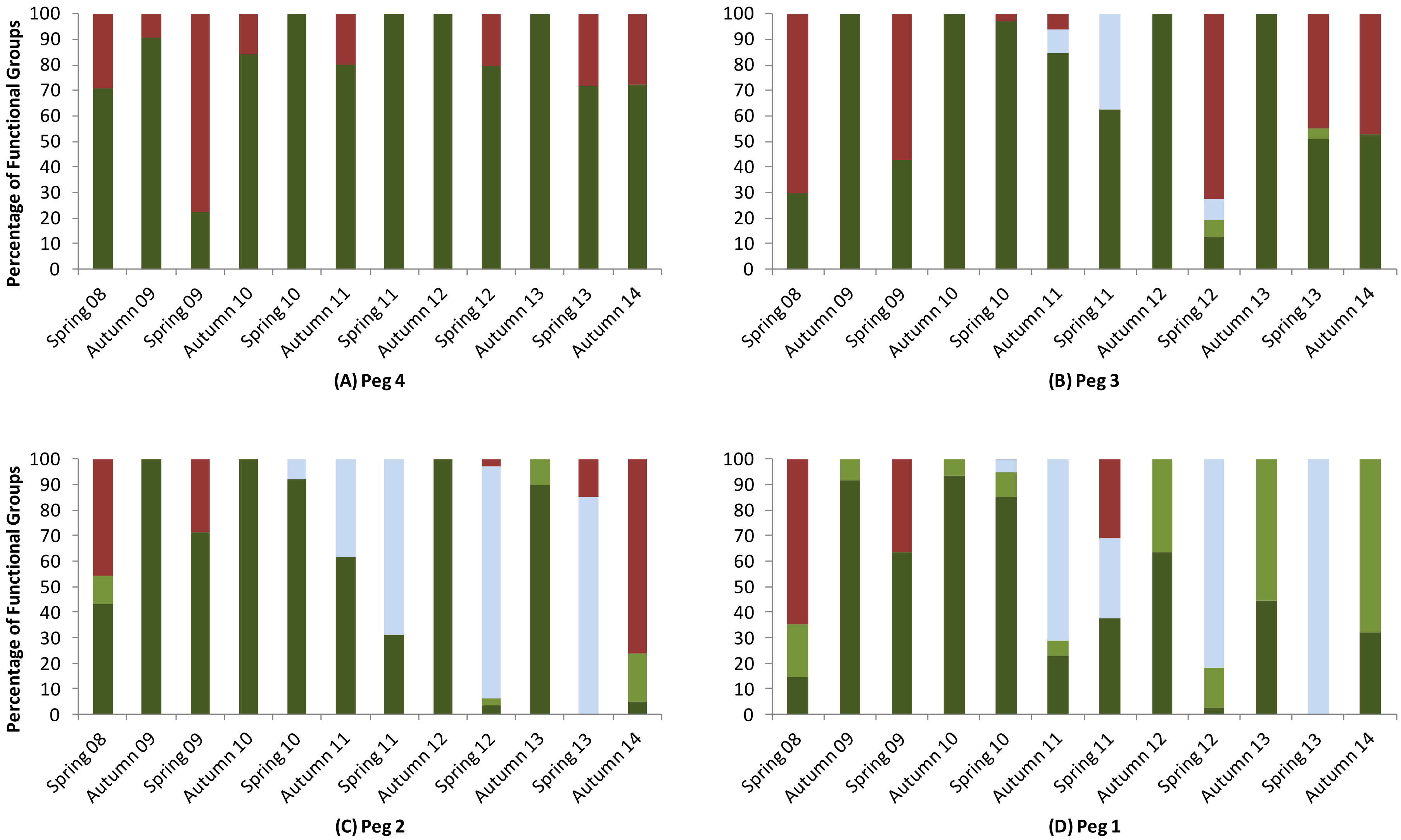

Figure 15: Percentage of plant functional groups across highest elevation (A: peg 4) to lowest elevation (D: peg 1) in Poltalloch wetland from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

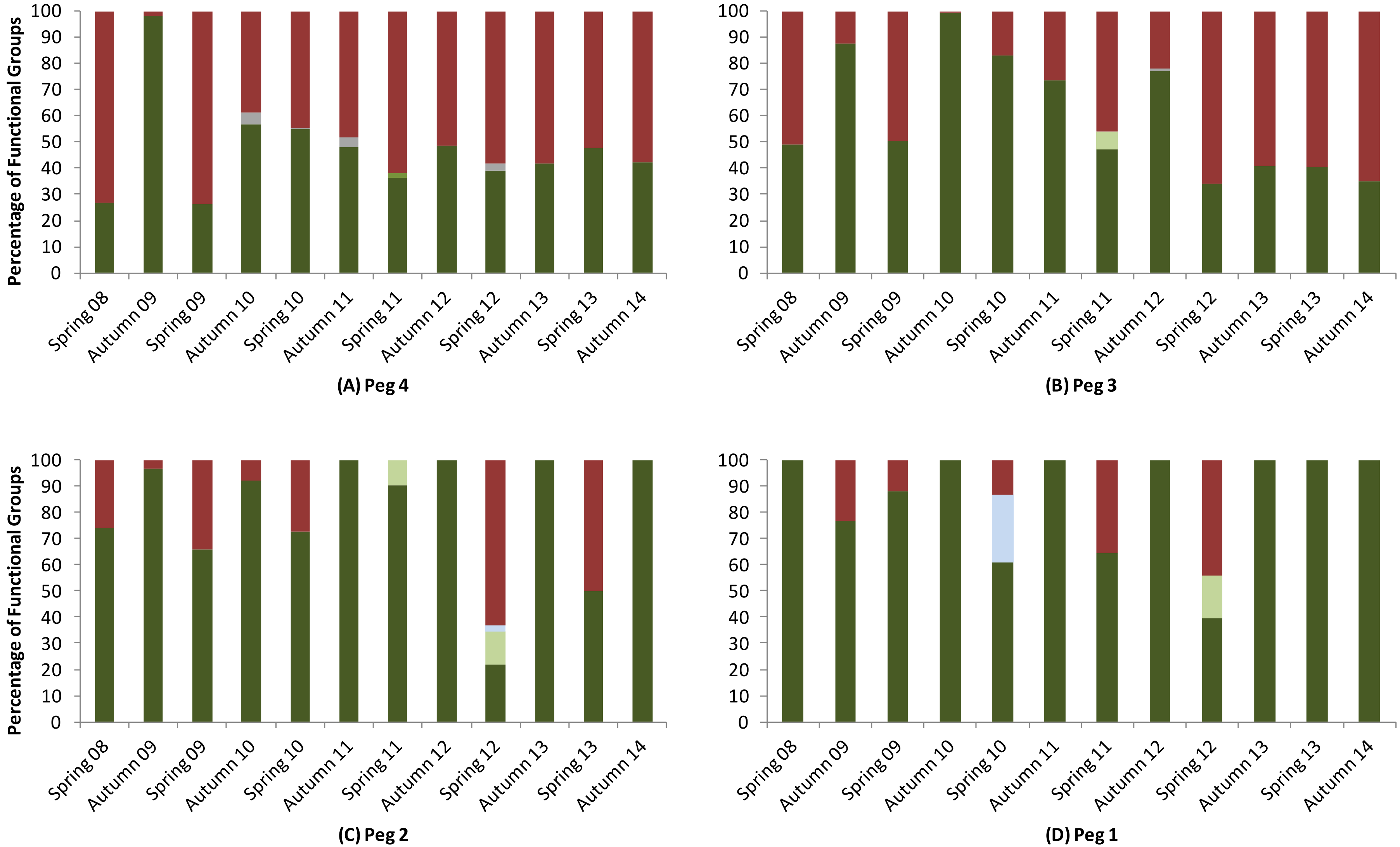

Figure 16: Percentage of plant functional groups across highest elevation (A: peg 4) to lowest elevation (D: peg 1) in Teringie wetland from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

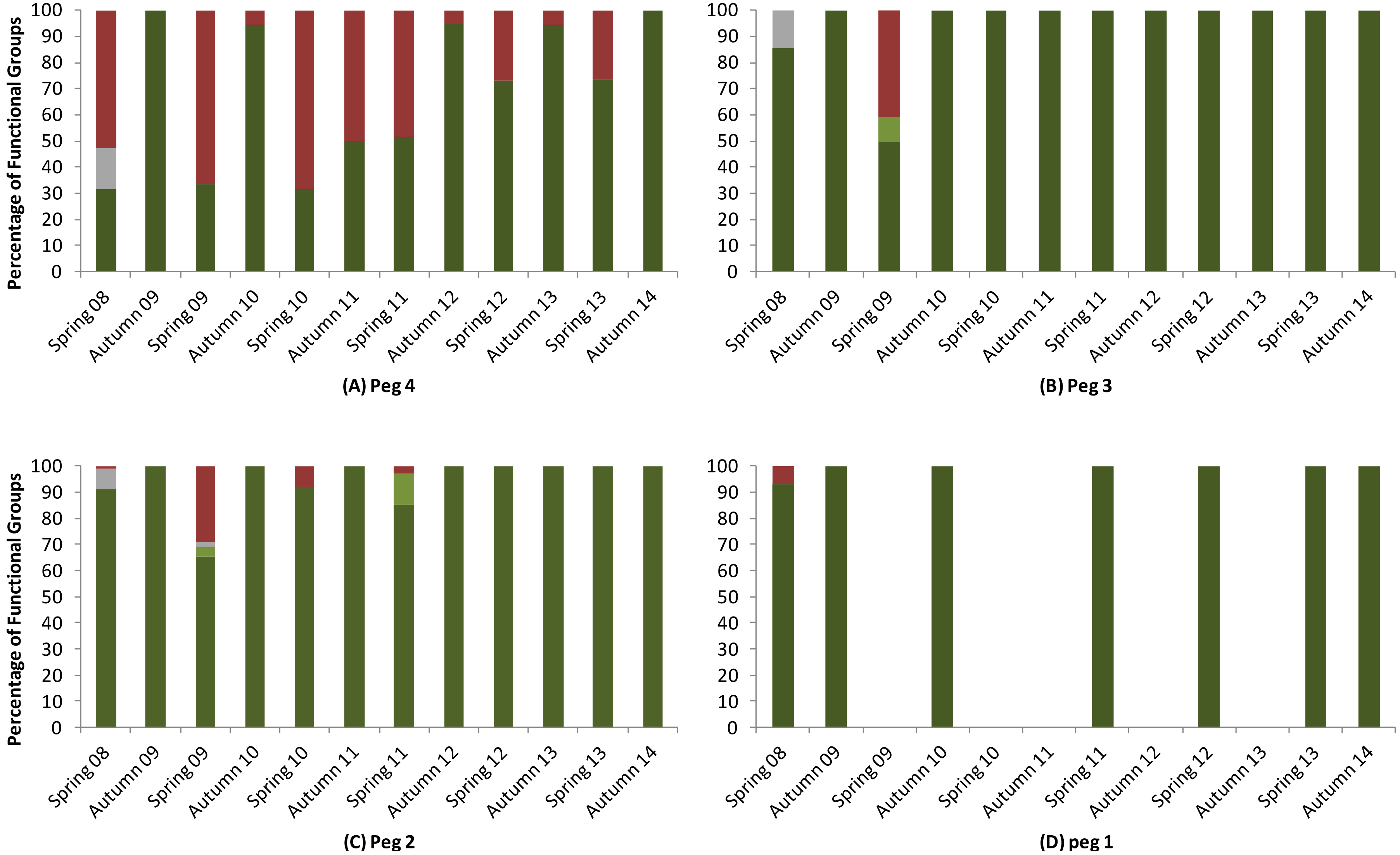

Figure 17: Percentage of plant functional groups across highest elevation (A: peg 4) to lowest elevation (D: peg 1) in Waltowa wetland from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

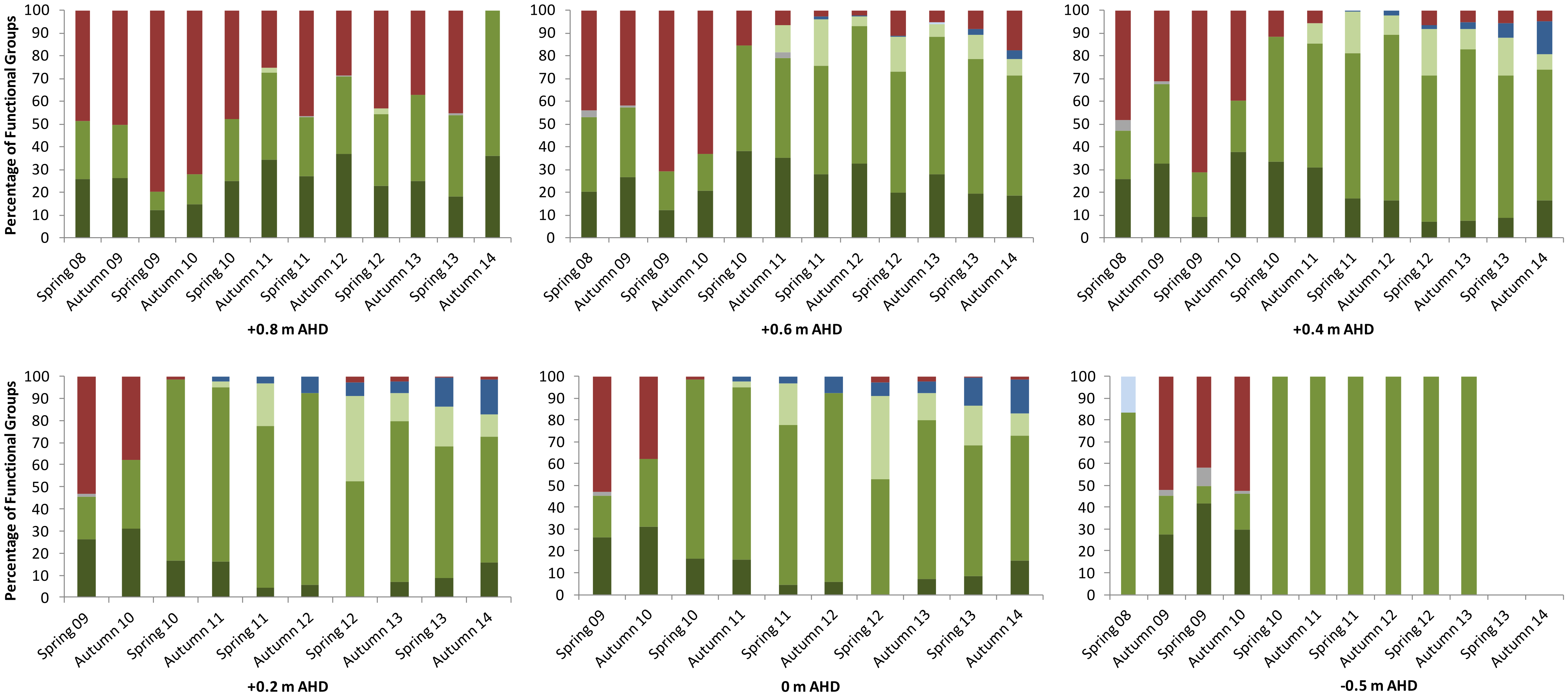

Figure 18: Percentage of plant functional groups from highest elevation (+0.8 m AHD) to lowest elevation (-0.5 m AHD) in Lake Alexandrina from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

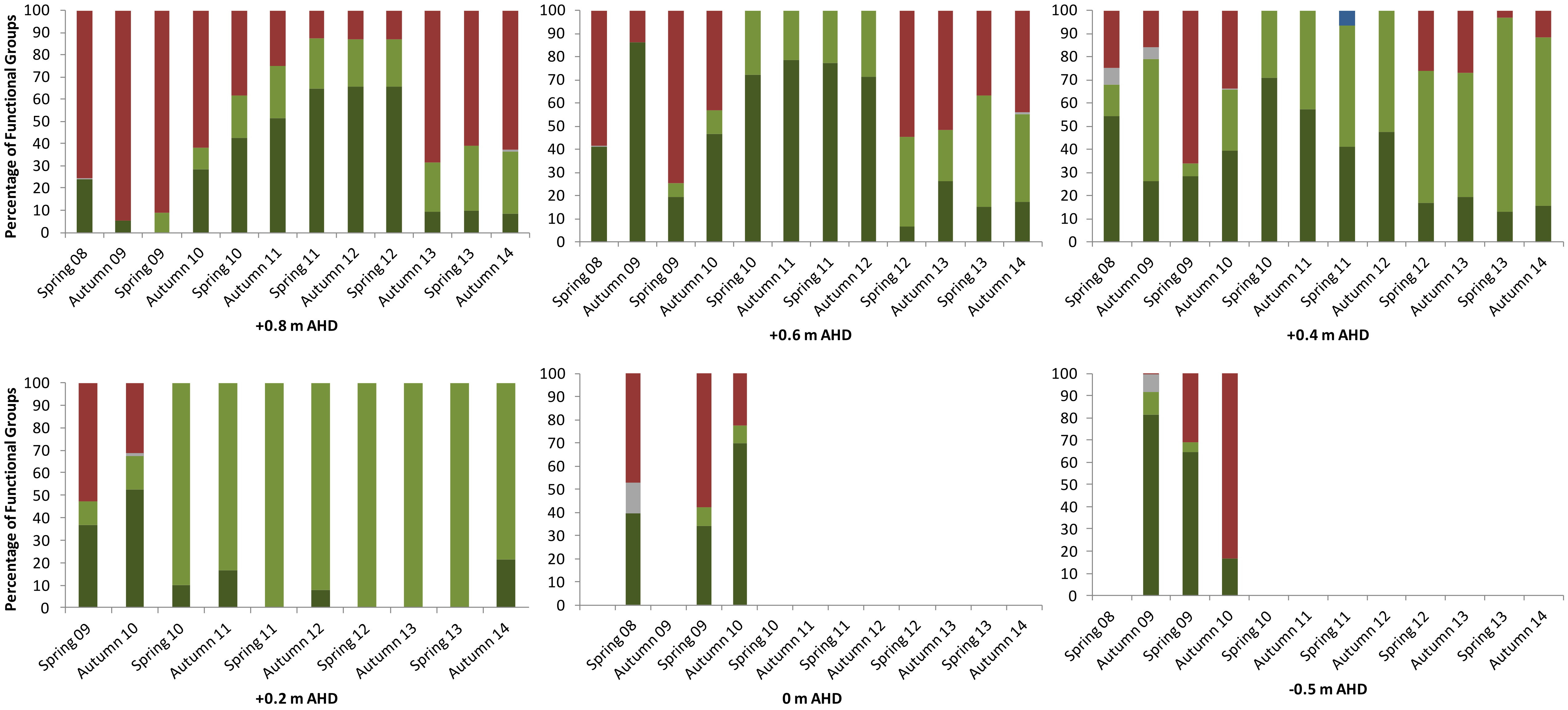

Figure 19: Percentage of plant functional groups from highest elevation (+0.8 m AHD) to lowest elevation (-0.5 m AHD) in Lake Albert from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

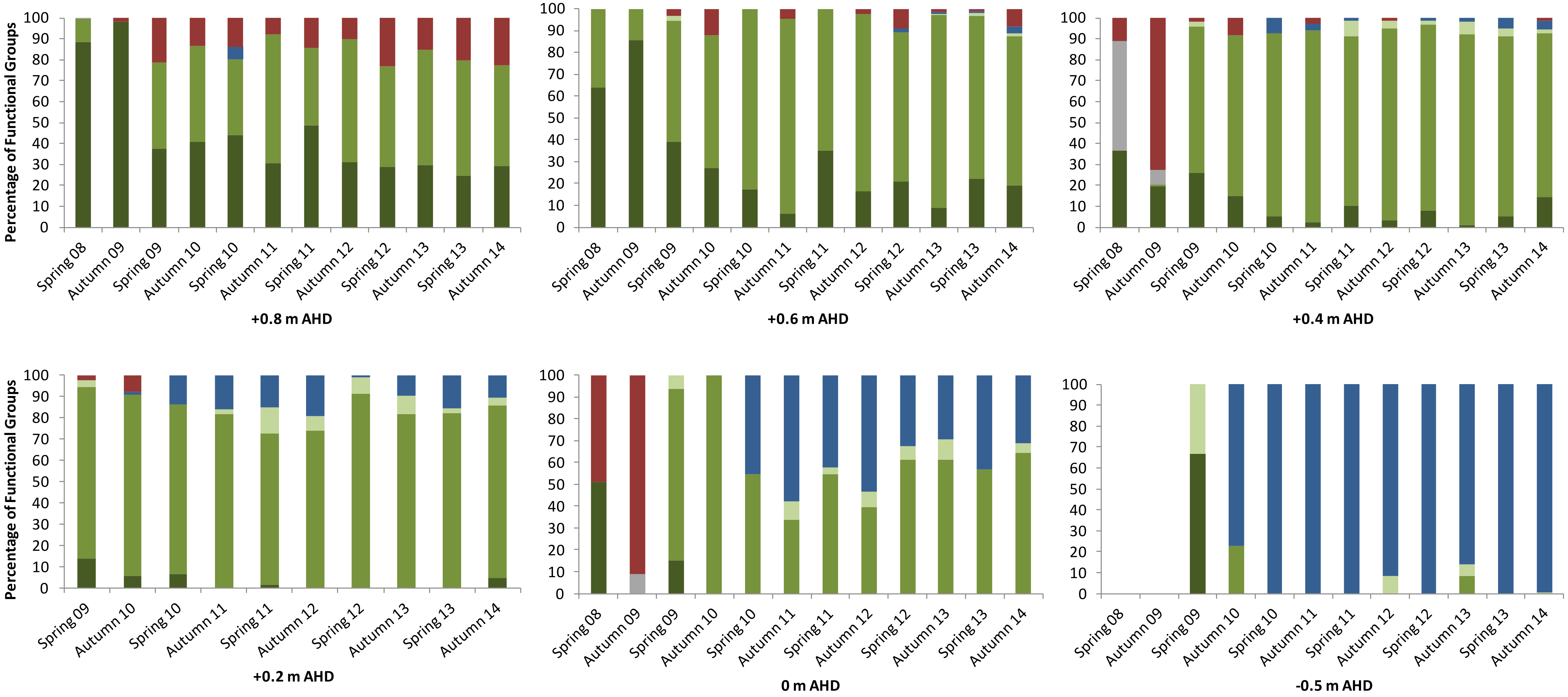

Figure 20: Percentage of plant functional groups from highest elevation (+0.8 m AHD) to lowest elevation (-0.5 m AHD) in Goolwa Channel from spring 2008 to autumn 2014 (functional group key is provided in Table 7).

3.2. *Melaleuca halmaturorum* age class structure

The age class structure of *Melaleuca halmaturorum* throughout the Lower Lakes showed that almost all trees recruited in the last 50 years because there were very few old trees (age class >7) and these older trees were only present at Hunters Creek in the 2014 survey (Figure 21). Despite the scarcity of old trees, the age class structure of stands differed between sites and there were changes in age class structure between 2008 and 2014 (Figure 21).

Goat Island had the greatest range of age classes with trees present in each age class between one and six in 2008 (age range 1 to >28 years) and between one and seven (age range 1 to >28 years) in 2014 (Figure 21). There were a lower proportion of young trees (age classes one and two, age range 1 to 5 years) present in 2014; however, there was evidence of germination events between 2008 and 2014 due to the presence of seedling and saplings (age classes one and two) (Figure 21).

There was little change in the age class structure of the *Melaleuca halmaturorum* stand at Boggy Creek between 2008 and 2014 (Figure 21). Age classes from two to six were present in 2008 but no young trees were present (age class two) in 2014 (Figure 21) indicating there has been no recruitment over this time.

The *Melaleuca halmaturorum* stand at Hunters Creek was dominated by older trees in 2008 (age classes four to seven) (Figure 21). In 2014 the older trees were still present; however, there had been significant germination since 2008 with a large proportion of the trees present between two and five years old (age class two) (Figure 21).

Five age classes of trees were present at Kennedy Bay in 2008 and 2014 (Figure 21). The majority (approximately 80%) were older trees (age class six >28 years); however, in 2008 there were a small number of seedlings (age class one) that were not recorded again in 2014 (Figure 21) indicating they did not survive.

The *Melaleuca halmaturorum* stand at Salt Lagoon contained the largest proportion of seedlings and saplings with over 95% of trees surveyed in 2008 in age class one (<2 years) (Figure 21). Unfortunately this site was not able to be resurveyed in 2014.

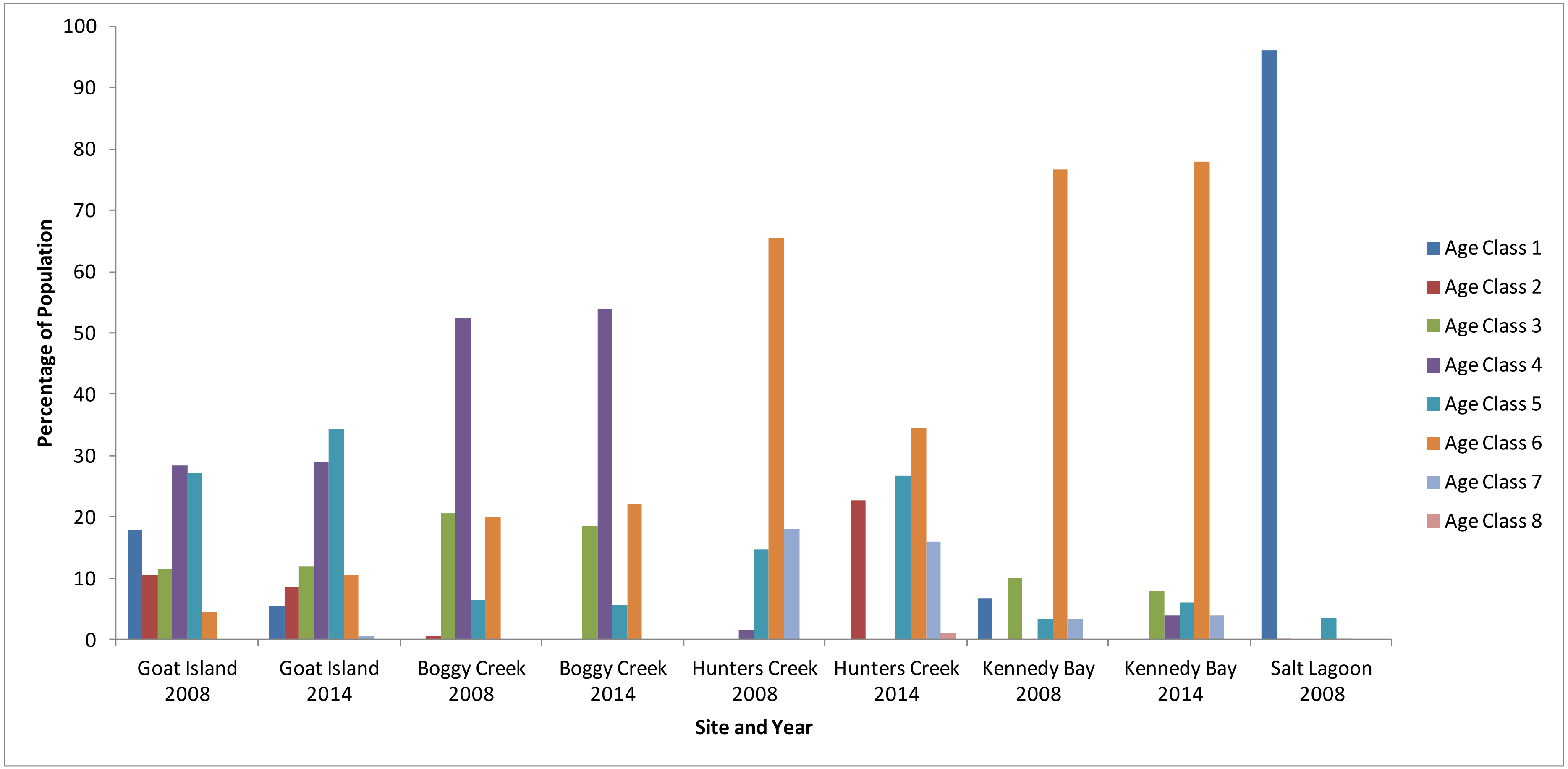

Figure 21: Graph showing the percentage of *Melaleuca halmaturorum* trees in the respective age class (see Table 4) at Goat Island, Boggy Creek, Hunters Creek and Kennedy Bay in spring 2008 and autumn 2014 and Salt Lagoon in spring 2008.

4. DISCUSSION AND MANAGEMENT IMPLICATIONS

During the most recent survey period (spring 2013 to autumn 2014) water levels and salinity in Lake Alexandrina and Goolwa Channel remained similar to those recorded in the previous two years (2011–2013) and electrical conductivity continued to decrease in Lake Albert, although the decrease was probably not biologically significant for the plant species present. During the drought-induced draw down period (2007 to 2010), plant communities shifted towards an assemblage of terrestrial and floodplain taxa, but following restoration of water levels in the Lower Lakes in late August 2010 (and the subsequent reconnection of most wetlands) there has been an increase in the abundance and diversity of aquatic dependent taxa (e.g. submergent, amphibious, floating and emergent), suggesting the vegetation of the system is still recovering.

During 2012/13, water level management in the Lower Lakes involved two draw down and refilling cycles (between +0.4 and +0.8 m AHD) with the aim to reduce salinity in Lake Albert (Figure 2). There were no deliberate lake level cycles during 2013/14 due to a lack of environmental water or unregulated flows to enable refilling; however, the typical seasonal cycle of high water levels in spring and low water levels in autumn occurred providing approximately 60 cm difference between the highest and lowest levels recorded in Lake Alexandrina (Figure 2). Stable water levels have been identified as detrimental to aquatic plant communities, with a greater diversity of aquatic plants generally in systems with fluctuating water levels (e.g. Nielsen and Chick 1997). The water level fluctuations in the Lower Lakes periodically exposed the fringes of lakeshores and wetlands, which provides opportunities for species requiring exposure to germinate (e.g. *Persicaria lapathifolia, Ludwigia peploides, Juncus* spp.) (Nicol 2004). However, in the Lower Lakes there is probably limited opportunity for recruitment of species that require exposure to germinate due to extensive fringing areas being densely vegetated with emergent species such as *Typha domingensis* or *Phragmites australis*. Generally, shorelines that are not densely vegetated are subjected to wave action which can prevent seedlings from establishing (e.g. Foote and Kadlec 1988); nevertheless, water level fluctuations between +0.8 and +0.4 m AHD are recommended because areas of submergent vegetation are then maintained, the establishment of amphibious taxa in areas protected from wave action is facilitated (e.g. wetlands and shorelines planted with *Schoenoplectus validus*).

4.1. Wetlands

Prior to 2007, the plant communities in the Lower Lakes wetlands were a diverse assemblage of submergent, amphibious, floating and emergent taxa (Renfrey *et al.* 1989; Holt *et al.* 2005; Nicol *et al.* 2006). However, 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 draw down (e.g. Nicol 2010). Furthermore, 46 submergent, emergent and amphibious taxa that were recorded in the 2004 (Holt *et al.* 2005) and 2005 (Nicol *et al.* 2006) baseline surveys were not recorded between October 2008 and March 2010 (Gehrig *et al.* 2010). The only wetlands that supported wetland plant communities during this period were 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, particularly 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 australis*) 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. germinated in response to watering.

In August 2010, water levels in the Lower Lakes returned to normal pool levels; however, hydrological restoration of wetlands occurred at different times (and in the case of Waltowa only occurred following the survey in autumn 2012). Wetlands with efficient 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 by an excavator. Areas of Milang Wetland are perched and primarily receive water from local runoff (A. Rumbelow 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 permanent freshwater wetlands (Dunn's Lagoon, Hunters Creek, Angas River Mouth and Bremer River Mouth) there has generally been a steady (albeit gradual) increase in the abundance of aquatic species (amphibious, emergent, floating and submergent functional groups) since lake levels were reinstated. This has been particularly evident for the submergent taxa, which have been generally increasing in abundance each survey and in many wetlands in 2013/14 were the only functional group present at low elevations. Furthermore, *Ceratophyllum demersum* was a significant indicator of the autumn 2014 survey at the lower elevations of several wetlands indicating that its abundance was highest at this time. This trend indicates that the aquatic plant community is still recovering from the low water levels and may continue some time into the future. Whilst direct comparisons cannot be made between the baseline surveys of 2004 (Holt *et al.* 2005) and 2005 (Nicol *et al.* 2006), results from these surveys suggest that the cover of aquatic species (particularly submergents) at the time of the spring 2013 and autumn 2014 surveys was lower than in 2004 and 2005.

The response of the seasonal (Milang, Poltalloch, Teringie, Loveday Bay, Point Sturt and Goolwa Channel Drive) and managed (Narrung and Waltowa) wetlands was variable. 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 vigor and improved condition from spring 2010 and autumn 2011 onwards, which did not result in a significant increase in percentage cover because percentage cover values were close to 100% (especially for *Phragmites australis* in 2013/14 at areas close to the Lake Alexandrina shoreline). It is unclear whether this observation was due to above average local rainfall between 2011 and 2014 or increased lake levels. Between 2012/13 and 2013/14, the plant community changed very little.

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. In 2012/13, the vegetation communities changed very little, although there was an increase in emergent taxa and terrestrial weeds in the middle elevations. In 2013/14, there was little change at the upper elevations; however, at the lower elevations submergent species were absent. Submergent species were only present at Narrung wetland shortly after a drying cycle; therefore, it is recommended that the wetland be dried over summer and autumn 2014/2015 and refilled in spring 2015 to promote the recruitment of submergent r-selected species at the low elevations of the wetland.

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 elevations close to Lake Alexandrina in Teringie Wetland remained inundated from 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 yet recolonised the wetland. In 2012/13 and 2013/14 filamentous algae and *Ruppia tuberosa* were abundant at the lower elevations in spring. At the higher elevations there was a marked increase in the abundance of emergents and amphibious taxa in 2012/13 but little change after then except for an increase in abundance of *Paspalum distichum*. The recent increase in abundance of *Paspalum distichum* has been a concern for the landholder of Loveday Bay Wetland and several control measures (including crash grazing in summer) have been proposed. In autumn 2014 control of *Paspalum distichum* using line trimmers was trialed; however, the results are not yet available and whether this technique is effective in reducing *Paspalum distichum* biomass and providing conditions suitable for native wetland species recruitment is unknown.

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. Despite a slight increase in the abundance of terrestrial weeds in spring 2012, the plant community in Waltowa Wetland remained largely unchanged in 2012/2013 and 2013/14, continuing to be dominated by salt tolerant species and terrestrial species and will probably remain dominated by these functional groups in the future (unless extended inundation at a higher elevation occurs).

There were large changes in the plant community in Poltalloch Wetland over the survey period. At the highest elevation, the plant community was dominated by amphibious (predominantly halophytes) and terrestrial species, which was expected because this elevation is rarely inundated and only for short periods. Prior to spring 2010 lower elevations were also dominated by amphibious (predominantly halophytes) and terrestrial species; however, the terrestrial taxa were extirpated once water levels were reinstated and submergent r-selected species recruited and persisted until spring 2011 (water levels remained elevated in autumn 2011). The wetland dried by autumn 2012 and the lower elevations were dominated by amphibious and terrestrial species but refilled in spring 2012 and dominated by submergent r-selected species (*Ruppia tuberosa* and charophytes). The pattern was repeated in spring 2013 and autumn 2014; however, in spring 2013 the plant community was dominated by *Lamprothamnium macropogon* (nearly 100% cover in the inundated areas). It is unclear why there was an increase in this species and absence of other submergent species in spring 2013. Nevertheless, the seasonal wetting and drying regime in the last two years of this wetland has facilitated the recruitment of submergent r-selected species and why this site has responded in this way and there has been very little response at other sites (e.g. Point Sturt Wetland) is unknown.

Point Sturt Wetland was also dominated by terrestrial and amphibious species whilst water levels were low; however, in contrast to Poltalloch, there was no recruitment of submergent r-selected species when water levels were reinstated. In 2005, this wetland was dominated by *Ruppia polycarpa* (Nicol *et al.* 2006) but despite the seasonal water regime present in Point Sturt Wetland since spring 2011 (which should favour submergent r-selected species such as *Ruppia polycarpa*) this functional group has been absent. There is evidence to suggest that this wetland become anoxic when water levels were reinstated and the limited flushing by lake water has resulted in the anoxia being prolonged, which may have resulted in the lack of recruitment of submergent species (*sensu* Aldridge *et al.* 2011).

Paspalum distichum has steadily increased in abundance at all wetlands (except Waltowa) and lakeshores over the last two years. *Paspalum distichum* is a rhizomatous and stolonifierous grass that in situations of high soil moisture can colonise large areas and outcompete native species (Cunningham *et al.* 1992). It is recommended that different control strategies (e.g. crash grazing in summer, herbicides, mowing) are trialed and monitored with the aim to developing a whole of system control strategy for this species.

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 resulted in disconnection 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 not inundated.

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, Duma florulenta, Typha domingensis* and *Calystegia sepium*. At intermediate elevations (0 to+0.4 m AHD) emergent species such as *Typha domingensis* and *Schoenoplectus validus*, that are adapted to deeper water, were common. At -0.5 m AHD only submergents (*Potamogeton pectinatus, Vallisneria australis, 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 2010b; Nicol and Ward 2010a).

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 these 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 reproducing 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 and from +0.8 to +0.2 m AHD in Lake Albert. In addition, submergent species recruited in Lake Alexandrina between +0.6 and 0 m AHD in areas that were protected from wave action (Raukkan, Loveday Bay and adjacent to the Bremer River Mouth). *Schoenoplectus validus* was abundant at the aforementioned sites (planted at Raukkan and naturally occurring at the other sites) and provided a “breakwater” creating a low energy environment suitable for the establishment of submergent species (*sensu* Nicol *et al.* 2013). Nicol *et al.* (2013) reported that submergent species were present between +0.6 and +0.2 m AHD in Lake Albert in areas planted with *Schoenoplectus validus*; therefore, it is likely that the absence of submergent species at TLM monitoring sites in Lake Albert (and throughout most of Lake Alexandrina) is due to high wave energy.

The -0.5 m AHD elevation was generally devoid of plants in Lakes Albert and Alexandrina from spring 2010 onwards, except in one site near Clayton Bay in Lake Alexandria, where *Typha domingensis* and *Schoenoplectus validus* were present in low numbers until autumn 2013, after which it was also devoid of plants. 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). *Myriophyllum salsugineum* continued to increase in abundance in Goolwa Channel and other less salt tolerant species such as *Ceratophyllum demersum, Potamogeton crispus* and *Vallisneria australis* colonised areas also increased in abundance from autumn 2011 for the remainder of the survey period.

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 australis*) to colonise these areas, which occurred from autumn 2011 and has continued throughout the remainder of the survey period.

Emergent taxa also responded to lower salinities in Goolwa Channel after September 2010 (Gehrig *et al.* 2011a). There has been 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) reduced 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 and are also present in throughout Lake Alexandrina and in numerous wetlands. 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 between 2007 and spring 2012. The absence of *Myriophyllum caput-medusae* during this period was probably initially due to elevated salinity in Goolwa Channel, which exceeded the maximum reported salinity tolerance (Bailey *et al.* 2002) but after the breaching of the Clayton regulator was most likely due to a depauperate seed bank and/or lack of dispersal.

Results from six 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 or provide ecological benefits at the site scale (e.g. pumping of Narrung wetland to benefit submergent vegetation). Nevertheless, regulated inundation in Goolwa Channel resulted in recruitment of *Potamogeton pectinatus, Vallisneria australis* and *Myriophyllum salsugineum* and maintained emergent taxa, but salinities remained elevated throughout Goolwa Channel (water levels were not sufficiently high to inundate fringing vegetation in Lake Albert prior to reconnection). Furthermore, pumping of Narrung Wetland provided conditions suitable for the germination of submergent r-selected species. 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 since April 2011 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. *Melaleuca halmaturorum* age class structure

There was limited recruitment of *Melaleuca halmaturorum* between spring 2008 and autumn 2014 at Goat Island and Hunters Creek (Figure 21). Results suggest there is continuous recruitment at Goat Island because of the continuous age classes and presence of age class one and two plants during both surveys (Figure 21). In contrast, there was probably one recruitment event between 2008 and 2014 (probably in 2010 or 2011) at Hunters Creek because there are gaps in the age class structure in 2014 with a cohort of two to five year old trees present (Figure 21). The ongoing recruitment on Goat Island is probably due to land management with all seedlings and saplings present in areas that were mowed, which reduced competition from weeds. It is unclear why there was a recruitment event at Hunters Creek; however, there is little competition from fast growing emergent species such as *Typha domingensis* or *Phragmites australis* at this site due to high salinities, an influence of the site’s proximity to the estuary.

The lack of recruitment at Hindmarsh Island and Kennedy Bay was probably due to competition from *Phragmites australis*, which formed dense monospecific stands excluding all other species. Furthermore, the seedlings present at Kennedy Bay in 2008 had germinated below +0.8 m AHD and would have been inundated when water levels were reinstated in winter 2010, which would have resulted in their deaths (*sensu* Denton and Ganf 1994).

Salt Lagoon was unable to be surveyed in 2014; hence, the fate of the large number of seedlings present in 2008 (which was due to a lightning strike and subsequent fire that burned half of the stand) is unknown. It is likely that some of the seedlings would have survived because the stand was only rarely inundated when lake levels are very high and there is a strong northerly wind.

Variable water levels may result in *Melaleuca halmaturorum* recruitment (*sensu* Nicol and Ganf 2000); however, the range of elevations that plants can persist is limited. Seedlings that germinate when water levels are low over autumn will not persist because they will be flooded the following spring (Denton and Ganf 1994). All of the seedlings observed in autumn 2014 were present at the edges of stands at upper elevations (i.e. further away from the lake edge) with only adult plants adjacent to the shoreline. Therefore, surcharging the lakes for short periods to briefly inundate high elevation areas may be required to facilitate *Melaleuca halmaturorum* germination because at low elevations the duration of drawdown in late summer and autumn is insufficient for plants to persist. Furthermore, at the low elevations there are often dense stands of emergent species that will outcompete any *Melaleuca halmaturorum* germinants. Hence, recruitment may be facilitated at the edges of stands (at their current elevations) by controlling the emergent vegetation and providing areas where seedlings can grow in the absence of competition from *Phragmites australis* or *Typha domingensis*.

4.4. The Living Murray Target V3

Whilst there has been an increase each year 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 still probably 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) have not re-established at all sites by autumn 2014. 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 (pers. obs.) but were not present in autumn 2014. Furthermore, one species (*Lepilaena cylindrocarpa*) recorded in the 2004 (Holt *et al.* 2005) and 2005 (Nicol *et al.* 2006) baseline surveys was not present in wetlands or lakeshores. However, extensive beds (468 ha) of *Myriophyllum salsugineum* have 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 2013/14 and whilst not measured directly probably increased in extent but still not to the level observed before the drought.

Therefore, TLM target V3 (which is currently under review) has not been met when compared to the plant community present prior to drawdown; nevertheless, there has been a steady increase in the abundance of submergent, emergent and amphibious species since water levels were reinstated that has continued to autumn 2014 as evidenced with several species in these groups being significant indicators of 2013/14 surveys. All but one (*Lepilaena cylindrocarpa*) of the 46 species recorded in 2004 and 2005, that were lost when water levels decreased, were present in 2013/14. Results showed that the plant community shifted from being dominated by terrestrial taxa during the drought to submergent, emergent, floating and amphibious taxa after water levels were reinstated. 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.

4.5. 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 the condition monitoring program and gain a better understanding of vegetation dynamics at the landscape scale.
- Investigate salinity tolerances of potential local ecotypes of key species.
- Investigate the effects of sub-lethal salinities on key species.
- Determine propagule longevity under different conditions (e.g. salinity, pH, soil moisture).
- Investigate the current submergent plant propagule bank in key wetlands and Goolwa Channel.
- Investigate the relationships (e.g. habitat preferences) between plant communities and other biotic groups such as fish, birds and invertebrates.
- Investiagte different control methods for *Paspalum distichum* such as controlled summer grazing, herbicides and mowing.
- Trial emergent vegetation control at *Melaleuca halmaturorum* stands to determine whether competition is restricting recruitment.

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APPENDICES

Appendix 1: GPS coordinates (UTM format, map datum WGS84) for lakeshore and wetland understorey vegetation monitoring sites (site numbers correspond with site numbers in Figure 1).

Site #	Site	Easting	Northing	Site type
1	Bremer Mouth Lakeshore	323061	6081991	lakeshore
2	Brown Beach 1	350172	6052777	lakeshore
3	Brown Beach 2	350287	6053158	lakeshore
4	Clayton Bay	311301	6070626	lakeshore
5	Currency Creek 3	296772	6074222	lakeshore
6	Currency Creek 4	301013	6071800	lakeshore
7	Goolwa North	303330	6070156	lakeshore
8	Goolwa South	300490	6066366	lakeshore
9	Hindmarsh Island Bridge 01	299670	6068521	lakeshore
10	Hindmarsh Island Bridge 02	299695	6068616	lakeshore
11	Lake Reserve Rd	339298	6089987	lakeshore
12	Loveday Bay	329431	6058407	lakeshore
13	Loveday Bay Lakeshore	326621	6061647	lakeshore
14	Lower Finniss 02	305131	6076401	lakeshore
15	Milang	315964	6079870	lakeshore
16	Milang Lakeshore	316081	6079746	lakeshore
17	Pt Sturt Lakeshore	322811	6069643	lakeshore
18	Pt Sturt Water Reserve	317673	6070784	lakeshore
)19	Teringie Lakeshore	327461	6066887	lakeshore
20	Upstream of Clayton Regulator	312281	6069151	lakeshore
21	Wally's Landing	303066	6079631	lakeshore
22	Warrengie 1	347722	6049163	lakeshore
23	Lower Finniss 03	305131	6072406	lakeshore
24	Narrung Lakeshore	333762	6069807	lakeshore
25	Nurra Nurra	341786	6063837	lakeshore
26	Warrengie 2	348487	6049133	lakeshore
27	Angas Mouth	318391	6081206	wetland
28	Bremer Mouth	323056	6082019	wetland
29	Dunns Lagoon	312417	6070300	wetland
30	Goolwa Channel Drive	307024	6064437	wetland
31	Hunters Creek	308219	6065526	wetland
32	Poltalloch	343248	6071554	wetland
33	Pt Sturt	322778	6069794	wetland
34	Teringie	327334	6065286	wetland
35	Waltowa	353908	6057756	wetland
36	Narrung	334542	6068744	wetland

Appendix 2: Nomenclature changes since 2012 (Centre for Australian National Biodiversity Research and Council of Heads of Australasian Herbaria 2014).

	Previous scientific name		Revised scientific name	
Common Name	**Genus**	**Species**	**Genus**	**Species**
Blackseed samphire	*Halosarcia*	*pergranulata*	***Tecticornia***	*pergranulata*
Lignum	*Muehlenbeckia*	*florulenta*	***Duma***	*florulenta*
Weedy cudweed	*Pseudognaphalium*	*luteoalbum*	***Helichrysum***	*luteoalbum*
Brome grass	*Bromus*	*uniloides*	*Bromus*	***catharticus***
Soft Brome	*Bromus*	*mollis*	*Bromus*	***hordeaceus* ssp. *hordeaceus***
Angled Lobelia	*Lobelia*	*alata*	*Lobelia*	***anceps***
Native Picris	*Picris*	*hieracoides*	*Picris*	***angustifolia* ssp. *angustifolia***
Bog yellowcress	*Rorippa*	*islandica*	*Rorippa*	***palustris***
Ribbonweed	*Vallisneria*	*spiralis var. americana*	*Vallisneria*	***australis***
Thread-leaved water-crowfoot	*Batrachium*	*trichophyllum*	***Ranunculus***	***trichophyllus***
Prickly saltwort, tumbleweed	*Salsola*	*kali*	*Salsola*	***australis***
Short stem sand-spurrey	*Spergularia*	*marina*	*Spergularia*	***brevifolia****

Appendix 3: 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 Kaeheneuhl (2001) from all sites and survey dates (*denotes exotic taxon, **denotes proclaimed pest plant in South Australia, ***denotes weed of national significance # 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
*Anagallis arvensis**	Terrestrial damp	Annual	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
*Asphodelus fistulosus***	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 spp.	Terrestrial dry	Perennial	Native
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
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 catharticus**	Terrestrial dry	Annual	Exotic
*Bromus diandrus**	Terrestrial dry	Annual	Exotic
Bromus hordeaceus ssp. *hordeaceus**	Terrestrial dry	Annual	Exotic
*Bromus rubens**	Terrestrial dry	Annual	Exotic

Taxon	Functional Group	Life history strategy	Status and Comments
Calystegia sepium	Amphibious fluctuation tolerator-emergent	Perennial	Native-Listed as Uncommon in the Murray and Southern Lofty Regions
Carex fasicularis	Amphibious fluctuation tolerator-emergent	Perennial	Native
Carpobrotus rossii	Terrestrial dry	Perennial	Native
*Centaurea calcitrapa**	Terrestrial damp	Annual	Exotic
*Centaurium tenuiflorum**	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
Crassula helmsii	Amphibious fluctuation tolerator-low growing	Perennial	Native
Crinum sp.*	Terrestrial dry	Perennial	Exotic-garden escapee not in any of the identification keys and could not be identified to species, probably a horticultural hybrid
Cyperus exaltatus	Amphibious fluctuation tolerator-emergent	Perennial	Native
Cyperus gymnocaulos	Amphibious fluctuation tolerator-emergent	Perennial	Native
Dianella revoluta	Terrestrial dry	Perennial	Native
Disphyma crassifolium	Terrestrial dry	Perennial	Native
Distichlis distichophylla	Terrestrial damp	Perennial	Native-Listed as Uncommon in the Murray Region
Duma florulenta	Amphibious fluctuation tolerator-woody	Perennial	Native
*Echinochloa crus-galli**	Terrestrial damp	Annual	Exotic
*Ehrharta longiflora**	Terrestrial damp	Annual	Exotic
Einadia nutans	Terrestrial dry	Perennial	Native
Eleocharis acuta	Emergent	Perennial	Native
Enchylaena tomentosa	Terrestrial dry	Perennial	Native
Epilobium pallidiflorum	Terrestrial damp	Perennial	Native-Listed as Uncertain in the Murray Region and uncommon in the Southern Lofty Region
Eragrostis australasica	Floodplain	Perennial	Native
*Eragrostis curvula***	Terrestrial damp	Annual	Exotic-Proclaimed pest plant in SA
Eragrostis sp.	Terrestrial damp	Annual	Native-could not identify to species
*Erodium cicutarium**	Terrestrial dry	Annual	Exotic
*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
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

Taxon	Functional Group	Life history strategy	Status and Comments
*Hypochoeris glabra**	Terrestrial dry	Annual	Exotic
*Hypochoeris radicata**	Terrestrial dry	Annual	Exotic
Iris spp.*	Terrestrial dry	Perennial	Exotic
Isolepis platycarpa	Amphibious fluctuation tolerator-low growing	Perennial	Native
Isolepis producta	Amphibious fluctuation tolerator-low growing	Perennial	Native
*Juncus acutus**	Amphibious fluctuation tolerator-emergent	Perennial	Exotic
Juncus holoschoenus	Amphibious fluctuation tolerator-emergent	Perennial	Native
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 spp.	Floating	Perennial	Native
Limosella australis	Amphibious fluctuation responder-plastic	Perennial	Native
Lobelia anceps	Terrestrial damp	Perennial	Native
Lolium spp.*	Terrestrial dry	Annual	Exotic-*Lolium* spp. comprises of *Lolium perenne* and *Lolium rigidum*
Ludwigia peploides ssp. *montevidensis*	Amphibious fluctuation responder-plastic	Perennial	Native
*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
*Malva parviflora**	Terrestrial dry	Annual	Exotic
*Marrubium vulgare***	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 albus**	Terrestrial dry	Annual	Exotic
*Melilotus indicus**	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 gunnii	Terrestrial dry	Perennial	Native
Myriophyllum caput-medusae	Submergent k-selected	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

Taxon	Functional Group	Life history strategy	Status and Comments
*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 angustifolia ssp. *angustifolia*	Terrestrial dry	Annual	Native
*Plantago coronopus**	Terrestrial dry	Annual	Exotic
*Plantago lanceolata**	Terrestrial dry	Annual	Exotic
*Plantago major**	Terrestrial dry	Annual	Exotic
*Poa annua**	Terrestrial damp	Annual	Exotic
*Polygonum aviculare**	Terrestrial dry	Perennial	Exotic
*Polypogon monspeliensis**	Amphibious fluctuation tolerator-emergent	Annual	Exotic
Potamogeton crispus	Submergent k-selected	Perennial	Native
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 trichophyllus**	Submergent (r-selected)	Annual	Exotic
*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
Rumex bidens	Amphibious fluctuation responder-plastic	Perennial	Native
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 australis	Terrestrial dry	Perennial	Native
Samolus repens	Terrestrial damp	Perennial	Native- Listed as Rare in the Murray Region and Uncommon the Southern Lofty Region
Sarcocornia quinqueflora	Amphibious fluctuation tolerator-emergent	Perennial	Native
*Scabiosa atropurpurea**	Terrestrial dry	Annual	Exotic
Scaevola calendulacea	Terrestrial dry	Perennial	Native
Schoenoplectus pungens	Amphibious fluctuation tolerator-emergent	Perennial	Native-Listed as Rare in the Southern Lofty Region
Schoenoplectus validus	Emergent	Perennial	Native
Sclerolaena blackiana	Terrestrial dry	Perennial	Native-Listed as Rare in SA
Senecio cunninghamii	Floodplain	Perennial	Native
*Senecio pterophorus**	Terrestrial dry	Annual	Exotic
Senecio runcinifolius	Floodplain	Perennial	Native-Listed as Uncommon in the Murray Region
*Silybum marianum***	Terrestrial damp	Annual	Exotic-Proclaimed pest plant in SA
*Solanum nigrum**	Terrestrial damp	Annual	Exotic
*Sonchus asper**	Terrestrial damp	Annual	Exotic
*Sonchus oleraceus**	Terrestrial damp	Annual	Exotic
*Spergularia brevifolia**	Terrestrial damp	Annual	Exotic
Suaeda australis	Amphibious fluctuation tolerator-emergent	Perennial	Native

Taxon	Functional Group	Life history strategy	Status and Comments
*Tamarix aphylla****	Terrestrial dry	Perennial	Exotic
Tecticornia pergranulata	Amphibious fluctuation tolerator-emergent	Perennial	Native
Trifolium spp.*	Terrestrial dry	Annual	Exotic-*Trifolium* spp. comprises of *Trifolium angustifolium, Trifolium arvense, Trifolium repens* and *Trifolium subterraneum*
Triglochin procerum	Emergent	Perennial	Native-Listed as Uncommon in the Southern Lofty Region
Triglochin striatum	Amphibious fluctuation tolerator-low growing	Perennial	Native
Triticum sp.*	Terrestrial dry	Annual	Exotic-could not be identified to species
Typha domingensis	Emergent	Perennial	Native
*Urtica urens**	Terrestrial damp	Annual	Exotic
Vallisneria australis	Submergent k-selected	Perennial	Native-Listed as Uncommon in the Murray Region and Threatened in the Southern Lofty Region
*Vicia sativa**	Terrestrial dry	Annual	Exotic
Wilsonia rotundifolia	Terrestrial damp	Perennial	Native

Appendix 4: Taxa present (green shading) in each wetland from spring 2008 to autumn 2014 (*denotes exotic taxon; **denotes proclaimed pest plant in South Australia; ***denotes weed of national significance; #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 spp.			*					*		*	
Atriplex stipitata					*						
Atriplex suberecta								*		*	
Avena spp.*	*	*				*		*		*	
Azolla filiculoides	*	*		*		*				*	
Berula erecta	*										
Bolboschoenus caldwellii			*	*	*	*	*	*	*		
*Brassica rapa**		*									
*Brassica tournifortii**		*				*				*	
*Bromus catharticus**		*			*	*				*	
*Bromus diandrus**		*			*	*		*		*	
Bromus hordeaceus ssp. *hordeaceus**		*				*		*		*	
Calystegia sepium		*									
*Centaurea calcitrapa**	*		*		*				*		
Ceratophyllum demersum#	*	*		*							
Chara spp.			*				*	*	*		
*Chenopodium album**	*	*				*		*		*	
*Chenopodium glaucum**		*			*			*	*		
*Conyza bonariensis**	*	*	*		*	*					
*Cotula coronopifolia**	*	*	*	*	*	*	*	*	*	*	
Crassula helmsii				*							
Crinum sp.*						*					
Cyperus exaltatus	*										
Cyperus gymnocaulos		*			*	*			*	*	
Dianella revoluta		*									
Disphyma crassifolium ssp. *clavellatum*							*			*	*
Distichlis distichophylla		*	*	*	*	*	*	*	*	*	
Duma florulenta		*				*				*	
*Echinochloa crus-galli**				*							
*Ehrharta longiflora**						*					
Einadia nutans								*			
Eleocharis acuta		*		*	*	*					
Enchylaena tomentosa		*				*		*		*	
*Eragrostis curvula***`		*		*	*	*	*	*	*	*	*
Eragrostis sp.		*				*	*	*		*	
*Erodium cicutarium**										*	
Ficinia nodosa		*	*	*					*		
Frankenia pauciflora			*		*	*	*			*	
*Fumaria bastardii**						*					
Gahnia filum		*									
Glyceria australis			*							*	*
Helichrysum luteoalbum		*			*						
*Heliotropium europaeum**										*	
*Holcus lanatus**						*					
*Hordeum vulgare**		*			*	*	*	*	*	*	*
Hydrocotyle verticillata		*									
*Hypochaeris glabra**		*			*						
*Hypochaeris radicata**	*	*									
Iris sp.*	*										
Isolepis producta		*	*	*	*	*					
*Juncus acutus**		*									
Juncus kraussii		*	*	*	*	*					
Juncus subsecundus		*		*	*	*					
Juncus usitatus						*					
Lachnagrostis filiformis	*	*	*	*	*	*	*	*		*	

Species	Angas and Bremer Mouths	Dunns Lagoon	Goolwa Channel Drive	Hunters Creek	Loveday Bay	Milang	Narrung	Point Sturt	Poltalloch	Teringie	Waltowa
*Lactuca saligna**		*			*	*					
*Lactuca serriola**	*	*			*	*			*	*	
*Lagurus ovatus**			*			*		*		*	
Lamprothamnium macropogon					*				*	*	
Lemna sp.	*	*		*		*		*		*	
Lobelia anceps										*	
Lolium sp.*	*	*	*	*	*	*	*	*	*	*	*
Ludwigia peploides	*	*									
*Lycium ferocissimum****						*		*	*	*	
Lycopus australis		*									
Lythrum hyssopifolia						*					
*Malva parviflora**						*			*		
*Marrubium vulgare***					*						
Medicago spp.*		*		*	*	*	*	*	*	*	*
Melaleuca halmaturorum		*							*	*	
*Melilotus albus**					*						
*Melilotus indica**		*			*			*	*		
Mentha spp.*		*									
Mimulus repens		*		*		*	*	*	*	*	
Myriophyllum caput-medusae		*		*							
Myriophyllum salsugineum	*	*		*	*	*					
*Oxalis pes-caprae***						*				*	
*Paspalum distichum**	*	*	*	*	*	*	*	*	*	*	
*Pennisetum clandestinum**	*					*					
Persicaria lapathifolia	*	*									
Phragmites australis	*	*	*			*	*				
*Phyla canescens**					*						
Picris angustifolia ssp. *angustifolia*		*			*						
*Plantago coronopus**	*	*	*	*	*	*		*		*	
*Poa annua**											*
*Polygonum aviculare**								*			
*Polypogon monspeliensis**	*		*	*	*	*	*	*	*	*	
Potamogeton crispus		*		*							
Potamogeton pectinatus		*	*	*	*		*				
Puccinellia sp.*							*				
*Ranunculus trichophyllus**					*						
*Ranunculus trilobus**					*						
*Reichardia tingitana**	*	*	*		*	*		*		*	*
*Rorippa nasturtium-aquaticum**	*										
*Rorippa palustris**							*				
Rumex bidens	*	*			*	*					
Ruppia megacarpa				*							
Ruppia polycarpa			*	*		*	*	*	*	*	
Ruppia tuberosa				*	*		*		*	*	
Salsola australis										*	
Samolus repens		*	*		*	*	*	*	*	*	
Sarcocornia quinqueflora		*	*	*	*	*	*	*	*	*	*
*Scabiosa atropurpurea**		*				*					
Schoenoplectus pungens		*	*	*	*	*					
Schoenoplectus validus		*		*	*						
*Senecio pterophorus**	*	*	*	*	*	*	*	*		*	*
Senecio runcinifolius		*									*
*Silybum marianum***					*	*					
*Sonchus asper**		*				*					
*Sonchus oleraceus**	*	*	*	*	*	*	*	*	*	*	*
Spergularia brevifolia *		*	*		*	*	*	*	*	*	*
Suaeda australis		*	*	*	*	*	*	*	*	*	*
Tecticornia pergranulata ssp. *pergranulata*											*
Trifolium sp.*	*	*			*	*		*	*	*	
Triglochin procerum	*	*									
Triglochin striatum	*	*	*	*	*	*	*	*	*	*	
Typha domingensis	*	*	*	*	*	*					
*Urtica urens**		*									
Vallisneria australis	*	*		*							

Species	Angas and Bremer Mouths	Dunns Lagoon	Goolwa Channel Drive	Hunters Creek	Loveday Bay	Milang	Narrung	Point Sturt	Poltalloch	Teringie	Waltowa
*Vicia sativa**						*					
Wilsonia rotundifolia		*	*		*	*					

Appendix 5: Taxa present (green shading) at lakeshore sites from spring 2008 to autumn 2014 (*denotes exotic taxon; **denotes proclaimed pest plant in South Australia; ***denotes weed of national significance; #denotes listed as rare in South Australia).

Species	Lake Albert	Lake Alexandrina	Goolwa Channel
Acacia myrtifolia	*		
Lachnagrostis filiformis	*	*	*
*Anagallis arvensis**	*		
*Apium graveolens**		*	
*Arctotheca calendula**	*	*	
*Asparagus officinalis**			*
*Aster subulatus**	*	*	*
*Atriplex prostrata**		*	*
Atriplex spp.		*	*
Atriplex suberecta		*	
Avena spp.*	*	*	
Azolla filiculoides	*	*	*
*Berula erecta**		*	*
Bolboschoenus caldwellii	*	*	*
*Brassica rapa**		*	
*Brassica tournifortii**		*	*
*Briza minor**	*	*	
*Bromus catharticus**	*		
*Bromus diandrus**	*	*	*
*Bromus hordeaceus**	*	*	*
*Bromus rubens**		*	
*Bromus uniloides**		*	
Calystegia sepium	*	*	*
Carex fascicularis		*	
*Centaurium tenuiflorum**	*	*	
*Centaurea calcitrapa**	*	*	*
Ceratophyllum demersum#	*	*	*
Chara spp.		*	
*Chenopodium album**	*		
*Chenopodium glaucum**	*	*	*
Chenopodium nitrariaceum		*	
*Conyza bonariensis**	*	*	*
*Cotula coronopifolia**	*	*	*
Cyperus exaltatus			*
Cyperus gymnocaulos	*	*	*
Distichlis distichophylla	*		
*Ehrharta longiflora**	*	*	
Einadia nutans		*	
Eleocharis acuta	*	*	*
Enchylaena tomentosa	*	*	*
Epilobium pallidiflorum	*		*
Eragrostis australasica	*		
*Eragrostis curvula***	*	*	
Eragrostis sp.	*	*	*
*Euphorbia terracina***	*		
*Foeniculum vulgare**	*		
Frankenia pauciflora		*	
*Fumaria bastardii**		*	
Glyceria australis		*	
*Holcus lanatus**		*	
*Hordeum vulgare**	*	*	
Hydrocotyle verticillata	*	*	*
*Hypochaeris glabra**	*	*	
*Hypochaeris radicata**	*	*	
Ficinia nodosa	*	*	*
Isolepis producta	*	*	
*Juncus acutus**		*	
Juncus holoschoenus		*	
Juncus kraussii	*	*	*
Juncus usitatus	*	*	*

Species	Lake Albert	Lake Alexandrina	Goolwa Channel
*Lactuca saligna**		*	*
*Lactuca serriola**	*	*	
*Lagurus ovatus**	*	*	
Lemna sp.	*	*	*
Limosella australis		*	
Lobelia anceps		*	
Lolium spp.*	*	*	*
Ludwigia peploides		*	
*Lupinus cosentinii**			*
Lycopus australis		*	*
Lythrum hyssopifolia	*		*
Lythrum salicaria			*
Medicago spp.*	*	*	*
*Melilotus indica**	*	*	*
Melaleuca halmaturorum	*		
Mentha australis		*	*
Mentha spp.*		*	*
Mimulus repens	*	*	*
Duma florulenta	*	*	*
Myriophyllum caput-medusae			*
Myriophyllum salsugineum	*	*	*
*Onopordum acanthium**		*	
*Paspalum distichum**	*	*	*
*Pennisetum clandestinum**	*	*	*
Persicaria lapathifolia	*	*	*
Phragmites australis	*	*	*
Picris angustifolia ssp. *angustifolia*	*	*	*
*Plantago coronopus**	*	*	*
*Plantago lanceolata**		*	*
*Polypogon monspeliensis**	*	*	*
*Polygonum aviculare**		*	*
Potamogeton crispus	*		*
Potamogeton pectinatus	*	*	*
Helichrysum luteoalbum	*	*	
Puccinellia spp.	*	*	
*Ranunculus trilobus**		*	*
*Reichardia tingitana**	*	*	
*Rorippa palustris**		*	
*Rorippa nasturtium-aquaticum**	*		
Rumex bidens	*	*	*
Ruppia tuberosa		*	
*Salix babylonica**		*	*
Samolus repens			*
Sarcocornia quinqueflora	*	*	
*Scabiosa atropurpurea**			*
Scaevola sp.	*		
Schoenoplectus pungens	*	*	*
Schoenoplectus validus	*	*	*
Sclerolaena blackiana		*	
Senecio cunninghamii		*	
*Senecio pterophorus**	*	*	
Senecio runcinifolius		*	
*Solanum nigrum**		*	*
*Sonchus asper**		*	
*Sonchus oleraceus**	*	*	*
*Spergularia brevifolia**	*	*	
Suaeda australis	*	*	*
*Silybum marianum***		*	*
Trifolium sp.*	*	*	*
Triglochin procerum		*	*
Triglochin striatum	*	*	*
Triticum spp.*		*	
Typha domingensis	*	*	*

Species	Lake Albert	Lake Alexandrina	Goolwa Channel
*Urtica urens**		*	
Vallisneria australis	*	*	*
*Vicia sativa**	*	*	
Wilsonia rotundifolia		*	