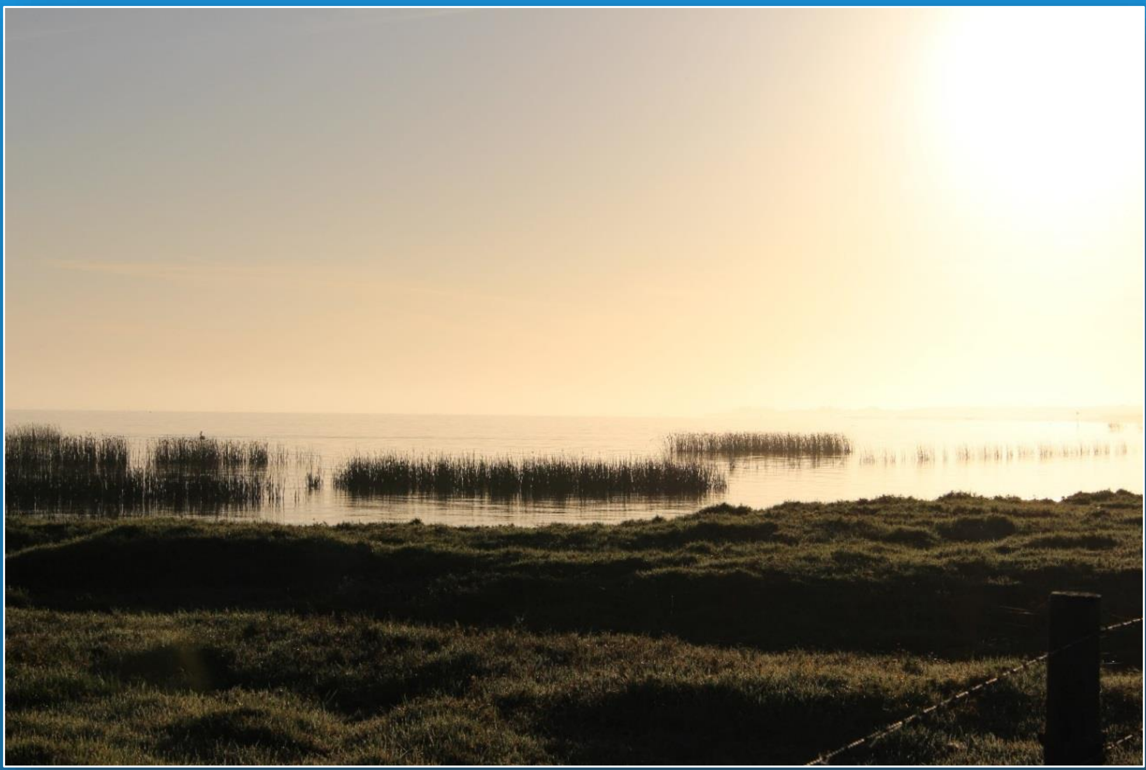
Inland Waters & Catchment Ecology

Lower Lakes Vegetation Condition Monitoring – 2015-16



Jason Nicol, Kate Frahn, Susan Gehrig and Kelly Marsland

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Cover Photo: Northern shoreline of Lake Albert showing *Juncus kraussii, Phragmites australis* and *Schoenoplectus tabernaemontani* (Josh Fredberg).

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EXECUTIVE SUMMARY

The Condition Monitoring Plan for the Lower Lakes, Coorong and Murray Mouth (LLCMM) icon site (Maunsell Australia Pty Ltd 2009) identified that a monitoring program was required to evaluate The Living Murray (TLM) Target V3: *maintain or improve aquatic and littoral vegetation in the Lower Lakes*. A review undertaken by Robinson (2015) suggested that the initial aquatic and littoral vegetation target for the Lower Lakes could be improved by developing a series of quantitative targets for the site. To develop the quantitative targets the Lower Lakes was divided into five different habitats (Lake Alexandrina, Lake Albert, Goolwa Channel, permanent wetlands and seasonal wetlands), with each habitat comprising different zones based on elevation. Targets were developed for species and functional groups for each zone in each habitat (see Table 1 to Table 5 for detailed description of targets) and the progress of target achievement through time was assessed. This report presents the findings of the first eight years of a monitoring program established to evaluate TLM Target V3 from spring 2008 to autumn 2016.

Vegetation surveys were conducted at selected wetlands and lakeshore sites across Lakes Alexandrina and Albert, Goolwa Channel, the lower Finniss River, lower Currency Creek and the mouths of the Angas and Bremer Rivers. Sites established in spring 2008, 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, 2013 and 2015) and autumn (March 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2016). 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 plant 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.

Over the eight year period (spring 2008 to autumn 2016), 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).

NMS ordination shows the changes through time of the plant community in each habitat indicated a shift in floristic composition during the condition monitoring program. Furthermore, for each habitat (except seasonal wetlands), there was greater change in the plant community between the early surveys that reduced through time resulting in very little change in vegetation between the more recent surveys. The large changes in vegetation between the early surveys were due to the colonisation of terrestrial taxa between 2008 and 2010 and subsequent extirpation and colonisation of submergent, emergent and amphibious taxa after spring 2010. The reduced rate of change between the recent surveys suggests that a stable plant community may be developing. However, sustained small changes over time may result in a significant shift in the pant community in the future. In the seasonal wetlands there were strong seasonal patterns in the plant community after spring 2010 due to seasonal inundation patterns. Submergent species are abundant in spring, when seasonal wetlands are inundated but they are absent in autumn, replaced by amphibious and emergent taxa.

Target achievement varied between habitats through time; generally very few targets were achieved in all habitats when water levels were low but shortly after water levels were reinstated there was an increase in the number of targets achieved. After spring 2010, the patterns of target achievement were variable. In lakes Alexandrina and Albert, the number of targets achieved remained stable until the last two years when the abundance of several desirable taxa increased such that additional targets were then achieved. In Goolwa Channel, the number of targets achieved peaked in spring 2011 after which the number of targets achieved decreased due to the increase in abundance of *Typha domingensis* and *Phragmites australis* and the decrease in submergent species. In permanent wetlands, the number of targets achieved has remained constant since spring 2010 and in temporary wetlands it peaked in autumn 2011 and has been highly variable.

Plots of progress towards achievement for each target over the condition monitoring program has shown most targets were tracking towards being achieved in the future, although there are numerous targets yet to be achieved for the most recent surveys. Therefore, under current conditions it is likely that the number of targets achieved in the future will increase and the TLM Target V3: *maintain or improve aquatic and littoral vegetation in the Lower Lakes*, will be achieved.

1. INTRODUCTION

1.1. Background

The Lower Lakes, Coorong 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 Lower Lakes, Coorong and Murray Mouth icon site (herein referred to as the "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 eight years of the understorey component of the condition monitoring program designed to evaluate TLM Target 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; 2014).

Scientifically defensible and statistically robust monitoring programs need to be established to assist in meeting the ecological targets in the, Lower Lakes, Coorong and Murray Mouth Environmental Water Management Plan (2014) 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 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; 2014).

The Condition Monitoring Plan for the LLCMM 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: the first component involves the monitoring of aquatic and littoral understorey vegetation in spring (high lake levels) and autumn (low lake levels) to determine the current condition, seasonal changes and medium- to long-term changes in floristic composition, and the second component monitors the mid- to long-term population dynamics of *Melaleuca halmaturorum*. The *Melaleuca halmaturorum* component of the monitoring program is undertaken every five years, with the first survey conducted in 2008/09 and stand demographics monitored 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 salsugineum* 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 in Point Sturt 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, in Lake Alexandrina near Raukkun and in Loveday Bay

Wetland. *Lamprothamnium macropogon* was also present 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. This is because 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 impacts of 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* and charophytes).

In August 2010, flows into South Australia increased, and as a result water levels in Lake Alexandrina were reinstated to historical levels (~+0.75 m AHD) and significant flow through the Murray Barrages (five flow control structures located at Goolwa, Tauwitchere, Ewe Island, Boundary Creek and Mundoo to prevent saltwater intrusion in the Lower Lakes; Figure 1) was possible 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 the 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.* 1999b; 1999a; 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; Kingsford *et al.* 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. Aquatic and littoral vegetation target revision

A review undertaken by Robinson (2015) suggested that the initial aquatic and littoral vegetation target for the Lower Lakes (TLM V3): *maintain or improve aquatic and littoral vegetation in the Lower Lakes* (Maunsell Australia Pty Ltd 2009) could be improved by developing a series of quantitative targets for the site. In response to this, targets were developed for the aquatic and littoral vegetation of the Lower Lakes. The targets were based largely on expert opinion; however, pre drought information was available for wetlands through the 2004 (Holt *et al.* 2005) and 2005 (Nicol *et al.* 2006) River Murray wetlands baseline surveys, conservation reserves around the Murray Mouth (Brandle *et al.* 2002), habitat mapping for the entire system (Seaman 2003) and Hindmarsh Island (Renfrey *et al.* 1989). Generally, these studies showed that there was a diverse submergent, emergent and amphibious plant community in the Lower Lakes wetlands, along low energy shorelines in lakes Alexandrina and Albert and in aquatic habitats, on and around Hindmarsh Island, prior to 2007. Whilst these studies represent the only documented baseline prior to 2007 for the Lower Lakes, they were snapshots that did not provide an indication of temporal variability.

The vegetation condition monitoring review divided the Lower Lakes into different habitats based on hydrology and geomorphology. Five habitats were identified: Lake Alexandrina, Lake Albert, Goolwa Channel, permanent wetlands and seasonal (temporary) wetlands. Within lakes Alexandrina and Albert and Goolwa Channel, three zones were identified based on elevation: the littoral zone (+0.8 to +0.6 m AHD), the aquatic zone (+0.4 to 0 m AHD) and the deep water zone (deeper than 0 m AHD). Permanent wetlands are typically shallow and have no deep water zone; hence they were divided into littoral and aquatic zones. Seasonal wetlands were divided into two zones: the wetland edge and wetland bed. In addition, there is a seasonal component for temporary wetlands with targets for spring (high water level) and autumn (low water level).

Due to the large number of plant species present in the Lower Lakes, native species were classified into functional groups based on water regime using the classification in Gehrig and Nicol (2010; Appendix 1).

Exotic species and potentially invasive native species (e.g. *Typha domingensis and Phragmites australis*) were also taken into consideration. The dominant exotic species in the Lower Lakes are *Cenchrus clandestinus* (formerly named *Pennisetum clandestinum*) and *Paspalum distichum* (Frahn *et al.* 2014). Both are low profile rhizomatous and stoloniferous, warm season growing grasses (Jessop *et al.* 2006) that grow well in the littoral zone throughout the Lower Lakes, except in areas where there is high soil salinity (Frahn *et al.* 2014). Native emergent and amphibious species are often absent when these species are abundant (Frahn *et al.* 2014). *Typha domingensis* and *Phragmites australis* are tall rhizomatous emergent species that are common throughout the Lower Lakes (Frahn *et al.* 2014) and are adapted to stable water levels (Blanch *et al.* 1999b; 2000). They are an important component of the vegetation in the Lower Lakes; however, they often form monospecific stands and it is undesirable for these species to occupy large areas of the littoral and aquatic zones.

Targets for aquatic and littoral understory vegetation were based on a minimum proportion of quadrats in each habitat and zone having a minimum cover score of desirable species and a maximum number of quadrats having a maximum cover score of undesirable species in any given survey. Species were classified into water regime functional groups to assess targets except *Paspalum distichum, Cenchrus clandestinus, Phragmites australis* and *Typha domingensis*.

Vegetation targets for Lake Alexandrina are presented in Table 1. General objectives of the targets were to improve the abundance of diverse reed beds (shorelines with a diverse assemblage of emergent, submergent and amphibious species) and limit the amount of shoreline dominated by invasive species and to a lesser extent shorelines dominated by *Typha* *domingensis* and *Phragmites aus*tralis. The deep water zone in Lake Alexandrina is generally unsuitable for submergent or emergent species; hence, there were no vegetation targets for this zone but it was recognised that this zone needs to be inundated to maintain the hydrological connection between zones and prevent acid sulfate soil development (Fitzpatrick *et al.* 2009a; 2009b; 2010).

Table 1: Revised vegetation targets for Lake Alexandrina.

Zone	Target
Littoral +0.8 to +0.6 m AHD	<40% of quadrats in any given survey containing >75% combined cover (Braun-Blanquet score 5) of *Typha* and *Phragmites*
	<20% of quadrats in any given survey containing >50% combined cover (Braun-Blanquet score 4 or greater) of *Cenchrus* and *Paspalum*
	Minimum of 50% of quadrats in any given survey contain native amphibious species with a combined cover of >5% (BB score 2 or greater)
	Minimum of 50% of quadrats in any given survey contain native emergent species (other than *Typha* and *Phragmites*) with a combined cover of >5% (Braun-Blanquet score 2 or greater)
Aquatic +0.4 to 0 m AHD	<40% of quadrats in any given survey containing >50% combined cover (Braun-Blanquet score 4 or greater) of *Typha* and *Phragmites*
	Minimum of 20% of quadrats in any given survey contain native emergent species (other than *Typha* and *Phragmites*) with a combined cover of >5% (Braun-Blanquet score 2 or greater)
	Minimum of 35% of quadrats in any given survey contain native submergent species with a combined cover of >5% (Braun-Blanquet score 2 or greater)
Deep Water <0 m AHD	Permanent inundation

Vegetation targets for Lake Albert are presented in Table 2. The targets for Lake Albert were similar to those for Lake Alexandrina except that there was an expectation of a lower proportion of diverse reed beds and lower proportions of submergent, amphibious and emergent species (except *Typha domingensis* and *Phragmites australis*).

Table 2: Revised vegetation targets for Lake Albert.

Zone	Target
Littoral +0.8 to +0.6 m AHD	<40% of quadrats in any given survey containing >75% combined cover (Braun-Blanquet score 5 or greater) of *Typha* and *Phragmites*
	<20% of quadrats in any given survey containing >50% combined cover (Braun-Blanquet score 4 or greater) of *Cenchrus* and *Paspalum*
	Minimum of 35% of quadrats in any given survey contain native amphibious species with a combined cover of >5% (Braun-Blanquet score 2 or greater)
	Minimum of 35% of quadrats in any given survey contain native emergent species (other than *Typha* and *Phragmites*) with a combined cover of >5% (Braun-Blanquet score 2 or greater)
Aquatic +0.4 to 0 m AHD	<40% of quadrats in any given survey containing >50% combined cover (Braun-Blanquet score 4 or greater) of *Typha* and *Phragmites*
	Minimum of 20% of quadrats in any given survey contain emergent species (other than *Typha* and *Phragmites*) with a combined cover of >5% (Braun-Blanquet score 2 or greater)
	Minimum of 20% of quadrats in any given survey contain submergent species with a combined cover of >5% (Braun-Blanquet score 2 or greater)
Deep Water <0 m AHD	Permanent inundation

Vegetation targets for Goolwa Channel are presented in Table 3. Targets for Goolwa Channel were also similar to Lake Alexandrina but there was an expectation that submergent species are present in the deep water zone and a higher proportion of quadrats are dominated by *Typha domingensis* and *Phragmites australis*.

Table 3: Revised vegetation targets for Goolwa Channel.

Zone	Target
Littoral +0.8 to +0.6 m AHD	<50% of quadrats in any given survey containing >75% combined cover (Braun-Blanquet score 5 or greater) of *Typha* and *Phragmites*
	<20% of quadrats in any given survey containing >50% combined cover (Braun-Blanquet score 4 or greater) of *Cenchrus* and *Paspalum*
	Minimum of 50% of quadrats in any given survey contain native amphibious species with a combined cover of >5% (Braun-Blanquet score 2 or greater)
	Minimum of 50% of quadrats in any given survey contain native emergent species (other than *Typha* and *Phragmites*) with a combined cover of >5% (Braun-Blanquet score 2 or greater)
Aquatic +0.4 to 0 m AHD	<50% of quadrats in any given survey containing >50% combined cover (Braun-Blanquet score 4 or greater) of *Typha* and *Phragmites*
	Minimum of 20% of quadrats in any given survey contain native emergent species (other than *Typha* and *Phragmites*) with a combined cover of >5% (Braun-Blanquet score 2 or greater)
	Minimum of 40% of quadrats in any given survey contain native submergent species with a combined cover of >5% (Braun-Blanquet score 2 or greater)
Deep Water <0 m AHD	Minimum of 20% of quadrats in any given survey contain native submergent species with a combined cover of >5% (Braun-Blanquet score 2 or greater)

Vegetation targets for permanent wetlands are presented in Table 4. Prior to 2007, many wetlands contained a diverse assemblage of submergent, emergent and amphibious species (Holt *et al.* 2005; Nicol *et al.* 2006), which was reflected in the targets. The proportion of quadrats dominated by *Typha domingensis* and *Phragmites australis* is lower compared to Goolwa Channel, Lake Alexandrina and Lake Albert and proportion of quadrats with submergents is higher (Table 5). However, there is a maximum target of 50% cover for submergent species in the aquatic zone, which was related to small bodied fish habitat (S. Wedderburn pers. com.). The deep water zone is not included because wetlands are generally shallow and this zone is not surveyed in most wetlands.

Table 4: Revised vegetation targets for permanent wetlands (Dunns Lagoon, Hunters Creek, Angas River Mouth and Bremer River Mouth).

Zone	Target
Littoral >+0.6 m AHD	<35% of quadrats in any given survey containing >75% combined cover (Braun-Blanquet score 5 or greater) of *Typha* and *Phragmites*
	<20% of quadrats in any given survey containing >50% combined cover (Braun-Blanquet score 4 or greater) of *Cenchrus* and *Paspalum*
	Minimum of 50% of quadrats in any given survey contain native amphibious species with a combined cover of >5% (Braun-Blanquet score 2 or greater)
	Minimum of 50% of quadrats in any given survey contain native emergent species (other than *Typha* and *Phragmites*) with a combined cover of >5% (Braun-Blanquet score 2 or greater)
Aquatic <+0.6 m AHD	<40% of quadrats in any given survey containing >50% combined cover (Braun-Blanquet score 4 or greater) of *Typha* and *Phragmites*
	Minimum of 20% of quadrats in any given survey contain native emergent species (other than *Typha* and *Phragmites*) with a combined cover of >5% (Braun-Blanquet score 2 or greater)
	Minimum of 50% of quadrats in any given survey contain native submergent species with a combined cover of 5 to 50% (Braun-Blanquet score 2 to 4)

Vegetation targets for seasonal wetlands are presented in Table 6. Prior to 2007, seasonal wetlands in spring generally contained high numbers of submergent species (submergent r-selected species such as *Ruppia tuberosa, Ruppia polycarpa, Lepilaena cylindrocarpa* and charophytes) (Holt *et al.* 2005; Nicol *et al.* 2006). This is reflected in the spring target of 50% of quadrats containing greater than 25% cover of submergent species (Table 6a) because the regular wetting and drying cycle present in these wetlands favours this functional group (Casanova 2011). Furthermore, the wetting and drying cycle will favour amphibious species that require exposed sediment to germinate but persist as adults whilst standing water is present (Nicol *et al.* 2003; Casanova 2011). *Typha domingensis* and *Phragmites australis* are generally not highly abundant in seasonal wetlands (Frahn *et al.* 2014); hence, there were no targets relating to these species.

Table 5: Revised vegetation targets for seasonal wetlands in a. spring and b. autumn (Goolwa Channel Drive, Milang Wetland, Narrung Wetland, Loveday Bay Wetland, Point Sturt Wetland and Teringie).

a.

Zone	Target
Edge	<20% of quadrats in any given survey containing >50% combined cover (Braun-Blanquet score 4 or greater) of *Cenchrus* and *Paspalum*
	Minimum of 50% of quadrats in any given survey contain native amphibious species with a combined cover of >5% (Braun-Blanquet score 2 or greater)
	Minimum of 50% of quadrats in any given survey contain native emergent species with a combined cover of >5% (Braun-Blanquet score 2 or greater)
Bed	Minimum of 20% of quadrats in any given survey contain native emergent species with a combined cover of >5% (Braun-Blanquet score 2 or greater)
	Minimum of 50% of quadrats in any given survey contain native submergent species with a combined cover of >25% (Braun-Blanquet score 3 or greater)
	Minimum of 25% of quadrats in any given survey contain native amphibious species with a combined cover of >5% (Braun-Blanquet score 2 or greater)

b.

Zone	Target
Edge	<20% of quadrats in any given survey containing >50% combined cover (Braun-Blanquet score 4 or greater) of *Cenchrus* and *Paspalum*
	Minimum of 50% of quadrats in any given survey contain native amphibious species with a combined cover of >5% (Braun-Blanquet score 2 or greater)
	Minimum of 50% of quadrats in any given survey contain native emergent species with a combined cover of >5% (Braun-Blanquet score 2 or greater)
Bed	Minimum of 20% of quadrats in any given survey contain native emergent species with a combined cover of >5% (Braun-Blanquet score 2 or greater)
	Minimum of 25% of quadrats in any given survey contain native amphibious species with a combined cover of >5% (Braun-Blanquet score 2 or greater)

In addition to quantitative aquatic and littoral vegetation targets, habitat and whole of lakes condition scores were developed. The habitat condition score represents the proportion of targets achieved in a particular habitat and the whole of lakes condition score represents the proportion of targets achieved in the different habitats.

1.3. Objectives

The monitoring undertaken in 2015/16 builds on data collected between 2008 and 2015 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 event, 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 are to:

- continue the statistically robust, quantitative understorey aquatic and littoral vegetation monitoring program in the Lower Lakes to assess TLM Target V3;
- report on the revised vegetation targets for each habitat and determine habitat and whole of site condition scores;
- monitor the recovery of the aquatic plant community after hydrological restoration following extended drought, drawdown, fragmentation and desiccation of aquatic habitats.

2. METHODS

2.1. Study site, hydrology and salinity

Vegetation surveys were undertaken in the Goolwa Channel, Lake Alexandrina, Lake Albert and 11 associated wetlands (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 this 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, resulting in impounded water from the Finniss River and Currency and Tookayerta Creeks (Figure 1). In addition, water was pumped into the 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.* (2014).

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 the 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).

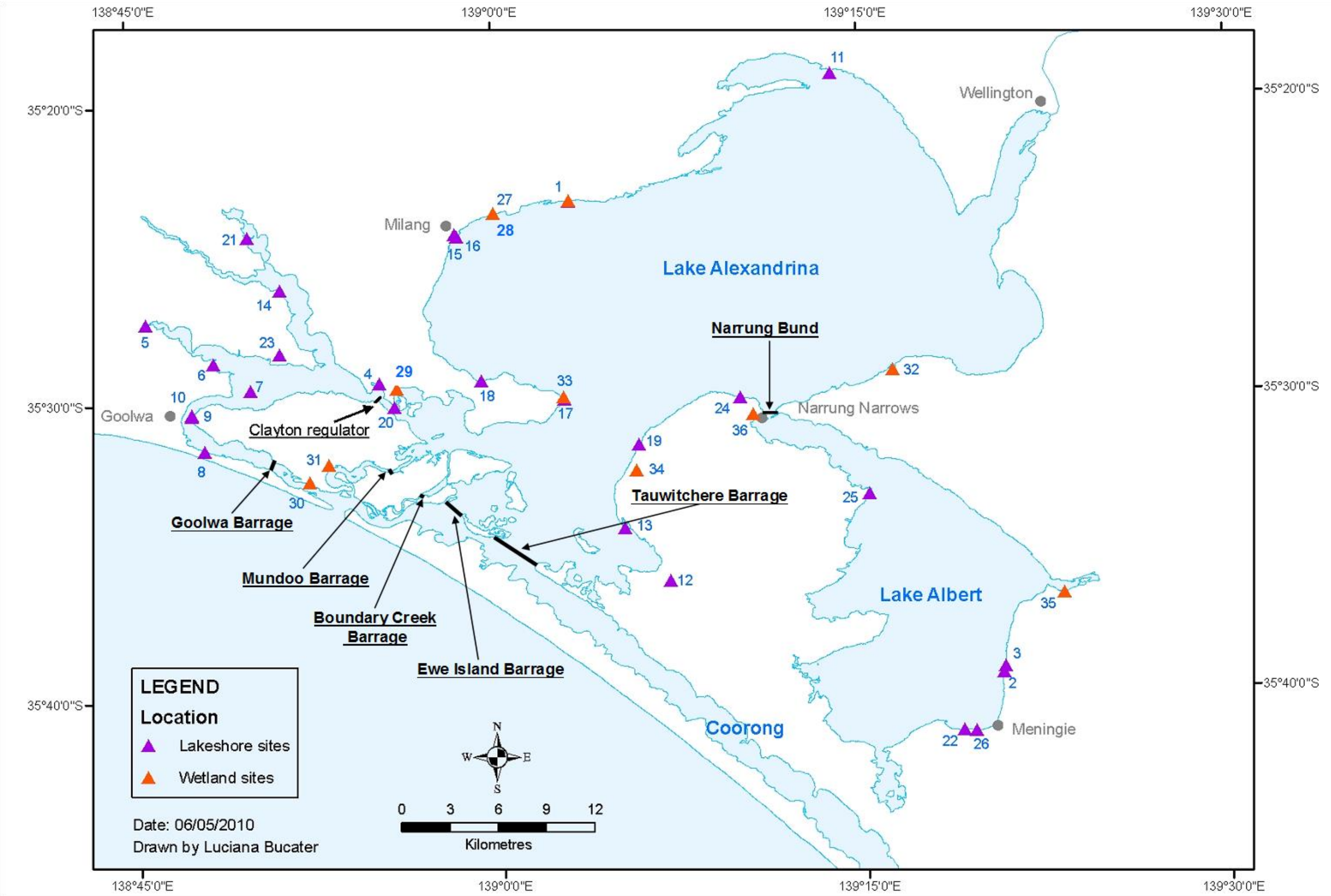

Figure 1: Map of Lakes Alexandrina and Albert and Goolwa Channel showing the location of lakeshore and wetland vegetation monitoring sites (site numbers correspond to Table 6) and major flow control structures present in winter 2010 (where sites are in close proximity they may not be visible on map).

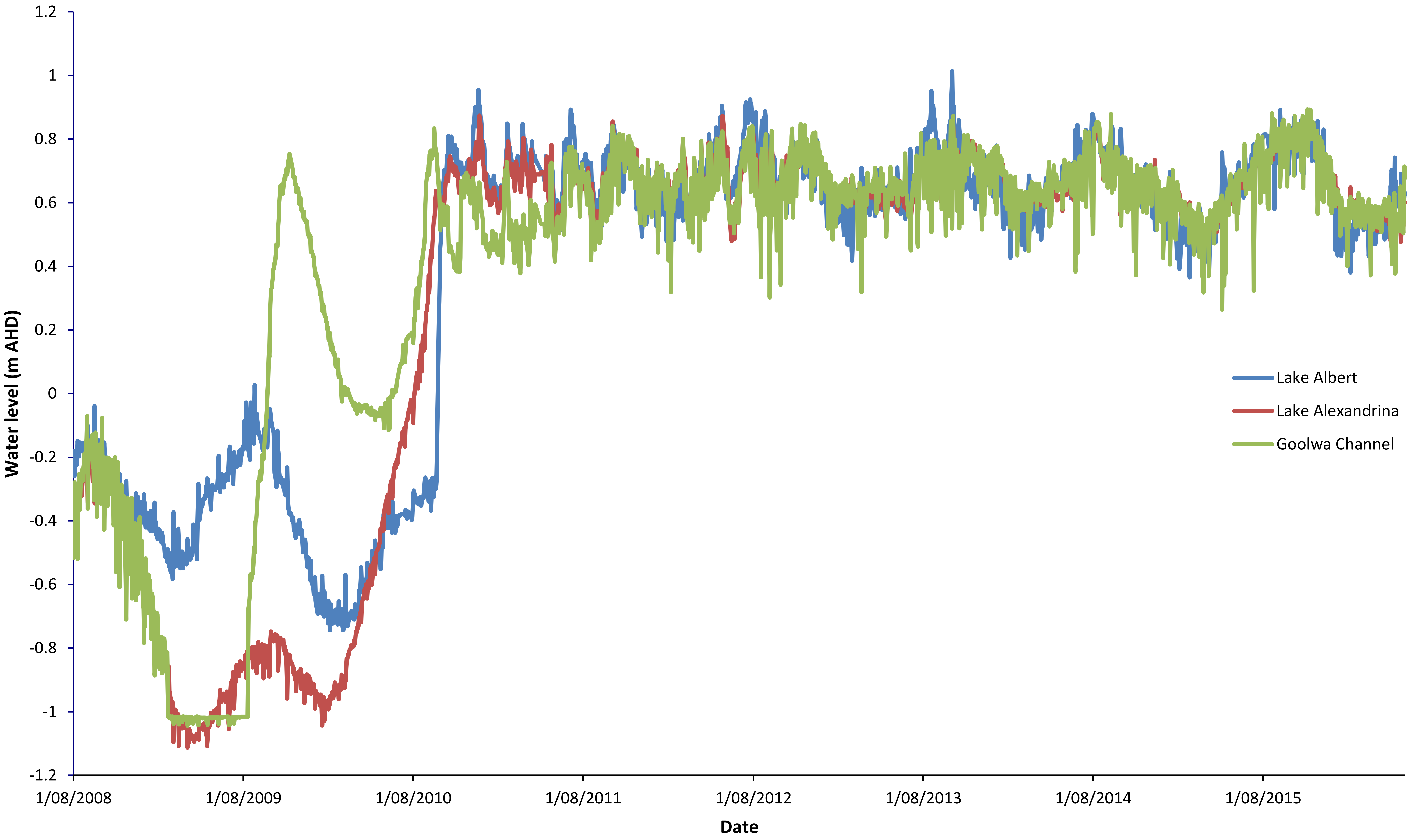

Figure 2: Daily mean water levels in Goolwa Channel (Signal Point), Lake Alexandrina (Milang) and Lake Albert (Meningie) from August 2008 to May 2016 (Department of Environment, Water and Natural Resources 2016b).

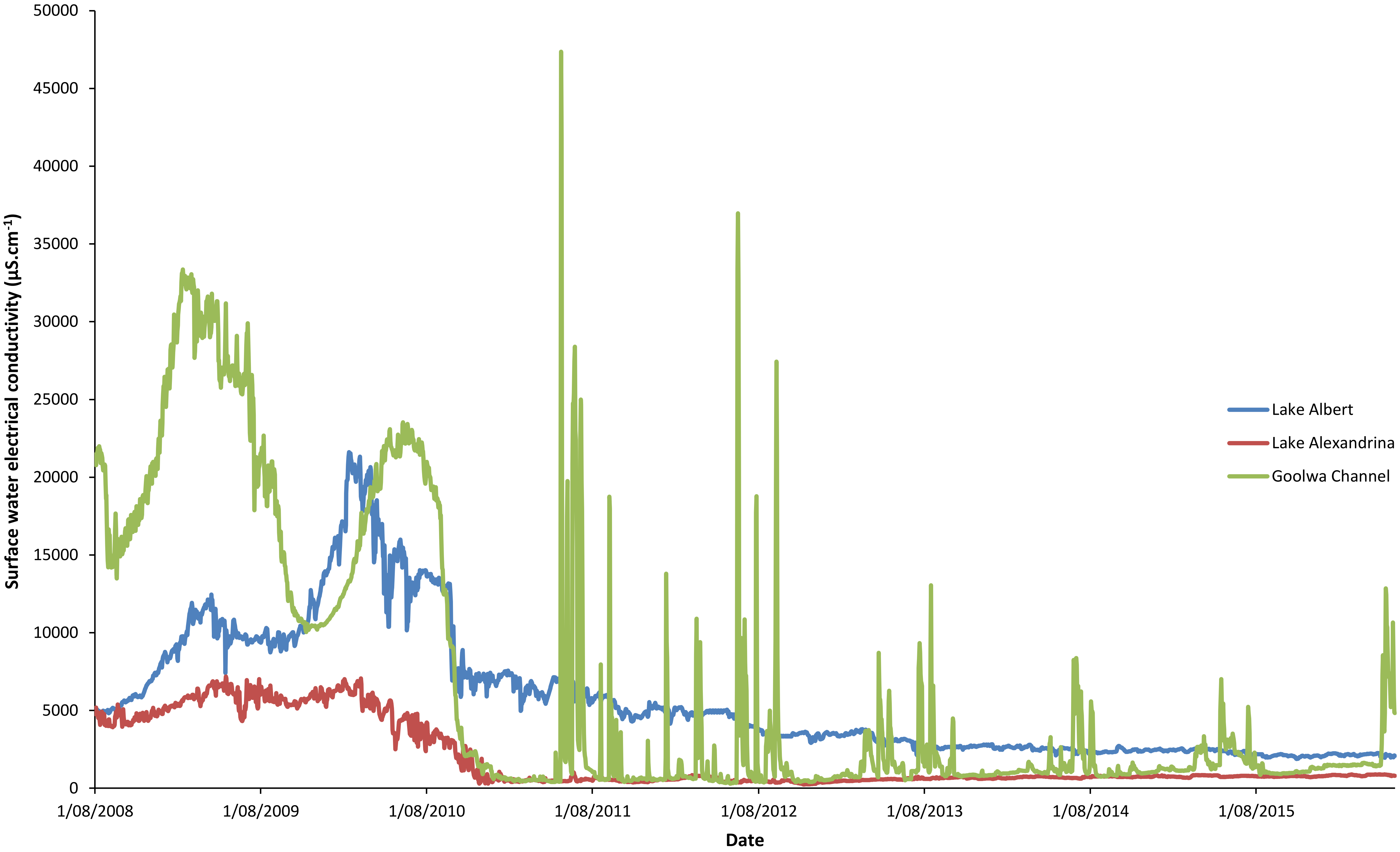

Figure 3: Daily mean surface water electrical conductivity (EC) in Goolwa Channel (Signal Point), Lake Alexandrina (Milang) and Lake Albert (Meningie) from August 2008 to May 2016 (Department of Environment, Water and Natural Resources 2016a).

2.2. Understorey vegetation survey protocol

Monitoring of understorey vegetation was conducted at 11 wetland and 25 lakeshore sites each spring and autumn from October 2008 to March 2014, March 2015, October 2015 and March 2016 (for sites established in 2008 or earlier) and during spring and autumn from October 2009 to March 2014, March 2015, October 2015 and March 2016 for sites established in 2009 (Table 6). Sites were grouped on the basis of habitat (lakeshore, permanent wetland or seasonal wetland) and location (Lake Alexandrina, Lake Albert or Goolwa Channel). GPS coordinates for each site are listed in (Appendix 2).

Table 6: 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 (SAMDBNRM denotes, South Australian Murray-Darling Basin Natural Resources Management Board).

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	seasonal 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	seasonal 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	permanent wetland	1	2008
28	Bremer Mouth	Lake Alexandrina	permanent wetland	1	2008
29	Dunns Lagoon	Lake Alexandrina	permanent wetland	4	2008
30	Goolwa Channel Drive	Lake Alexandrina	seasonal wetland	3	2008
31	Hunters Creek	Lake Alexandrina	wetland	5	2008
32	Poltalloch	Lake Alexandrina	seasonal wetland	2	2008
33	Pt Sturt	Lake Alexandrina	seasonal wetland	2	2008
34	Teringie (existing SAMDBNRM Board community monitoring site)	Lake Alexandrina	seasonal wetland	4	pre-2008
35	Waltowa (existing SAMDBNRM Board community monitoring site)	Lake Albert	seasonal wetland	2	pre-2008
36	Narrung (existing SAMDBNRM Board community monitoring site)	Lake Alexandrina	seasonal wetland	4	pre-2008

Wetlands

At each survey site (Figure 1, Table 6), 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, Point 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 at 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 7).

Table 7: 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).

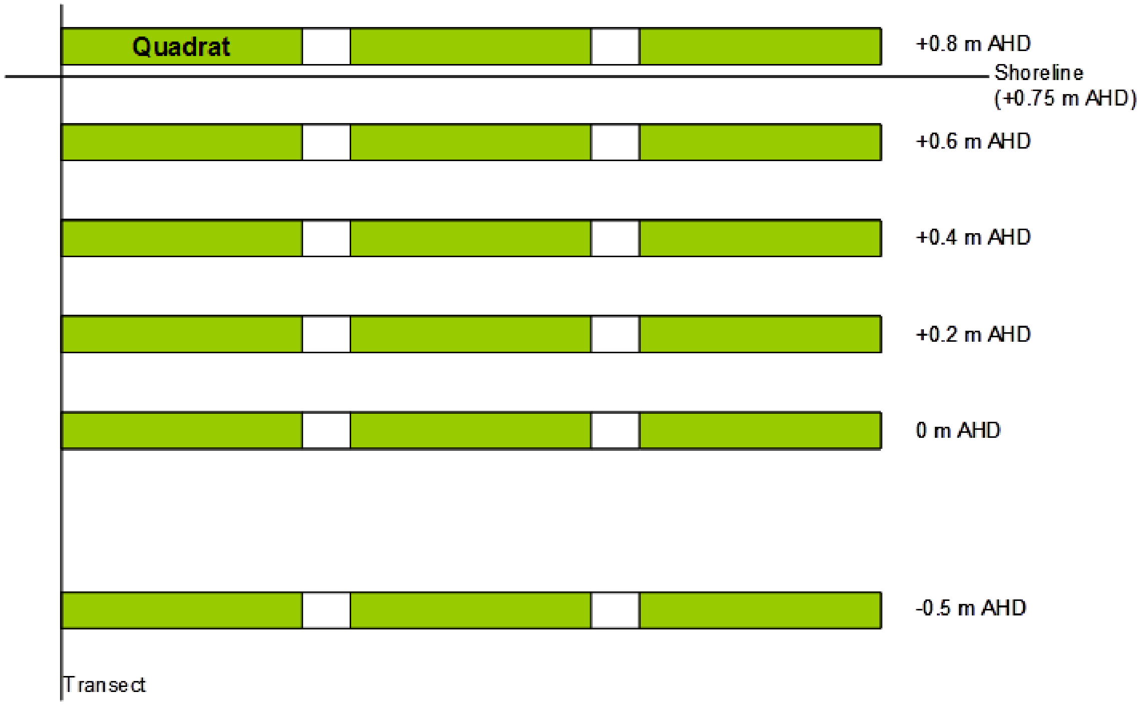

Figure 4: Vegetation surveying protocol for lakeshore sites: plan view showing placement of quadrats relative to the shoreline.

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 (2016).

2.3. Data Analysis

Changes in floristic composition through time, at all elevations, in each of the five habitats (Lake Alexandrina, Lake Albert, Goolwa Channel, permanent wetlands and temporary wetlands) were assessed using MDS ordination using the package PRIMER version 6.1.12 (Clarke and Gorley 2006). Bray-Curtis (1957) similarities were used to construct the similarity matrices for the MDS ordinations.

3. RESULTS

3.1. Change through time of the Lower Lakes plant community from spring 2008 to autumn 2016

Over the eight years of condition monitoring (spring 2008 to autumn 2016), 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 (Appendices 3 and 4). At wetland sites, 128 taxa were recorded (including 62 exotics) (Appendix 3) and at lakeshore sites 127 taxa were recorded (including 63 exotics) (Appendix 4).

NMS ordination depicting temporal changes in the plant community for each habitat showed a shift in floristic composition over the condition monitoring program (Figure 5 to Figure 9). Furthermore, for each habitat except the seasonal wetlands, there was greater change in the plant community between the early surveys that reduced through time with very little change in vegetation between the more recent surveys (Figure 5 to Figure 9).

In spring 2008, water levels in Lake Alexandrina were at historical lows (Figure 2) and the plant community was dominated by terrestrial species (predominantly agricultural weeds). The plant community remained dominated by terrestrial taxa until spring 2010, when water levels were reinstated (Figure 2) and the terrestrial species were extirpated resulting in a large change in floristic composition (Figure 5). From spring 2010 to autumn 2013, there was an increase in the abundance of emergent, amphibious and submergent species (Frahn *et al.* 2014). However, there were also seasonal patterns over this period (Figure 5) with emergent and amphibious taxa typically more abundant in autumn (Frahn *et al.* 2014). From autumn 2013 to autumn 2016 the change in the plant community has been small, in comparison to previous years, but there are still seasonal patterns (Figure 5) driven by higher abundances of amphibious and emergent species in autumn (Frahn *et al.* 2014).

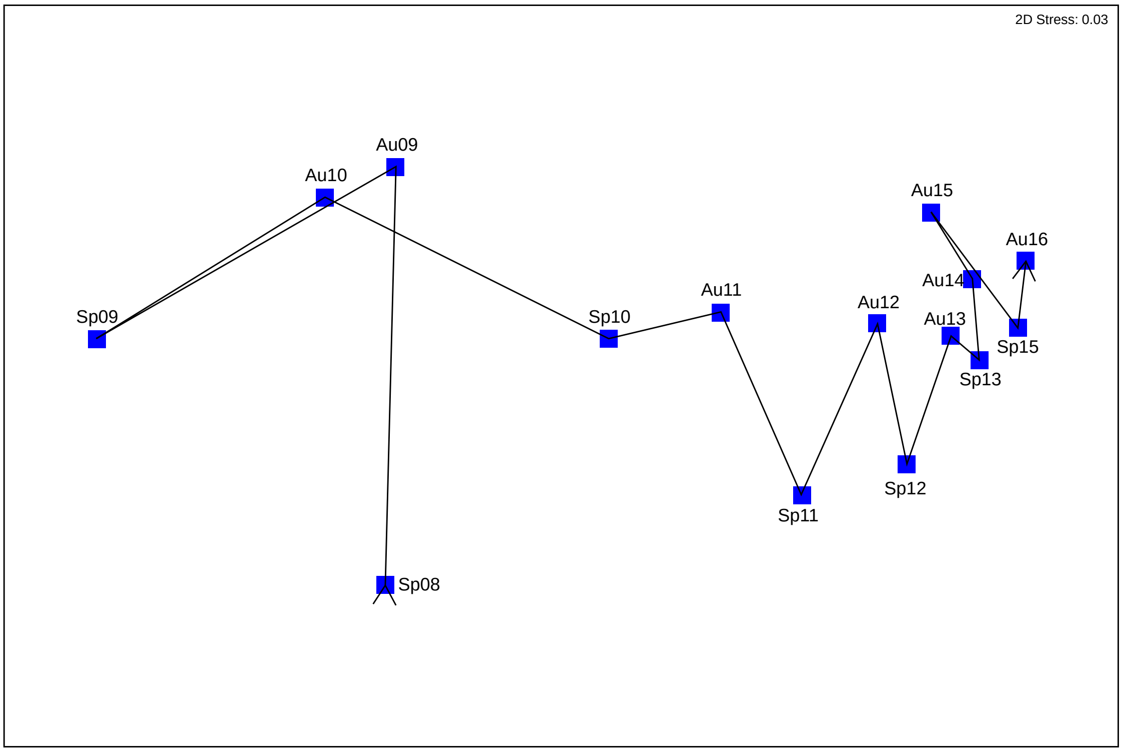

Figure 5: MDS ordination comparing the plant community between spring 2008 and autumn 2016 in Lake Alexandrina (Sp denotes spring; Au denotes autumn).

Similar to Lake Alexandrina (Figure 5), the plant community in Lake Albert was dominated by terrestrial species with large changes in floristic composition (Figure 6) whilst water levels were low during the millennium drought (Figure 2). After water levels were reinstated in spring 2010 (Figure 2) the change in plant community (Figure 6) was driven by an increase in emergent and amphibious species. Since spring 2010, there has been a gradual change in floristic composition (Figure 6) primarily driven by an increase in the abundance of *Typha domingensis*. In contrast to Lake Alexandrina, seasonal changes in floristic composition were not evident (Figure 6).

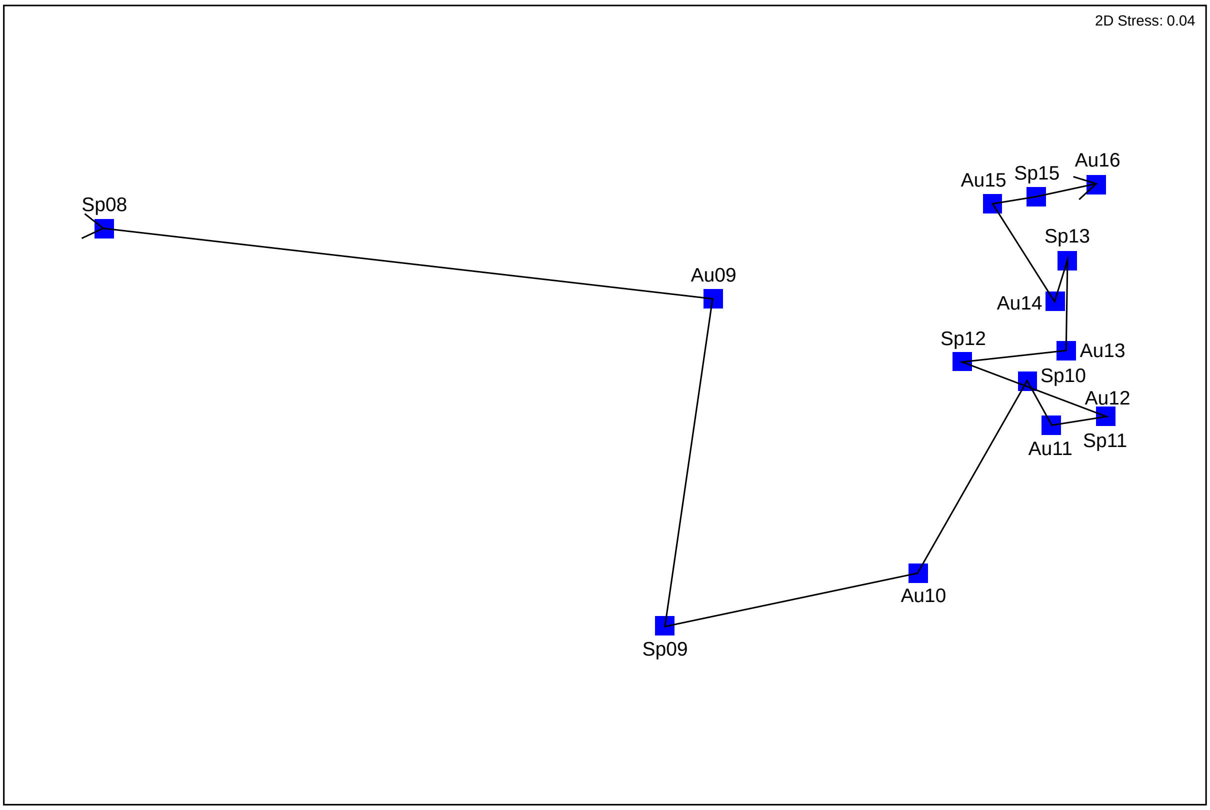

Figure 6: MDS ordination comparing the plant community between spring 2008 and autumn 2016 in Lake Albert (Sp denotes spring; Au denotes autumn).

Similar to lakes Alexandrina (Figure 5) and Albert (Figure 6), the plant community in Goolwa Channel was dominated by terrestrial taxa whilst water levels were low prior to spring 2009 (Figure 2). Water levels rose to around 0.8 m AHD in spring 2009 (Figure 2) due to the completion of the Clayton Regulator and there was a large change in floristic composition (Figure 7). This change was driven by terrestrial species being extirpated with extensive beds of the submergent species *Potamogeton pectinatus* recruiting throughout the Goolwa Channel, the lower Finniss River and Lower Currency Creek (Gehrig and Nicol 2010a). There was a significant change in the plant community between spring 2009 and spring 2010 (Figure 7), which was a result of the Clayton Regulator being breached and a rapid reduction in surface water salinity (Figure 3). The changes in floristic composition were driven by a decrease in the abundance of *Potamogeton pectinatus* and increase in submergent species adapted to lower salinity environments (e.g. *Ceratophyllum demersum, Potamogeton crispus, Myriophyllum salsugineum* and *Vallisneria australis*) (Bailey *et al.* 2002). After spring 2010, water levels and salinities returned to historical levels (Figure 2 and Figure 3) but the plant community continued to change (Figure 7). The change between spring 2010 and spring 2011 (Figure 7) was driven primarily by an increase in the abundance of *Typha domingensis*. There were seasonal changes in vegetation between spring 2011 spring 2013 (Figure 7) driven by higher abundances of *Typha domingensis* and *Phragmites australis* in autumn. After spring 2013, there was very little change in floristic composition and no seasonal patterns (Figure 7).

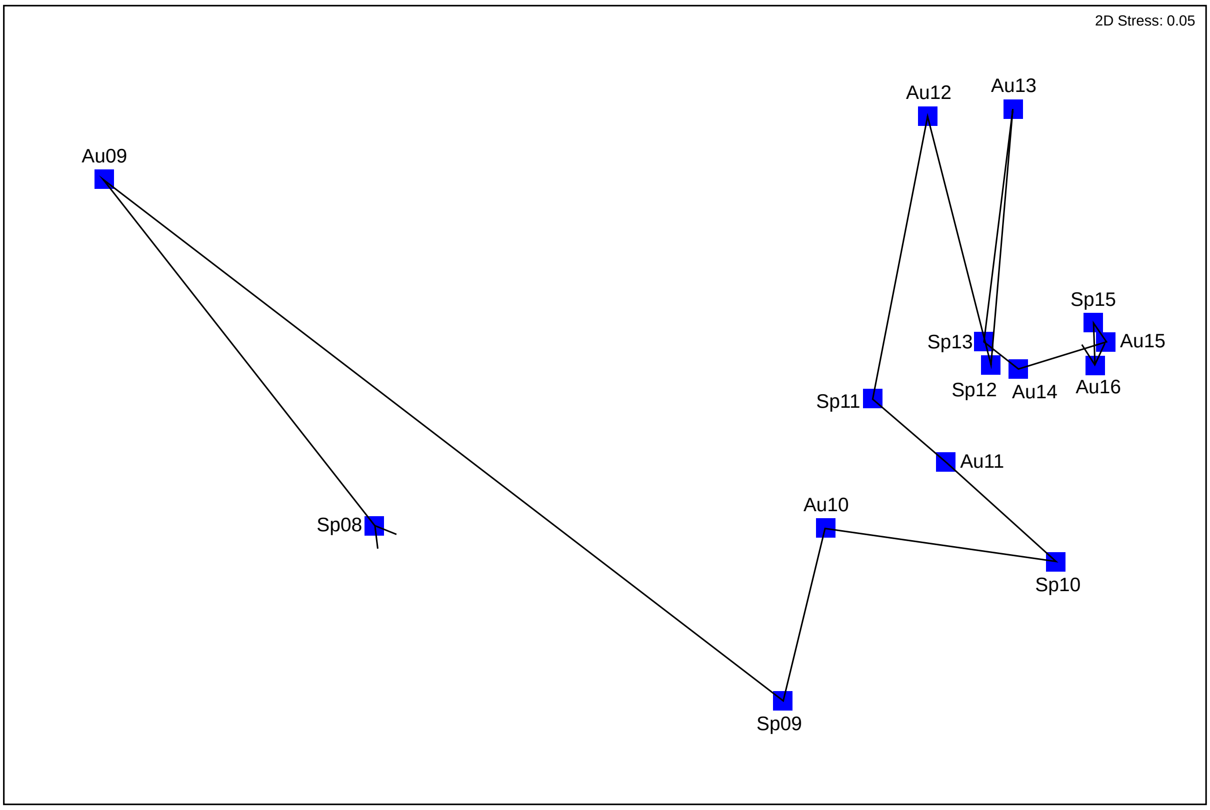

Figure 7: MDS ordination comparing the plant community between spring 2008 and autumn 2016 in Goolwa Channel (Sp denotes spring; Au denotes autumn).

All permanent wetlands surveyed in the condition monitoring program are hydrologically connected to Lake Alexandrina; therefore, water levels (and salinities to a lesser degree) in these habitats reflect conditions in Lake Alexandrina (Figure 2 and Figure 3). Similar to the other habitats in the Lower Lakes, permanent wetlands were dominated by terrestrial taxa whilst water levels were low, most of which were extirpated when water levels were reinstated in spring 2010 (Figure 2). Since spring 2010, there has generally been an increase in the abundance of emergent, submergent and amphibious species in permanent wetlands, which has driven the change in floristic composition (Figure 8). Since autumn 2013, the change in the plant community was much smaller than observed in the earlier surveys of the condition monitoring program (Figure 7).

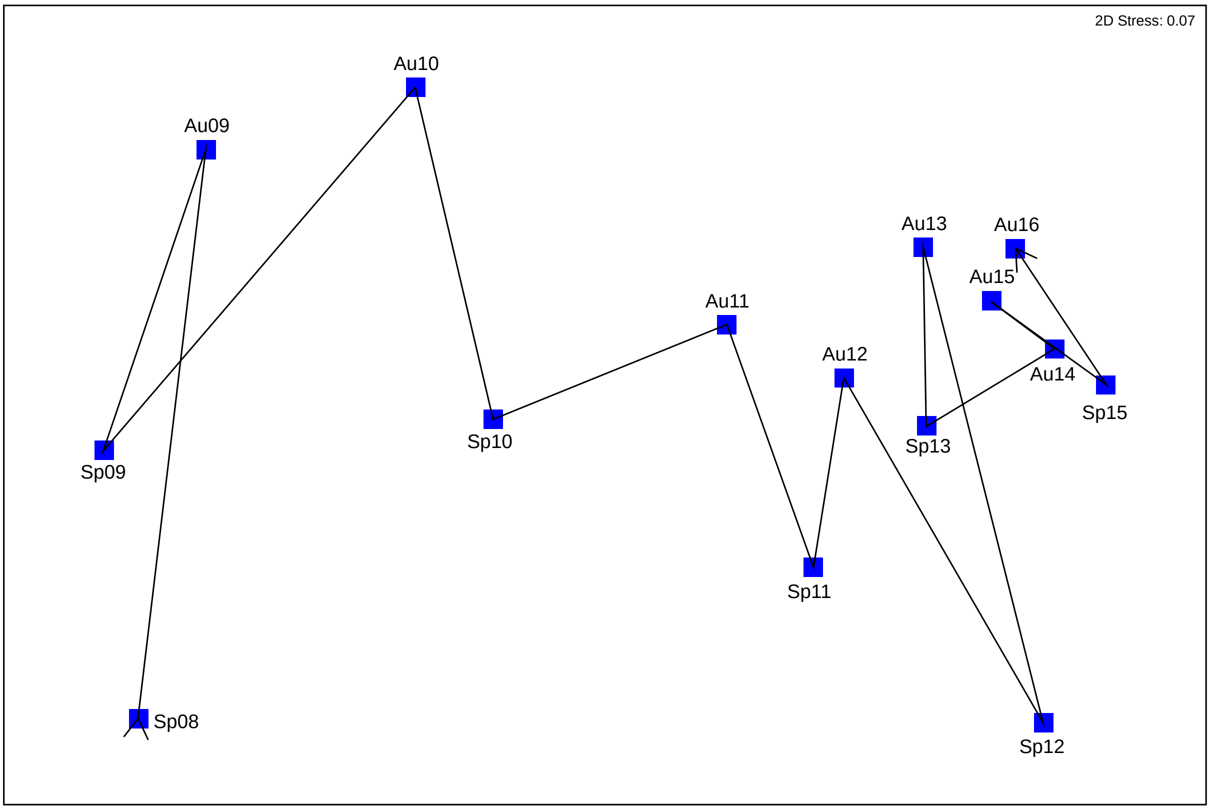

Figure 8: MDS ordination comparing the plant community between spring 2008 and autumn 2016 in permanent wetlands (Sp denotes spring; Au denotes autumn).

Strong seasonal changes in vegetation are evident in the seasonal wetlands that were surveyed (Figure 9). Despite lack of hydrological connectivity to the Lower Lakes between spring 2008 and autumn 2010, all wetlands were partially inundated in spring 2008 and spring 2009 due to local rainfall and runoff hence the seasonal patterns in floristic composition during this period (Figure 7). The submergent species *Ruppia tuberosa* and *Lamprothamnium macropogon* were present in the inundated areas of several of the seasonal wetlands in spring 2008 and spring 2009 and absent in autumn 2009 and 2010 when the wetlands were dominated with terrestrial taxa. After water levels were reinstated in spring 2010 and the hydrological connection with the lakes restored, in contrast to the other habitats, the plant community was more similar to the community present in spring 2009 than in spring 2011 (Figure 9). There was; however, a change between spring 2010 and autumn 2011, after which there was very little change in floristic composition between autumn surveys (Figure 7). The change was driven by an increase in the abundance of *Typha domingensis* and *Bolboschoenus caldwellii* and *Schoenoplectus pungens* between spring 2010 and autumn 2011. The seasonal patterns observed between autumn 2011 and autumn 2016 (Figure 7) were due to the presence of submergent species (*Ruppia tuberosa, Ruppia polycarpa, Myriophyllum verrucosum, Myriophyllum salsugineum, Chara fibrosa* and *Lamprothamnium macropogon*) in spring.

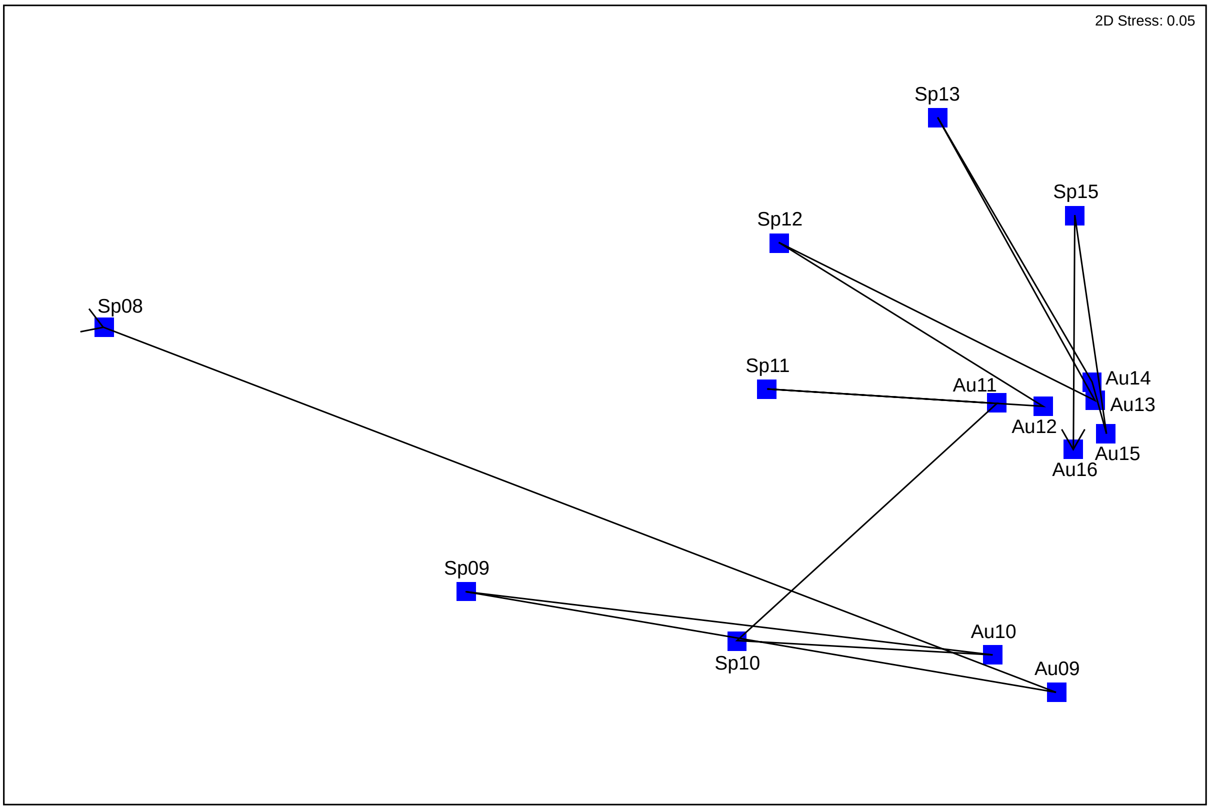

Figure 9: MDS ordination comparing the plant community between spring 2008 and autumn 2016 in seasonal wetlands (Sp denotes spring; Au denotes autumn).

3.2. TLM targets

The following section graphically presents the progress of achievement for each of the targets for each habitat outlined in Tables 1-5 over the duration of the condition monitoring program (spring 2008 to autumn 2016). Target thresholds were defined by the proportion (percentage) of quadrats containing a species or functional group above a certain percentage cover (Tables 1-5). Target thresholds presented in red on the graphs denote targets are that achieved when the percentage of quadrats is lower than the threshold (undesirable taxa) and thresholds presented in blue are met when the percentage of quadrats is higher than the threshold (desirable taxa). In addition, the habitat condition score calculated from the targets achieved from each habitat and the whole of lakes condition score (calculated from the habitat condition scores) are presented for the duration of the condition monitoring program.

Lake Alexandrina targets

Littoral Zone

Figure 10 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone of Lake Alexandrina from spring 2008 to autumn 2016. Whilst there has been an upward trend in the number of quadrats that contain a combined cover of *Typha* and *Phragmites* greater than 75% since water levels were reinstated in spring 2010 (peaking in autumn 2015), the percentage did not exceed 40% and the target was consistently achieved. However, if this upward trend continues, the target may not be met in the future.

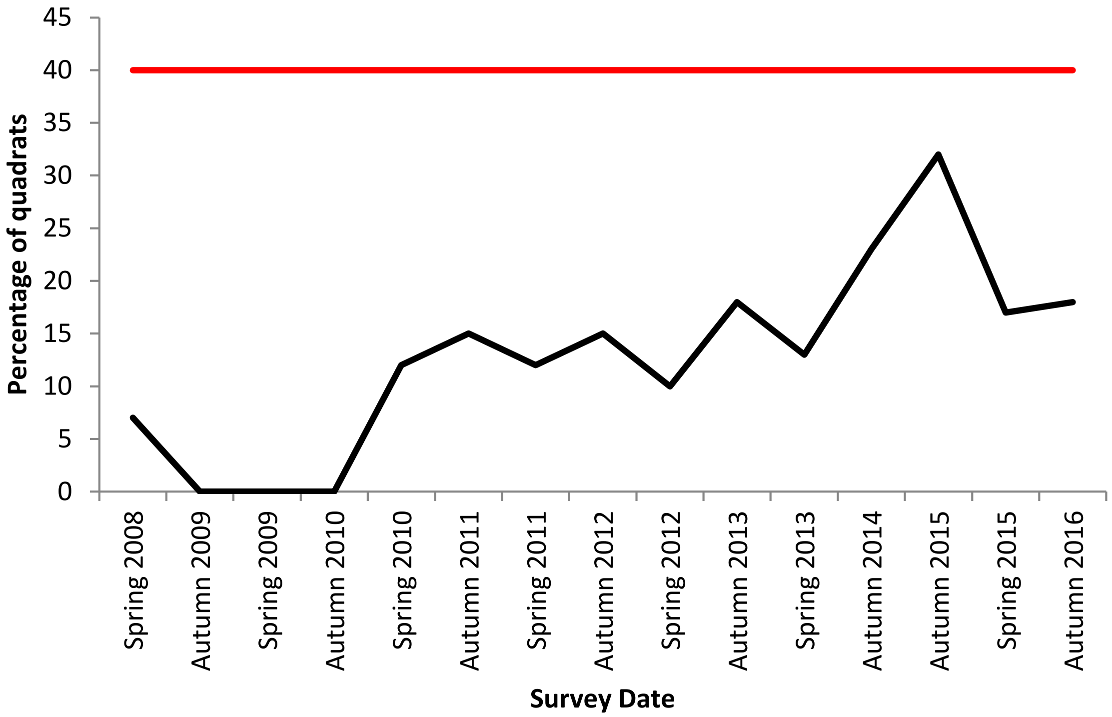

Figure 10: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone of Lake Alexandrina from spring 2008 to autumn 2016.

Figure 11 shows the percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone of Lake Alexandrina from spring 2008 to autumn 2016. Between autumn 2009 and autumn 2010, more than 20% of quadrats contained a combined cover of these species greater than 50%; hence, the target was not met. However, when water levels were reinstated in spring 2010 the number of quadrats with a combined cover comprising greater than 50% of these species fell below 20% and the target was achieved (Figure 11).

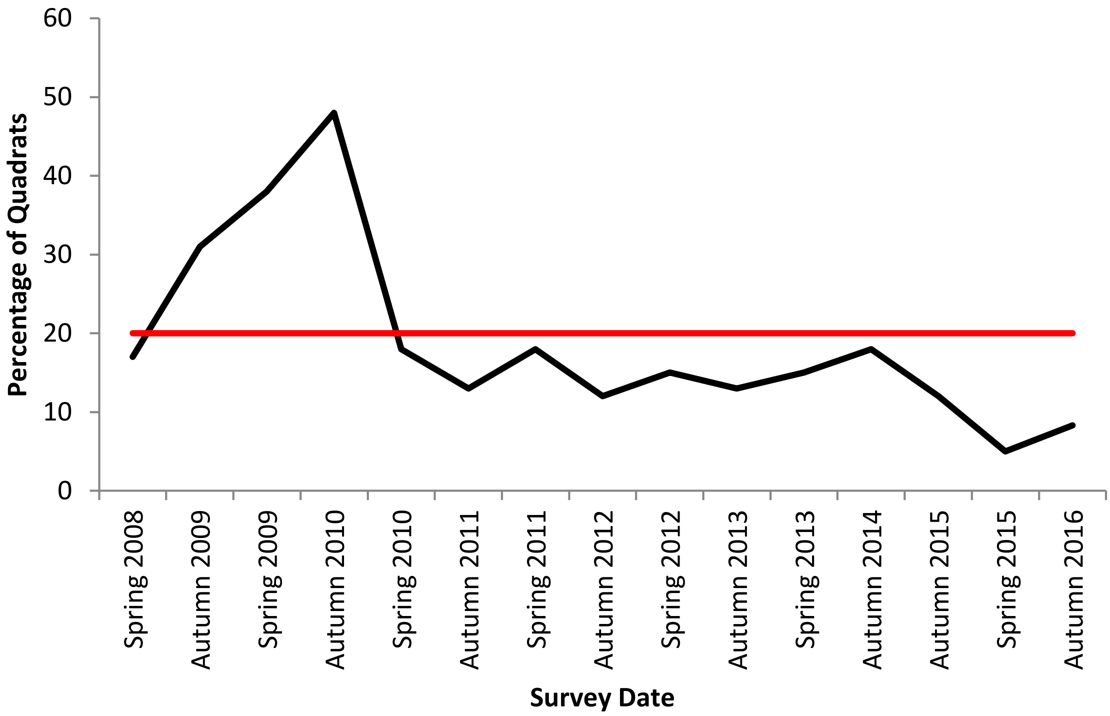

Figure 11: Percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone of Lake Alexandrina from spring 2008 to autumn 2016.

Figure 12 shows the percentage of quadrats containing a cover of native amphibious species greater than 5% in the littoral zone of Lake Alexandrina from spring 2008 to autumn 2016. There has been an upward trend in the number of quadrats contains greater than 5% of native amphibious taxa since water levels were reinstated; however, the number did not exceed 50% of quadrats until autumn 2015 after which it has always been achieved (Figure 12).

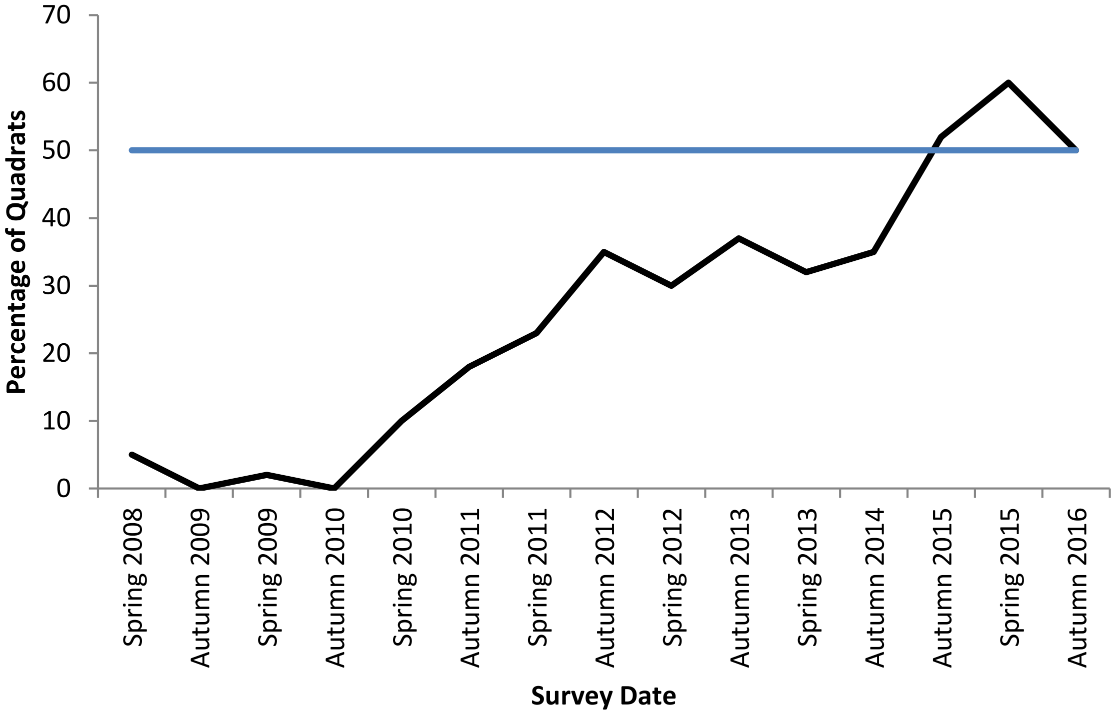

Figure 12: Percentage of quadrats containing a cover native amphibious species greater than 5% in the littoral zone of Lake Alexandrina from spring 2008 to autumn 2016.

Figure 13 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the littoral zone of Lake Alexandrina from spring 2008 to autumn 2016. The percentage of quadrats with a cover of native emergent species, other than *Typha domingensis* and *Phragmites australis,* that is greater than 5% has not exceeded 50% and peaked in spring 2015 (12% of quadrats). Therefore, this target has not been achieved during the condition monitoring program (Figure 13). However, the number of quadrats containing a cover of these species greater than 5% has generally increased since water levels were reinstated (Figure 13).

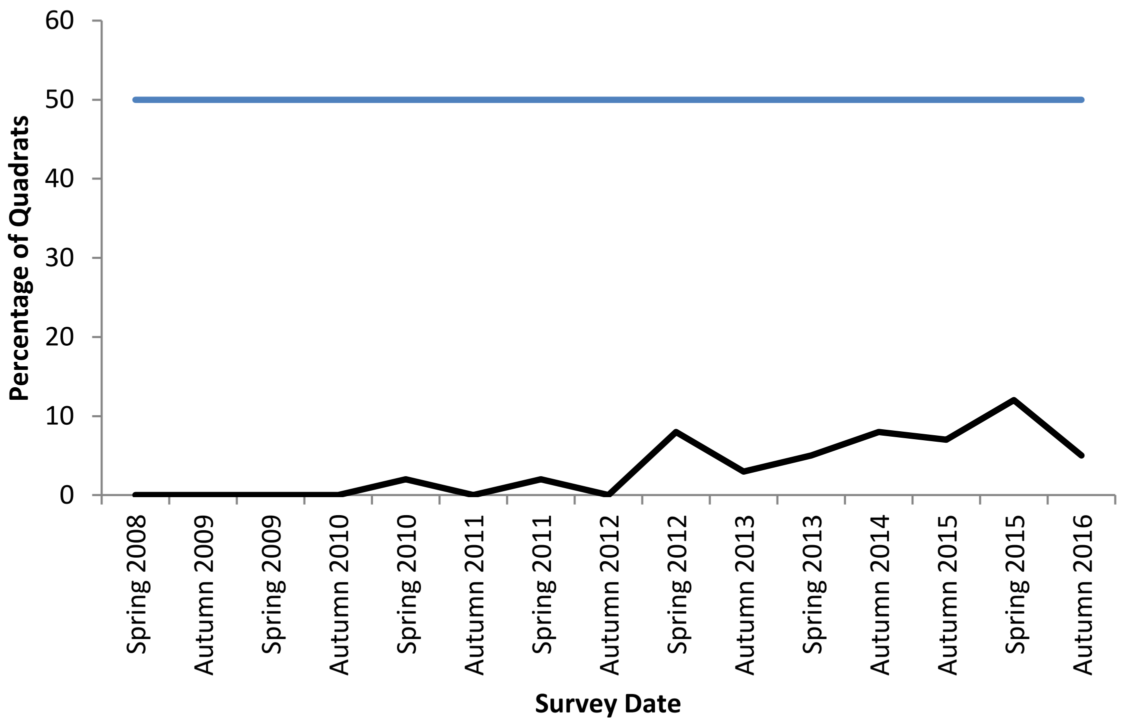

Figure 13: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the littoral zone of Lake Alexandrina from spring 2008 to autumn 2016.

Aquatic Zone

Figure 14 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone of Lake Alexandrina from spring 2008 to autumn 2016. There has generally been an upward trend in the number of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50%; however, it has not exceeded 40% and the target has been achieved since spring 2008 (Figure 14).

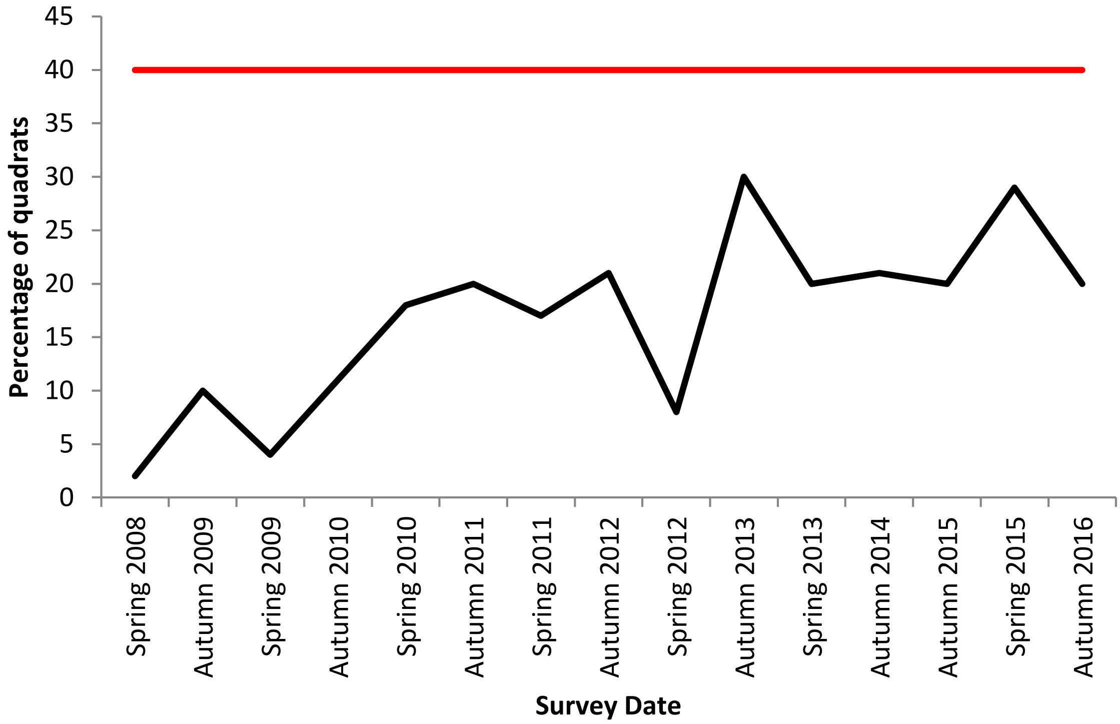

Figure 14: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone of Lake Alexandrina from spring 2008 to autumn 2016.

Figure 15 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the aquatic zone of Lake Alexandrina from spring 2008 to autumn 2016. There was a general upward trend in the number of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% since water levels were reinstated, peaking in spring 2015 (18%) (Figure 15). However, the target of 20% of quadrats has not yet been achieved.

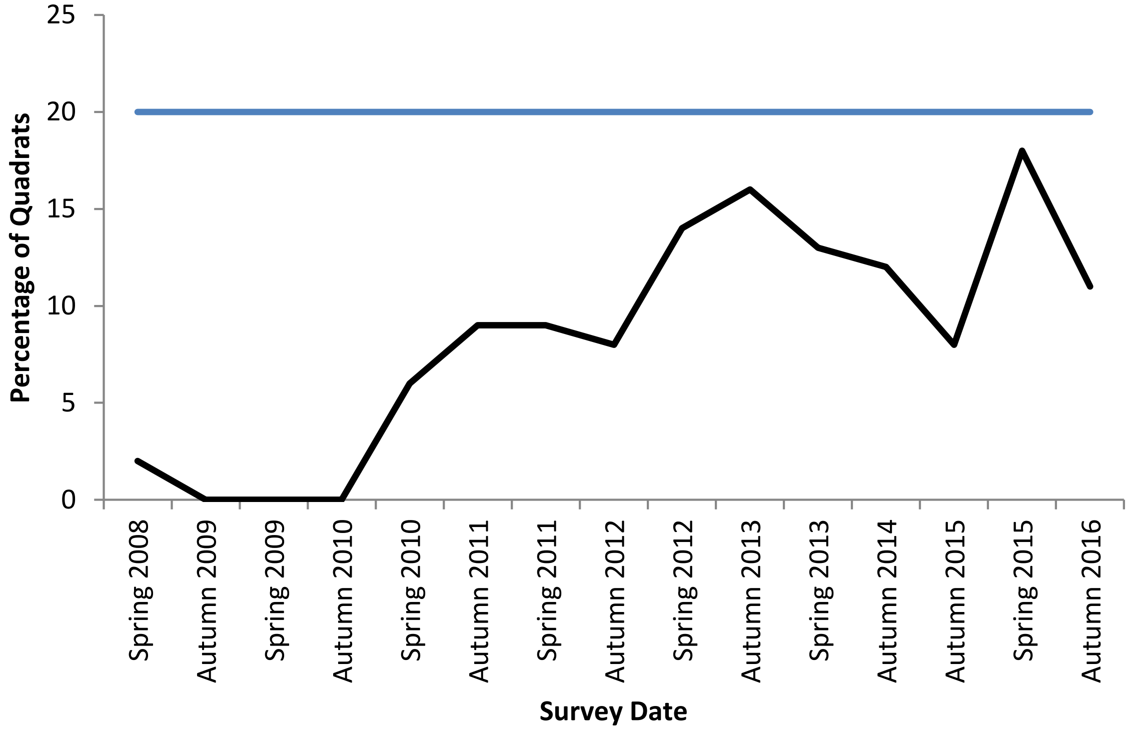

Figure 15: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the aquatic zone of Lake Alexandrina from spring 2008 to autumn 2016.

Figure 16 shows the percentage of quadrats containing a cover of native submergent species greater than 5% in the aquatic zone of Lake Alexandrina from spring 2008 to autumn 2016. During the drought the aquatic zone was dry; hence, no submergent species were present and it was not until spring 2011 before a significant number of quadrats contained native submergent species with a combined cover greater than 5%. There was an increasing trend after spring 2011 that peaked in autumn 2015 (26% of quadrats) after which, there was a decrease (Figure 16). However, there was an increase to the second highest level observed between spring 2015 and autumn 2016 (14.5%) (Figure 16). The percentage of quadrats containing greater than 5% cover of native submergent species in the aquatic zone of Lake Alexandrina target has not reached 35%; hence, the target has not yet been achieved.

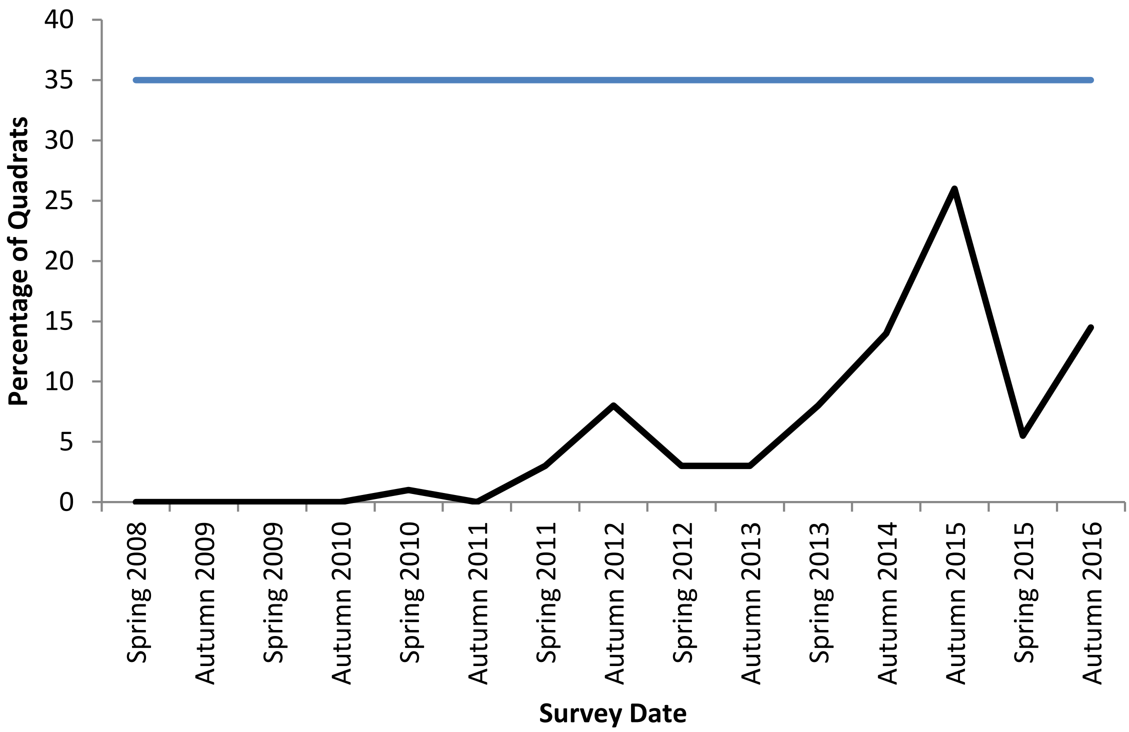

Figure 16: Percentage of quadrats containing a cover of native submergent species greater than 5% in the aquatic zone of Lake Alexandrina from spring 2008 to autumn 2016.

Whole of habitat condition

The whole of habitat condition score (the proportion of targets achieved) in Lake Alexandrina is shown in Figure 17. The increase between autumn 2010 and spring 2010 was due to water levels being reinstated and the target for the deep water zone being achieved and the number of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone falling below 20% (Figure 11). No additional targets were achieved until autumn 2015 when the number of quadrats containing cover of native amphibious species greater than 5% in the littoral zone exceeded 50% and the target was achieved (Figure 12). No further targets were achieved after autumn 2015 (Figure 17).

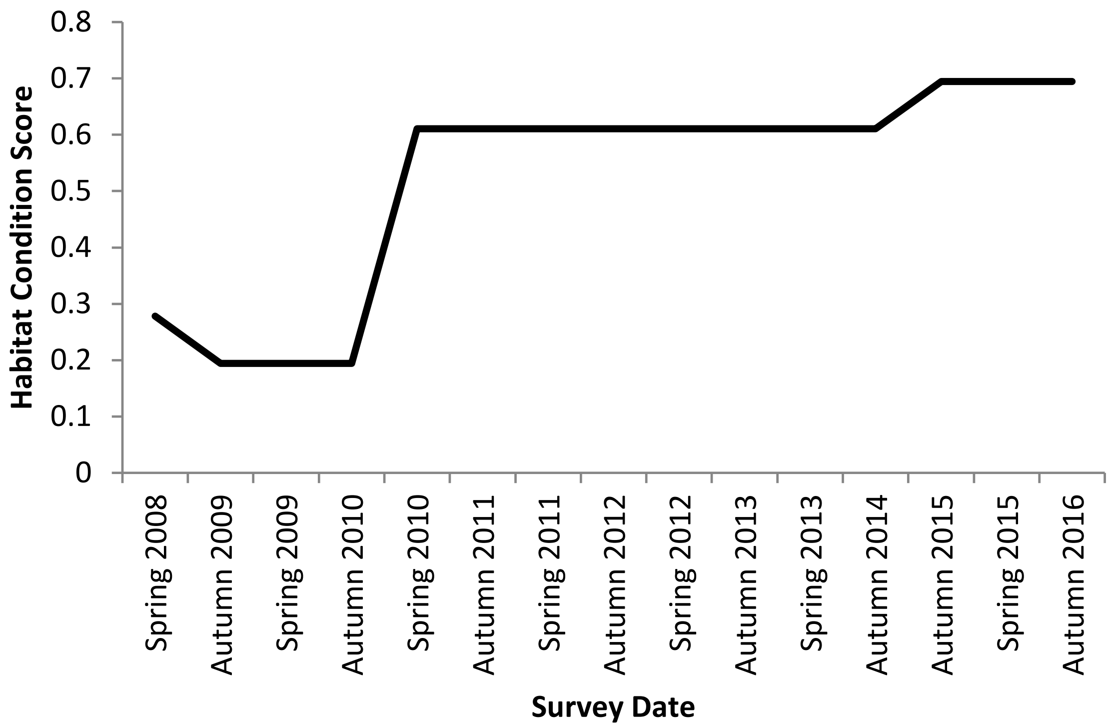

Figure 17: Whole of habitat condition score for Lake Alexandrina from spring 2008 to autumn 2016.

Lake Albert

Littoral Zone

Figure 18 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone of Lake Albert from spring 2008 to autumn 2016. There were no quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone until spring 2013, after which, there was a general upward trend peaking at 13% in autumn 2016 (Figure 18). The number of quadrats has remained well below 40%; therefore, the target has always been achieved since spring 2008.

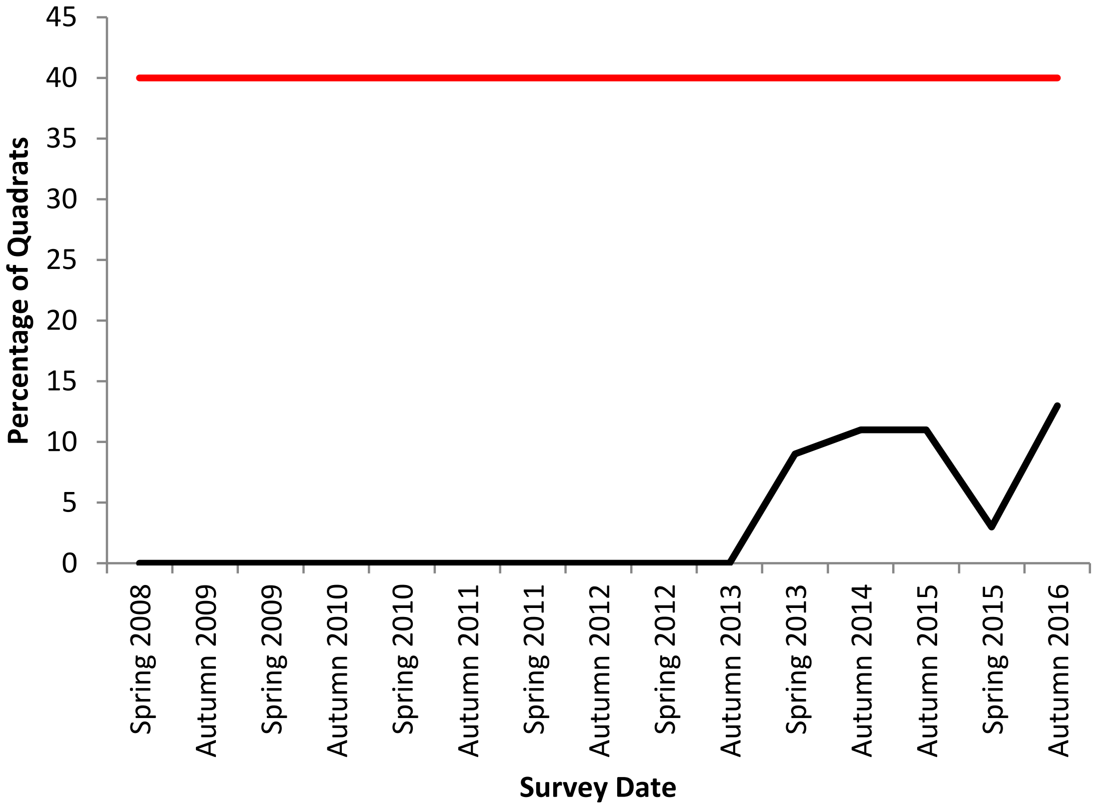

Figure 18: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone of Lake Albert from spring 2008 to autumn 2016.

Figure 19 shows the percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone of Lake Albert from spring 2008 to autumn 2016. Since autumn 2010 there has been a downward trend in the number of quadrats containing a combined cover of these species greater than 50%; however, the number of quadrats did not fall to below 20% until spring 2015 (Figure 19). The target has been achieved from spring 2015 and autumn 2016 (Figure 19).

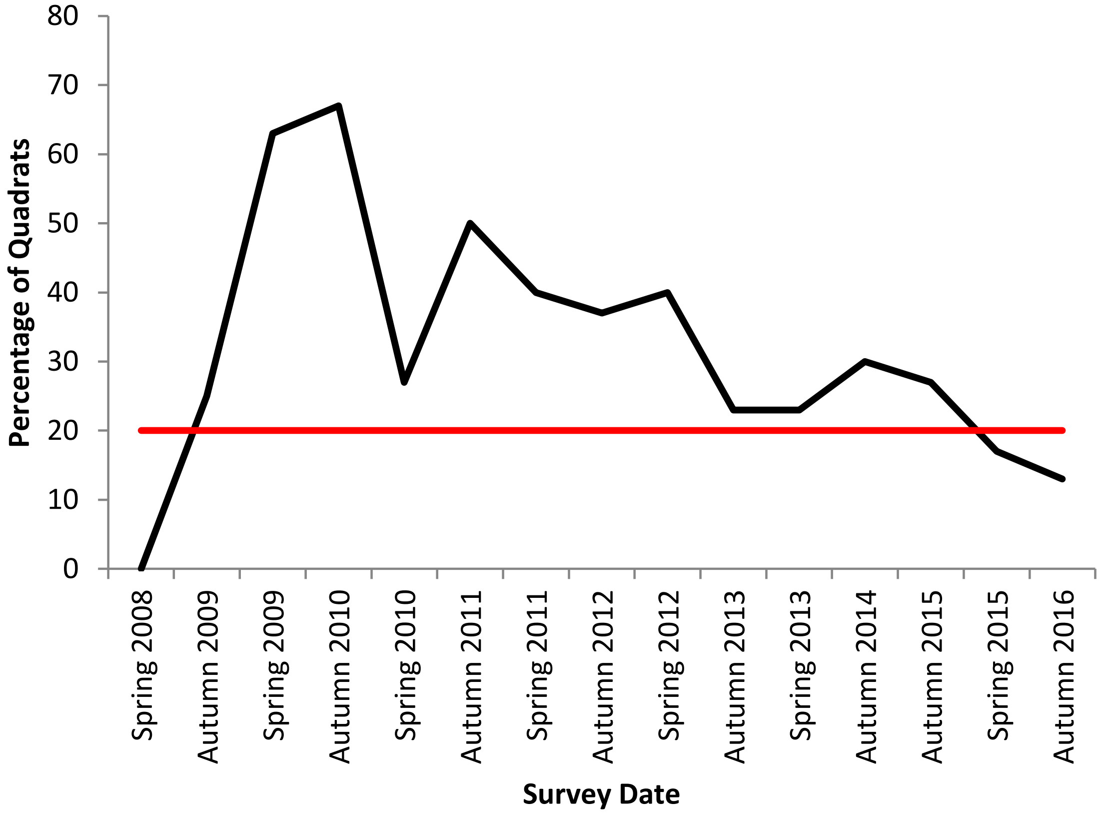

Figure 19: Percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone of Lake Albert from spring 2008 to autumn 2016.

Figure 20 shows the percentage of quadrats containing a cover of native amphibious species greater than 5% in the littoral zone of Lake Albert from spring 2008 to autumn 2016. The number of quadrats containing these species with a cover of greater than 5% has been variable since spring 2008 and peaked during the drought (25%) (Figure 20). After water levels were reinstated the largest number of quadrats containing these species with a cover of greater than 5% was in autumn 2015 (20%) and the target has never been achieved (Figure 20).

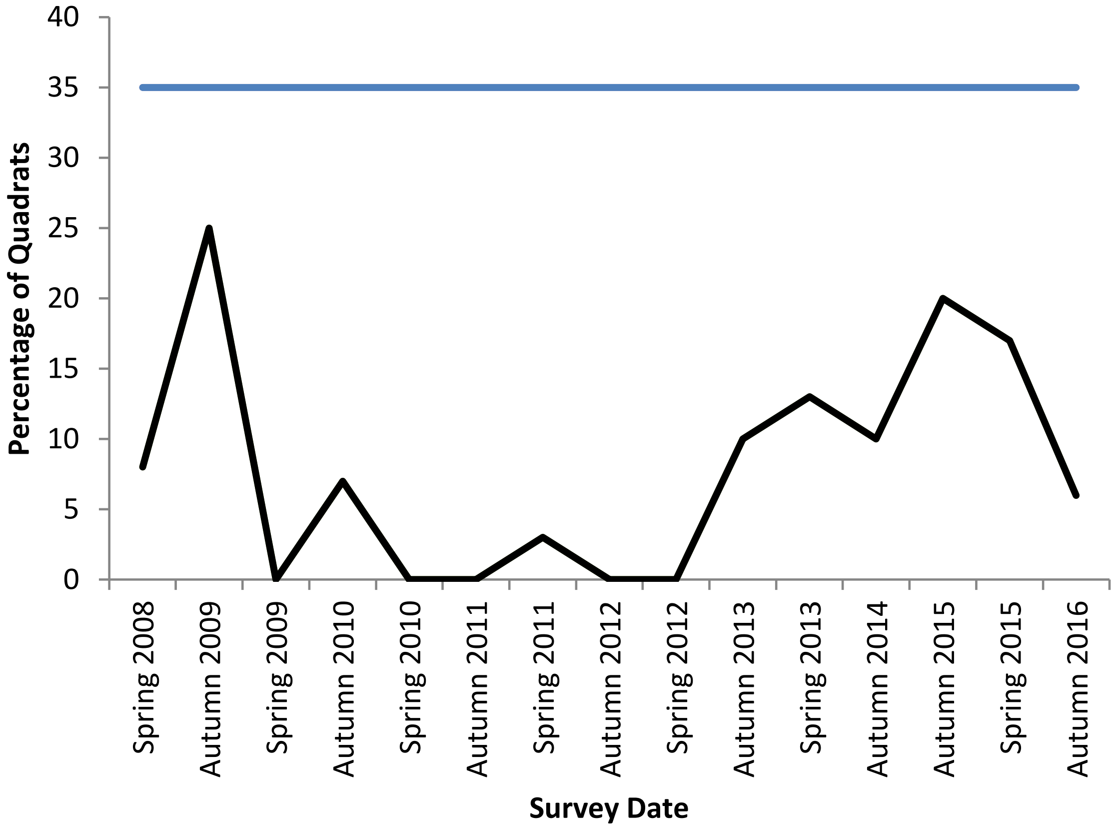

Figure 20: Percentage of quadrats containing a cover of native amphibious species greater than 5% in the littoral zone of Lake Albert from spring 2008 to autumn 2016.

The combined cover of native emergent species other than *Typha domingensis* and *Phragmites australis* has not exceeded 5% in any quadrats in the littoral zone of Lake Albert since spring 2008; therefore, this target has not been achieved (Table 2).

Aquatic Zone

Figure 21 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone of Lake Albert from spring 2008 to autumn 2016. There has generally been an upward trend in the number of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50%; however, it has not exceeded 40% (the largest number of quadrats was 13% in autumn 2013) and the target has been achieved since spring 2008 (Figure 21).

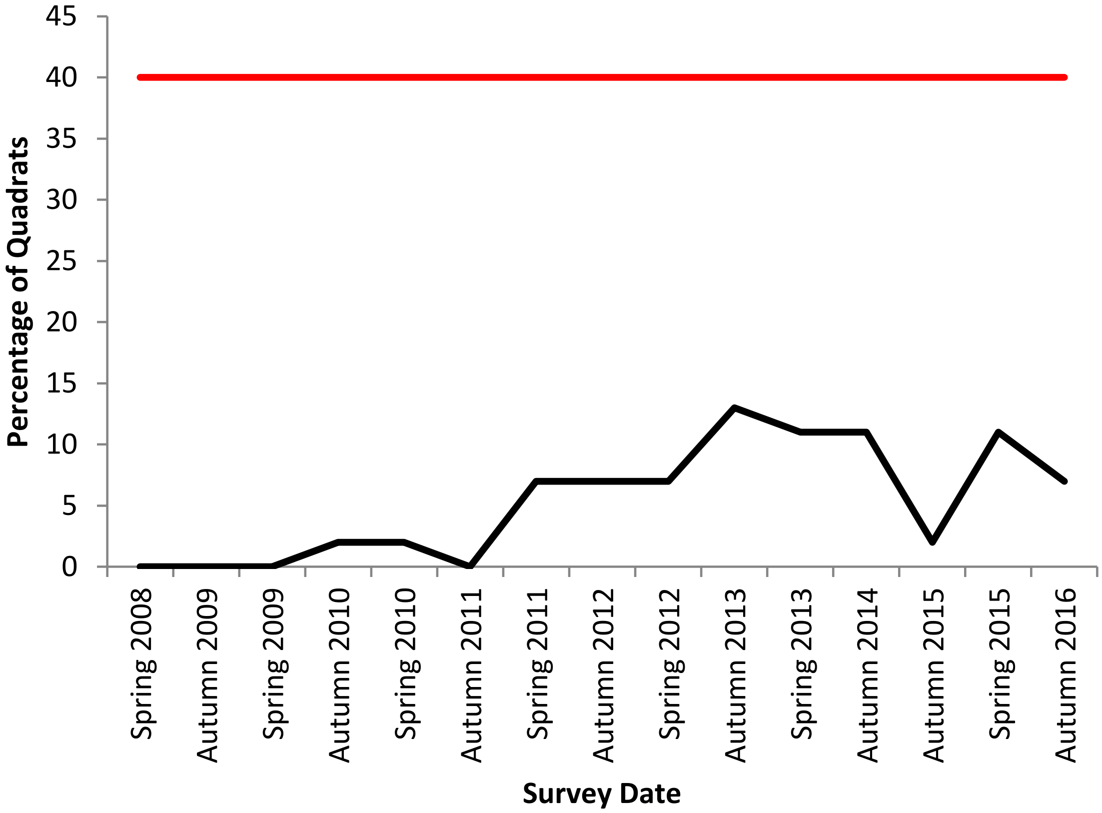

Figure 21: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone of Lake Albert from spring 2008 to autumn 2016.

Figure 22 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the aquatic zone of Lake Albert from spring 2008 to autumn 2016. These species are uncommon in Lake Albert and their combined cover in the aquatic zone exceeded 5% on only three occasions; autumn 2013, autumn 2015 (7% of quadrats, the highest number recorded) and autumn 2016 (Figure 22). Therefore, the target has not be achieved over the survey period.

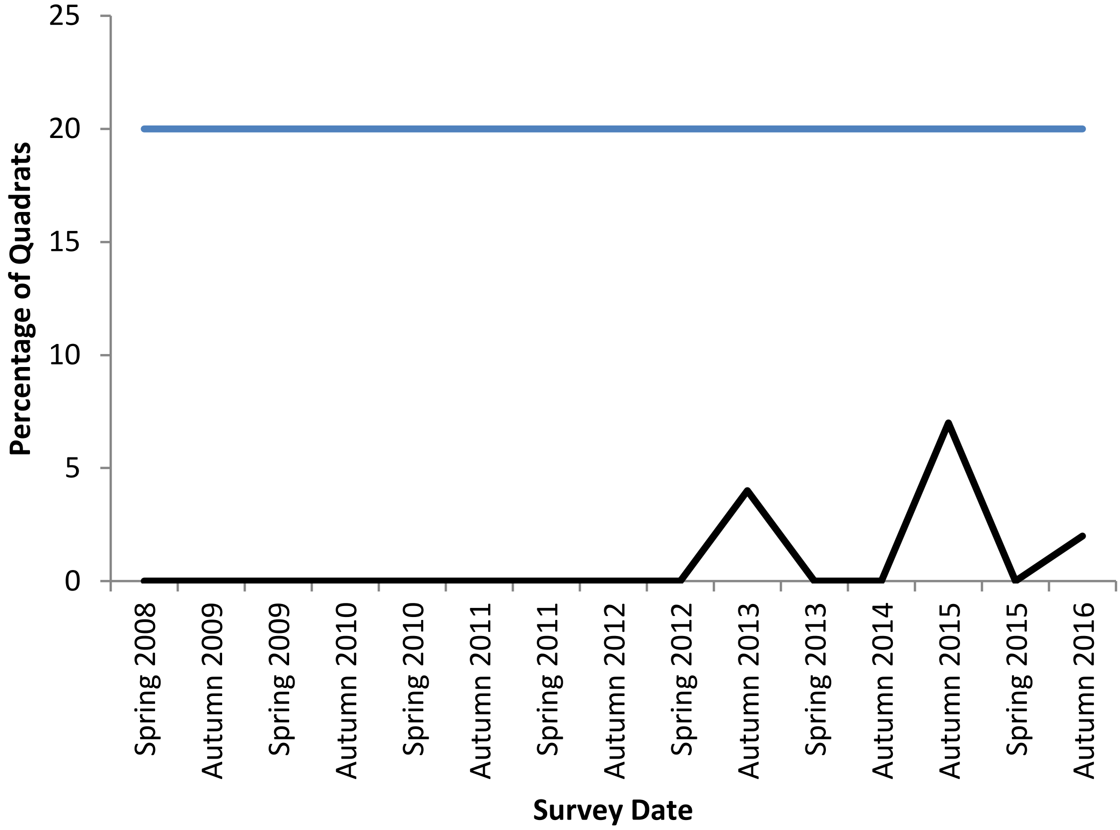

Figure 22: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the aquatic zone of Lake Albert from spring 2008 to autumn 2016.

Figure 23 shows the percentage of quadrats containing a cover of native submergent species greater than 5% in the aquatic zone of Lake Albert from spring 2008 to autumn 2016. During the drought the aquatic zone was dry; hence, no submergent species were present and there was only one occasion (spring 2011, 6% of quadrats) when native submergent species were present with more than 5% cover (Figure 23); hence, the target has not yet been achieved.

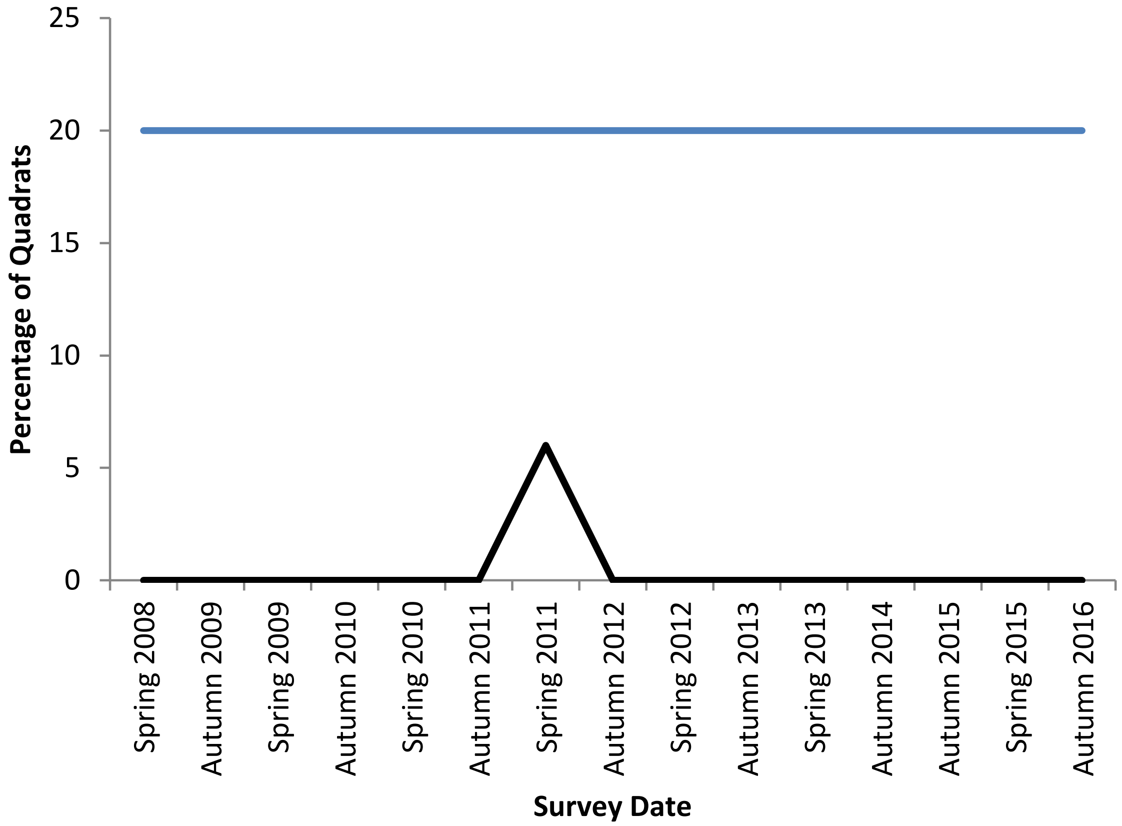

Figure 23: Percentage of quadrats containing a cover of native submergent species greater than 5% in the aquatic zone of Lake Albert from spring 2008 to autumn 2016.

Whole of habitat condition

The whole of habitat condition score for Lake Albert is shown in Figure 24. The increase between autumn 2010 and spring 2010 was due to water levels being reinstated and the target for the deep water zone being achieved (Figure 24). No additional targets were achieved until spring 2015 when the number of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone fell below 20% (Figure 19). No further targets were achieved after spring 2015 (Figure 24).

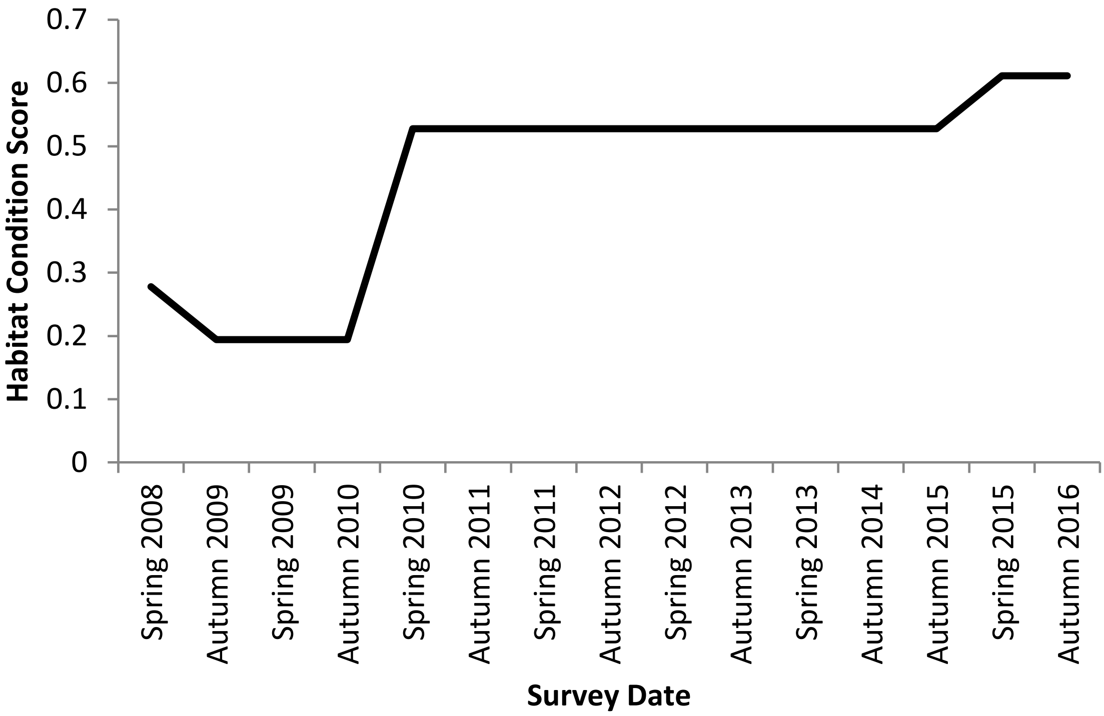

Figure 24: Whole of habitat condition score for Lake Albert from spring 2008 to autumn 2016.

Goolwa Channel

Littoral Zone

Figure 25 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone of Goolwa Channel from spring 2008 to autumn 2016. The number of quadrats in the littoral zone containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% has exceeded 50% on four occasions including spring 2015 and autumn 2016 (Figure 25). Therefore, this target has not been achieved in the two most recent surveys.

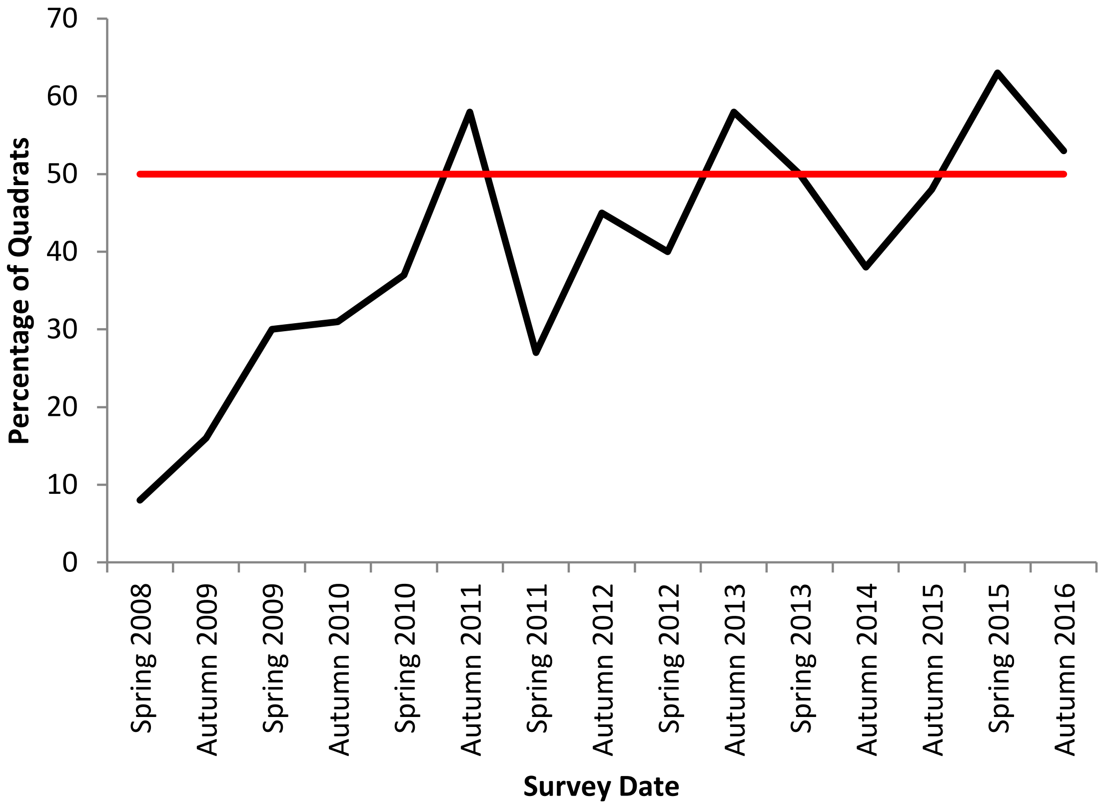

Figure 25: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone of Goolwa Channel from spring 2008 to autumn 2016.

Figure 26 shows the percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone of Goolwa Channel from spring 2008 to autumn 2016. The only time this target was not achieved was in autumn 2010, after which there has been a downward trend in the number of quadrats containing a combined cover of these species greater than 50% (Figure 26).

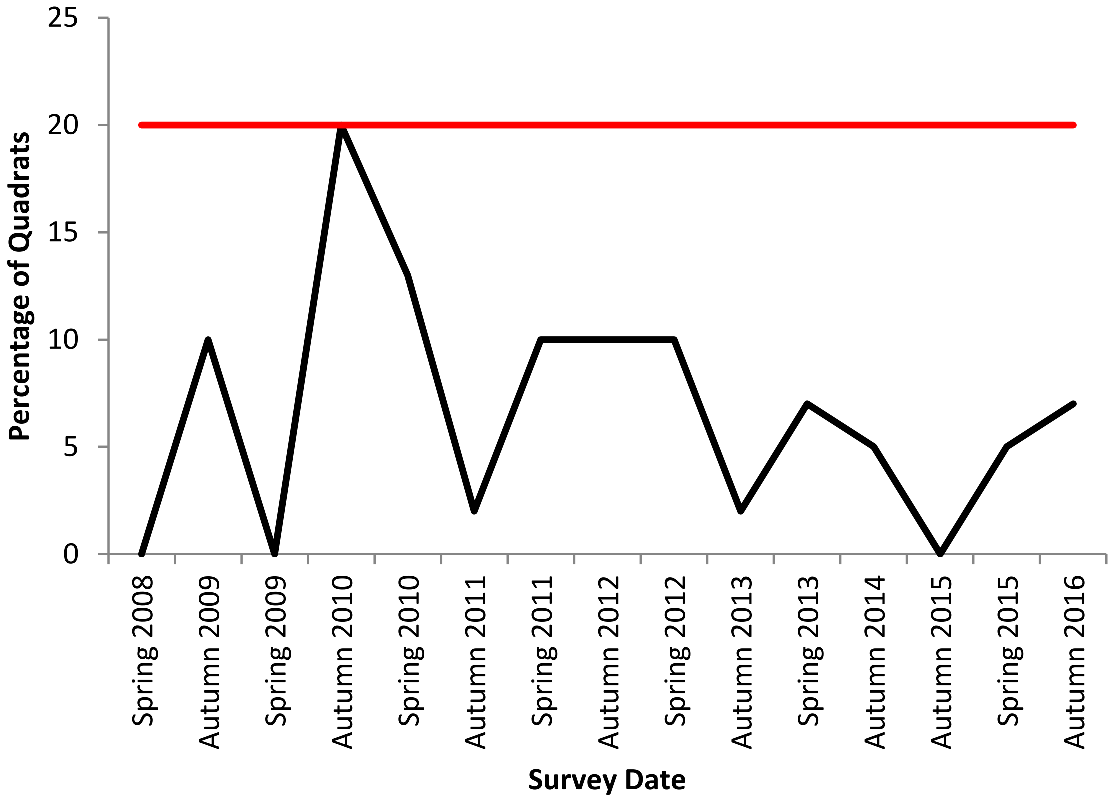

Figure 26: Percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone of Goolwa Channel from spring 2008 to autumn 2016.

Figure 27 shows the percentage of quadrats containing a cover of native amphibious species greater than 5% in the littoral zone of Goolwa Channel from spring 2008 to autumn 2016. The percentage of quadrats with a cover of native amphibious species greater than 5% has trended upwards since spring 2008; however, there were also strong seasonal patterns from spring 2009 to spring 2013 with higher abundances of these species in spring (Figure 27). After spring 2013 there were no seasonal patterns and the target has been achieved each following survey (Figure 27).

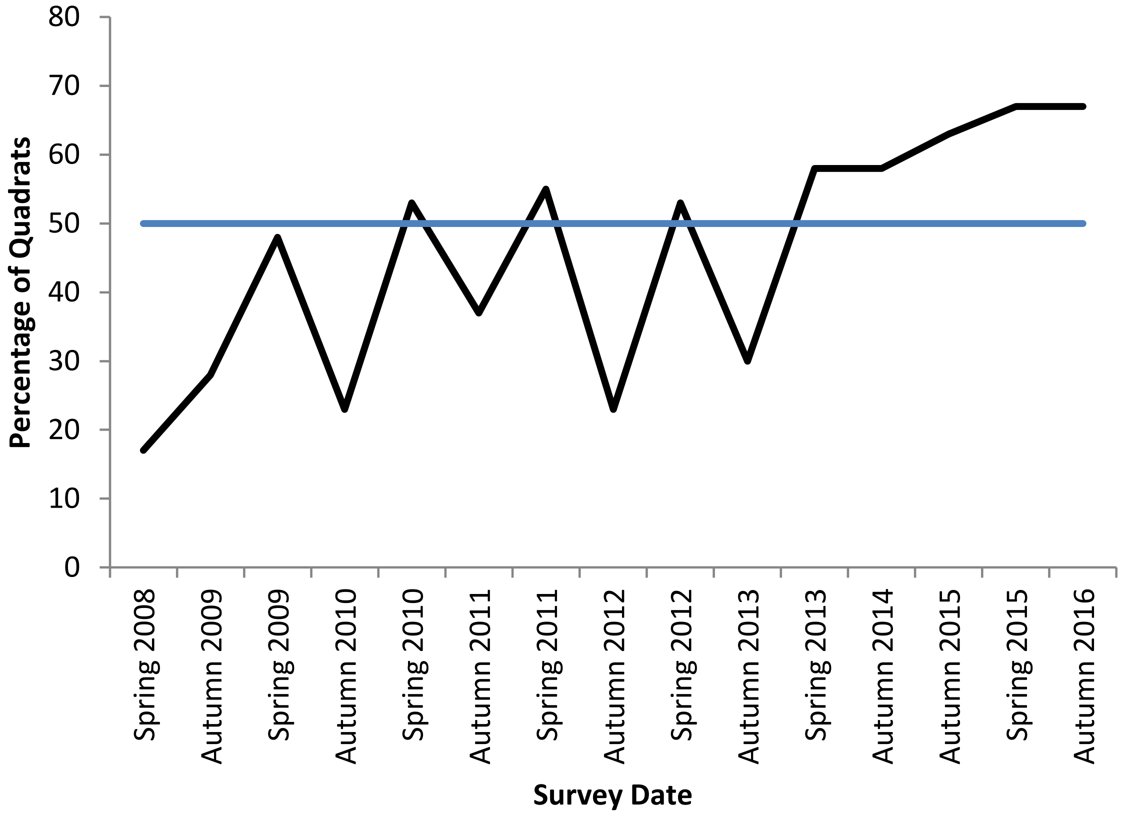

Figure 27: Percentage of quadrats containing a cover native amphibious species greater than 5% in the littoral zone of Goolwa Channel from spring 2008 to autumn 2016.

Figure 28 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the littoral zone of Goolwa Channel from spring 2008 to autumn 2016. The percentage of quadrats with a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% has not exceeded 50% of quadrats; therefore, this target has not been achieved during the condition monitoring program (Figure 28). However, there was an increasing trend from spring 2009 to spring 2013 (13% of quadrats) (Figure 28). Furthermore, there was a seasonal pattern (higher abundances in spring) from spring 2012.

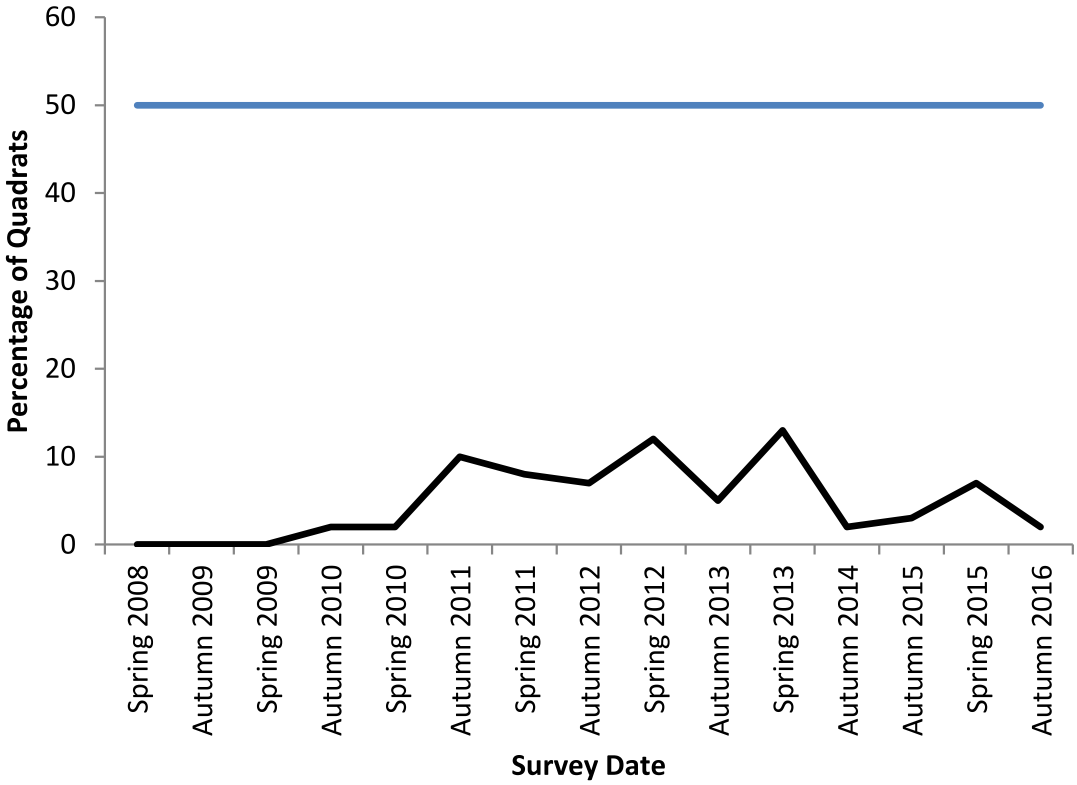

Figure 28: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the littoral zone of Goolwa Channel from spring 2008 to autumn 2015.

Aquatic Zone

Figure 29 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone of Goolwa Channel from spring 2008 to autumn 2016. The number of quadrats in the littoral zone containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% has exceeded 50% of quadrats on four occasions including spring 2015 (Figure 29).

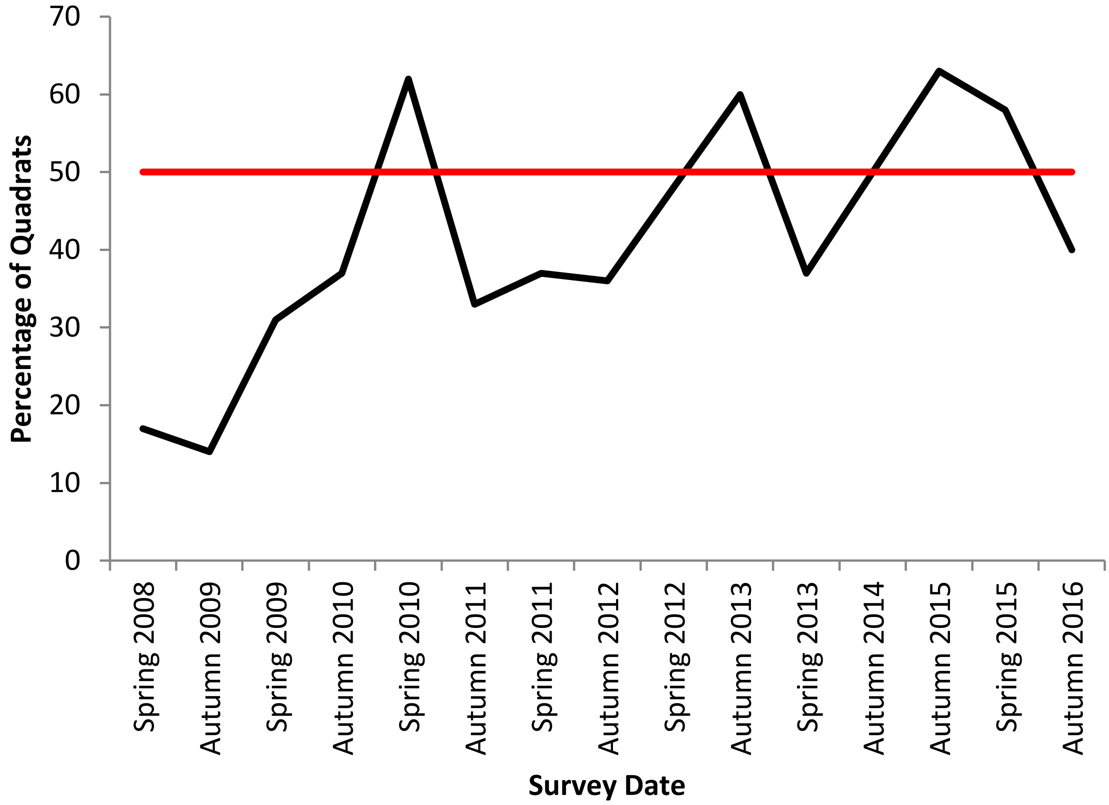

Figure 29: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone of Goolwa Channel from spring 2008 to autumn 2016.

Figure 30 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the aquatic zone of Goolwa Channel from spring 2008 to autumn 2016. The percentage of quadrats with a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% has not exceeded 50% of quadrats; therefore, this target has not been achieved during the condition monitoring program (Figure 30). However, there has been an increasing trend from spring 2009 (Figure 30).

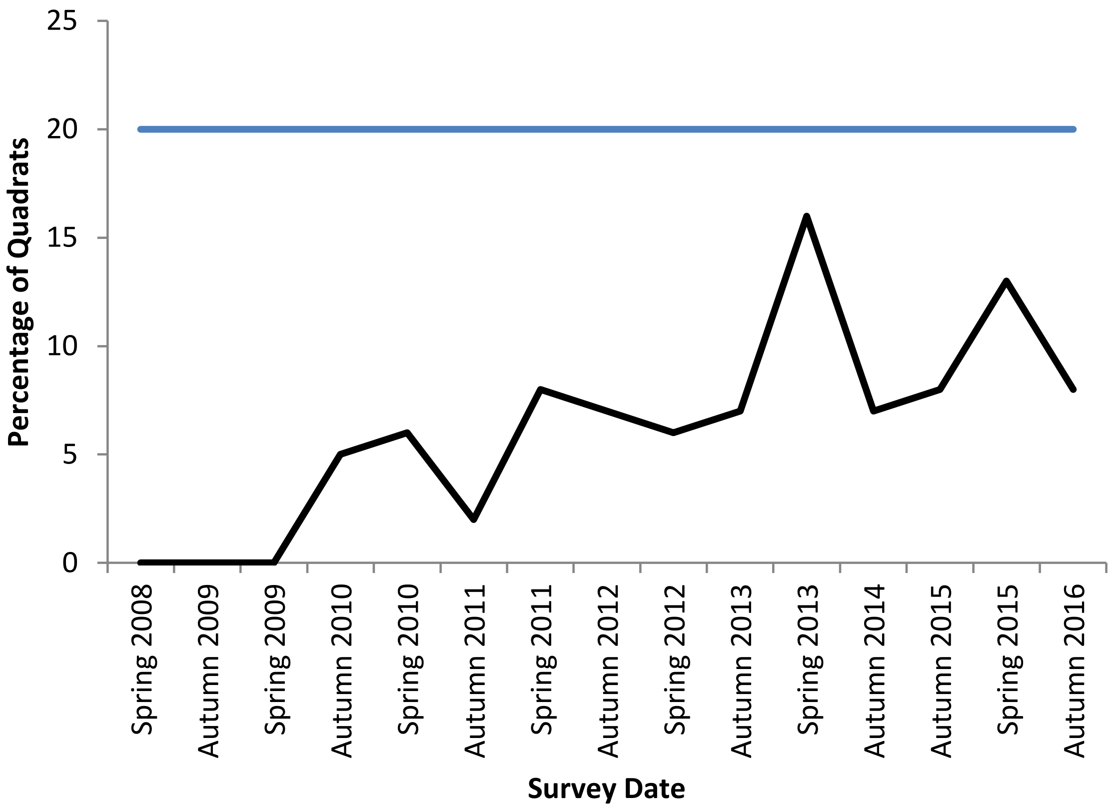

Figure 30: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the aquatic zone of Goolwa Channel from spring 2008 to autumn 2016.

Figure 31 shows the percentage of quadrats containing a cover of native submergent species greater than 5% in the aquatic zone of Goolwa Channel from spring 2008 to autumn 2016. Before spring 2009 the aquatic zone was dry; hence, no submergent species were present but after then there has been an increasing trend in the number of quadrats containing native submergent species with a cover of greater than 5% (Figure 31). However, the target of 40% of quadrats has not been achieved over the survey period (Figure 31).

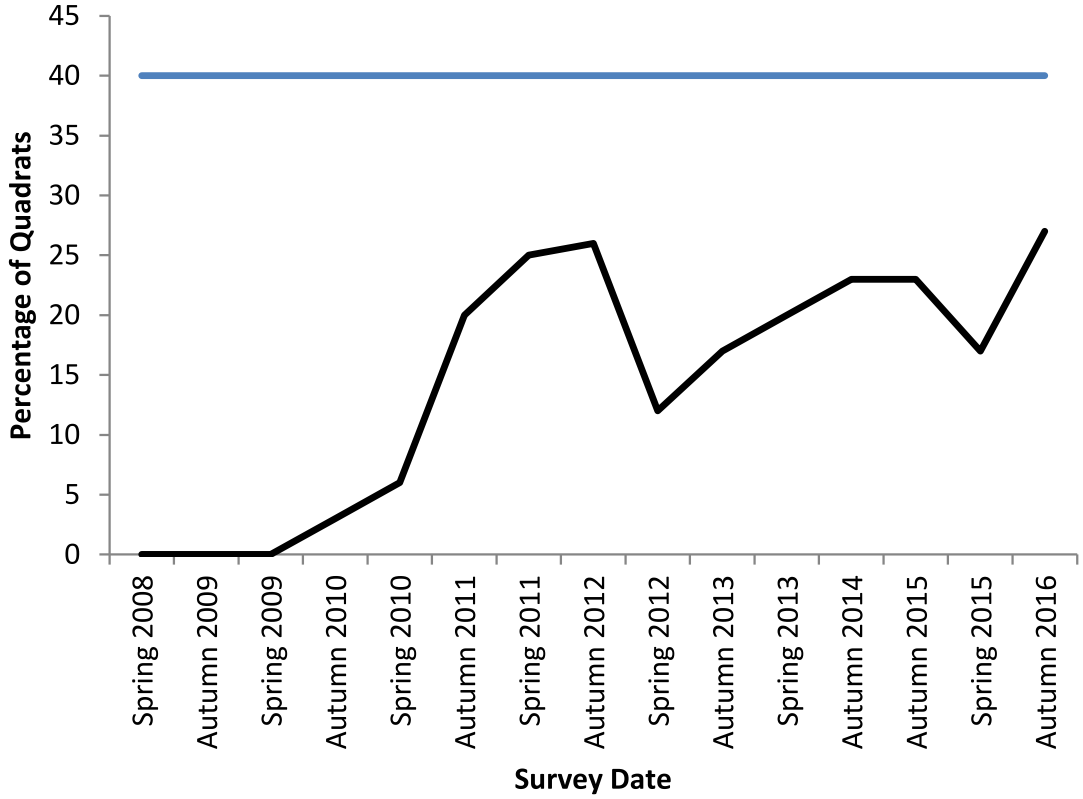

Figure 31: Percentage of quadrats containing a cover of native submergent species greater than 5% in the aquatic zone of Goolwa Channel from spring 2008 to autumn 2016.

Deep water zone

Figure 32 shows the percentage of quadrats containing a cover of native submergent species greater than 5% in the deep water zone of Goolwa Channel from spring 2008 to autumn 2016. Before spring 2009 much of the deep water zone was dry; hence, no submergent species were present (Figure 32). Between spring 2009 and spring 2010 there was a large increase in the number of quadrats with greater than 5% cover of native submergent species (79% of quadrats in spring 2010) due to the dominance of *Potamogeton pectinatus* after the Clayton Regulator was constructed. After the Clayton Regulator was breached there was a decrease in quadrats with greater than 5% cover of native submergents but the number remained at or above the target of 20% of quadrats until spring 2015 when it decreased and the target was not achieved for the two most recent surveys (Figure 32).

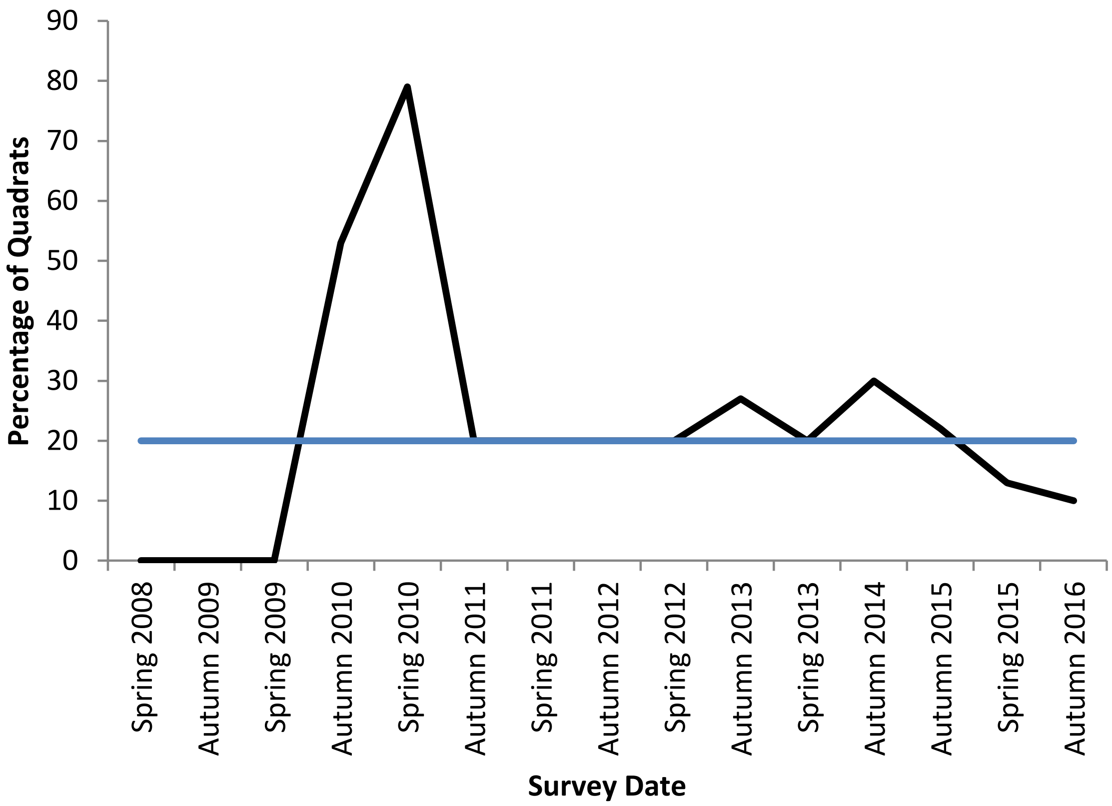

Figure 32: Percentage of quadrats containing a cover of native submergent species greater than 5% in the deep water zone of Goolwa Channel from spring 2008 to autumn 2016.

Whole of habitat condition

The whole of habitat condition score for Goolwa Channel is shown in Figure 33. In contrast to lakes Alexandrina (Figure 17) and Albert (Figure 24) there has not been a sustained increase in habitat condition score over the condition monitoring program for Goolwa Channel (Figure 33). The generally increasing trend between spring 2008 and autumn 2015 was due to the deep water target being achieved over this period (Figure 32). The minor fluctuations over this period were due to the *Typha domingensis* and *Phragmites australis* targets in the littoral (Figure 25) and aquatic (Figure 29) zones and native amphibious species target (Figure 27) in the littoral zone being achieved for some surveys and not achieved for others (seasonal patterns in abundance). The decrease in habitat condition score between autumn 2015 and autumn 2016 was due to the deep water (Figure 32) and littoral *Typha domingensis* and *Phragmites australis* targets (Figure 25) not being achieved.

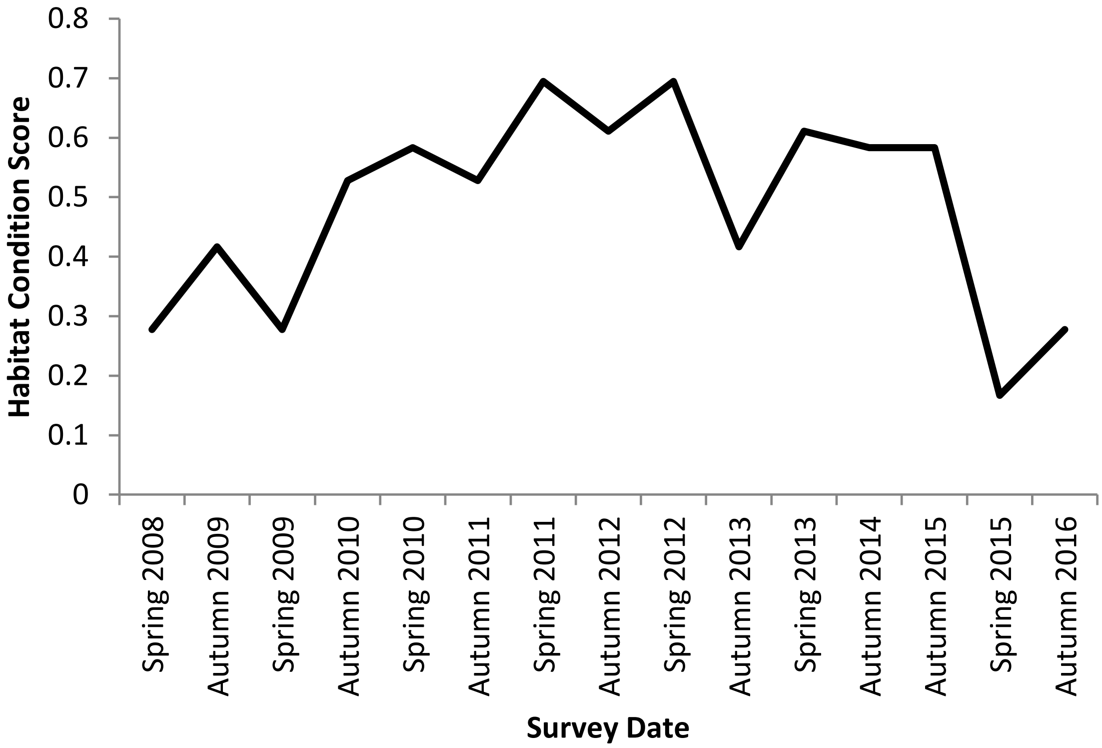

Figure 33: Whole of habitat condition score for Goolwa Channel from spring 2008 to autumn 2016.

Permanent wetlands

Littoral zone

Figure 34 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone of permanent wetlands from spring 2008 to autumn 2016. Quadrats in the littoral zone containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% were uncommon in permanent wetlands and has never exceeded the target of 35% of quadrats (Figure 34). Therefore, this target has been achieved throughout the condition monitoring program (Figure 34).

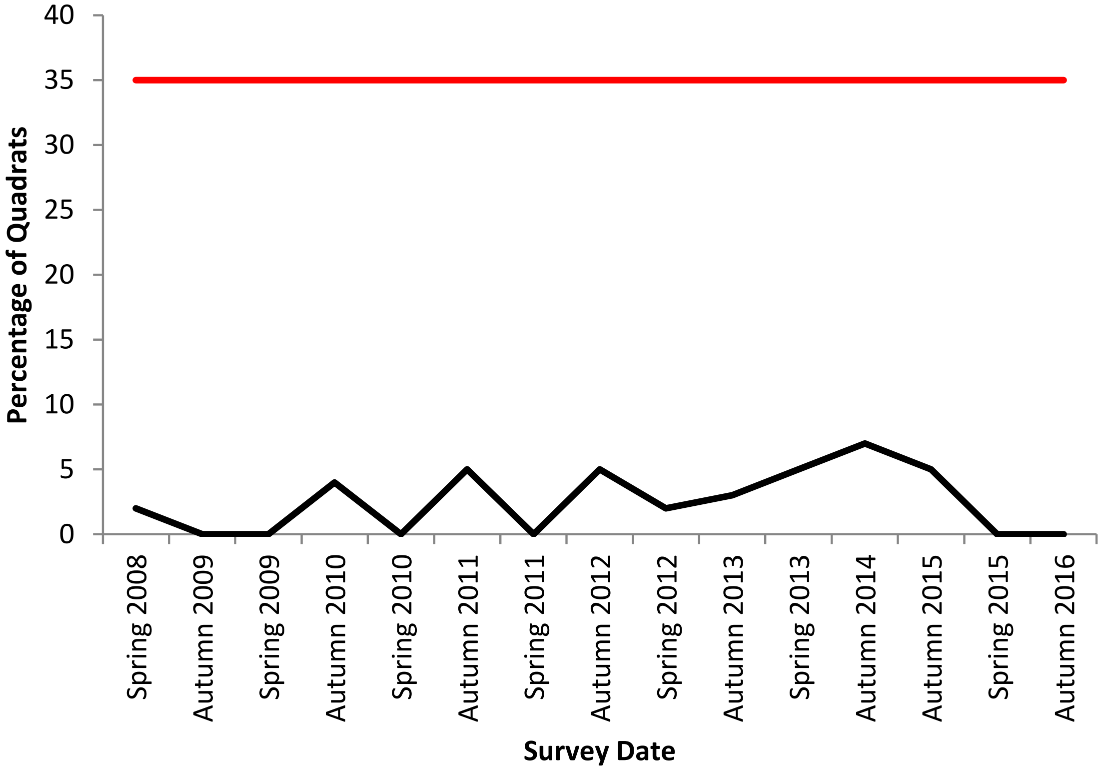

Figure 34: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the littoral zone of permanent wetlands from spring 2008 to autumn 2016.

Figure 35 shows the percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone of permanent wetlands from spring 2008 to autumn 2016. In contrast to lakes Alexandrina (Figure 11) and Albert (Figure 19) and Goolwa Channel (Figure 26), the reinstatement of water levels did not result in a decrease in the number of quadrats with the combined cover these species of over 50%. However, since autumn 2010 there has been a decreasing trend but the number of quadrats is yet to fall below the target of 20% of quadrats (Figure 35).

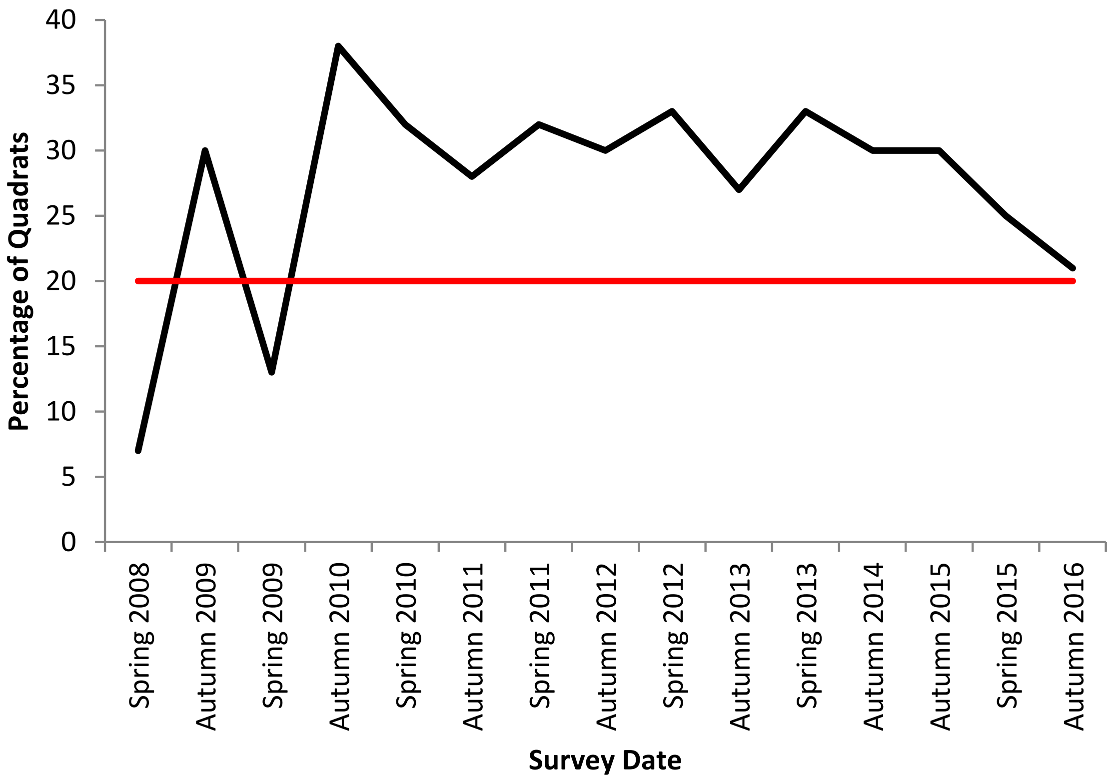

Figure 35: Percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone of permanent wetlands from spring 2008 to autumn 2016.

Figure 36 shows the percentage of quadrats containing a cover of native amphibious species greater than 5% in the littoral zone of permanent wetlands from spring 2008 to autumn 2016. The percentage of quadrats with a cover of native amphibious species greater than 5% has trended upwards from spring 2008 to spring 2015 (Figure 36). However, there is a pattern of sharp increases followed by sharp decreases in the number of quadrats with a cover of native amphibious species greater than 5% and the target of 50% of quadrats has not been achieved (Figure 36).

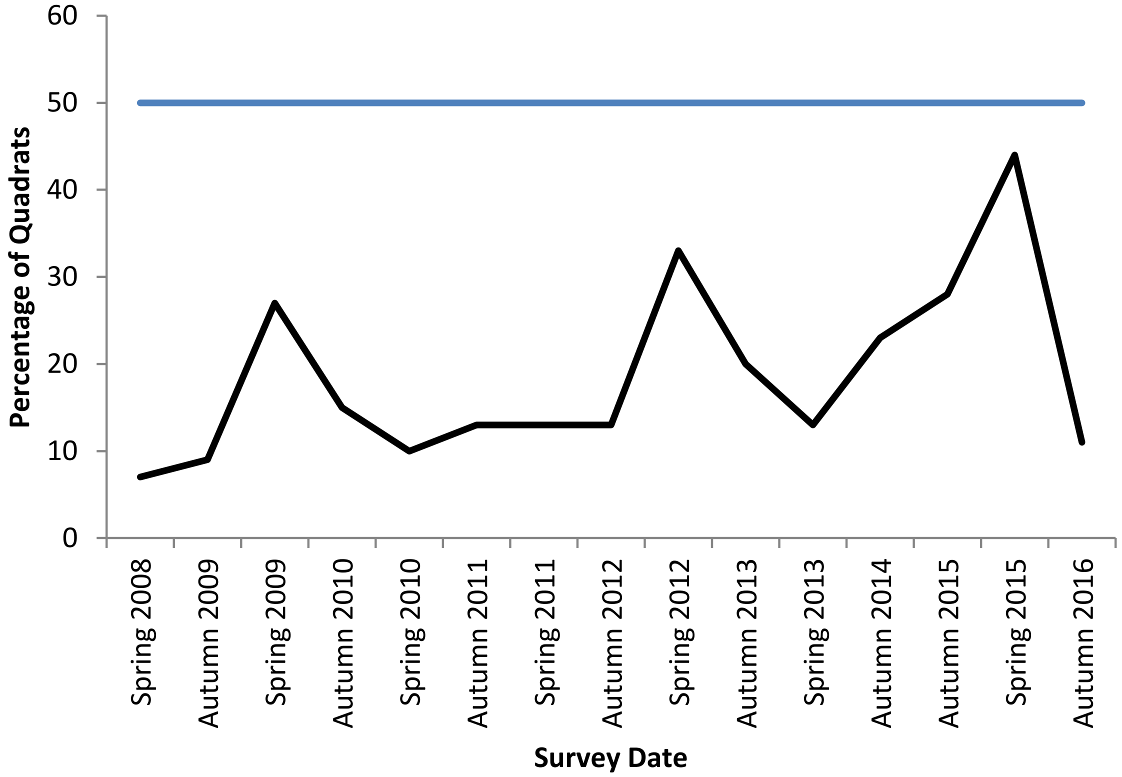

Figure 36: Percentage of quadrats containing a cover native amphibious species greater than 5% in the littoral zone of permanent wetlands from spring 2008 to autumn 2016.

Figure 37 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the littoral zone of permanent wetlands from spring 2008 to autumn 2016. The percentage of quadrats with a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% has not exceeded 50% of quadrats; therefore, this target has not been achieved during the condition monitoring program (Figure 37). However, there was an increasing trend from spring 2009 to autumn 2016 (Figure 37).

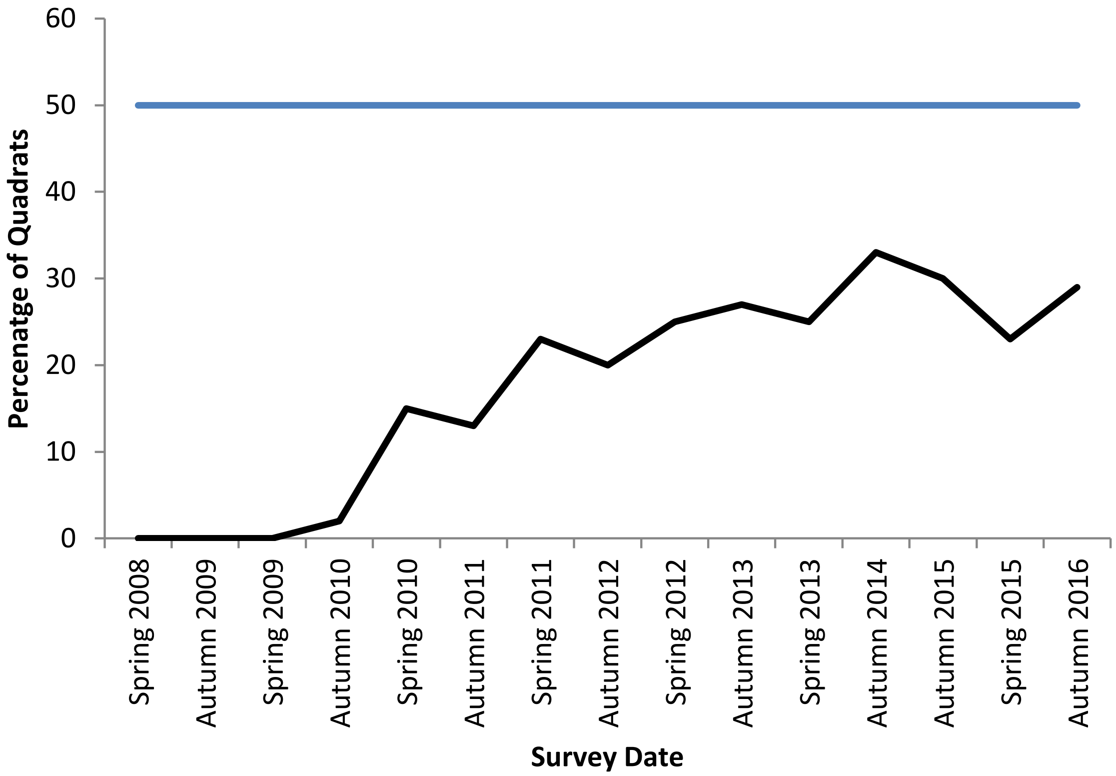

Figure 37: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the littoral zone of permanent wetlands from spring 2008 to autumn 2016.

Aquatic zone

Figure 38 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone of permanent wetlands from spring 2008 to autumn 2016. The number of quadrats in the aquatic zone containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% showed an increasing trend between autumn 2009 and autumn 2016; however, the number of quadrats did not exceed 40% and the target was achieved over the survey period (Figure 38).

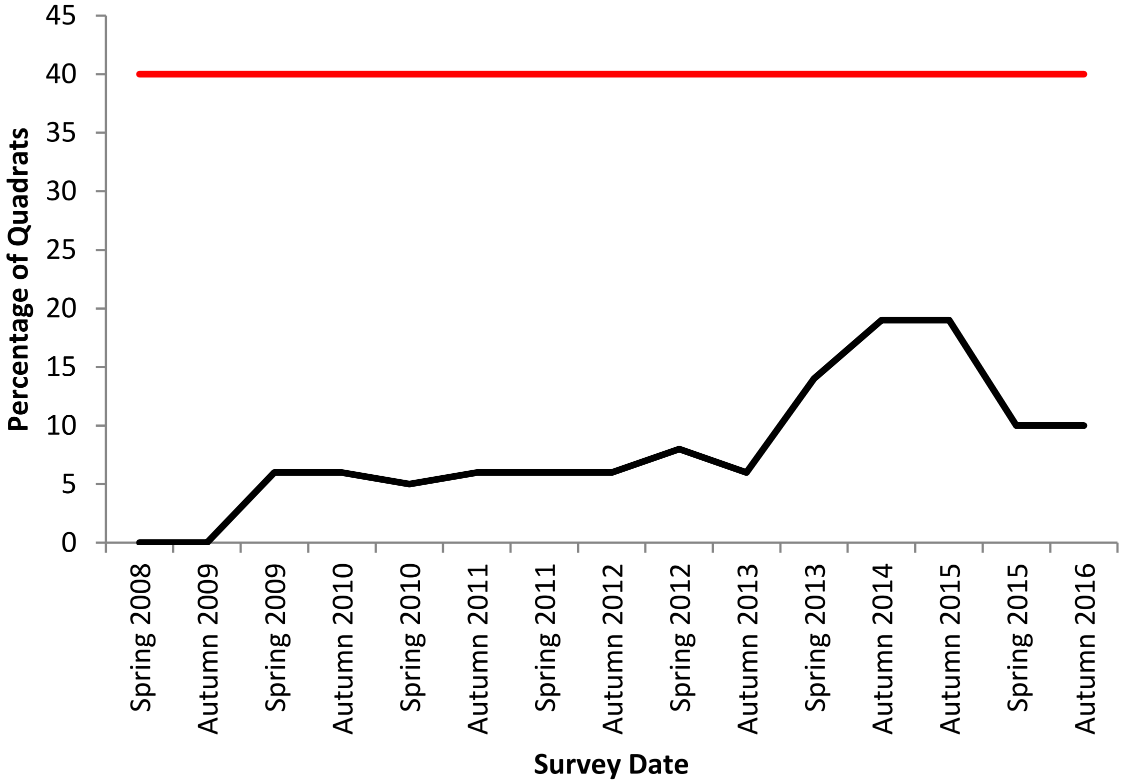

Figure 38: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone of permanent wetlands from spring 2008 to autumn 2016.

Figure 39 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the aquatic zone of permanent wetlands from spring 2008 to autumn 2016. There was an increase in quadrats with a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% after water levels were reinstated but that decreased to zero by autumn 2013 (Figure 39). The number of quadrats remained at 5% or lower for the remainder of the survey period and this target has not been achieved during the condition monitoring program (Figure 39).

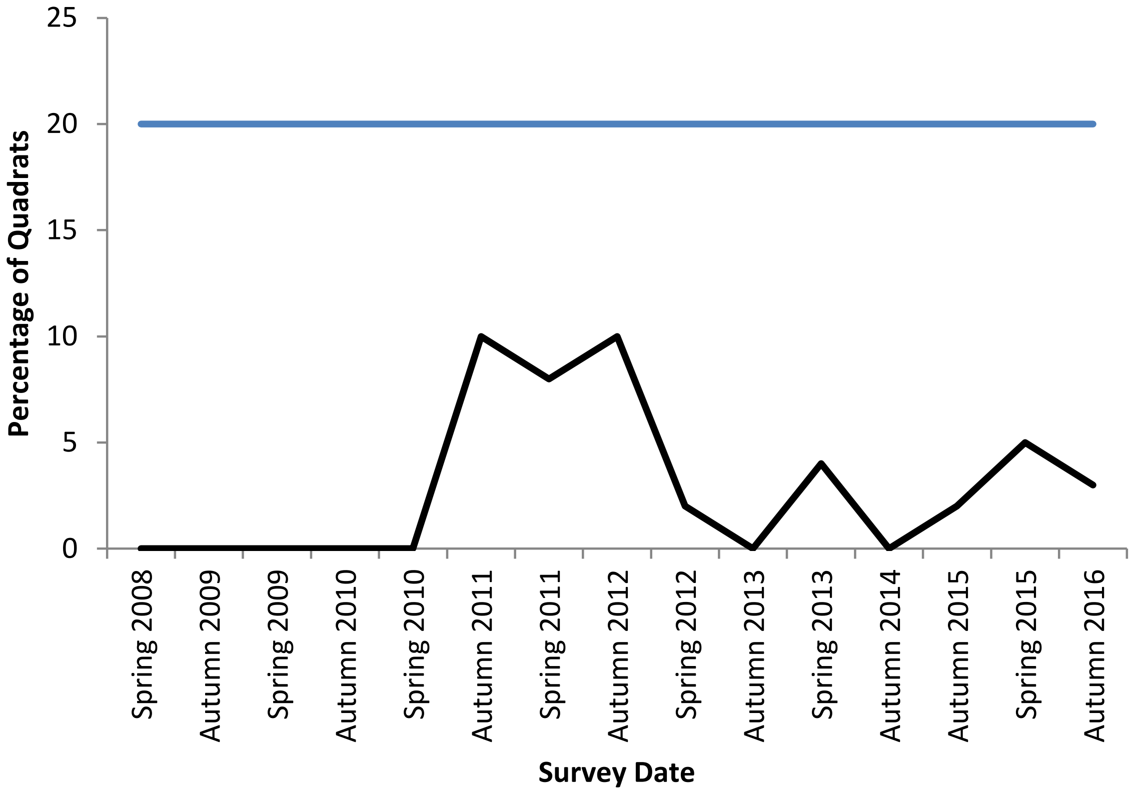

Figure 39: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the aquatic zone of permanent wetlands from spring 2008 to autumn 2016.

Figure 40 shows the percentage of quadrats containing a cover of native submergent species greater than 5% in the aquatic zone of permanent wetlands from spring 2008 to autumn 2016. Before spring 2010 the cover of native emergent species was low due to this zone largely being dry (although there were isolated puddles in spring 2008 and 2009 that supported submergent species) (Figure 40). After water levels were reinstated there has been an increasing trend in the number of quadrats containing native submergent species with a cover of greater than 5% (Figure 40). However, the target of 50% of quadrats has not been achieved over the condition monitoring program (Figure 40).

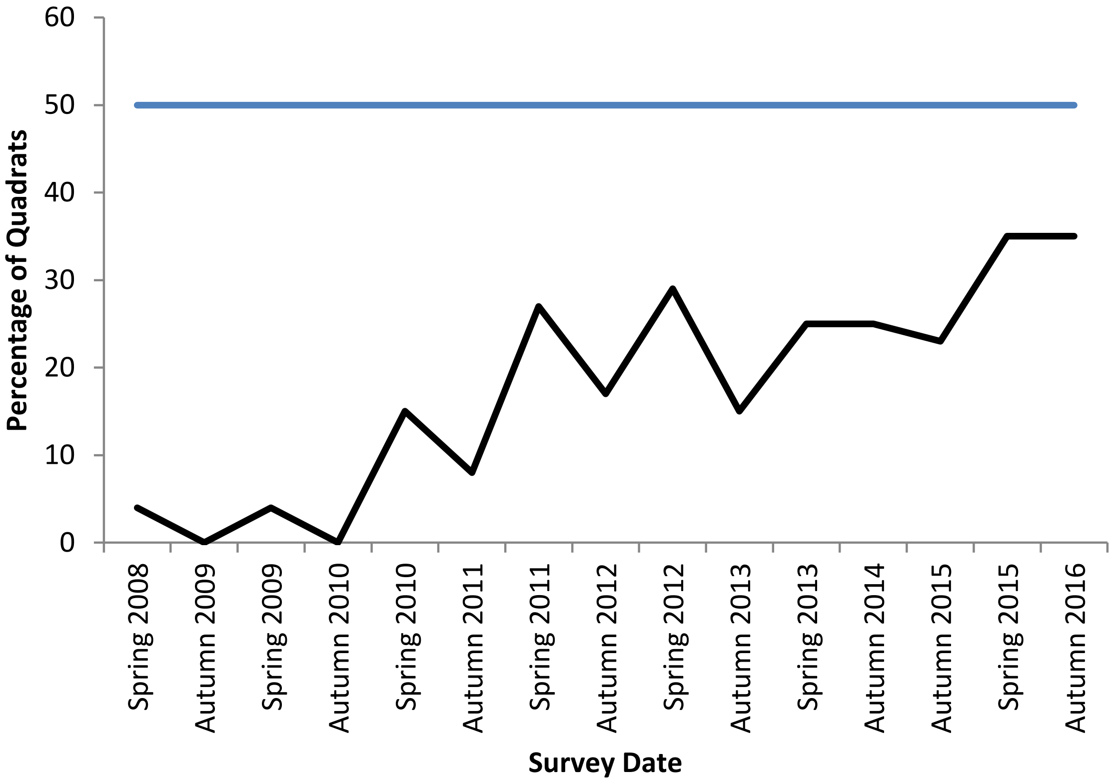

Figure 40: Percentage of quadrats containing a cover of native submergent species between 5 and 50% in the aquatic zone of permanent wetlands from spring 2008 to autumn 2016.

Whole of habitat condition

The whole of habitat condition score for permanent wetlands is shown in Figure 41. There has been little change in the habitat condition score for permanent wetlands between spring 2008 and autumn 2016 (Figure 41). The fall in condition score between spring 2008 and autumn 2009, rise between autumn 2009 and spring 2009 and fall between spring 2009 and autumn 2010 was due the littoral zone *Paspalum distichum* and *Cenchrus clandestinus* being achieved in spring 2008 and spring 2009 (Figure 35). From autumn 2010 there has been no change in condition score with the only targets that were achieved consistently over the survey period the *Typha domingensis* and *Phragmites australis* targets in the littoral (Figure 34) and aquatic (Figure 38) zones.

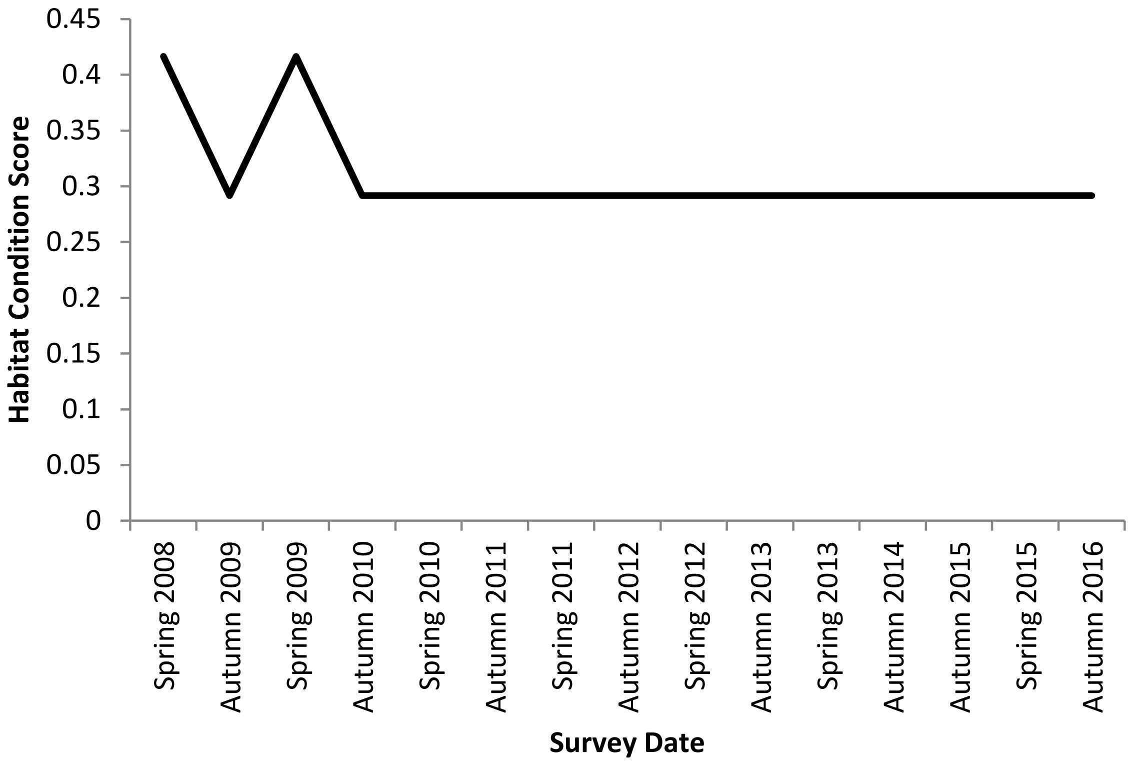

Figure 41: Whole of habitat condition score for permanent wetlands from spring 2008 to autumn 2016.

Seasonal wetlands

Wetland edge

Figure 42 shows the percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% around the edges of seasonal wetlands from spring 2008 to autumn 2016. There has been an increasing trend in the number of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% around the edges of seasonal wetlands over the duration of the condition monitoring program (Figure 42). In addition, there was a seasonal pattern with higher abundances in autumn when water levels are low (Figure 42). The target of a maximum of 20% of quadrats was exceeded (and not achieved) in autumn 2012, autumn 2013 and from autumn 2014 onwards (Figure 42).

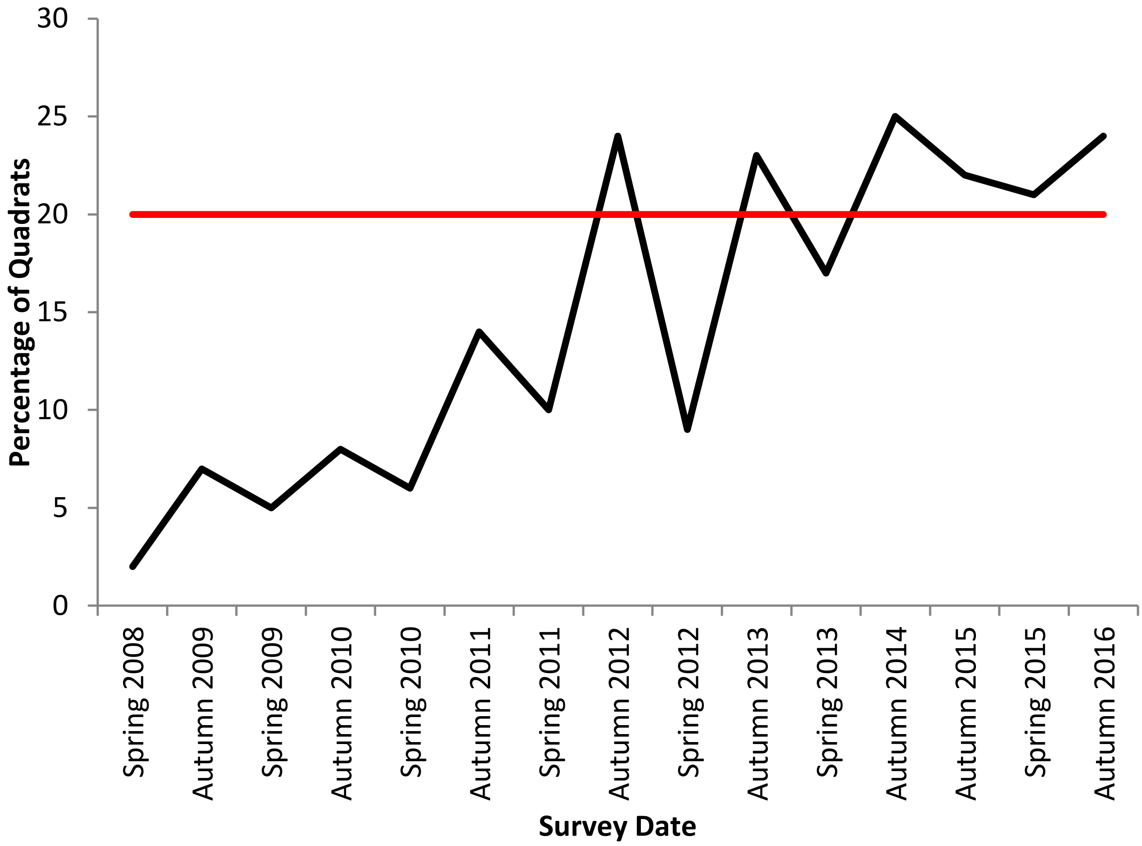

Figure 42: Percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% around the edge of seasonal wetlands from spring 2008 to autumn 2016.

Figure 43 shows the percentage of quadrats containing a cover of native amphibious species greater than 5% in the around the edges of seasonal wetlands from spring 2008 to autumn 2016. Native amphibious species were common around the edges of seasonal wetlands and the number of quadrats with a cover of greater than 5% was higher than the 50% target throughout the survey period (Figure 43). Therefore, this target was achieved over the condition monitoring program (Figure 43).

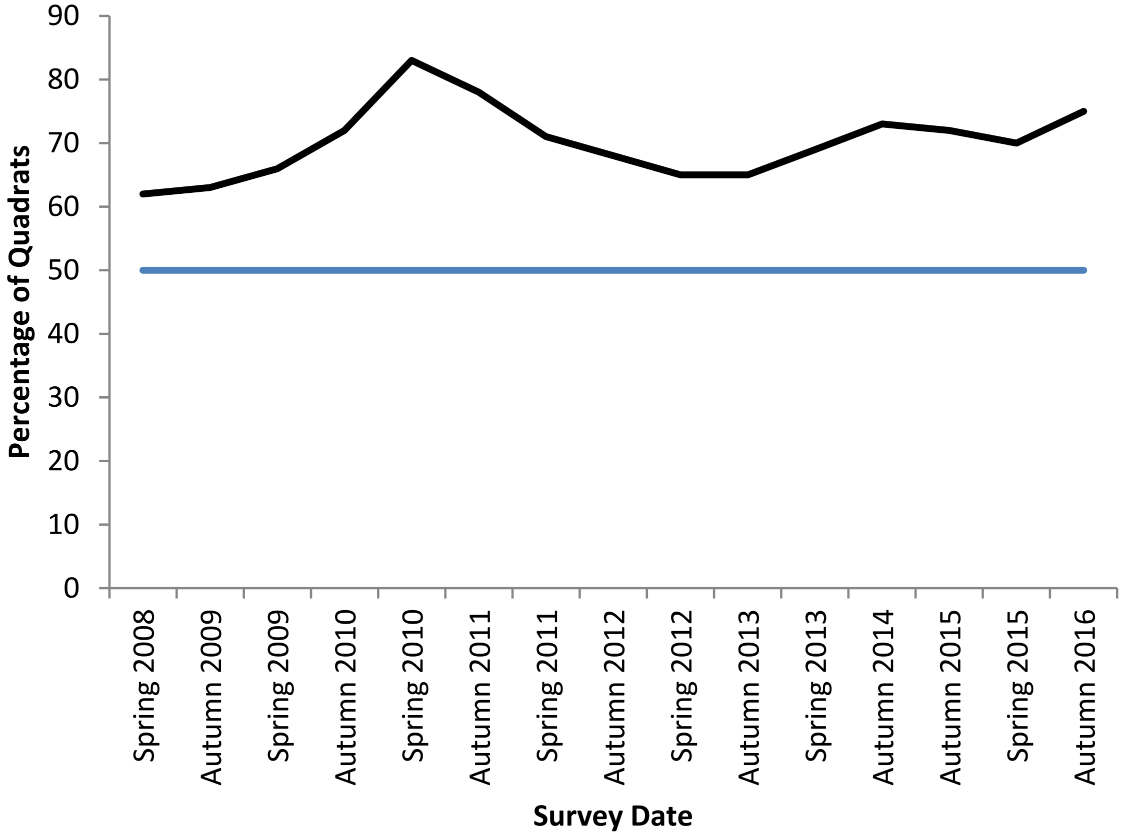

Figure 43: Percentage of quadrats containing a cover native amphibious species greater than 5% around the edge of seasonal wetlands from spring 2008 to autumn 2016.

Figure 44 shows the percentage of quadrats containing a cover of native emergent species greater than 5% around the edges of seasonal wetlands from spring 2008 to autumn 2016. The percentage of quadrats with a cover of native emergent species greater than 5% has not exceeded 50% of quadrats; therefore, this target has not been achieved during the condition monitoring program (Figure 44). However, there was an increasing trend from spring 2008 to autumn 2016 (Figure 44).

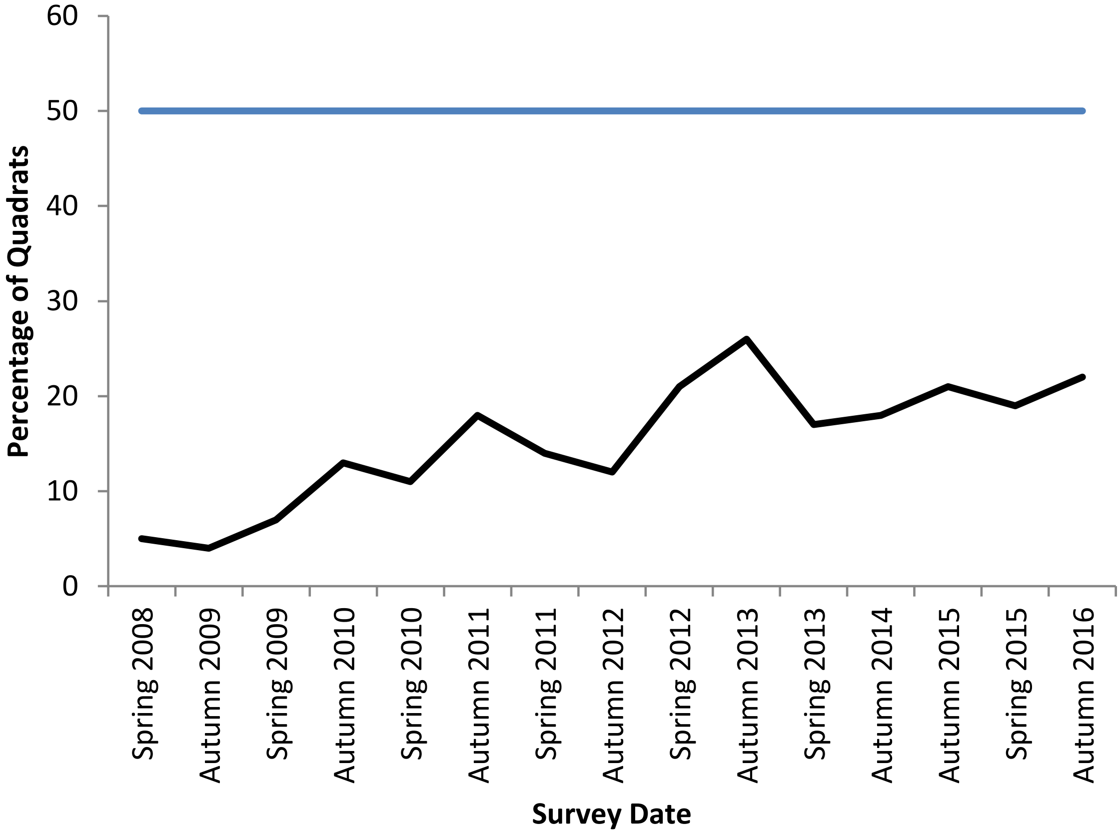

Figure 44: Percentage of quadrats containing a cover of native emergent species greater than 5% around the edge of seasonal wetlands from spring 2008 to autumn 2016.

Wetland bed

Figure 45 shows the percentage of quadrats containing a cover of native amphibious species greater than 5% on the beds of seasonal wetlands from spring 2008 to autumn 2016. Native amphibious species were less common on the beds of seasonal wetlands compared to the edges (Figure 43). The number of quadrats with a combined cover of these species greater than 5% peaked in spring 2010 (59%), after which it fell to 26% and fluctuated between 15% and 32% for the remainder of the survey period (Figure 45). The target was achieved ten times over the condition monitoring program (Figure 45).

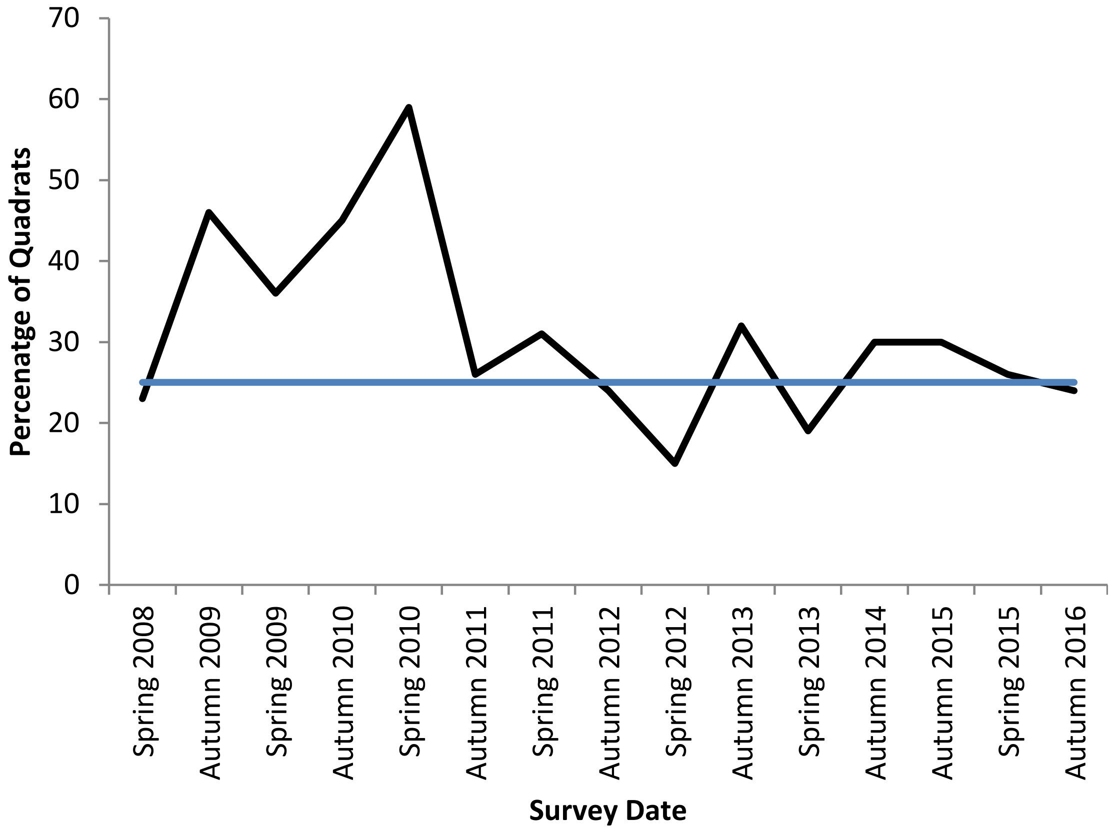

Figure 45: Percentage of quadrats containing a cover of native amphibious species greater than 5% on the bed of seasonal wetlands from spring 2008 to autumn 2016.

Figure 46 shows the percentage of quadrats containing a cover of native emergent species greater than 5% on the beds of seasonal wetlands from spring 2008 to autumn 2016. Between spring 2008 and spring 2009 there was a decrease in the number of quadrats containing a combined cover of native emergent species on the beds of temporary wetlands (Figure 46). However, the number of quadrats increased between spring 2009 and autumn 2011, after which there was a seasonal pattern with higher abundances in autumn compared to spring (Figure 46). The target of 20% of quadrats was first achieved in autumn 2011 and was achieved each subsequent survey, except in spring 2013 (Figure 46).

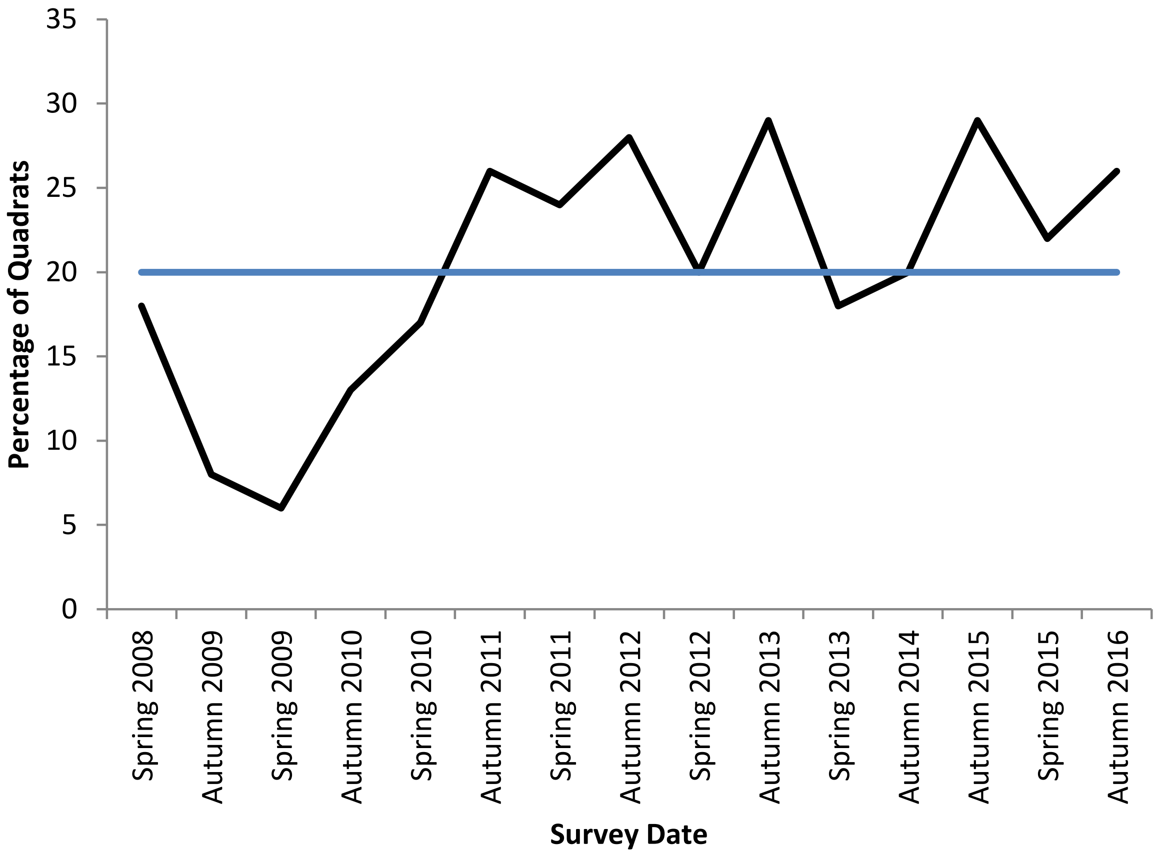

Figure 46: Percentage of quadrats containing a cover of native emergent species greater than 5% on the beds of seasonal wetlands from spring 2008 to autumn 2016.

Figure 47 shows the percentage of quadrats containing a cover of native submergent species greater than 25% on the beds of seasonal wetlands in spring from 2008 to 2016. Before spring 2011 the cover of native emergent species was low due to seasonal wetlands beds largely being dry (although there were isolated puddles in spring 2008 and 2009 that supported submergent species) (Figure 40). After water levels were reinstated in spring 2010, there has been an increasing trend in the number of quadrats containing native submergent species with a cover of greater than 25% (Figure 40). However, the target of 50% of quadrats has not been achieved over the duration of the condition monitoring program (Figure 40).

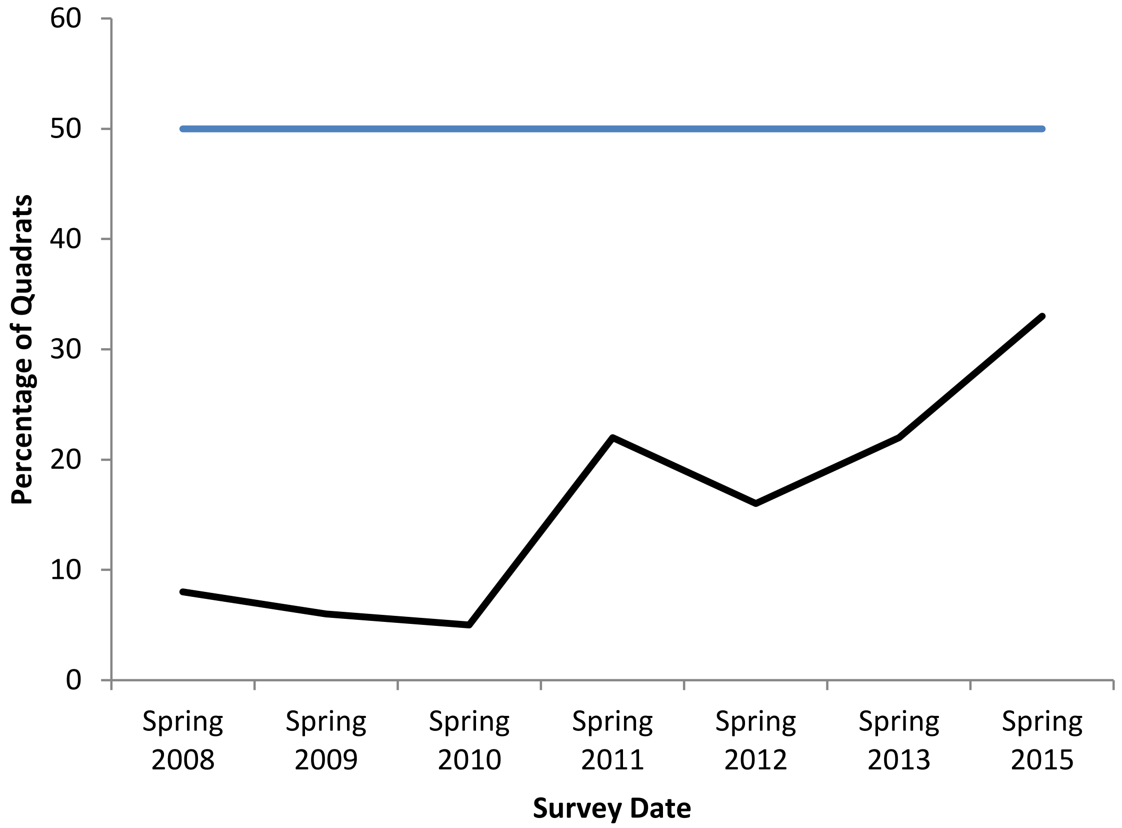

Figure 47: Percentage of quadrats containing a cover of native submergent species greater than 25% in spring on the beds of seasonal wetlands from 2008 to 2015.

Whole of habitat condition

The whole of habitat condition score for seasonal wetland is shown in Figure 48. There has not been a sustained increase in habitat condition score over the condition monitoring program for temporary wetlands (Figure 48). There is a seasonal pattern in wetland condition score with scores usually higher in autumn compared to spring, which is due to the higher abundance of native amphibious (Figure 43; Figure 45) and emergent (Figure 44; Figure 46) species and there being no submergent species target (Figure 47) in autumn.

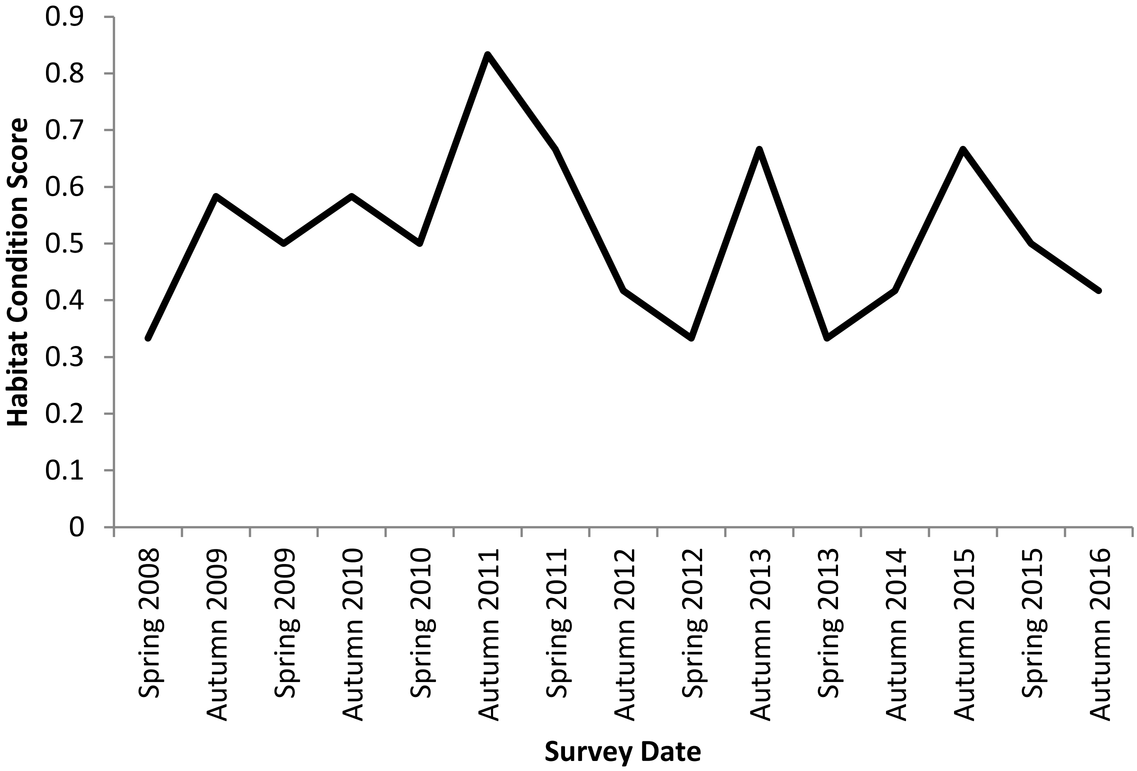

Figure 48: Whole of habitat condition score for seasonal wetlands from spring 2008 to autumn 2016.

Whole of lakes condition

The whole of lakes condition for aquatic and littoral vegetation represents the proportion of targets achieved throughout the five different habitats. There was an increase in the number of targets met between spring 2009 and spring 2011, after which there was a slight decrease before an increase between autumn 2014 and autumn 2015 followed by another slight decrease (Figure 49). The increase in condition score between spring 2009 and spring 2010 was due to increases in habitat condition scores in Lake Alexandrina (Figure 17), Lake Albert (Figure 24), Goolwa Channel (Figure 33) and seasonal wetlands (Figure 48). The decrease between spring 2011 and spring 2013 was due to decreases in habitat condition scores in Goolwa Channel (Figure 33) and seasonal wetlands (Figure 48) and the increase between spring 2013 and autumn 2015 was due to increases in habitat condition scores in Lake Alexandrina (Figure 17), Goolwa Channel (Figure 33) and seasonal wetlands (Figure 48). The decrease in condition score for the two most recent surveys was due to decreases in condition score in Goolwa Channel (Figure 33) and seasonal wetlands (Figure 48).

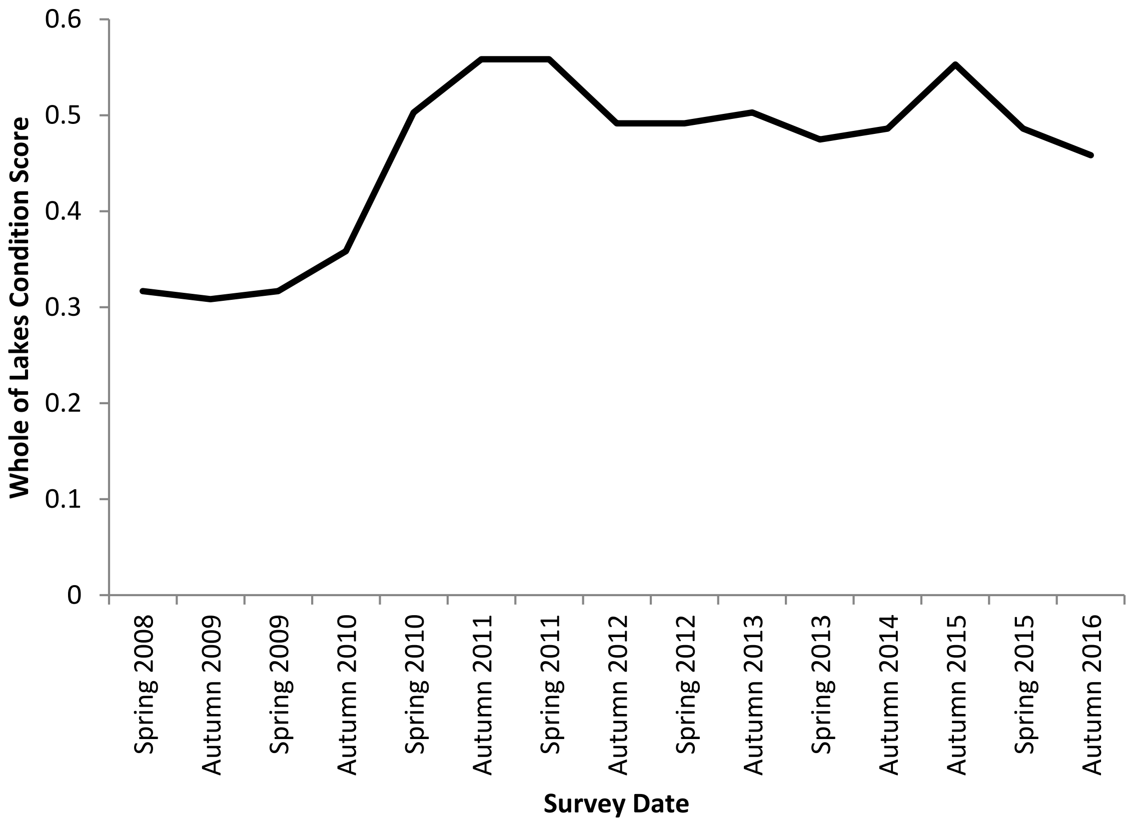

Figure 49: Whole of lakes condition score from spring 2008 to autumn 2016.

4. DISCUSSION AND MANAGEMENT IMPLICATIONS

4.1. Impacts of water level and salinity

During the most recent survey period (autumn 2015 to autumn 2016) water levels (Figure 2) and salinity (Figure 3) in Lake Alexandrina and the Goolwa Channel remained similar to those recorded since spring 2010. Electrical conductivity continued to decrease in Lake Albert, although the decrease throughout this period 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 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 have been no deliberate lake level cycles since then 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 did occur, 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 tabernaemontani*) (Nicol *et al.* 2016).

4.2. Change in plant community, spring 2008 to autumn 2016

The change in floristic composition observed over the duration of the condition monitoring program (spring 2008 to autumn 2016) has provided information regarding the recovery of the aquatic and littoral plant community after a catastrophic event that resulted in complete loss of the submergent plant community and a decrease in the abundance of amphibious and emergent species. Pooling data from each habitat, whilst losing information regarding the response of individual wetlands, has enabled the change in floristic composition to be assessed at a broader spatial scale. There were similarities in the patterns of change among habitats, such as the (unsurprising) large change when water levels were reinstated in spring 2010, the decrease in change between surveys through time and the seasonal patterns evident in some habitats.

The smaller change in floristic composition in recent surveys for all habitats except seasonal wetlands may indicate that the current plant community is one that may persist into the future with only minor changes, providing the recent salinity and water level regimes are maintained. However, multiple minor non-cyclic (seasonal) changes through time can result in there being a large (albeit gradual) change in the plant community through time. There is evidence this may have occurred in recent years in all habitats except temporary wetlands. The points on the ordinations from the latest surveys in these habitats, whilst showing less change in floristic composition between surveys, still exhibit a temporal directional change that is evident on the ordinations. Furthermore, many of the TLM targets have shown decreasing or increasing trends in the abundances of species or functional groups in recent years that suggests there may be a gradual change in floristic composition occurring through time.

The patterns observed in the temporary wetlands were expected due to the patterns in seasonal inundation and spring surveys being undertaken when submergent species were present. Whilst the spring plant community in seasonal wetlands was variable, the autumn plant community was similar among surveys. The variability between the spring surveys was due to difference in the abundances of submergent species over time. In comparison, the plant community in autumn was dominated by *Phragmites australis, Sarcocornia quinqueflora* and *Paspalum distichum*.

It is unknown whether the plant community present in recent years is comparable to the community prior to 2007 because direct quantitative comparisons between the condition monitoring data and the small amount of data collected prior to 2007 cannot be made. However, for sites where data do exist (Teringie, Narrung, Clayton Bay, Dunns Lagoon, Milang, Loveday Bay, Point Sturt and Hunters Creek) the diversity and abundance of submergent species was higher prior to 2007 compared to the recent surveys (Holt *et al.* 2005; Nicol *et al.* 2006). For example, Holt *et al.* (2005) reported extensive beds of *Vallisneria australis* and *Myriophyllum salsugineum* throughout Dunn's Lagoon almost completely covering the permanently inundated areas in spring 2004. In addition, Nicol *et al.* (2006) reported a bed of dense *Ruppia polycarpa* covering the entire inundated area of Point Sturt wetland. In the most recent surveys *Myriophyllum salsugineum* and *Vallisneria australis* were present in Dunns Lagoon and abundant in places but cover across the lagoon was patchy. In addition, *Ruppia polycarpa* has not been recorded in Point Sturt Wetland during the condition monitoring program.

4.3. The Living Murray targets and condition scores

The original vegetation target (V3) for the Lower Lakes: *maintain or improve aquatic and littoral vegetation in the Lower Lakes*, whilst an appropriate management aim and ecological objective for the system, could not properly be assessed because there is no quantitative baseline. Furthermore, baseline data would need to be collected over 5–10 years to determine the natural (acceptable) variability of the system. Davis and Brock (2008) identified this as a problem when determining limits of acceptable change for wetlands of international importance under the Ramsar Convention. They proposed that conceptual models be developed to determine limits of acceptable change and to design a monitoring program to assess and refine the proposed limits of acceptable change (Davis and Brock 2008). Nicol (in review) proposed limits of acceptable change (and management triggers) for aquatic and littoral vegetation in the Coorong and Lakes Alexandrina and Albert Ramsar Wetland using conceptual models (*sensu* Davis and Brock 2008) and TLM aquatic and littoral vegetation targets were based on proposed limits of acceptable change management triggers.

The refined targets were based largely on expert opinion; however, data from the 2005 (Holt *et al.* 2005), 2006 (Nicol *et al.* 2006), habitat mapping (Seaman 2003), biological surveys of conservation reserves adjacent to the Murray Mouth (Brandle *et al.* 2002), a survey of the aquatic vegetation of Hindmarsh Island (Renfrey *et al.* 1989) and condition monitoring data were also used to develop the targets. The condition monitoring program was designed prior to the development of the refined targets but was sufficiently robust to assess and (in the future) refine the targets in addition to providing data to monitor change in floristic composition through time.

The habitat with the highest proportion of targets achieved in the most recent surveys and; therefore, the highest condition score was Lake Alexandrina. The condition score for Lake Alexandrina has either been stable or increasing since water levels were reinstated. In addition, there has generally been progress towards achieving the targets that require an increase in the abundance of desirable species (e.g. native amphibious, submergent and emergent species other than *Typha domingensis* and *Phragmites australis*) that have not yet been achieved. There was also a downward trend in the number of quadrats that were dominated by *Paspalum distichum* and *Cenchrus clandestinus* after spring 2010; however, there was an increase in the number of quadrats dominated by *Typha domingensis* and *Phragmites australis*. These trends suggest that the condition score in Lake Alexandrina will continue to improve through time as more targets are achieved.

The condition score for Lake Albert has also been stable or increasing since water levels were reinstated. There has been a downward trend in quadrats dominated by *Paspalum distichum* and *Cenchrus clandestinus* after spring 2010 and the increase in the number of quadrats dominated by *Typha domingensis* and *Phragmites australis* has been much lower than Lake Alexandrina. However, the progress towards achievement of targets that require an increase in the abundance of desirable species observed in Lake Alexandrina has generally not been observed in Lake Albert. Therefore, an increase in condition score in the future is less likely in Lake Albert compared to Lake Alexandrina.

In contrast to lakes Alexandrina and Albert, the condition score in the Goolwa Channel has decreased in recent surveys. This was primarily due to an increase in the number of quadrats dominated by *Typha domingensis* and *Phragmites australis* in the littoral zone and a decrease in the abundance of submergent species in the deep water zone in recent surveys. However, since spring 2010 the number of quadrats dominated by *Typha domingensis* and *Phragmites australis* in the littoral and aquatic zones has been relatively stable (with the exception of the most recent surveys in the littoral zone) and fluctuated around the target levels. Similar to Lake Alexandrina, there has generally been progress towards achieving the targets that require an increase in the abundance of desirable species that suggests the condition score for Goolwa Channel will increase in the future.

The condition score for permanent wetlands has remained constant since spring 2009 and is lower than that for lakes Alexandrina and Albert. However, there has been a downward trend in the number of quadrats dominated by *Paspalum distichum* and *Cenchrus clandestinus* to levels approaching the target. Furthermore, there has been progress towards achieving the targets that require an increase in the abundance of desirable species since water levels were reinstated (except emergent species other than *Typha domingensis* and *Phragmites australis* in the aquatic zone). Therefore, an increase in condition score for permanent wetlands in expected in the future.

The condition score for seasonal wetlands over the duration of the condition monitoring program has been variable. The peaks in autumn are due to there being not being a submergent vegetation target for this season and recent downward trend was due to an increase in the number of quadrats dominated by *Paspalum distichum* and *Cenchrus clandestinus* (which has shown an increasing trend since spring 2008). However, the number of quadrats containing submergent species with a cover of greater than or equal to 25% on the wetland bed in spring and cover of native emergent species on the wetland bed and around the edge have generally increased since spring 2010. These trends, if they continue, suggest that the condition score for seasonal wetlands will increase in the future.

The progress towards achieving most of the targets that require an increase in the abundance of desirable taxa (i.e. upward trend in abundance of quadrats containing the target species above a certain cover) in most zones of most habitats suggests that there will be an increase in the whole of lakes condition score in the future as these targets are achieved. These trends suggest that under the current hydrological and salinity regime the plant community is recovering from the period of low water levels and condition is improving through time. Therefore, it is important that the current salinity and water level regimes are maintained to provide conditions for the continual (albeit slowing) improvement of vegetation condition.

4.4. Further studies

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

- continue to extend the time-series data generated by 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 the 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 (e.g. *Typha domingensis, Phragmites australis, Schoenoplectus tabernaemontani, Vallisneria australis, Myriophyllum salsugineum*);
- investigate the effects of elevated but 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 the Goolwa Channel;
- investigate the relationships between plant communities and other biotic groups such as fish, birds and invertebrates;
- investiagte different control methods for *Paspalum distichum* and *Cenchrus clandestinus* 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: 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
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

Taxon	Functional Group	Life history strategy	Status and Comments
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
*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

Taxon	Functional Group	Life history strategy	Status and Comments
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
*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

Taxon	Functional Group	Life history strategy	Status and Comments
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
*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 2: 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 3: Taxa present (green shading) in each wetland from spring 2008 to autumn 2016 (*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		*									
*Cenchrus clandestinus**	*					*					
*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	*	*	*	*	*	*	*	*		*	
*Lactuca saligna**		*			*	*					

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

Appendix 4: 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		*	
*Pennisetum clandestinum**	*	*	*
*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	*	*	*

Species	Lake Albert	Lake Alexandrina	Goolwa Channel
Juncus usitatus	*	*	*
*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**	*	*	*
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 tabernaemontani	*	*	*
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	*	*	*
*Urtica urens**		*	

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