An initial assessment of the potential for wetlands in the South East and Lower Lakes regions of South Australia to support key species of Coorong waterbirds

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Executive summary

The primary aim of this study was to list and assess a series of wetlands in the South East (SE) of South Australia and around the Lower Lakes (Lake Alexandrina and Albert) on their potential, either as they are or with appropriate management, to provide habitat for key species of waterbirds disadvantaged by deteriorating conditions in the southern Coorong. Therefore, the assessment of these wetlands focussed primarily on the provision of suitable habitats for a suite of small migratory and other non-migratory shorebirds, namely Red-necked Stint (*Calidris ruficollis*), Sharp-tailed Sandpiper (*Calidris acuminata*), Curlew Sandpiper (*Calidris ferruginea*), Common Greenshank (*Tringa nebularia*), Red-necked Avocet (*Recurvirostra novaehollandiae*), Banded Stilt (*Cladorhynchus leucocephalus*), Black-winged Stilt (*Himantopus leucocephalus*) and Red-capped Plover (*Charadrius ruficapillus*). Other waterbirds of concern included Chestnut Teal (*Anas castanea*), Black Swan (*Cygnus atratus*) and Fairy Tern (*Sternula nereis*).

We use a systems analysis approach and multi criteria decision analysis (MCDA) with a weighted sum technique to evaluate 30 wetlands (23 wetlands in the SE and 7 wetlands around the Lower Lakes) using 21 criteria that included: value for shorebirds; proximity to the Coorong; costs of on-ground works; and suitability for modification inter alia. The initial inventory of the wetlands was compiled using historic data, reports and the knowledge of local wetland experts. For each criterion, wetland data were classified, most often into three or four classes. For each wetland, 16 of the 21 criteria were subsequently assigned a numeric score representing the wetland's value for key species. The remaining five criteria were unable to be scored but are still included in the assessment as they provide useful information for each wetland.

The MCDA identified two wetlands in the SE of South Australia, Lake Hawdon North and Lake Frome Conservation Park, that had the overall highest MCDA score. Tolderol Game Reserve and Teringie South Lagoon were the highest scoring wetlands around the Lower Lakes. These four wetlands should be the first assessed in greater detail to determine the feasibility of delivering additional suitable habitat. An important component of such assessments is community engagement.

A key management consideration is appreciating that individual wetlands are temporally dynamic and may not provide suitable habitat for key waterbird species continuously. Thus, an integrated network of wetlands that each provide habitat at appropriate times may be required across the broader landscape to deliver a succession of suitable habitats and so contribute to viable populations of waterbirds. The wetland inventory coupled with the MCDA indicates considerable potential amongst the available wetlands to do this for most of the key waterbird species. However, this assumes that the key waterbird species regularly move between wetlands within the broader landscape. Furthermore, for some key waterbird species, such as Banded Stilt and Fairy Tern, opportunities to provide suitable habitat in the South East of South Australia and around the Lower Lakes are limited.

The assessments of wetlands made using the MCDA can be easily updated as new information arises. Sensitivity analyses of the scoring system used for each of the individual criteria, and their weightings, will improve the robustness of the assessments. Importantly, there is considerable potential amongst the 21 wetlands assessed using the tool to provide suitable habitats for the key waterbird species. Given that the poor conditions in the southern Coorong are likely to continue for the foreseeable future, there is some urgency to complete more advanced assessments and to do the necessary on-ground works to provision new habitat.

Acknowledgments

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We thank Jeff Campbell, Maureen Christie and Keith Frost for assistance with the field surveys and property access. We also thank Abby Goodman, Claire Harding, Melissa Herpich, Ross Anderson, Jeff Campbell, Maureen Christie, Bryan Haywood and Lucy Dodd for participating in the SE wetland workshop on 13 February 2019. Special thanks to Abby Goodman, Claire Harding, Mark de Jong, Melissa Herpich, Ross Anderson, Jeff Campbell, Maureen Christie, Bryan Haywood, Jody O'Connor and Kate Mason for freely sharing their time, experience and detailed knowledge to help compile wetland information. We appreciate support and consultation on the project from The Friends of Shorebirds SE, Nature Glenelg Trust, Wetlands and Wildlife, and Natural Resources South East.

We would like to acknowledge and pay respect to the Ngarrindjeri Traditional Owners, the traditional owners of the ancestral lands of the South East, including the Bungandidj, Meintangk and Bodaruwitj, and all Elders past, present and future. We respect the deep feelings of attachment and relationship of Aboriginal peoples to country.

1 Introduction

The Coorong and Lakes Alexandrina and Albert Wetland is a Wetland of International Importance under the Ramsar Convention and is one of The Living Murray's (TLM) icon sites within the Murray-Darling Basin. Several hundred thousand small migratory (e.g. sandpipers, stints) and non-migratory shorebirds (e.g. stilts and avocets), piscivorous birds (pelicans, cormorants, grebes and terns) and waterfowl (swans and ducks) use this wetland system regularly, particularly during summer (e.g. Paton 2010, Paton *et al.* 2019a). This abundance and diversity of waterbirds was one of the prime reasons for this system being listed as a Wetland of International Importance. Most waterbirds use the shallow but often highly productive margins of wetlands for foraging, and the permanent wetlands of the Coorong, Lower Lakes and Murray Mouth (CLLMM) region have historically provided extensive areas of shallow productive wetland habitat, even in droughts (Paton *et al.* 2018a). However, under current management, water levels in the Lower Lakes are often too high to provide shallow wading habitats or exposed shorelines around their margins and, consequently, the Coorong mudflats are the most important habitat for foraging shorebirds (Paton *et al.* 2018a). Most shorebirds forage in water that is less than 10 cm deep, and some of the smaller sandpipers (e.g. Red-necked Stint, which have legs less than 4 cm long) are largely limited to mudflats covered by less than 2 cm of water (Zeffer *et al.* 2003; Paton 2010).

Many shorebird species have experienced substantial declines in abundances since the 1980s, at least for the southern Coorong, coinciding with reductions in key food resources, such as *Ruppia tuberosa* and the chironomid *Tanytarsus barbitarsis* (Paton *et al.* 2009, Paton 2010). Changes in the salinity and water levels of the southern Coorong have influenced the availability and accessibility of food resources for waterbirds (Paton 2010).

Further, in recent years, there has been an added pressure on the waterbird populations, with extensive blooms of filamentous green algae present in spring (Paton *et al.* 2016a, 2016b, 2017b, 2018c, 2019b). The algal blooms were also extensive in the southern Coorong during the summers of 2016-17 and 2017-18 (Paton *et al.* 2017b, 2018c), with Paton *et al.* (2017a) observing that in January 2017 "algae accumulated as thick blankets, several centimetres thick, both above the shoreline where it rotted, and over most of the mudflats covered with shallow water". The extent of occurrence of filamentous green algae within the southern Coorong will be confirmed from surveys being conducted during spring 2019.

The algae have effectively excluded a suite of shorebirds that forage on mudflats covered with shallow (<10 cm) water (Paton *et al.* 2017a, 2018b, 2019a). These shorebirds include a suite of migratory shorebirds, namely Red-necked Stint, Curlew Sandpiper, Sharp-tailed Sandpiper and Common Greenshank. All four species have experienced substantial historical declines in abundances in the Coorong (Paton *et al.* 2009) and, more recently, their abundances have often been below their recent (2000-2015) long-term median abundances (Paton *et al.* 2019a). These species are protected under international migratory bird agreements between Australia and various Asian countries (where these shorebirds stopover on their migratory flights), namely Japan, China and the Republic of South Korea. Those international bird agreements place obligations on Australia to protect these species and the habitats that they use while in Australia. A range of non-migratory waders are also disadvantaged by these algal blooms, including Banded Stilt, Red-necked Avocet, Black-winged Stilt and Red-capped Plover. For example, filamentous algae disrupt the emergence of chironomids (Peters 2018) and ultimately affect the abundance of chironomid larvae, the key aquatic invertebrate and food source for many shorebirds (e.g. Red-necked Avocet), in the southern Coorong (Brookes *et al.* 2018; Paton *et al.* 2017a, 2018b, 2019a).

In some parts of the southern Coorong, the outbreaks of filamentous algae are so extensive that they cover the surfaces of the water out to depths of 50 cm. At these deeper depths, various species of waterfowl (e.g. Chestnut Teal, Black Swan) may also be disadvantaged because of reduced access to and abundances of a key aquatic plant, *Ruppia tuberosa*. These waterfowl feed extensively on *R. tuberosa* in the southern Coorong and continued low abundances of *R. tuberosa* may limit their ability to use the southern Coorong in the future. Already there is heavy grazing pressure from herbivorous waterfowl on the modest *R. tuberosa* populations

that still exist in the southern Coorong, such that around 70% of all *R. tuberosa* shoots have been grazed to about 1 cm in length by January, suggesting that food resources may not last until autumn (Paton *et al.* 2019a). Even piscivorous waterbird species that forage in shallow water (e.g. Fairy Tern, Common Greenshank) are likely to be disadvantaged, as the algal cover may restrict their ability to see and catch small-bodied fish.

The abundances of eleven key waterbird species in the southern Coorong over the last six years are presented in Table 1. Eight of these species are species for which the Coorong has traditionally supported at least 1% of their global populations. The abundances of the migratory and non-migratory shorebirds have been consistently lower and/or have remained low during the last three years (i.e. since the summer of 2016-17 when the first extensive blooms of filamentous algae blanketed shorelines with suitable foraging habitat for shorebirds).

Table 1: Abundances of key waterbird species in the southern Coorong in January over the last six years. The southern Coorong consists of the South Lagoon, plus the southernmost 15 km of North Lagoon (e.g., see Paton *et al.* 2009). This area encloses the extent of occurrence of *Ruppia tuberosa.* Those species for which the Coorong supports at least 1% of their global populations are indicated with an asterisk. Copies of database held by The Department of Environment and Water and the Murray-Darling Basin Authority.

Species	2014	2015	2016	2017	2018	2019
Migratory shorebirds						
Curlew Sandpiper*	2108	1188	548	106	406	199
Common Greenshank	52	57	63	60	72	42
Red-necked Stint*	31546	44899	21364	4747	7337	11340
Sharp-tailed Sandpiper*	7642	10149	4364	26	1827	4088
Non-migratory shorebirds						
Banded Stilt*	1373	963	11806	73	613	539
Black-winged Stilt	227	248	175	138	223	73
Red-necked Avocet*	3369	5811	3482	1333	2059	1989
Red-capped Plover*	2580	1313	2532	106	891	715
Herbivorous waterfowl						
Black Swan	636	871	923	360	2431	2445
Chestnut Teal*	1758	666	1829	1753	2383	1724
Piscivorous species						
Fairy Tern*	344	363	367	240	299	223

Although the abundances of the two herbivorous waterfowl have generally been maintained or have increased in recent years, heavy grazing of *R. tuberosa* by January suggests that these waterfowl abundances are not sustainable, as the available plant biomass is likely to diminish further over time and potentially be unable to sustain the January abundances of waterfowl in the autumn (Paton *et al.* 2019a). Black Swans are of cultural importance to the Ngarrindjeri, adding further support for their populations to be managed well. Further monitoring of waterbirds and changes in food resources across the spring-autumn period in relation to any seasonal patterns to the abundances of filamentous algae is required to better determine what the consequences are for all of these birds. This should be a priority for future research. In the interim, there is a need to manage these birds to prevent further losses.

Further research and trials are needed before methods for eliminating filamentous green algae from the southern Coorong can be implemented. Thus, conditions are likely to remain poor and may deteriorate further from a waterbird, and particularly a shorebird, perspective. Consequently, solutions are required to (a) prevent further declines of waterbirds and their habitats and (b) meet Australia's international obligations under the Ramsar Convention and migratory waterbird agreements that are embedded within the Environment Protection Biodiversity and Conservation (EPBC) Act 1999. As solutions are not currently at hand to manipulate habitat within the southern Coorong for a better outcome for waterbirds, additional habitat areas are needed to complement the southern Coorong's diminished capacity to support waterbirds.

Given that many wetland bird species operate on at least a regional scale and are highly mobile in their movements, there is the potential to counter the declines of the key waterbird species within the Coorong by providing habitat elsewhere within the broader regional landscape. Consequently, to ensure the populations of key Coorong waterbird species are maintained in the region, future management should not simply focus on the southern Coorong, but on the network of wetlands (including the southern Coorong) in the broader regional landscape that provide habitat for the key species of concern. Since the quality of a wetland varies with time, managing the watering regimes of wetlands within the wetland network in an integrated manner will be necessary to ensure that habitats for these key species exist within the broader regional landscape at critical times for these key species. This will require considerable innovation underpinned by good science to deliver the outcomes expected. A first step is to identify what other wetlands may provide suitable habitats for key species of Coorong waterbirds in the broader landscape, including, but not limited to, the CLLMM and South East of South Australia. This may include protecting or enhancing these wetlands. Given that some of the species of concern are listed as vulnerable or endangered under the EPBC Act and under South Australian legislation, e.g. Curlew Sandpiper, there is an urgency to secure sufficient, suitable habitat for key species of concern.

The purpose of this research is to create an inventory of wetlands near to the Coorong, namely in the South-East of South Australia and the CLLMM region, that currently support or have the potential to support the key waterbird species of concern. The key species are those that are most at-risk from a failure to provide suitable habitats in the southern Coorong, namely the migratory shorebirds and, to a lesser extent, the non-migratory shorebirds and a few herbivorous and piscivorous bird species (Table 1).

We use systems analysis (Biswas 1976) and multi-criteria decision analysis (MCDA) with a weighted sum technique to evaluate the wetlands for multiple criteria, such as cost, value for shorebirds and feasibility (e.g. Pressey *et al.* 1993, Lyons *et al.* 2008). The approach taken is to provide a framework and make an initial assessment of the wetlands using this framework. Adjustments to the criteria scores and weights can then be made as part of further work (e.g. as part of a sensitivity analysis to test the robustness of the wetland prioritisation). This will be particularly important with the collation and inclusion of more detailed information on the wetlands.

2 Methods

The framework for wetland assessment is based on the five steps of systems analysis, defined as "an analytical study that helps a decision-maker to identify and select a preferred course of action among several feasible alternatives": (1) selection of objectives, (2) translation of objectives into measurable criteria, (3) identification of alternatives, (4) assessment of alternatives in terms of the nominated criteria, and (5) comparative evaluation of results from the assessment of alternatives (Biswas 1976). A flowchart illustrating these steps and the input data used in each step is provided in Figure 1.

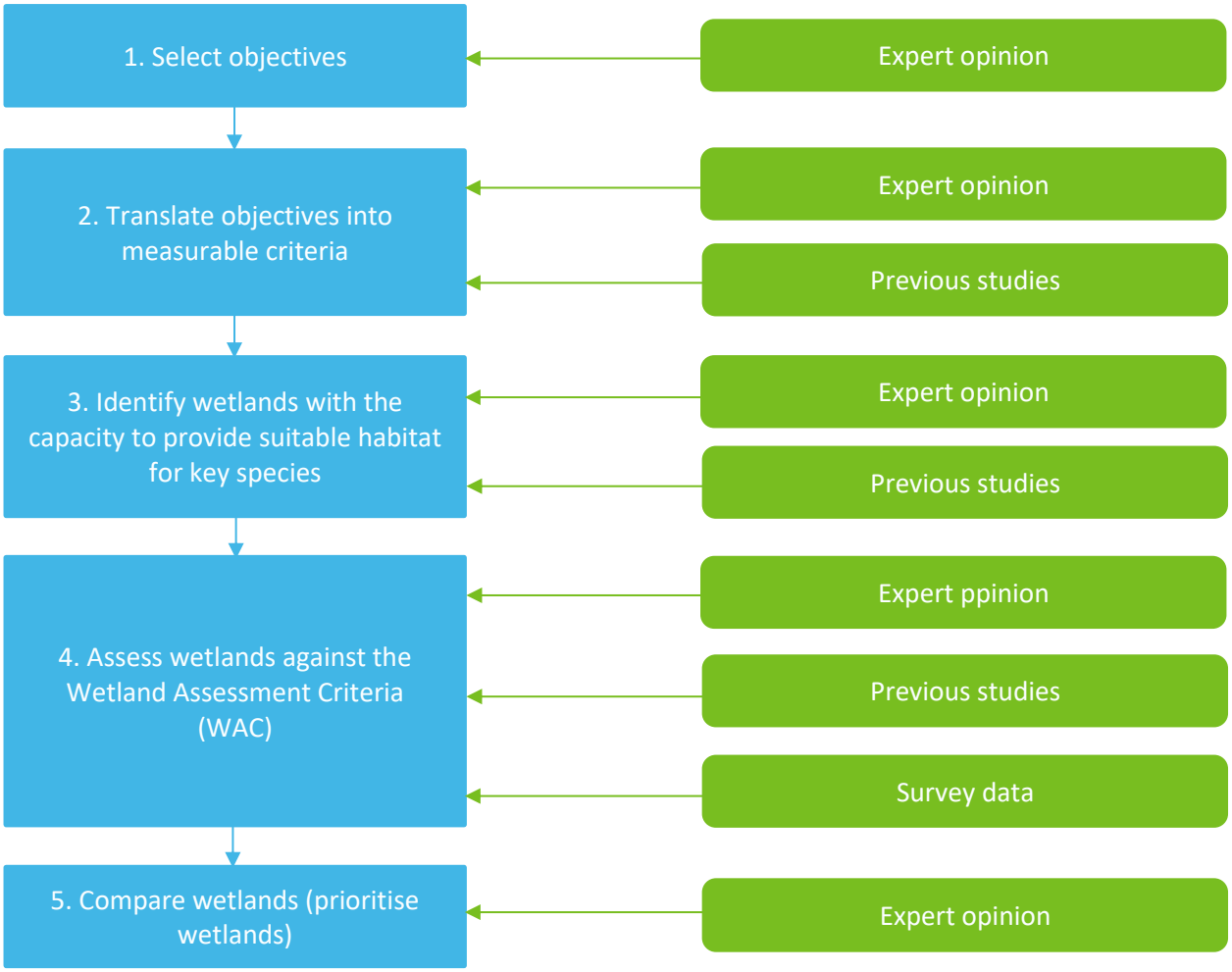

Figure 1: Flowchart of wetland assessment framework, indicating the steps used and the sources of input data that informed each step, based on systems analysis (Biswas 1976).

2.1 Select objectives and translate into measurable criteria

To meet the aim of this research, wetlands were sought that: (1) were accessible, (2) were currently known to, or if modified would be, used by key waterbird species, (3) contained site attributes that would readily accommodate the key waterbird species and (4) were able to be modified. The 21 Wetland Assessment Criteria (WAC) used to compare wetlands follow these objectives and fall under four categories: (1) Accessibility, (2) Value for Birds, (3) Site Attributes, and (4) Ability for Modification. The details of each of these criteria are summarised in Table 3, including the sources of the data used to populate them, an explanation of the data sought for each criterion, and the purpose of their inclusion for this project.

Most of the WAC were adapted from survey methods, model parameters and prioritisation criteria that have been used in previous wetland assessment studies (Ye *et al.* 2002; Butcher and Hale 2005; Lyons *et al.* 2008, Rogers *et al.* 2008; Brandis *et al.* 2009; O'Connor *et al.* 2013; Wegener *et al.* 2016). Additional criteria, such as the proximity of the wetland to the Coorong and the value of the wetlands for the different functional bird groups, were included in the assessments to better capture the specific requirements of this study.

2.2 Identify wetlands with the capacity to provide suitable habitat for key species

Wetlands providing and potentially providing suitable habitat for key species were identified using consultation with wetland experts, information from previous studies and knowledge of the largely coastal distributions of some of the key species (e.g. Figure A6, Appendix 6.5).

For the SE wetlands, a workshop was held on 13 February 2019 and attended by wetland and waterbird experts from the Department of Environment and Water (Natural Resources SE), Birdlife SE, Friends of Shorebird SE, Nature Glenelg Trust and the SE Drainage Board (see Acknowledgements for attendee list). A list of 23 wetlands and wetland complexes in the SE were identified by the workshop participants as providing or having the potential to provide suitable habitat for the key species, at least for part of the summer/autumn period (see Figure 2 for wetlands and locations). Fourteen of these wetlands were chosen for more detailed assessment (classed as 'primary opportunities') because they were known to be used by at least some of the key species or, in the opinion of workshop participants, had the potential to provide suitable habitat for the key species with changed management. This selection of 14 wetlands does not exclude further investigation of the remaining nine wetlands (classed as 'secondary opportunities') but assessing all 23 wetlands was not possible within the time constraints of this project. Some data on these secondary opportunity wetlands was collected and is documented in Table A6, Appendix 6.5, but beyond this these wetlands are not discussed further.

The shorelines of the Lower Lakes do not provide suitable habitat for the key species under current management regimes, as deep water covers any extensive areas of mudflats around the shoreline of the Lower Lakes, thus excluding wading birds like stints and sandpipers (e.g. Paton *et al.* 2019a). However, adjacent to the Lower Lakes are a series of wetlands that have the potential to provide suitable habitat. Seven of these wetlands were chosen as 'primary opportunities' for assessment (see Figure 4 for wetlands and locations), based on the expertise of the authors and Kate Mason (Natural Resources SAMDB) and previous assessments (Bjornsson 2005, 2006a, 2006b; Rogers *et al.* 2008; O'Connor *et al.* 2013; and Oerman and Mason 2015). Several small, ephemeral wetlands (e.g. Poltalloch) were not included, as these were deemed to be of minor benefit to key species and have limited scope for modification (Kate Mason pers. comm.). These ephemeral wetlands could also be assessed formally in due course but were not further investigated in this study because of limited time.

2.3 Assess alternative wetlands against nominated criteria

The 30 wetlands (23 wetlands in the SE and 7 wetlands around the Lower Lakes) were then assessed using the WAC. Data were collected from: (a) experts, (b) wetland reports, relevant literature, historical bird surveys, management plans and feasibility studies (Bjornsson 2005, 2006a, 2006b; Ecological Associates 2009; O'Connor *et al.* 2013; Oerman and Mason 2015; Farrington *et al.* 2018; and Hartvigsen-Power *et al.* 2019), and (c) field surveys (see Sections 2.3.1 and 2.3.2 for details). Where applicable, the sources of information used in the WAC are provided for each of the wetlands (Table A6, Appendix 6.5). For those situations where a robust assessment could not be made using existing data, expert opinion was used to provide information. The following experts were used for the SE wetlands: Melissa Herpich, Mark de Jong and Abigail Goodman (Natural Resources SE), Claire Harding (DEW), and Maureen Christie and Jeff Campbell (Friends of Shorebirds SE). Kate Mason (Natural Resource SAMDB) provided expert advice for the Lower Lakes wetlands.

For each of the criteria, we classified the wetland data, most often into three or four classes, such as 'Low', 'Medium', 'High' and 'Very high'. For quantitative criteria (e.g., percentages or areas), the classes were defined within specific quantitative ranges for those data. For each wetland, 16 of the 21 criteria were given a score. Five other criteria could not be scored because the criteria did not differentiate wetlands in terms of their value for the key species (e.g. the salinity regime) or the criterion's characteristics would change after wetland modification (e.g. hydrological regime). However, these five criteria are still included in the WAC table as they provide useful data for each wetland. For the 16 criteria that were scored, the better a wetland was in meeting the objective of the criteria, the higher its score. For example, for the cost criterion, wetlands that were costly to modify scored poorly for that criterion compared to those where the cost was lower. Given the varied nature of the data collected, scoring was purely ordinal and did not reflect standardised measures either within or between criteria. Classifications of each criterion and justifications for the scoring system are presented in Table 4. The classification and scoring of these criteria allowed a translation of different types of data into numeric values that fed into the prioritisation framework (see Section 2.4). This process followed recognised wetland prioritisation methods such as those in Butcher and Hale (2005) and Rogers *et al.* (2008).

2.3.1 SURVEY DATA FOR SOUTH EAST (SE) WETLANDS

Field surveys were undertaken across the SE region in February and March 2019 to assist in assessing the wetlands against the WAC. Specifically, they were undertaken to: (a) confirm use of wetlands by key species, (b) document the numbers of key species that were currently supported by the wetlands, (c) assess how the birds were using the wetlands (e.g. foraging, roosting), and (d) describe the habitat features provided by the wetlands. For further details of survey methods, see Appendix 6.1.1.

2.3.2 SURVEY DATA FOR LOWER LAKES WETLANDS

For the Lower Lakes, no field surveys were undertaken; however, we used annual January–February census data collected for the Lower Lakes and associated wetlands as part of The Living Murray Program (e.g. Paton *et al.* 2019a) to gauge the importance of these wetlands for the key species. The census of waterbirds consists of counting the numbers of each species of waterbird in each 1 km by 1 km grid cell that contained shorelines, as described in Paton *et al.* (2019a). Those surveys show very limited use of the Lower Lakes and associated wetlands by the key species. For the purpose of this study we extracted cells in which the three key species of small migratory shorebirds, namely Sharp-tailed Sandpiper, Curlew Sandpiper and Red-necked Stint, were detected in one or more years. We used the counts and frequency of use from one year to the next to assess the value of these other wetlands in providing suitable habitats for these key species. For more detail on the results of these survey assessments, see Appendix 6.2.

2.4 Comparing wetlands (prioritisation)

A multi-criteria decision analysis (MCDA) was then applied to rank wetlands from the SE and from around the Lower Lakes. This is a common method of comparing options that must take into account multiple and often conflicting criteria (e.g. Marler and Arora 2010; Stralberg *et al*. 2009). A simple weighting was applied for 16 of the 21 scored criteria according to the perceived importance of each criteria in meeting the needs of key waterbird species. The weighting was based on the opinions of the authors and other experts and the justifications for the weighting of each criterion are detailed in Table 4. Thus, for each wetland, the assessment score for each criterion was multiplied by the weighting factor for that criterion, and these weighted scores for all criteria were then summed to establish a total score. Those wetlands with the highest scores are the wetlands that should be the first to undergo more detailed assessment including the feasibility and costs of managing them to deliver outcomes for key waterbird species.

This is a simple application of an MCDA and future iterations should undertake sensitivity analyses (e.g. of the scores and weights) to improve the robustness of the results. However, this was beyond the scope of this study.

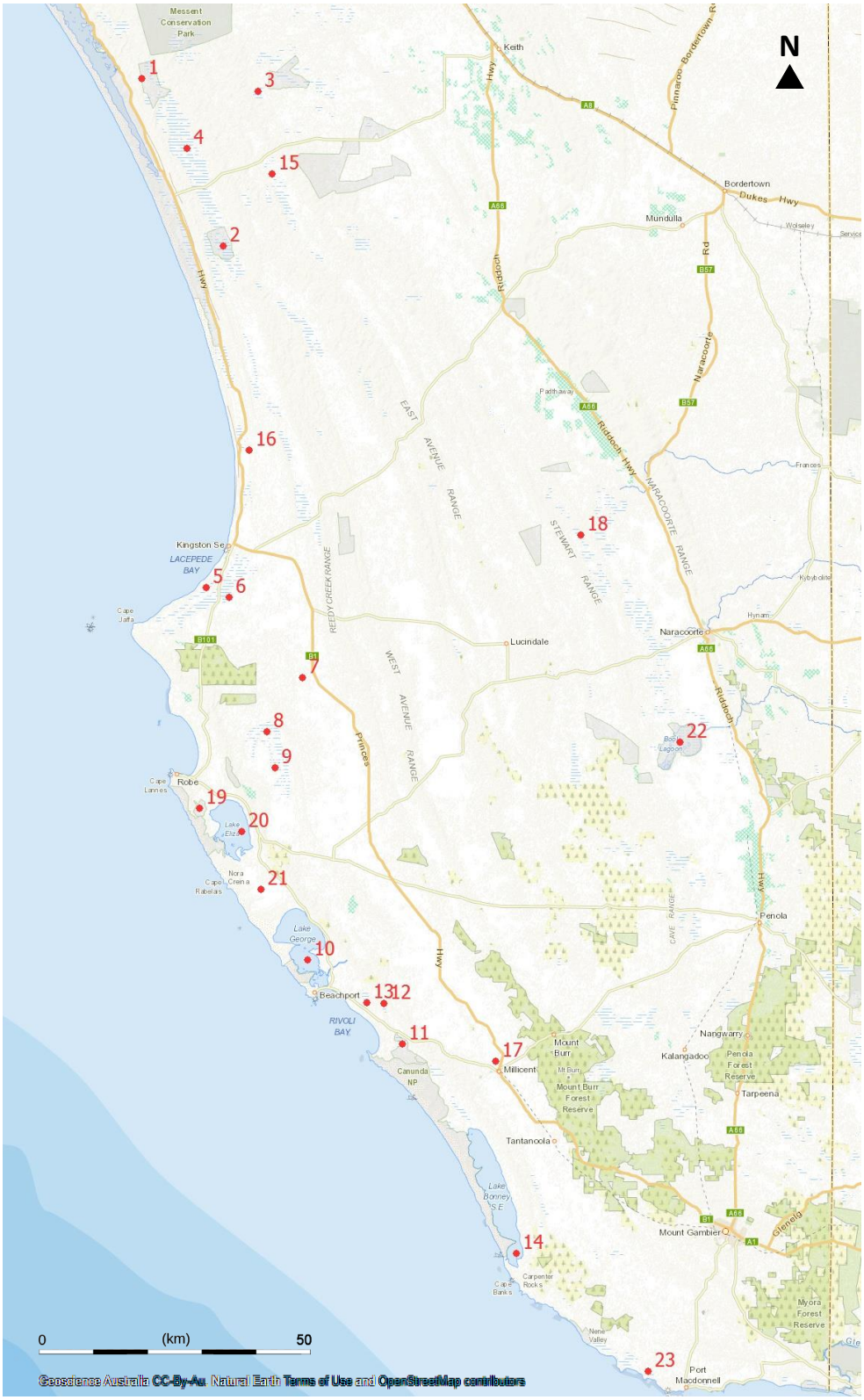

Figure 2. Location of primary and secondary wetland sites in the South East of South Australia. Topographic basemap sourced from Geoscience Australia (2019). See Table 2 for key to numbered sites.

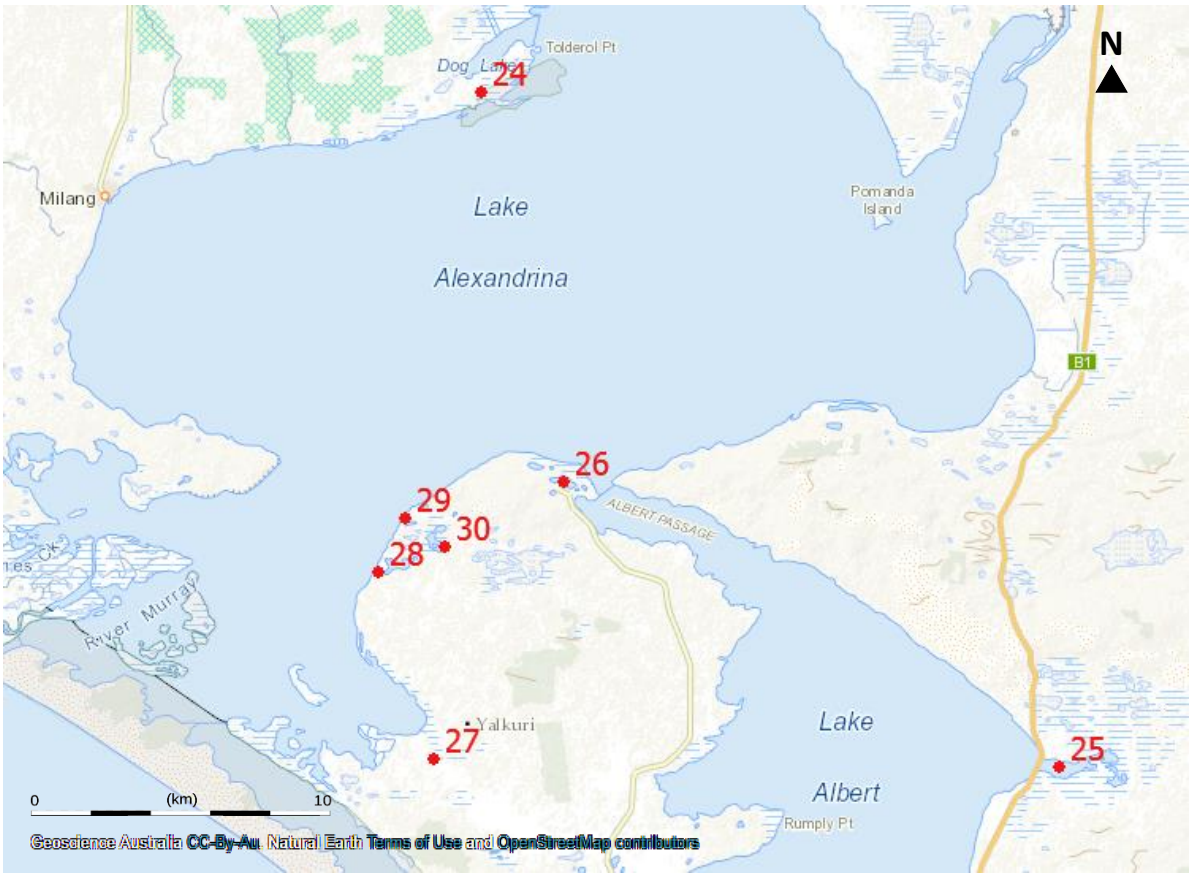

Figure 3. Location of primary wetland sites around the Lower Lakes of South Australia. Topographic basemap sourced from Geoscience Australia (2019). See Table 2 for key to numbered sites.

Table 2: Key to numbered primary and secondary wetland sites in the South East of and Lower Lakes regions of South Australia in Figures 3 and 4. Site numbers are for reference only and do not indicate ranking.

PRIMARY OPPORTUNITIES: SOUTH EAST	SECONDARY OPPORTUNITIES: SOUTH EAST	PRIMARY OPPORTUNITIES: LOWER LAKES
1) Morella Basin	**15)** Mandina Marshes/Cortina Lakes	**24)** Tolderol Game Reserve
2) Tilley Swamp Conservation Park	**16)** Paranki Conservation Park	**25)** Waltowa
3) Tilley Swamp- Brinkworth (Hindmarsh Park)	**17)** Lake McIntyre	**26)** Narrung
4) Tilley Swamp- Cortina Lakes, Banff, Stoneleigh Park, Frostys Swamp (Wetlands and Wildlife)	**18)** Lochaber Swamp	**27)** Jenny's Lagoon (Yalkuri Station)
5) Butcher Gap Conservation Park	**19)** Lake Robe	**28)** Teringie South Lagoon
6) Wangolina Swamp	**20)** Lake Eliza	**29)** Teringie North Lagoon
7) Kungari Conservation Park	**21)** Lake St Clair	**30)** Teringie East
8) Lake Hawdon North	**22)** Bool Lagoon/Hacks Lagoon	
9) Lake Hawdon South	**23)** Middlepoint Swamp	
10) Lake George/Admella Lake, Bucks Lake		
11) Lake Frome Conservation Park		
12) Mullins Swamp		
13) Iluka		
14) Lake Bonney SE/Bucks Lake		

Table 3: Wetland Assessment Criteria and their information sources, explanation of each criterion, and the purpose of including each criterion.

Assessment categories and criteria	Sources	Explanation of criteria	Purpose of inclusion
ACCESSIBILITY			
Ease of wetland access	Field assessment, expert advice	An indication of how the wetland can be accessed, usually either by 4WD or on foot. May indicate different access methods depending on water levels.	Indicates ability to easily assess waterbird responses in the field.
Seasonality	Expert advice, previous studies	Indicates if seasonal flooding may inhibit access at certain times of year, indicate if all year, summer only, summer–autumn etc.	Indicates ability to easily assess waterbird responses in the field, especially during the drier season. These are under current management regimes and modification will alter these values, so this criterion was not considered in wetland prioritisation.
Percent of surveyable wetland	Field assessment, expert advice	A broad estimate of the percentage of the wetland (especially the shoreline) that it is possible to survey given access limitations, viewing opportunities, including through binoculars or a scope.	Indicates ability to comprehensively assess waterbird responses and measure impact of any wetland management in the field.
VALUE FOR BIRDS			
Value in current state	Expert advice, field assessment	How important the wetland is for waterbirds in its current state. High values indicate it would make a good monitoring site for waterbirds in the region and that its character needs to be maintained by good management.	Provides a baseline for comparison of value before modification and highlights those wetlands that are currently providing productive habitat for waterbirds. This value is based on expert knowledge of each wetland through time and does not necessarily correspond to data on bird abundances (largely because comparable longitudinal waterbird data for these wetlands has not been collected). However, some SE wetland surveys were undertaken for this study, and were also used to assess their value for wetland birds (see Appendix 6.1.2).
Potential value if modified	Expert advice	Value of the wetland for waterbirds if actively managed using environmental water, hydrological alterations and/or infrastructure works.	Indicates how valuable the wetland could be for waterbirds if actively managed. These were based on expert knowledge and perceived potential of wetlands to provide additional habitat for wetland birds after successful modification.
Current value for shorebirds	Field assessment, expert advice	Do shorebirds such as sandpipers, stint or plovers use the wetland, especially in regionally significant numbers? There need to be large expanses of shallow water or an extensive shoreline that provides good foraging habitat, especially in summer for migratory shorebirds. Relative estimates based on expert knowledge in the field. A majority of the key waterbird species are shorebirds.	Indicates whether appropriate habitat and/or resources currently exist for/are currently known to be used by shorebirds, therefore implying value for those species if the site is actively managed and a greater potential for these species to use the site after modification. To help inform this criterion, some SE wetland surveys were undertaken for this study, and were also used to assess their value for shorebirds (see Appendix 6.1.2).
Current value for waterfowl	Field assessment; expert advice	Do waterfowl such as ducks and swans use the wetland, especially in regionally significant numbers? Often slightly deeper water is favoured, especially where there is a high occurrence of aquatic plants or algae. Relative estimates based on expert knowledge in the field.	Indicates whether appropriate habitat and/or resources currently exist for/are currently known to be used by waterfowl, therefore implying value for those species if the site is actively managed and a greater potential for these species to use the site after modification. To help inform this criterion, some SE wetland surveys were undertaken for this

			study, and were also used to assess their value for waterfowl (see Appendix 6.1.2).
Current value for piscivores	Field assessment, expert advice	Do piscivores (fish eaters such as terns, cormorants, herons and egrets etc.) use the wetland, especially in regionally significant numbers? A significant fish population is needed, and there may be deep areas for cormorants to fish, or shallower areas for wading piscivores. Relative estimates based on expert knowledge in the field.	Indicates whether appropriate habitat and/or resources currently exist for/are currently known to be used by piscivores, therefore implying value for those species if the site is actively managed and a greater potential for these species to use the site after modification. To help inform this criterion, some SE wetland surveys were undertaken for this study, and were also used to assess their value for piscivores (see Appendix 6.1.2).
SITE ATTRIBUTES			
Proximity to Coorong	Mapping data	Gives an indication of how near wetlands are to any part of the Coorong system.	The closer the wetlands, the more suitable they may be for waterbirds displaced from the Coorong.
Bathymetry	Field assessment, expert advice, previous studies, mapping data	A broad assessment describing shoreline extent, shoreline slope, banks, shallow (<1 m depth) and deep areas (>1 m depth) of the wetlands. May also include the composition of wetland soils and proximity to other topographical features.	Those wetlands with predominantly extensive, shallow, lightly sloping shorelines are often most productive for waterbirds, especially shorebirds, so have the most potential for management for key species. Some SE wetland surveys were undertaken for this study and were used to assess wetland bathymetry (see Appendix 6.1.2). See Colwell (2010).
Current salinity	Expert advice, previous studies	An indication of the salinity of the water which may have management implications or impact waterbird use. Salinity may vary across the course of the year (usually increasing in warmer months), so this range is also noted.	Salinity can determine whether particular wetland bird species may favour the site, though this was not used in assessing prioritisation.
Land tenure and use	Expert advice, previous studies	A description of the wetland's current land tenure and management regime. Both public and private land can be managed for conservation purposes, whilst other areas of good wetland habitat may be predominantly used for grazing or mining.	Indicates what processes and permissions may be required for implementing future management regimes.
Current extent of vegetation incursion	Field assessment, expert advice, previous studies	Vegetation incursion is defined as the extent of vegetation growth along the wetland shoreline and/or into the waterbody at average water levels. If wetlands are mostly kept dry, terrestrial vegetation may have encroached. Long periods of permanent water may mean aquatic vegetation dominates.	Vegetation incursion can have a detrimental impact for waterbirds, and particularly for shorebird use, so removal may considerably improve a wetlands value for waterbirds. High level of vegetation incursion does not preclude prioritisation, though it is an additional step for effective management and so affects prioritisation. Some SE wetland surveys were undertaken for this study and were used to assess the extent of wetland vegetation incursion (see Appendix 6.1.2). See Colwell (2010).
Current hydrological regime	Expert advice, previous studies	Describes the current hydrological regime of the wetland, including natural inflows and active management.	Allows an understanding of how the wetland currently functions, which can inform current importance for waterbirds. As hydrological alterations are common management option, regimes may change markedly after alteration so are not considered in prioritisation.
Current peak season for waterbirds	Expert advice	In the current management state, gives an estimate of the season during which water levels are most appropriate for birds, usually when the greatest extents of shallow areas exist. For deeper wetlands, this is usually summer, for shallower/ephemeral ones, winter (as they may dry in summer).	Gives an idea of when the wetland is most productive or most important for waterbird species, especially as seasonal refugia.
SUITABILITY FOR MODIFICATION			

Modification options	Expert advice, previous studies	An outline of key modification options available to improve the wetland.	Modification options highlight the nature of the work, though do not necessarily indicate suitability for prioritisation. As such, these have not been scored for prioritisation.
Modification cost or value (estimate)	Expert advice, previous studies	If evaluated, an estimate of the cost of any on-ground modification work to the wetland. If not costed, an estimate of the value of wetland modification may be provided. Costs were either taken from previous studies or were broad estimates based on expert advice.	Though an estimate only, provides an idea of the investment that may be required if the project were to proceed, which needs to be considered in prioritisation.
Potential area of new or improved habitat	Expert advice, previous studies	An estimate of the number of hectares of habitat that could be created or markedly improved from modification.	Those wetlands where there is potential to create large areas of waterbird habitat are good candidates for prioritisation.
Feasibility	Expert advice, previous studies	How feasible modification is, particularly the proximity to a source of water, the amount of infrastructure/on-ground modification required, and the maintenance needed.	Wetlands with higher feasibility for modification or restoration improve the chances of successful outcomes so are preferred for prioritisation.
Existing plans	Expert advice, previous studies	Notes if management plans, project management frameworks or feasibility studies are already in action or have already been produced. Where relevant, documents have been cited.	Existing plans mean many of the options and issues have already been identified allowing more robust assessment for prioritisation and reducing implementation time
Potential issues	Expert advice, previous studies	Wetland modifications may be politically or socially sensitive in certain areas or have direct or indirect impacts on stakeholders/landholders or adjacent properties. Some may have positive benefits for community.	Potential issues need to be identified early and addressed in any future plans for modifications. As such they are important to account for in prioritisation.

Table 4: Wetland Assessment Criteria table listing the assessment categories and each of their criteria, the classification of those criteria and how they were scored for prioritisation, the justification for the scoring used in each classification and – where relevant – the weighing of each criterion, and a justification of that weighting.

Assessment categories and criteria	Classification and scoring for prioritisation	Scoring justification	Weighting (multiplier)	Weighting justification
ACCESSIBILITY				
Ease of wetland access	[1] Walking only; [2] 4WD and walking; [3] 4WD.	Higher scores are given to wetlands with 4WD access as they can be surveyed and assessed more efficiently.	0.5	Lower importance. Whilst useful to have a wetland that can be easily accessible for surveying purposes, walking is possible to access all wetlands.
Seasonality	Dry early summer; Dry mid-summer; Dry late summer; Permanent/ year-round.	Criterion not used in calculations of wetland prioritisation, so classifications are unscored.	NA	NA
Percent of surveyable wetland	Classifications based on 25% increments: [1] 0–25%; [2] 26–50%; [3] 51–75%; [4] 76–100%.	Higher surveyable areas are given a higher score as waterbird responses can be better monitored, so increasing their value for prioritisation.	1	Moderate importance. Ideally, prioritised wetlands should be able to be surveyed relatively completely.
VALUE FOR BIRDS				

Value in current state	Broad classification estimates based on expert advice: [1] Low; [2] Moderate; [3] High.	Higher values receive a higher score.	1	Moderate importance. Ideally modification will improve wetland value, but it is important to prioritise maintenance of current high value sites.
Potential value if modified	Broad classification estimates based on expert advice: [1] Low; [2] Moderate; [3] High; [4] Very high.	Higher values receive a higher score.	3	Very high importance as – according to expert opinion – there is relative confidence that a wetland with a high score will have good value for key waterbird species if modified successfully.
Current value for shorebirds	In lieu of standardised baseline data for every wetland, broad estimates of value based on expert knowledge are used: [1] Low; [2] Moderate; [3] High.	Higher values receive a higher score.	1	Moderate importance. The majority of the key wetland species in this study are shorebirds, so if they are currently using a wetland there is a good chance they will know the location of and continue to use a wetland if its value is improved.
Current value for waterfowl	In lieu of standardised baseline data for every wetland, broad estimates of value based on expert knowledge are used: [1] Low; [2] Moderate; [3] High.	Higher values receive a higher score.	0.5	Lower importance. Majority of waterfowl are not of key concern in this study, though increasing habitat value for these species is still beneficial.
Current value for piscivores	In lieu of standardised baseline data for every wetland, broad estimates of value based on expert knowledge are used: [1] Low; [2] Moderate; [3] High.	Higher values receive a higher score.	0.5	Lower importance. Majority of piscivores are not of key concern in this study, though increasing habitat value for these species is still beneficial.
SITE ATTRIBUTES				
Proximity to Coorong	Classifications of 50km distances are used: [4] Near (1–50 km); [3] Mid-range (50–100 km); [2] Far (100–150 km); [1] Distant (150–200 km).	Further distance classifications are given lower scores, as birds displaced from the Coorong will have further to move.	0.5	Lower importance. Proximity to Coorong may have an influence on how readily species can access improved wetland habitat if displaced from the Coorong, though we also assume a good degree of mobility for many wetland species.
Bathymetry	[1] Deeper water body and/or predominantly steep shoreline; [2] Some shallow areas and extensive shoreline, with steeper and deeper areas; [3] Primarily shallow shoreline and depths.	Wetlands with extensive shorelines and/or shallow depths are given the highest scores as they will be the most suited for waterbirds, particularly key shorebird species. Wetlands with large expanses of deeper water are less suitable for most waterbird species.	2	High importance. A large, shallow wetland with extensive shorelines provides an ideal area for key waterbird species if managed well, especially for shorebird species.
Current salinity	Units in uS/cm: Fresh (0–800); Brackish (800–15000); Saline (15000-50000); Hypersaline (>50000).	Criterion not used in calculations of wetland prioritisation, so classifications are unscored.	NA	NA
Land tenure and use	[1] Private, not for conservation (e.g. grazed); [2] Private, managed for conservation, or public with other current uses; [3] Public, e.g. conservation park (CP), crown land, game reserve)	Public land or land managed for conservation may make negotiations for modification easier.	1	Moderate importance. Public land and conservation outcomes help with management but are not always imperative for success.
Current extent of vegetation incursion	Classifications based on a percent estimate of wetland affected by vegetation incursion: [3]	Higher scores are given to wetlands with lower vegetation incursion, as this may make management easier.	0.5	Lower importance. Vegetation incursion can be an issue for wetland birds, but modification options

	Low (0–20%); [2] Moderate (21–60%); [1] High (61–100%).			often include its control to improve a site's value, so this should not be a barrier for prioritisation.
Current hydrological regime	Any combination of: Seasonal; Ephemeral; Permanent; Regulated; Naturally inundated; Drain inflow; Groundwater.	Criterion not used in calculations of wetland prioritisation, so classifications are unscored.	NA	NA
Peak season for waterbirds	Classified by season.	Criterion not used in calculations of wetland prioritisation, so classifications are unscored.	NA	NA
SUITABILITY FOR MODIFICATION				
Modification options	May include levee construction, installation of regulators, increased inflow, control of encroaching vegetation, altering drainage, reducing or increasing water levels.	Criterion not used in calculations of wetland prioritisation, so classifications are unscored.	NA	NA
Modification cost or value (estimate)	Cost classifications are as follows: [4] No cost (e.g. only requires community consultation) or low cost (e.g. modifications already undertaken), [3] Moderate cost (> $50,000); [2] High cost ($50,000 to S1M); [1] Very high cost (>$1M).	Higher costs are given lower ranking scores, though these may be offset if the project is of particularly high value or benefit.	3	Very high importance. Though only estimates, costs can be a significant barrier to successful project outcomes so need to be weighted accordingly.
Potential area of new or improved habitat	Classifications based on area of habitat as follows: [1] Low (<50 ha); [2] Moderate (50–500 ha); [3] High (500–1000 ha); [4] Very high (>1000 ha).	Larger areas of habitat restoration receive a higher score.	3	Very high importance. For a given site, the larger the wetland area that can be added or improved, the more habitat available for key waterbird species. Note, however, that wetland area does not always translate into the area of valuable waterbird habitat, and small areas can also support significant numbers of key waterbird species if habitat quality is high.
Feasibility	Classifications are a guide, though most wetlands identified as primary opportunities have moderate feasibilities or higher: [1] Low; [2] Moderate; [3] High.	The higher the feasibility the better the score for prioritisation.	3	Very high importance. A wetland with a high feasibility has fewer barriers to delivering successful project outcomes, often with multiple options for implementation.
Existing plans	[1] No plans; [2] Some management plans investigated; [3] Detailed plans, reports and/or project frameworks.	Existing plans increase the score for prioritisation.	2	High importance. Though further investigation and plans will be required for future wetland modifications, pre-existing detailed plans and investigations significantly increases the confidence that a project is suitable for modification.
Potential issues	Classifications based roughly on perceived number of issues: [3] Few/positive outcomes; [2] Some; [1] Many.	High prioritisation scores are given for those projects with fewer hurdles to implementation.	2	High importance. Though unforeseen problems can occur, initial identification of a project with few issues indicates that successful implementation is more likely.

3 Results and preliminary discussion

3.1 Assessment of wetland criteria

Considerable detail is provided for each of the wetlands assessed using the WAC in Table A6, Appendix 6.5. Because wetlands varied dramatically in the scoring of the criteria, the following sections briefly highlight some of the variability between wetlands in the SE and around the Lower Lakes, respectively, in terms of the characteristics that were being assessed.

3.1.1 SOUTH EAST (SE) WETLANDS

Many of the assessed wetlands in the SE were dry in either mid- or late summer, with only Morella Basin, the Lake George System, and Illuka holding water year-round under current management regimes. However, all SE wetlands except Mullins Swamp and Iluka (which are already privately managed) could, for at least part of the summer-autumn period, become high or very high value sites for waterbirds with active management and modification (see WAC summaries in Tables 5 and 6).

Lake Hawdon North, Lake Hawdon South and Lake George all had high scores for shorebirds with Lake Hawdon South and Lake George also having high value for waterfowl, and moderate to high value for piscivores (Table A6, Appendix 6.5). However, some wetlands with large areas of extensive shoreline (ostensibly good habitat for shorebirds) such as areas of Lake Bonney SE, supported comparatively few waterbirds (see Table A3, Appendix 6.3).

The extent of vegetation incursion encroaching on the wetlands was often a negative predictor of its value for waterbirds, and particularly shorebirds (e.g. Figure A3, Appendix 6.1). Many of the modification options available to improve the SE wetlands included vegetation control (particularly in those areas that have not had water for significant periods and have become 'terrestrialised', such as Kurangi Conservation Park (CP), and Lake Hawdon North and South). Whilst wetlands like Morella Basin and Tilley Swamp are already in the South East Flows Restoration Project (SEFRP) scheme, several other SE wetlands (e.g. Butcher Gap CP, Wangolina Swamp and Lake George) require the construction of levees, regulators or sill modifications for optimal management (Tables 5 and 6).

Potential on-ground works to improve the quality of SE wetlands for key species of waterbirds ranged from relatively low cost (e.g. those SE wetlands that are already part of the works in the SEFRP such as Morella Basin), up to hundreds of thousands or millions of dollars where significant on-grounds works were required for habitat improvement (e.g. Butcher Gap CP, Lake George). However, many of the more costly projects also have the potential to greatly increase the area of potential new habitat, so scored highly on those criteria (e.g. Lake Hawdon North could create ~2475 ha, and Lake George could restore up to 6000 ha).

Inundation of properties adjacent to wetlands following management was a risk that could be managed through communication and agreements with affected stakeholders, including grazing and mining licensees. Some management options had potential for other environmental benefits such as improved water quality in Rivoli Bay with the management of Lake George.

3.1.2 LOWER LAKES WETLANDS

As with the SE wetlands, few of the assessed wetlands in the Lower Lakes region currently hold permanent water through summer (with the exception of Tolderol Game Reserve (GR) and Teringie North Lagoon), and only Tolderol GR scored highly for key waterbird species. However, appropriate management interventions at all wetlands were estimated to deliver a marked improvement to moderate, high, or very high value (see WAC summaries in Table 7).

On-ground works ranged from no cost (e.g. those Lower Lakes wetlands that just required community involvement such as Teringie South Lagoon), up to hundreds of thousands or millions of dollars where significant works were required for habitat improvement (e.g. Tolderol GR and Waltowa Swamp). Additionally, Waltowa Swamp has stakeholder issues with rising saline groundwater impacting surrounding low-lying grazing country. However, some shorebird species, particularly at-risk species, such as Red-necked Stint and Banded Stilt, may benefit more with the establishment of saline wetlands. Further, there is a strong Ngarrindjeri cultural connection to this wetland. Consequently, while this wetland did not rank highly in our assessments, it may warrant further assessment for other reasons.

Overall, the wetlands associated with the Lower Lakes had less potential to create large areas of suitable habitat compared with those in the SE (tens to hundreds of hectares compared with hundreds to thousands of hectares). However, if managed well, even small wetland areas can provide high value habitat for birds, as is demonstrated by the current management of Tolderol GR (Colwell 2010). In addition, their proximity is much closer to the Coorong lagoons than most of the SE sites and so they scored highly on this criterion.

Vegetation encroachment was less of an issue for the wetlands associated with the Lower Lakes, and options for management focused more on improving flow regimes and creating structures to inundate wetland areas for longer. The biggest potential issues flagged with improving these wetlands stem from drainage modifications causing overflow of or inundation of agricultural land. Most projects would also require dedicated landholder, community, and Ngarrindjeri consultations to be approved.

3.2 Outcomes of the multi criteria decision analysis

The two highest scoring wetlands for the SE were Lake Hawdon North and Lake Frome CP (see Table 8) and the two highest scoring wetlands from around the Lower Lakes wetlands were Tolderol GR and Teringie South Lagoon (see Table 9).

3.2.1 LAKE HAWDON NORTH

Lake Hawdon North currently dries in early December, but when it contains water it is of high value to shorebirds and moderate value to waterfowl and piscivores. The installation of a regulator would likely be costly compared to other sites, but the potential benefits for waterbirds are very high, particularly given that up to 2475 ha of habitat could be created and maintained through summer. Restoration and feasibility reports have already been created (Ecological Associates 2009, Farrington *et al.* 2018), though support would be required from stakeholders and be compatible with mining operations. To further increase the value of the wetland to waterbirds, encroaching vegetation would also need to be controlled to enable easy access for shorebirds to the shoreline. Surveys at other wetlands showed a strong negative correlation between the amount of emergent terrestrial vegetation and use by migratory shorebirds (e.g. Figure A3, Appendix 6.1).

3.2.2 LAKE FROME CONSERVATION PARK

With modification, Lake Frome CP could extend the availability of substantial amounts of suitable habitat for the key waterbird species through summer and into autumn. This could be achieved through on-ground works to maintain an inflow from Drain L (which contains water through summer) and control structures to retain water, creating a shallow wetland area over 1000 ha that would benefit not just the key species but all types of waterbirds. The project has not been costed and negotiations with adjoining landholders would be crucial to either purchase adjacent areas of low-lying land or be compensated for inundation.

3.2.3 TOLDEROL GAME RESERVE

Tolderol GR is a completely man-made and managed wetland system consisting of 19 basins that have the potential to be managed independently of each other. However, only some of the basins are watered and watering of other basins is inefficient, so Tolderol GR is not operating at full capacity (Hartvigsen-Power *et al.* 2019). Despite this, Tolderol GR supports reasonable numbers of small migratory shorebirds, likely to be disadvantaged by the ecological conditions currently present in the southern Coorong (Hartvigsen-Power *et al.* 2019). The area of habitat that could support shorebirds could be increased by 83.5 ha. With careful management, including adjustments of water levels, suitable habitat for foraging shorebirds throughout the critical summer-autumn period can be provided within the total wetland area of 200 ha. One of the key attributes of Tolderol GR is the capacity (with modification) to allow water levels in different basins to be drawn down at different times over the summer and autumn period to provide a succession of suitable habitat for the key species. While the cost of modification of Tolderol GR could be much higher than that for other wetlands (up to $1.4M), the project is scalable and could be delivered gradually over a number of years. Further, Tolderol GR already has a reputation amongst birdwatchers as an accessible and valuable habitat for waterbirds. Investing and upgrading Tolderol GR value-adds to that existing interest. In this way, any investments are conspicuous to the general public, as well as providing some economic return to local communities through increased visitation (Hartvigsen-Power *et al.* 2019).

3.2.4 TERINGIE SOUTH

Whilst management of Teringie South Lagoon would only create around 60 ha of new habitat, it has the potential for improvement for little to no cost. Currently, water levels are often kept high creating little shoreline and rendering the wetland of lower value for shorebirds. Engagement with landholders and Ngarrindjeri could improve the timing, volumes and duration of environmental watering events to ensure shallow water levels and extensive shorelines are maintained for shorebirds at critical periods.

Table 5: Summary of Wetland Assessment Criteria for primary South East wetland sites 1–7, extracted from Table A6, Appendix 6.5. Colours indicate the scoring of the data listed: □ = 1; □ = 2; □ = 3; □ = 4; □ = unscored. See Table 4 for more detail on classification and scoring.

Wetland assessment categories and criteria	1) Morella Basin	2) Tilley Swamp Conservation Park	3) Tilley Swamp (Hindmarsh Park)	4) Tilley Swamp (Cortina Lakes)	5) Butcher Gap Conservation Park	6) Wangolina Swamp	7) Kungari Conservation Park
ACCESSIBILITY							
Ease of wetland access	4WD, walking	4WD	4WD	4WD	4WD, walking	4WD, walking	4WD, walking
Seasonality	Year round	Dry end of summer	Dry end of summer	Dry end of summer	Permanent/damp	Dry end of summer	Dry end of summer
Percent of surveyable wetland	90%	2%	100%	50%	60%	50%	10%
VALUE FOR BIRDS							
Value in current state	High	Low	Moderate	Moderate	Moderate	Moderate	Moderate
Potential value if modified	High	High	High	High	Moderate	High	High
Current value for shorebirds	Moderate	Low	Moderate	Low	Moderate	Low	Low
Current value for waterfowl	High	Low	High	Moderate	Moderate	Moderate	Moderate
Current value for piscivores	Low	Low	Low	Low	Low	Moderate	Moderate
SITE ATTRIBUTES							
Proximity to Coorong	Near	Near	Near	Near	Mid-range	Mid-range	Mid-range
Bathymetry	Mainly shallow	Shallow	Shallow	Mostly deeper	Shallow lake, shores	Shallow floodplain	Shallow, deep areas
Current salinity	Brackish	Brackish	Brackish	Brackish	Brackish–saline	Brackish	Fresh–brackish
Land tenure and use	Conservation Park	Conservation Park	Private, grazed	Private, grazed	Conservation Park	Private, grazed	Conservation Park
Extent of vegetation incursion	Low	Moderate	Low	Moderate	Moderate	Moderate	Moderate
Current hydrological regime	Seasonal flows	Regulated	Seasonal inflows	Seasonal inflows	Regulator flows	Seasonal inflows	Seasonal drainage
Current peak season	Spring–autumn	Wetter months	Wetter months	Wetter months	Wetter months	Wetter months	Wetter months
SUITABILITY FOR MODIFICATION							
Modification options	Few. Some risks.	Clear vegetation	Inundation (SEFRP)	Inundation (SEFRP)	Update regulator	Levee or regulator	Levees, expansion
Modification cost or value (est.)	SEFRP initiated	$200,000	SEFRP initiated	SEFRP initiated	$70,000 -$200,000	$20,000-40,000	$20,000
Potential area of new habitat	Low	Moderate–high	High	Moderate	Moderate	High (727 ha)	High (564 ha)
Feasibility	High	High	High	High (dependant)	High	High (dependant)	High
Existing plans	Yes	Part of SEFRP	Part of SEFRP	Part of SEFRP	Outflows managed	Yes	Yes
Potential issues	Inundating habitat	Landholder impact	Landholder negot.	Landholder negot.	Landholder impact	Landholder impact	Landholder impact

Table 6: Summary of Wetland Assessment Criteria for primary South East wetland sites 8–14, extracted from Wetland Assessment Criteria Table A6, Appendix 6.5. Colours indicate the scoring of the data listed: □ = 1; □ = 2; □ = 3; □ = 4; □ = unscored. See Table 4 for more detail on classification and scoring.

Wetland assessment categories and criteria	8) Lake Hawdon North	9) Lake Hawdon South	10) Lake George Admella etc.	11) Lake Frome Conservation Park	12) Mullins Swamp	13) Iluka	14) Lake Bonney SE & Bucks Lake
ACCESSIBILITY							
Ease of wetland access	4WD	4WD, walking	4WD, walking	4WD, walking	4WD, walking	4WD	4WD, walking
Seasonality	Dry early summer	Dry mid-summer	Mostly permanent	Dry end of summer	Year round	Year round	Permanent
Percent of surveyable wetland	80–100%	20–50%	80%	5%	40%	90%	60%
VALUE FOR BIRDS							
Value in current state	Moderate	High	High	Moderate	Moderate	Moderate	Moderate
Potential value if modified	Very High	Very High	High	Very high	Moderate	Moderate	High
Current value for shorebirds	High	High	Moderate	Low	Moderate-Low	Low	Moderate
Current value for waterfowl	Moderate	High	High	Moderate	High	Moderate	Moderate
Current value for piscivores	Moderate	High	Moderate	Moderate	Moderate	Moderate	Moderate
SITE ATTRIBUTES							
Proximity to Coorong	Mid-range	Mid-range	Far	Far	Far	Far	Distant
Bathymetry	Shallow	Shallow and deep	Shallow	Lake and marsh	Lake and marsh	Marsh	Shallow and deep
Current salinity	Fresh–brackish	Fresh–brackish	Brackish–saline	Fresh	Fresh	Fresh	Saline–hypersaline
Land tenure and use	Crown land	Conservation Park	Crown land	Conservation Park	Private conservation	Private conservation	Public and private
Extent of vegetation incursion	High	High, increasing	Low	Moderate	High	High	Low
Current hydrological regime	Seasonal drainage	Seasonal inflows	Permanent	Seasonal	Permanent	Seasonal inflows	Permanent lake
Current peak season	Spring	Summer	Spring–summer	Wetter months	Summer (refuge)	Wetter months	Summer
SUITABILITY FOR MODIFICATION							
Modification options	Regulator. Vegetation	Clear vegetation	Flow structures	Inflows, build weir	Clear vegetation	Clear vegetation	Inflows, regulator
Modification cost or value (est.)	$500,000+, high value	Not costed, mod.?	$2.5M	Not costed, high?	Not costed, mod.?	Moderate value	Not costed, mod.?
Potential area of new habitat	Very high, 2475 ha	Maintain	Very high, ~6000 ha	Very high, 1020 ha	Moderate	Moderate, 130 ha	Low
Feasibility	Very High (Drain L)	High	Moderate (Drain M)	High (Drain L)	Moderate	Moderate	Moderate
Existing plans	Yes	Yes	Partial	Yes	None	Yes	Partial
Potential issues	Stakeholder support	Stakeholder support	Community benefit	Landholder impact	None known	Few	Water quality

Table 7: Summary of Wetland Assessment Criteria for primary Lower Lakes wetland sites 1–7, extracted from Wetland Assessment Criteria Table A6, Appendix 6.5. Colours indicate the scoring of the data listed: □ = 1; □ = 2; □ = 3; □ = 4; □ = unscored. See Table 4 for more detail on classification and scoring.

Wetland assessment categories and criteria	24) Tolderol Game Reserve	25) Waltowa	26) Narrung	27) Jenny's Lagoon (Yalkuri)	28) Teringie South Lagoon	29) Teringie North Lagoon	30) Teringie East
ACCESSIBILITY							
Ease of wetland access	4WD	4WD, walking	4WD, walking	Walking, some 4WD	4WD	4WD	4WD
Seasonality	Permanent water	Dry mid-summer	Can be dry summer	Dry mid-summer	Dry mid-summer	Year round	Dry mid-summer
Percent of surveyable wetland	100%	100%	100%	100%	80%	100%	100%
VALUE FOR BIRDS							
Value in current state	High	Low for most	Moderate	Moderate	Moderate	Low	Low
Potential value if modified	Very high	Very high	Moderate	High	High	Moderate	Moderate
Current value for shorebirds	High	Low	Low	Moderate	Low	Low	Low
Current value for waterfowl	Moderate	Low	Moderate	Moderate	Low	Low	Low
Current value for piscivores	Moderate	Low	Moderate	Moderate	Moderate	Low	Low
SITE ATTRIBUTES							
Proximity to Coorong	Near	Near	Near	Near	Near	Near	Near
Bathymetry	Constructed basins	Shallow basin	Shallow mudflats	Shallow, flat	Shallow, flat	Shallow, sloping	Shallow, sloping
Current salinity	Variable	Hypersaline	Brackish	Fresh–brackish	Brackish	Fresh–brackish	Hypersaline
Land tenure and use	Reserve	Conservation	Conservation	Conservation	Grazing	Conservation	Grazing
Extent of vegetation incursion	Variable	None	Low to none	Low–moderate	Moderate	Moderate	None
Current hydrological regime	Pumping	Now ephemeral	Managed	Managed	Permanent	Permanent	Seasonal rainfall
Current peak season							
SUITABILITY FOR MODIFICATION							
Modification options	Add basins, stagger	Upgrade regulator	Manage water level	Extend inundation	Manage water level	Install regulator	Connect inflows
Modification cost or value (estimate)	$100,000+	$100,000–$300,000	No cost	Unknown, $10,000?	No cost	$400,000–$500,000	Unknown, $50,000?
Potential area of new or improved habitat	83–203 ha	~260 ha	Moderate	~26 ha	~60 ha	30 ha	~70 ha
Feasibility	High	High	High	High	High	High	Moderate
Existing plans	Yes	Yes	Yes	None	Partial	Yes	Yes
Potential issues	Community support	Landholder impact	Community support	Few	Ngarrindjeri support	Few	Few

Table 8: Wetland Assessment Criteria with weightings, criteria scores and priority calculations for primary SE wetlands 1–14. Scores are extracted from Wetland Assessment Criteria Table A6, Appendix 6.5. Priority score was calculated by multiplying each of the scores for a wetlands' criteria by the weighting value, and then totalling the resulting values for each wetland. Colours indicate the scoring of the data listed: □ = 1; □ = 2; □ = 3; □ = 4. Priority classes were defined from priority scores as follows: □ = Low (<55); □ = Moderate (55–63); □ = High (>63). See Table 4 for details on scoring and weighting.

Wetland assessment categories and criteria (scored criteria only)	Weighting	1) Morella Basin	2) Tilley Swamp CP	3) Tilley Swamp (Hindmarsh Pk)	4) Tilley Swamp (Cortina Lakes)	5) Butcher Gap CP	6) Wangolina Swamp	7) Kungari CP	8) Lake Hawdon North	9) Lake Hawdon South	10) Lake George Admella etc.	11) Lake Frome CP	12) Mullins Swamp	13) Iluka	14) Lake Bonney SE & Bucks Lake
ACCESSIBILITY															
Ease of wetland access	0.5	2	3	3	3	2	2	2	3	2	2	2	2	3	2
Percent of surveyable wetland	1	4	1	4	2	3	2	1	4	2	4	1	2	4	3
VALUE FOR BIRDS															
Value in current state	1	3	1	2	2	2	2	2	2	3	3	2	2	2	2
Potential value if modified	3	3	3	3	3	2	3	3	4	4	4	4	2	2	3
Current value for shorebirds	1	2	1	2	1	2	1	1	3	3	2	1	2	1	2
Current value for waterfowl	0.5	3	1	3	2	2	2	2	2	3	3	2	3	2	2
Current value for piscivores	0.5	1	1	1	1	1	2	2	2	3	2	2	2	2	2
SITE ATTRIBUTES															
Proximity to Coorong	0.5	4	4	4	4	3	3	3	3	3	2	2	2	2	1
Bathymetry	1	2	3	3	2	3	3	2	3	2	2	3	3	2	3
Land tenure and use	1	3	3	1	1	3	1	3	2	3	2	3	2	2	2
Extent of vegetation incursion	0.5	3	2	3	2	2	2	2	1	1	3	2	1	1	3
SUITABILITY FOR MODIFICATION															
Modification value and costs	3	3	2	3	3	3	3	2	2	2	1	3	2	3	2
Potential new habitat	3	2	2	3	2	2	3	3	4	3	4	4	2	2	1
Feasibility	3	3	3	3	3	3	3	3	4	2	2	3	2	2	2
Existing plans	2	3	3	3	3	2	3	3	3	2	2	3	1	3	2
Potential issues	2	2	2	1	1	2	2	2	2	2	3	2	3	3	2
Priority score		62.25	53.75	61.75	54	55	59.5	56.5	70.5	59.25	61	66	47	54	48
Priority class		Mod.	Low	Mod.	Low	Low	Mod.	Mod.	High	Mod.	Mod.	High	Low	Low	Low
Priority rank		3	12	4	10	9	6	8	1	7	5	2	14	10	13

Table 9: Wetland Assessment Criteria with weightings, criteria scores and priority calculations for primary Lower Lakes Wetlands 24–30. Scores are extracted from Wetland Assessment Criteria Table A6, Appendix 6.5. Priority scores were calculated by multiplying each wetland's criterion scores by the corresponding weighting and totalling the resulting values for that wetland. Colours indicate the scoring of the data listed: □ = 1; □ = 2; □ = 3; □ = 4. Priority classes were defined from priority scores as follows: □ = Low (<55); □ = Moderate (55–63); □ = High (>63). See Table 4 for details on scoring and weighting.

Wetland assessment categories and criteria (scored criteria only)	Weighting	24) Tolderol Game Reserve	25) Waltowa	26) Narrung	27) Jenny's Lagoon (Yalkuri)	28) Teringie South Lagoon	29) Teringie North Lagoon	30) Teringie East
ACCESSIBILITY								
Ease of wetland access	0.5	3	2	2	1	3	3	3
Percent of surveyable wetland	1	4	4	4	4	4	4	4
VALUE FOR BIRDS								
Value in current state	1	3	1	2	2	2	1	1
Potential value if modified	3	4	4	2	3	3	2	2
Current value for shorebirds	1	3	1	1	2	1	1	1
Current value for waterfowl	0.5	2	1	2	2	1	1	1
Current value for piscivores	0.5	2	1	2	2	2	1	1
SITE ATTRIBUTES								
Proximity to Coorong	0.5	4	4	4	4	4	4	4
Bathymetry	1	3	3	3	3	3	3	3
Land tenure and use	1	3	2	2	2	2	2	1
Extent of vegetation incursion	0.5	2	3	3	2	2	1	3
SUITABILITY FOR MODIFICATION								
Modification value and costs	3	2	2	4	3	4	2	2
Potential new habitat	3	2	2	1	1	2	1	2
Feasibility	3	3	3	3	3	3	3	2
Existing plans	2	3	3	3	1	2	3	3
Potential issues	2	3	2	2	3	3	3	3
Priority score		66.5	58.75	57.5	55.5	63	51.25	51.25
Priority class		High	Mod.	Mod.	Mod.	High	Low	Low
Priority rank		1	3	4	5	2	6	6

4 Discussion

Based on the criteria used for assessment (Table 3) and the scoring and weighting system (Table 4), the high priority wetlands that should now undergo more detailed feasibility assessments are:

1. Lake Hawdon North
2. Lake Frome CP

in the South East, and

1. Tolderol Game Reserve
2. Teringie South Lagoon

around the Lower Lakes. Detailed feasibility assessments of a greater number of wetlands would be better, but for the sake of prioritising immediate effort, only the two highest ranking wetlands for each area have been listed.

For each of these wetlands, there is the potential to source water (e.g. through drains) to improve their capacity to support key species of waterbirds. These wetlands also provide opportunities for substantial amounts of additional habitat, particularly the South East wetlands, albeit at potentially a greater cost.

More detailed planning is now required to determine if these wetlands can be managed to provide additional high-quality habitat within budget constraints. This higher-level planning was outside the scope of this study, which was aimed primarily at providing a list of priority sites to consider for provisioning suitable habitat for key waterbird species. For some of these high-ranked wetlands (e.g. Lake Hawdon North), more detailed planning has already been undertaken and could be used to expedite the interventions. For many wetlands, key aspects of advancing their management include negotiations with stakeholders and community engagement. Furthermore, an important aspect of these works should involve establishing good monitoring programs, so that the benefits of on-ground works can be measured and reported and allow minor adjustments to management actions (see Lyons *et al.* 2008).

This study provides a functional decision-making tool for assessing and evaluating wetlands and while the framework has been applied to rank wetlands of the South East and around the Lower Lakes, this is not a final prioritised list of sites for management. As new data and information is collected, it should be incorporated to refine the wetland prioritisation. Of particular importance will be incorporating seasonal information of the wetlands, as this will indicate when (and not just where) suitable habitat needs to be made available in the broader regional landscape for key waterbird species. Wetlands are dynamic and their quality from a waterbird perspective is likely to change through time across a season, e.g. Tolderol Game Reserve (Hartvigsen-Power *et al.* 2019), and between years, e.g. the Coorong (Paton *et al.* 2019a). The challenge for managers and scientists is to establish a network of wetlands that provides a succession of suitable habitats throughout the year, particularly for times when the southern Coorong is unable to provide suitable habitat. At present, the use of the Coorong by waterbirds is only assessed at one time of the year (January). Without knowledge of its capacity to support waterbirds at other critical times (e.g. late spring and early autumn, when migratory waders arrive and depart, respectively), our ability to manage these birds is limited. Therefore, a critical piece of work needed is to assess the Coorong's capacity to support waterbird populations seasonally, in conjunction with similar assessments of other wetlands in the broader landscape. The actual timing of management actions needs to differ from one year to the next based on the overall availability of suitable habitat at the broader landscape level. To have a responsive, dynamic management program that serves the interest of the birds will require an adaptive management approach driven by real-time assessments of waterbird use of wetlands. However, given that a wetland will need to be primed and that it takes time for a wetland to be productive from a waterbird perspective, lead times will need to be accounted for and seasonal forecasts may be necessary in such an approach.

One of the assumptions in identifying wetlands that could be managed to provide suitable habitat for key species of Coorong waterbirds is that these waterbirds move at regional or larger scales and so have a

reasonable prospect of locating the new wetland opportunities. Little is known about these movements, but for the few waterbird species that have been studied, mobility is often high (e.g. Roshier *et al.* 2016; Pedler *et al.* 2018). Based on preliminary observations and historical data, migratory shorebirds are largely restricted to areas along the coast (e.g. Figure A6, Appendix 6.4), suggesting that some species may be constrained to near coastal areas. However, until detailed studies of the movements of some of key species in this region have been undertaken, there is no assurance that the birds will find and use the wetlands that have been improved or re-instated. There is a clear knowledge gap regarding how these birds move in the broader landscape and the factors that influence those movements. Detailed studies of such movements across the region would help confirm that key species are likely to respond to on-ground works and management, thus strengthening the case for further investment.

A precautionary note is needed with respect to waterbird use of wetlands reported in this study, as there is likely to be great variability in the numbers of waterbirds that use each of the wetlands through time. Some care therefore is required in assuming that wetlands with few birds in February and March 2019 in the South East and in late January 2011–2019 in the Lower Lakes do not have capacity to support key waterbird species at other times of the year or in other years. For example, in wetter years, wetlands that were dry when surveyed may hold water and support key species of waterbirds. Some of the permanent wetlands along the coastal regions of the South East that had extensive shorelines supported comparatively few shorebirds in February and March 2019 (e.g. Butcher Gap CP and Lake Bonney SE). However, at present, those wetlands are not ranked highly.

Other biotic factors also need to be considered in assessing the suitability of wetlands for providing habitat for shorebirds, a key target guild. For example, the presence of large numbers of fish may reduce the food available to certain bird species. Thus, management programs may need to consider options to limit the establishment of significant fish populations, so that more resources are available to birds. For example, drying out wetlands regularly, may limit fish abundance. Few piscivorous birds, however, were detected using the wetlands that were assessed in February and March 2019. Another important management consideration will be reducing the encroachment of terrestrial vegetation onto wetlands to provide more conducive habitat for shorebird use. Abundances of shorebirds were higher in areas with less emergent terrestrial vegetation during the South East surveys (Figure A3, Appendix 6.1). For some wetlands, removal of this terrestrial vegetation is recommended.

More shorebirds congregated where the width of shallow water and or extent of damp mud surfaces was greater around the margins of a wetland (Figure A2, Appendix 6.1). So, while some wetlands may be expansive, if the majority of that area is deep, open water, then total wetland size is of little value for most species (see Colwell 2010). As such, prioritising wetlands based simply on their current area (or the area modifications could create) may be misleading, so data reporting areas of wetlands need to be assessed in context. Future wetland assessments should attempt to detail areas of key habitat, such as shoreline, from areas of less useable open water. Thus, an important part of further assessments will be collecting detailed bathymetry of the targeted wetlands to parse out the areas of key habitat from less useable areas. This will allow refinement of some of the scoring of criteria and refinement of wetland management to ensure that the amounts of suitable habitat are maximised at critical times.

Benefits for some key species may not be met by the provision of suitable habitats identified in this study. For example, one of the deficiencies amongst the potential wetlands in the South East and around the Lower Lakes is the lack of more saline habitats. Saline habitats tend to be used more extensively by species such as Banded Stilt, Chestnut Teal and Fairy Tern (Paton *et al.* 2018a). For Banded Stilts, which readily use highly saline waters, opportunities to use disbanded salt fields to provide some hypersaline areas may be warranted, for example the salt fields associated with the Adelaide International Bird Sanctuary just north of Adelaide. Assessing those opportunities fell outside the scope of the study but are important in managing the broader waterbird communities that have historically thrived in the southern Coorong. Understanding the movements of Chestnut Teal, such as by satellite tracking, will be required to identify better opportunities in providing suitable habitat for this species. For Fairy Terns, successful breeding in the southern Coorong is largely determined by having ready access to their main prey item, Small-mouth Hardyhead (*Atherinosoma*

microstoma), close to their traditional breeding islands that are free from mainland predators (Paton *et al.* 2018b). Furthermore, Fairy Terns do not use freshwater wetlands. Consequently, there are few opportunities to improve their population prospects within the broader landscape, and so ensuring access to the Small-mouth Hardyhead and their traditional breeding islands (via maintenance of appropriate water levels) in the southern Coorong is paramount.

In summary, there is considerable potential to provide suitable habitats across an array of other wetlands in the broader regional landscape to assist in compensating key waterbird species likely to be disadvantaged by poor ecological conditions in the southern Coorong. Given little prospect of recovering the ecological conditions of the southern Coorong within the next few years, there is a high level of urgency to bring some of these wetlands online as soon as possible to help the key species maintain viable populations within the region.

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6 Appendix

6.1 Waterbird abundance and use of South East wetlands

To further identify where critical waterbird habitat away from the Coorong lagoons may occur, evidence of key waterbird species at wetlands in the South East (SE) was sought. The perceived ability of wetlands to be able to deliver foraging habitats for key waterbird species can be further established if there are data that indicate: 1) these species were using the wetland; 2) these species use the wetland over a significant period of time; and 3) these species use the wetland when the southern Coorong is not providing functional habitat.

Investigation of the second and third aspects was not possible over the timeframe of this study, for which longitudinal survey data is needed across seasons and across years. However, for those wetlands that were holding water in February and March 2019, the first point was assessed through systematic waterbird surveys of wetlands. These surveys were only undertaken across SE wetlands due to time constraints, though other wetland bird species beyond the key waterbird species were also surveyed. To establish the differences in waterbird abundances between wetlands, and to understand how species were using the wetland area, data on abundances, behaviour and habitat features were also recorded.

Waterbird and habitat data were also used to inform criteria in the WAC table for those wetlands surveyed, notably their value for different waterbird functional groups, bathymetry, and extent of vegetation incursion (see Table 3).

6.1.1 SE WETLANDS SURVEYS: METHODS

With these objectives in mind, waterbird counts were conducted during site assessment visits to SE wetlands on the 26–28 February and 14–15 March 2019. Jeff Campbell and Maureen Christie from The Friends of Shorebirds SE helped to identify a number of SE wetlands where significant numbers of key waterbird species (particularly shorebirds) had been observed over the 2018/2019 summer season. These wetlands were surveyed for waterbirds in both February and March 2019.

Counts were undertaken across five wetland areas that were still holding water (Morella Basin, Butcher Gap CP, Lake Robe, Lake Bonney SE, and Lake George) in 1 km x 1 km cells (aligning to the thousands of easting and northing bearings) chosen in areas of wetlands where the majority of birds present were visible and accurate counts could be made. Several 1 km sections of the southern Coorong were also surveyed for comparison to these sites, providing data on six wetland areas in total. All waterbird observations were made using either binoculars (8–10x magnification), or spotting scopes (20–60x magnification). Not every cell was surveyed in both February and March, though repeat counts were conducted for some. In each cell, all birds were identified to species level, counted, and their activity classified as either foraging, resting, or flying (see Paton *et al.* 2019a). The habitat features for each of these cells were also recorded (see Table A2, Appendix 6.3), based on assessment categories in Ye *et al.* (2002), and included: current water level; the shoreline slope; the total extent of exposed shoreline (in metres, minimum and maximum); the extent of exposed shoreline that was damp (in metres, minimum and maximum, representing the potential foraging area for waterbirds, especially shorebirds); the substrate composition of the shoreline (e.g. clay, sand, rocks, vegetation); and the extent of vegetation incursion in the wetland.

The waterbird and habitat data were compiled into a database for desktop analysis. Waterbird species observed in these bird surveys (n = 42, see Table A1, Appendix 6.3) were categorised into broad functional groups based on feeding behaviour, adapted from Rogers (2011): piscivores (including large wading birds; n = 16), shorebirds (including small waders and rails, n = 13), and waterfowl (n = 13). Recording the abundance and distribution of different food resources in the wetlands surveyed was beyond the scope of this study, but the presence and abundance of species foraging from each of these guilds can be used as a proxy to identify what food resources are likely to be present (e.g. Goss-Custard *et al.* 2006; Rogers 2011). For example, foraging

by piscivores indicates the presence of fish, macroinvertebrates, or amphibians; shorebird foraging indicates the presence of small terrestrial or aquatic invertebrates and their larvae, and plant seeds; and waterfowl foraging indicate the growth of aquatic vegetation or (for filter feeding waterfowl) phyto- and zooplankton.

Due to their common food resources, these functional groups are broadly similar in the wetland areas they use, with piscivores using both open and deep water, shorebirds using the littoral zone and mudflats, and waterfowl using shallow water and the littoral zone (Rogers 2011). To determine how waterbird groups in these surveys responded to the habitat attributes in the SE wetlands, variation in bird numbers from each group were correlated to wetland bathymetry, substrate and vegetation growth. These trends were analysed in Microsoft Excel 2016 by calculating the number of waterbird types observed per cell and determining the averages observed between different wetlands, and between different habitat criteria (e.g. extent of exposed damp shoreline, extent of vegetation incursion).

6.1.2 SE WETLANDS SURVEYS: RESULTS

The six SE wetland sites surveyed across February and March (Coorong South Lagoon, Morella Basin, Butcher Gap CP, Lake Robe, Lake George, Lake Bonney SE) showed large variation in the numbers of waterbirds they supported, though the number of 1 km x 1 km surveys cells per wetland also varied.

Only two wetlands could be counted in their entirety, with 24,501 waterbirds recorded on Morella Basin and 9,507 recorded on Lake Robe in March (see Table A3, Appendix 6.3). Total waterbird counts for other wetlands ranged from 80 in Butcher Gap CP across 2 cells surveyed as the site was mostly dry, to 60,045 in Lake George across 17 cells surveyed (note that this represents a small percentage of the 5,000 ha area of the lake, though most of this is less productive open water that is only used by a few waterbird species).

Whilst wetland habitat features vary between each survey cell (even within a single wetland), average counts of species from 1 km x 1 km cells allow a more standardised comparison of waterbird numbers across a survey areas (see Table A3, Appendix 6.3). The maximum cell count of a species in a wetland also gives an idea of the capacity a given area to support waterbirds, as it provides an upper estimate of the bird numbers a given 1 km x 1 km cell of habitat can support. Using these metrics, the birds recorded in each wetland are considered here, with averages ("av.") rounded to the nearest whole number and maximum counts indicated ("max."). All data can be found in Table A3, Appendix 6.3.

The Coorong South Lagoon and Morella Basin had a similar diversity of waterbird species (18 vs 19 species, respectively), but different abundances (av. 214 vs 2227 birds per cell, respectively). The Coorong had more piscivorous species, whilst Morella Basin had a greater diversity of waterfowl. Morella Basin had high numbers of Grey Teal (av. 1477, max. 7300), and the State-vulnerable Freckled Duck (av. 304, max. 1650), as well as shorebirds like Red-necked Stint (av. 305, max. 1040), Banded Stilt (av. 67, max. 230) and Red-necked Avocet (av. 45, max. 240).

Butcher Gap CP had the lowest number of species (eight) and lowest abundance (av. 40 birds per cell), but it was largely dry with only a few small patches of water and extensive shoreline with low numbers of waterfowl and shorebirds, though this included a pair of Double-banded Plovers. Lake Robe had 16 species, and large numbers of waterfowl including Australian Shelduck (av. 732, max 1370) and Chestnut Teal (av. 435, max. 1710), as well as some Grey Teal (av. 146, max. 380) and Black Swan (av. 59, max. 95). Flocks of Red-necked Stint were also present (av. 141, max. 380).

Lake George and Lake Bonney SE, the two wetlands in the far SE, had significant differences in waterbird diversity and abundance. At Lake Bonney SE, survey cells recorded 16 species of waterbird and averaged 545 birds per cell, whilst Lake George recorded the highest diversity and abundance of any wetland with 35 species and an average of 3532 birds per cell. Both were dominated by waterfowl though, in the cells surveyed, Lake George had higher maximum abundances than Lake Bonney SE for all species including Australian Shelduck (max. 275 vs 100), Black Swan (max. 870 vs 160), Chestnut Teal (max. 325 vs 30), and Grey Teal (max. 5800 vs 398). Lake George also hosted higher numbers of Red-necked Stint (max. 1050 vs 233), Eurasian Coot (max. 840 vs 34), Sharp-tailed Sandpipers (max. 40 vs 28) and hosted a very large flock of 18,950 Banded Stilt, and a

small group of six Double-banded Plovers. Four Freckled Duck were only seen on Lake Bonney SE. Lake George was the only wetland where the state-endangered Fairy Tern and the state-vulnerable Hooded Plover were seen, with five and two individuals counted, respectively.

Piscivores were recorded at most wetland sites (Figure). Comparatively, waterfowl were much more abundant everywhere except the Coorong South Lagoon and Butcher Gap CP (the latter which had very low water levels). Some shorebird species were present at all wetlands, but the highest numbers were seen in Morella Basin, Lake Robe and Lake George (note that a high proportion of those at Lake George were the flock of 18,950 Banded Stilt, which made up 68% of the total shorebird count there). In late summer, these three wetlands are characterised by extensive shorelines and low levels of vegetation incursion.

Analyses of bird abundances according to the habitat features of the cells they were recorded in showed that the shorebird guild heavily favoured those areas where the extent of damp shoreline was high (between 15 and 50 m, Figure A2) and the extent of vegetation incursion into the wetland area was low (Figure A3). Waterfowl showed a similar response, though the effect of damp shoreline extent was less apparent. Piscivores were encountered in abundances too low to see any significant response to these habitat criteria, though other wetland features that were not measured (such as water depth or hydrology history) are more likely to determine the distribution of these species.

The activities that birds were engaged in were varied, though some species consistently showed a high allocation of time to foraging, particularly Eurasian Coots (93%), Curlew Sandpipers (100%), Red-necked Stint (94%), and Sharp-tailed Sandpipers (96%). The latter three of these species are migratory shorebirds, and their high foraging rates may be indicative of a lack of readily available resources in the broader landscape (Loegering and Fraser 1995; Goss-Custard *et al.* 2006; Paton *et al.* 2019a, Hartvigsen-Power *et al.* 2019). For all data on bird activities see Table A4, Appendix 6.3.

Some seasonal changes were recorded from Morella Basin, which was surveyed for birds in both January during surveys of the Coorong Lagoons, and during the SE waterbird surveys in March (for all survey data including comparisons to historical data see Table A5, Appendix 6.3). The number of Grey Teal was similar in both January and March (15,829 vs 16,246), and both Banded Stilt (928 vs 736) and Red-necked Avocet (280 vs 500) were still present in their hundreds. Most Australian Shelduck seen in January had left by March (1268 vs 81, and numbers of Black Swan (698 vs 47), Sharp-tailed Sandpiper (1000 vs 2) and Whiskered Tern (1028 vs 0) were down considerably. However, Freckled Duck were only observed in March (0 vs 3345) and many more Red-necked Stint were seen using the shallow and damp mudflats (20 vs 3335).

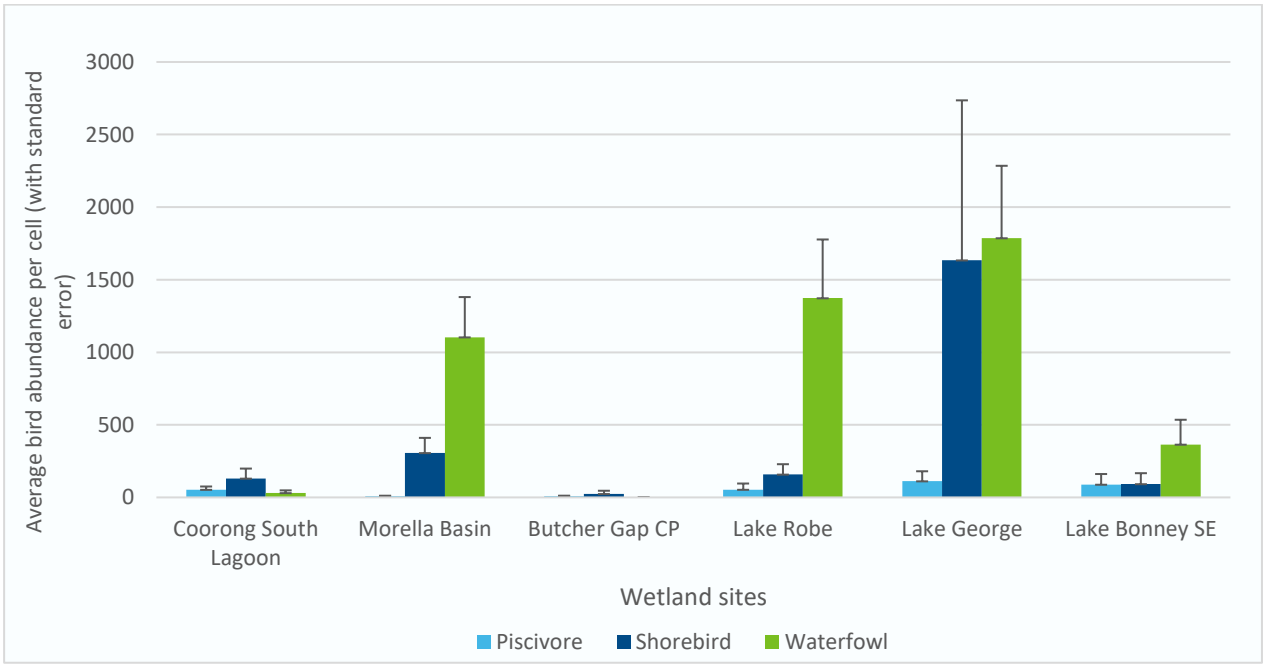


Figure A1. Average abundances of wetland bird groups for wetland survey cells surveyed in February and March 2019.

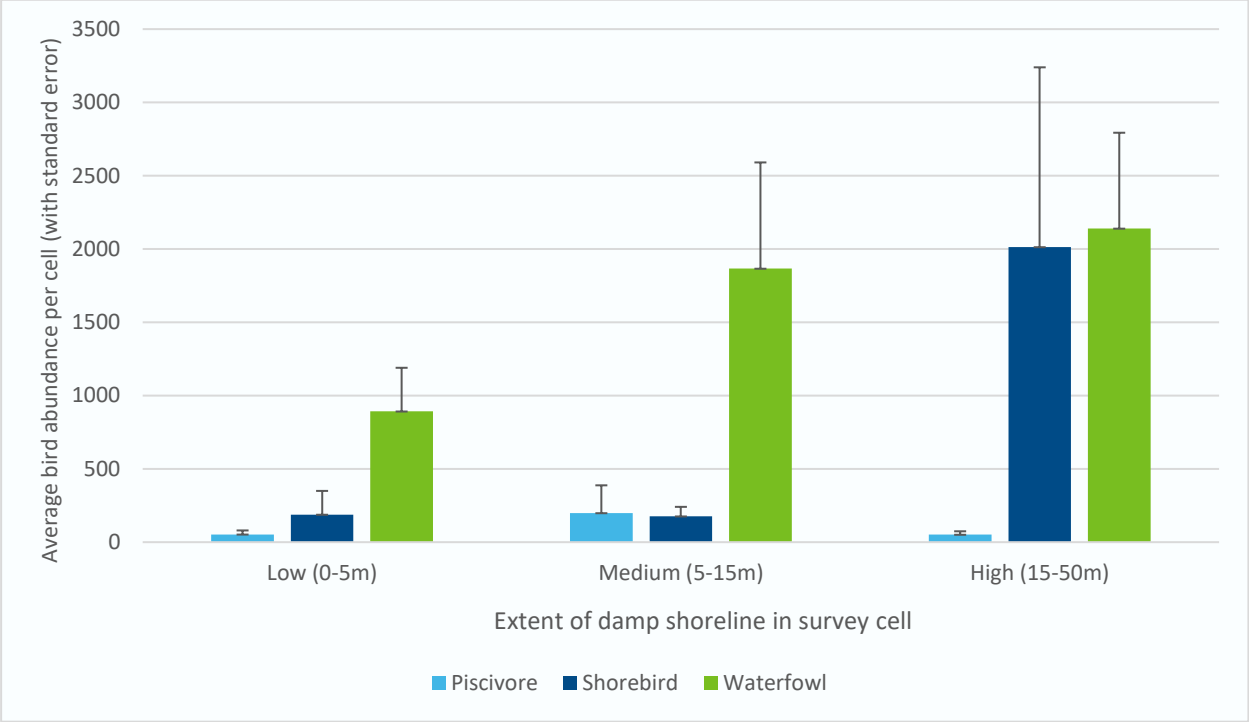


Figure A2. Average abundances of wetland bird groups in February and March 2019 in survey cells with low (0–5 m), medium (5–15 m) and high (15–50 m) extents of damp shorelines.

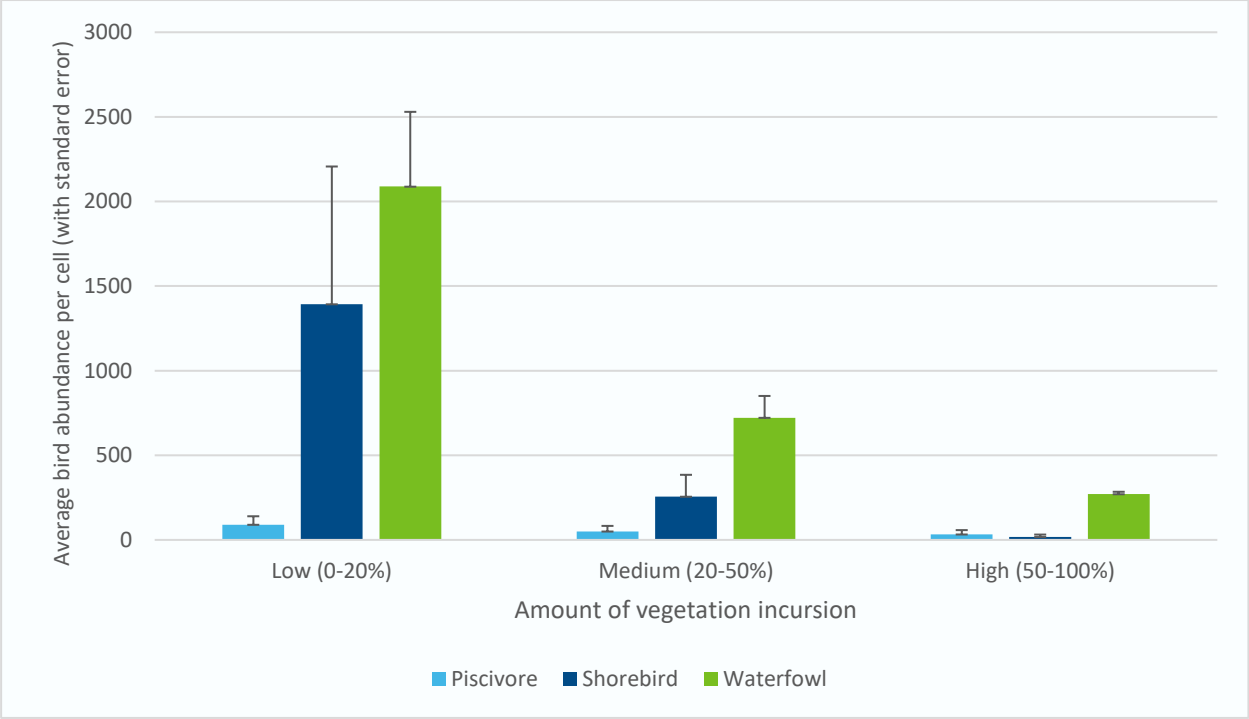


Figure A3. Average abundances of wetland bird groups in February and March 2019 in survey cells with low (0–20%), medium (20–50%) and high (50–100%) of terrestrial vegetation incursion.

6.2 Regional waterbird distributions around the Lower Lakes

The most abundant shorebird using the wetlands around the Lower Lakes in the January–February surveys was Sharp-tailed Sandpiper, being observed in all nine years (from 2011 to 2019) in numbers ranging from 101 birds in 2014 to 1503 birds in 2019. Red-necked Stints were similarly observed using fringing wetlands annually, albeit in much smaller numbers, with an annual maximum of 301 birds recorded in 2012. However, Curlew Sandpipers were only observed in four of the nine years and numbers ranged from a single bird in 2012 to 52 birds in 2015. In all, 94 grid cells of around 400 grid cells were used by the three key migratory species. However, in any one year the number of cells used by these shorebird species varied considerably, ranging from four cells in 2011 to 30 cells in 2016. Most cells (76) were used only in one year, 12 cells were used in two years, five cells were used in three years, while only one cell was used in four years. These cells were widely spread around the margins of the Lower Lakes. For the distribution of Sharp-tailed Sandpipers around the Lower Lakes from 2012–2019 as an example, see Figure A4 and Figure A5 in Appendix 6.4. Those cells with the greatest use by the three key small migratory shorebird species over multiple years corresponded to Tolderol Game Reserve, Mosquito Point wetland and Pelican Lagoon (adjacent Lake Alexandrina) and wetlands near or part of Waltowa Swamp (adjacent Lake Albert). Waltowa Swamp, however, did not contain water in each year and access to Pelican Lagoon has been denied in recent years. Importantly, cells that were part of Tolderol Game Reserve accounted for the greatest abundances. For example, in 2019, about two thirds of the three small migratory waterbird species that were using the Lower Lakes were observed at Tolderol Game Reserve.

However, the abundances of these small migratory shorebirds using the fringing wetlands of the Lower Lakes is small compared to the numbers still using the Coorong. This relatively low use indicates that these wetlands are currently not of high-value, except for Tolderol Game Reserve, where (a) for Sharp-tailed Sandpipers and Curlew Sandpipers, numbers over summer are comparable to those found in recent years in January in the southern Coorong, and (b) there is potential to enhance current water management and increase the area of habitat for shorebirds (Hartvigsen-Power *et al.* 2019). Although Waltowa Swamp is not currently ranked highly, the fact that shorebirds have used it in the past when it contained water suggests this swamp may have substantial potential, particularly given its area. There may be further opportunities to improve small, fringing wetlands around the Lower Lakes, such as near Poltalloch and Narrung, where management of water levels could further enhance shorebird use at critical times, e.g. when the southern Coorong is least productive. However, these are also relatively small wetlands, so their ability to support substantial numbers of shorebirds is limited and they were not researched further for the WAC table in this report.

6.3 Supplementary tables

Table A1: The common and scientific names of waterbird species encountered in the South East wetland surveys during February and March 2019, and the functional group they are placed in. Functional group categories adapted from Rogers (2011). Waterbird names are based on taxonomy followed by Birdlife Australia (2018).

PISCIVORES		SHOREBIRDS		WATERFOWL	
Common name	**Scientific name**	**Common name**	**Scientific name**	**Common name**	**Scientific name**
Australian Pelican	*Pelecanus conspicillatus*	**Banded Stilt**	*Cladorhynchus leucocephalus*	**Australasian Shoveler**	*Anas rhynchotis*
Australian White Ibis	*Threskiornis moluccus*	**Black-tailed Native-hen**	*Tribonyx ventralis*	**Australian Shelduck**	*Tadorna tadornoides*
Caspian Tern	*Hydroprogne caspia*	**Black-winged Stilt**	*Himantopus leucocephalus*	**Black Swan**	*Cygnus atratus*
Crested Tern	*Thalasseus bergii*	**Common Greenshank**	*Tringa nebularia*	**Blue-billed Duck**	*Oxyura australis*
Fairy Tern	*Sternula nereis*	**Curlew Sandpiper**	*Calidris ferruginea*	**Cape Barren Goose**	*Cereopsis novaehollandiae*
Great Cormorant	*Phalacrocorax carbo*	**Double-banded Plover**	*Charadrius bicinctus*	**Chestnut Teal**	*Anas castanea*
Great Crested Grebe	*Podiceps cristatus*	**Hooded Plover**	*Thinornis rubricollis*	**Eurasian Coot**	*Fulica atra*
Great Egret	*Ardea alba*	**Masked Lapwing**	*Vanellus miles*	**Freckled Duck**	*Stictonetta naevosa*
Hoary-headed Grebe	*Poliocephalus poliocephalus*	**Pied Oystercatcher**	*Haematopus longirostris*	**Grey Teal**	*Anas gracilis*
Little Black Cormorant	*Phalacrocorax sulcirostris*	**Red-capped Plover**	*Charadrius ruficapillus*	**Hardhead**	*Aythya australis*
Little Egret	*Egretta garzetta*	**Red-necked Avocet**	*Recurvirostra novaehollandiae*	**Musk Duck**	*Biziura lobata*
Little Pied Cormorant	*Microcarbo melanoleucos*	**Red-necked Stint**	*Calidris ruficollis*	**Pacific Black Duck**	*Anas superciliosa*
Royal Spoonbill	*Platalea regia*	**Sharp-tailed Sandpiper**	*Calidris acuminata*	**Pink-eared Duck**	*Malacorhynchus membranaceus*
Silver Gull	*Chroicocephalus novaehollandiae*				
Straw-necked Ibis	*Threskiornis spinicollis*				
White-faced Heron	*Egretta novaehollandiae*				

Table A2: Locations, 1 km x 1 km survey cell coordinates, and habitat assessments for wetland bird surveys conducted in February and March 2019 in SE South Australia. Damp shoreline categories are defined as Low (0–5 m), Moderate (5–15 m) or High (15–50 m), and vegetation incursion categories are determined by percentage of total waterline covered in vegetation, defined as Nil (0%), Low (1–20%), Moderate (20–50%), or High (50–100%).

Location	Site name	Cell easting	Cell northing	Survey date	Water level	Shoreline slope	Extent exposed shore (m)	Extent damp shore (m)	Damp shore category	Shoreline composition	Vegetation incursion category
Lake Bonney SE	Lake Bonney SE	447000	5811000	26/02/2019	Moderate	Shallow	30–40	9–12	Moderate	Clay, small areas of rock	Low
Lake Bonney SE	Lake Bonney SE	446000	5812000	26/02/2019	Moderate	Shallow	30–80	15–40	High	Clay, one third some sedge and low grass	Moderate
Lake Bonney SE	Lake Bonney SE	445000	5814000	26/02/2019	Moderate	Shallow	25–50	20–40	High	Mud, limestone, some rushes, algae on shore	Low
Lake Bonney SE	Lake Bonney SE	442000	5842000	26/02/2019	High	Moderate	2–5	1.6–4	Low	Mostly rushes, algae, low veg, rocks	High
Lake George	Foster Point north-east	410000	5859000	27/02/2019	High	Moderate	2–5	0.6–1.5	Low	Sand, shell	High
Lake George	Foster Point south-east	410000	5858000	27/02/2019	High	Moderate	5–10	1–2	Low	Sand, shell, rocky on islet	Low
Lake George	Foster Point north-west	409000	5859000	27/02/2019	High	Moderate	5–6	0.5–0.6	Low	Sand	Low
Lake George	Foster Point south-west	409000	5858000	27/02/2019	High	Moderate	1–5	0.3–1.5	Low	Sand, shell, some rock	Nil
Lake George	Lake George Bush Camp	409000	5854000	27/02/2019	High	Shallow	2–5	1–2.5	Low	Clay, some sand, reeds on south side	Moderate
Lake George	Wooley Point north	412000	5854000	27/02/2019	High	Shallow	100–152	10–15.2	Moderate	Sand, shell grit, some clay	Low
Lake George	Woakwine Cutting south	413000	5859000	27/02/2019	High	Shallow	100–200	20–40	High	Clay	Low
Lake Robe	Lake Robe south	393000	5879000	27/02/2019	Moderate	Shallow	5–20	1–4	Low	Shell grit, sand, rocky patches, algae	Low
Butcher Gap Conservation Park	Butcher Gap CP east	394000	5917000	28/02/2019	Low	Shallow	50–200	2.5–10	Moderate	Clay (100%). Dried algae washed up	Low
Butcher Gap Conservation Park	Cape Jaffa Road east	395000	5916000	28/02/2019	Dry	Shallow	0–1	0–0.3	Low	Pasture / Rocks and clay	Moderate
Morella Basin	MB01	380000	6001000	14/03/2019	Moderate	Steep	0–1	0–0.5	Low	Clay, rocks, grass	Low
Morella Basin	MB07	382000	5998000	14/03/2019	Moderate	Shallow	5–50	1–10	Moderate	Clay, sand, some vegetation	Low
Morella Basin	MB05	382000	5997000	14/03/2019	Low	Shallow	20–100	6–30	High	Clay, sand, samphire	Moderate
Morella Basin	MB03	382000	5996000	14/03/2019	Moderate	Shallow	10–100	2–20	High	Clay, samphire	Low

Morella Basin	MB12	383000	5997000	14/03/2019	High	Shallow	0–5	0–4	Low	Clay, dead Melaleucas, samphire	High
Morella Basin	MB04	381000	5998000	14/03/2019	Moderate	Shallow	5–50	1–10	Moderate	Clay, samphire, some rock	Moderate
Morella Basin	MB08	382000	5999000	14/03/2019	Moderate	Shallow	5–10	2.5–5	Low	Clay, rock, samphire, dead Melaleuca	Low
Morella Basin	MB14	380000	5999000	14/03/2019	Moderate	Shallow	20–100	6–30	High	Clay, some samphire	Low
Morella Basin	MB02	381000	5999000	14/03/2019	Moderate	Shallow	10–50	5–25	High	Clay, sand, some samphire	Low
Morella Basin	MB06	380000	6000000	14/03/2019	Moderate	Shallow	30–100	9–30	High	Clay, sand, some rock	Low
Morella Basin	MB10	381000	6000000	14/03/2019	Moderate	Shallow	5–20	2.5–10	Moderate	Clay, sand, rocks on islands. Samphire on edge	Low
Lake Robe	Lake Robe north-east	394000	5881000	14/03/2019	Moderate	Shallow	10–100	2–20	High	Clay, sand, shells, gravel, algae	Low
Lake Robe	Lake Robe north-west	393000	5881000	14/03/2019	Moderate	Shallow	5–30	1.5–9	Moderate	Clay, sand, shells	Low
Lake Robe	Lake Robe east	394000	5880000	14/03/2019	Moderate	Shallow	20–100	4–20	High	Sand, shells, algae	Low
Lake Robe	Lake Robe west	393000	5880000	14/03/2019	Moderate	Moderate	5–10	1–2	Low	Sand, shells, algae, vegetation	Low
Lake Robe	Lake Robe south	393000	5880000	14/03/2019	Low	Shallow	5–50	2.5–25	High	Sand, shells, algae	Moderate
Lake George	Woakwine Cutting north	413000	5861000	14/03/2019	Low	Shallow	50–200	10–40	High	Sand, shells	Low
Lake George	Woakwine Cutting outlet	413000	5860000	15/03/2019	Low	Shallow	50–100	20–40	High	Sand, shells, some clay, algae on shore	Low
Lake George	Woakwine Cutting south	413000	5859000	15/03/2019	Low	Shallow	30–80	12–32	High	Clay, sand, shells, algae on shore	Low
Lake George	Wooley Point west	410000	5854000	15/03/2019	Moderate	Shallow	2–15	0.6–4.5	Low	Clay, sand, some reeds	Moderate
Lake George	Wooley Point centre	411000	5854000	15/03/2019	Moderate	Shallow	15–150	1.5–15	Moderate	Clay, sand, shall, some samphire	Low
Lake George	Wooley Point north	412000	5854000	15/03/2019	Moderate	Shallow	50–250	10–50	High	Sand, clay	Low
Lake George	Lake George Bush Camp	409000	5854000	15/03/2019	Moderate	Shallow	1–15	0.3–4.5	Low	Clay, vegetation, reeds	High
Lake George	Foster Point south-west	409000	5858000	15/03/2019	High	Moderate	2–5	0.4–1	Low	Sand, clay, algae, reeds, foam	Moderate
Lake George	Foster Point south-east	410000	5858000	15/03/2019	High	Moderate	5–20	0.5–2	Low	Sand, shells, foam	Low

Table A3: Mean species counts (and maximum counts) per 1 x 1 km survey cell in South East wetland sites in February and March 2019. Also shown are total means across 1 x 1 km surveyed cells for both species and wetlands, sum totals of wetland counts, sum totals of species counts, and total number of species recorded per wetland. Number of cell counts per wetland are also noted ("n = *x*").

Species	Coorong South Lagoon (n = 8)	Morella Basin (n = 11)	Butcher Gap Conservation Park (n = 2)	Lake Robe (n = 6)	Lake George (n = 17)	Lake Bonney SE (n = 3)	Species mean (and species max count) (n = 47)
Australasian Shoveler					1.41 (18)	2.33 (5)	0.66 (24)
Australian Pelican	10.75 (64)	8.45 (57)			69.53 (1140)	2.00 (6)	29.09 (1140)
Australian Shelduck	0.13 (1)	7.36 (49)		731.67 (1370)	89.76 (275)	33.33 (100)	129.74 (1370)
Australian White Ibis					0.35 (6)		0.13 (6)
Banded Stilt	17.50 (140)	66.91 (230)		16.00 (95)	1388.24 (18950)		522.81 (18950)
Black Swan		4.27 (17)		58.67 (174)	228.18 (870)	53.67 (160)	94.45 (870)
Black-tailed Native-hen	1.25 (8)	3.18 (28)					0.96 (28)
Black-winged Stilt	0.63 (4)						0.11 (4)
Blue-billed Duck				0.33 (2)			0.04 (2)
Cape Barren Goose					0.18 (3)		0.06 (3)
Caspian Tern	1.88 (14)				4.41 (69)		1.91 (69)
Chestnut Teal	6.00 (32)	0.18 (2)	2.00 (4)	435.33 (1710)	54.35 (325)	10.67 (30)	77.06 (1710)
Common Greenshank	0.63 (2)	0.45 (3)	1.00 (2)		0.65 (5)		0.49 (5)
Crested Tern	2.88 (21)				0.06 (1)		0.51 (21)
Curlew Sandpiper					3.00 (23)	1.67 (5)	1.19 (23)
Double-banded Plover			1.00 (2)		0.71 (6)		0.30 (6)
Eurasian Coot					122.29 (840)	8.33 (34)	44.77 (840)
Fairy Tern					0.29 (5)		0.11 (5)
Freckled Duck		304.09 (1650)				4.33 (12)	71.45 (1650)
Great Cormorant					0.94 (13)		0.34 (13)
Great Crested Grebe					0.29 (4)		0.11 (4)
Great Egret	0.13 (1)				0.12 (1)		0.06 (1)
Grey Teal	24.13 (117)	1476.91 (7300)	6.00 (12)	145.67 (380)	1275.88 (5800)	251.00 (398)	846.13 (7300)
Hardhead					0.47 (8)		0.17 (8)
Hoary-headed Grebe	3.88 (31)	0.64 (7)		39.00 (210)	3.00 (26)		6.87 (210)
Hooded Plover					0.12 (2)		0.04 (2)
Little Black Cormorant					4.18 (63)		1.51 (63)
Little Egret					0.06 (1)		0.02 (1)
Little Pied Cormorant				0.33 (1)	0.06 (1)		0.06 (1)
Masked Lapwing	1.00 (2)	0.73 (4)	4.50 (6)	1.17 (4)	1.71 (11)	3.00 (7)	1.49 (11)
Musk Duck				0.67 (2)	6.41 (60)		2.40 (60)
Pacific Black Duck				0.67 (4)	7.53 (64)		2.81 (64)
Pied Oystercatcher					2.88 (49)		1.04 (49)
Pink-eared Duck						0.67 (2)	0.04 (2)
Red-capped Plover	0.75 (2)	0.55 (6)	22.00 (44)	1.00 (6)	8.53 (40)	2.00 (3)	4.53 (44)
Red-necked Avocet	42.50 (340)	45.45 (240)		0.17 (1)			17.89 (340)
Red-necked Stint	68.25 (220)	305.00 (1040)		140.83 (380)	225.88 (1050)	79.00 (233)	187.72 (1050)
Royal Spoonbill		2.27 (25)					0.53 (25)
Sharp-tailed Sandpiper		0.18 (2)			3.82 (40)	9.33 (28)	2.02 (40)
Silver Gull	29.25 (115)	0.09 (1)	1.00 (2)	12.17 (51)	24.53 (217)	25.33 (65)	17.09 (217)
Straw-necked Ibis					1.88 (32)	53.67 (161)	4.11 (161)
White-faced Heron	2.00 (7)	0.64 (2)	2.50 (4)	0.83 (3)	0.35 (2)	4.33 (8)	1.11 (8)
Total count	1708	24501	80	9507	60045	1634	97475
Mean of total count	213.50	2227.36	40.00	1584.50	3532.06	544.67	2073.94
No. species recorded	18	19	8	16	35	17	42

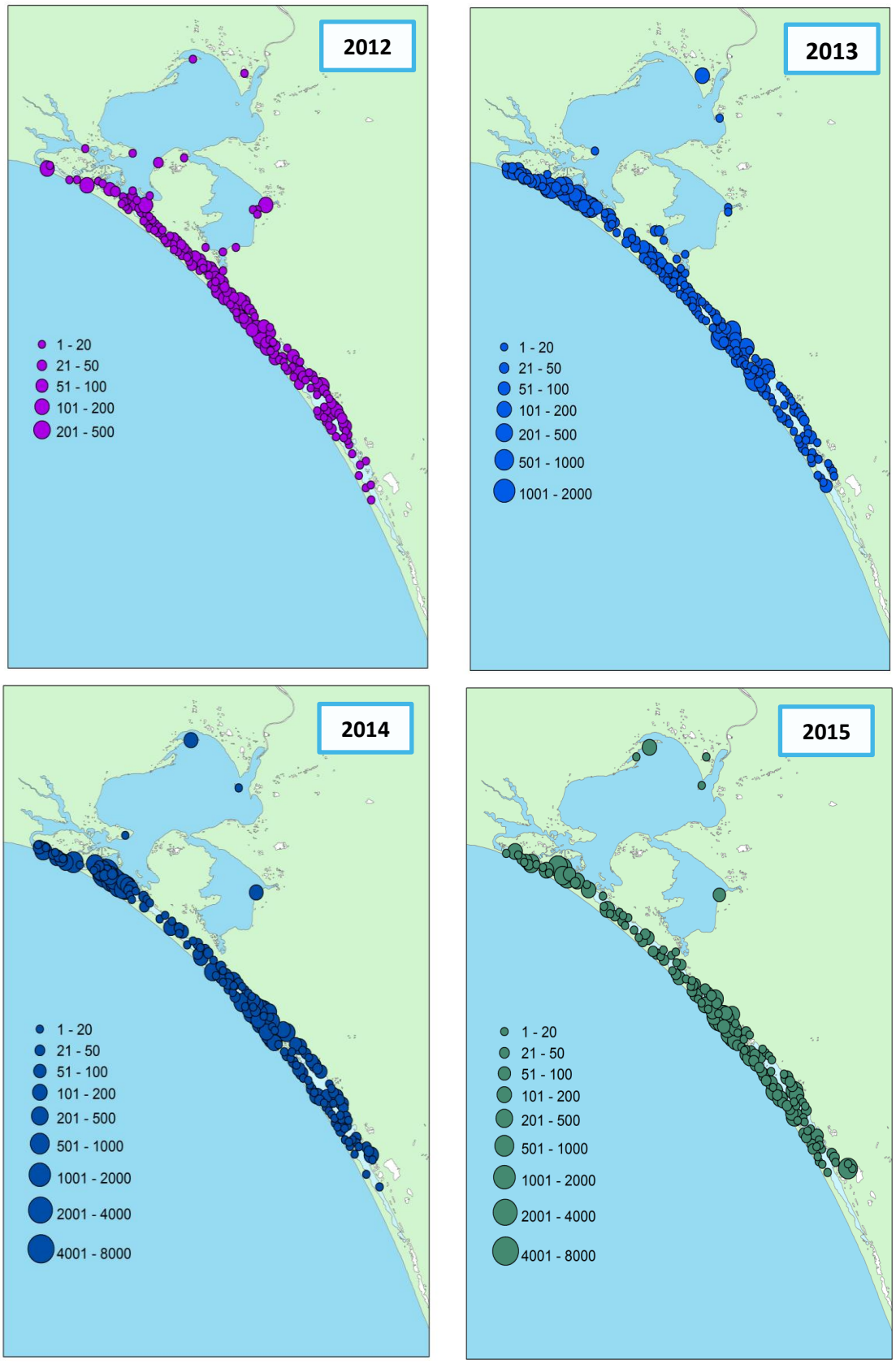
Table A4: Activities bird species were engaged in when surveyed in the South East wetland surveys in February and March 2019, and the percentage of those birds seen foraging.

Species	Foraging	Flying over	Resting	Total	% foraging (excl. flying birds)
Australian Pelican	1131	33	203	1367	84.78
Australian Shelduck	2721	35	3342	6098	44.88
Australasian Shoveler	6		25	31	19.35
Australian White Ibis			6	6	0.00
Blue-billed Duck			2	2	0.00
Banded Stilt	2685		21887	24572	10.93
Black Swan	2730	30	1679	4439	61.92
Black-tailed Native-hen	41		4	45	91.11
Black-winged Stilt	5			5	100.00
Caspian Tern		2	88	90	0.00
Cape Barren Goose			3	3	0.00
Chestnut Teal	701		2921	3622	19.35
Eurasian Coot	1965		139	2104	93.39
Crested Tern	3	4	17	24	15.79
Curlew Sandpiper	56			56	100.00
Double-banded Plover	2		12	14	14.29
Freckled Duck	2530		828	3358	75.34
Fairy Tern	5			5	100.00
Common Greenshank	10		13	23	43.48
Great Crested Grebe			5	5	0.00
Great Cormorant			16	16	0.00
Great Egret	2		1	3	66.67
Grey Teal	17158	70	22540	39768	43.22
Hardhead			8	8	0.00
Hoary-headed Grebe	174		149	323	53.87
Hooded Plover			2	2	0.00
Little Black Cormorant			71	71	0.00
Little Egret			1	1	0.00
Little Pied Cormorant	1	1	1	3	50.00
Musk Duck	22		91	113	19.47
Masked Lapwing	18		52	70	25.71
Pacific Black Duck	38	4	90	132	29.69
Pink-eared Duck	2			2	100.00
Pied Oystercatcher			49	49	0.00
Red-capped Plover	159		54	213	74.65
Red-necked Avocet	335		506	841	39.83
Red-necked Stint	8286	10	527	8823	94.02
Royal Spoonbill			25	25	0.00
Silver Gull	235	28	540	803	30.32
Straw-necked Ibis	7	66	120	193	5.51
Sharp-tailed Sandpiper	49	44	2	95	96.08
White-faced Heron	32	1	19	52	62.75

Table A5: Totals of annual species counts in Morella Basin from 2010 to 2019. All surveys were conducted in January of the year stated, except those in 2019 where the month surveyed is indicated. Changes in numbers between January and March surveys (light blue columns) in 2019 are calculated, with changes in abundances between January and March 2019 either shaded blue indicating an increase in abundance, and red indicating a decrease in abundance. No wetland surveys were conducted in Morella Basin in 2016. This data is the property of D. Paton (unpub.) and cannot be used beyond this report.

Species	2010	2011	2013	2014	2015	2016 (NA)	2017	2018	2019 January	2019 March	2019 change (Jan to Mar)
Australasian Shoveler			35	37	32		3	6	32		-32
Australian Pelican	20		80	3	20		26	7	55	93	38
Australian Shelduck	8000	10930	335	1656	76		2787	213	1268	81	-1187
Australian White Ibis					1						0
Banded Stilt			2771	3296	3385			1479	928	736	-192
Black Swan	2200	210	1868	40	228		2045	98	698	47	-651
Black-tailed Native-hen			15	17				34	8	35	27
Black-winged Stilt	4				25						0
Cape Barren Goose					12						0
Caspian Tern					1						0
Chestnut Teal	2000	160	806	42	140		8	2	8	2	-6
Common Greenshank	10		8	1	1				2	5	3
Curlew Sandpiper				14							0
Eurasian Coot	100		3550								0
Fairy Tern		6	2	1							0
Freckled Duck	8		2		484					3345	3345
Great Cormorant								1			0
Great Egret							1	1	2		-2
Grey Teal	20000		906	19682	5613		12210	6998	15829	16246	417
Hardhead			72	2							0
Hoary-headed Grebe	4		6						12	7	-5
Little Black Cormorant					261						0
Little Egret				2					1		-1
Little Pied Cormorant				1	5			1			0
Masked Lapwing	10	22	9	8	3		2		5	8	3
Pacific Black Duck	1	2	53	20			23	2	2		-2
Pink-eared Duck			20	30	387						0
Red-capped Plover	100	53	25	31	114		25	94		6	6
Red-necked Avocet					1435			466	280	500	220
Red-necked Stint	250	1610	528	704	2766		484	4105	20	3355	3335
Royal Spoonbill	36				2			9		25	25
Sharp-tailed Sandpiper	2700		610	922	555			662	1000	2	-998
Silver Gull	100	16	4	7	5		18	40	11	1	-10
Whiskered Tern	400		121	93	21			81	1028		-1028
White-faced Heron	8	4	11	13	5		5	1	5	7	2
Total	36004	13013	11970	26664	15578	0	17637	14300	21194	24501	3307

6.4 Supplementary figures



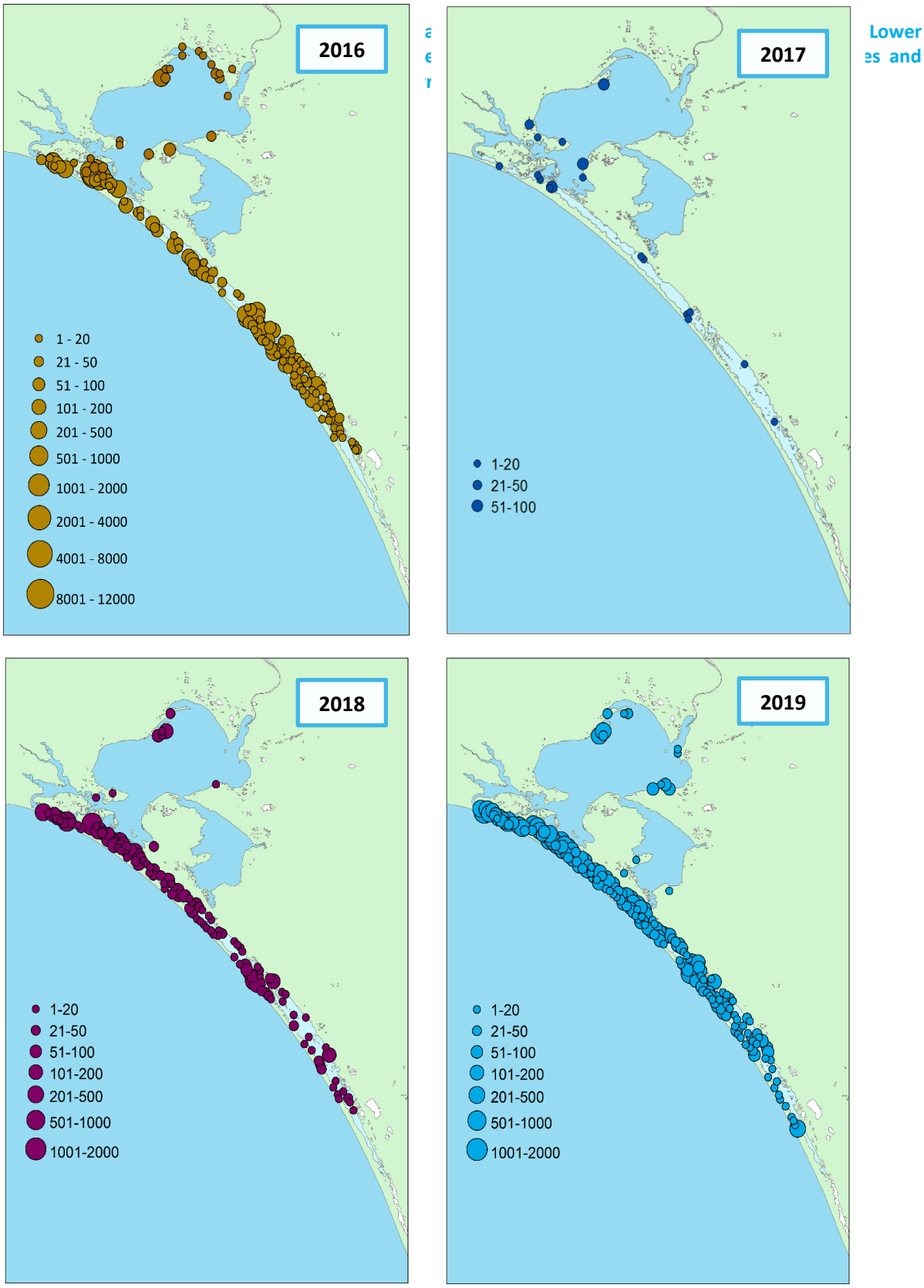


Figure A5. Distribution and abundances of Sharp-tailed Sandpiper present along the Coorong and the Lower Lakes (2016–2019). Data from annual January–February census data collected for the Lower Lakes and associated wetlands as part of The Living Murray Program (e.g. Paton *et al.* 2019a).

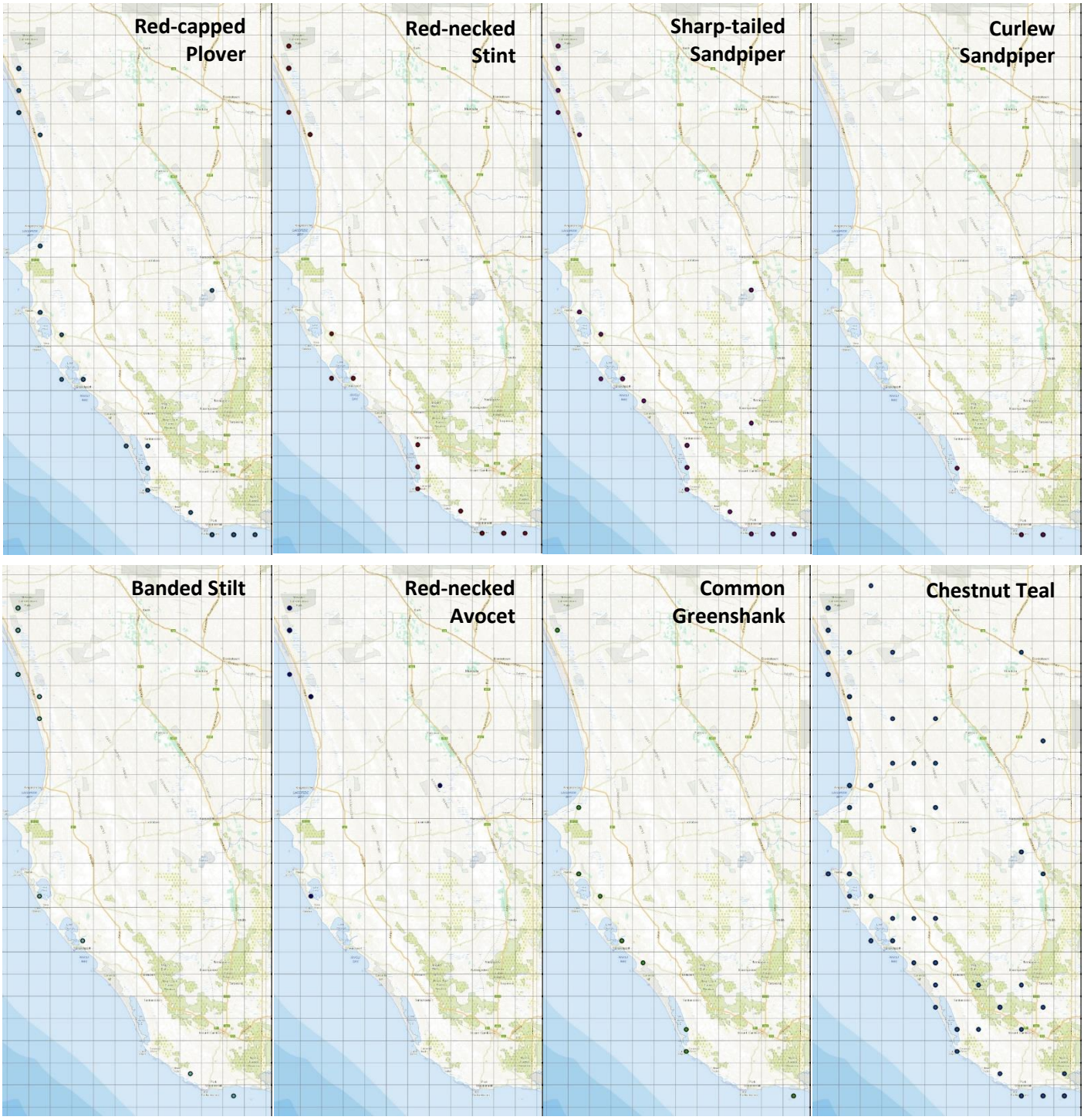


Figure A6: Distribution maps of seven key shorebird species and a key waterfowl species across the South East during the SE Bird Atlas 2015–2018 (D. Paton unpubl). Points represent the presence of a species anywhere within the 10 km x 10 km grid cell overlay. Species maps from top left, then bottom left: Red-capped Plover, Red-necked Stint, Sharp-tailed Sandpiper, Curlew Sandpiper, Banded Stilt, Red-necked Avocet, Common Greenshank, Chestnut Teal. ArcMap10 (ESRI 2010) was used to produce distribution maps for key at-risk shorebird and waterfowl species from data collected for the South-east South Australian Bird Atlas 2015–2018 (D. Paton unpubl.). This atlas data was mapped onto a 10 km x 10 km grid cell map, with coloured points in each cell representing the presence of a species record anywhere in that cell. The topographical basemap layer was sourced from GeoScience Australia online (GeoScience Australia 2019). These data were not collected as part of this study and are not available for use beyond this report.

6.5 Wetland Assessment Criteria tables

Table A6. Wetland assessment criteria table for Primary and Secondary management options in South East and Lower Lakes wetlands. Colours of wetland criteria fields indicate the scoring of the data listed: □ = 1; □ = 2; □ = 3; □ = 4; □ = unscored. Priority classes (see bottom of Table) were defined from priority scores as follows: □ = Low (<55); □ = Moderate (55–63); □ = High (>63); □ = NA/not prioritised. See Table 4 for more detail on classification, scoring and weighting.

PRIMARY OPPORTUNITIES: SOUTH EAST	1) Morella Basin	2) Tilley Swamp Conservation Park	3) Tilley Swamp- Brinkworth (Hindmarsh Park)	4) Tilley Swamp- Cortina Lakes, Banff, Stoneleigh Park, Frostys Swamp	5) Butcher Gap Conservation Park
ACCESSIBILITY					
Ease of wetland access	[2] 4WD, walking	[3] 4WD	[3] 4WD	[3] 4WD	[2] 4WD, walking
Seasonality	Year round	Dry at end of summer.	Dry at end of summer	Dry at end of summer	Permanently damp…
Percent of surveyable wetland	[4] ~90% Eastern side tougher to get around (permanent water)	[1] 2% - dense shrubs.	[4] 100%	[2] ~50%; much is difficult to access	[3] 60%?
VALUE FOR BIRDS					
Value in current state	[3] High	[1] Low	[2] Moderate	[2] Moderate (though mostly inaccessible)	[2] Moderate
Potential value if modified	[3] High (use current infrastructure differently - different management outcomes, but may compete with current Coorong targets)	[3] High	[3] High	[3] High	[2] Moderate
Current value for shorebirds	[2] Moderate	[1] Low	[2] Moderate	[1] Low	[2] Moderate?
Current value for waterfowl	[3] High	[1] Low	[3] High	[2] Moderate	[2] Moderate
Current value for piscivores	[1] Low	[1] Low	[1] Low	[1] Low	[1] Low
SITE ATTRIBUTES					
Proximity to Coorong	[4] Near	[4] Near	[4] Near	[4] Near	[3] Mid-range
Bathymetry	[2] Mainly shallow clay shore, with some deeper areas. Few steep banks	[3] Large, shallow interdunal wetland basin with clay base.	[3] Large, shallow interdunal floodplain	[2] Extensive shorelines, with deeper areas of waterbody.	[3] Shallow coastal lake and extensive shorelines
Current salinity	Brackish	Brackish	Brackish	Brackish	Brackish to saline

Land tenure and use	[3] Conservation Park (Martin Washpool CP)	[3] Conservation Park	[1] Private. Grazed with rights to inundate	[1] Private. Grazed, but parts are also managed for waterfowl.	[3] Conservation Park
Current extent of vegetation incursion	[3] Low (occasionally moderate, depending on water level)	[2] Moderate. Dense shrubland, particularly melaleuca	[3] Low, samphire and pasture grasses.	[2] Moderate. Cortina is samphire. Banff and Bonneys Camp have had some areas cleared for ecological purposes, more can be done.	[2] Moderate. Gahnia/samphire/ melaleuca
Current hydrological regime	Driven by winter inflow. Managed. Permanent areas.	Regulated. Could be managed as permanent.	Seasonal, inundation dependent on flows	Seasonal, inundation dependent on flows	Butchers Gap Drain runs through with flows into wetland managed by regulator.
Current peak season for waterbirds	Autumn (as refuge habitat). Highest diversity in Spring and summer.	Wetter months	Wetter months, dries in early summer	Wetter months	Wetter months, dries by end of December in dry years.
SUITABILITY FOR MODIFICATION					
Modification options	Infrastructure already in place. Investigate alternate operation of infrastructure. Additional fish ladders required.	Clearing of encroaching shrubs, particularly invading melaleuca	Infrastructure in place to allow water in (via SEFRP)	Infrastructure in place to allow water in (via SEFRP)	Update regulator to better manage flows into the wetland.
Modification cost or value (estimate)	[3] SEFRP already initiated	[2] $200,000 (Much done in Banff and Bonneys)	[3] SEFRP could be employed, but additional costs could easily run into tens of thousands	[3] SEFRP could be employed, but additional costs could easily run into tens of thousands	[3] $70,000-$200,000 depending on if only one or both regulators are replaced (both needed).
Potential area of new or improved habitat	[2] Low (already inundated) - based on current management…scope for modifying fringing shrub vegetation that is encroaching.	[2] Moderate. Good potential to create a few hundred hectares of open areas and mudflats.	[3] High	[2] Moderate (wetlands cover large area but works could only be done on limited areas at a time)	[2] Moderate (would be higher if the shacks were removed)
Feasibility	[3] High (along drain to Salt Creek)	[3] High	[3] High	[3] High (dependant on water availability)	[3] High
Existing plans	[3] Large-scale Habitat Restoration in the South East NRM Region (Farrington et al. 2018)	[3] Part of SEFRP; to be inundated more frequently duration dependent upon water availability. Detailed in NGT: Large-scale Habitat Restoration report	[3] Part of SEFRP; to be inundated more frequently and/or greater duration.	[3] Part of SEFRP; to be inundated more frequently and/or greater duration.	[2] Some. Outflows managed at outlet regulator - better regulator would allow water to be kept in wetland when opening drain to the ocean.
Potential issues	[2] Risk of inundating too large an area and reducing shoreline, therefore reducing feeding areas for waders and	[2] NVC approval. Neighbouring landholder issues if impacting drainage services.	[1] Landholder negotiation may be an issue	[1] Landholder negotiation may be an issue	[2] Need to be sensitive to maintain a waterlevel that doesn't impact on nearby

	other waterbirds. Need to ensure not overfilled to maintain habitat for birds, especially during summer when few other wetlands have water remaining.				shacks. Will get more inundated with sea level rise
Priority score	62.25	53.75	61.75	54	55
Priority class	Moderate	Low	Moderate	43.5	Moderate
Priority rank	3	12	4	41.5	9

PRIMARY OPPORTUNITIES: SOUTH EAST	6) Wangolina Swamp	7) Kungari Conservation Park	8) Lake Hawdon North	9) Lake Hawdon South
ACCESSIBILITY				
Ease of wetland access	[2] 4WD, walking	[2] 4WD, walking (large areas)	[3] 4WD	[2] 4WD, walking
Seasonality	Dry at end of summer, could retain water longer	Dry at end of summer	Dry early December	Dry by mid-January (deepest parts of southern basin maintain some permanent water)
Percent of surveyable wetland	[2] 50%	[1] 10%?	[4] 80-100%	[2] 20-50% (currently has lots of vegetation)
VALUE FOR BIRDS				
Value in current state	[2] Moderate (Grazed but good value when inundated)	[2] Moderate	[2] Moderate	[3] High
Potential value if modified	[3] High	[3] High	[4] Very High	[4] Very High
Current value for shorebirds	[1] Low?	[1] Low?	[3] High	[3] High (wet through to end of January)
Current value for waterfowl	[2] Moderate	[2] Moderate (not high numbers of ducks and swans)	[2] Moderate?	[3] High
Current value for piscivores	[2] Moderate	[2] Moderate (lots of native hens, egrets, herons, ibis etc)	[2] Moderate	[3] High
SITE ATTRIBUTES				
Proximity to Coorong	[3] Mid-range	[3] Mid-range	[3] Mid-range	[3] Mid-range
Bathymetry	[3] Shallow Gahnia floodplain	[2] Shallow floodplain with some deeper basins.	[3] Large, shallow waterbody with open areas and shallow slopes, 0.65m at	[2] Some shallow areas, with deep water. Sill elevation of approximately 4.25 m AHD

			deepest point when water level 4.3 mAHD	
Current salinity	Brackish	Fresh to brackish	Fresh to brackish	Fresh to brackish
Land tenure and use	[1] Private. Grazed, but has remnant vegetation in reasonable condition	[3] Conservation Park	[2] Crown lands. Mining and grazing under annual licensing	[3] Conservation Park
Current extent of vegetation incursion	[2] Moderate. Gahnia/brackish herbland (Samolous, Silsonia etc)	[2] Moderate. Shrub density and terrestrialisation has increased post removal of grazing when established as CP	[1] High. Potential to decrease shrub density. Mining operations clear vegetation	High and increasing, especially melaleuca. Some open water basins.
Current hydrological regime	Seasonal. Surface water within Wangolina Swamp currently drains into the Butchers Gap drain	Is wet nearly every year, with winter/spring inundation and summer/autumn exposure. Nearly the only site wet in 2006 drought conditions. Water flows south from Kungari through private drains into Drain L, but also north, through Sections 120 and 119, into the Kingston Main Drain, which discharges into the sea at Kingston	Seasonal, dependent on flows down Drain L	Seasonal, but stays wet 6 weeks longer than Lake Hawdon Nth. Some permanent water in southern basin
Current peak season for waterbirds	Wetter months	Wetter months	Spring	Summer
SUITABILITY FOR MODIFICATION				
Modification options	Could involve the construction of a levee along the Butchers Gap Drain reserve to isolate the swamp from the drain. The levee would likely incorporate a spillway, creating a new (higher) sill elevation for the wetland, thus holding water in the swamp as water levels in the drain recede. This would self-manage. Alternatively, could put a regulator in the cut in the lunette to retain water in a slightly smaller area of the wetland - this would require management.	Expand Kungari to include Rushy Swamp, enabling hydrological restoration to occur and increasing seasonal wetland duration. Design and construct levees and spillways along the northern and southern boundaries of the enlarged reserve to contain surface water within the reserve. Road culverts under Woolmit Rd could be modified to regulate and retain water in current extent.	A regulator could be installed in the Woakwine cutting to improve the hydrology of lake Hawdon North. Vegetation control, maintaining water levels.	Vegetation management to control melaleuca (burn or grazing regime). Could increase sill level.
Modification cost or value (estimate)	[3] $20,000-$40,000 (compensation or incentive to landholder/s may be required)	[2] Major cost for expanding area including land purchase, perhaps $1M? $20,000 for culverts.	[2] Potential high value, but cost could be significant as regulator required to increase water duration: 500K - 1M	[2] Not costed. Moderate value?
Potential area of new or improved habitat	[3] 727 ha when inundated	[3] 564 ha existing reserve (652 ha proposed addition of Rushy Swamp)	[4] Very high (~2475 ha) with correct inundation levels and sill reinstated	[2] Moderate. Protecting/enhancing existing open water habitat possible.

Feasibility	[3] High…dependent on local catchment	[3] High	[4] Very High, Drain L cuts through wetland area.	[3] High
Existing plans	[3] Large-scale Habitat Restoration in the South East NRM Region (Farrington et al. 2018). An agreement to install a weir to manage the wetland in the 2007-2009 era failed	[3] Large-scale Habitat Restoration in the South East NRM Region (Farrington et al. 2018)	[3] Native Vegetation and Restoration Potential of Lake Hawdon North (Ecological Associates 2019)	[2] Has been burnt 2018. Existing infrastructure - weir on the connecting channel on old Naracoorte Road. Managed by landholders.
Potential issues	[2] Careful consideration would need to be given to the elevation of the new sill and the capacity of the spillway in order to prevent inundation of surrounding agricultural land and create an appropriate water regime within the swamp.	[2] Agreement from adjoining landholders will need to be gained before hydrological restoration works can be designed and constructed. Any works would need to prevent inundation of surrounding agricultural land	[2] Support needed from key stakeholders (grazing licensees, adjoining/nearby landholders, SE Water Conservation and Drainage Board) and compatibility with mining operations	[2] Surrounding landholders, DEW Parks, SEWCDB
Priority score	59.5	56.5	70.5	59.25
Priority class	Moderate	Moderate	High	Moderate
Priority rank	6	8	1	7

PRIMARY OPPORTUNITIES: SOUTH EAST	**10) Lake George/Admella Lake, Bucks Lake**	**11) Lake Frome Conservation Park**	**12) Mullins Swamp**	**13) Iluka**	**14) Lake Bonney SE/Bucks Lake**
ACCESSIBILITY					
Ease of wetland access	[2] 4WD, walking	[2] 4WD, walking	[2] 4WD, walking	[3] 4WD (farm access all round wetland)	[2] 4WD, walking
Seasonality	Mostly year round	Dry at end of summer (permanently damp)	Permanent (managed)	Year round	Year round
Percent of surveyable wetland	[4] 80% (limited ability for surveying centre)	[1] 5% (lots of emergent vegetation)	[2] ~40%? Lots of vegetation, difficult to survey edges	[4] 90%	[3] Perhaps 60% when water low, very large area making walking access prohibitive
VALUE FOR BIRDS					
Value in current state	[3] High	[2] Moderate	[2] Moderate	[2] Moderate	[2] Moderate
Potential value if modified	[4] Very high	[4] Very high	[2] Moderate	[2] Moderate	[3] High
Current value for shorebirds	[2] Moderate	[1] Low	[2] Moderate-Low	[1] Low	[2] Moderate

Current value for waterfowl	[3] High	[2] Moderate (reduced areas of open water due to Typha encroachment)	[3] High	[2] Moderate	[2] Moderate
Current value for piscivores	[2] Moderate	[2] Moderate	[2] Moderate	[2] Moderate	[2] Moderate
SITE ATTRIBUTES					
Proximity to Coorong	[2] Far	[2] Far	[2] Far	[2] Far	[1] Distant
Bathymetry	[2] Shallow, gently sloping shoreline; open mudflats; large expanses of deeper water	[3] Large low-lying area of shallow lake and marshland. Extensive shallow shoreline when inundated.	[3] Largely shallow with limited shoreline. Coastal lake, freshwater marsh.	[2] Smaller freshwater marsh with shallow and deep areas.	[3] Large areas of shallow shoreline, large expanse of deep water.
Current salinity	Brackish to saline	Fresh	Fresh	Fresh	Saline to hypersaline
Land tenure and use	[2] Crown land managed by council. Multiple uses	[3] Conservation Park	[2] Private. Managed for conservation	[2] Private. Grazed and managed for conservation	[2] Public and private. Multiple uses
Current extent of vegetation incursion	[3] Low, some samphire around edges	[2] Moderate. Density of Typha and Phragmites has increased since dedication as a CP and removal of grazing. This has been to the detriment of open water/low herb/grassland habitat	[1] High and encroaching	[1] High and re-establishing	[3] Low. Some samphire and reeds around edges
Current hydrological regime	Permanent	Seasonal. Part of a 30km wetland corridor, but drains have lowered the full supply level of the wetland.	Permanent	Part of a corridor of coastal wetlands spanning Lake George to Lake Frome, and including Mullins Swamp	Permanent lake, some water quality issues
Current peak season for waterbirds	Spring/summer (shallow areas for birds)	Wetter months	Summer (refuge)	Wetter months	Summer
SUITABILITY FOR MODIFICATION					
Modification options	Increase inflow at the right time and to the right level by building flow structures. Remove sediment build up and improve management of Lake George Outlet at the southern end	Increase inflow (from Drain L) and construct a control structure and weir on the outlet of Lake Frome to allow retention of water in this lake. Raise the outlet sill (increase full supple level) to increase the extent, depth and duration of surface water inundation (Raising the sill elevation by 1.1 m, from 1.7 to 2.8 mAHD)	Encroaching vegetation control. Potential for large-scale connectivity restoration: Bucks Lake to Illuka?	Hydrological restoration has been undertaken, reversing artificial drainage by constructing a levee across low lying, drained ground. Additional works could control encroaching vegetation	Some inflows of fresh water would be beneficial. Regulator at outlet.

Modification cost or value (estimate)	[1] Budget estimate $2.5M	[3] Not currently costed, but would likely be high value	[2] Not costed. Moderate value?	[3] Potentially low cost, but comparatively limited value of more work	[2] Not costed. Moderate value?
Potential area of new or improved habitat	[4] Very high. Could restore up to 6000 ha of wetlands (though much of it would open water, not necessarily useful habitat for waterbirds).	[4] Very high, area of 1020 ha (much of this shallow water).	[2] Moderate if connected	[2] 130 ha when inundated	[1] Low
Feasibility	[2] Moderate. Divert water from the lake Frome Catchment (Mount Hope Reidy Creek Drain) to the Lake George Catchment (Drain M). The works involve a control structure and a new flow path of approximately 1.7km across a cleared road reserve. Modelling indicates on average 13 Gigalitres of excess water flow thorough Lake Frome each year which is available for diversion.	[3] High. Potential to get inflow from Drain L. Requires on-ground works and the cooperative management of surface water flows by DEWNR and the SEWCDB	[2] Moderate. Landholder currently manages for conservation	[2] Moderate.	[2] Moderate. Lake still has water quality issues
Existing plans	[2] Project Management FrameWork has been produced	[3] Large-scale Habitat Restoration in the South East NRM Region (Farrington et al. 2018); Project Management FrameWork has been produced	[1] None	[3] Large-scale Habitat Restoration in the South East NRM Region (Farrington et al. 2018).	[2] Partial
Potential issues	[3] Will benefit Rivoli Bay with reduced inflows	[2] Would require the future negotiation of a right to inundate, or purchase, low lying adjacent land, which is currently private agricultural property. Neighbouring landholders sensitive to initiatives to retain water	[3] None known.	[3] Few	[2] EPA (water quality regulations for release)
Priority score	61	66	47	54	48
Priority class	Moderate	High	Low	Low	Low
Priority rank	5	2	14	10	13

SECONDARY OPPORTUNITIES: SOUTH EAST	15) Mandina Marshes/Cortina Lakes	16) Paranki CP	17) Lake McIntyre	18) Lochaber Swamp	19) Lake Robe	20) Lake Eliza	21) Lake St Clair	22) Bool Lagoon/Hacks Lagoon	23) Middlepoint Swamp
ACCESSIBILITY									
Ease of wetland access			Walking						Via private land
Seasonality		Year round		Year round					Year round
Percent of surveyable wetland									60%
VALUE FOR BIRDS									
Value in current state		Probably high			High				Moderate
Potential value if modified									Moderate-High
Current value for shorebirds	High (best wader habitat is Mandina Lakes which are seasonal)	Suspected high			Moderate	Low-moderate	Low-moderate	Moderate	Moderate (high value habitat - although small area)
Current value for waterfowl				Present	High	Low-moderate	Low-moderate	High	Moderate
Current value for piscivores					Moderate			High	Moderate
SITE ATTRIBUTES									
Proximity to Coorong	Near	Near	Near	Mid-range	Mid-range	Far	Far	Far	Distant
Bathymetry		Open salt lake	Landscaped quarry on edge of Millicent township	Mud flats, open water habitat	Large extents of shallow water and mud flats	Large extents of shallow water and mud flats		Large extents of shallow water	
Current salinity		Saline		Brackish	Saline	Saline			Fresh - brackish
Land tenure and use		Conservation Park							Grazing/ conservation
Current extent of vegetation incursion		Fringed with Gahnia and tea tree		Low	Low	Low			Moderate (lots of veg, but with some open

									water Ruppia dominated basins)
Current hydrological regime	Mandina Marshes are mostly dry. Cortina Lakes permanently inundated	Groundwater fed and seasonal surface water	Permanent water	Seasonal/ permanent	Permanent			Some inundation remains in the main basin	Seasonal (permanent in main basin in wet years)
Current peak season for waterbirds		Summer		Currently retaining water				Spring/summer	Spring/summer
SUITABILITY FOR MODIFICATION									
Modification options		Unknown. Requires investigation.						Water levels could be kept at the right level for shorebirds (often too high or low)	Modifications to existing weirs to raise water level.
Modification cost or value (estimate)									Requires purchase of private land
Potential area of new or improved habitat									200 ha approx.
Feasibility				Fed by Drain E flows from Naracoorte Creek and Mosquito Plains					Fed by springs, unconfined aquifer discharge and local catchment (Winterfield Creek)
Existing plans				Inundation level is currently managed by an outlet regulator					NGT / DEW
Potential issues									Surrounding landholders
Priority score	NA	NA	NA	NA	NA	NA	NA	NA	NA
Priority class	NA	NA	NA	NA	NA	NA	NA	NA	NA
Priority rank	NA	NA	NA	NA	NA	NA	NA	NA	NA

PRIMARY OPPORTUNITIES: LOWER LAKES	24) Tolderol Game Reserve	25) Waltowa	26) Narrung
ACCESSIBILITY			
Ease of wetland access	[3] 4WD, comprehensive track access	[2] 4WD and walking	Walking, 4WD (when dry)
Seasonality	Permanent water. Year-round access	Usually dry in summer (a portion can always be observed from Princes Hwy)	Sometimes dry in summer "drawdown". Year-round access
Percent of surveyable wetland	[4] 100%	[4] 100%	[4] 100%
VALUE FOR BIRDS			
Value in current state	[3] High (relative to fringing wetlands of the Lower Lakes). See Hartvigsen-Power et al. 2019	[1] Low for most species (though species like Banded Stilt could benefit). It is a degraded and salinised basin which would once have been an extension of Lake Albert. The inability to export salt due to the size and elevation of the small culvert under the Princes Hwy inhibits meaningful management Currently, water is released into the basin during spring/summer as small pulses which provide foraging habitat for small numbers of shorebirds. Salt tolerant micro and macroinvertebrate eggbanks and, to a lesser extent, Ruppia seedbanks are viable. Current agreement with the landholders is to fill only to 0.3mAHD to reduce the impact on surrounding groundwater tables. Water can only be delivered in sufficient quantities when lake levels exceed 0.6mAHD. Wind-blown saline wetland bed sediments have created small dunes smothering fringing samphire shrublands.	[2] Moderate
Potential value if modified	[4] Very high. Especially for shorebirds, however additional basins could be 'restored' and brought back into the watering program. This would involve investment in earthworks and infrastructure. In addition, improvements can be made to increase the productivity of the currently watered basins by undertaking earthworks to enable independent watering of each basin instead of in sequence (allowing better control of water levels at shorebird's preferred depths).	[4] Very high (shorebirds, and Banded Stilt if hypersaline). Upgrading the existing culvert structure would enable a more productive and appropriate water regime to be implemented. Depending on landholder support, this would ideally include drawdown events to mimic more pre-European settlement cycles.	[2] Moderate. Modifying current management will require community support. Odour issues during draw down events and the close proximity to housing limits hydrological management.
Current value for shorebirds	[3] High	[1] Low. Only intermittent ideal foraging conditions can be achieved in spring/summer.	Low. Shorebirds are generally observed when water levels are drawn down as part of a 'snap dry' in

			late summer every 1-3 years or on fringes when lake levels are drawn down to 0.5mAHD.
Current value for waterfowl	[2] Moderate	[1] Low. Water fowl have not been observed utilising the wetland during water events except for roosting/resting and in low numbers. Historically, Waltowa was an important place for Ngarrindjeri people for swan egg collecting and was known as a hot spot for water birds.	[2] Moderate. Waterfowl diversity and abundance was highest as part of e-watering events during and following drought, however current management balancing odour issues and the need to occasionally consolidate the sediments is achieving a good diversity and abundance of waterfowl.
Current value for piscivores	[2] Moderate (mainly terns)	[1] Low	[2] Moderate (mainly terns)
SITE ATTRIBUTES			
Proximity to Coorong	[4] Near	[4] Near	[4] Near
Bathymetry	[3] Generally flat beds and shallow water levels. No deep areas. Constructed embayments, channels and drains. If waterlevel too high can have steep banks.	[3] Shallow large basin, wetland bed generally 0.2-0.3mAHD, deepest 0mAHD. Steeper at edges. Ephemeral but should be permanent.	[3] Gradual gradient, generally flat in wetland, wetland bed approx. 0mAHD at deepest. Generally permanent, mudflats exposed via management.
Current salinity	Brackish-saline. Variable depending on elevation and watering regime. Salinity generally decreases with watering over time. Future management might include 'resting' basins to allow salts to re-accumulate.	Hypersaline. Groundwater has been recorded in the eastern region >200,000uS/cm but is variable. Surface water predominantly saline yet highly variable and will increase rapidly following watering events.	Brackish. Maintained around 10,000uS/cm
Land tenure and use	[3] Public. Game reserve.	[2] Private. Managed for conservation. The surrounding landholders have fenced the wetland fringes to prevent access to stock.	[2] Private. Managed for conservation
Current extent of vegetation incursion	[2] Low-moderate, depending on watering history and embayment. Ranges from samphire dominated shrublands to Typha/Bolboschoenus sedgelands	[3] None.	[3] Little to none - small patches of Phragmites. Typha and Phragmites within smaller basin. Abundant submerged vegetation (charophytes, Ruppia, Potamogeton) when conditions are suitable although heavily grazed by herbivorous birds.
Current hydrological regime	Pumping. General - aim to fill, draw down and maintain levels at the point where bird activity peaks. Reactive to site conditions and volunteers.	At present - spring and summer pulses. Current agreement with the landholders are to fill only to 0.3mAHD to reduce the impact on surrounding groundwater tables. Water can only be delivered in sufficient quantities when lake levels exceed 0.6mAHD. Maintaining suitable conditions is currently resource intensive to operate within the limitations.	The management target is 10,000EC which is achieved by maintaining restricted connectivity to the Narrung Narrows. Occasional 'snap dries' in late summer to consolidate sediments

Current peak season for waterbirds	Manipulated - when desired.	Spring/summer if lake levels permit.	Spring/summer. For shorebirds - during a drawdown event.
SUITABILITY FOR MODIFICATION			
Modification options	Extend watering area + improve existing.	Upgrade wetland regulating structure	Negotiate water regime with community
Modification cost or value (estimate)	[2] $100,000 - $1.4M, but inherently scalable	[2] Initial investigations and engineering detailed designs $100,000-$300,000. Construction cost will depend on the detailed design and funding source (both federal funding cost, and DPTI on-costs). Difficult for DEW to gain approval to self-manage infrastructure project on a state highway). Ideally modification works would be incorporated at an opportunity when roadworks are already occurring.	[4] No cost associated with altering the water regime - community engagement time.
Potential area of new or improved habitat	[2] Improvements to existing basins = 119.55 hectares. Potential additional basins = 83.25 ha (total 202.8 ha)	[2] Waltowa wetland is approximately ~260ha in size (depending on how you map surrounding low-lying areas) and is currently highly degraded. With improved connectivity to Lake Albert the entire site provides potential area for all functional groups, depending on the time point in a variable water regime. Following infrastructure upgrade it will likely take 1-3 years for the re-establishment of fringing vegetation. There will likely be a productivity 'boom' following initial reconnection and a salinity gradient from east-west.	~10 hectares. Better shorebird habitat could be provided if community were open to longer drawndown periods. This is limited by the odour issues at the site.
Feasibility	[3] High	[3] High	[3] High. Existing wetland regulators in place.
Existing plans	[3] Developing Ecological Justification for Proposed On-Ground Works in the CLLMM Icon Site (Rogers et al. 2008), Tolderol Environmental Watering Trial 2014/15 (Oerman and Mason 2015)	[3] Waltowa Wetland Management Plan (Bjornsson 2005), Developing Ecological Justification for Proposed On-Ground Works in the CLLMM Icon Site (Rogers et al. 2008)	[3] Narrung Wetland Management Plan (Bjornsson 2006a), Developing Ecological Justification for Proposed On-Ground Works in the CLLMM Icon Site (Rogers et al. 2008)
Potential issues	[3] The additional basins are located within the hunting zone. Good community engagement and communication essential. Potential exists to gazette the basins out of the hunting zone which would bring opposition from hunting groups but unlikely to be required. Watering regimes to promote shorebird habitat are less likely to support waterfowl.	[2] Landholder, community, Ngarrindjeri and council visions for the site may be more aligned with a more freshwater/permanent wetland state - a desire to see the site 'as it once was'. Providing regular and extensive shorebird habitat is achievable but will require good community engagement. Particularly regarding influences on groundwater and the impact to surrounding low-lying grazing country, where landholders are averse to increasing water levels.	[2] Community consultation required before any alterations to the management regime.
Priority score	66.5	58.75	57.5
Priority class	High	Moderate	Moderate
Priority rank	1	3	4

PRIMARY OPPORTUNITIES: LOWER LAKES	27) Jenny's Lagoon (Yalkuri Station)	28) Teringie South Lagoon	29) Teringie North Lagoon	30) Teringie East
ACCESSIBILITY				
Ease of wetland access	[4] 4WD, walking (extensive)	[3] 4WD	[3] 4WD	[3] 4WD
Seasonality	Generally dry by mid-summer (accessibility altered by crops and wet weather)	Dry by mid-summer. Can access southern area all year	Most areas all year, always accessible	Dry in summer, access limited when wet
Percent of surveyable wetland	[4] 100%	[4] 80% (some dense samphire shrublands)	[4] 100%	[4] 100% (using multiple vantage points)
VALUE FOR BIRDS				
Value in current state	[2] Moderate	[2] Moderate	[1] Low	[1] Low
Potential value if modified	[3] High	[3] High	[2] Moderate	[2] Moderate
Current value for shorebirds	[2] Moderate	[1] Low	[1] Low	[1] Low
Current value for waterfowl	[2] Moderate	[1] Low	[1] Low	[1] Low
Current value for piscivores	[2] Moderate	[2] Moderate (mainly terns)	[1] Low	[1] Low
SITE ATTRIBUTES				
Proximity to Coorong	[4] Near	[4] Near	[4] Near	[4] Near
Bathymetry	[3] Shallow wetland. Wetland bed approx. -0.1mAHD at deepest. Paspalum or samphire fringes. Seasonally exposed mudflats.	[3] Ephemeral wetland fringing Lake Alexandrina. Seasonally inundated by rainfall and high lake levels, dries in summer. Shallow, generally flat with gentle sloping banks. Bed approx 0mAHD at deepest.	[3] Permanent wetland fringing Lake Alexandrina. Wetland bed approx. 0mAHD at deepest, bed generally flat, gently sloping banks, some areas will lip.	[3] Isolated saline basin east of Teringie North Basin. Gentle gradients, generally flat centre. Salt crust when dry.
Current salinity	Fresh-brackish	Brackish	Fresh-brackish	Hypersaline
Land tenure and use	[2] Private. Managed for conservation	[2] Private. Grazed but also managed for conservation.	[2] Private. Managed for conservation	[1] Private. Grazed.
Current extent of vegetation incursion	[2] Low-moderate. Main basin - minimal, some Bolboschoenus and Paspalulm, herbs. Submerged aquatics - generally charophytes. Channel - dense Paspalum and sedges.	[2] Moderate. Areas of extensive Samphire shrubland. A reasonable portion has been drowned from regular e-watering. Charophytes and Ruppia when conditions suit.	[1] High. Fringing Typha, Schoenoplectus, Bolboschoenus, paspalum.	[3] None
Current hydrological regime	Partially managed - seasonal. Generally dry by mid-summer.	Ephemeral/Seasonal - dry by mid summer unless e-water delivered.	Permanent	Seasonal - rainfall pooling

Current peak season for waterbirds	Spring and summer.	Spring and summer. E-watering too deep for shorebirds	Spring/summer	N/a
SUITABILITY FOR MODIFICATION				
Modification options	Remove impediments to flow to extend inundation in summer and/or e-watering are proposed.	Negotiate environmental watering regime with landholders (currently targeting volumes, not water levels)	Install wetland regulating structure. Detailed designs completed.	E-watering from Teringie North or undertake earthworks to increase connection to Lake Alexandrina
Modification cost or value (estimate)	[3] Unknown (~10,000?)	[4] No cost - community engagement	[2] $400,000-500,000	[2] Unknown (likely over $50,000 for significant earthworks).
Potential area of new or improved habitat	[1] ~26ha	[2] ~60ha	[1] 30ha	[2] ~70ha
Feasibility	[3] High - regulating structures exist	[3] High - alter e-water regime	[3] High	[2] Moderate. Trade-offs with condition of Teringie North Lagoon.
Existing plans	[1] None	[2] Teringie Wetland Pre-Feasibility Fact Sheet (SAMDB 2013)	[3] Teringie Wetland Complex Management Plan (Bjornsson 2006b) Detailed engineering design completed - R&K Engineering.	[3] Teringie Wetland Management Plan (Bjornsson 2006b)
Potential issues	[3] Few	[3] Support from Ngarrindjeri Regional Authority, though they are interested in delivering water	[3] Few	[3] Few
Priority score	55.5	63	51.25	51.25
Priority class	Moderate	High	Low	Low
Priority rank	5	2	6	6

PRIMARY OPPORTUNITIES : LOWER LAKES	**27) Jenny's Lagoon (Yalkuri Station)**	**28) Teringie South Lagoon**	**29) Teringie North Lagoon**	**30) Teringie East**
ACCESSIBILITY				
Ease of wetland access	[4] 4WD, walking (extensive)	[3] 4WD	[3] 4WD	[3] 4WD
Seasonality	Generally dry by mid-summer (accessibility altered by crops and wet weather)	Dry by mid-summer. Can access southern area all year	Most areas all year, always accessible	Dry in summer, access limited when wet

Percent of surveyable wetland	[4] 100%	[4] 80% (some dense samphire shrublands)	[4] 100%	[4] 100% (using multiple vantage points)
VALUE FOR BIRDS				
Value in current state	[2] Moderate	[2] Moderate	[1] Low	[1] Low
Potential value if modified	[3] High	[3] High	[2] Moderate	[2] Moderate
Current value for shorebirds	[2] Moderate	[1] Low	[1] Low	[1] Low
Current value for waterfowl	[2] Moderate	[1] Low	[1] Low	[1] Low
Current value for piscivores	[2] Moderate	[2] Moderate (mainly terns)	[1] Low	[1] Low
SITE ATTRIBUTES				
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Current salinity	Fresh-brackish	Brackish	Fresh-brackish	Hypersaline
Land tenure and use	[2] Private. Managed for conservation	[2] Private. Grazed but also managed for conservation.	[2] Private. Managed for conservation	[1] Private. Grazed.
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Current hydrological regime	Partially managed - seasonal. Generally dry by mid summer.	Ephemeral/Seasonal - dry by mid summer unless e-water delivered.	Permanent	Seasonal - rainfall pooling

Current peak season for waterbirds	Spring and summer.	Spring and summer. E-watering too deep for shorebirds	Spring/summer	N/a
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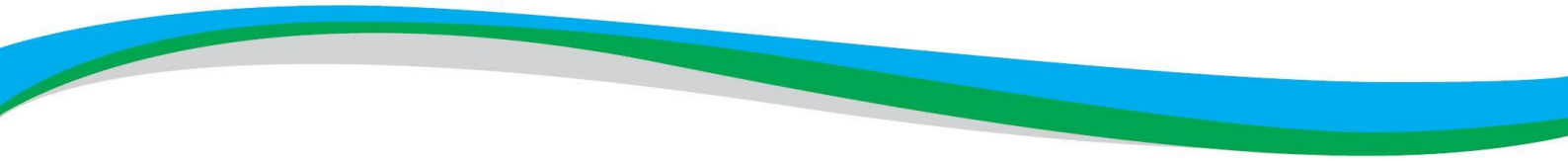
Potential issues	[3] Few	[3] Support from Ngarrindjeri Regional Authority, though they are interested in delivering water	[3] Few	[3] Few
Priority score **Priority class** **Priority rank**	55.5 Moderate 5	63 High 2	51.25 Low 6	51.25 Low 6



The Goyder Institute for Water Research is a partnership between the South Australian Government through the Department for Environment and Water, CSIRO, Flinders University, the University of Adelaide, the University of South Australia, and the International Centre of Excellence in Water Resource Management.