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Lower Lakes Vegetation Condition Monitoring 2021-22

J.M. Nicol, K.A. Frahn, S.L. Gehrig,
K.B. Marsland and L. Bucater

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Report to the Department for Environment and Water

Government of South Australia
Department of Primary Industries and Regions

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SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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Cover Photo: *Schoenoplectus tabernaemontani* in Lake Albert at Meningie (J.M Nicol).

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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EXECUTIVE SUMMARY

The Lower Lakes, Coorong and Murray Mouth region is one of six icon sites under "The Living Murray" (TLM) program and is an indicator site under the "Basin Plan". The Condition Monitoring Plan for the Lower Lakes, Coorong and Murray Mouth (LLCMM) Icon Site (Maunsell Australia Pty Ltd 2009) identified that existing monitoring programs would not adequately assess TLM target V3, *maintain or improve aquatic and littoral vegetation in the Lower Lakes*; therefore, a monitoring program that expanded and built upon existing programs was established in spring 2008. 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 nested under the original target (now included as an objective and reported on using the same index as the Basin Plan environmental outcome reporting (Matter 8). The updated quantitative targets and methodologies are outlined in the Condition Monitoring Plan (Revised) 2017 for the Lower Lakes, Coorong and Murray Mouth Icon Site (Department for Environment, Water and Natural Resources 2017). To develop the quantitative targets the Lower Lakes were divided into five different habitats (Lake Alexandrina, Lake Albert, Goolwa Channel, permanent wetlands and seasonal wetlands), with each habitat comprising zones based on elevation. Targets were developed for species and functional groups in each zone and 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 12 years of a monitoring program established to evaluate TLM Target Objective V3 from spring 2008 to autumn 2022.

Vegetation surveys were conducted at selected wetlands and lakeshore sites across lakes Alexandrina and Albert, Goolwa Channel, lower Finniss River, lower Currency Creek and the mouths of the Angas and Bremer Rivers. Sites established in spring 2008 and 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 one metre were positioned 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 in spring (October 2008, 2009, November 2010, October 2011, 2012, 2013, 2015, in temporary wetlands in December 2016, all sites in November 2017, 2018, 2019, December 2020 and 2022) and autumn (March 2009 to 2017, April 2018, May 2021 and April 2022). In addition, *Melaleuca halmaturorum* age class structure (using

the method described in Stewart *et al.* (2000) and Telfer et al. (2000)) and stand extent were monitored in spring 2008, autumn 2014 and autumn 2022.

The first two years of the monitoring program coincided with a period of record low water levels in the Lower Lakes. During this period, significant engineering interventions (i.e. construction of the Clayton Regulator and Narrung Bund and pumping of water for the environment into Narrung Wetland) also influenced plant communities and were assessed 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 +1.1 and +0.4 m AHD, and connectivity throughout the system, continued from 2010 throughout the remainder of the monitoring program.

Over the 13 years of condition monitoring (spring 2008 to autumn 2022), a total of 167 taxa (including 77 exotics, two weeds of national significance, five proclaimed pest plants in South Australia and one species listed as rare in South Australia) were recorded throughout the Lower Lakes (Appendix 1). Lake Alexandrina was the most species rich of the habitats with 121 taxa (including 56 exotics) recorded between spring 2008 and autumn 2022, followed by permanent wetlands (99 taxa, including 36 exotics), then temporary wetlands (96 taxa, including 43 exotics), Goolwa Channel (80 taxa, including 30 exotics) and Lake Albert the least species rich with 61 taxa (including 32 exotics).

Changes through time of the plant community in each habitat indicated a shift in floristic composition during the condition monitoring program (nMDS ordination 2008–2022). 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 less 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 plant community in the future. In the seasonal wetlands there were strong seasonal patterns in the plant community after spring 2010 due to seasonal inundation. Submergent species were abundant in spring, when seasonal wetlands were inundated but absent in autumn, replaced by amphibious and emergent taxa.

Achievement of the targets varied among habitats through time; generally, very few targets were achieved in all habitats when water levels were low but shortly after water levels were reinstated the number of targets achieved generally increased. After spring 2010, patterns in achieved targets were variable. In lakes Alexandrina and Albert, the number of targets achieved remained stable until the last six years when the abundance of several desirable taxa increased such that additional targets were achieved. In Goolwa Channel, the number of targets achieved increased until spring 2011, then decreased due to the increase in abundance of *Typha domingensis* and *Phragmites australis* and a decrease in submergent species. There was an increase in submergents in the deep-water zone in autumn 2018 resulting in the target being met for this zone and an increase in the habitat condition score; however, this target was not met in spring 2018 and the habitat condition score decreased but the deep water submergents and other targets were met in subsequent surveys resulting in an increase in habitat condition score. In permanent wetlands, the number of targets achieved has remained constant from spring 2010 to spring 2019 after which there was an increase. In temporary wetlands, it peaked in autumn 2011 although it was highly variable with the most recent survey having the second highest habitat condition score. The Whole of Icon Site Score (WOISS) for assessing the condition of the Lower Lakes has remained relatively stable from autumn 2011 to spring 2018 after which there was an increasing trend. The vegetation of the Lower Lakes has been in good condition using the Matter 8 condition scale for the four most recent surveys. Progress of most targets in all habitats (yet to be achieved) shows they are tracking towards being achieved in the future. Therefore, under current hydrological conditions it is likely that the number of targets achieved in the future will further increase (and habitat and WOISS condition will improve) resulting in the TLM Objective V3: *maintain or improve aquatic and littoral vegetation in the Lower Lakes* continuing to be achieved.

Melaleuca halmaturorum trees were generally <50 years old throughout the Lower Lakes, except for the stand at the mouth of Hunters Creek where older trees were present. Recruitment between 2014 and 2022 was limited to Hunters Creek (although some juvenile trees may have been planted). The seedlings and saplings detected on Goat Island in 2008 and 2014 did not survive to 2022, probably due to grazing by sheep and goats. Despite limited recruitment in recent years, the spatial extent of *Melaleuca halmaturorum* stands increased over the condition monitoring program due to canopy expansion of existing trees.

Keywords: Lake Alexandrina, Lake Albert, aquatic vegetation, *Melaleuca halmaturorum*.

1. INTRODUCTION

1.1. Background

The Lower Lakes, Coorong and Murray Mouth region is one of six icon sites under "The Living Murray" (TLM) program and is 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 includes results from the first 13 years of the understorey component of the condition monitoring program designed to evaluate TLM Target V3 (now referred to as objective 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; Nicol *et al.* 2016a; 2017; 2019a; 2019b; 2020; 2021).

Marsland and Nicol (2006) identified that monitoring programs in existence in 2006 could not adequately assess TLM target V3; therefore, a monitoring program that expanded and built upon the 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 former River Murray Catchment Water Management Board 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 were subsequently included in TLM Condition Monitoring Program (Gehrig *et al.* 2010; 2011b; 2012; Frahn *et al.* 2013; 2014; Nicol *et al.* 2016a; 2017; 2019a; 2019b; 2020; 2021).

The 2009 Condition Monitoring Plan for the Lower Lakes, Coorong and Murray Mouth (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, discussions concluded that the entire understorey aquatic and littoral vegetation assemblage would be monitored with a separate technique used for the dominant tree species *Melaleuca halmaturorum* (which was monitored in spring 2008, autumn 2014 and autumn 2022).

Monitoring aquatic and littoral understorey vegetation involves surveys 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.

From 1996 to 2010, the Murray-Darling Basin experienced 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 the 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, Althenia* (formerly named *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 (Jenny's Lagoon) 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 Raukkan and in Loveday Bay Wetland). The charophyte *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 (completed in early 2008), the Clayton Regulator and the Currency Creek Regulator (both completed in August 2009) (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 megalitres (ML) of water for the environment being pumped from Lake Alexandrina 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 water release in 2006-07 to operate fishways). Furthermore, the Clayton Regulator and Narrung Bund were breached in September 2010, and Lake Alexandrina was reconnected with Goolwa Channel and Lake Albert. After spring 2010, water levels were restored to historical levels ranging from +0.9 m AHD in spring when lakes were surcharged to +0.4 m AHD in autumn during periods of managed draw-down. The impacts of the regulators, pumping, unregulated River Murray flows and managed draw down on salinity and water levels throughout the condition monitoring program 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, entitlement flows and managed draw-down 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 <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 largely reflected historical patterns.

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 vegetation information was available for wetlands through the 2004 (Holt *et al.* 2005) and 2005 (Nicol *et al.* 2006) River Murray wetlands baseline surveys, biological surveys of 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 there was a diverse submergent, emergent and amphibious plant community in 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 updated quantitative targets and methodologies are outlined in the Condition Monitoring Plan (Revised) 2017 for the Lower Lakes, Coorong and Murray Mouth Icon Site (Department for Environment, Water and Natural Resources 2017). Within this Plan, the original target V3 is now referred to as an objective, with the quantitative targets nested below the objective.

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 was a seasonal component for temporary wetlands with targets for spring (high water level) and autumn (low water level).

Due to the 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 monitored. 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 understorey 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 the undesirable species: *Paspalum distichum, Cenchrus clandestinus, Phragmites australis* and *Typha domingensis*.

Vegetation targets for Lake Alexandrina are presented in Table 1. The 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

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

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 were present in the deep water zone and a higher proportion of quadrats 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)

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 than 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 present 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)

Targets for seasonal wetlands are presented in Tables 5a and b. Prior to 2007, seasonal wetlands in spring generally contained high numbers of submergent species (submergent r-selected species (*sensu* Casanova 2011) such as *Ruppia tuberosa, Ruppia polycarpa, Althenia 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 5a) 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 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 Icon Site Scores (WOISS) were developed to assess the condition of the lakes. The habitat condition score represents the proportion of targets achieved in a particular habitat and the WOISS represents the proportion of targets achieved in the different habitats. The WOISS is also used for Basin Plan environmental outcome reporting (Matter 8) and will be used to report on objective V3 using the same scale (Table 6) (DEW in prep.). A Matter 8 condition rating of good represents aquatic and littoral vegetation being maintained and a rating of very good represents condition is improving.

Table 6: Icon site scores for aquatic and littoral vegetation for the Lower Lakes with the condition rating used in Matter 8 Report Cards (Department for Environment and Water 2019).

Icon site score	Matter 8 condition rating
0.80-1.00	Very good
0.60-0.79	Good
0.40-0.59	Fair
<0.40	Poor

1.3. Objectives

The surveys undertaken in spring 2021 and autumn 2022 builds on data collected between spring 2008 and autumn 2021 and provides information regarding the change in plant communities over this period. However, in spring 2016 surveys were only undertaken in seasonal wetland habitats with all sites surveyed in autumn and spring 2017. From autumn 2018 onwards, surveys were not undertaken in Milang and Waltowa wetlands.

The monitoring program includes a period of record low water levels in Lake Alexandrina, several engineering interventions, two large unregulated River Murray flow events (one in 2010/11 that reinstated historical water levels and one in spring/summer 2016), three in-channel flow pulses, entitlement flows, water for the environment provisions (that maintained historical water levels), managed draw-down to +0.5 m AHD in late summer and autumn 2018 and surcharge in spring 2019 to +0.9 m AHD. Therefore, this monitoring program collected information regarding the change in aquatic and littoral plant communities in response to draw-down, desiccation, increased water levels due to regulated inundation, natural flooding, spring surcharging of the lakes and managed drawn-down 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 Objective V3 (Department for Environment, Water and Natural Resources 2017);
- report on the revised vegetation targets for each habitat and determine habitat condition using the WOISS;
- monitor the recovery of the aquatic plant community after hydrological restoration following extended drought, draw-down, fragmentation and desiccation of aquatic habitats;
- investigate the longevity of the managed draw-down in late summer and autumn 2018
- compare the age class structure and extent of *Melaleuca halmaturorum* stands between 2008, 2014 and 2022.

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 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 inflows and barrage operations. Water level and surface water electrical conductivity in the Lower Lakes from August 2008 to April 2020 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 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).

Since 2011/12, water level management objectives for the Lower Lakes have focused on annual fluctuations within a range from +0.4 to +0.9 m AHD to achieve ecological benefits. In late summer and autumn 2018 water levels were drawn down to around +0.5 m AHD for the longest period since the Millennium Drought. Water levels were also drawn down to a similar level in autumn 2019 and surcharged to +0.9 m AHD in spring 2019 with a similar pattern in autumn 2019 and spring 2020. In autumn 2021 and 2022 water levels were drawn down to around +0.6 m AHD (Figure 2). It is expected that these management actions will promote the establishment of amphibious species in the littoral zone. Figure 2 indicates that lakes levels have generally followed this pattern with the exception of water levels reaching maximums of >+0.9 m AHD in spring 2016, 2019, 2020 and 2021.

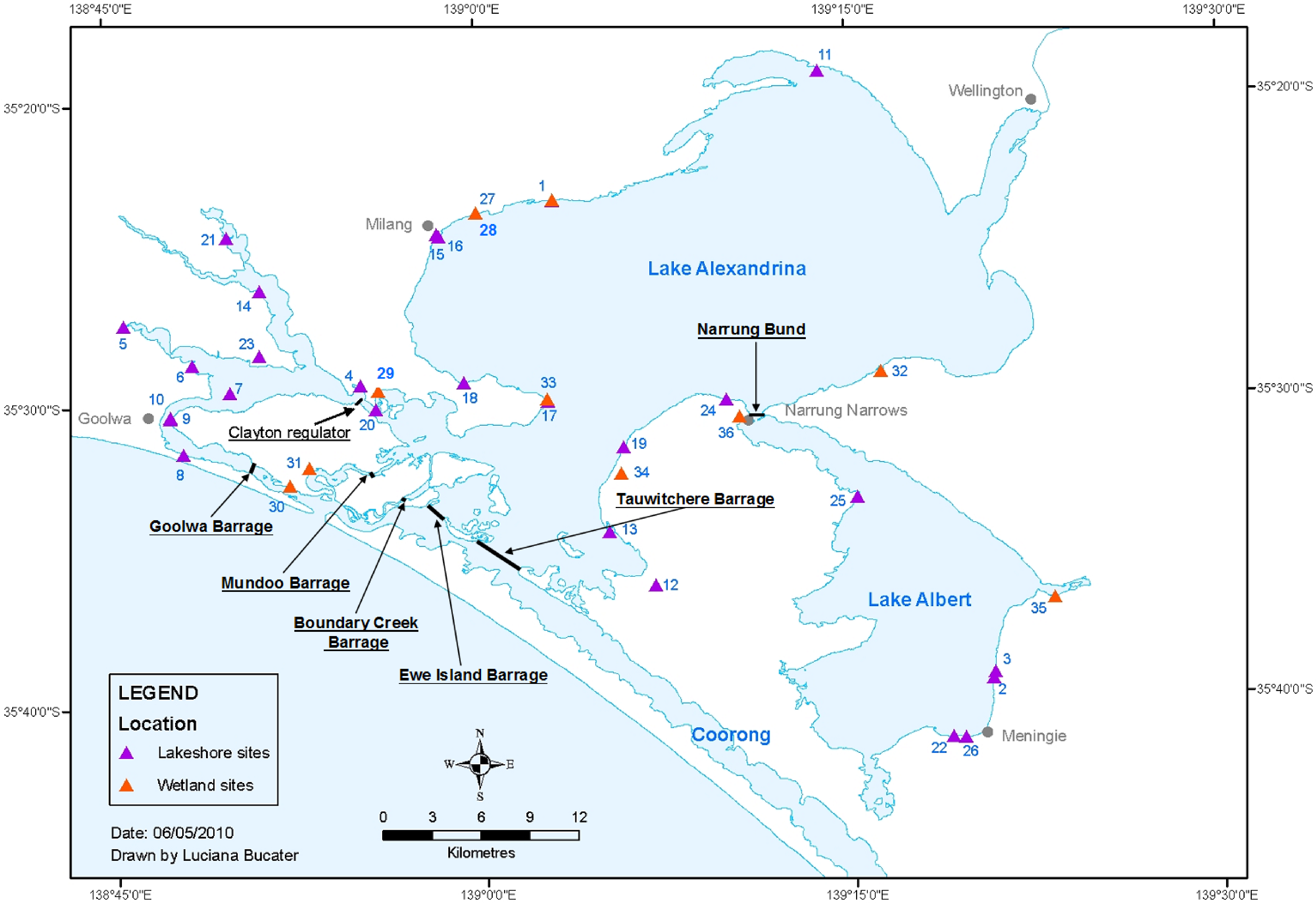


Figure 1: Map of Lakes Alexandrina and Albert and Goolwa Channel showing the location of lakeshore and wetland vegetation monitoring sites (site numbers correspond to Table 7) and major flow control structures present in winter 2010 (where sites are in close proximity they may not be visible on map).

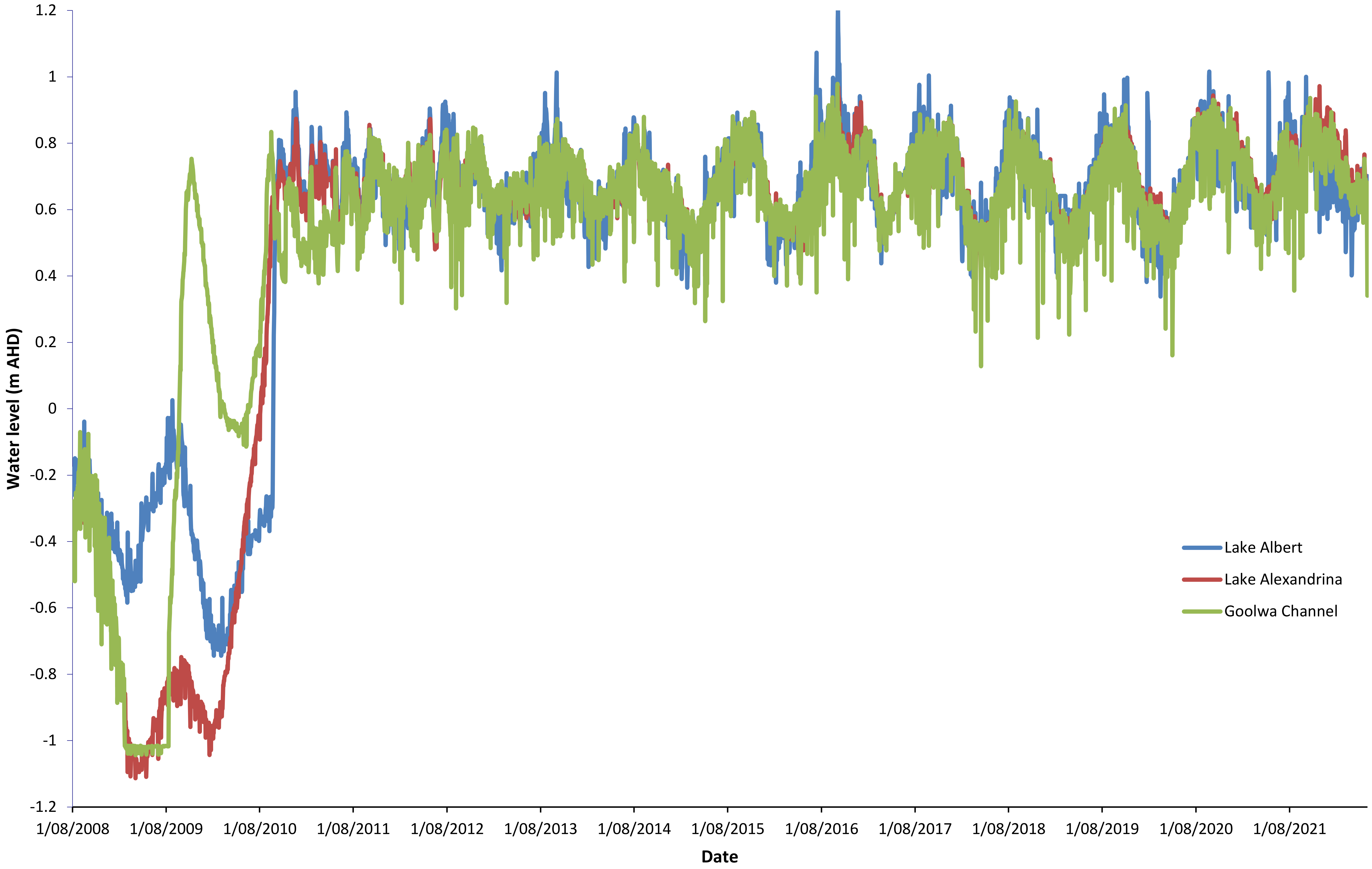


Figure 2: Daily mean water levels in Goolwa Channel (Signal Point), Lake Alexandrina (Milang) and Lake Albert (Meningie) from August 2008 to May 2022 (Department for Environment and Water 2022b).

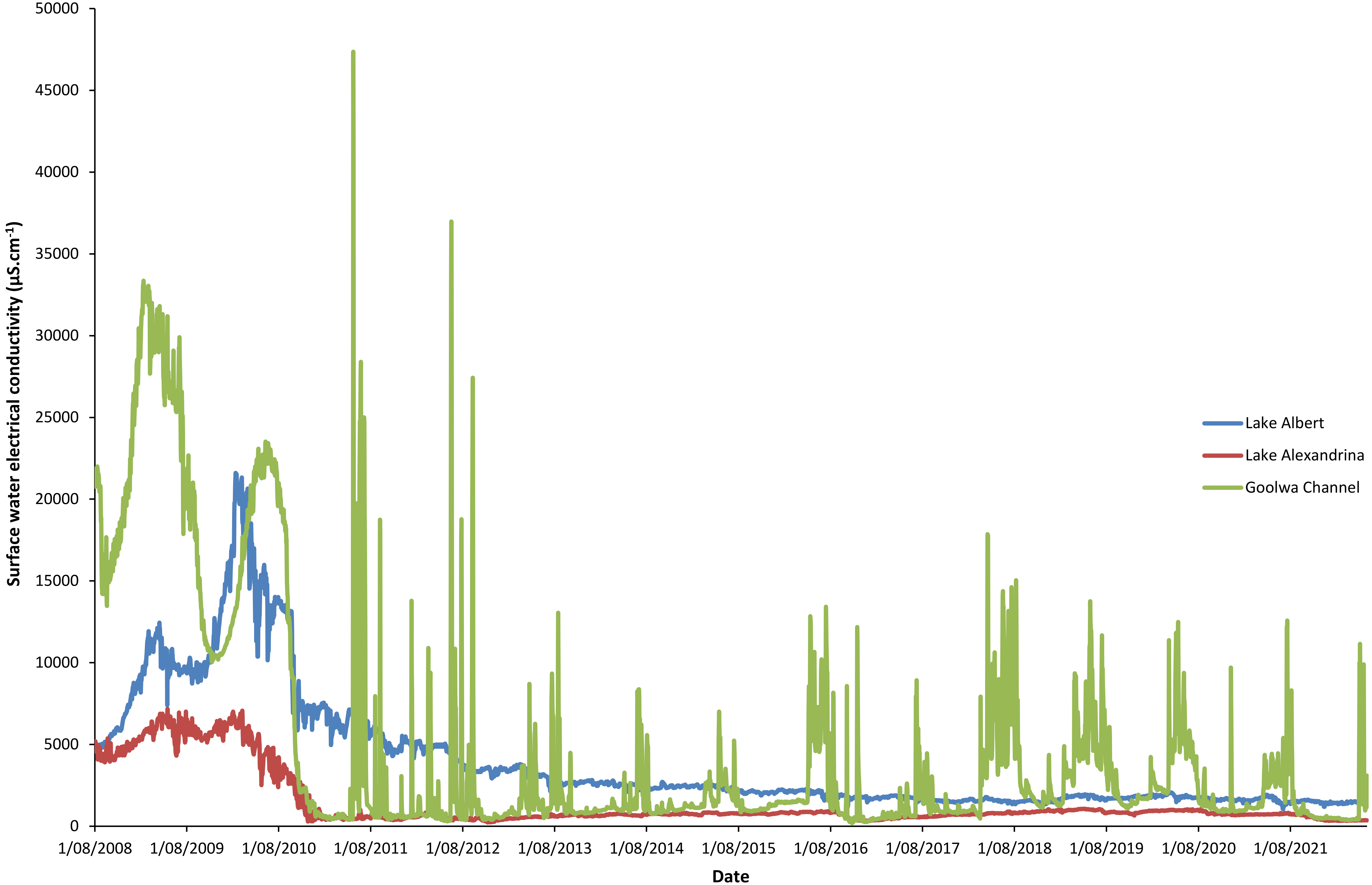


Figure 3: Daily mean surface water electrical conductivity (EC) in Goolwa Channel (Signal Point), Lake Alexandrina (Milang) and Lake Albert (Meningie) from August 2008 to May 2022 (Department for Environment and Water 2022a).

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, March 2016, December 2016 (temporary wetlands only), March 2017, November 2017, April 2018 (except Milang and Waltowa wetlands), November 2018, November 2019, December 2020, May 2021, December 2021 and April 2022 (Table 7). Sites were grouped based on 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 7: 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 7), a transect running perpendicular to the shoreline and three, 1 x 3 m quadrats, separated by one metre, were established (Figure 4) at regular elevation intervals that represented the dominant plant communities (A. Rumbelow 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 8).

Table 8: 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

Apart from 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 one metre, 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 (2022).

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 by non-metric multidimensional scaling (nMDS) ordination using the package PRIMER version 7.0.12 (Clarke and Gorley 2015). Bray-Curtis (1957) similarities were used to construct the similarity matrices for the nMDS ordinations on untransformed data.

Native species richness at +0.6 m AHD in Lakes Alexandrina, Lake Albert and Goolwa Channel was plotted through time to assess the benefit of the managed draw down in autumn 2018. This elevation was chosen because it represented the zone that was inundated in spring and exposed by the managed draw-down in autumn 2018, 2019 and 2020.

2.4. *Melaleuca halmaturorum* age class structure and extent

Age class structure and recruitment of *Melaleuca halmaturorum* was determined using the method developed for this species as part of the Deep Swamp (Stewart 2000) and Tilley Swamp (Telfer *et al.* 2000) vegetation monitoring programs (Table 9). Three transects running perpendicular to the lakeshore that spanned the entire stand (where possible and if it was not possible to walk through the stand extra transect were established on the edges of stands) were established at Salt Lagoon, Hunters Creek, Kennedy Bay, Goose Island and Boggy Creek in spring 2008 (Figure 5). All trees within 5 m of the centre of each transect were assessed. Age class structure was assessed at all sites in spring 2008 and at all sites except Salt Lagoon in autumn 2014 and autumn 2022. It was deemed unnecessary to monitor *Melaleuca halmaturorum* annually as they are long-lived trees.

Table 9: *Melaleuca halmaturorum* age class structure assessment (Stewart 2000).

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

Spatial extent of *Melaleuca halmaturorum* stands was measured using high resolution aerial imagery. Polygons were drawn around existing ground-truthed stands on images taken in 2003, 2008, 2014 and 2022 and the area of each polygon calculated using ARC-GIS.

Figure 5: Map of the southern section of lakes Alexandrina and Albert showing the locations of *Melaleuca halmaturorum* monitoring sites.

3. RESULTS

3.1. Change through time of the Lower Lakes plant community from spring 2008 to autumn 2022

Over the 13 years of condition monitoring (spring 2008 to autumn 2022), a total of 167 taxa (including 77 exotics, two weeds of national significance, five proclaimed pest plants in South Australia and one species listed as rare in South Australia) were recorded throughout the Lower Lakes (Appendix 1). Species lists of each habitat (Lake Alexandrina, Lake Albert, Goolwa Channel, permanent wetlands and temporary wetlands) and the surveys they were recorded are presented in Appendices 3 to 7). Lake Alexandrina was the most species rich of the habitats with 121 taxa (including 56 exotics) recorded between spring 2008 and autumn 2022, followed by permanent wetlands (99 taxa, including 36 exotics), then temporary wetlands (96 taxa, including 43 exotics), Goolwa Channel (80 taxa, including 30 exotics) and Lake Albert the least species rich with 61 taxa (including 32 exotics).

Patterns of temporal change in the plant community for each habitat showed a shift in floristic composition over the condition monitoring program (nMDS ordination; Figures 5 to 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 (Figures 6 to 10).

Lake Alexandrina

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 6). 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 6) with emergent taxa typically more abundant in spring and amphibious taxa in autumn (Frahn *et al.* 2014). From autumn 2013 to spring 2017 the change in the plant community has been small, in comparison to previous years, but seasonal patterns were similar (Figure 6) with emergent taxa more abundant in spring and amphibious and submergent taxa in autumn. There was a small shift in the plant community between spring 2017 and autumn 2018 due to an increase in species richness in the littoral zone and less change between autumn and spring 2018 (compared to previous years) as most of these species persisted, after which there has been little change in the plant community (Figure 6).

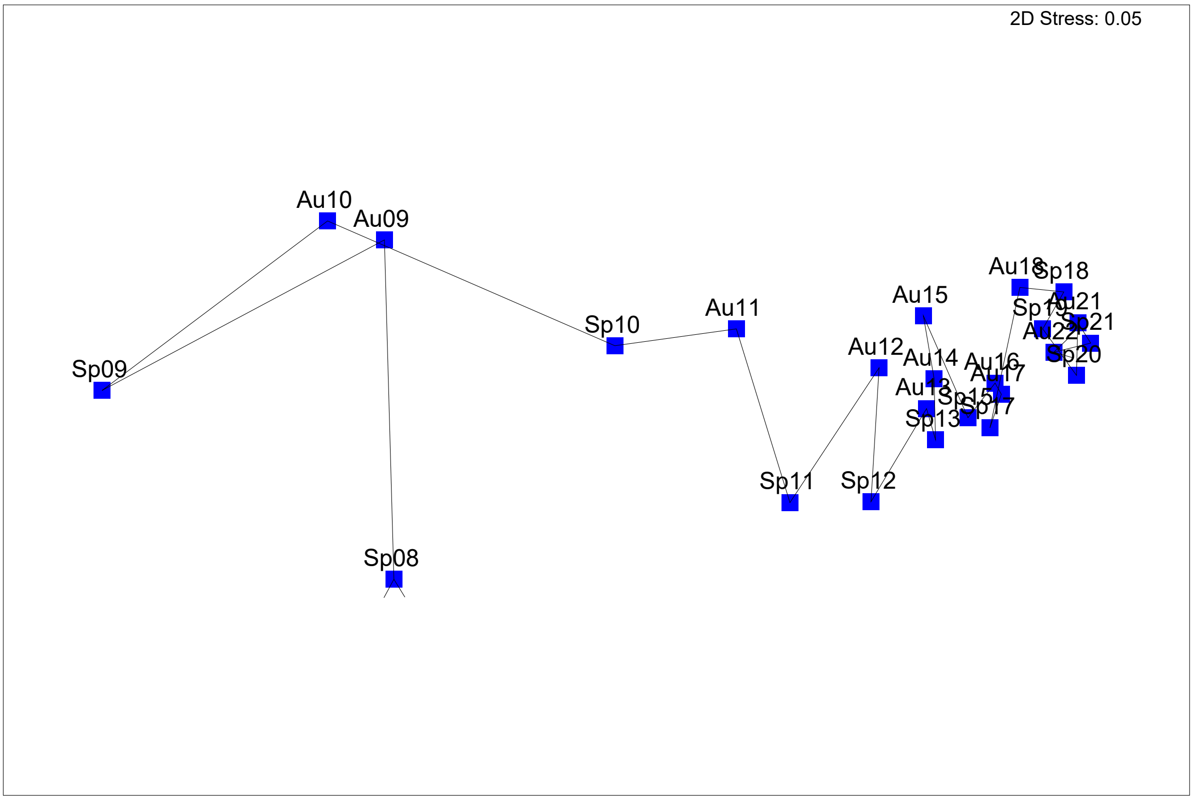


Figure 6: nMDS ordination comparing the plant community between spring 2008 and autumn 2022 in Lake Alexandrina (Sp denotes spring; Au denotes autumn).

Lake Albert

Similar to Lake Alexandrina (Figure 6), the plant community in Lake Albert was dominated by terrestrial species with large changes in floristic composition (Figure 7) 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 7) was driven by an increase in emergent and amphibious species. Since spring 2010, there has been a gradual change in floristic composition (Figure 7) primarily driven by an increase in the abundance of *Typha domingensis*. In contrast to Lake Alexandrina, seasonal changes in floristic composition were not evident and there was little change between autumn 2017 and spring 2019 (Figure 7). However, between spring 2019 and spring 2020 there was a comparatively large change in the plant community driven by decreases in abundance of native amphibious species and *Paspalum distichum* and *Cenchrus clandestinus* (Figure 7). There was little change in floristic composition until autumn 2022 when the community became similar to spring 2018 and autumn 2019 (Figure 7).

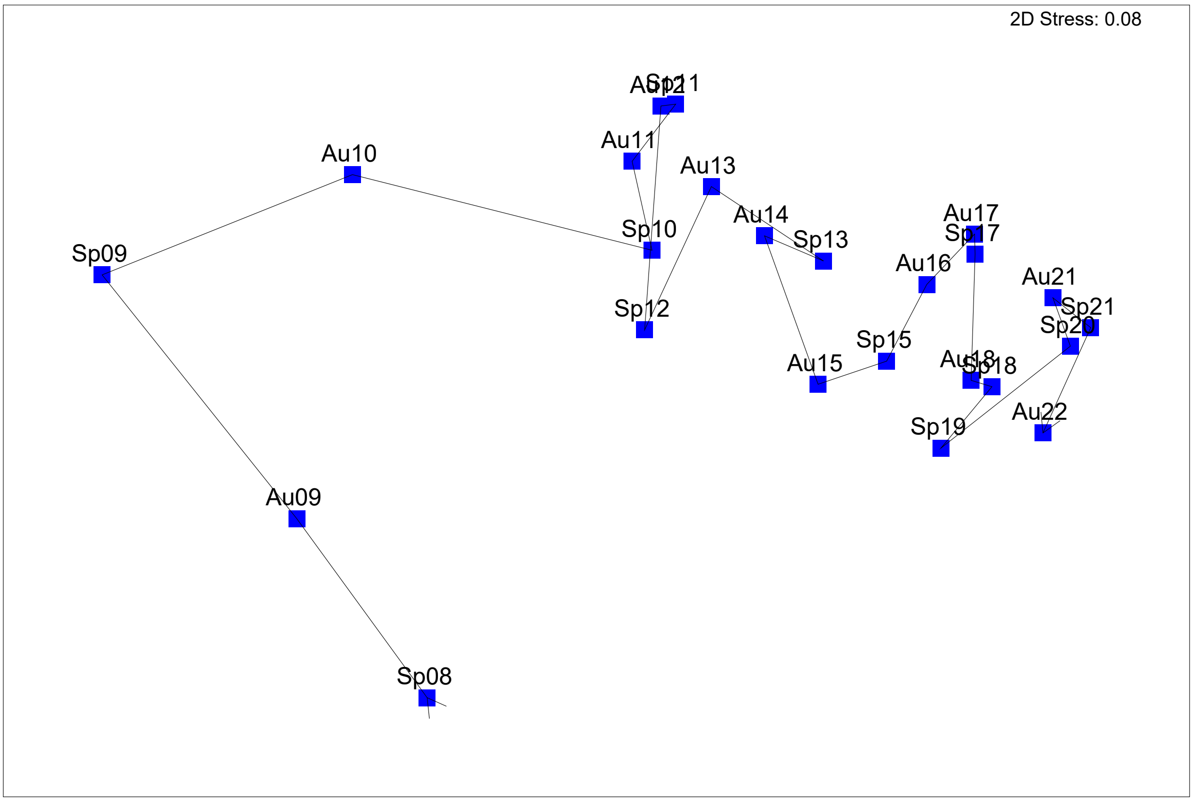


Figure 7: nMDS ordination comparing the plant community between spring 2008 and autumn 2022 in Lake Albert (Sp denotes spring; Au denotes autumn).

Goolwa Channel

Similar to lakes Alexandrina (Figure 6) and Albert (Figure 7), 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 8). This change was driven by terrestrial species being extirpated with extensive beds of the submergent species *Potamogeton pectinatus* recruiting throughout 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 of 2009 and 2010 (Figure 8), which was a result of the Clayton Regulator being breached and a rapid reduction in surface water salinity (Figure 3). These 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 8). The change between spring 2010 and spring 2011 (Figure 8) was driven primarily by an increase in the abundance of *Typha domingensis*. There were seasonal changes in vegetation between spring 2011 spring 2013 (Figure 8) driven by higher abundances of *Typha domingensis* and *Phragmites australis* in autumn. After spring 2013, there was very little change in floristic composition and until autumn 2018 when there was an increase in amphibious taxa in the littoral zone and submergents in the deep-water zone with little change since then (Figure 8).

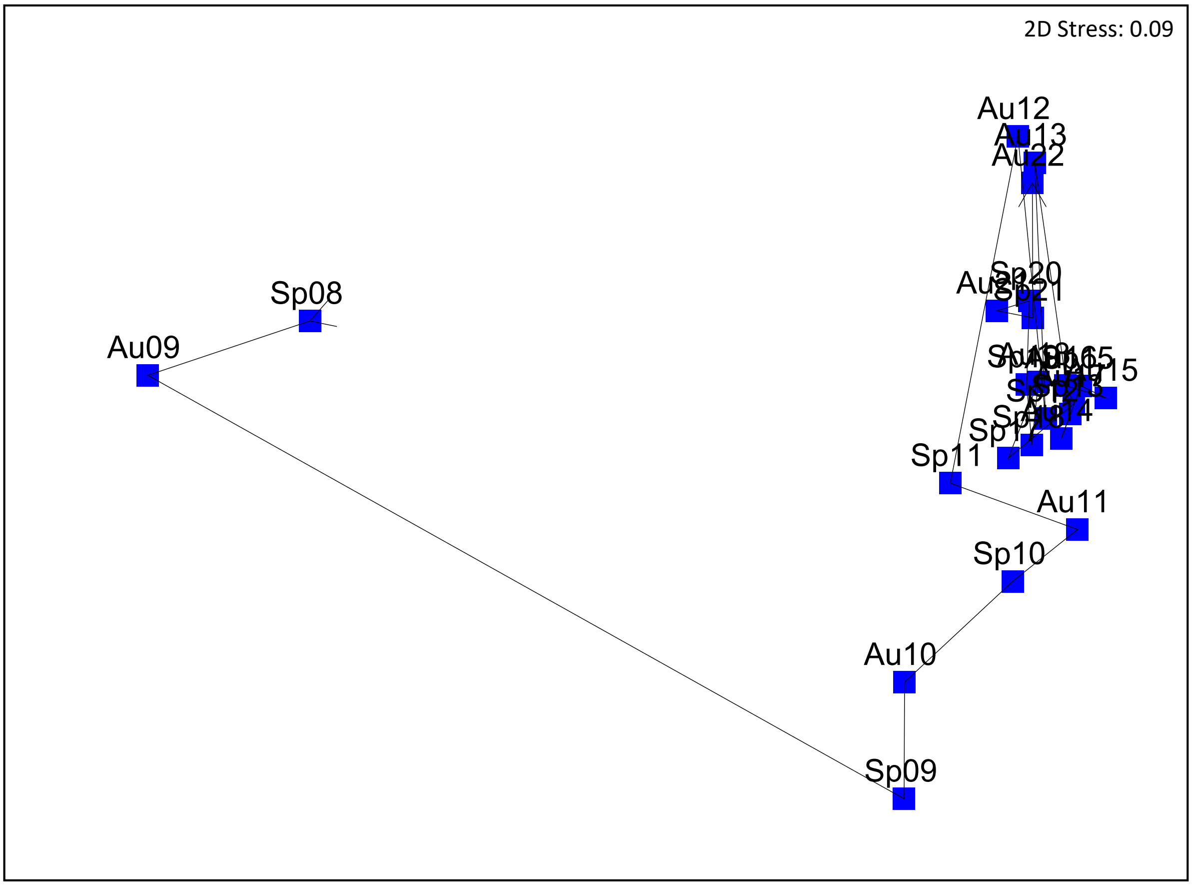


Figure 8: nMDS ordination comparing the plant community between spring 2008 and autumn 2022 in Goolwa Channel (Sp denotes spring; Au denotes autumn).

Permanent Wetlands

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 (Figures 2 and 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 9). Since autumn 2013, the change in the plant community was much smaller than observed in the earlier surveys of the condition monitoring program (Figure 8). There was little change in floristic composition between autumn 2018 and spring 2019 but a larger shift between spring 2019 and spring 2020 (Figure 8). This change was driven by an increase in submergent species in the aquatic zone and amphibious taxa in the littoral zone, after which there has been very little change (Figure 8).

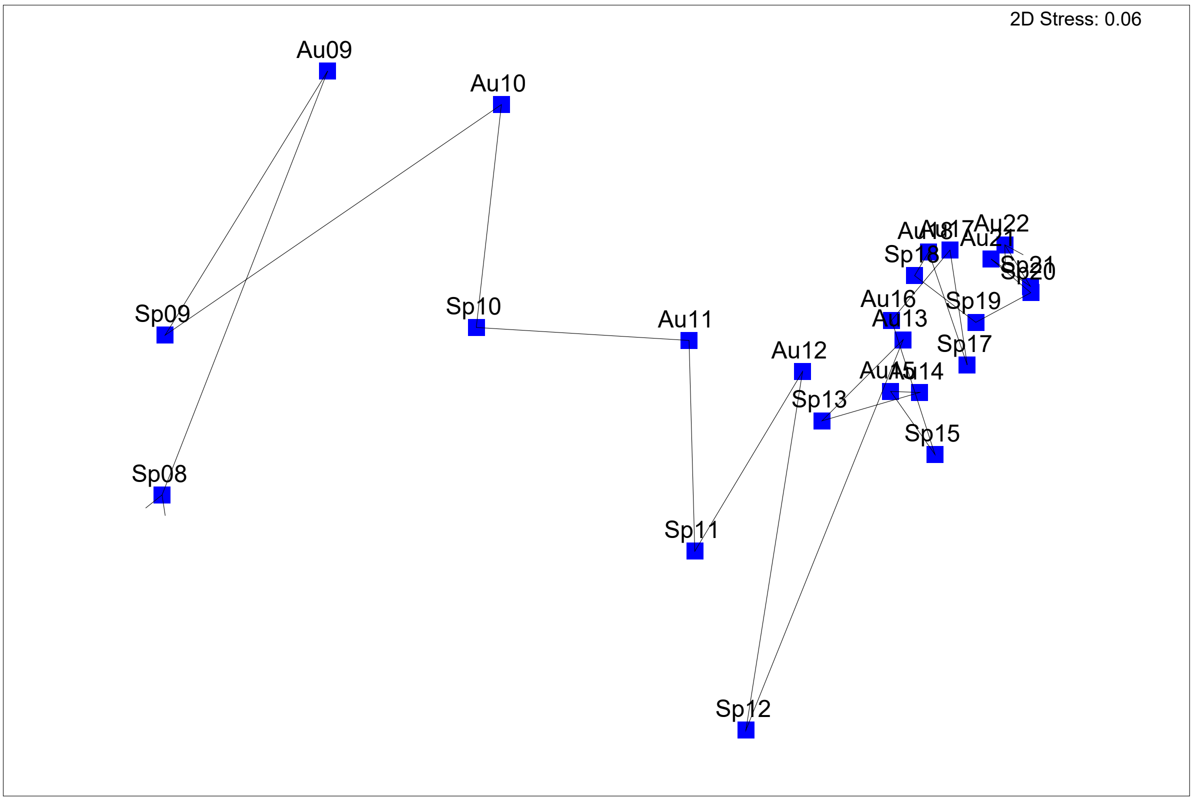


Figure 9: nMDS ordination comparing the plant community between spring 2008 and autumn 2022 in permanent wetlands (Sp denotes spring; Au denotes autumn).

Temporary Wetlands

Strong seasonal changes in vegetation are evident in the seasonal wetlands that were surveyed (Figure 10). 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 8). 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 by 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 10). 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 8). The change was driven by an increase in the abundance of *Typha domingensis*, *Bolboschoenus caldwellii* and *Schoenoplectus pungens* between spring 2010 and autumn 2011. The seasonal patterns observed between autumn 2011 and autumn 2021 (Figure 8) were due to the presence of submergent species (*Ruppia tuberosa, Ruppia polycarpa, Myriophyllum verrucosum, Myriophyllum salsugineum, Althenia cylindrocarpa, Chara* sp. and *Lamprothamnium macropogon*) in spring.

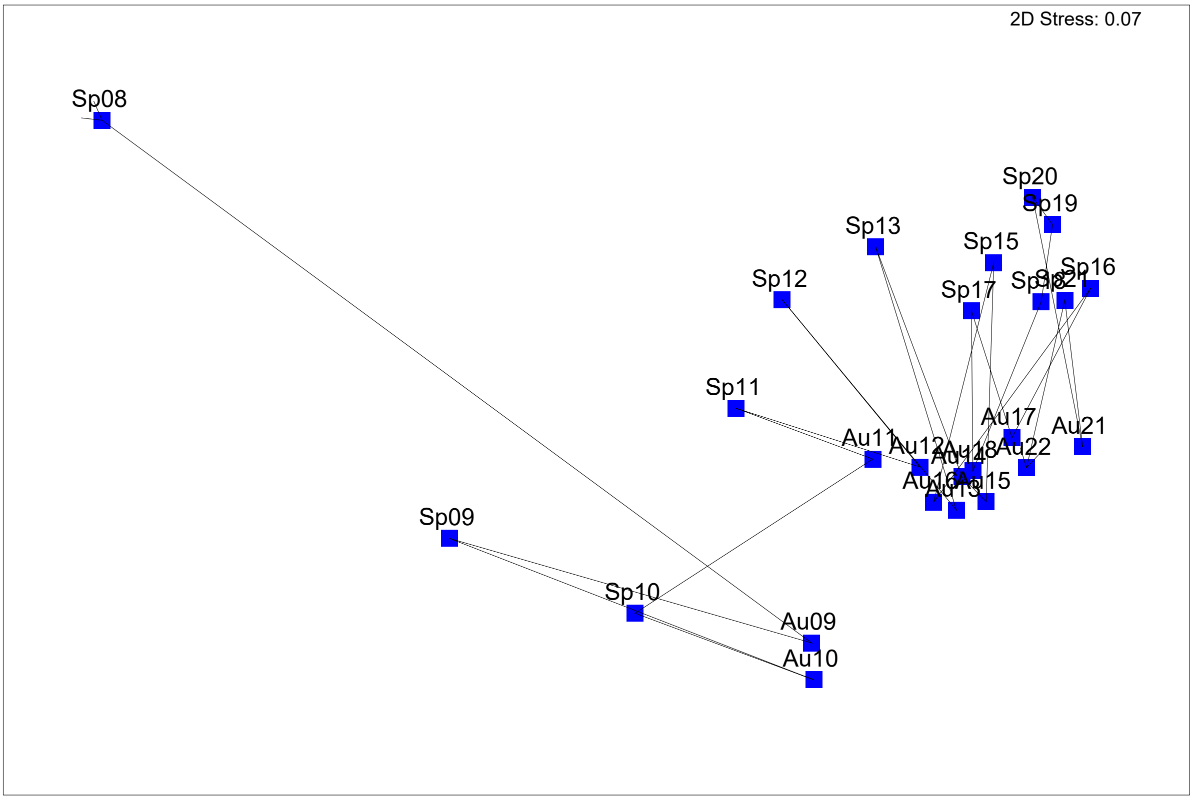


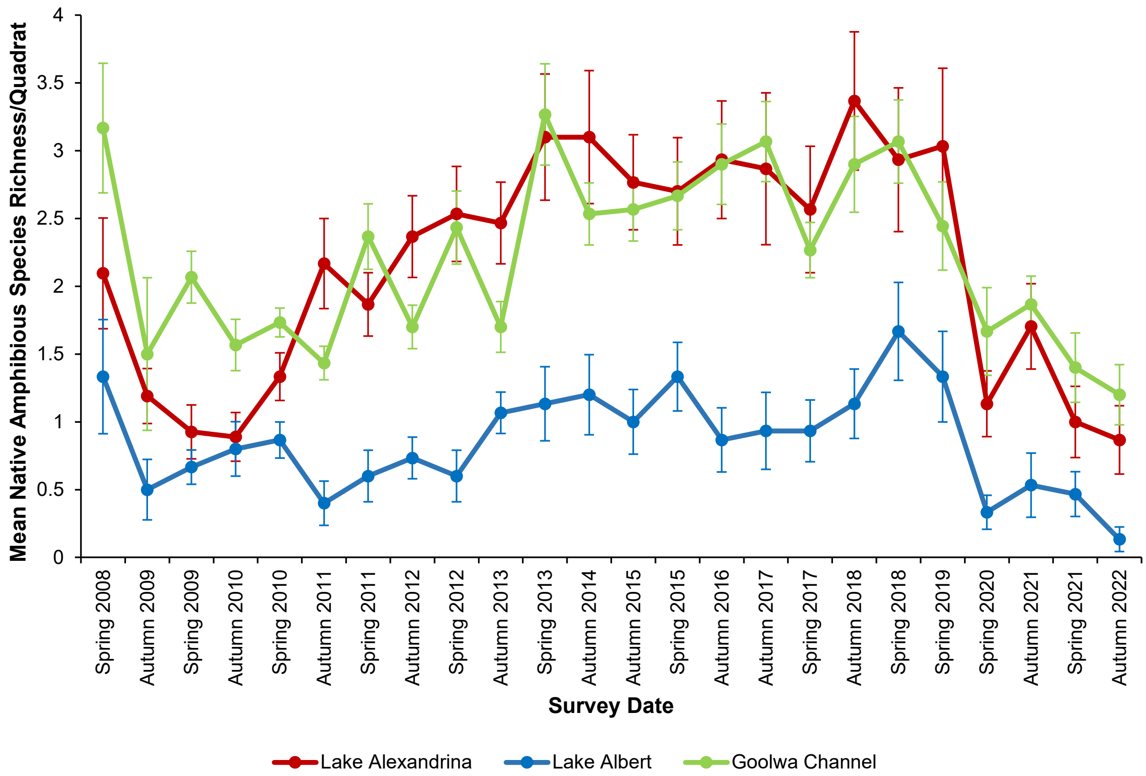
Figure 10: nMDS ordination comparing the plant community between spring 2008 and autumn 2021 in seasonal wetlands (Sp denotes spring; Au denotes autumn).

Effect of variable water levels

Managed water level cycling for ecological outcomes has been undertaken in the Lower Lakes with spring surcharging (when water is available) and draw-down in late summer/autumn being undertaken between autumn 2018 and 2020 (Figure 2). This has resulted in quadrats at +0.6 m AHD being subjected to repeated patterns of inundation and exposure (Figure 2). Native amphibious species richness in Lake Alexandrina, Lake Albert and Goolwa Channel was plotted over the condition monitoring program to assess the benefit of the extended draw-down on the vegetation of the aforementioned habitats (Figure 11a). Native amphibious species richness at +0.6 m AHD declined during the drought but has generally increased since water levels were reinstated until the two latest surveys (Figure 11). The plant community at +0.6 m AHD in Lake Albert is depauperate compared to Lake Alexandrina and Goolwa Channel (Figure 11). Native amphibious species richness at +0.6 m AHD increased between spring 2017 and spring 2018 in all habitats except Lake Alexandrina, with the highest species richness over the condition monitoring program recorded in this habitat in autumn 2018 (Figure 11). Native species richness declined between spring 2018 and spring 2019 in Lake Albert and Goolwa Channel but remained similar in Lake Alexandrina (Figure 11a). Further declines across all habitats were observed between spring 2019 and spring 2020, with a small increase in autumn 2021, after which there has been a decline in all habitats (Figure 11a).

Native amphibious species richness at +0.8 m AHD decreased across all habitats during the drought but generally increased after water levels were reinstated and from spring 2015 has remained relatively stable (Figure 11b). In contrast to +0.6 m AHD, this elevation is exposed more often and for longer so there is a greater opportunity for species that require exposure to recruit but there may be periods of low soil moisture. There are generally less native amphibious species at +0.8 m AHD compared to +0.6 m AHD across all habitats with Lake Albert having the lowest native amphibious species richness (Figure 11b).

a.



b.

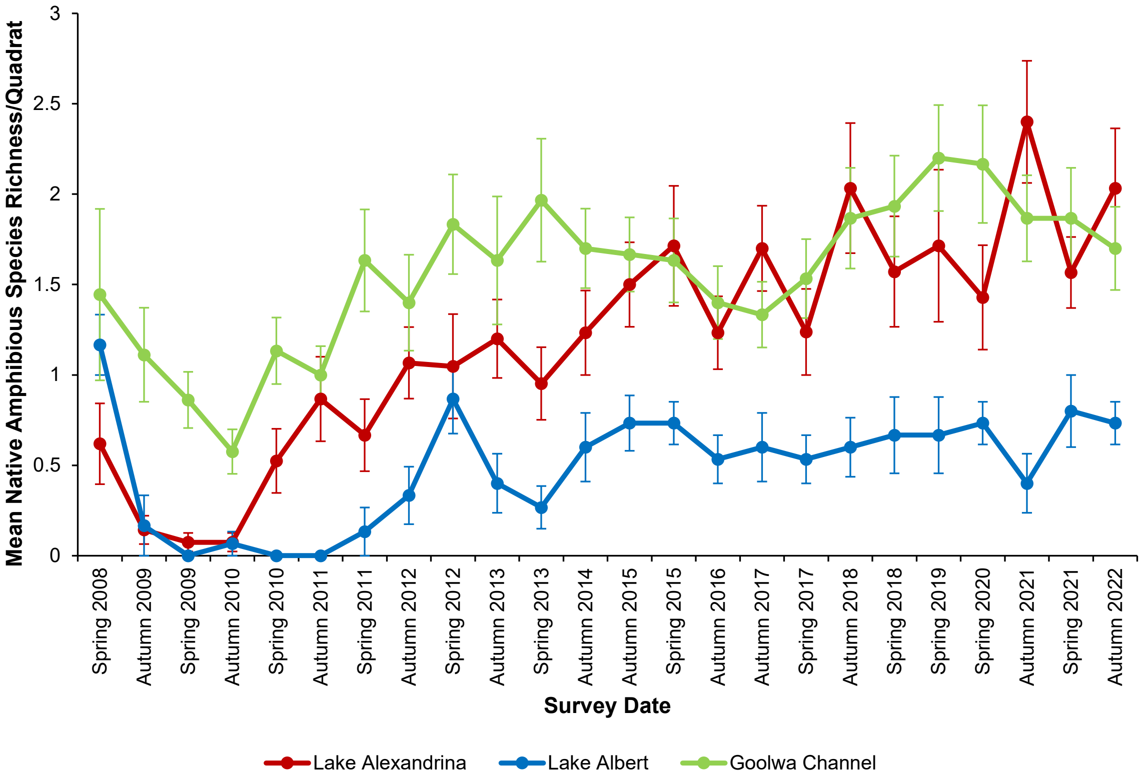


Figure 11: Mean native amphibious species richness per quadrat for Lake Alexandrina, Lake Albert and Goolwa Channel at a. +0.6 m and b. +0.8 m AHD over the condition monitoring program (error bars = ±1 S.E.).

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 2022). 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 that are 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 WOISS (calculated from the habitat condition scores) are presented for the duration of the condition monitoring program.

Lake Alexandrina targets

Littoral Zone

Figure 12 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone from spring 2008 to autumn 2022. Prior to spring 2018, there was a seasonal trend with a higher proportion of quadrats containing a combined cover of these species greater than 75% in autumn compared to spring (Figure 12). In addition, there was a general upward trend of the indicator since water levels were reinstated in spring 2010 to autumn 2015, followed by a sharp decline then another upward trend. The percentage of quadrats with a combined cover greater than 75% did not exceed 40% and the target was consistently achieved (Figure 12).

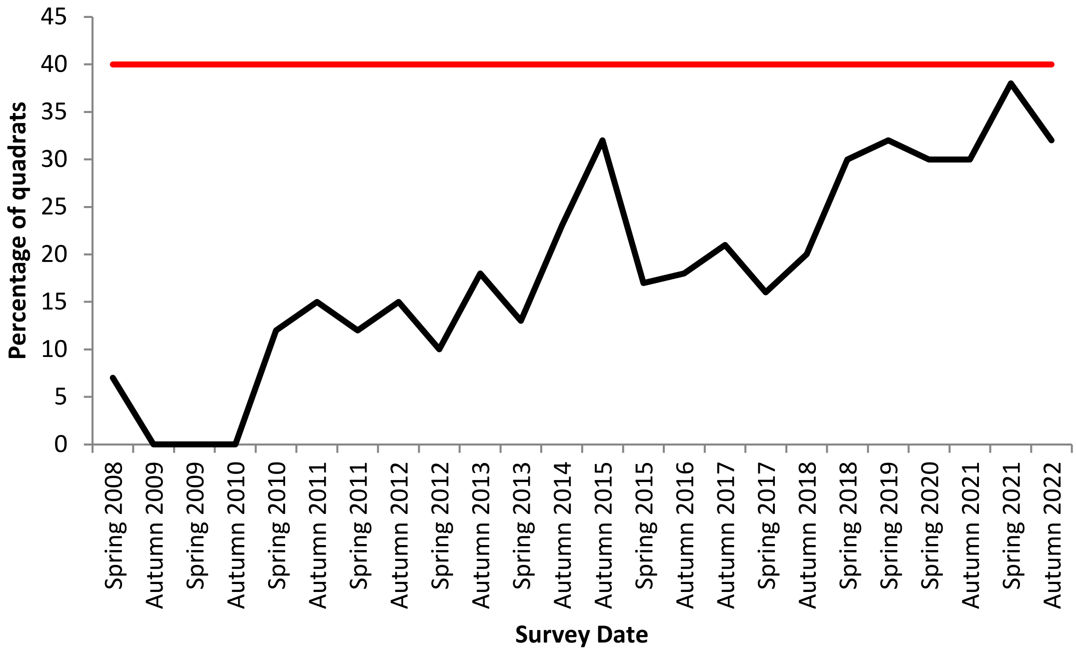


Figure 12: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone of Lake Alexandrina from spring 2008 to autumn 2022.

Figure 13 shows the percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone from spring 2008 to autumn 2022. 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 greater than 50% of these species fell below 20%, the target was achieved and there has been a general downward trend (Figure 13). The lowest proportion of quadrats with these species with a combined cover of greater than 50% was in spring 2018 (Figure 13).

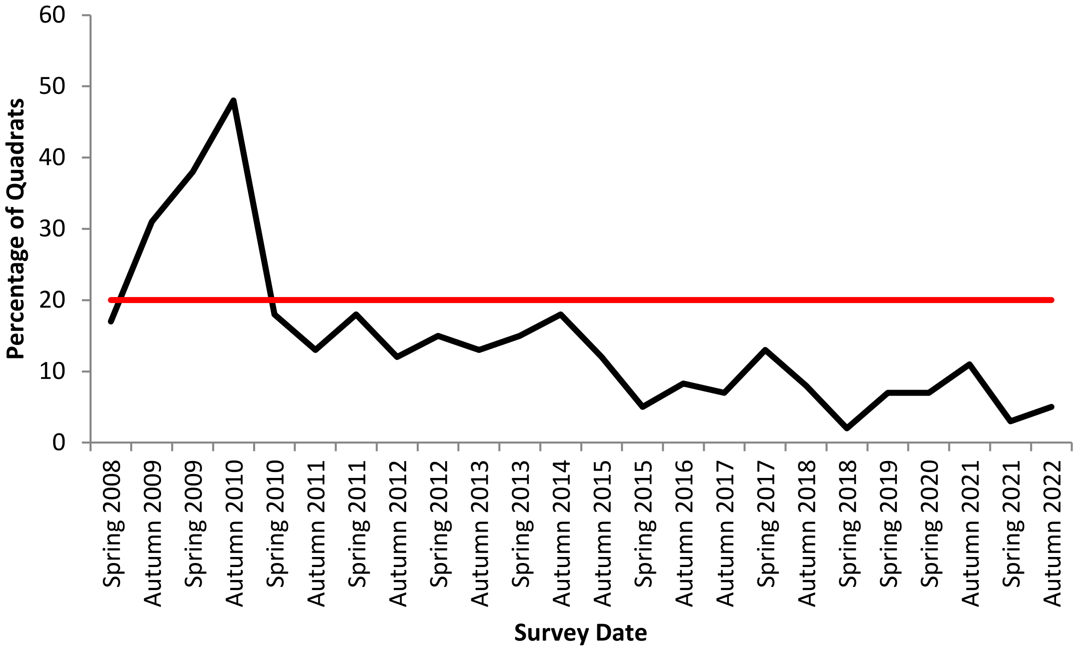


Figure 13: Percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone of Lake Alexandrina from spring 2008 to autumn 2022.

Figure 14 shows the percentage of quadrats containing a cover of native amphibious species ≥5% in the littoral zone from spring 2008 to autumn 2022. There has been an upward trend of the indicator since water levels were reinstated; however, this indicator did not exceed 50% of quadrats until autumn 2015 after which it has been consistently achieved, except in spring 2017 (Figure 14).

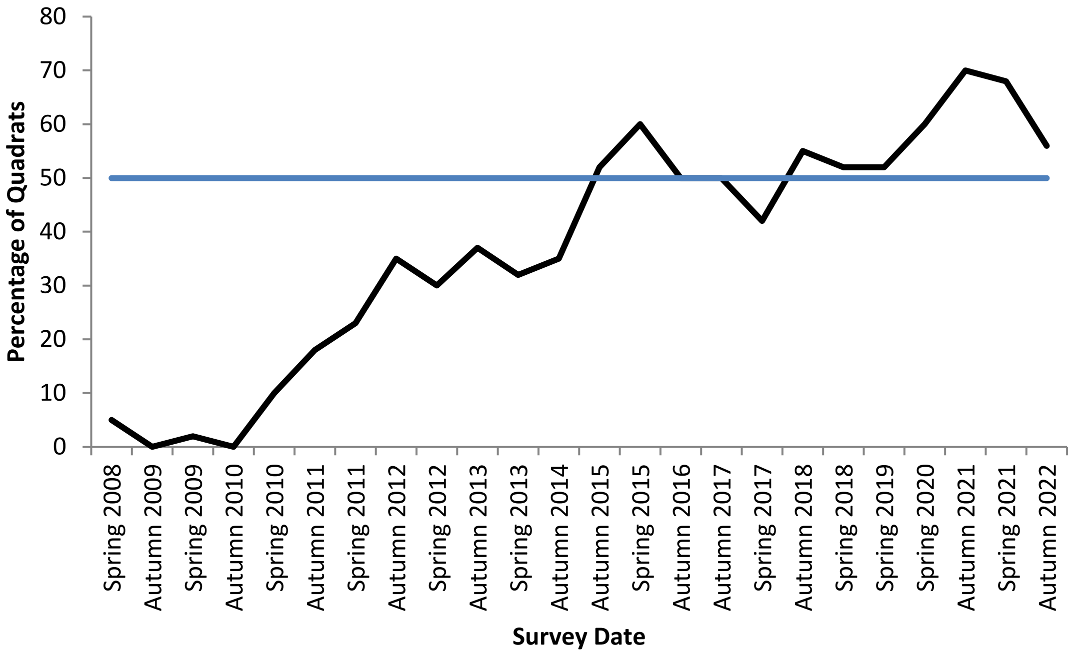


Figure 14: Percentage of quadrats containing a cover native amphibious species greater than 5% in the littoral zone of Lake Alexandrina from spring 2008 to autumn 2022.

Figure 15 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* ≥5% in the littoral zone from spring 2008 to autumn 2022. The indicator 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 15). The number of quadrats containing a cover of these species ≥5% has generally increased since water levels were reinstated until autumn 2017 but declined in spring 2017 and has since remained low (Figure 15).

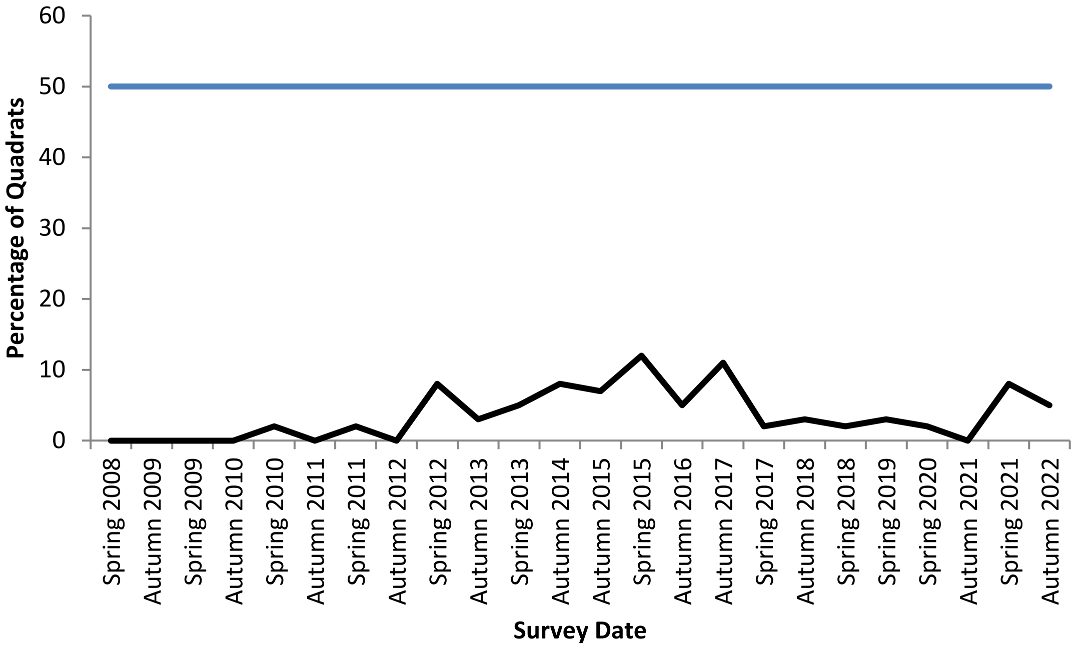


Figure 15: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the littoral zone of Lake Alexandrina from spring 2008 to autumn 2022.

Aquatic Zone

Figure 16 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone from spring 2008 to autumn 2022. This indicator has generally increased until spring 2017 after which there has been a general decrease. The proportion of quadrats has not exceeded 40% and the target has been achieved since spring 2008 (Figure 16).

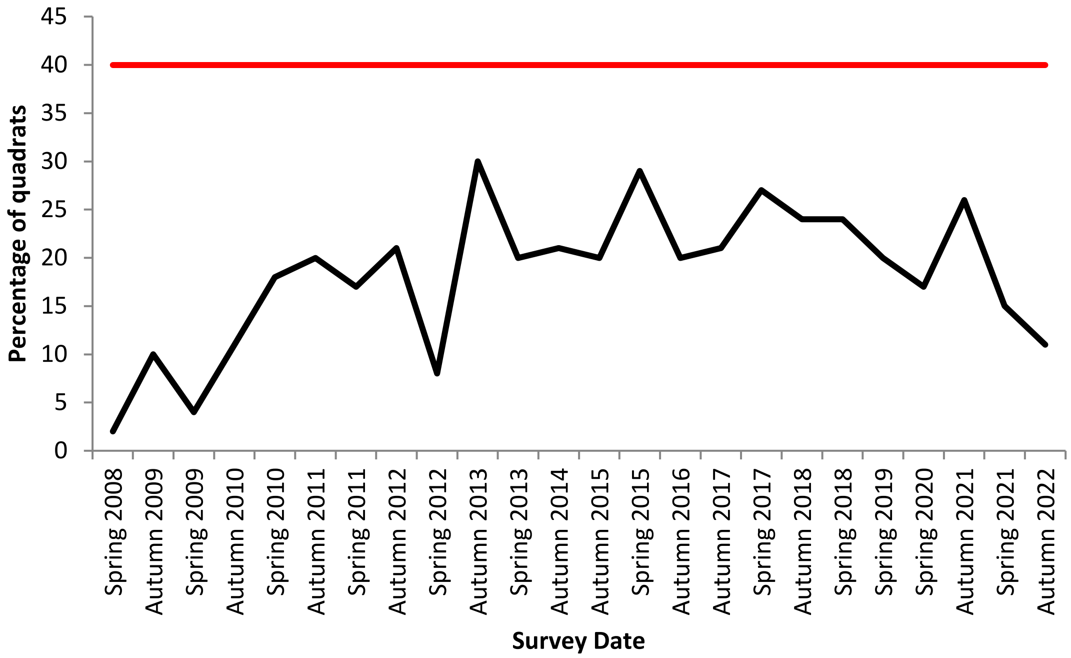


Figure 16: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone of Lake Alexandrina from spring 2008 to autumn 2022.

Figure 17 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* ≥5% in the aquatic zone from spring 2008 to autumn 2022. This indicator generally increased since water levels were reinstated, peaking in spring 2021 when the target was first acheived. There was a seasonal pattern after spring 2013 with higher proportions of quadrats containing these species with a cover of greater than 5% in spring compared to autumn (Figure 17).

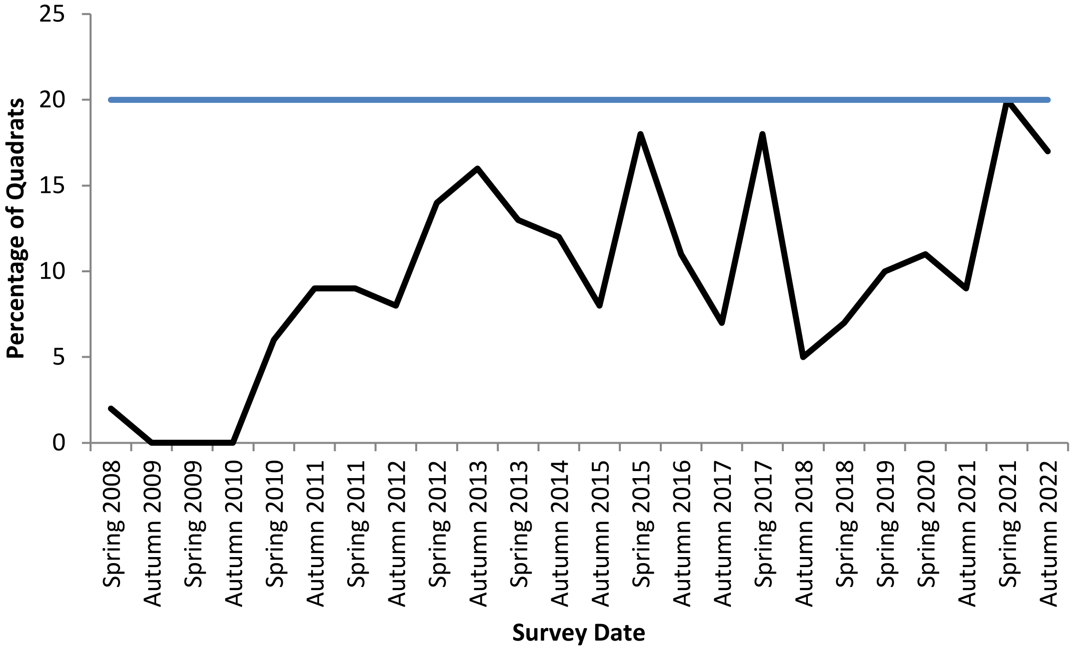


Figure 17: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the aquatic zone of Lake Alexandrina from spring 2008 to autumn 2022.

Figure 18 shows the percentage of quadrats containing a cover of native submergent species ≥5% in the aquatic zone from spring 2008 to autumn 2022. 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. There was an increasing trend for this indicator after spring 2011 until autumn 2015, followed by a general decrease until spring 2017 and another increase peaking in spring 2021 when the target was achieved for the first time (Figure 18).

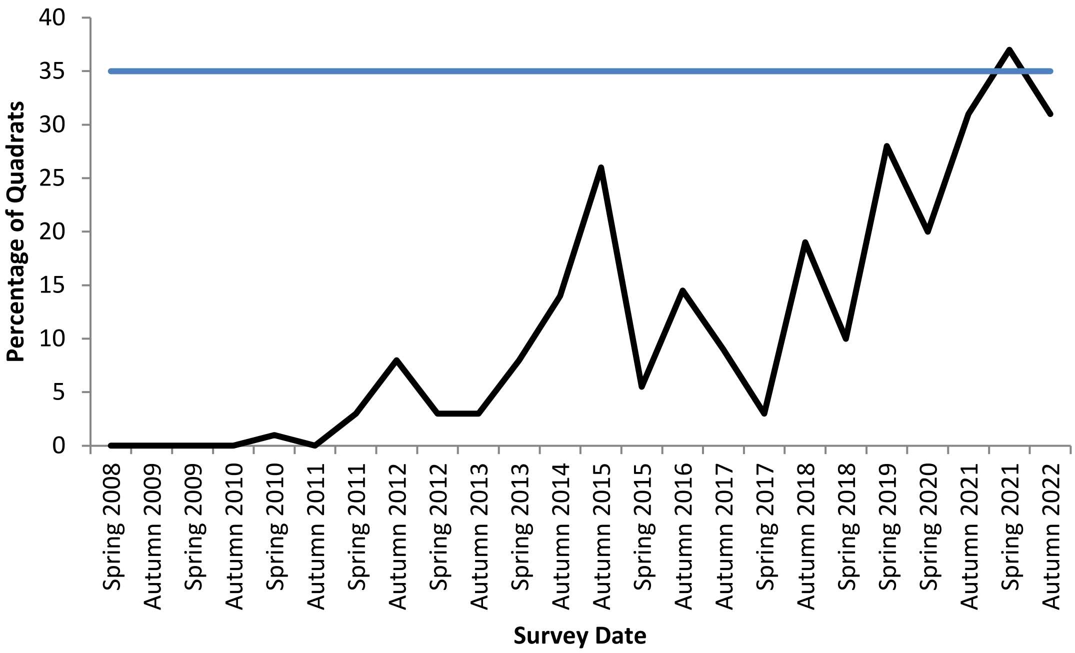


Figure 18: Percentage of quadrats containing a cover of native submergent species greater than 5% in the aquatic zone of Lake Alexandrina from spring 2008 to autumn 2022.

Whole of habitat condition

The whole of habitat condition score (the proportion of targets achieved) in Lake Alexandrina is shown in Figure 19. 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 13). No additional targets were achieved until autumn 2015 when the number of quadrats containing cover of native amphibious species ≥5% in the littoral zone exceeded 50% and the target was achieved every year since, except in spring 2017 (Figure 14). The increase in spring 2021 (Figure 14) was due to two targets in the aquatic zone (native emergent other than *Typha domingensis* and *Phragmites australis* and submergents) being achieved for the first time (Figure 17 and Figure 18).

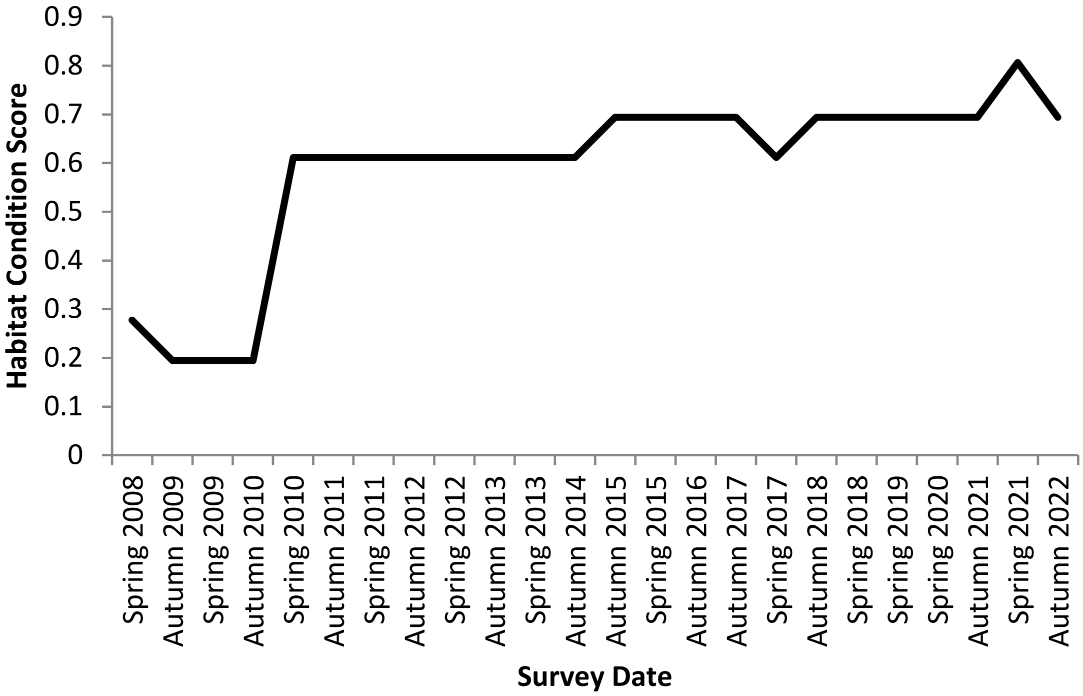


Figure 19: Whole of habitat condition score for Lake Alexandrina from spring 2008 to autumn 2022.

Lake Albert

Littoral Zone

Figure 20 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone from spring 2008 to autumn 2022. There were no quadrats containing a combined cover of these species greater than 75% in the littoral zone until spring 2013, after which, there was a general upward trend peaking at 23% in autumn 2018 (Figure 20). The number of quadrats has remained well below 40%; therefore, the target has consistently been achieved since spring 2008.

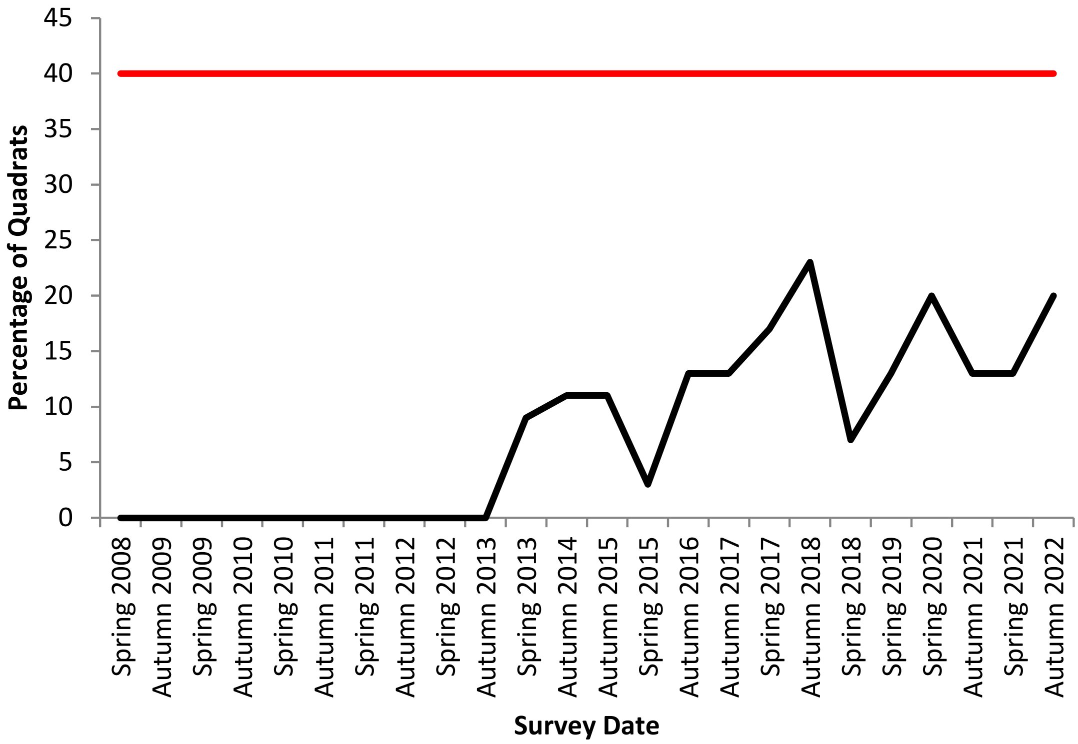


Figure 20: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone of Lake Albert from spring 2008 to autumn 2022.

Figure 21 shows the percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone from spring 2008 to autumn 2022. Since autumn 2010 this indicator has generally decreased, with the number of quadrats falling below 20% in spring 2015 and the target achieved thereafter except in autumn 2018 (Figure 21). There were no quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone in spring 2018, spring 2020 and autumn 2021 (Figure 21).

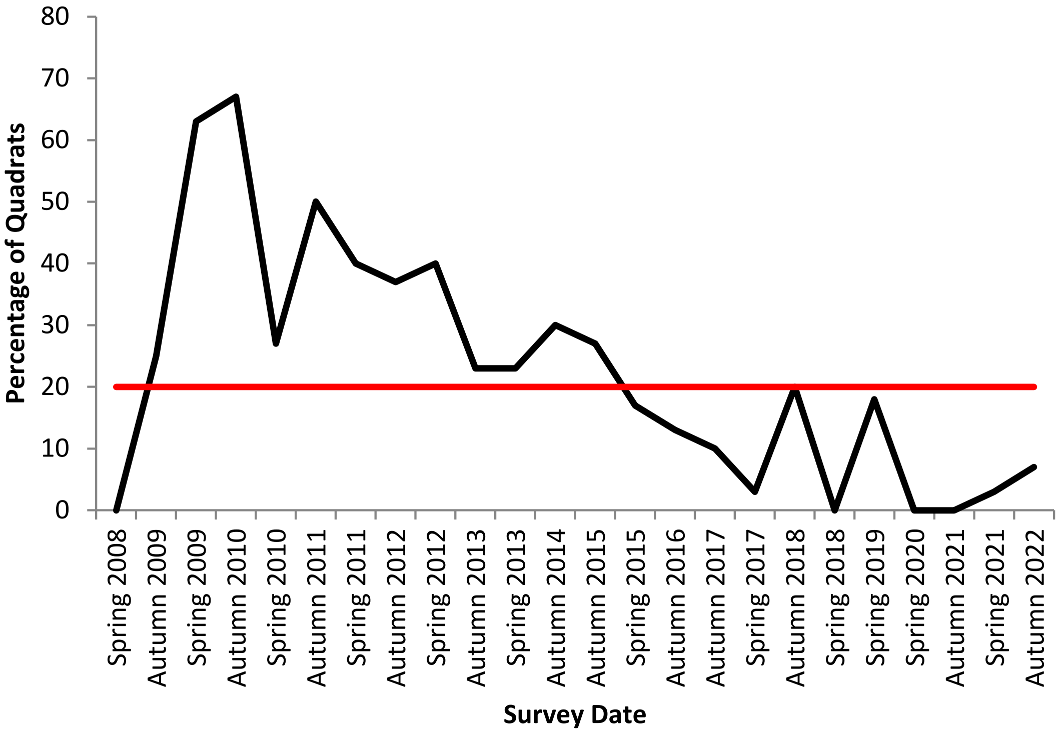


Figure 21: Percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone of Lake Albert from spring 2008 to autumn 2022.

Figure 22 shows the percentage of quadrats containing a cover of native amphibious species ≥5% in the littoral zone from spring 2008 to autumn 2022. The number of quadrats containing these species with a cover of ≥5% has been variable since spring 2008 showing no seasonal patterns or general trends over the condition monitoring program (Figure 22). However, there was an increase from spring 2017 with the target being achieved for the first time in spring 2019 after which, there was a decline and followed by an increase with the target being achieved for the two most recent surveys (Figure 22).

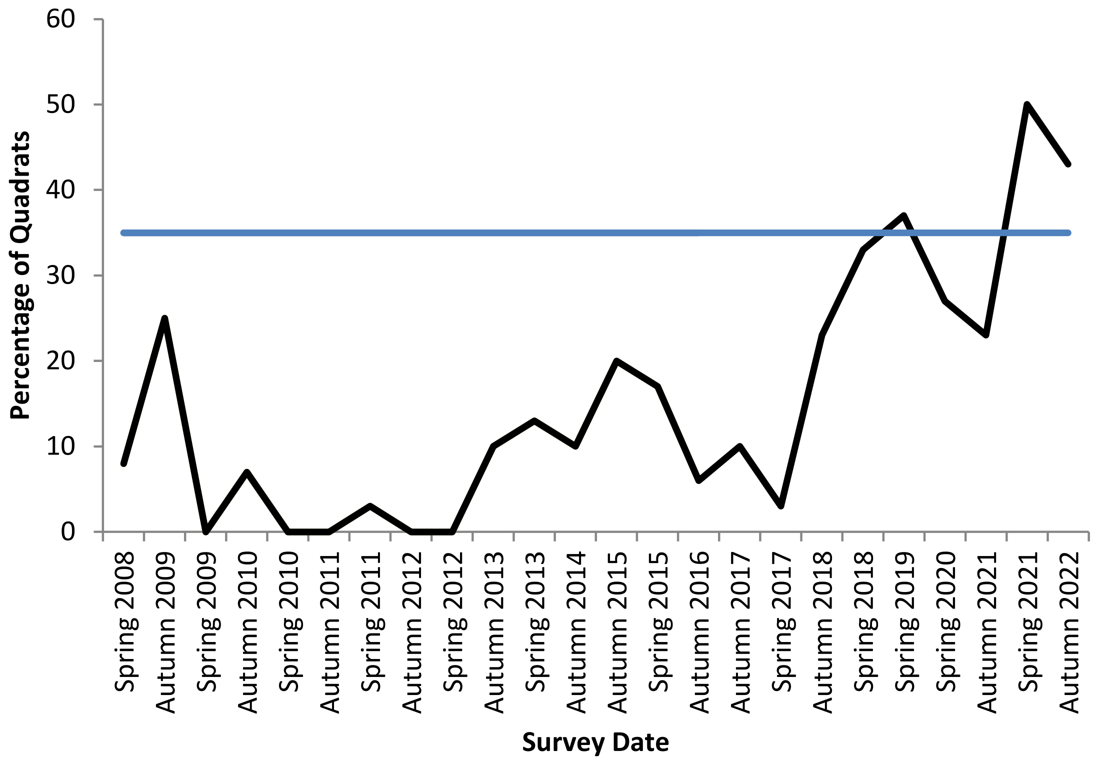


Figure 22: Percentage of quadrats containing a cover of native amphibious species greater than 5% in the littoral zone of Lake Albert from spring 2008 to autumn 2022.

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 23 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone from spring 2008 to autumn 2022. There was a general upward trend of the indicator after water levels were reinstated, except in autumn 2014 and spring 2020 (Figure 23). The proportion of quadrats with a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% has not exceeded 40% (the largest number of quadrats was 18% in spring 2019) in the aquatic zone of Lake Albert and the target has been achieved since spring 2008 (Figure 23).

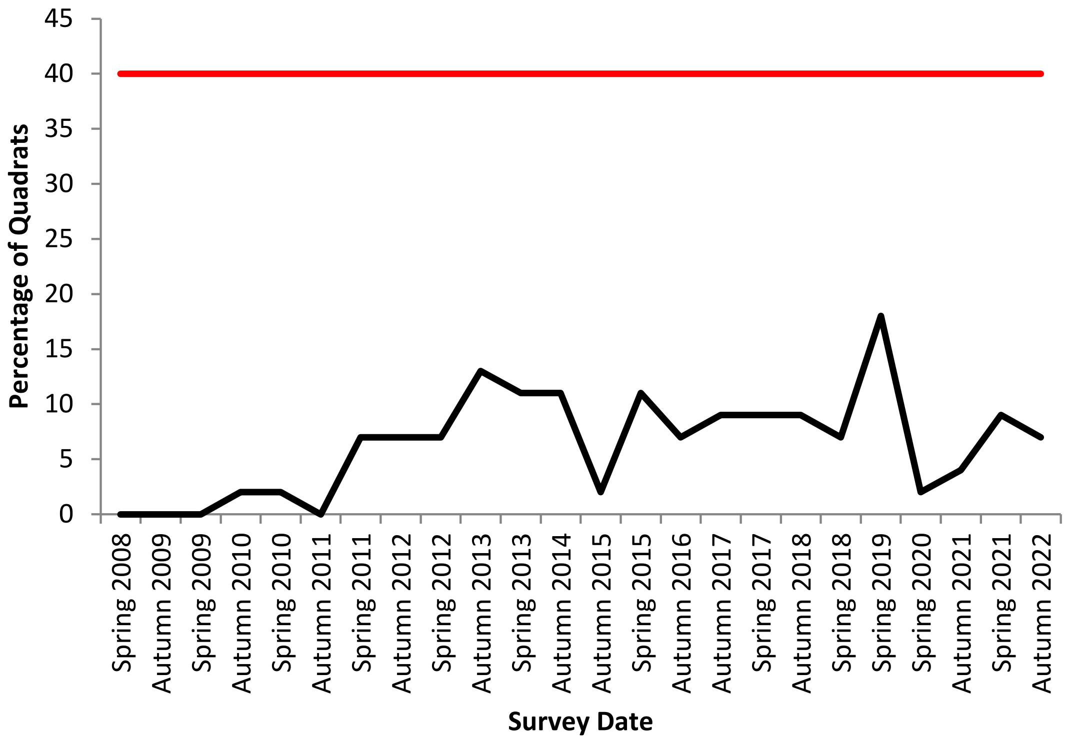


Figure 23: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone of Lake Albert from spring 2008 to autumn 2022.

Figure 24 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* ≥5% in the aquatic zone from spring 2008 to autumn 2022. These species are uncommon in Lake Albert and quadrats with a combined cover in the aquatic zone ≥5% were recorded on seven occasions; autumn 2013, autumn 2015, autumn 2016, autumn 2017, spring 2019, spring 2021 and autumn 2022 (peaking at 7% in autumn 2015, autumn 2017, spring 2019 and spring 2021) (Figure 24). Therefore, the target has not be achieved over the survey period.

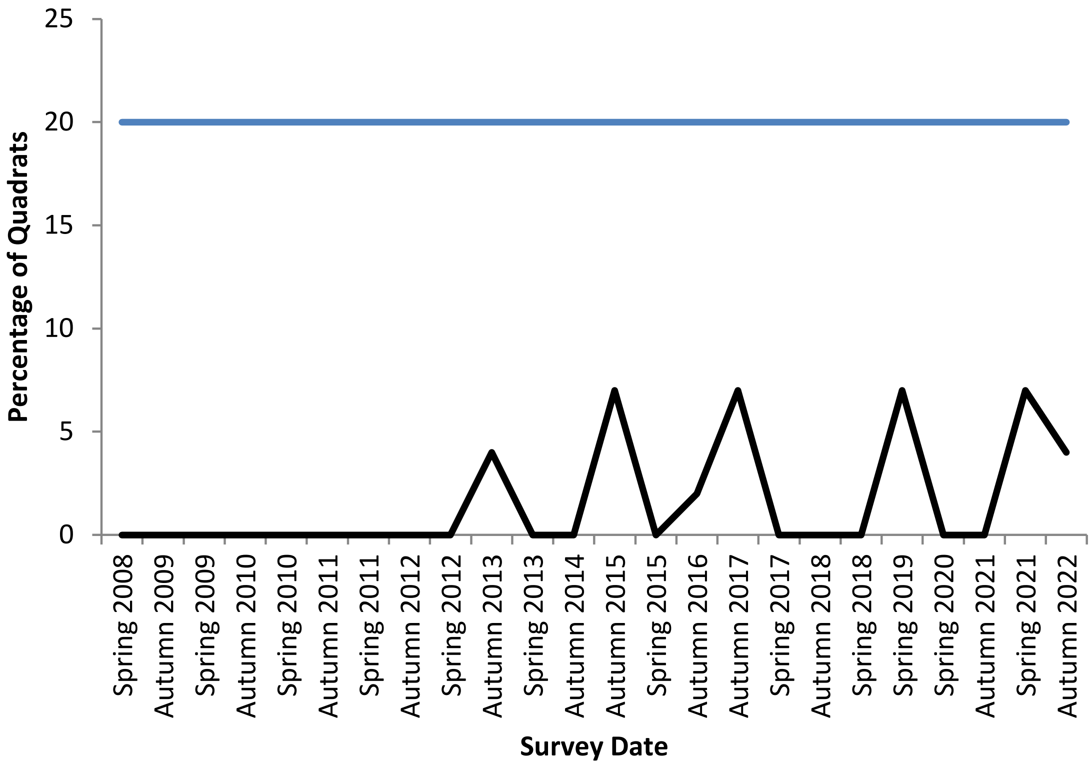


Figure 24: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the aquatic zone of Lake Albert from spring 2008 to autumn 2022.

Figure 25 shows the percentage of quadrats containing a cover of native submergent species ≥5% in the aquatic zone from spring 2008 to autumn 2022. During the drought the aquatic zone was dry; hence, no submergent species were present. There was only one occasion (spring 2011, 6% of quadrats) when native submergent species were present ≥5% cover (Figure 25) in any quadrats; hence, the target has not been achieved.

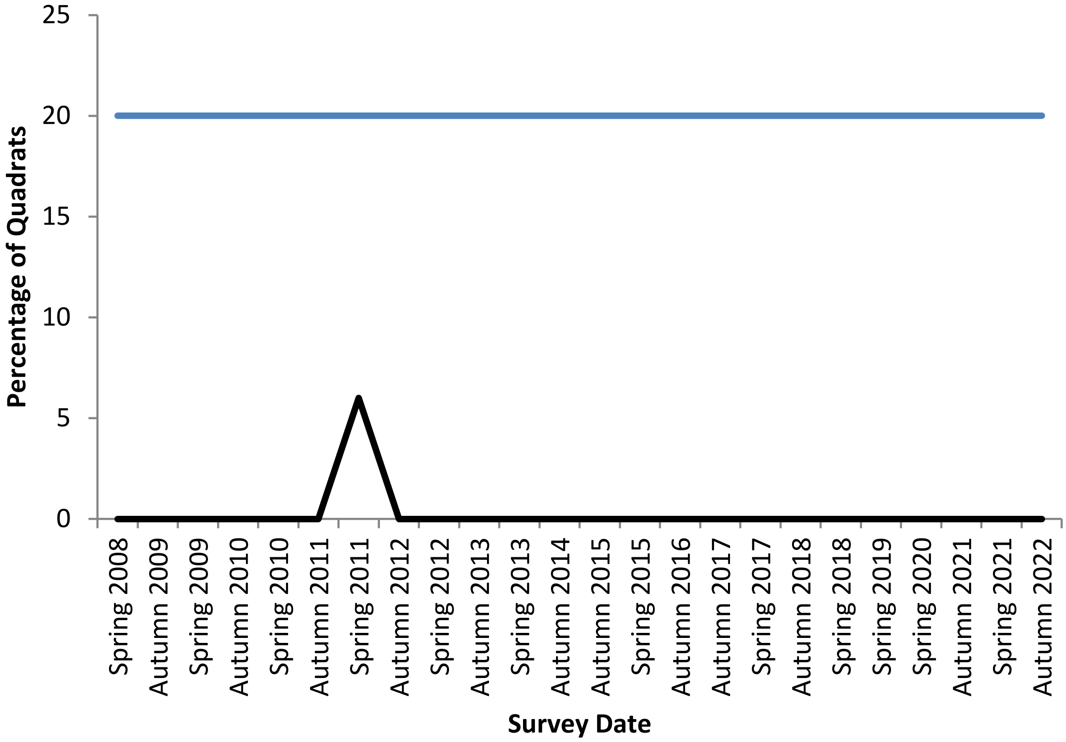


Figure 25: Percentage of quadrats containing a cover of native submergent species greater than 5% in the aquatic zone of Lake Albert from spring 2008 to autumn 2022.

Whole of habitat condition

The whole of habitat condition score for Lake Albert is shown in Figure 26. The increase between autumn and spring of 2010 was due to water levels being reinstated and the target for the deep water zone being achieved (Figure 26). 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 21). However, the proportion of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone increased to 20% in autumn 2018 (Figure 21) and the target was not achieved for this survey; hence, the decrease in condition score in autumn 2018 (Figure 26). This target was achieved in spring 2018 (Figure 21), resulting in an increase in habitat condition score between autumn and spring 2018 (Figure 26). There was a further increase between spring 2018 and spring 2019 (Figure 26), which was due to the percentage of quadrats containing cover of native amphibious species ≥5% in the littoral zone exceeding 35%, resulting in the target being achieved for the first time (Figure 22). This target was not achieved in spring 2020 and autumn 2021; however, was achieved in the two most recent surveys (Figure 22) resulting in a decline followed by an increase in condition score (Figure 26).

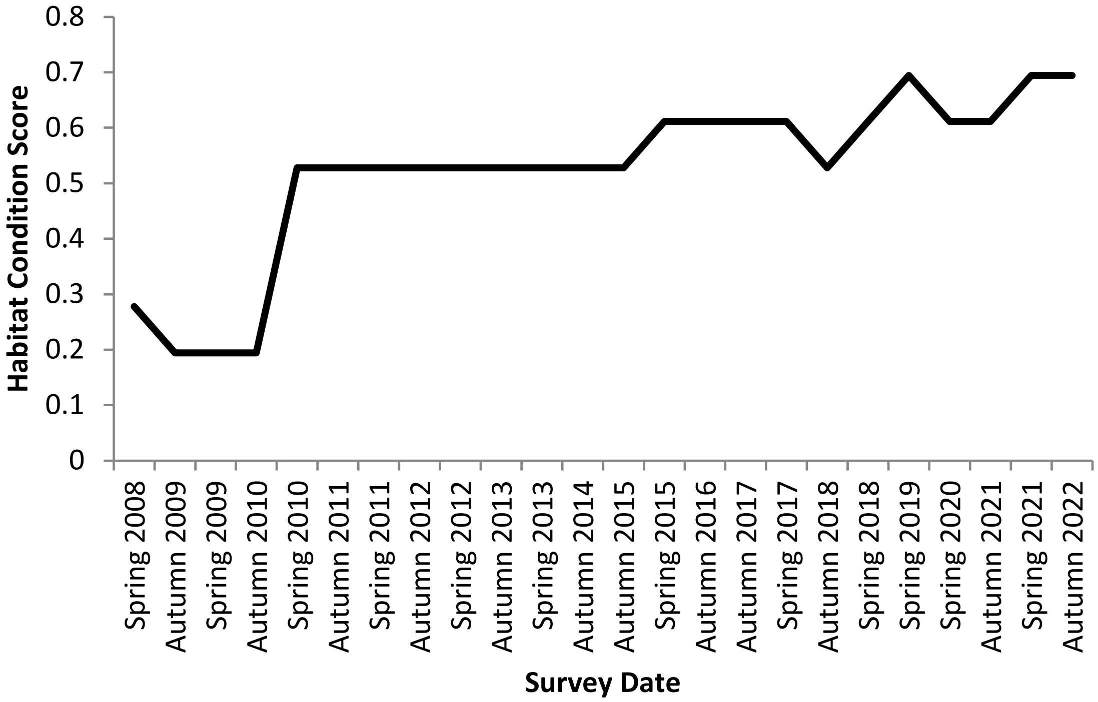


Figure 26: Whole of habitat condition score for Lake Albert from spring 2008 to autumn 2022

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Goolwa Channel

Littoral Zone

Figure 27 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone from spring 2008 to autumn 2022. There was an upward trend after water levels were reinstated then fluctuation around the target followed by a decline after spring 2015 (Figure 27). The indicator exceeded 50% of quadrats on six occasions (Figure 27). Since spring 2017 it was below 50%, except in spring 2018, resulting in the target being achieved except in spring 2018 (Figure 27).

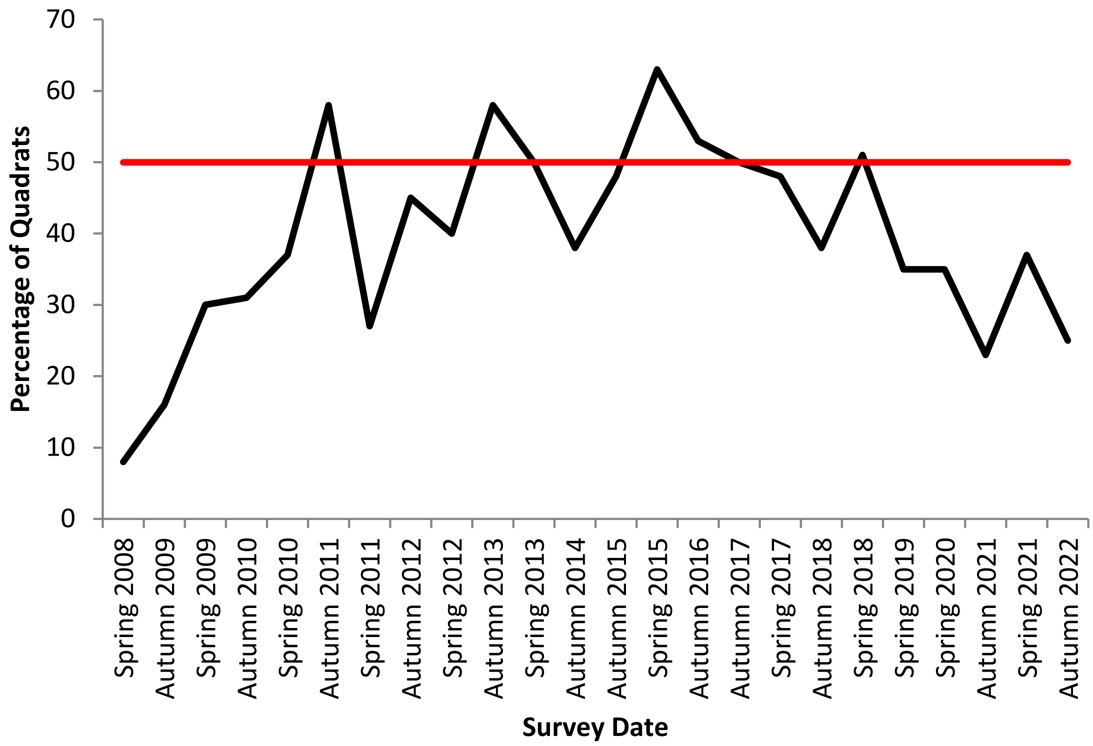

Figure 27: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone of Goolwa Channel from spring 2008 to autumn 2022.

Figure 28 shows the percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone from spring 2008 to autumn 2022. The only time this target was not achieved was in autumn 2010, after which there has been a general downward trend (except between autumn 2015 and spring 2017) of the indicator (Figure 28).

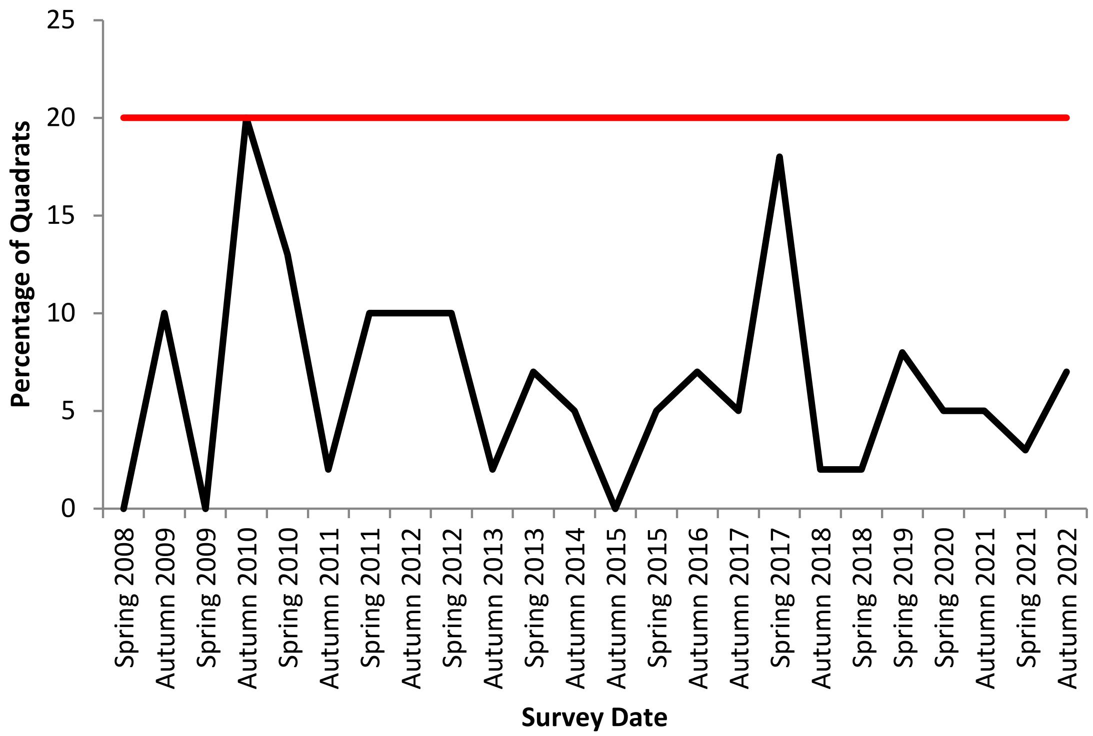

Figure 28: Percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone of Goolwa Channel from spring 2008 to autumn 2022.

Figure 29 shows the percentage of quadrats containing a cover of native amphibious species ≥5% in the littoral zone from spring 2008 to autumn 2022. The indicator 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 29). After spring 2013 there were no seasonal patterns, and the target has been achieved each subsequent survey (Figure 29).

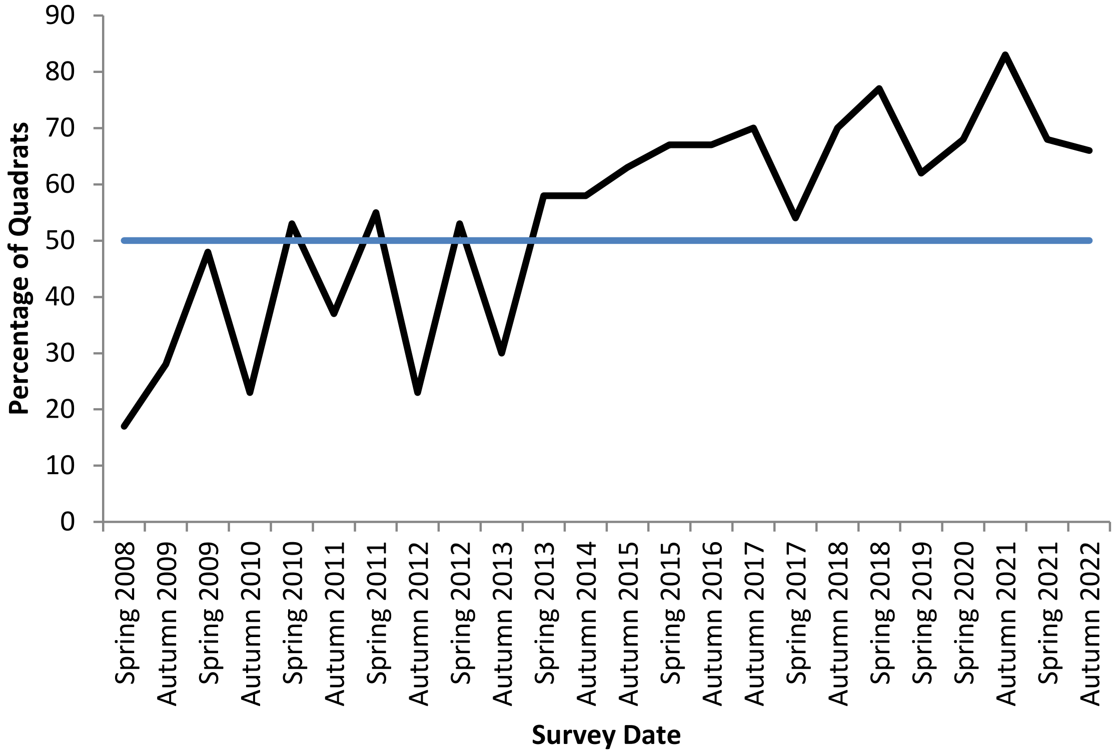

Figure 29: Percentage of quadrats containing a cover native amphibious species greater than 5% in the littoral zone of Goolwa Channel from spring 2008 to autumn 2022.

Figure 30 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* ≥5% in the littoral zone from spring 2008 to autumn 2022. The indicator has not exceeded 50% of quadrats; therefore, this target has not been achieved during the condition monitoring program (Figure 30). However, there was an increasing trend from spring 2009 to spring 2013 (13% of quadrats) followed by a decrease in autumn 2014 (Figure 30). After autumn 2014 there was another upward trend peaking in spring 2018 followed by a downward trend but increasing for the two most recent surveys peaking in autumn 2022 at 25% of quadrats (Figure 30).

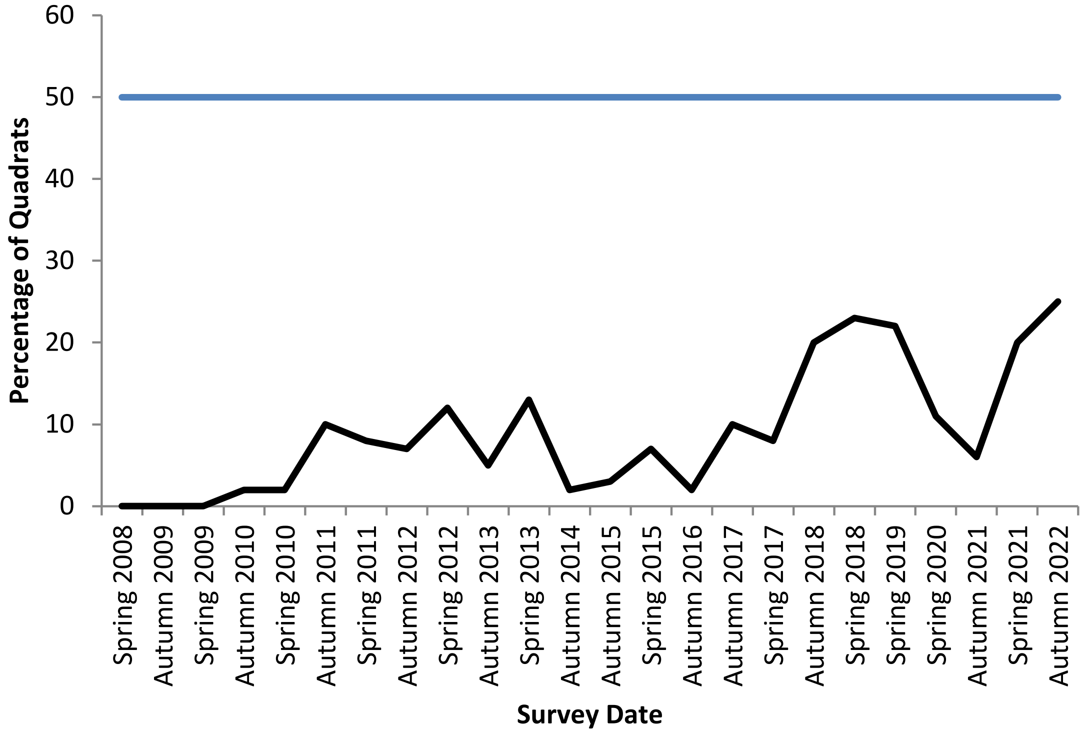

Figure 30: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the littoral zone of Goolwa Channel from spring 2008 to autumn 2022.

Aquatic Zone

Figure 31 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone from spring 2008 to autumn 2022. The indicator has exceeded 50% of quadrats on four occasions with the target achieved since autumn 2016 (Figure 31).

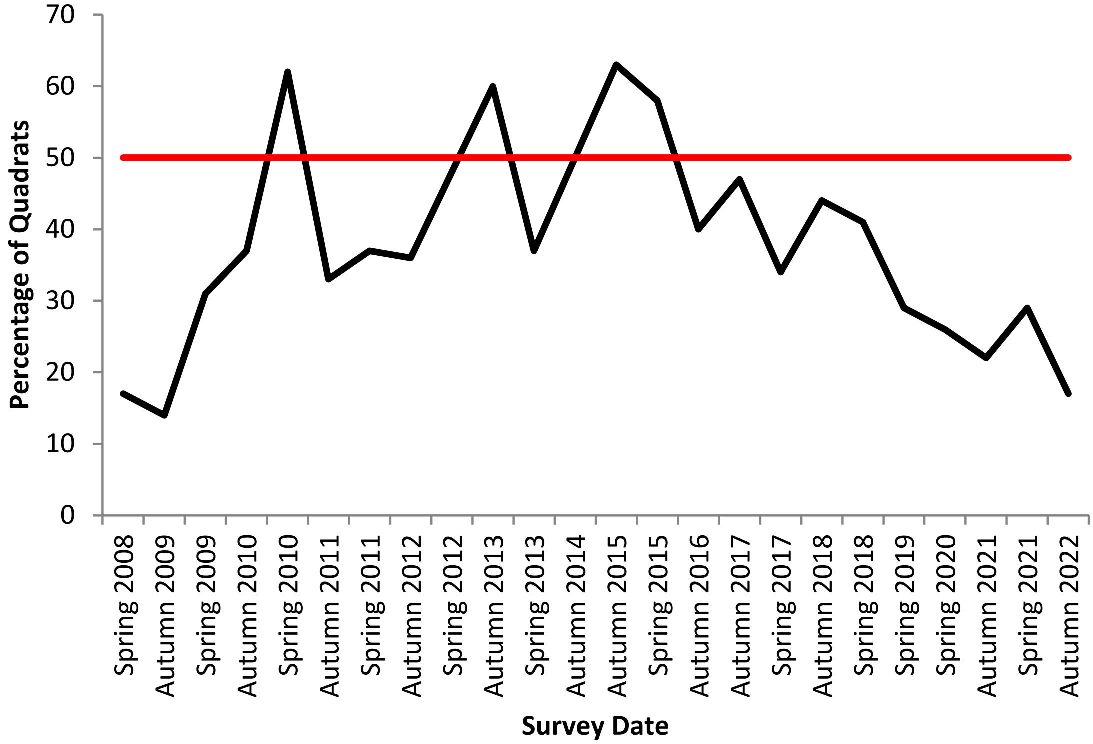

Figure 31: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone of Goolwa Channel from spring 2008 to autumn 2022.

Figure 32 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* ≥5% in the aquatic zone from spring 2008 to autumn 2022. The indicator exceeded 50% of quadrats (and the target was achieved) for the first time in spring 2018, again in spring 2020 and spring 2021 with a general upwards trend since spring 2009 (Figure 32).

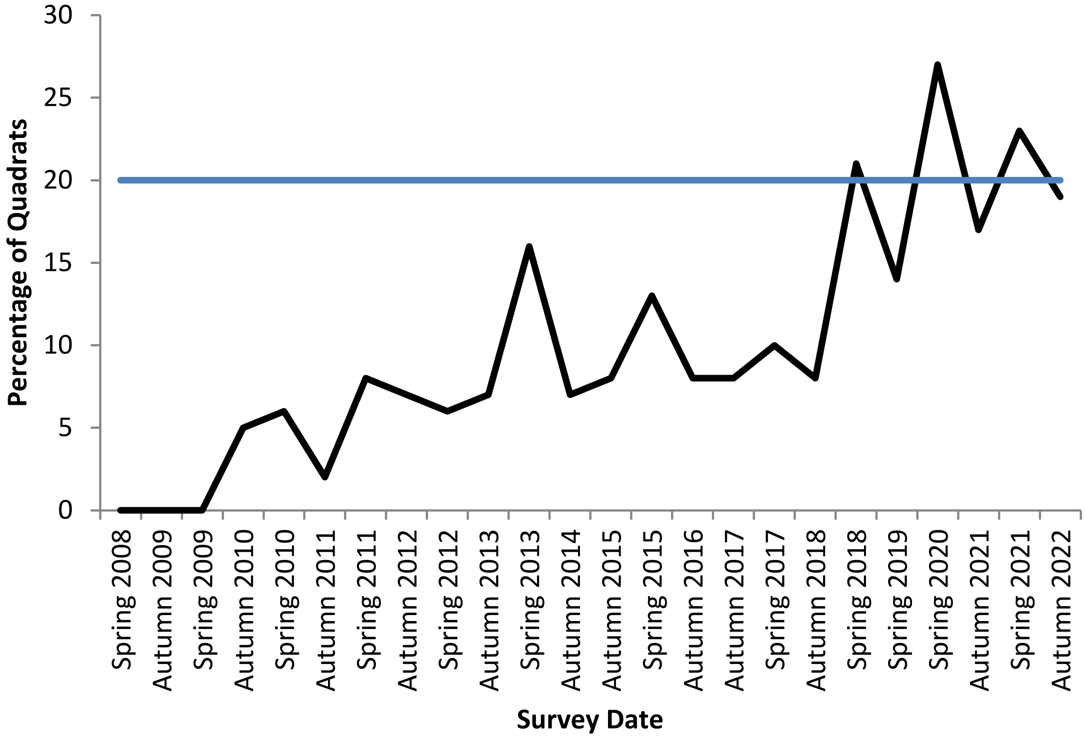

Figure 32: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the aquatic zone of Goolwa Channel from spring 2008 to autumn 2022.

Figure 33 shows the percentage of quadrats containing a cover of native submergent species ≥5% in the aquatic zone from spring 2008 to autumn 2022. Before spring 2009 the aquatic zone was dry; hence, no submergent species were present but after 2009 there was an increasing trend in the number of quadrats containing native submergent species with a cover of ≥5% peaking in autumn 2016 at 27% of quadrats (Figure 33). Between autumn 2016 and spring 2017 there was a downwards trend followed by an upwards trend with the target being achieved for the first time in spring 2020 and again in the two most recent surveys (Figure 33).

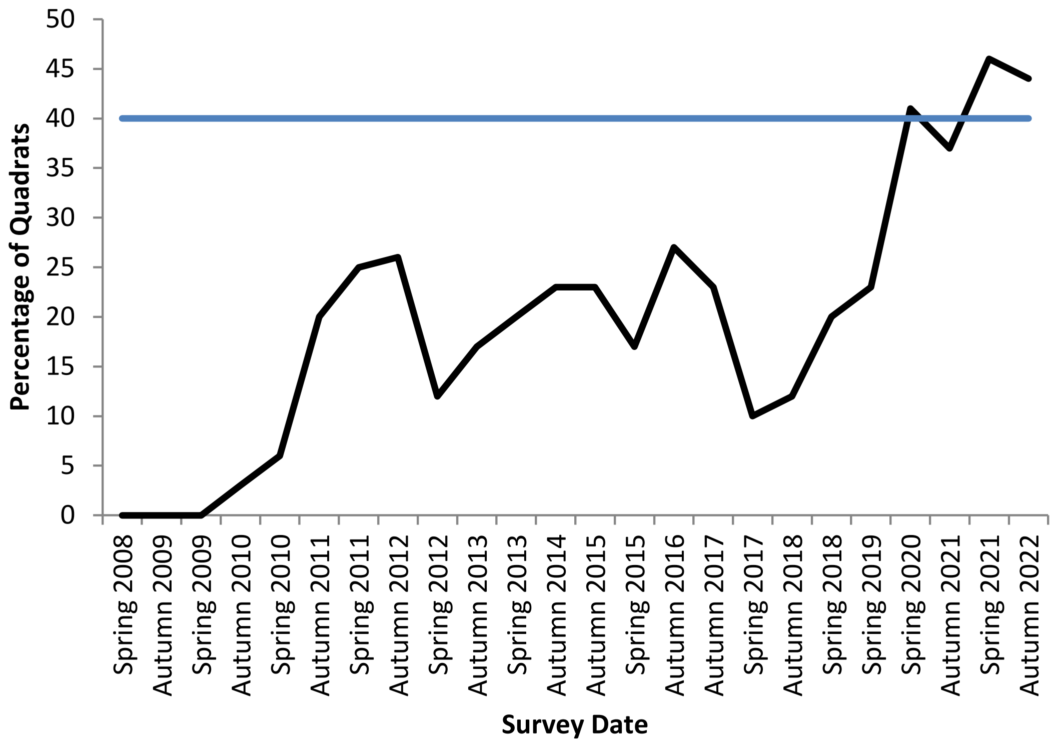

Figure 33: Percentage of quadrats containing a cover of native submergent species greater than 5% in the aquatic zone of Goolwa Channel from spring 2008 to autumn 2022.

Deep water zone

Figure 34 shows the percentage of quadrats containing a cover of native submergent species ≥5% in the deep water zone from spring 2008 to autumn 2022. Before spring 2009, much of the deep water zone was dry; hence, no submergent species were present (Figure 34). Between spring 2009 and spring 2010, there was a large increase in the number of quadrats with ≥5% cover of native submergent species (79% in spring 2010) due to the dominance of *Potamogeton pectinatus* after the Clayton Regulator was constructed. After the Clayton Regulator was breached in spring 2010 and there was a decrease in the number of quadrats with ≥5% cover of native submergents but the number remained above the target until spring 2015 when it decreased (Figure 34). The target was not achieved again until autumn 2018 and from spring 2020 onwards (Figure 34).

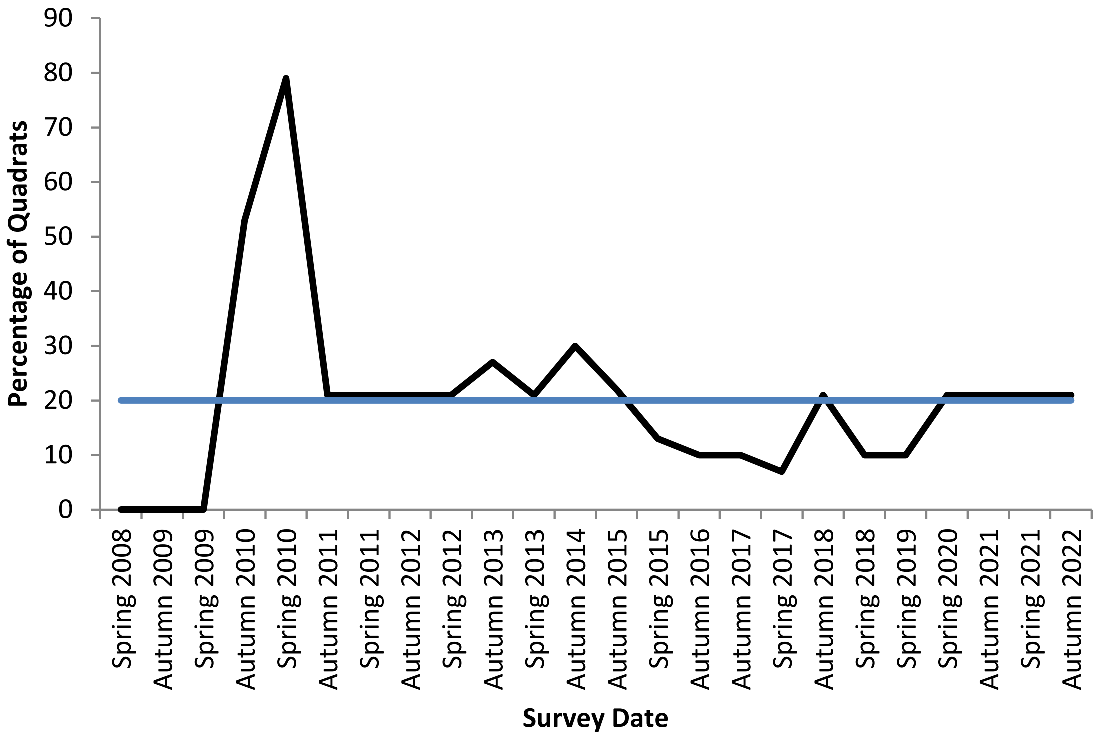

Figure 34: Percentage of quadrats containing a cover of native submergent species greater than 5% in the deep water zone of Goolwa Channel from spring 2008 to autumn 2022.

Whole of habitat condition

The whole of habitat condition score for Goolwa Channel is shown in Figure 35. In contrast to lakes Alexandrina (Figure 19) and Albert (Figure 26) there was greater fluctuation in habitat condition score over the condition monitoring program for Goolwa Channel (Figure 35). The generally increasing trend between spring 2008 and autumn 2015 was due to the deep water target being achieved over this period (Figure 34). The minor fluctuations over this period were due to the *Typha domingensis* and *Phragmites australis* targets in the littoral (Figure 27) and aquatic (Figure 31) zones and the native amphibious species target (Figure 29) in the littoral zone being achieved for some surveys and not others (seasonal patterns in abundance). The decrease in habitat condition score between autumn 2015 and autumn 2016 was because the deep water (Figure 34) and littoral *Typha domingensis* and *Phragmites australis* targets (Figure 27) were not achieved. The increase in condition score between autumn 2017 and autumn 2018 was due to the littoral *Typha domingensis* and *Phragmites australis* target being achieved in spring 2017 and autumn 2018 (Figure 27) and the deep water target being achieved in autumn 2018 (Figure 34). The decline in condition score between autumn 2018 and spring 2019 was due to the littoral zone *Typha domingensis* and *Phragmites australis* (Figure 27) and deep water submergent vegetation (Figure 34) targets not being achieved, despite the emergent species other than *Typha domingensis* and *Phragmites australis* target being achieved in the aquatic zone (Figure 32). The further decline between spring 2018 and 2019 was due to the emergent species other than *Typha domingensis* and *Phragmites australis* target not being achieved in the aquatic zone in spring 2019 (Figure 32). The increase between spring 2019 and spring 2020 was due to the deep water (Figure 34) and the aquatic zone native submergent targets being met (Figure 33). The decline between spring 2020 and autumn 2021 was due to the native submergent target in the aquatic zone not being achieved, the increase in spring 2021 due to this target and the native emergent other than *Typha domingensis* and *Phragmites australis* in the aquatic zone being achieved (Figure 32 and Figure 33). The small decrease in the most recent survey was due native emergent other than *Typha domingensis* and *Phragmites australis* in the aquatic zone not being achieved (Figure 32).

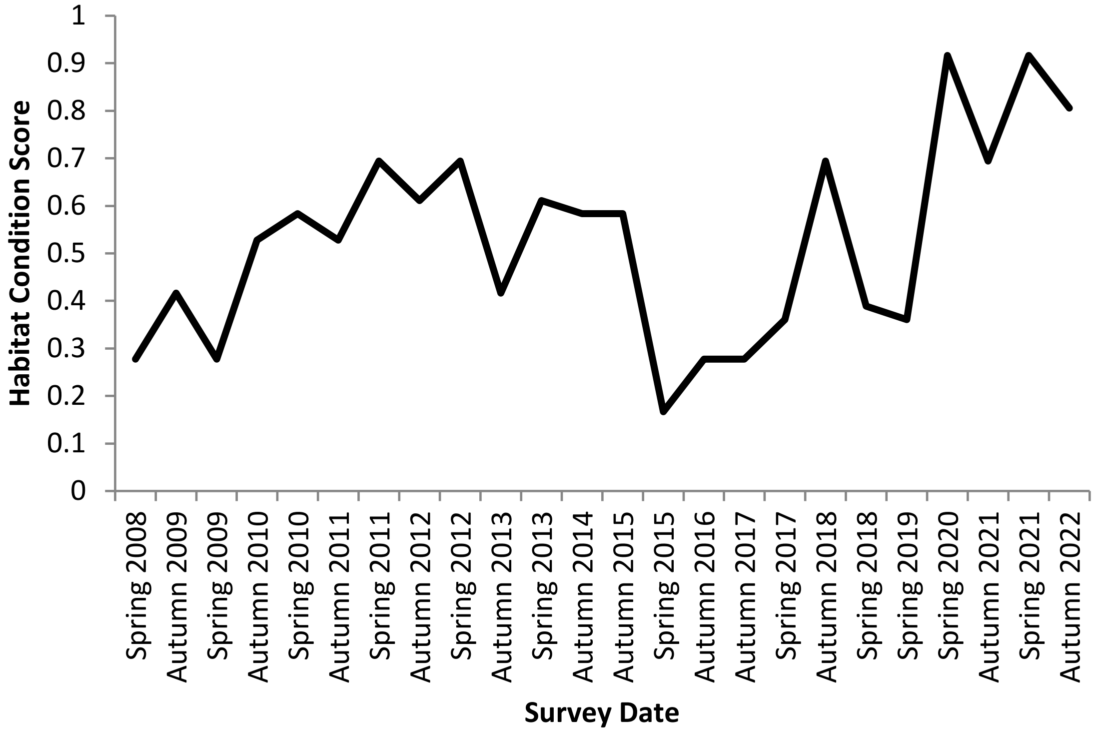

Figure 35: Whole of habitat condition score for Goolwa Channel from spring 2008 to autumn 2022.

Permanent wetlands

Littoral zone

Figure 36 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 75% in the littoral zone from spring 2008 to autumn 2022. 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 36). Therefore, this target has been achieved throughout the condition monitoring program despite there being an upward trend since autumn 2016 (Figure 36).

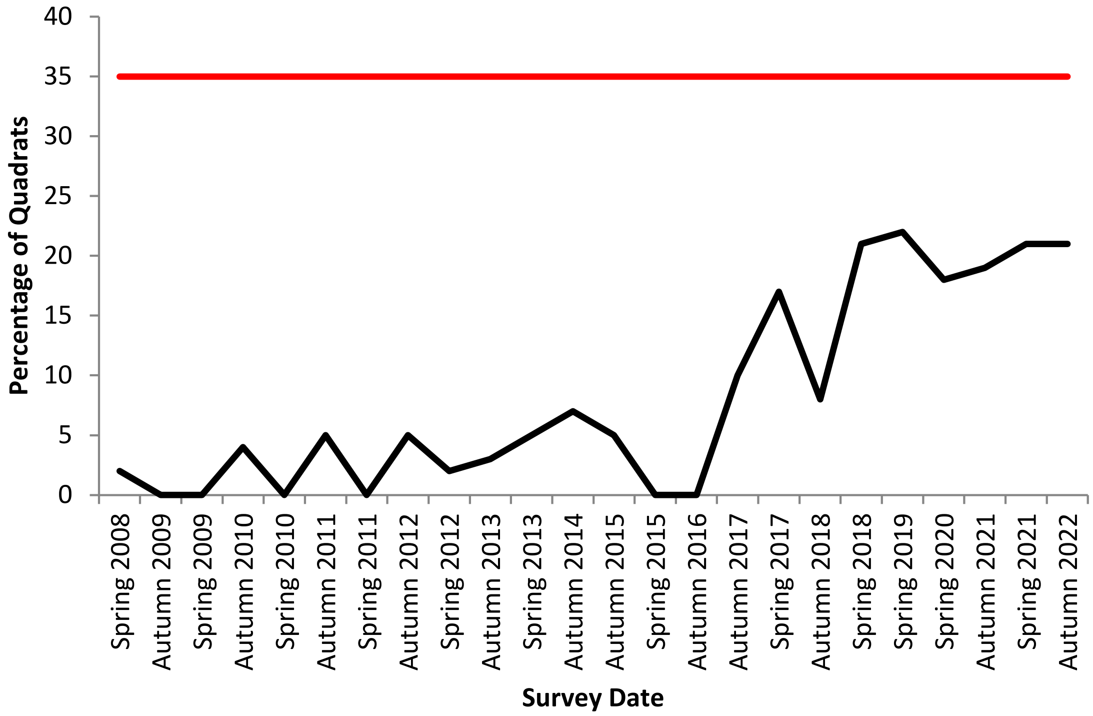

Figure 36: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the littoral zone of permanent wetlands from spring 2008 to autumn 2022.

Figure 37 shows the percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone from spring 2008 to autumn 2022. In contrast to lakes Alexandrina (Figure 13) and Albert (Figure 21) and Goolwa Channel (Figure 28), the reinstatement of water levels did not result in a decrease in the indicator. Between autumn 2010 and autumn 2016 there was a decreasing trend but a large increase between autumn 2016 and autumn 2018 (Figure 37). The highest proportion of quadrats (54%) containing more than 50% cover of these species was in autumn 2018, after which the proportion of quadrats remained between 40 and 55% (Figure 37). The target was only achieved in spring 2008 and spring 2009 (Figure 37).

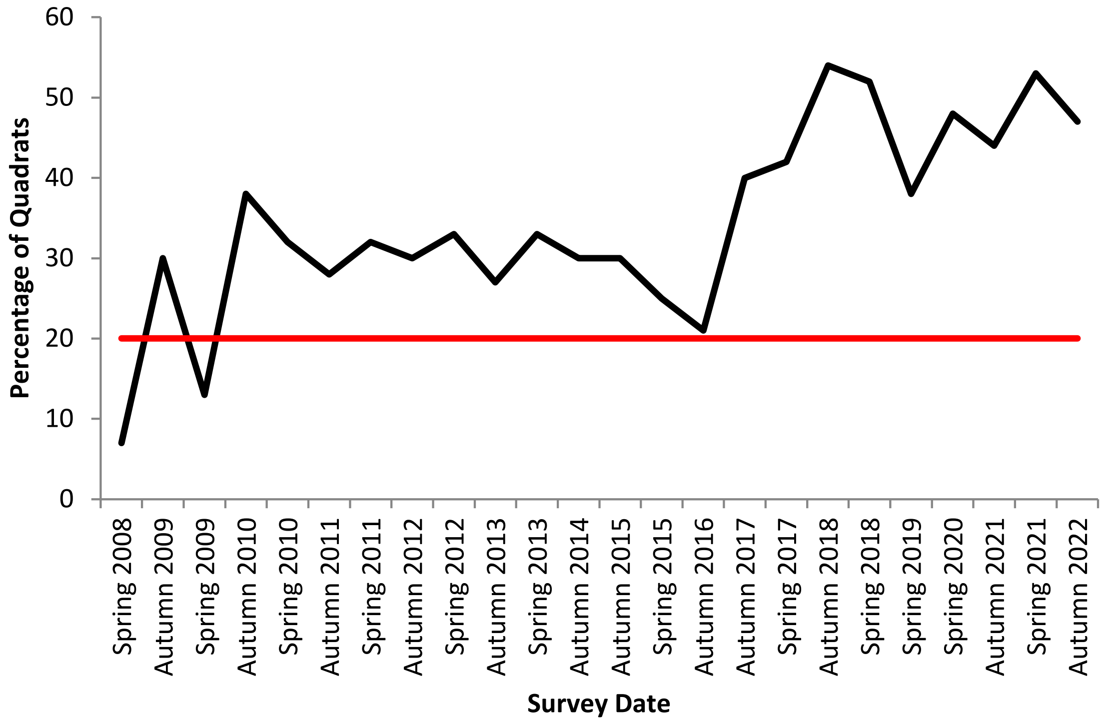

Figure 37: Percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% in the littoral zone of permanent wetlands from spring 2008 to autumn 2022.

Figure 38 shows the percentage of quadrats containing a cover of native amphibious species ≥5% in the littoral zone from spring 2008 to autumn 2022. Percentage cover was highly variable but has generally tended upwards for the duration of the monitoring (Figure 38). The target of 50% of quadrats having a cover of native amphibious species ≥5% was achieved for the first time in spring 2020 and every following survey (Figure 38).

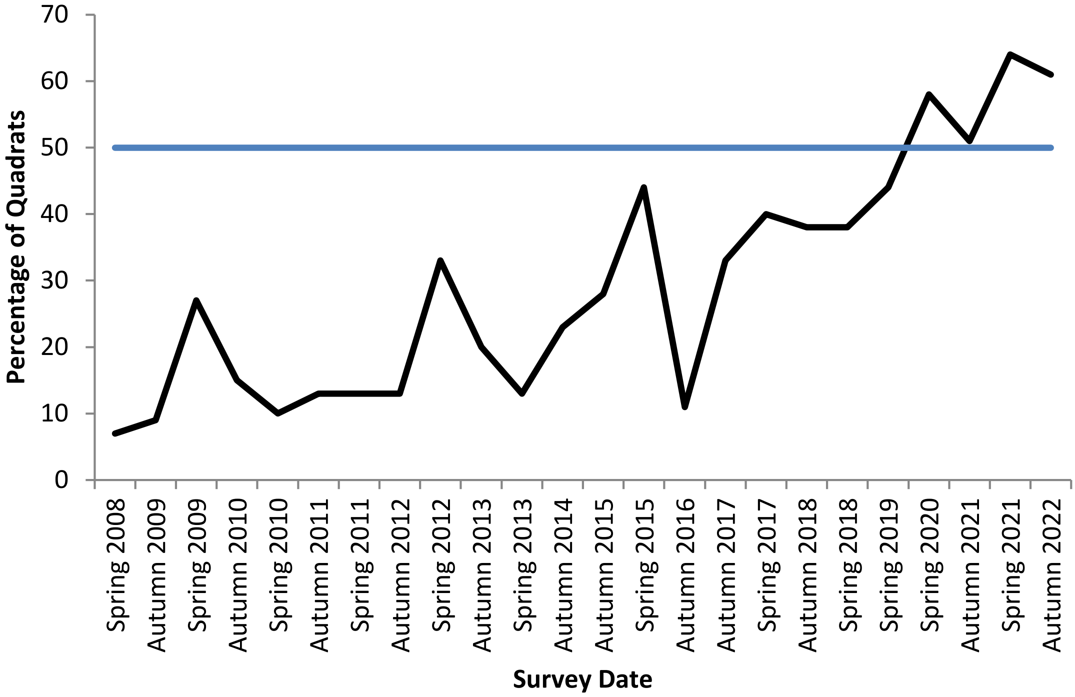

Figure 38: Percentage of quadrats containing a cover native amphibious species greater than 5% in the littoral zone of permanent wetlands from spring 2008 to autumn 2022.

Figure 39 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* ≥5% in the littoral zone from spring 2008 to autumn 2022. The indicator has not exceeded 50% of quadrats; therefore, this target has not been achieved during the condition monitoring program (Figure 39). There was a general increasing trend of the indicator until autumn 2016, after which it decreased sharply but there has been an increasing trend since autumn 2018 (Figure 39).

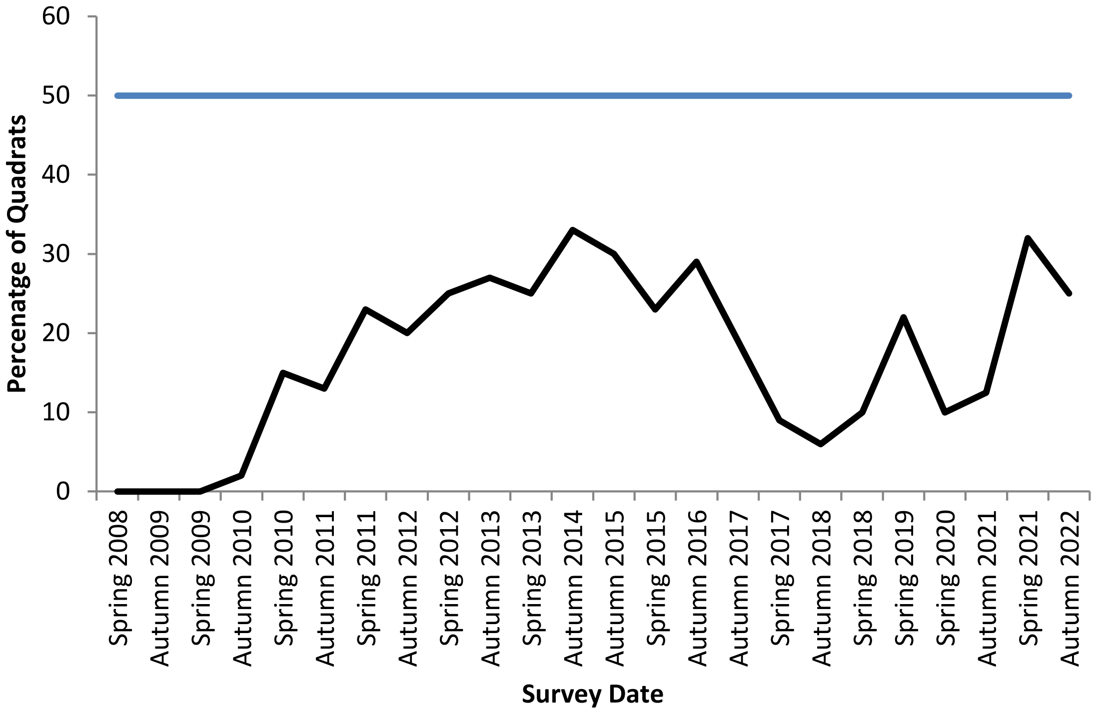

Figure 39: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the littoral zone of permanent wetlands from spring 2008 to autumn 2022.

Aquatic zone

Figure 40 shows the percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone from spring 2008 to autumn 2022. The indicator showed an increasing trend between autumn 2009 and autumn 2015 after which it levelled and decreased to zero in spring 2019 (Figure 40). The number of quadrats has not exceeded 40% and the target was consistently achieved over the monitoring program (Figure 40).

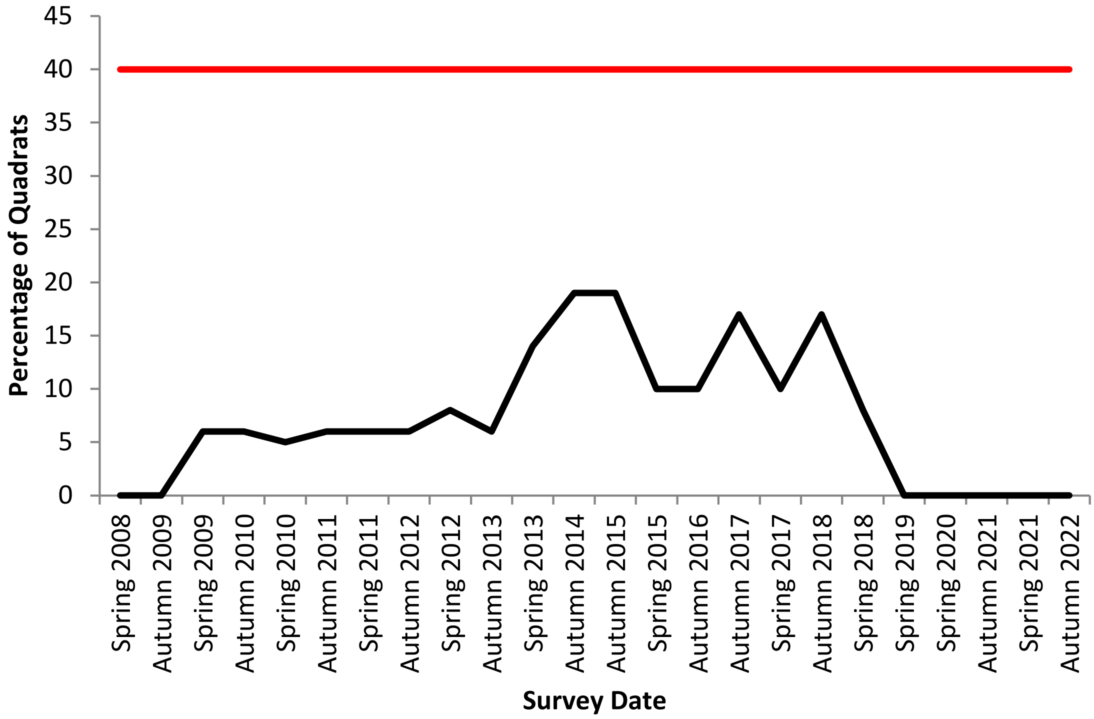

Figure 40: Percentage of quadrats containing a combined cover of *Typha domingensis* and *Phragmites australis* greater than 50% in the aquatic zone of permanent wetlands from spring 2008 to autumn 2022.

Figure 41 shows the percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* ≥5% in the aquatic zone from spring 2008 to autumn 2022. There was an increase in the indicator after water levels were reinstated but that decreased to zero by autumn 2013 (Figure 41). The number of quadrats remained at 5% or lower until spring 2017 and peaked in autumn 2018 with 17%, decreased to 5% in spring 2018 and has since shown an upward trend (Figure 41). The target has not been achieved during the condition monitoring program (Figure 41).

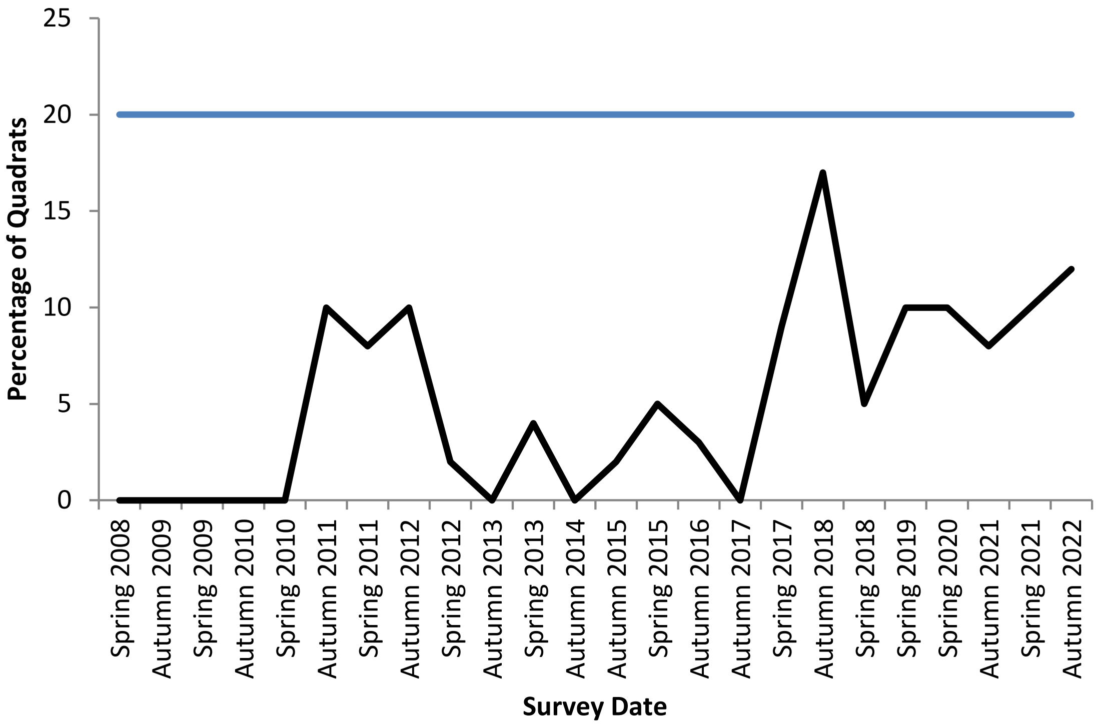

Figure 41: Percentage of quadrats containing a cover of native emergent species other than *Typha domingensis* and *Phragmites australis* greater than 5% in the aquatic zone of permanent wetlands from spring 2008 to autumn 2022.

Figure 42 shows the percentage of quadrats containing a cover of native submergent species between 5 and 50% in the aquatic zone from spring 2008 to autumn 2022. Before spring 2010 the cover of native submergent 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 42). After water levels were reinstated there has been a general increasing trend, with the target being achieved for the first time in spring 2020 and each following survey (Figure 42).

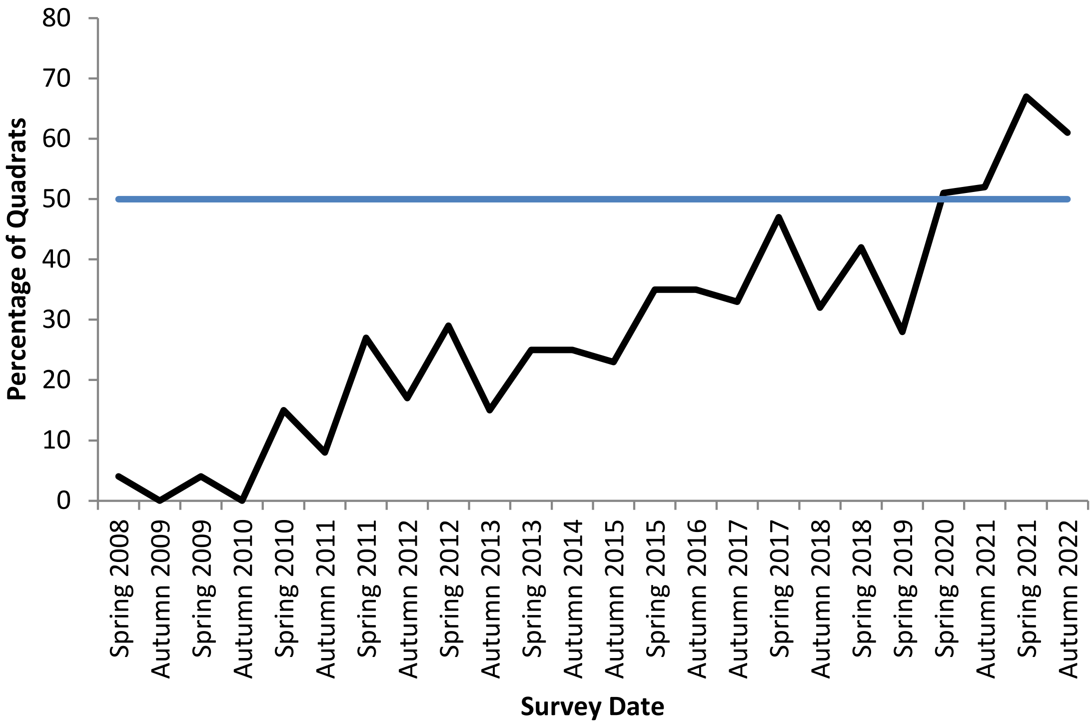

Figure 42: Percentage of quadrats containing a cover of native submergent species between 5 and 50% in the aquatic zone of permanent wetlands from spring 2008 to autumn 2022.

Whole of habitat condition

The whole of habitat condition score for permanent wetlands is shown in Figure 43. There has been little change in the habitat condition score for permanent wetlands between spring 2008 and spring 2019 (Figure 43). The variability in condition score between spring 2008 and autumn 2010 was due to the littoral zone *Paspalum distichum* and *Cenchrus clandestinus* being achieved in spring 2008 and spring 2009 (Figure 37). From autumn 2010 there was no change in condition score until spring 2020 with the only targets that were achieved consistently over this period being the *Typha domingensis* and *Phragmites australis* targets in the littoral (Figure 36) and aquatic (Figure 40) zones. In spring 2020 and each subsequent survey the littoral zone amphibious (Figure 46) and aquatic zone submergent (Figure 48) targets were achieved resulting in an increase in habitat condition score.

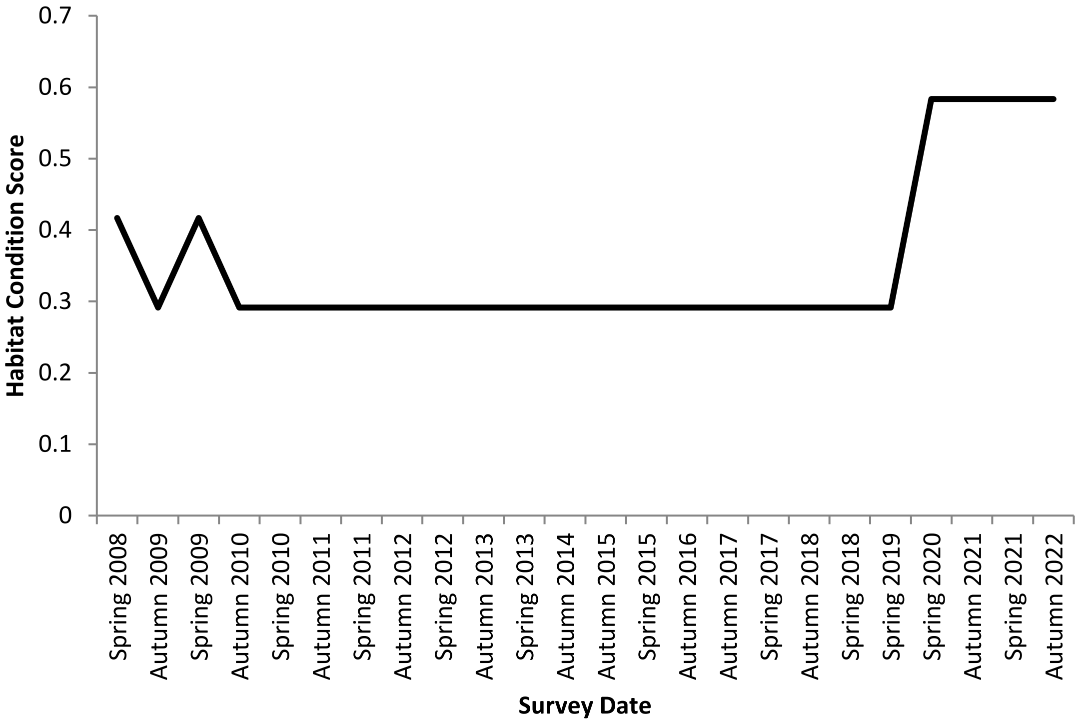

Figure 43: Whole of habitat condition score for permanent wetlands from spring 2008 to autumn 2022.

Seasonal wetlands

Wetland edge

Figure 44 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 2022. There has been an increasing trend in the indicator around the edges of seasonal wetlands over the duration of the condition monitoring program (Figure 44). In addition, there was a seasonal pattern with higher abundances in autumn when water levels are low (Figure 44). The target of a maximum of 20% of quadrats was exceeded (target not achieved) in autumn 2012, autumn 2013 and from autumn 2014 onwards (Figure 44).

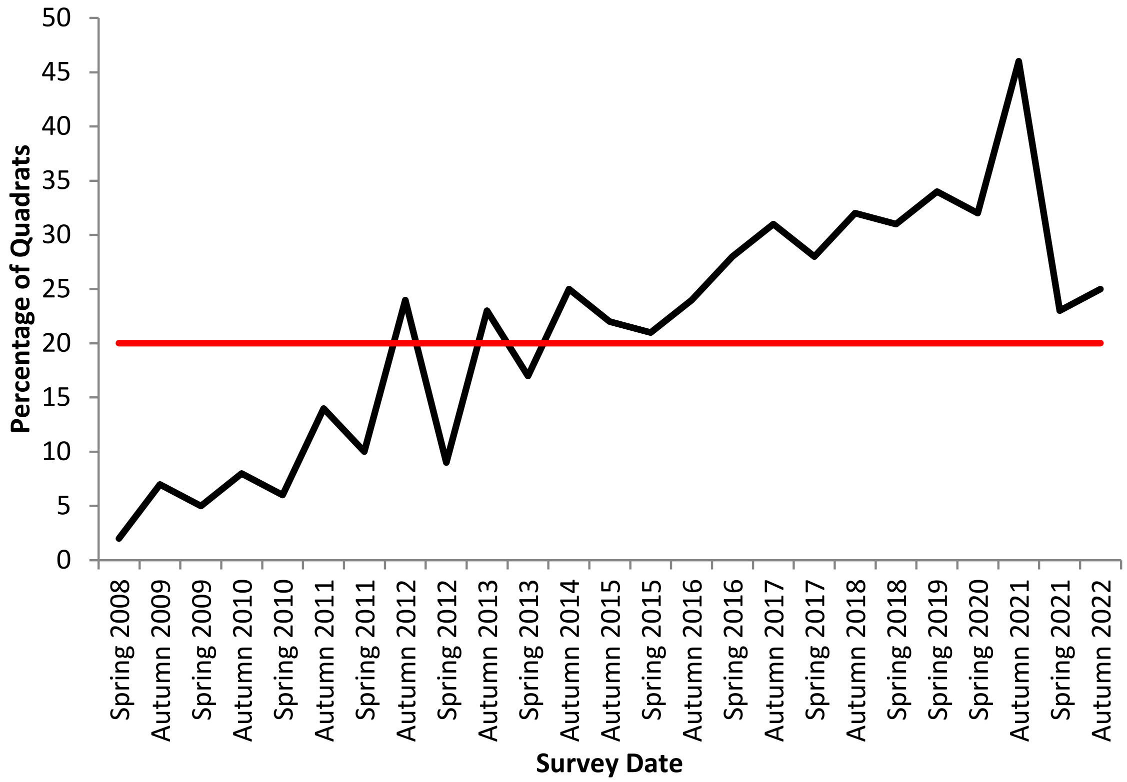

Figure 44: Percentage of quadrats containing a combined cover of *Paspalum distichum* and *Cenchrus clandestinus* greater than 50% around the edge of seasonal wetlands from spring 2008 to autumn 2022.

Figure 45 shows the percentage of quadrats containing a cover of native amphibious species ≥5% in the around the edges of seasonal wetlands from spring 2008 to autumn 2022. Native amphibious species were common around the edges of seasonal wetlands and the number of quadrats with a cover of ≥5% was higher than the 50% target throughout the survey period despite the downward trend from autumn 2016 to spring 2021 (Figure 45). Therefore, this target was consistently achieved over the condition monitoring program (Figure 45).

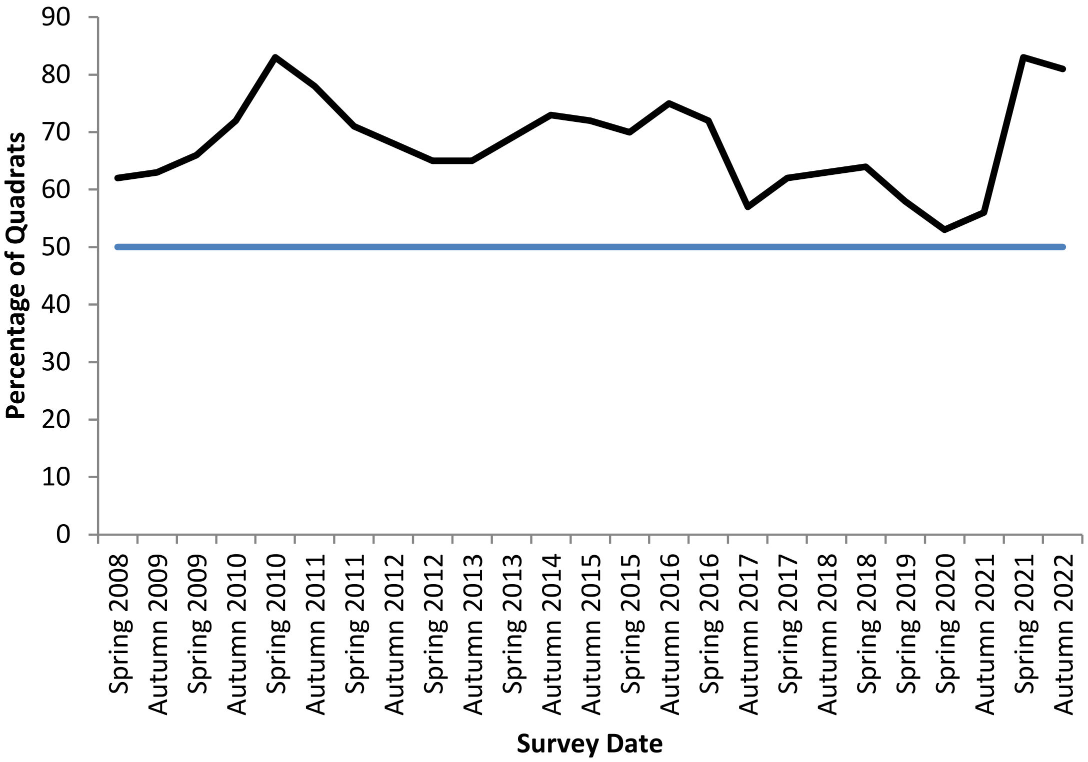

Figure 45: Percentage of quadrats containing a cover native amphibious species greater than 5% around the edge of seasonal wetlands from spring 2008 to autumn 2022.

Figure 46 shows the percentage of quadrats containing a cover of native emergent species ≥5% around the edges of seasonal wetlands from spring 2008 to autumn 2022. The percentage of quadrats with a cover of native emergent species ≥5% has not exceeded 50% of quadrats; therefore, this target has not been achieved during the condition monitoring program (Figure 46). However, there was a general increasing trend from over the condition monitoring program, with a sharp increase between autumn 2021, peaking in spring 2021 with 45% of quadrats containing native emergent species with a cover of ≥5% (Figure 46).

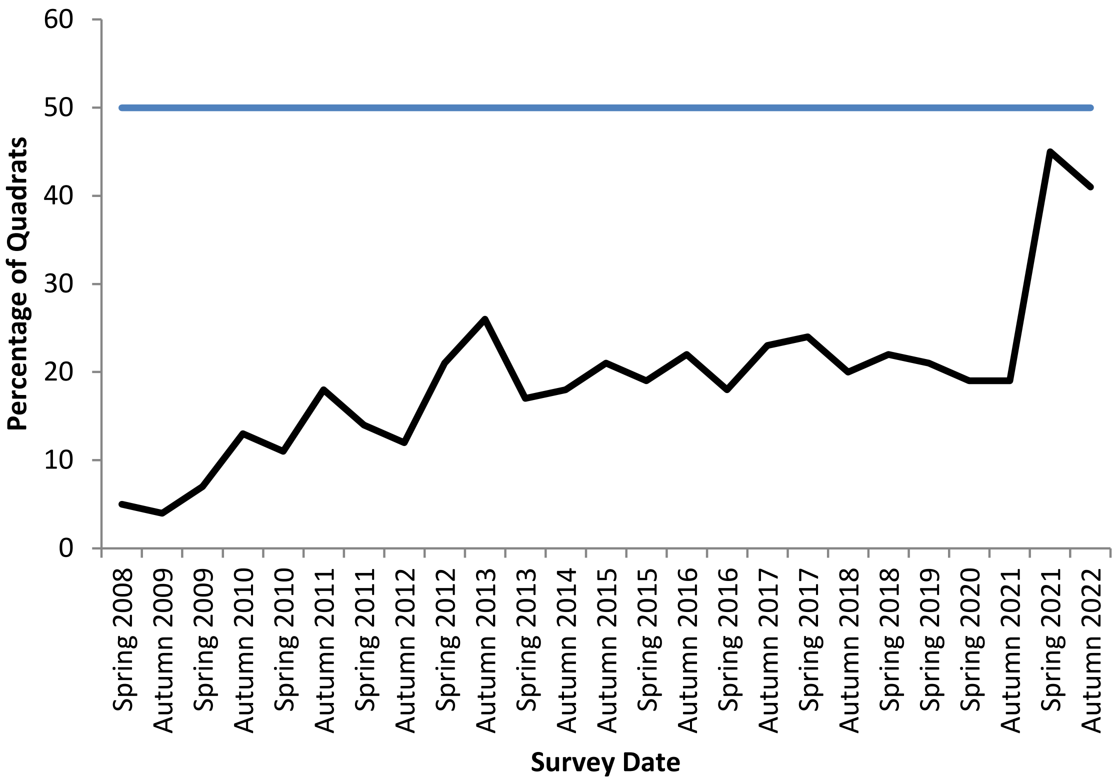

Figure 46: Percentage of quadrats containing a cover of native emergent species greater than 5% around the edge of seasonal wetlands from spring 2008 to autumn 2022.

Wetland bed

Figure 47 shows the percentage of quadrats containing a cover of native amphibious species ≥5% on the beds of seasonal wetlands from spring 2008 to autumn 2022. Native amphibious species were less common on the beds of seasonal wetlands compared to the edges (Figure 45). The number of quadrats with a combined cover of these species ≥5% peaked in spring 2010 (59%), after which it fell to 26% and fluctuated between 15% and 32% until spring 2016 when it rose to 50% but fell to 18% in autumn 2017 (Figure 47). The target was achieved 14 times over the condition monitoring program (including the most recent survey), with spring 2020 having the lowest percentage (13%) of quadrats containing native amphibious species with a cover of ≥5% (Figure 47).

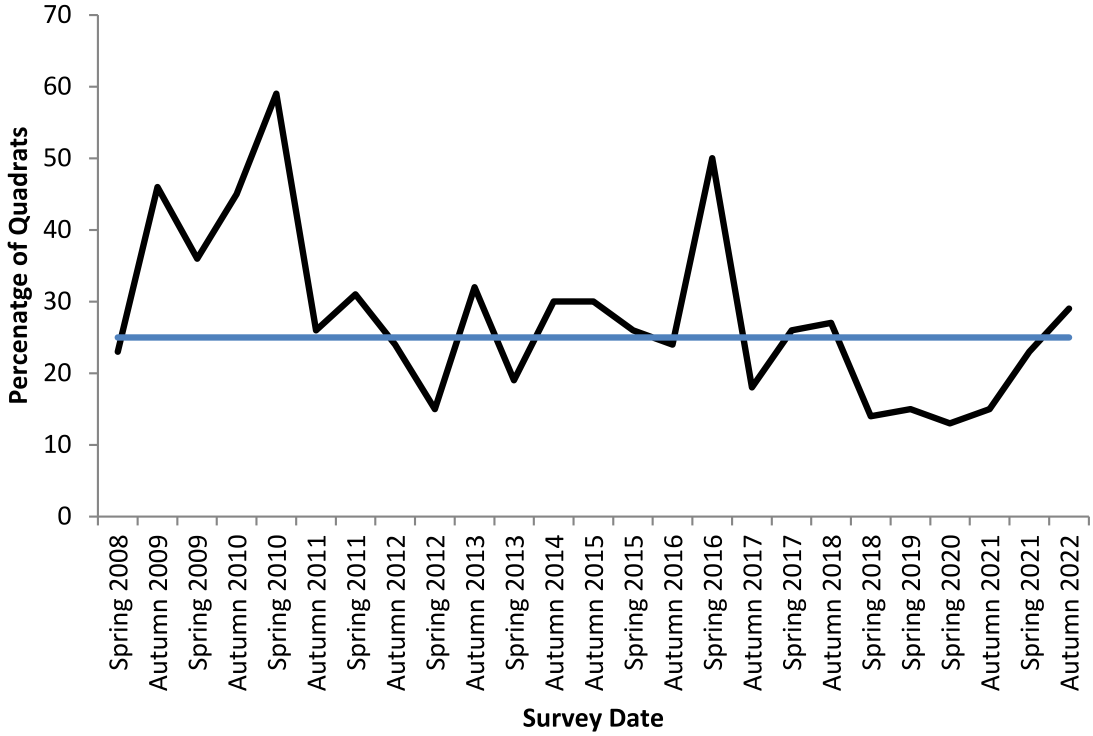

Figure 47: Percentage of quadrats containing a cover of native amphibious species greater than 5% on the bed of seasonal wetlands from spring 2008 to autumn 2022.

Figure 48 shows the percentage of quadrats containing a cover of native emergent species ≥5% on the beds of seasonal wetlands from spring 2008 to autumn 2022. Between spring 2008 and spring 2009 there was a decrease of the indicator (Figure 48). 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 48). The target of 20% of quadrats was first achieved in autumn 2011 and was achieved each subsequent survey, except in spring 2013 and spring 2018 (Figure 48).

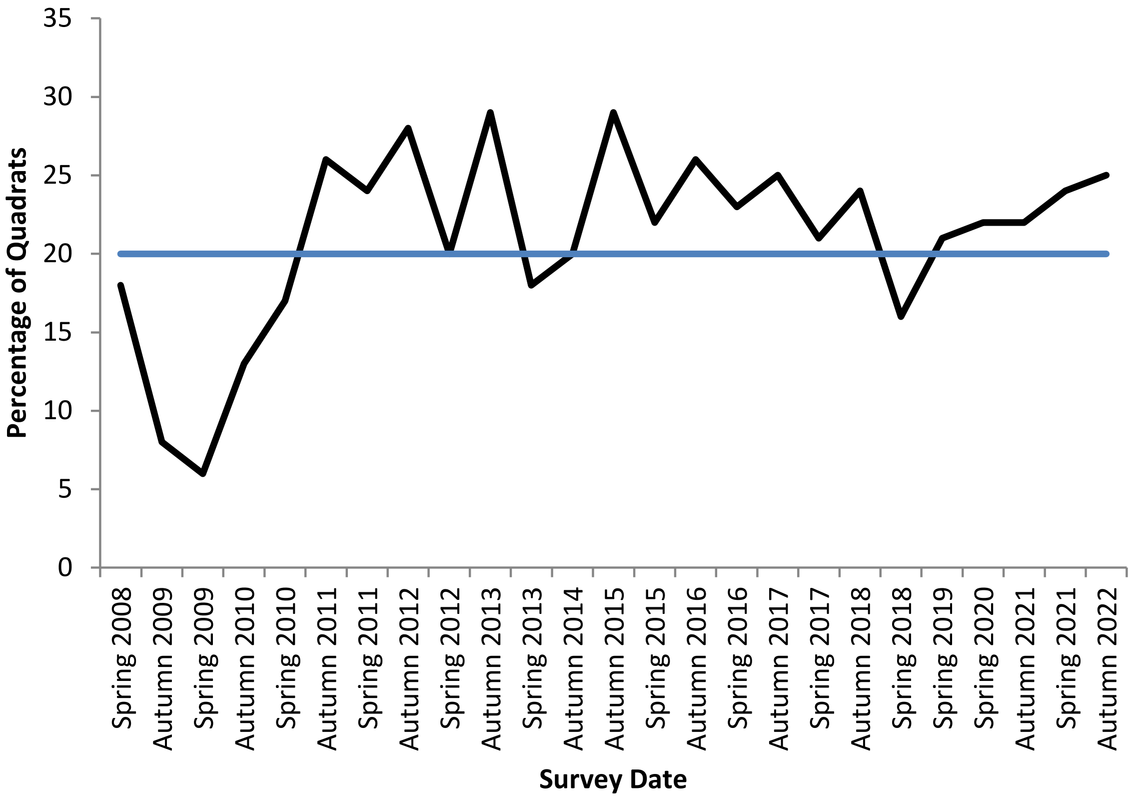

Figure 48: Percentage of quadrats containing a cover of native emergent species greater than 5% on the beds of seasonal wetlands from spring 2008 to autumn 2022.

Figure 49 shows the percentage of quadrats containing a cover of native submergent species ≥25% on the beds of seasonal wetlands in spring from 2008 to spring 2021. 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 42). After water levels were reinstated in spring 2010, there has been a generally increasing trend in the indicator, with the highest percentage of quadrats with submergent species greater than 25% cover (49%) in spring 2021 (Figure 42). However, the target of 50% of quadrats has not been achieved over the duration of the condition monitoring program (Figure 42).

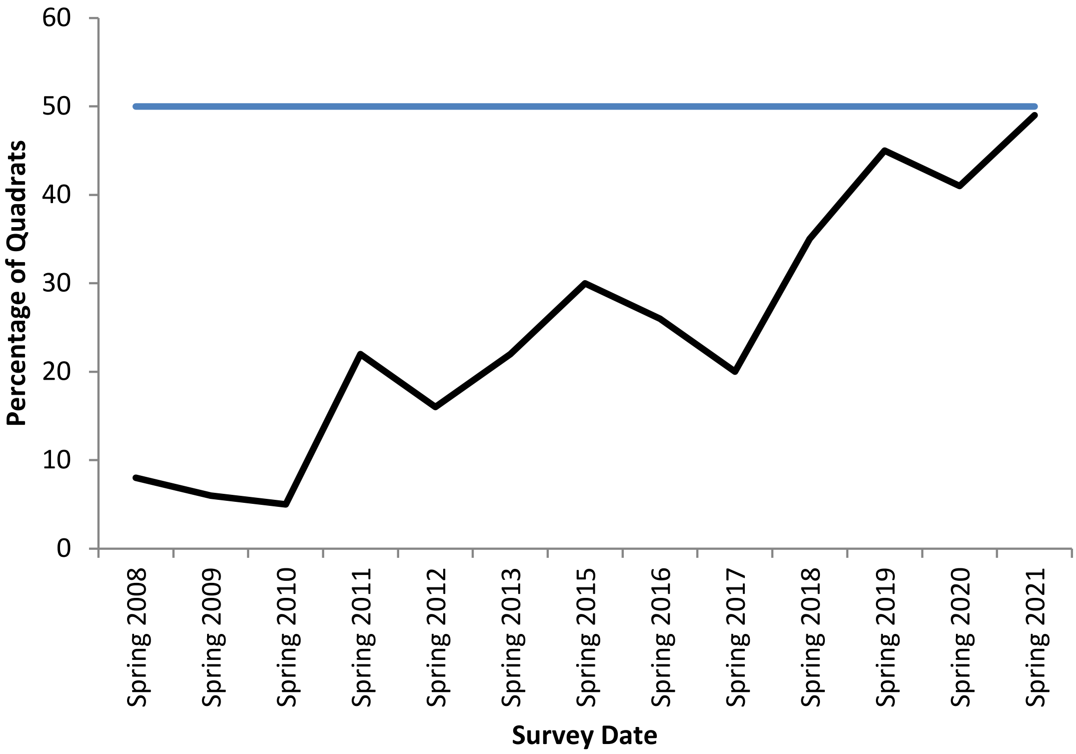

Figure 49: Percentage of quadrats containing a cover of native submergent species greater than 25% in spring on the beds of seasonal wetlands from spring 2008 to spring 2021.

Whole of habitat condition

The whole of habitat condition score for seasonal wetlands is shown in Figure 50. There has not been a sustained increase in habitat condition score over the condition monitoring program for temporary wetlands (Figure 50). 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 45; Figure 47) and emergent (Figure 46; Figure 48) species and there being no submergent species target in autumn (which has never been achieved in spring) (Figure 49). There was no change in score between autumn 2017 and autumn 2018 after which there was a decrease resulting in the lowest habitat condition score over the condition monitoring program (Figure 50). The decrease between autumn and spring 2018 was due to the native amphibious (Figure 47) and emergent species (Figure 48) targets for the wetland beds not being achieved in spring 2018. However, there has been a general upward trend since spring 2018 due multiple targets being achieved, with a sharp increase between spring 2021 and autumn 2022 due to the amphibious target being achieved on the wetlands bed and there being no submergent target (Figure 48).

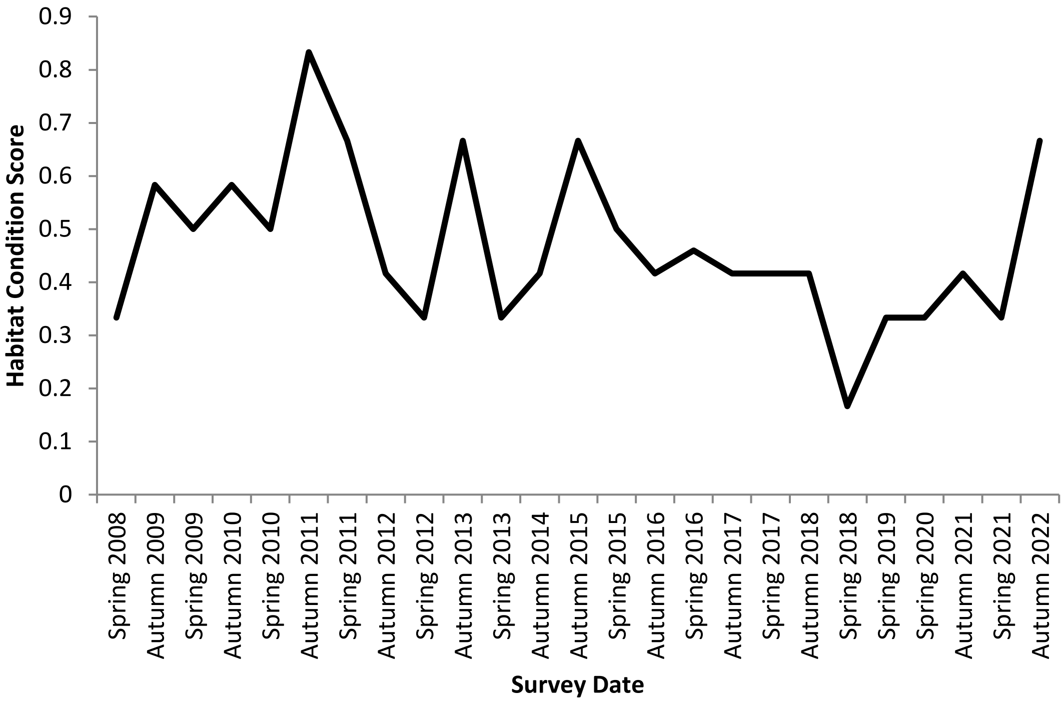

Figure 50: Whole of habitat condition score for seasonal wetlands from spring 2008 to autumn 2022.

Whole of lakes condition

The whole of Icon Site Score (WOISS) for aquatic and littoral vegetation represents the proportion of targets achieved throughout the five different habitats and using the Matter 8 condition rating. Based on this score, objective V3 has been achieved because a 'good' rating (defined by Matter 8 criteria) has been reached in the four most recent surveys (Table 10).

During the period of low water levels (surveys prior to spring 2010) the WOISS was low and fluctuated between 0.32 and 0.34 (poor condition rating (Figure 51, Table 10)). There was an increase between spring 2009 and spring 2011, after which it fluctuated between 0.43 and 0.55 ('fair' condition) until spring 2018 after which there was upwards trend and a 'good' rating was achieved in the four latest surveys (Figure 51, Table 10).

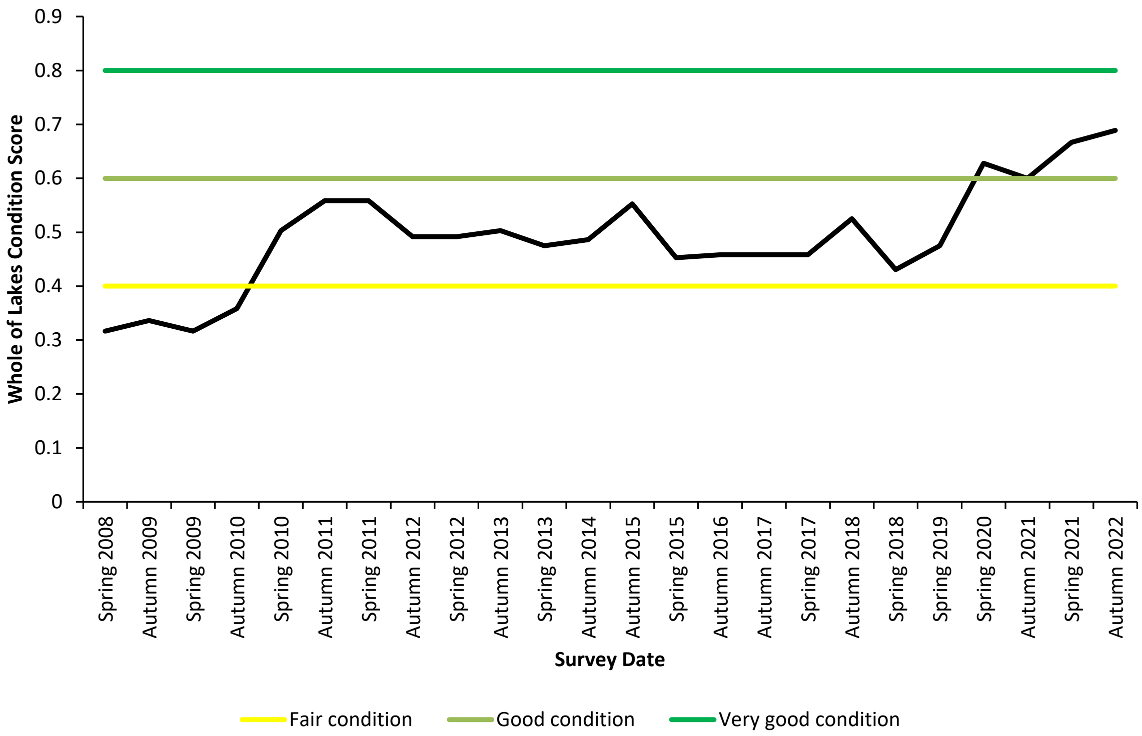

Figure 51: Whole of lakes condition score from spring 2008 to autumn 2022.

Table 10: Whole of lakes condition score and Matter 8 condition rating (Department for Environment and Water 2019) from spring 2008 to autumn 2022.

Survey Date	Whole of lakes condition score	Condition rating
Spring 2008	0.32	Poor
Autumn 2009	0.34	Poor
Spring 2009	0.32	Poor
Autumn 2010	0.36	Poor
Spring 2010	0.50	Fair
Autumn 2011	0.56	Fair
Spring 2011	0.56	Fair
Autumn 2012	0.49	Fair
Spring 2012	0.49	Fair
Autumn 2013	0.50	Fair
Spring 2013	0.48	Fair
Autumn 2014	0.49	Fair
Autumn 2015	0.55	Fair
Spring 2015	0.45	Fair
Autumn 2016	0.46	Fair
Autumn 2017	0.46	Fair
Spring 2017	0.46	Fair
Autumn 2018	0.53	Fair
Spring 2018	0.43	Fair
Spring 2019	0.48	Fair
Spring 2020	0.63	Good
Autumn 2021	0.60	Good
Spring 2021	0.67	Good
Autumn 2022	0.69	Good

3.3. *Melaleuca halmaturorum* age class structure and extent

The age class structure of *Melaleuca halmaturorum* throughout the Lower Lakes showed that almost all trees recruited in the last 50 years (post construction of the Barrages) because there were very few old trees (age class >7), and these older trees were only present at Hunters Creek (Figure 52). Age class structure of stands differed between sites and there were changes in age class structure between 2008, 2014 and 2022 at most sites (Figure 52).

In 2008 and 2014, Goat Island had the greatest range of age classes with trees present in each age class between one and six in 2008 (age range 1 to >28 years) and between one and seven (age range 1 to >28 years) in 2014 (Figure 52). There were a lower proportion of young trees (age classes one and two, age range 1 to 5 years) present in 2014; however, there was evidence of germination events between 2008 and 2014 due to the presence of seedling and saplings (age classes one and two) (Figure 52). In 2022, no seedlings or saplings were present (no evidence of germination) with the youngest trees present in age class 4 (>10 years old) and only three age classes present (age classes four, five and six) (Figure 52).

There was little change in the age class structure of the *Melaleuca halmaturorum* stand at Boggy Creek between 2008, 2014 and 2022 (Figure 52). Age classes from two to six were present in 2008 but no young trees were present (age class two) in 2014 or 2022 (Figure 52) indicating there has been no recruitment over this time. Furthermore, the stand is aging with an increase in the proportion of age classes four, five and six and a decrease in age class three (Figure 52).

The *Melaleuca halmaturorum* stand at Hunters Creek was dominated by older trees in 2008 (age classes four to seven) (Figure 52). In 2014, the older trees were still present; however, there had been significant germination since 2008 with a large proportion of the trees present between two and five years old (age class two) (Figure 52). In 2022, the older trees were also present and there had been significant recruitment with trees from age classes from two to eight present (Figure 52). These results also indicate high survivorship of the trees from age classes two and three in 2014, which are now age classes three and four.

Five age classes of trees were present at Kennedy Bay in 2008, 2014 and 2022 (Figure 52). The majority (approximately 80%) were older trees (age class six >28 years); however, in 2008 there were a small number of seedlings (age class one) that did not survive as there were no trees from ages class two present in 2014 (Figure 52). There was little change in age class structure between 2014 and 2022 (Figure 52) with high survivorship and the stand aging.

The *Melaleuca halmaturorum* stand at Salt Lagoon contained the largest proportion of seedlings and saplings with over 95% of trees surveyed in 2008 in age class one (<2 years) (Figure 52). Unfortunately, this site was not able to be resurveyed in 2014 and 2022.

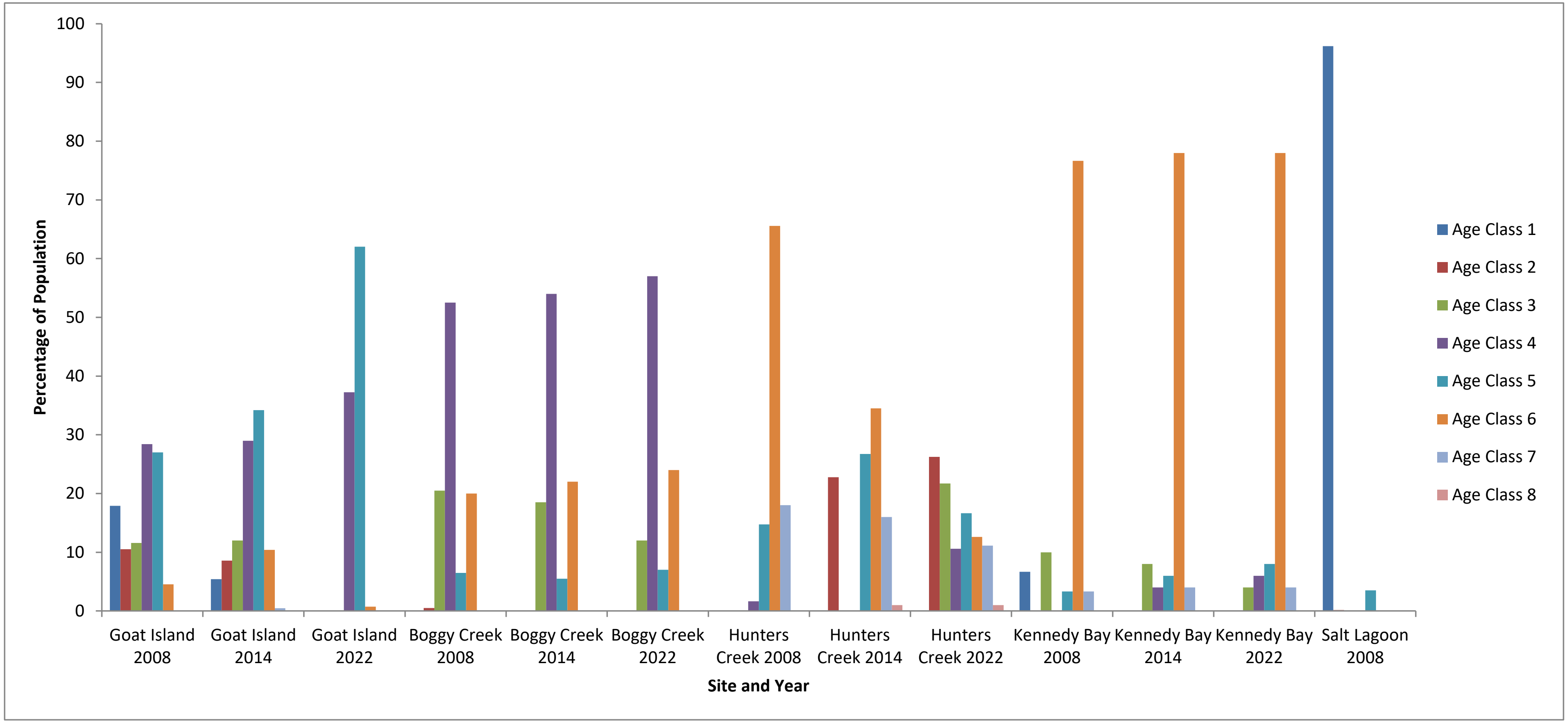

Figure 52: Age class structure of *Melaleuca halmaturorum* trees at five sites in the Lower Lakes in 2008, 2014 and 2022.

Mapping from aerial photographs indicated that in 2003 the total area of *Melaleuca halmaturorum* stands was 0.387 km^2, there was an increase to 0.450 km^2 in 2008 and a further increase in 2020 to 0.489 km^2. At all monitoring locations established in 2008 there has been and increase through time (Figure 53 to Figure 57) despite recruitment only being recorded at Hunters Creek. The increase in area is primarily due to the increased canopy size of trees which has been detected through aerial imagery. The *Melaleuca halmaturorum* stands have also moved from open to closed stands though time.

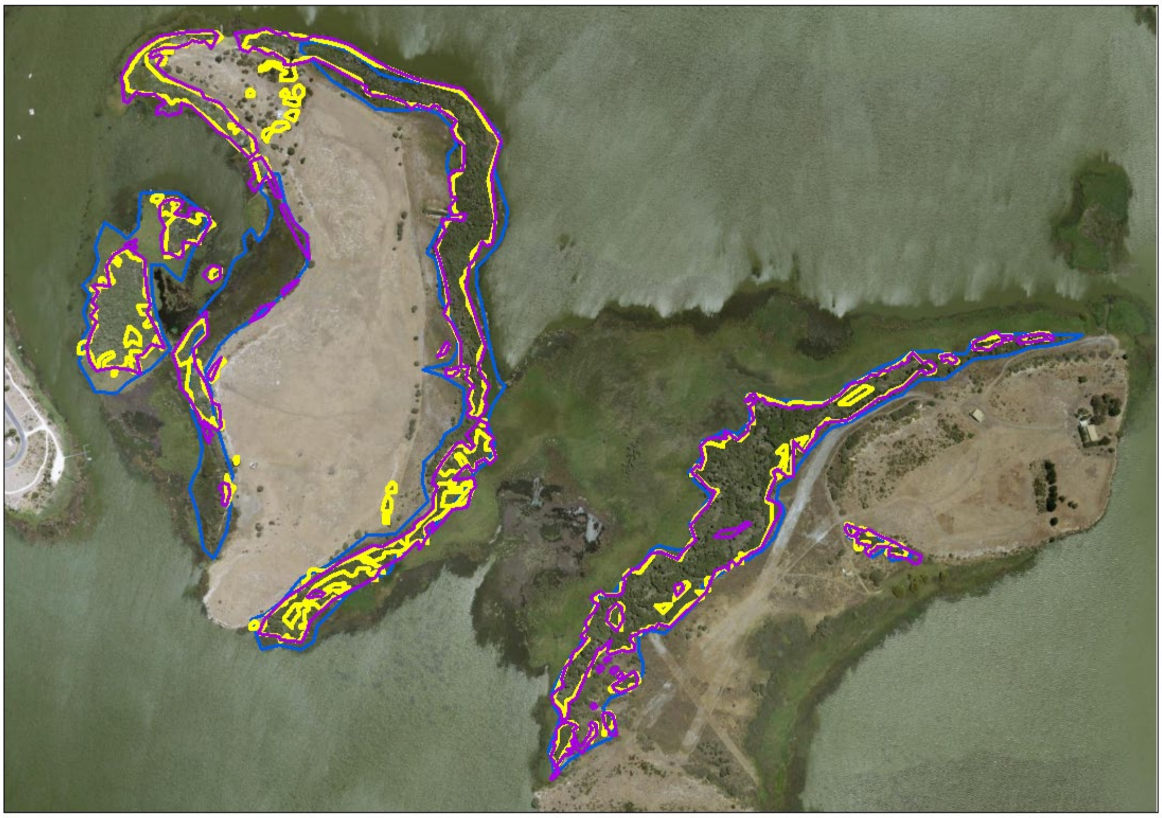

Figure 53: *Melaleuca halmaturorum* stand extent at Goat and Goose Islands in 2003 (yellow polygons) 2008 (purple polygons), and 2022 (blue polygons).

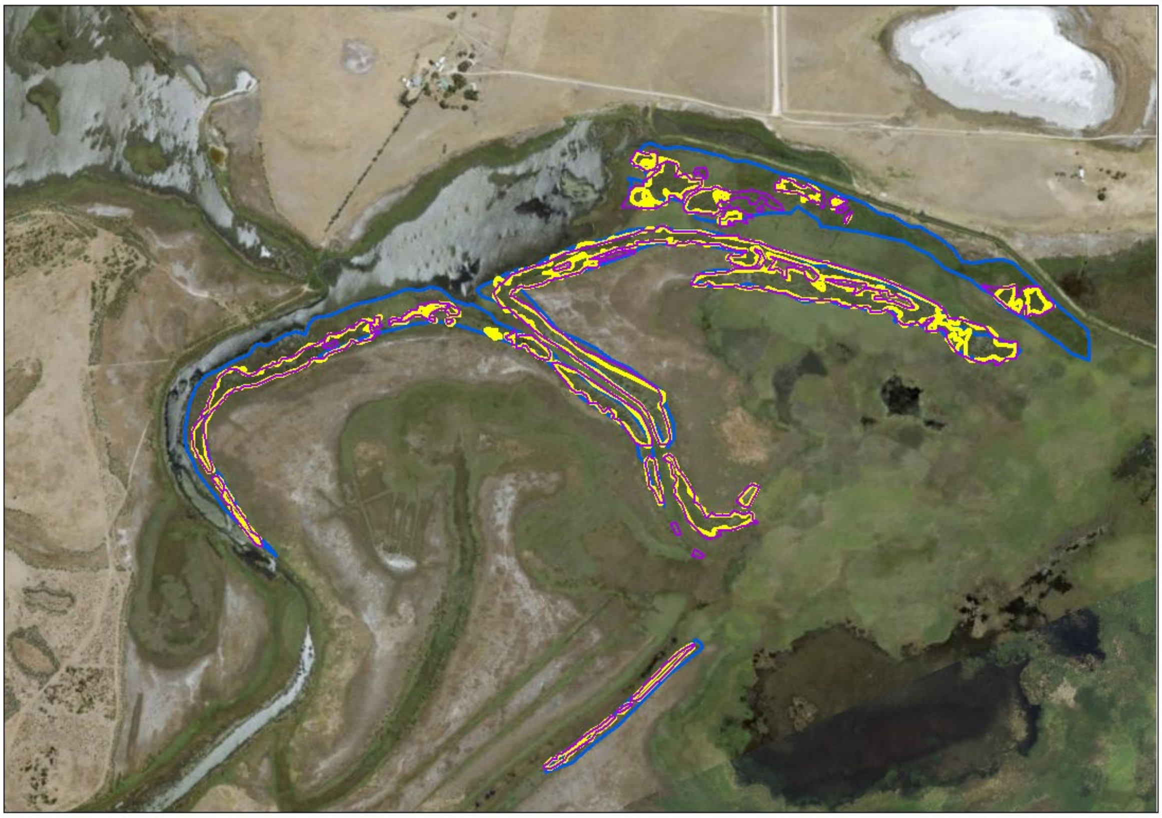

Figure 54: *Melaleuca halmaturorum* stand extent at Boggy Creek in 2003 (yellow polygons) 2008 (purple polygons), and 2022 (blue polygons).

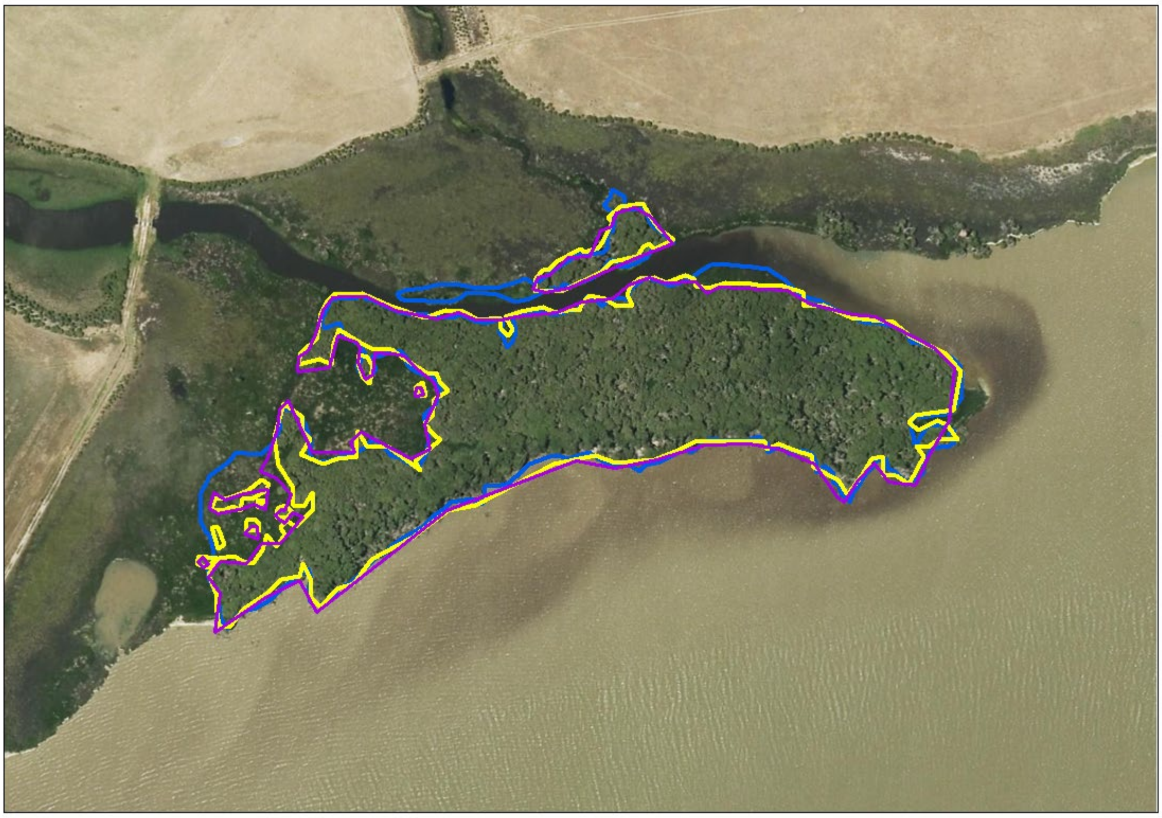

Figure 55: *Melaleuca halmaturorum* stand extent at Hunters Creek in 2003 (yellow polygons) 2008 (purple polygons), and 2022 (blue polygons).

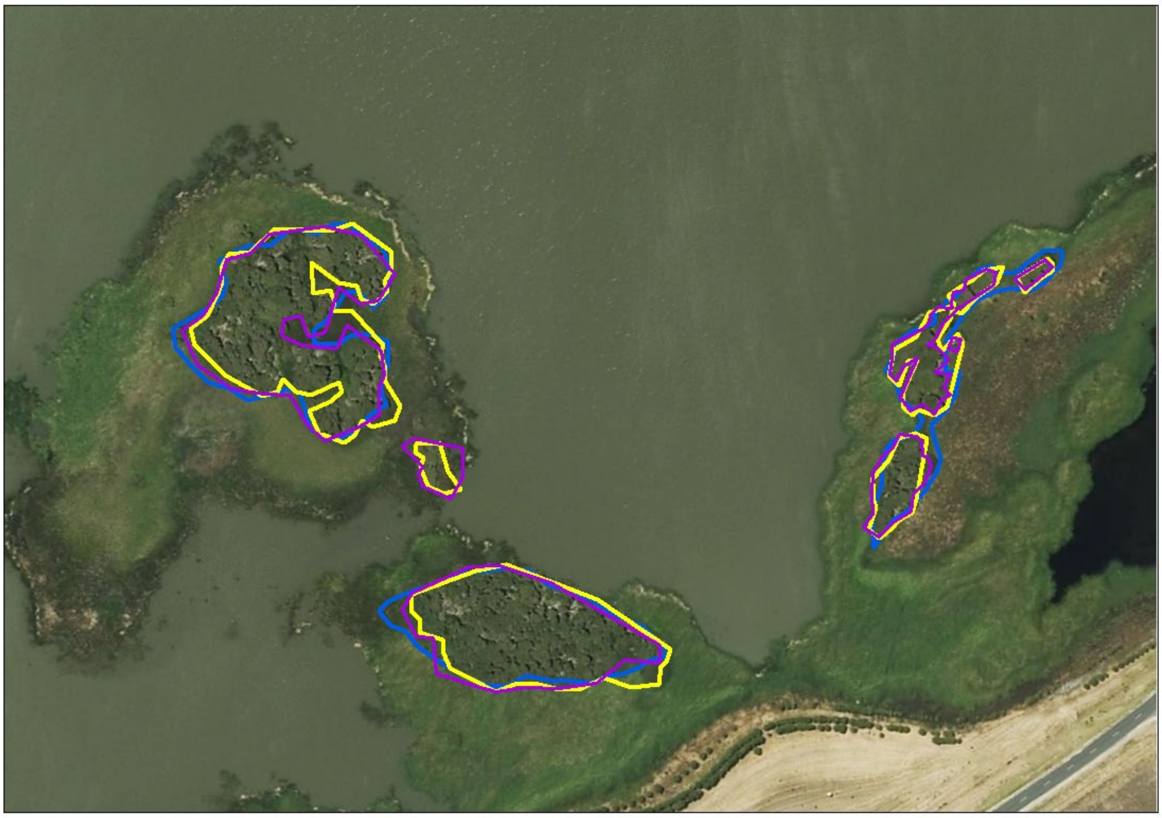

Figure 56: *Melaleuca halmaturorum* stand extent at Kennedy Bay in 2003 (yellow polygons) 2008 (purple polygons), and 2022 (blue polygons).

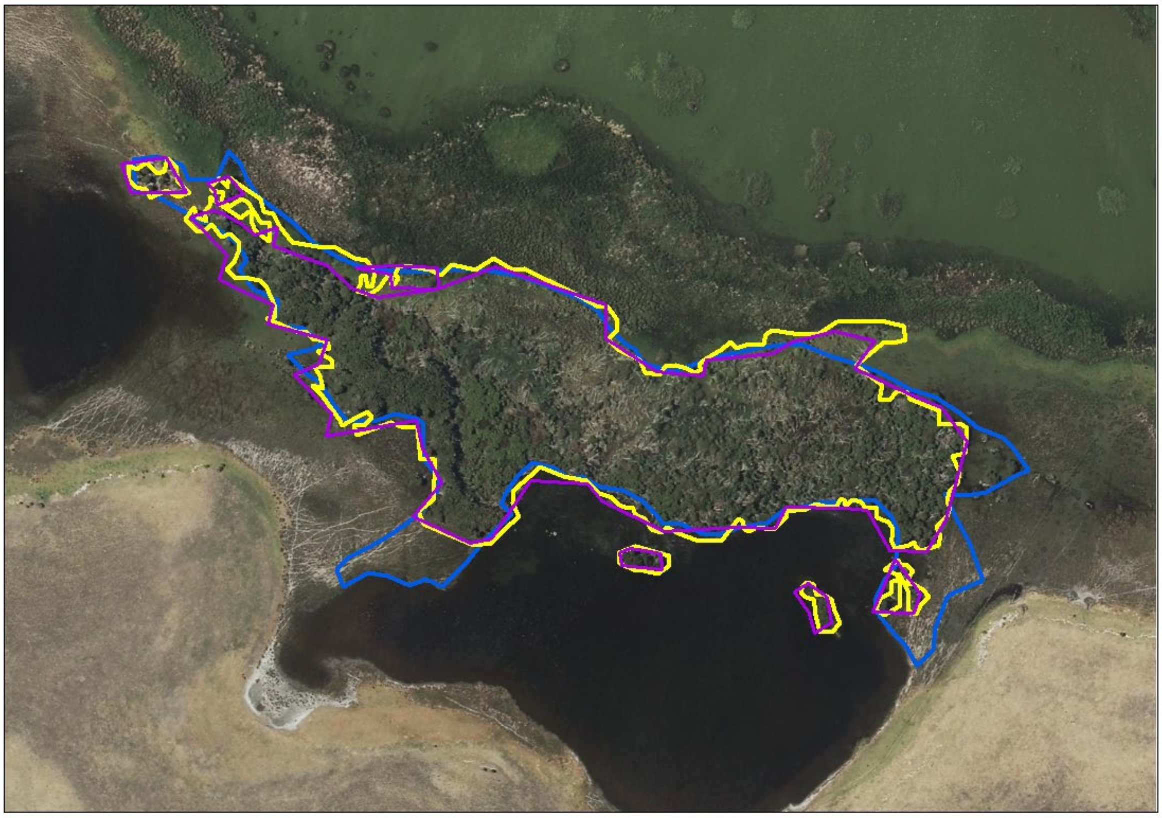

Figure 57: *Melaleuca halmaturorum* stand extent at Salt Lagoon in 2003 (yellow polygons) 2008 (purple polygons), and 2022 (blue polygons).

4. DISCUSSION AND MANAGEMENT IMPLICATIONS

4.1. Impacts of water level and salinity

During the most recent survey period (spring 2021 to autumn 2022), salinity (Figure 3) in Lake Alexandrina and the Goolwa Channel remained similar to values recorded since spring 2010. Electrical conductivity also remained stable in Lake Albert but was higher than Lake Alexandrina, although the higher salinity in Lake Albert is probably not biologically significant for the plant species present. Water levels in summer/autumn 2021-22 were not drawn-down as far as in previous years with the minimum water level around +0.6 m AHD.

During the drought-induced draw-down (2007 to 2010), plant assemblages had shifted towards terrestrial taxa. However, following restoration of water levels in the Lower Lakes in late August 2010 (and the subsequent reconnection of most wetlands) there has been a general increasing trend 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; however, the typical seasonal cycle of high water levels in spring and early summer and low water levels in autumn has occurred each year (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). Increases in water levels between autumn 2016 and autumn 2017 periodically inundated areas at higher elevations (above +0.9 m AHD) in spring 2016, which may have resulted in the increase in abundance of *Cenchrus clandestinus* and *Paspalum distichum* in permanent and temporary wetland habitats. The lower water levels in autumn 2017, 2018 and 2019 exposed the fringes of lakeshores and wetlands, which provided opportunities for species requiring exposure to germinate (e.g. *Persicaria lapathifolia, Berula erecta, Calystegia sepium, Ludwigia peploides, Juncus* spp., *Cyperus gymnocaulos*) (Nicol 2004). There may be limited opportunity for recruitment of species that require exposure to germinate due to fringing areas being densely vegetated with emergent species such as *Typha domingensis* or *Phragmites australis*. However, native amphibious plant species richness at +0.6 m AHD at the site scale was higher in the autumn 2017 and 2018 surveys compared to spring 2017 in all habitats indicating draw-down provided opportunities for species to recruit. Furthermore, native amphibious species richness in spring 2018 and 2019 (despite decreasing during this period in Lake Albert and Goolwa Channel) was higher than spring 2017 across all habitats (Figure 10) indicating an increase that persisted for several years, most likely due to seasonal lake level cycling. However, there was a decrease in native amphibious species richness at +0.6 m AHD in the four most recent surveys across all habitats that may be due to the higher lake levels throughout the 2020-21 and 2021-22 water years. Despite the decrease in native amphibious species richness at +0.6 m AHD, it was maintained at +0.8 m AHD indicating that these species have not been lost from the littoral zone and should recruit in the future at lower elevations when drawn-down below +0.6 m AHD. Often shorelines that are not densely vegetated are subjected to wave action, which can prevent seedlings from establishing (e.g. Foote and Kadlec 1988). Nevertheless, seasonal water level fluctuations between >+0.8 and +0.5 m AHD are recommended because areas of submergent vegetation are maintained and the establishment of amphibious taxa in areas protected from wave action is facilitated. The main downside to these water level fluctuations is the increase in abundance of *Paspalum distichum* and (to a lesser extent) *Cenchrus clandestinus* in recent years.

4.2. Change in plant community, spring 2008 to autumn 2022

The change in floristic composition observed over the duration of the condition monitoring program (spring 2008 to autumn 2022) has provided information regarding the recovery of the aquatic and littoral plant community, after the Millennium Drought, which 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, although at the cost of losing information regarding the response of individual wetlands or sites, has enabled the change in floristic composition to be analysed at a broader spatial scale. There were similarities in the patterns of change among habitats, such as the expected large changes observed 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 may persist into the future with only minor changes, providing recent salinity and water level regimes are maintained. However, multiple, minor, non-seasonal changes through time can result in large (albeit gradual) changes in the plant community through time. There is evidence this may have occurred in recent years in all habitats (Figure 6). The points on this ordination from the latest surveys, whilst showing less change in floristic composition among surveys compared to those prior to autumn 2011, exhibited a temporal directional change. 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 gradual changes in floristic composition that will continue to occur.

The patterns observed in the temporary wetlands were expected due to the patterns in seasonal inundation and spring surveys that occurred when submergent species were present. Whilst the spring plant community in seasonal wetlands was variable, the autumn plant community was similar among surveys post 2010. The variability among the spring surveys was due to differences 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, Dunn's Lagoon, Milang, Loveday Bay, Point Sturt and Hunters Creek), the diversity and abundance of submergent species were higher before 2007 compared to 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 Dunns 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 overall vegetation cover across the lagoon was patchy. In addition, *Ruppia polycarpa* has not been recorded in Point Sturt Wetland during the condition monitoring program but in the four most recent spring surveys, the low elevations were dominated by *Ruppia tuberosa. Althenia cylindrocarpa* (formerly *Lepilaena cylindrocarpa*) was observed for the first time in the condition monitoring program in Loveday Bay spring 2021. This species was recorded at the same site in the 2005 River Murray Wetlands Baseline Surveys (Nicol *et al.* 2006).

4.3. The Living Murray targets and condition scores

The original vegetation target (now an objective) (V3): *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 was no quantitative baseline. Furthermore, baseline data would need to be collected over a minimum of 5–10 years (or even longer) 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. These authors 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 (2016) 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. In addition, the Whole of Icon Site Scores (WOISS) have been used for the South Australian Basin Plan environmental outcome reporting (Matter 8) and the scale used to report on the achievement of Objective V3.

The refined targets (Department for Environment, Water and Natural Resources 2017) were based largely on expert opinion; however, data from the 2005 (Holt *et al.* 2005) and 2006 (Nicol *et al.* 2006) baseline surveys, 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. Continued repeated surveys will support further refinement of the targets.

The habitats with the highest proportion of targets achieved in the most recent surveys and; therefore, having the highest condition scores were lakes Alexandrina and Albert and Goolwa Channel. The condition scores for lakes Alexandrina and Albert have generally been stable or increasing since water levels were reinstated. In contrast, the condition score for Goolwa Channel was highly variable but has been trending upwards since spring 2018.

In Lake Alexandrina, there have generally been upward trends for targets for desirable taxa, emergent species other than *Typha domingensis* and *Phragmites australis* in the littoral and aquatic zones have generally declined in recent surveys. 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 providing the abundances of *Typha domingensis* and *Phragmites australis* remain at current levels and there is not an increase in *Paspalum distichum* and *Cenchrus clandestinus* abundance as observed in permanent and temporary wetlands.

The habitat condition score for Lake Albert has also been generally stable or increasing since water levels were reinstated. There has been a general downward trend in quadrats dominated by *Paspalum distichum* and *Cenchrus clandestinus* after spring 2010 except between spring 2017 and autumn 2018 and the target was not achieved for this survey; hence, the decline in habitat condition score over this period. Between autumn 2018 and autumn 2021 there was a general decrease in quadrats dominated by *Paspalum distichum* and *Cenchrus clandestinus* and the target was achieved resulting in an increase in habitat score. Similar to the trend for Lake Alexandrina, there has been an increase in the number of quadrats dominated by *Typha domingensis* and *Phragmites australis* but not to a level close to the target. The progress towards achievement of targets that require an increase in the abundance of desirable species observed in Lake Alexandrina has generally not occurred in Lake Albert, except for native amphibious species in the littoral zone (which was achieved in the two most recent surveys) (Figure 21).

In contrast to condition scores in lakes Alexandrina and Albert, the condition score in Goolwa Channel was highly variable. 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. 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 and has fluctuated around the target level (Figure 26 and Figure 30). However, the target was met for the five most recent surveys in both zones and shows a downwards trend (Figure 26 and Figure 30). The deep water zone target was achieved in autumn 2018 for the first time since autumn 2015 and again for the four most recent surveys. In spring 2020 and spring 2021 for all targets, except the emergent species other than *Typha domingensis* and *Phragmites australis* in the littoral zone (Figure 29), were achieved resulting in the highest habitat condition scores for the condition monitoring program (Figure 34). The emergent species other than *Typha domingensis* and *Phragmites australis* in the aquatic zone (Figure 31) was not met in the most recent survey resulting in a decrease in habitat condition score but still the second highest score over monitoring program. Similar to the trend for Lake Alexandrina, there has generally been progress towards achieving the targets that require an increase in the abundance of desirable species and if these trends continue, the condition score for Goolwa Channel will increase again and be maintained at a high level.

The condition habitat score for permanent wetlands has remained constant between spring 2009 and spring 2019 and was lower than that for lakes Alexandrina and Albert over the same period. There was a downward trend in the number of quadrats dominated by *Paspalum distichum* and *Cenchrus clandestinus* between spring 2010 and autumn 2016 but since then there has been a general increase (probably due to water level fluctuations) and the target has not been achieved since spring 2009. There has been progress towards achieving the targets that require an increase in abundance of desirable species since water levels were reinstated (except emergent species other than *Typha domingensis* and *Phragmites australis* in the littoral and aquatic zones) with the targets for amphibious taxa in the littoral zone (Figure 37) and submergents in the aquatic zone (Figure 41) being achieved in the four most recent surveys. This resulted in an increase in the habitat condition score similar to the values in Lakes Alexandrina (Figure 18) and Albert (Figure 25).

The condition score for seasonal wetlands over the duration of the condition monitoring program was variable until autumn 2015, after which it has trended downwards with the lowest score in spring 2018. The peaks in autumn were due to the absence of a submergent vegetation target for this season. The downward trend since autumn 2015 and autumn 2017 was due to an increase in the number of quadrats dominated by *Paspalum distichum* and *Cenchrus clandestinus* (which has shown an increasing trend from spring 2008 to autumn 2021). Furthermore, the percentage of quadrats containing native amphibious and emergent species with a cover of greater than 5% on the wetland bed have fluctuated around the target with both targets not being met in spring 2018 but the emergent target achieved in spring 2019 onwards and the amphibious target being achieved in autumn 2022. This resulted in an increasing trend in the habitat score from spring 2018 onwards. The number of quadrats containing submergent species with a cover ≥25% on the wetland bed in spring (the most recent survey had the highest percentage recorded (49%)) and quadrats with a cover of native emergent species around the edge of ≥5% have generally increased since spring 2010, peaking in spring 2021. These trends, if they continue, suggest that the condition score for seasonal wetlands will increase in the future.

The WOISS has fluctuated between 0.56 and 0.43 between autumn 2011 and spring 2019, which is classed as being in fair condition but not achieving objective V3. Many of the individual indicators have fluctuated around their target values, which has resulted in small to moderate variations in the habitat condition scores and hence the whole of lakes condition score. However, in the four most recent surveys, several of the increasing trends for targets that require an increase in the abundance of desirable taxa exceeded the threshold for targets being achieved, resulting in increases in habitat scores and the whole of lakes condition score. Each survey between spring 2020 and autumn 2022 the whole of lakes condition score was higher than 0.6, which resulted in the condition rating improving from fair to good and meeting the ecological objective. Furthermore, most of the targets not achieved in the two most recent surveys are trending towards being met, suggesting that under the current hydrological and salinity regime the plant community is improving through time.

Therefore, it is important that the current salinity and water level regimes are maintained to provide conditions for the continual improvement of vegetation condition.

4.4. *Melaleuca halmaturorum* age class structure and extent

There was limited recruitment of *Melaleuca halmaturorum* between spring 2008 and autumn 2014 at Goat Island and Hunters Creek but only at Hunters Creek between 2014 and 2022. Results suggested there was continuous recruitment at Goat Island between 2008 and 2014 because of the continuous age classes and presence of age classes one and two during the 2008 and 2014 surveys. The ongoing recruitment on Goat Island is probably due to land management at the time with all seedlings and saplings present in areas that were mowed, which reduced competition from weeds. There were no young plants present in 2022, which was probably due to the change in ownership and subsequent change in land management of the island. In 2008 and 2014 grazing was restricted with most *Melaleuca halmaturorum* stands fenced and ungrazed but in 2022 there was an increase in the number of sheep and goats that were grazing unrestricted over the island including throughout the *Melaleuca halmaturorum* stands. Results from Goat Island suggest that plants younger than age class four (<10 years) are susceptible to grazing by sheep and goats.

In contrast, there were probably multiple but sporadic recruitment events between 2008 and 2022 at Hunters Creek because there are gaps in the age class structure in 2014 with a cohort of two to five year old trees present. There was high survivorship of these plants because there were no gaps in age class structure from age classes two to eight in 2022. It is unclear why there was a recruitment at Hunters Creek; however, there was little competition from fast growing emergent species such as *Typha domingensis* or *Phragmites australis* at this site due to high salinities, an influence of the site's proximity to the estuary. Some of the younger plants observed at Hunters Creek in 2022 may also have been planted.

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

Salt Lagoon was unable to be surveyed in 2014 or 2022; hence, the fate of the large number of seedlings present in 2008 (which was due to a lightning strike and subsequent fire that burned half of the stand) is unknown. It is likely that some of the seedlings would have survived because the stand was only rarely inundated when lake levels are very high and there is a strong northerly wind.

Variable water levels may result in *Melaleuca halmaturorum* recruitment (*sensu* Nicol and Ganf 2000); however, the range of elevations at which plants can persist is limited. Seedlings that germinate below +0.8 m AHD when water levels are low during autumn will not persist because they will be flooded the following spring (Denton and Ganf 1994). All of the seedlings (age class one) observed in autumn 2014 and saplings (age class two) in autumn 2022 were present at the edges of stands at upper elevations (i.e. further away from the lake edge) with only adult plants adjacent to the shoreline. Therefore, surcharging the lakes for short periods to briefly inundate high elevation areas may be required to facilitate *Melaleuca halmaturorum* germination because at low elevations the duration of drawdown in late summer and autumn is insufficient for plants to persist. Furthermore, at the low elevations there were often dense stands of emergent species that will outcompete any *Melaleuca halmaturorum* germinants. Hence, recruitment may have been facilitated at the edges of stands (at their current elevations) by controlling the emergent vegetation and providing areas where seedlings can grow in the absence of competition from *Phragmites australis* or *Typha domingensis*.

The increase in extent of *Melaleuca halmaturorum* stands appears to be primarily driven by increases in canopy area of existing trees at all sites except Hunters Creek. However, Salt Lagoon was not able to be accessed in 2022 and it was not possible to collect demographic information. Furthermore, the transects were established in 2008, when water levels were low in existing stands. Recruitment was generally absent amongst mature trees because it typically occurs around the edges of stands or in areas under gaps in the canopy (J. Nicol pers. obs.) and may not be detected using the current method. Sites in Kennedy Bay and Hindmarsh Island are now difficult to access with water levels at historical levels.

4.5. Further studies

Suggested further studies (in priority order) to improve the understanding of the vegetation dynamics of the Lower Lakes and the impacts of changes in water levels and salinity include:

1. continuation of the condition monitoring program (with both spring and autumn surveys and *Melaleuca halmaturorum* demographics) to continue to improve understanding of the medium to long-term vegetation dynamics of the system, monitor the recovery trajectory post hydrological restoration (e.g. do current trends persist or is there an equilibrium state?) and to refine indicators;
2. mapping of 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;

3. integration of existing data sets for plant and other biotic groups such as fish, birds and invertebrates to better understand relationships among components of the wider aquatic ecosystem to inform (a) development of broader ecological indicators and (b) future research directions;
4. investigation of different control methods for *Paspalum distichum* and *Cenchrus clandestinus* such as controlled summer grazing, herbicides and mowing and monitor to determine effectivenss and native species recovery;
5. investigation of the salinity tolerances of potential local ecotypes of key species (e.g. *Typha domingensis, Phragmites australis, Schoenoplectus tabernaemontani, Vallisneria australis, Myriophyllum salsugineum*);
6. investigation of the effects of elevated but sub-lethal salinities on key species;
7. determine propagule longevity under different conditions (e.g. salinity, pH, soil moisture);
8. investigation of the the current submergent plant propagule bank in key wetlands and Goolwa Channel;
9. trial emergent vegetation control at *Melaleuca halmaturorum* stands and monitor 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
Althenia cylindrocarpa	Submergent (r-selected)	Annual	Native
*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
*Atriplex prostrata**	Terrestrial damp	Perennial	Exotic
Atriplex spp.	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
Baumea juncea	Amphibious fluctuation tolerator-emergent	Perennial	Native
*Berula erecta**	Emergent	Perennial	Exotic
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 apressa	Amphibious fluctuation tolerator-emergent	Perennial	Native
Carex fasicularis	Amphibious fluctuation tolerator-emergent	Perennial	Native
Cenchrus clandestinus	Terrestrial dry	Perennial	Exotic
*Centaurea calcitrapa**	Terrestrial damp	Annual	Exotic
*Centaurium tenuiflorum**	Terrestrial damp	Annual	Exotic
Centella asiatica	Amphibious fluctuation responder-plastic	Perennial	Native
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
Cycnogeton procera	Emergent	Perennial	Native-Listed as Uncommon in the Southern Lofty Region
Cyperus exaltatus	Amphibious fluctuation tolerator-emergent	Perennial	Native
Cyperus gymnocaulos	Amphibious fluctuation tolerator-emergent	Perennial	Native
Dianella revoluta	Terrestrial dry	Perennial	Native

Taxon	Functional Group	Life history strategy	Status and Comments
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 clarkii	Amphibious fluctuation tolerator-emergent	Perennial	Native
Gahnia filum	Amphibious fluctuation tolerator-emergent	Perennial	Native-Listed as Rare in the Murray and Southern Lofty Regions
*Galenia secunda**	Terrestrial dry	Perennial	Exotic
Glyceria australis	Emergent	Perennial	Native
*Heliotropium europaeum**	Floodplain	Annual	Exotic
*Holcus lanatus**	Terrestrial damp	Annual	Exotic
*Hordeum vulgare**	Terrestrial dry	Annual	Exotic
*Hypochoeris glabra**	Terrestrial dry	Annual	Exotic
*Hypochoeris radicata**	Terrestrial dry	Annual	Exotic
Iris spp.*	Terrestrial dry	Perennial	Exotic
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 pallidus	Amphibious fluctuation tolerator-emergent	Perennial	Native
Juncus subsecundus	Amphibious fluctuation tolerator-emergent	Perennial	Native
Juncus usitatus	Amphibious fluctuation tolerator-emergent	Perennial	Native
Lachnagrostis filiformis	Floodplain	Annual	Native
*Lactuca saligna**	Terrestrial dry	Annual	Exotic
*Lactuca serriola**	Terrestrial dry	Annual	Exotic
*Lagurus ovatus**	Terrestrial dry	Annual	Exotic
Lamprothamnium macropogon	Submergent r-selected	Annual	Native
Lemna spp.	Floating	Perennial	Native
Limosella australis	Amphibious fluctuation responder-plastic	Perennial	Native
Lobelia anceps	Terrestrial damp	Perennial	Native
Lolium spp.*	Terrestrial dry	Annual	Exotic-*Lolium* spp. comprises of *Lolium perenne* and *Lolium rigidum*

Taxon	Functional Group	Life history strategy	Status and Comments
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*
Myoporum insulare	Terrestrial dry	Perennial	Native
Myriophyllum caput-medusae	Submergent k-selected	Perennial	Native
Myriophyllum muelleri	Amphibious fluctuation responder-plastic	Perennial	Native
Myriophyllum salsugineum	Submergent k-selected	Perennial	Native-Listed as Uncertain in the Southern Lofty Region
Myriophyllum verrucosum	Amphibious fluctuation responder-plastic	Perennial	Native
*Onopordum acanthium**	Terrestrial damp	Annual	Exotic
*Paspalum distichum**	Terrestrial damp	Perennial	Exotic
Persicaria lapathifolia	Amphibious fluctuation responder-plastic	Perennial	Native
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
*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
Pseudognaphalium luteoalbum	Floodplain	Annual	Native
Puccinellia sp.*	Terrestrial damp	Annual	Exotic-could not be identified to species but was not *Puccinellia stricta* or *Puccinellia perlaxa*
*Ranunculus trichophyllus**	Submergent (r-selected)	Annual	Exotic
*Ranunculus trilobus**	Amphibious fluctuation tolerator-emergent	Annual	Exotic
*Reichardia tingitana**	Terrestrial dry	Annual	Exotic
*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

Taxon	Functional Group	Life history strategy	Status and Comments
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 tabernaemontani	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 lycopersicum**	Terrestrial dry	Annual	Exotic
*Solanum nigrum**	Terrestrial damp	Annual	Exotic
*Sonchus asper**	Terrestrial damp	Annual	Exotic
*Sonchus oleraceus**	Terrestrial damp	Annual	Exotic
*Spergularia brevifolia**	Terrestrial damp	Annual	Exotic
*Stenotaphrum secundatum**	Terrestrial dry	Perennial	Exotic
Suaeda australis	Amphibious fluctuation tolerator-emergent	Perennial	Native
Symphyotrichum subulatum *	Terrestrial damp	Annual	Exotic
Thyridia repens	Amphibious fluctuation tolerator-low growing	Perennial	Native
Trifolium spp.*	Terrestrial dry	Annual	Exotic-*Trifolium* spp. comprises of *Trifolium angustifolium, Trifolium arvense, Trifolium repens* and *Trifolium subterraneum*
Triglochin striata	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 Lake Alexandrina spring 2008 to autumn 2022 (*denotes exotic taxon; **denotes proclaimed pest plant in South Australia; ***denotes weed of national significance; #denotes listed as rare in South Australia).

	Survey Date																							
Taxon	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**	**Spring 2011**	**Autumn 2012**	**Spring 2012**	**Autumn 2013**	**Spring 2013**	**Autumn 2014**	**Autumn 2015**	**Spring 2015**	**Autumn 2016**	**Autumn 2017**	**Spring 2017**	**Autumn 2018**	**Spring 2018**	**Spring 2019**	**Spring 2020**	**Autumn 2021**	**Spring 2021**	**Autumn 2022**
*Apium graveolens**		*	*				*	*	*		*		*	*	*		*	*						
*Arctotheca calendula**	*		*																					
*Atriplex prostrata**	*	*		*	*																			
Atriplex spp.				*																				
Atriplex suberecta		*	*														*							
Avena spp.*	*		*		*				*															
Azolla filiculoides						*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*
*Berula erecta**	*							*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Bolboschoenus caldwellii		*		*	*	*	*		*	*	*	*	*	*		*	*	*			*	*	*	*
*Brassica rapa**	*																							
*Brassica tournifortii**				*								*												
*Briza minor**			*																					
*Bromus diandrus**	*		*																					
Bromus hordeaceus ssp. *hordeaceus**			*						*															
*Bromus rubens**									*															
Calystegia sepium	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Carex apressa															*					*			*	
Carex fasicularis									*				*				*	*		*				
*Cenchrus clandestinus**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Centaurea calcitrapa**	*	*	*	*					*				*	*								*	*	
*Centaurium tenuiflorum**	*		*																					
Centella asiatica	*							*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*
Ceratophyllum demersum#						*	*	*	*	*	*	*	*	*	*	*	*	*		*	*			
Chara spp.										*			*											
*Chenopodium glaucum**		*		*																				
Chenopodium nitrariaceum				*																				
*Conyza bonariensis**	*	*	*	*									*	*										
*Cotula coronopifolia**	*	*	*		*	*	*	*	*					*	*			*	*	*	*			*
Crassula helmsii																*		*	*	*	*	*	*	*
Cycnogeton procera					*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Cyperus gymnocaulos	*	*	*	*	*	*	*	*	*	*		*		*			*				*			
Distichlis distichophylla	*		*																					
Duma florulenta	*				*																			
*Ehrharta longiflora**			*																					
Einadia nutans		*		*																				
Eleocharis acuta							*		*	*	*	*		*	*	*	*	*	*	*	*	*	*	*
Enchylaena tomentosa			*																					
Epilobium pallidiflorum												*		*		*		*			*	*	*	*
*Eragrostis curvula***	*		*																					
Eragrostis sp.	*	*	*																					
Ficinia nodosa		*	*	*	*							*	*				*							*
*Foeniculum vulgare**	*	*		*																				
Frankenia pauciflora		*																						
*Fumaria bastardii**			*																					
*Galenia secunda**													*											
Glyceria australis							*																	
*Holcus lanatus**	*						*										*							
*Hordeum vulgare**	*		*		*																			

Taxon	Survey Date																							
	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011	Spring 2011	Autumn 2012	Spring 2012	Autumn 2013	Spring 2013	Autumn 2014	Autumn 2015	Spring 2015	Autumn 2016	Autumn 2017	Spring 2017	Autumn 2018	Spring 2018	Spring 2019	Spring 2020	Autumn 2021	Spring 2021	Autumn 2022
*Hypochoeris glabra**	*		*		*																			
*Hypochoeris radicata**	*	*	*	*																				
Isolepis producta	*	*	*						*													*		
*Juncus acutus***	*	*	*	*																			*	
Juncus holoschoenus												*		*	*	*								
Juncus kraussii	*	*	*	*	*	*	*	*	*	*	*				*	*								*
Juncus pallidus																							*	
Juncus usitatus		*	*	*	*	*			*					*			*	*	*	*	*		*	
Lachnagrostis filiformis	*	*	*	*		*	*	*			*		*			*								
*Lactuca saligna**			*																					
*Lactuca serriola**		*	*	*	*						*	*	*											
*Lagurus ovatus**			*																					
Lemna spp.						*	*				*	*		*	*	*	*	*						*
Limosella australis								*		*														*
Lobelia anceps			*										*					*						
Lolium spp.*	*		*		*		*		*		*			*			*				*	*		
Ludwigia peploides ssp. *montevidensis*						*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Lycopus australis		*	*	*			*			*		*	*	*		*	*	*	*	*	*	*	*	*
Lythrum hyssopifolia											*											*		
Medicago spp.*	*		*				*	*		*											*	*		
*Melilotus indicus**	*		*										*							*				
Mentha australis	*							*										*	*	*			*	*
Mentha spp.*		*	*	*	*	*				*	*	*	*	*	*	*	*							
Myriophyllum muelleri																*		*						
Myriophyllum salsugineum							*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Onopordum acanthium**	*																							
*Paspalum distichum**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Persicaria lapathifolia	*		*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Phragmites australis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Picris angustifolia ssp. *angustifolia*	*	*	*	*																				
*Plantago coronopus**	*	*	*	*	*																			
*Plantago lanceolata**									*															
*Polygonum aviculare**		*	*			*																		
*Polypogon monspeliensis**	*	*	*	*		*	*		*	*	*			*					*					
Potamogeton crispus											*			*			*		*	*		*	*	
Potamogeton pectinatus									*		*	*	*		*					*	*	*	*	
Pseudognaphalium luteoalbum	*		*	*							*													
Puccinellia sp.*			*																					
Ranunculus sp.																							*	*
*Ranunculus trichophyllus**									*			*	*	*	*	*	*	*	*	*	*			
*Reichardia tingitana**	*		*	*																				
*Rorippa nasturtium-aquaticum**										*	*				*			*						
*Rorippa palustris**	*																							
Rumex bidens	*						*	*	*	*	*		*	*	*	*	*		*	*	*	*	*	*
Ruppia tuberosa	*																							
*Salix babylonica**	*																							
Sarcocornia quinqueflora	*	*	*	*																				
Schoenoplectus pungens	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*		*		*
Schoenoplectus tabernaemontani	*		*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

	Survey Date																							
Taxon	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**	**Spring 2011**	**Autumn 2012**	**Spring 2012**	**Autumn 2013**	**Spring 2013**	**Autumn 2014**	**Autumn 2015**	**Spring 2015**	**Autumn 2016**	**Autumn 2017**	**Spring 2017**	**Autumn 2018**	**Spring 2018**	**Spring 2019**	**Spring 2020**	**Autumn 2021**	**Spring 2021**	**Autumn 2022**
Sclerolaena blackiana	*																							
Senecio cunninghamii			*																					
*Senecio pterophorus**	*	*	*	*				*	*	*	*	*		*	*		*	*						
Senecio runcinifolius		*											*											
*Silybum marianum***			*																					
*Solanum lycopersicum**															*									
*Solanum nigrum**		*	*			*		*		*					*									
*Sonchus asper**			*	*		*	*	*																
*Sonchus oleraceus**	*	*	*	*	*		*		*	*			*		*		*							
*Spergularia brevifolia**	*		*	*																				
Suaeda australis	*	*	*	*									*											
*Symphyotrichum subulatum**	*	*	*	*		*	*	*	*	*		*	*		*	*		*	*	*		*		
Thyridia repens		*										*												
Trifolium spp.*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*			
Triglochin striata			*	*		*														*				
Triticum sp.*			*																					
Typha domingensis	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Urtica urens**			*	*																				
Vallisneria australis											*	*			*		*			*	*	*	*	*
*Vicia sativa**	*		*				*										*	*						
Wilsonia rotundifolia		*																						

Appendix 4: Taxa present (green shading) in Lake Albert spring 2008 to autumn 2022 (*denotes exotic taxon; **denotes proclaimed pest plant in South Australia; ***denotes weed of national significance; #denotes listed as rare in South Australia).

	Survey Date																							
Taxon	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**	**Spring 2011**	**Autumn 2012**	**Spring 2012**	**Autumn 2013**	**Spring 2013**	**Autumn 2014**	**Autumn 2015**	**Spring 2015**	**Autumn 2016**	**Autumn 2017**	**Spring 2017**	**Autumn 2018**	**Spring 2018**	**Spring 2019**	**Spring 2020**	**Autumn 2021**	**Spring 2021**	**Autumn 2022**
Acacia myrtifolia		*	*	*																				
*Anagallis arvensis**										*														
*Arctotheca calendula**			*																					
Avena spp.*	*		*						*															
Bolboschoenus caldwellii									*															
*Bromus catharticus**									*															
*Bromus diandrus**	*		*																					
Bromus hordeaceus ssp. *hordeaceus**			*																					
Calystegia sepium									*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Cenchrus clandestinus**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Centaurea calcitrapa**	*		*						*															
*Chenopodium album**				*									*											
*Chenopodium glaucum**				*																				
*Conyza bonariensis**	*							*																
*Cotula coronopifolia**	*		*	*			*	*																
Cyperus gymnocaulos	*	*	*	*	*		*		*	*		*	*				*	*	*					*
Distichlis distichophylla	*																							
Duma florulenta							*						*			*		*	*	*	*	*	*	*
*Ehrharta longiflora**			*																					
Enchylaena tomentosa				*																				
Eragrostis australasica		*		*																				
*Eragrostis curvula***			*																					
*Euphorbia terracina***			*																					
Ficinia nodosa		*	*	*	*																			
*Hordeum vulgare**	*		*																					
*Hypochoeris glabra**			*																					
*Hypochoeris radicata**			*	*																				
Isolepis producta	*			*									*											
Lachnagrostis filiformis	*	*										*	*											
*Lactuca serriola**									*															
*Lagurus ovatus**			*																					
Lolium spp.*	*		*						*															
Lythrum hyssopifolia									*			*			*									
Lythrum salicaria													*											
Medicago spp.*	*		*																					
Melaleuca halmaturorum			*	*									*											
*Melilotus indicus**	*		*	*														*						
Myriophyllum salsugineum																			*			*		
*Paspalum distichum**		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Phragmites australis		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Plantago coronopus**			*	*					*		*													
*Polypogon monspeliensis**	*	*	*																					

	Survey Date																							
Taxon	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**	**Spring 2011**	**Autumn 2012**	**Spring 2012**	**Autumn 2013**	**Spring 2013**	**Autumn 2014**	**Autumn 2015**	**Spring 2015**	**Autumn 2016**	**Autumn 2017**	**Spring 2017**	**Autumn 2018**	**Spring 2018**	**Spring 2019**	**Spring 2020**	**Autumn 2021**	**Spring 2021**	**Autumn 2022**
Potamogeton pectinatus							*										*							
Puccinellia sp.*			*	*																				
*Reichardia tingitana**	*	*	*	*																				
Rumex bidens									*							*					*		*	*
Sarcocornia quinqueflora		*	*	*		*																		
Scaevola calendulacea				*																				
Schoenoplectus pungens	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			*	*	*		*		
Schoenoplectus tabernaemontani	*				*	*			*	*			*		*	*		*	*	*			*	*
*Senecio pterophorus**			*																					
*Sonchus oleraceus**	*		*	*				*	*			*												
*Spergularia brevifolia**			*	*																				
Suaeda australis			*	*																				
*Symphyotrichum subulatum**	*		*	*				*				*	*					*		*		*	*	*
Thyridia repens	*			*				*		*												*	*	*
Trifolium spp.*	*		*	*					*				*						*					
Triglochin striata			*	*																				
Typha domingensis										*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Vicia sativa**	*		*						*															

Appendix 5: Taxa present (green shading) in Goolwa Channel spring 2008 to autumn 2022 (*denotes exotic taxon; **denotes proclaimed pest plant in South Australia; ***denotes weed of national significance; #denotes listed as rare in South Australia).

	Survey Date																							
Taxon	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**	**Spring 2011**	**Autumn 2012**	**Spring 2012**	**Autumn 2013**	**Spring 2013**	**Autumn 2014**	**Autumn 2015**	**Spring 2015**	**Autumn 2016**	**Autumn 2017**	**Spring 2017**	**Autumn 2018**	**Spring 2018**	**Spring 2019**	**Spring 2020**	**Autumn 2021**	**Spring 2021**	**Autumn 2022**
Acacia myrtifolia												*	*	*	*			*		*	*	*		
*Asparagus asparagoides****																				*				
*Asparagus officinalis**		*							*															
*Atriplex prostrata**		*		*								*												
Atriplex spp.		*																						
Azolla filiculoides			*			*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*
*Berula erecta**						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Bolboschoenus caldwellii			*	*	*	*	*	*		*	*							*	*	*	*	*	*	*
*Bouteloua dactyloides**														*			*				*	*	*	*
*Brassica tournifortii**			*																					
*Bromus diandrus**			*																					
Bromus hordeaceus ssp. *hordeaceus**			*				*																	
Calystegia sepium	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Carex fasicularis																							*	
*Cenchrus clandestinus**			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Centaurea calcitrapa**	*																					*	*	
Centella asiatica							*		*	*	*	*	*	*	*	*	*	*	*	*	*	*		*
Ceratophyllum demersum#						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Chenopodium glaucum**	*	*		*																				
*Conyza bonariensis**			*																					
*Cotula coronopifolia**	*		*	*	*		*				*													
Crassula helmsii																				*	*	*		
Cycnogeton procera			*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Cyperus exaltatus			*																					
Cyperus gymnocaulos	*		*		*																			
Duma florulenta	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Eleocharis acuta					*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Enchylaena tomentosa			*										*											
Epilobium pallidiflorum		*																					*	
Eragrostis sp.									*															
Ficinia nodosa			*		*		*				*				*		*	*	*	*			*	*
Gahnia clarkii																						*		
Juncus kraussii	*	*			*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Juncus usitatus			*	*		*	*																	
Lachnagrostis filiformis	*	*	*																					
*Lactuca saligna**							*		*															
Lemna spp.					*		*				*	*		*	*		*							
Lobelia anceps													*											
Lolium spp.*			*				*																	
*Lupinus cosentinii**			*																					
Lycopus australis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Lythrum hyssopifolia									*															
Lythrum salicaria	*																*							

	Survey Date																							
Taxon	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**	**Spring 2011**	**Autumn 2012**	**Spring 2012**	**Autumn 2013**	**Spring 2013**	**Autumn 2014**	**Autumn 2015**	**Spring 2015**	**Autumn 2016**	**Autumn 2017**	**Spring 2017**	**Autumn 2018**	**Spring 2018**	**Spring 2019**	**Spring 2020**	**Autumn 2021**	**Spring 2021**	**Autumn 2022**
Medicago spp.*							*				*													
*Melilotus indicus**			*				*																	
Mentha australis								*										*	*	*	*	*	*	*
Mentha spp.*			*				*		*	*	*	*	*	*	*	*	*							
Myriophyllum caput-medusae									*						*									
Myriophyllum muelleri																		*						
Myriophyllum salsugineum				*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Paspalum distichum**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Persicaria lapathifolia											*	*		*		*	*	*	*	*	*	*	*	*
Phragmites australis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Picris angustifolia ssp. *angustifolia*		*		*		*		*				*												
*Plantago coronopus**			*		*																			
*Plantago lanceolata**			*		*			*	*	*														
*Polygonum aviculare**				*																				
*Polypogon monspeliensis**	*																							
Potamogeton crispus					*	*								*				*			*	*		*
Potamogeton pectinatus				*	*				*				*								*		*	*
*Ranunculus trilobus**							*		*		*	*	*	*	*									
Rumex bidens					*		*	*	*		*	*		*			*		*	*			*	*
*Salix babylonica**				*	*	*		*	*	*														
Samolus repens									*	*	*			*			*				*	*	*	
*Scabiosa atropurpurea**			*																					
Schoenoplectus pungens			*	*	*		*		*		*	*												
Schoenoplectus tabernaemontani	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Silybum marianum***			*																					
*Solanum nigrum**			*																					
*Sonchus oleraceus**	*		*				*	*	*		*													
Suaeda australis			*																					
*Symphyotrichum subulatum**	*	*	*	*				*	*	*	*		*	*		*	*	*				*		
Thyridia repens				*																				
Trifolium spp.*												*												
Triglochin striata		*																						
Typha domingensis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Vallisneria australis							*	*		*	*	*					*	*	*		*	*	*	*

Appendix 6: Taxa present (green shading) in permanent wetlands spring 2008 to autumn 2022 (*denotes exotic taxon; **denotes proclaimed pest plant in South Australia; ***denotes weed of national significance; #denotes listed as rare in South Australia).

	Survey Date																							
Taxon	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011	Spring 2011	Autumn 2012	Spring 2012	Autumn 2013	Spring 2013	Autumn 2014	Autumn 2015	Spring 2015	Autumn 2016	Autumn 2017	Spring 2017	Autumn 2018	Spring 2018	Spring 2019	Spring 2020	Autumn 2021	Spring 2021	Autumn 2022
*Atriplex prostrata**	*	*	*	*	*					*						*			*					
Avena spp.*			*		*												*							
Azolla filiculoides						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Baumea juncea																			*	*	*	*	*	*
*Berula erecta**	*													*	*	*	*	*	*	*	*	*	*	*
Bolboschoenus caldwellii			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Brassica rapa**	*																							
*Brassica tournifortii**							*																	
*Bromus diandrus**	*		*		*		*										*							
Bromus hordeaceus ssp. *hordeaceus**	*		*														*							
*Bromus rubens**																				*				
Calystegia sepium				*								*				*				*	*	*	*	*
*Cenchrus clandestinus**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Centaurea calcitrapa**	*	*			*	*														*			*	
Centella asiatica	*		*									*			*	*		*	*					*
Ceratophyllum demersum#					*	*	*	*	*	*		*	*		*	*	*	*	*	*	*	*	*	*
*Chenopodium album**	*		*	*		*																		
*Chenopodium glaucum**		*																						
*Conyza bonariensis**	*				*																		*	*
*Cotula coronopifolia**	*		*		*	*	*	*	*		*	*												
Crassula helmsii											*		*	*				*	*	*		*	*	*
Cycnogeton procera	*		*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Cyperus exaltatus				*																				
Cyperus gymnocaulos				*	*		*		*			*												
Dianella revoluta									*															
Disphyma crassifolium																*	*	*						
Distichlis distichophylla	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Duma florulenta					*		*																	
*Echinochloa crus-galli**									*															
Eleocharis acuta					*	*	*	*	*	*	*	*		*				*	*	*	*	*	*	*
Enchylaena tomentosa			*																		*	*	*	*
*Eragrostis curvula***	*		*		*		*		*								*							
Eragrostis sp.	*		*				*		*															
Ficinia nodosa		*		*		*																		
Gahnia filum	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Hordeum vulgare**	*		*		*	*	*	*	*								*							
*Hypochoeris glabra**			*			*		*																
*Hypochoeris radicata**			*	*																				
Iris spp.*					*																			
Isolepis producta			*			*																		
*Juncus acutus***			*						*															
Juncus kraussii	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Juncus subsecundus							*																	
Lachnagrostis filiformis	*	*	*	*		*	*	*				*												

	Survey Date																							
Taxon	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**	**Spring 2011**	**Autumn 2012**	**Spring 2012**	**Autumn 2013**	**Spring 2013**	**Autumn 2014**	**Autumn 2015**	**Spring 2015**	**Autumn 2016**	**Autumn 2017**	**Spring 2017**	**Autumn 2018**	**Spring 2018**	**Spring 2019**	**Spring 2020**	**Autumn 2021**	**Spring 2021**	**Autumn 2022**
*Lactuca saligna**	*																							*
*Lactuca serriola**	*				*	*	*	*	*			*		*		*	*	*						
Lemna spp.					*		*			*	*	*	*	*	*		*		*	*	*	*	*	*
Lobelia anceps																						*	*	*
Lolium spp.*	*		*		*	*	*		*								*		*	*	*		*	
Ludwigia peploides ssp. *montevidensis*						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Lycium ferocissimum****																		*						
Lycopus australis										*					*		*						*	*
Medicago spp.*			*		*										*					*				
Melaleuca halmaturorum	*	*	*	*		*	*				*		*	*	*	*	*	*	*	*	*	*	*	*
*Melilotus indicus**	*		*														*		*					
Mentha australis																		*			*	*	*	*
Mentha spp.*	*											*	*	*		*	*							
Myoporum insulare																	*			*	*	*	*	*
Myriophyllum caput-medusae									*	*		*	*											
Myriophyllum muelleri																		*						
Myriophyllum salsugineum					*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Paspalum distichum**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Persicaria lapathifolia	*	*	*	*	*			*	*		*		*	*		*	*							*
Phragmites australis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Picris angustifolia ssp. *angustifolia*				*	*																			
*Plantago coronopus**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Polypogon monspeliensis**	*				*		*		*		*			*										
Potamogeton crispus					*		*		*		*	*	*	*					*		*	*		
Potamogeton pectinatus					*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*
Pseudognaphalium luteoalbum			*	*			*																	
*Reichardia tingitana**	*		*	*		*	*	*																
*Rorippa nasturtium-aquaticum**	*																		*					
Rumex bidens	*	*			*		*	*	*					*	*	*	*	*	*	*	*	*	*	*
Ruppia megacarpa					*	*	*																	
Ruppia polycarpa					*																			
Ruppia tuberosa	*		*																					
Samolus repens	*		*		*					*	*	*	*	*	*	*	*		*	*	*	*	*	*
Sarcocornia quinqueflora	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Scabiosa atropurpurea**						*																	*	*
Schoenoplectus pungens	*		*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*
Schoenoplectus tabernaemontani					*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Senecio pterophorus**	*	*	*	*		*			*	*	*	*												
Senecio runcinifolius			*																					
*Sonchus asper**			*	*	*																			
*Sonchus oleraceus**	*	*	*	*	*		*		*		*	*		*	*	*	*	*	*	*	*		*	

	Survey Date																							
Taxon	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**	**Spring 2011**	**Autumn 2012**	**Spring 2012**	**Autumn 2013**	**Spring 2013**	**Autumn 2014**	**Autumn 2015**	**Spring 2015**	**Autumn 2016**	**Autumn 2017**	**Spring 2017**	**Autumn 2018**	**Spring 2018**	**Spring 2019**	**Spring 2020**	**Autumn 2021**	**Spring 2021**	**Autumn 2022**
*Spergularia brevifolia**	*	*	*	*																				
Suaeda australis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Symphyotrichum subulatum**	*	*	*	*	*	*	*	*	*	*		*		*		*		*	*	*		*	*	*
Thyridia repens	*		*			*	*				*													
Trifolium spp.*			*														*							
Triglochin striata	*	*	*		*	*			*		*											*		
Typha domingensis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Urtica urens**	*																							
Vallisneria australis	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*		
Wilsonia rotundifolia	*	*			*	*							*	*	*		*	*						

Appendix 7: Taxa present (green shading) in temporary wetlands spring 2008 to autumn 2022 (*denotes exotic taxon; **denotes proclaimed pest plant in South Australia; ***denotes weed of national significance; #denotes listed as rare in South Australia).

	Survey Date																								
Taxon	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**	**Spring 2011**	**Autumn 2012**	**Spring 2012**	**Autumn 2013**	**Spring 2013**	**Autumn 2014**	**Autumn 2015**	**Spring 2015**	**Autumn 2016**	**Spring 2016**	**Autumn 2017**	**Spring 2017**	**Autumn 2018**	**Spring 2018**	**Spring 2019**	**Spring 2020**	**Autumn 2021**	**Spring 2021**	**Autumn 2022**
Althenia cylindrocarpa																								*	
*Atriplex prostrata**	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*
Atriplex spp.	*	*		*		*	*				*														
Atriplex suberecta		*	*	*	*								*		*			*							
Avena spp.*	*		*				*							*				*		*	*	*		*	
Azolla filiculoides							*		*					*	*			*			*	*		*	
*Berula erecta**																		*							
Bolboschoenus caldwellii	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Brassica tournefortii**	*																								
*Bromus diandrus**	*		*		*		*		*																
Bromus hordeaceus ssp. *hordeaceus**			*				*		*																
*Bromus rubens**																					*				
*Cenchrus clandestinus**													*												
*Centaurea calcitrapa**			*		*	*	*	*	*			*									*	*			
*Centaurium tenuiflorum**																					*				
Chara spp.						*	*	*	*					*				*							
*Chenopodium album**						*																			
*Chenopodium glaucum**	*				*			*		*			*		*		*		*				*		*
*Conyza bonariensis**	*				*																				
*Cotula coronopifolia**	*		*		*	*	*	*	*	*	*			*		*		*				*		*	
Cycnogeton procera																						*		*	
Cyperus gymnocaulos	*	*		*		*		*	*		*														
Disphyma crassifolium					*	*	*	*	*	*	*		*	*		*	*	*		*	*	*	*	*	*
Distichlis distichophylla	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Duma florulenta						*	*			*				*	*	*	*	*		*					
Einadia nutans		*																							
Eleocharis acuta					*		*		*		*			*						*	*	*	*	*	
Epilobium paladiflorum																							*	*	*
Enchylaena tomentosa	*	*	*	*	*	*		*	*			*	*		*			*							
*Eragrostis curvula***	*		*		*		*		*					*				*			*				
Eragrostis sp.	*		*				*																		
*Erodium cicutarium**								*							*										
Ficinia nodosa	*		*									*	*				*								
Frankenia pauciflora	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*
Glyceria australis					*		*																		
*Heliotropium europaeum**				*		*																			
*Hordeum vulgare**	*		*		*	*	*	*	*		*						*	*		*	*				
*Hypochoeris glabra**						*																			
Isolepis producta									*			*		*		*				*	*		*		
*Juncus acutus***													*												
Juncus kraussii	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*		
Juncus subsecundus								*															*		
Lachnagrostis filiformis	*		*		*			*	*	*	*				*			*	*			*			
*Lactuca saligna**	*		*				*																		
*Lactuca serriola**	*		*		*	*	*	*	*			*					*	*		*			*	*	*
*Lagurus ovatus**	*		*		*																				
Lamprothamnium macropogon	*		*		*	*	*		*		*			*		*		*		*	*	*	*	*	*
Lemna spp.						*			*							*		*		*	*	*		*	*
Limosella australis																						*			
Lobelia anceps					*																				
Lolium spp.*	*		*	*	*	*	*	*	*		*		*	*		*		*		*	*	*		*	

	Survey Date																								
Taxon	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**	**Spring 2011**	**Autumn 2012**	**Spring 2012**	**Autumn 2013**	**Spring 2013**	**Autumn 2014**	**Autumn 2015**	**Spring 2015**	**Autumn 2016**	**Spring 2016**	**Autumn 2017**	**Spring 2017**	**Autumn 2018**	**Spring 2018**	**Spring 2019**	**Spring 2020**	**Autumn 2021**	**Spring 2021**	**Autumn 2022**
Ludwigia peploides ssp. *montevidensis*													*		*					*					*
*Lycium ferocissimum****	*		*	*	*	*		*												*					
Lythrum hyssopifolia																						*			
Lythrum salicaria																		*							
*Malva parviflora**						*																			
*Marrubium vulgare***					*																				
Medicago spp.*	*		*		*	*	*	*		*					*										
Melaleuca halmaturorum							*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Melilotus albus**									*																
*Melilotus indicus**	*		*		*		*				*			*											
Myoporum insulare														*	*		*	*	*		*	*	*		
Myriophyllum salsugineum					*									*			*								
Myriophyllum verrucosum													*												
*Paspalum distichum**		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Phragmites australis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Phyla canescens**	*																								
Picris angustifolia ssp. *angustifolia*					*	*																			
*Plantago coronopus**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Polygonum aviculare**	*	*																							
*Polypogon monspeliensis**	*		*		*		*		*		*			*		*		*	*	*	*	*		*	*
Potamogeton pectinatus						*	*	*	*	*															
Pseudognaphalium luteoalbum					*		*																		
Puccinellia sp.*			*				*																		
Ranunculus trichophyllus					*		*		*	*	*	*								*	*	*			
*Reichardia tingitana**	*		*			*	*		*																
*Rorippa nasturtium-aquaticum**																				*					
*Rorippa palustris**			*																						
Rumex bidens	*		*			*					*	*		*		*		*		*	*	*	*	*	
Ruppia polycarpa					*	*	*		*													*			
Ruppia tuberosa	*		*		*	*		*	*		*			*		*		*		*	*	*	*	*	*
Salsola australis				*		*								*	*			*							
Samolus repens	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Sarcocornia quinqueflora	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Schoenoplectus pungens		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Schoenoplectus tabernaemontani					*																				
*Senecio pterophorus**	*		*	*						*								*	*	*			*	*	*
*Silybum marianum***					*																				
*Sonchus asper**															*						*	*			
*Sonchus oleraceus**	*		*	*	*	*	*	*	*	*	*	*		*		*				*	*	*			
*Spergularia brevifolia**	*	*	*	*	*	*	*		*																
Suaeda australis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*Symphyotrichum subulatum**	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*
Thyridia repens	*		*		*	*	*	*	*	*	*	*	*	*			*		*			*		*	
Trifolium spp.*	*		*		*	*	*		*		*	*		*		*		*		*	*	*	*		
Triglochin striata	*				*	*	*	*	*	*	*		*	*		*	*	*	*	*	*	*	*	*	*
Typha domingensis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Wilsonia rotundifolia	*				*	*	*	*	*			*	*		*	*			*		*		*	*	*