Assessment of Tolderol Game Reserve in autumn 2019 to support key species of Coorong waterbirds

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Goyder Institute for Water Research

Technical Report Series No. 19/19

www.goyderinstitute.org

Goyder Institute for Water Research Technical Report Series ISSN: 1839-2725

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This program is part of the Department for Water and Environment's Healthy Coorong Healthy Basin Program, which is jointly funded by the Australian and South Australian governments.

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Citation

Hartvigsen-Power, C.A., Furst, D.J., Paton, D.C., and Paton, F.L. (2019) *Assessment of Tolderol Game Reserve in autumn 2019 to support key species of Coorong waterbirds.* Goyder Institute for Water Research Technical Report Series No. 19/19.

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Executive summary

The primary aim of this short study was to assess the potential value of the managed wetlands of Tolderol Game Reserve (GR) in providing suitable habitat for key waterbirds species of the southern Coorong. The Coorong is primarily a summer refuge for many waterbirds, including migratory and non-migratory shorebirds. However, the ecological conditions in the southern Coorong have deteriorated in recent years and the numbers of shorebirds have declined with the deteriorating conditions. To be an effective waterbird refuge, Tolderol GR must provide suitable foraging opportunities for at least some of the key waterbird species that have been declining in the Coorong

We document changes in the abundances, behaviour and food resources of waterbirds using Tolderol GR for four months from February to June 2019 to illustrate the potential value of this managed wetland in providing suitable and productive refuge habitats for a range of key species of waterbirds.

Of key species that are disadvantaged by deteriorating conditions in the southern Coorong, three small migratory shorebirds, namely Curlew Sandpiper (*Calidris ferruginea*), Sharp-tailed Sandpiper (*Calidris acuminata*) and Red-necked Stint (*Calidris ruficollis*), and two non-migratory shorebirds, namely Red-capped Plover (*Charadrius ruficapillus*) and Black-winged Stilt (*Himantopus himantopus*), used Tolderol GR for foraging during this study. In February and March and prior to their migration, Curlew Sandpipers were in greater abundances than those observed in the southern Coorong in January 2019. However, Banded Stilt (*Cladorhynchus leucocephalus*), Red-necked Avocet (*Recurvirostra novaehollandiae*), Common Greenshank (*Tringa nebularia*), Fairy Tern (*Sternula nereis*) and Chestnut Teal (*Anas castanea*) are key species at risk from a deteriorating southern Coorong that were not detected or were detected only in small numbers at Tolderol GR during this study.

An assessment of food resources and foraging behaviour during the study confirmed that Tolderol GR provided suitable foraging opportunities for shorebirds during autumn. In February and March, chironomid larvae were relatively abundant in some basins compared to that found in January in the southern Coorong in recent years. In February and March, micro-invertebrate densities in some basins at Tolderol GR were as great as the highest densities measured throughout the Murray–Darling Basin and indicative of a highly productive system. A range of other prey were available at other times, including the larvae of various Diptera.

There was marked temporal variation in waterbird use, waterbird behaviour and food resources of Tolderol GR during autumn 2019. Generally, through autumn and into winter, there were declines in waterbird numbers, and a declining and changing food resource base. There was also variation in waterbird use and behaviour between basins, associated with water levels, as these affected the provision of suitable habitats for foraging and roosting. Of particular importance for the migratory and non-migratory shorebirds was the provision of areas of mudflats covered with shallow water of no more than 10 cm deep, with most species confining their foraging to areas of damp mudflats and those covered with less than 5 cm of water. The locations and amounts of these habitats across the various basins at Tolderol GR were in a continuous flux, largely because evaporative losses of water affected the location of mudflats covered with shallow water on a weekly if not daily basis. This is because once the basins filled in late spring, they were then allowed to draw-down over time, with or without subsequent topping up.

The Tolderol GR Wetlands Working Group currently manages Tolderol GR, with volunteers using their experience and intimate knowledge to manipulate water levels and undertake other management activities, with the goal of providing habitat for shorebirds. Considering Tolderol GR is effectively run entirely by volunteers on a very small operating budget, with water level manipulations restricted by the inefficient configuration of active basins and with only some basins able to receive water, the current waterbird numbers and behaviour are extremely promising. However, further research is required to properly document the use of the various basins by waterbirds at other times of the year from the time when individual basins are initialling filled with water in spring throughout summer and into autumn as the water levels drop, and not just autumn as is the case in this study. Given that there are 19 individual basins, there are opportunities to assess the timing of initial filling, different pre-filling treatments (grazing, slashing, and or ploughing), and subsequent topping up on the provision of food resources for different species of

waterbirds. Such knowledge will aid eventual management and potentially allow a succession of suitable foraging opportunities to be provided across the summer period at Tolderol GR.

For Tolderol GR to reach its full potential in providing alternative habitat for some of the key species that are at risk due to a deteriorating southern Coorong, the following actions are recommended:

1) Investment in infrastructure and instrumentation to (a) enable currently active basins to be watered independently of each other, so as to improve the ability to manipulate water levels of each basin at any point in time; (b) increase the number of basins that can be watered, thus increasing the total area of waterbird habitat; and (c) improve the ability to accurately measure and document watering regimes;
2) Research at Tolderol GR to determine the best watering regimes (timing, length of time inundated, length of time left dry) and other management techniques (ploughing, grazing, burning) of the basins to produce a succession of suitable foraging opportunities for key species of waterbirds across the summer-autumn period and/or at critical times when other wetlands, including the Coorong, are unable to provide such habitats; and
3) Development of an adaptive management program that is based on the experience of volunteers of the Tolderol GR Wetlands Working Group but incorporates new knowledge gained from the research being undertaken concurrently.

However, in the interim and for outcomes for the key small shorebird species, we recommend that at least some of basins at Tolderol GR be managed to provide:

4) mudflats that are either damp or covered by water that is typically no more than 5 cm in depth; and
5) a diverse macro-invertebrate community to provide food at different times of the year for these birds.

Even in undertaking above management recommendations, Tolderol GR will not be able to offset the declines in waterbird numbers that are occurring with the deterioration of the southern Coorong, due to the sheer size disparity between the two wetlands. Furthermore, some key species are not likely to benefit from Tolderol GR, for example Banded Stilt, because they have a preference for saline environments. Consequently, for the conservation of key waterbird species of the Coorong, the following actions are also recommended in addition to actions (1) to (5) above:

6) Research to better understand how other wetlands in the region, including the Coorong, provide resources suitable for key species across a season, to identify critical times when key species do not have the resources available to meet their needs;
7) Investment in infrastructure at, and management of, wetlands in the broader landscape (both existing and new and including the Coorong) to create a network of wetlands that can, as a whole, offset the declines in key waterbird species of the Coorong due to a deteriorating southern Coorong, for identified critical periods. Ultimately, the aim should be to establish a network of wetlands that not only provide resources at certain times of the year but collectively provide the resources needed by the birds all year round, whether or not the southern Coorong is restored as waterbird habitat; and
8) Research to determine whether birds unable to use the southern Coorong can locate and use any alternative habitats provided in the broader landscape. This will require the use of modern technologies, such as satellite tracking. This research will also aid in informing potential locations for newly constructed wetlands in the broader landscape.

Importantly, the deterioration of the southern Coorong in providing habitat for key species of waterbirds has resulted in their marked declines. Under current management of the Coorong, there is little hope of recovering their former abundances, with further declines likely, at least in the short-term. Consequently, there is a very short window of time in which to act before it is too late in sustaining these waterbird populations within the region. Apart from changing the management of the Coorong, the recommended actions (1) to (8) above should be executed immediately and concurrently in an adaptive management framework in order to support the restoration of waterbird populations of the region. A key strategic shift in management is required. The focus must be on managing the populations of waterbirds within the regional context, as opposed to simply managing wetlands, which will not be sufficient from a waterbird perspective.

Acknowledgments

This 2019 research was commissioned and funded from the *Healthy Coorong, Healthy Basin* Program of the South Australian Department of Environment and Water, which is jointly funded by the Australian and South Australian governments.

We thank Colin Bailey, Hayley Merigot and Casey O'Brien for assistance with the fieldwork and surveys. Special thanks to Chris Eckert, Peter Koch, Kate Mason and Colin Rogers for sharing their knowledge, and for their input and assistance in undertaking the fieldwork. The ability to assess waterbird use of Tolderol GR in autumn 2019 was only possible because of the hardworking and dedicated Tolderol GR Wetlands Working Group in maintaining some watered basins within Tolderol GR. We would like to acknowledge and pay respect to the Ngarrindjeri Traditional Owners, and all Elders past, present and future.

Thank you to Jody O'Connor, Daniel Rogers and Kane Aldridge for their insightful reviews that have improved this work.

1 Introduction

The Coorong forms part of the Coorong, Lakes Alexandrina and Albert wetland complex, and was listed as a wetland of international importance under the Ramsar Convention in 1985, primarily for its importance to a wide diversity of waterbirds. The region is regarded as the most important wetland refuge for waterbirds in the Murray–Darling Basin and during the Millennium drought hosted 90% of the waterbirds within the Murray–Darling Basin (Kingsford and Porter 2008). The Coorong, in particular, is important for a range of small migratory and non-migratory shorebirds as well as other waterbirds (Paton *et al.* 2009, 2018a; Paton 2010). For nine species of waterbirds, including seven species of shorebird, the Coorong supports in excess of 1% of their global populations and, for some species, more than 20% in some years (Paton *et al.* 2009). However, most of these species have experienced substantial declines in abundances since the 1980s, at least for the southern Coorong (Paton *et al.* 2009, Paton 2010).

Most waterbirds use the Coorong from late spring until sometime in autumn (Paton 2010). Large numbers of migratory shorebirds arrive from the northern hemisphere in spring and then depart in late summer or autumn. Other waterbirds also increasingly aggregate on the permanent wetlands of the Coorong in spring, as other ephemeral wetlands dry. Most of these also depart in autumn, presumably as the ephemeral wetlands begin to fill. The Coorong is therefore used primarily as critical non-breeding habitat, with only a few piscivorous bird species, such as terns and Australian Pelican (*Pelecanus conspicillatus*), regularly breeding on islands in the southern Coorong.

In recent years, the southern Coorong has experienced extensive blooms of filamentous green algae (Paton *et al.* 2019a). The seasonal timing, spatial extent and duration of these algal blooms is poorly documented. However, when abundant, the filamentous algae can blanket the shorelines where most of the migratory and non-migratory shorebirds feed, severely impeding their access to food resources (e.g., see Paton *et al.* 2017, 2018b). Furthermore, the algae interfere with some of the key food resources used by waterbirds in the southern Coorong. For example, the algae interfere with the reproduction of a key, largely annual, aquatic plant – *Ruppia tuberosa,* in the southern Coorong, either by preventing flower-heads from reaching the water surface where they shed and receive pollen or by attaching to the flower-heads adding drag which results in many of the flower-heads being snapped from the plant (e.g., see Paton *et al.* 2019b). As a consequence, the seed banks for this plant remain at historically low levels (e.g., see Paton *et al.* 2019b), and this is likely to limit the quantity of plant material available in subsequent years. In recent years, all populations of *R. tuberosa* have been affected in this way by filamentous algae (Paton *et al.* 2016b, 2016c, 2017b, 2018c, 2019b). Other factors, such as inadequate water levels over spring also contribute to poor reproductive outputs for this plant (Paton *et al.* 2016b, 2016c, 2017b, 2018c, 2019b). These low water levels are related to cessation of adequate flows over the barrages during spring, and when flows cease water levels drop by around 0.3 m (Webster 2010; Gibbs *et al.* 2018), exposing many of the plants to desiccation before they have reproduced (Paton *et al.* 2016b, 2016c, 2017b, 2018c, 2019b). Filamentous algae may also disrupt adult emergence of the salt-tolerant chironomid *Tanytarsus barbitarsis*, dampening subsequent densities of this species' aquatic larvae (Peters 2018), which are a key food resource for shorebirds in the southern Coorong (Paton *et al.* 2019a).

Key species at risk from these changes include migratory shorebirds that are listed on international agreements, namely Common Greenshank (*Tringa nebularia*) and the three, small, prominent species: Red-necked Stint (*Calidris ruficollis*), Sharp-tailed Sandpiper (*Calidris acuminata*) and Curlew Sandpiper (*Calidris ferruginea*). 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). Supporting these migratory species is considered a key 'service' of the site, as is supporting threatened waterbird species, such as the endangered piscivorous Fairy Tern (*Sternula nereis*) (DEWNR unpublished *in*

Brookes *et al.* 2018). Other species at risk in the southern Coorong include non-migratory shorebirds, such as Red-capped Plover (*Charadrius ruficapillus*), Banded Stilt (*Cladorhynchus leucocephalus*), Black-winged Stilt (*Himantopus himantopus*) and Red-necked Avocet (*Recurvirostra novaehollandiae*). Like the migratory shorebirds, when filamentous algae abound around the shores of the southern Coorong, the capacity of these birds to wade in shallow water searching for food is severely impeded. Other species likely to be affected are various herbivorous waterfowl, such as Chestnut Teal (*Anas castanea*) and potentially Black Swan (*Cygnus atratus*) (e.g., see Paton *et al.* 2019a). These species feed extensively on *R. tuberosa* in the southern Coorong. The 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 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).

The abundances of these eleven key waterbird species in the southern Coorong over the last six years is shown 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 2016 when the first extensive blooms of filamentous algae appeared). 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 abundances are not sustainable. Black Swans are of particular 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.

The poor ecological conditions in the southern Coorong are unlikely to change in the near future under current management and further deterioration in the conditions from a waterbird perspective seem likely for these key species. Urgent action is required to (a) prevent further declines of waterbirds and declines in the quality of 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.

Given constraints to water delivery to the Coorong from the River Murray and limited capacity to manipulate the southern Coorong habitat for a better waterbird outcome, the alternative is to build and manage other wetlands near the Coorong to provide at least some refuge habitat for these species, until the southern Coorong can be recovered, if it ever can be. To enable a network of wetlands to be established that can support key waterbird species of the Coorong in the broader landscape, research is required to:

(1) understand if and how existing wetlands in the broader landscape, including the Coorong, can provide suitable habitats for key species, particularly for a critical time period from late spring to late autumn when the Coorong acts as a refuge for waterbirds;
(2) identify and assess wetlands and areas where wetlands in the broader landscape could be constructed or manipulated in ways that would improve their capacity to support key species for critical time periods (an initial assessment is covered by Hunt *et al.* (2019)); and,
(3) determine whether birds unable to use the southern Coorong can locate and use any alternative habitats provided in the broader landscape.

This short four-month study begins to address the first of these research needs, with an initial assessment of the potential value of the managed wetlands of Tolderol Game Reserve (GR) in providing suitable habitat for key waterbirds species of the southern Coorong (Table 1). The key attribute that these managed wetlands needs to provide is suitable habitat, in which at least some of the key species of waterbirds are able to forage.

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 for Environment and Water and the Murray-Darling Basin Authority.

Species	Abundance of key waterbird species in different years					
	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

1.1 Tolderol Game Reserve

Tolderol GR is a wetland complex on the north-western shore of Lake Alexandrina, South Australia, and is within the boundary of the Coorong, Lakes Alexandrina and Albert Ramsar site. Established in the 1970s, Tolderol GR consists of a series of 19 artificial basins and interconnecting channels, as well as reed beds and protected waters within Lake Alexandrina (Figure 1). The artificial basins total 202 hectares (Table A 1, Appendix), have the potential to be managed and are the focus of this report.

Management of these basins is through the use of water pumped from Lake Alexandrina through a complex pathway of channels and access pipes between levee banks of adjacent basins (Figure 1; Oerman and Mason 2015). During the latter years of the Millennium drought none of the basins were watered because the water levels in Lake Alexandrina were too low to enable pumping. In addition, heavy restrictions to urban, irrigation and environmental water allocations due to lack of water availability across the Murray–Darling Basin made watering Tolderol GR untenable at these times. Substantial amounts of terrestrial vegetation established within many of the basins during this period when no water was being pumped.

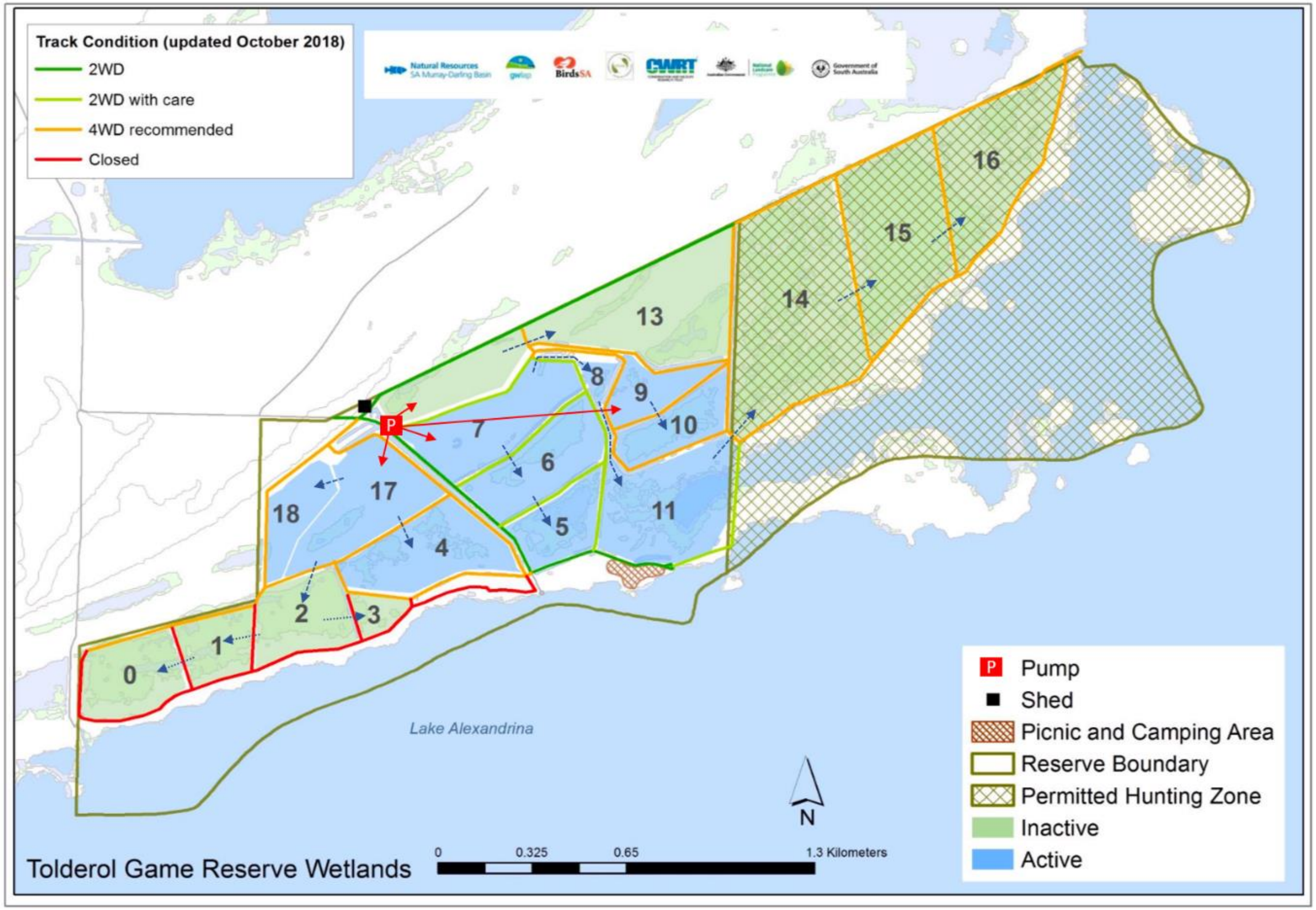

Figure 1. Map of Tolderol Game Reserve showing basin perimeters and numbering (Kate Mason, DEW, pers. comm., 2019). Flow path of water pumped from Lake Alexandrina is outlined in lines, with arrows indicating direction of water flow. Basins filled directly from the pump (and not through other basins), are shown in bold red arrows. Subsequent inter-basin water flow is indicated with blue dashed lines and arrows. Note that in addition to those basins indicated as active, basins 1 and 2 received their first water in spring 2018.

After more than six years without water, environmental watering recommenced at Tolderol GR in early November 2014, with water delivered to just three basins as part of a trial coordinated by Natural Resources South Australian Murray–Darling Basin and the Goolwa-Wellington Local Action Planning group and neighbouring landholders (Oerman and Mason 2015). These basins and some of the other basins have been watered annually since, but not all of the original 19 basins have received water since the Millennium drought.

The annual volumes of water pumped into the Tolderol GR basins since 2014 have ranged from 361 to 1124 ML (Table A 2, Appendix), depending on the number of basins being watered, seasonal conditions, and pump operability (i.e., pumping was not possible at times because the pump required repairs or maintenance). Currently, Tolderol GR's water licence permits an annual amount of 1030 ML. Additional volumes have been accounted for within the South Australian Government's environmental water reserve (Kate Mason, DEW, pers. comm., 2019).

The 19 basins vary in size and shape and each has some terrestrial (e.g. samphire) or emergent wetland vegetation (e.g. *Phragmites*). The floors of the 19 basins are also uneven such that when basins hold water, there are areas of deeper, as well as shallower, water.

Currently, Tolderol GR is managed by a team of committed volunteers, forming the Tolderol GR Wetlands Working Group. Apart from volunteering their time, the Working Group also frequently use their own vehicles and equipment in the management of Tolderol GR. In addition to these in-kind contributions from volunteers, operating costs include (a) electricity for pumping water, (b) pump maintenance and servicing, (c) plant hire for basin preparation and maintenance, and (d) channel maintenance to ensure water flow (Kate Mason, DEW, pers. comm., 2019).

The working group use their personal experiences and intimate knowledge of Tolderol GR to manage the basins in a way to achieve outcomes for shorebirds. This consists of managing the intrusion of vegetation (through ploughing or slashing basins when these are dry, grazing levee banks and dry basins with sheep, and burning *Phragmites australis* if required), and pumping water into one or more of the basins sometime in spring, and then allowing water levels to draw down over summer. No detailed records have been kept of when basins have been filled. Some of the basins are topped up with additional pumped water in summer or autumn before they dry out. Again, the details of these top-ups (dates, amounts) have not been recorded and there are no formal triggers in place for when a basin is topped up, or the extent of the top-up. However, none of the basins are permanently filled and they all dry out at some stage (or nearly so), usually during autumn, so all basins experience changes in water levels during the period that they hold water. In some cases, the only water present are temporary pools of water that form after rain events and these pools are more frequent in winter. Activities such as ploughing of particular basins are usually undertaken in spring once the floors of the basins have dried out sufficiently from winter rainfall to allow access for suitable machinery, and prior to any pumping in spring. Decisions about whether a basin is ploughed or not is largely left up to the volunteers that do the work. No basins were ploughed in 2018. Amongst the volunteers there is a general belief that ploughing the basins before filling them benefits waterbirds but there is no documented evidence to demonstrate any benefits.

A clear understanding of how different management actions influence waterbird use of Tolderol GR is required if this wetland system is to be used to maximise the amount of suitable habitat that is provided for waterbirds that are likely to be disadvantaged by a deteriorating southern Coorong. The initial steps in building that understanding includes carefully documenting the management actions that are implemented from now on, testing the benefits of different actions (e.g., ploughing, top-ups), while documenting changes in key habitat features and resources for waterbirds at Tolderol GR across the critical late spring to autumn period. At present there are constraints on how the different basins are watered. Although different series of basins can be watered independently, within each series of basins, one basin needs to be filled so that the next basin downstream can then be filled and so on (e.g., see Figure 1). Ideally, having the ability to manage each of the basins independently would provide the greatest ability to manage Tolderol for waterbird outcomes. Consideration should be given to how these constraints on filling cycles could be removed.

1.1.3 WATERBIRD USE OF TOLDEROL GR BASINS

The re-instatement of environmental watering at Tolderol GR following the Millenium drought began on 2 November 2014 and was treated as a trial, with a primary objective of assessing responses of migratory shorebirds to this watering event (Oerman and Mason 2015). About a month was required to fill the three interconnected basins (7, 6 and 5) which were then allowed to draw down with some topping up until 20 January 2015. The abundances of waterbirds using the basins of Tolderol GR were determined every 2-6 weeks during and after this watering. A total of 45 wetland-dependent bird species were observed (Oerman and Mason 2015). Although Whiskered Terns and some waterfowl used these basins in the first month, the use of the basins by migratory shorebirds was delayed until mid-late January 2015 when the water levels in the basins were sufficiently low to provide suitable mudflats covered by shallow water for these birds. Nine species of EPBC listed migratory shorebirds were recorded using Tolderol GR during the summer-autumn of 2014-15, including the three key small migratory shorebird species (Curlew Sandpiper, Sharp-tailed Sandpiper, and Red-necked Stint) of the southern Coorong. Of these three species, the most abundant was the Sharp-tailed Sandpiper, with around 4,000 counted on 18 January 2015 (Oerman & Mason 2015). This abundance is greater than 1% of their total estimated East-Asia Australasia Flyway population (Bamford *et al*. 2008). By 6 February 2015, however, the numbers of shorebirds present was substantially lower than on 18 January 2015, suggesting the suitability of the habitats being provided was short-lived, despite continuing to top up the basins into January. Thus although these findings are encouraging from the perspective of Tolderol GR being managed in a way that can support key species from the southern Coorong, if suitable habitat and food resources can only be provided for a short period of time, then the capacity of Tolderol GR to provision suitable habitat and food resources across the late-spring to autumn period may be limited.

Although these findings are encouraging, the individual basins at Tolderol GR may only be able to support migratory shorebirds for short periods of time. Thus a staggered watering program may be required where different basins are filled in turn to provide a succession of suitable habitat for the birds across the late-spring to autumn period.

To be an effective refuge habitat for waterbirds displaced from the southern Coorong, the basins at Tolderol GR need to provide suitable habitat and food resources for the birds across the late spring to autumn period, either individually or collectively. In this report we document the use of the basins at Tolderol GR by waterbirds from mid-February to mid-June 2019, with a focus on whether the birds were foraging within the basins. During the study, the only management actions involved pumping some additional water into some of the basins as they dried out, as is normally the case until early April (Oerman and Mason 2015, Kate Mason pers. comm. 2019). However due to a faulty timer key basins were overfilled in autumn 2019. Thus, the waterbird patterns we report may not be typical of other years.

1.2 Research aims

The primary aim of this short-term study was to assess the capacity of Tolderol GR to support key species of waterbirds disadvantaged by deteriorating conditions in the southern Coorong. The abundances, behaviour and food resources of waterbirds over a four-month period from mid-February to mid-June 2019 are used as a preliminary basis for assessing whether Tolderol GR provides suitable, productive, refuge habitats for a range of key species of waterbirds.

A secondary aim was to document the existing management levers (outlined above) that could be used to improve key waterbird outcomes, such that suitable trials could be established during spring 2019 with the aim of determined the benefits, if any, over the late spring-autumn period of 2019-2020.

2 Methods

The three field-based tasks for this work include: (a) five monthly censuses of the waterbird use of the Tolderol GR basins, (b) five monthly assessments of the behaviour of waterbirds to better document the extent to which various species were using Tolderol GR for foraging, and (c) initial measures of the food resources being provided within the basins.

2.1 Waterbird census of managed basins within Tolderol Game Reserve

To document the distribution and abundance of waterbirds using the 19 basins at Tolderol GR (Figure 1) each basin was visited in turn by at least two observers and waterbird counts were made from one of the levee banks using either binoculars (8-10x magnification), or spotting scopes (20-60x magnification). In addition to identifying and counting the birds, their activity was also classified to one of four categories (foraging, resting, flying, other) as per Paton *et al.* (2019). Observers moved between basins by vehicle. All counts were undertaken in the morning and typically took five hours to complete.

Of the 19 basins at Tolderol GR, seven basins were not operated (i.e. remained dry) in 2018-19 (basins 0, 3, 12, 13, 14, 15 and 16), while the other 12 basins contained water at some stage during the study. Water levels in these 12 basins were allowed to fall with some of these being topped up. In February and March 2019, these 12 basins contained water but by April basins 1 and 8 were dry, while basin 2 was dry by May. In May, the low water levels of basins 4 and 17 (connected) were topped up by pumping water from Lake Alexandrina. However, a malfunction of the pump's timing switch resulted in both basins being overfilled, as well as basins 8 and 9, resulting in little shorebird habitat being available in these basins. Winter rains provided damp or small areas of shallow waters in most of the other basins in June.

In conjunction with the counts of waterbirds, each of the basins was also scored qualitatively for the habitat features that were being provided, except for February 2019 because there was insufficient time. These qualitative assessments consisted of first recording if the basins were dry, damp or contained water. Second, the area of different types of habitat were scored for the margins of each basin and for the centre of each basin separately. To do this, the percent of the margins of each basin and the centre of each basin that consisted of different habitat features were estimated. The different habitat features were reeds, grass, low terrestrial vegetation (e.g., samphire and other ground covers), other terrestrial vegetation (e.g., lignum and tea-tree), algal mats, mud flats (with or without low terrestrial vegetation), and open water. For example, on the 18th March 2019, Basin 6 was given an edge habitat assessment of 60% grass and 40% reeds, and a centre habitat assessment of 40% open water, 30% algal mats, 15% mud flats with low terrestrial vegetation, and 15% low terrestrial vegetation.

2.2 Behavioural surveys of waterbirds within Tolderol Game Reserve

The census of waterbirds provides an instantaneous count of bird use in each of the basins at Tolderol GR, but as such may not provide a good measure of the extent to which Tolderol GR is being used for foraging. To better document the behaviour of the birds using Tolderol GR we recorded the behaviour of birds repeatedly from dawn to dusk on one day in each month for one basin. This involved counting the number of waterbirds of each species that were undertaking one of four activities (foraging, resting, flying, other), at intervals of 2-3 minutes for 2-3 hours, and repeating these observations for up to five three-hour periods of the day (0600-0900; 0900-1200; 1200-1500; 1500-1800; 1800-2100). This provided a minimum of 30, and usually 40, counts within each of these periods. However, as winter approached, the periods and counts within periods were adjusted to accommodate shorter day lengths. Two to three observers were needed to complete the counts depending on the numbers of each species that were present in the observation area. This methodology is based on Paton *et al.* (2019). Only a single basin (or part of a large basin) could be observed at a time. The basin (or part of a basin) chosen coincided with the basin that had the highest abundances of small, migratory waders. Where only part of a basin could be observed, the area that was observed was recorded on scaled maps. These repeated scans on the behaviour of the birds were used to confirm that the birds present at Tolderol GR were frequently using the basins for foraging. To be an effective alternative habitat for the southern Coorong, Tolderol GR must provide suitable foraging opportunities for at least some of the key species likely to be disadvantaged by poor foraging conditions in the southern Coorong. If the birds using Tolderol GR are frequently detected foraging then Tolderol GR can be considered to be an effective alternative habitat.

In conjunction with the behavioural scans, an additional observer recorded the water depths and substrates used by the birds when foraging, as well as pecking rates, and rates of minimum prey capture. In many cases, the prey being taken were too small for an observer to detect. When birds were foraging, the distance from the shoreline (either above or below the shoreline) was estimated to within one metre if close to the water line, or to the nearest five metres if distant (>10 m) from the waterline. In addition, for those birds feeding in water, the water depths were estimated relative to the lengths of the birds' legs, for example, ankle, knee or thigh deep. Those birds that were foraging in open water were noted as swimming and for those birds feeding away from the water's edge, the substrate on which they were foraging was also recorded, such as damp mud or pasture. To estimate pecking rates, the time to complete up to 10 foraging manoeuvres (pecks) was timed with a stopwatch. The approximate distances that the birds travelled while completing those pecks were also recorded to the nearest 5-10 cm, based on the known lengths of the birds. When prey captures were observed (usually detected as obvious swallowing after one or more pecks), the minimum numbers of prey collected (i.e., swallows) during those timings were also recorded. For some records, the substrates from which food were taken were also noted to help discern the type of prey being taken, e.g., within the water column or from the surface of the mud. The three migratory shorebird species that are the focus of this study (Curlew Sandpiper, Sharp-tailed Sandpiper, Red-necked Stint) were targeted for pecking rates. Data for these three shorebird species and for Black-winged Stilt and Red-capped Plover (two non-migratory shorebird species that are also key species of the Coorong, for which there were sufficient data) are provided in this report.

A widely used method for assessing and comparing the quality of habitats used by shorebirds is to document food intake rates of birds using different wetlands, or different components of a wetland (e.g., Piersma *et al.* 1993; Masero 2003). However, to do this requires that the prey items are relatively large, such that an observer can count the number being caught, handled and swallowed, or when only a single species of prey is available the swallowing actions are visible to an observer and can be counted. When the prey items are too small to be seen being swallowed and could consist of multiple species (as was the case at Tolderol GR), then documenting rates of food intake are not possible. Pecking behaviour and rates of pecking by shorebirds are likely to vary with changes in the type of prey, the size of prey, the density of prey, with the ease with which prey can be detected, whether tactile or visual methods of detection are being used, and with the nature of the substrates in or on which the birds are foraging. In this technical report, we provide data on pecking rates to allow an initial discussion of aspects of the foraging behaviours of the birds and the likely food resources being exploited.

The inability to measure food intake rates limits our ability to assess the quality of the foraging opportunities being provided at Tolderol GR. A possible alternative is to use the amount of time a bird allocates to foraging. Studies on other birds, notably honeyeaters, show that they increase the amount of daytime that they allocate to foraging when food resources are poorer and more difficult to collect (e.g., Paton 1982, 1985). Other species, including shorebirds, also adjust the time they allocate to foraging, reducing the time when resources are more easily harvested (e.g., Masero 2003). This method then may allow an initial assessment of the quality of an area from a foraging perspective when the other techniques are not possible. Essentially the method integrates the many factors that influence the ability of a bird to secure the food they require without having to measure all of the components that influence rates of food intake. Although further work is required to confirm the strength of the relationship between the quality of foraging habitats and time allocated to foraging for shorebirds, we nevertheless, present data on the amounts of time being allocated to foraging by birds at Tolderol GR and discuss the implications of these.

2.3 Food resource assessment within Tolderol Game Reserve basins

2.3.1 ASSESSING MACROINVERTEBRATE ABUNDANCE

Macroinvertebrates found on and just below the surface of wetland mud flats are a key food resource for many shorebirds. Abundances of macroinvertebrates were assessed by taking two to three sets of 10 core samples (core size 7.5 cm ø, 4 cm deep), targeting areas within each of two basins where shorebirds were foraging. Locations of each set of samples were recorded using a handheld GPS and the water depths of each sampling location were recorded to the nearest centimetre (ranging from <1 cm to 10 cm). Initial sampling in February was used to determine the number of samples needed to provide a reasonable estimate of prey abundances and applied to assess food resources in each of the subsequent months of the study. The mud samples collected from the corer were sifted *in situ* through an Endecott sieve (500 µm mesh size), and the abundance and approximate lengths of chironomid larvae were recorded. This sampling will only record the latter, larger instars of chironomids. This sampling also detected other prey, including crustaceans (e.g., amphipods), water beetles, dipteran and other larvae. Voucher specimens were collected in February, April and June and identified under a microscope to order level.

Further, some free-swimming macroinvertebrates found within the microinvertebrate samples (see Section 2.3.2) were identified under a microscope.

2.3.2 ASSESSING MICROINVERTEBRATE ABUNDANCES AND SPECIES COMPOSITION

Two assessments of microinvertebrate abundances and species composition were conducted during this study, one in February and one in March. In February, five basins were assessed (1, 2, 4, 17 and 18; Figure 1), while in March only three basins were assessed (2, 17 and 18), as the water level at Basins 1 and 4 were in the final stages of drying out and were too shallow to sample. Furthermore, monthly sampling of microinvertebrates in these basins in April was not possible because water levels were then too low. For February and March, each sample was generated using a 12-volt bilge pump, where between 5 and 20 L was transferred to a drum. The total volume of each sample was then concentrated to approximately 50 mL by filtering through a 50 µm net. Concentrated samples were then transferred to a 200 mL PET jar and preserved with 70% ethanol. Quantitative samples were inverted three times to evenly mix and suspend material and a 1 mL sub-sample transferred into a pyrex gridded Sedgewick-Rafter cell. The entire sub-sample was counted, and microinvertebrates identified using a Leica compound microscope. The average number of microinvertebrates were calculated and expressed as numbers of individuals per litre (ind.L^{-1}).

3 Results and preliminary discussion

3.1 Waterbird use of artificial basins at Tolderol Game Reserve from February to June 2019

A total of 40 waterbird species were detected across the five censuses conducted monthly between February and June 2019 (Table 2). Of the 40 species, eight were EPBC-listed migratory shorebird species and four of these have historically been prominent in the southern Coorong (Red-necked Stint, Curlew Sandpiper, Sharp-tailed Sandpiper and Common Greenshank). In addition, several non-migratory shorebird species that have declined in the Coorong were also present, including Red-capped Plover, Red-necked Avocet and Black-winged Stilt. The numbers of each of these species were generally small relative to what the Coorong has supported in the past (Paton *et al.* 2019a). Total abundances of all species varied from 3674 in February 2019 to 1436 in May 2019, with only one species present in numbers exceeding a thousand individuals in any one month (Grey Teal in March 2019; Table 2). For the four key migratory shorebirds, the maximum numbers in any month were 565 Red-necked Stints, 404 Sharp-tailed Sandpipers, 199 Curlew Sandpipers and 5 Common Greenshanks. Similarly, the maximum recorded abundances for the three key non-migratory shorebird species that were using the basins of Tolderol GR were 174, 114 and 51 for Black-winged Stilt, Red-capped Plover and Red-necked Avocet, respectively. Small numbers of largely fish-eating species were detected in the basins (Table 2) but were predominantly roosting (see Section 3.2). The numbers of most species fluctuated but in general declined across the five months of sampling, with the exception being Pink-eared Duck (Table 2). Declines of migratory shorebirds across this period were expected, since they depart for their breeding grounds in the northern hemisphere during autumn, although some individuals may remain through the southern winter.

Most species of waterbirds were using several and up to nine of the artificial basins at Tolderol GR during any one of the monthly counts. Basins 4, 5, 10 and 17 were generally used by more waterbirds followed by basins 2, 7 and 9. In general, this use was associated with the provision of suitable habitats for foraging and roosting within the basins, with the relative availability of different habitat features varying between basins and within basins over time (

Algal Mat | Dirt | Grass | Low Terrestrial Vegetation
Mud | Mud + Low Terrestrial Vegetation | Mud + Other Terrestrial Vegetation | Other Terrestrial Vegetation
Open Water | Reeds

Figure 2), in concert with changes in water levels. Dry basins were rarely being used, and if used, only used by a few birds (<5 individuals) and typically for roosting.

For the shorebirds that foraged primarily around the margins of the basins, there were also shifts in the nature of the food resources that they were exploiting. In February and March, shorebirds were foraging on damp mudflats and over mudflats covered with shallow water, primarily taking chironomid larvae from the sediment surface and aquatic invertebrates, such as small, 1-2 mm Hemiptera (in densities of at least 30 per 100 cm^2 surface area), from within the water column. By April, the abundances of these food resources had declined (e.g., Table 3). However, Dipteran larvae were present in April (identified from voucher specimens), ranging in size from 10-15 mm. In May, shorebirds were foraging on the mud surface and in the water column. Dipteran larvae were still prominent but much smaller, around 2-4 mm in length. Tiny flying insects (1-2 mm in length) were also present on the sediment and water surface (estimated at 20 insects per 100 cm^2) and Red-necked Stints were feeding on these in May.

Table 2: Abundance of waterbirds counted in Tolderol GR in each month from February to June 2019. The number of basins used by each species in each month is given in parentheses, while details of species per basin per month can be found in Tables A 3 to A 7 (see Appendix). The status of waterbird species under the State National Parks Wildlife (NPW) Act (SA), the Environment Protection Biodiversity and Conservation (EPBC) Act and the International Union for Conservation of Nature (IUCN) are also provided.

Species	Status* (SA, EPBC, IUCN)	Abundances in different months (number of basins used)				
		February	March	April	May	June
Black Swan		180 (5)	100 (4)	12 (2)	12 (2)	33 (3)
Australian Shelduck		5 (3)	42 (3)	13 (1)		
Pink-eared Duck		35 (1)	37 (1)	89 (1)	267 (2)	491 (2)
Australasian Shoveler	RA	29 (3)	5 (1)	32 (4)	36 (1)	3 (1)
Grey Teal		832 (6)	1130 (9)	912 (8)	546 (3)	664 (4)
Chestnut Teal			16 (2)	25 (3)	10 (1)	16 (2)
Pacific Black Duck		59 (4)	135 (8)	15 (4)	3 (1)	5 (1)
Hoary-headed Grebe		3 (2)	20 (3)	30 (2)	16 (3)	4 (3)
Little Pied Cormorant		2 (2)	2 (2)			1 (1)
Great Cormorant			1 (1)	2 (2)	68 (1)	
Australian Pelican		15 (5)	8 (2)	5 (3)	5 (2)	
Silver Gull		4 (3)	11 (1)	1 (1)		
Caspian Tern		60 (3)	17 (2)	32 (1)	19 (1)	10 (1)
Whiskered Tern		159 (11)	282 (6)	15 (1)		
Crested Tern		100 (2)	72 (2)	5 (1)	3 (1)	11 (1)
White-faced Heron		37 (8)	9 (5)	14 (6)	2 (2)	3 (3)
Australian White Ibis		50 (9)	33 (8)	11 (4)		
Straw-necked Ibis		12 (2)				
Glossy Ibis		14 (1)				
Royal Spoonbill		11 (6)	8 (6)	12 (3)	2 (1)	
Yellow-billed Spoonbill		12 (2)	1 (1)	19 (4)	2 (1)	4 (1)
Australian Spotted Crake		4 (2)		2 (2)		2 (1)
Spotless Crake						2 (1)
Eurasian Coot		42 (1)	89 (1)	23 (1)		
Black -tailed Native Hen		209 (6)	203 (5)	107 (5)	42 (3)	44 (2)
Purple Swamphen		43 (8)	70 (8)	54 (7)	27 (3)	31 (4)
Black-winged Stilt		68 (6)	174 (10)	148 (10)	58 (6)	118 (8)
Red-necked Avocet			14 (1)			51 (1)
Pacific Golden Plover	MIG		9 (1)			
Red-capped Plover		99 (3)	114 (3)	68 (4)	107 (2)	26 (3)
Red-kneed Dotterel		22 (4)	65 (4)	140 (9)	76 (3)	104 (5)
Black-fronted Dotterel				8 (1)	22 (2)	16 (3)
Masked Lapwing		53 (5)	41 (9)	55 (7)	15 (3)	15 (5)
Black-tailed Godwit	RA, MIG, NT					1 (1)
Common Greenshank	MIG	5 (4)	3 (1)	3 (2)	3 (2)	
Marsh Sandpiper	MIG	11 (4)	13 (4)	6 (4)		2 (2)
Wood Sandpiper	RA, MIG			7 (4)		
Red-necked Stint	MIG, NT	25 (3)	565 (8)	210 (6)	92 (3)	143 (2)
Sharp-tailed Sandpiper	MIG	404 (6)	186 (6)	73 (6)	3 (1)	27 (4)
Curlew Sandpiper	MIG, CR, NT	136 (2)	199 (4)	10 (1)		11 (1)
Grand Total		**2740**	**3674**	**2158**	**1436**	**1836**

*State NPW Act listed species where RA = Rare; EPBC listed species where CR = critically endangered and MIG = Migratory; IUCN-listed species where NT = Near-threatened

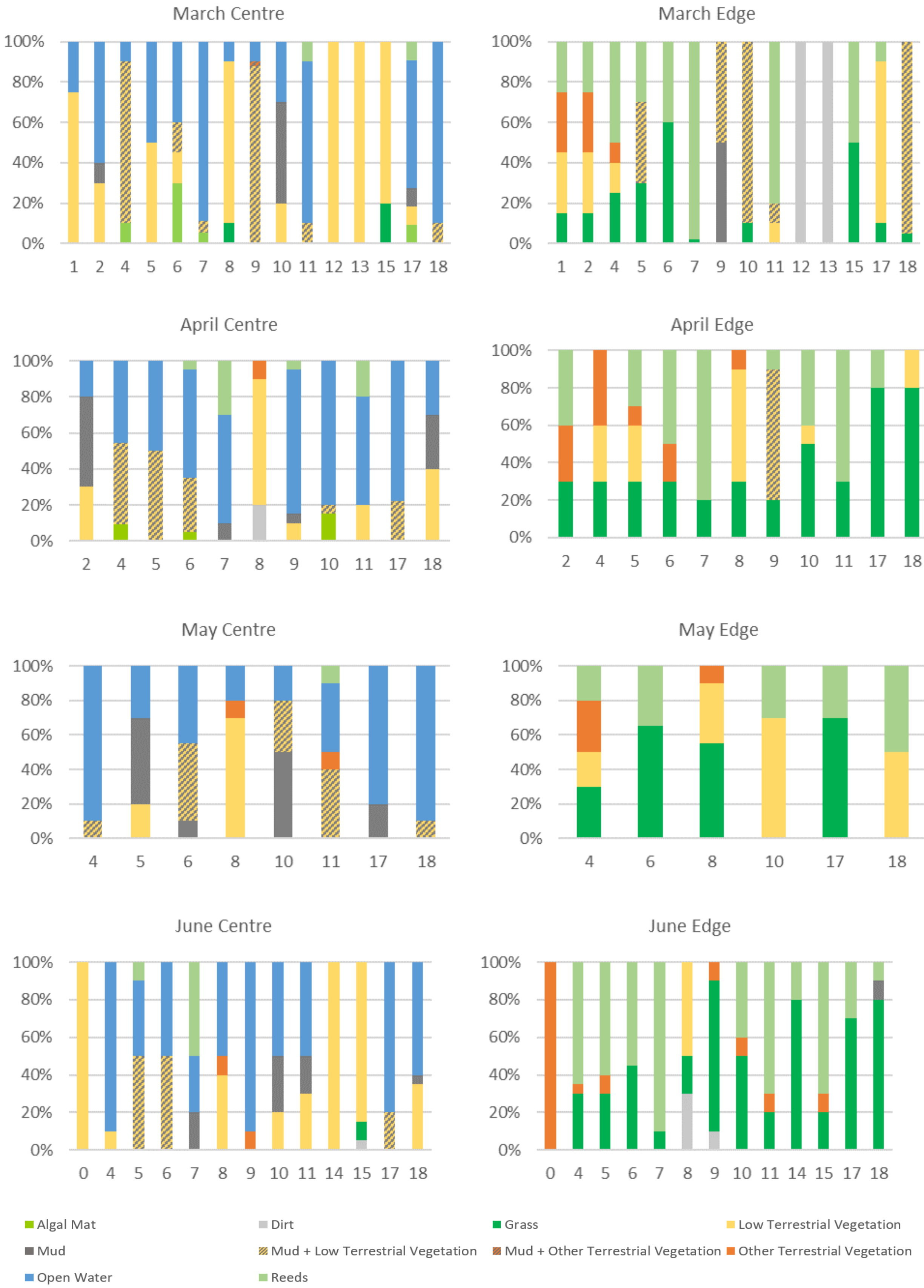

Figure 2. The habitat composition of the Tolderol GR basin centres and edges (as a percent) for March, April, May and June 2019 for those basins which had waterbirds using them during each of the respective monthly censuses. Basin numbers are indicated along the x-axis of each graph.

3.2 Food resources and micro-organism productivity of selected Tolderol Game Reserve basins

3.2.1 MEASURES OF FOOD RESOURCES FOR MARCH TO JUNE

Chironomid larvae were prominent in February (not measured) and March and declined dramatically from March onwards (Table 3). Abundances of chironomid larvae in March were substantially higher than in the southern Coorong in January 2019 (and most of the previous years), where the maximum average abundance for any site did not exceed 3.3 chironomids per core (Paton *et al.* 2019a). Within the basins at Tolderol GR, there was marked variation in the abundances of chironomid larvae, for example in Basin 17 in March, the three separate areas sampled produced average abundances of 4.8, 17.2 and 15.3 chironomids per core.

Table 3: Mean number of chironomid larvae (± standard error) per core (core size 7.5 cm ø, 4cm deep) from 20-30 cores taken in each basin from March to June 2019 at Tolderol GR. To convert these data to numbers per m^2 multiply by 226. There was a significant seasonal reduction in abundances (ANOVA, p<0.001).

	March	April	May	June
Basin 9	4.7 ± 1.0			
Basin 17	12.4 ± 1.8			
Basin 2		0.8 ± 0.2		
Basin 10		0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Basin 6			0.5 ± 0.2	0.0 ± 0.0

3.2.2 MICROINVERTEBRATES

In February, total microinvertebrate density varied from being relatively low in Basin 17 (2178 ind.L^{-1}) to extremely high in Basins 1 and 2 (10,803 and 11,112 ind.L^{-1}, respectively; Table 4). In March, total microinvertebrate density had decreased considerably in Basins 2 and 18 and increased in Basin 17 (Table 4). Basins 1 and 4 had dried to such an extent in March that they could not be sampled. The assemblage structure was very similar between basins and between February and March, with the primary genera of rotifer present being pelagic *Brachionus*, *Keratella* and *Polyarthra* taxa and abundant communities of cyclapoid copepods, benthic harpacticoid copepods and copepod nauplii (Figure 3).

Table 4: Summary of the average total density of microinvertebrates per litre (ind.L-1) (± standard deviation) including rotifers, cladocerans, copepods and ostracods at each basin sampled in February and March 2019.

	February	March
Basin 1	10,803 (±1388)	-
Basin 2	11,112 (±1544)	3747 (±1252)
Basin 4	4428 (±2030)	-
Basin 17	2178 (±733)	8105 (±7107)
Basin 18	7492 (±4159)	181 (±65)

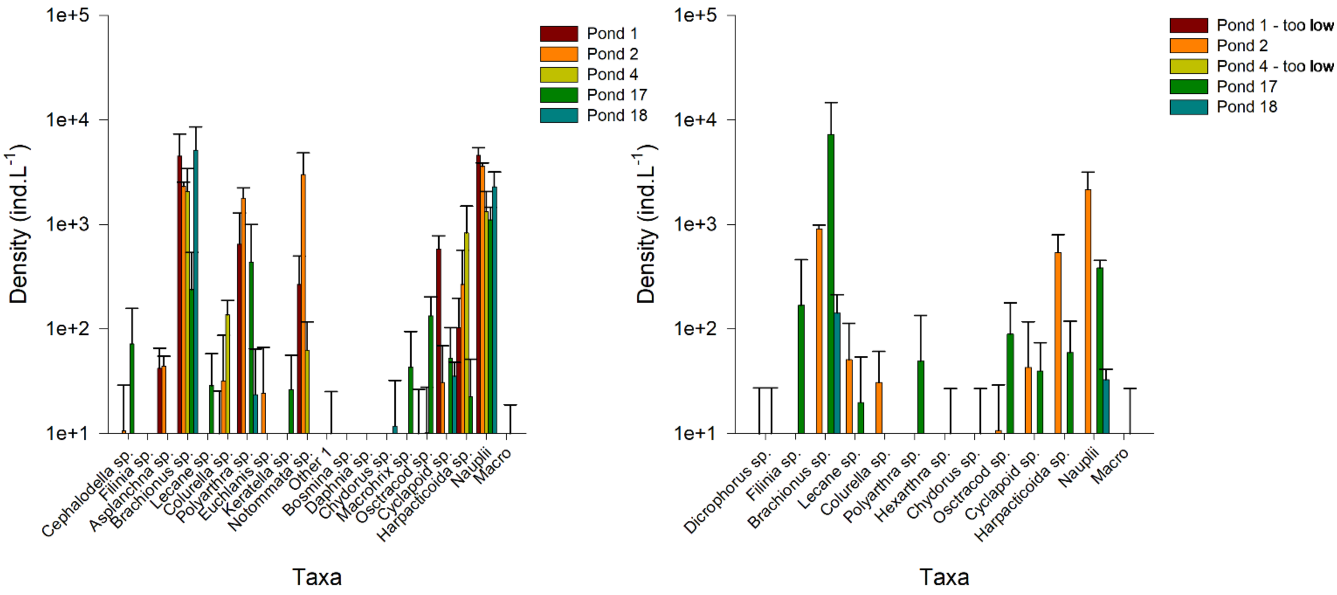

Figure 3. Average total density of microinvertebrate taxa (± standard deviation) including rotifers, cladocerans, copepods and ostracods at each basin sampled in February and March 2019.

A significant proportion of microinvertebrate productivity within the basins was due to high densities of benthic harpacticoid copepods. There are a number of reasons that are likely to be contributing to these productive communities. First, harpacticoid copepods live out the majority of their lives on the sediments. The large shallow ponds at Tolderol GR create a much higher ratio of benthic to pelagic habitat in comparison to what would commonly occur in lakes and wetlands, increasing the dominance of these benthic over pelagic organisms. Additionally, the undulating substratum throughout the ponds (potentially enhanced by ploughing) provide a highly heterogeneous substrate, a feature of habitats found to support larger populations due to its relationship with greater surface area (e.g., Hicks, 1980). Additionally, due to the high biomass of terrestrial and aquatic vegetation that occurs throughout the ponds, the sediment is expected to be high in organic material providing an abundance of food as many harpacticoids feed on the detritus and/or the associated bacteria (e.g., Perlmutter & Meyer, 1991; Ustach, 1982). Furthermore, these benthic organisms can then become suspended in the water column due to hydrological mixing (Lancaster & Robertson, 1995; Menéndez *et al.*, 2012). Due to the shallow nature of the Tolderol ponds, combined with the persistent winds that occur throughout the area, mixing is likely to occur frequently. Once suspended in the open water, harpacticoid copepods are likely to become highly visible to predators and have limited ability to escape, as they are not morphologically designed for this environment. As these organisms can synthesise several nutritionally important essential fatty acids, they are thought to be a desirable food item for higher trophic organisms (e.g., Olivotto *et al.* 2008).

In addition to harpacticoid copepods, cyclopoid copepods also made up a significant proportion of the microinvertebrate community with the Tolderol ponds. Unlike harpacticoid copepods, cyclopoid copepods spend most of their lifecycle suspended in the water column and can occur in both littoral and pelagic habitats. It is not uncommon for them to occur in higher densities and have higher species richness in littoral habitats (e.g., Walseng *et al.* 2006), as vegetation can provide protection from predators and a more stable environment in areas prone to strong winds (Bergström *et al.* 2000). Both the terrestrial and the aquatic vegetation present throughout the Tolderol GR basins may be important in sustaining these communities. In addition to the presence or absence of vegetation, one of the key factors known to affect microinvertebrate populations is water residence time. Water residence time commonly has a strong positive relationship with microinvertebrate abundance and biomass and results in a shift from rotifer to cladoceran to copepod dominated communities (e.g., Baranyi *et al.* 2002; Basu & Pick 1996; Obertegger *et al.* 2007). The absence of high densities of cladocerans, in addition to the high densities of cyclopoid copepods and the high total microinvertebrate densities suggest that these communities were either at a late successional stage or that the cladocerans were being heavily predated upon. To fully understand the patterns, a full wetting and drying cycle needs to be followed. This was not possible in this short-term study.

3.3 Foraging activity of waterbirds at Tolderol Game Reserve from February to June 2019

3.3.1 FORAGING EFFORT

Between 26 and 50 percent of the small key species of shorebirds when counted in February during a census were foraging (Table 5), and consistent with this, these small shorebirds were allocating 7 to 22 percent of the day to foraging in February during all-day observations (Table 6). This indicates that, at this time, suitable foraging habitats were provided with abundant food resources that enabled the birds to spend extended periods of the day resting. In the Coorong, most shorebirds when counted during a census were foraging and, during all-day observations, allocated more than 80% of their time to foraging (Paton *et al.* 2019). Consequently, these data suggest that, for these shorebirds, the artificial wetlands at Tolderol GR can at times provide foraging opportunities that are better than those being provided in the Coorong in January under current conditions.

Table 5: Percentage of birds that were foraging when detected and counted as part of each monthly Tolderol GR bird census for February to June 2019, for species where counts of total birds were 100 or more in any one census.

	Percentage of birds that were foraging in different months				
Species	February	March	April	May	June
Black Swan	82				
Pink-Eared Duck				90	4
Grey Teal	10	27	32	8	34
Pacific Black Duck		20			
Whiskered Tern	47	6			
Black-tailed Native Hen	52	97	64		
Black-winged Stilt		98	99		84
Red-capped Plover		61		93	
Red-kneed Dotterel			90		82
Red-necked Stint		85	90		97
Sharp-tailed Sandpiper	50	66			
Curlew Sandpiper	26	100			

Table 6: Percentage of birds that were foraging over the course of a day at Tolderol GR from February to June 2019, for species where counts of total birds were 100 or more over the course of the day at a particular basin for each month, as indicated in the table.

Species	Percentage of birds that were foraging in different months				
	February (Basin 4)	March (Basin 17)	April (Basin 2)	May (Basin 6)	June (Basin 10)
Black Swan	48	86			
Pink-eared Duck	64				
Australasian Shoveler		83			
Grey Teal	28	35	96		69
Chestnut Teal		59			
Pacific Black Duck		57			
Australian Pelican	0				
Caspian Tern		0			
Whiskered Tern	4	0			
Crested Tern		0			
Australian White Ibis		100			
Royal Spoonbill		90			
Yellow-billed Spoonbill		100			
Purple Swamphen	96	92		91	
Black-tailed Native Hen					55
Black-winged Stilt	50	44	96	99	
Pacific Golden Plover	24				
Red-capped Plover	46				76
Red-kneed Dotterel	2	40		81	81
Black-fronted Dotterel			65		
Masked Lapwing	0	55	40		
Common Greenshank	94	72			
Marsh Sandpiper	87		96		
Wood Sandpiper			82		
Red-necked Stint	7	89*	87	95	88
Sharp-tailed Sandpiper	22	84*	84	90	
Curlew Sandpiper		95*			

* over-estimate, as relatively large numbers of shorebirds were resting for considerable parts of the day elsewhere in that basin (which was not part of the observation area)

In subsequent months, with reduced day lengths, the percent of time spent foraging for shorebirds was higher (Table 5 and Table 6) and similar to those in the Coorong in recent years. However, in March, the birds in the area of the basin being observed at Tolderol GR were foraging, but, elsewhere in that basin (which was not part of the observation area), relatively large numbers of shorebirds were resting for considerable parts of the day. This suggests that, in March, Tolderol GR may have provided as good, if not better, foraging opportunities for these shorebirds than the Coorong has in recent years. However, from April onwards, few shorebirds birds were observed roosting elsewhere at Tolderol GR, consistent with the reduction in both the numbers and sizes of food items (see Section 3.2) and in day length. Importantly the basins being used by the majority of small shorebirds in each month changed. This suggests that the relative suitability of each of the basins changes through time, with basins only providing suitable foraging opportunities temporarily.

The larger, migratory Common Greenshank and Marsh Sandpiper allocated substantial time to foraging in February and March or April (Table 6). These birds were foraging in deeper water and on different resources to the smaller shorebirds. Tolderol GR may not have provided these birds with the foraging opportunities that were as good as those being provided for the smaller shorebirds.

Some care is required in interpreting the time allocated to foraging for all species without information on the food resources being used by different species and at different times. For ducks and swans, use of different resources (aquatic plant versus aquatic animal) may account for the differences shown in their times allocated to foraging, while some of the fish-eating species (e.g., Australian Pelican) were primarily resting in the ponds but foraging in the adjacent Lake Alexandrina. Furthermore, the data summarised in Table 5 is a snapshot across all the basins, while data summarised in Table 6 includes data at a finer, temporal scale but for a selected part of Tolderol GR. Differences between the statistics shown in those tables may be due to the nature of the sampling.

3.3.2 FORAGING LOCATIONS AND DEPTHS

The key shorebird species that were detected using Tolderol GR during autumn foraged primarily around the margins of the basins and on mudflats that were either damp or covered by water that was typically much less than 5 cm in depth, except for the longer-legged Black-winged Stilt that foraged in water up to 10 cm in depth (Table 7). Thus, the provision of mudflats covered by shallow water is the primary habitat feature required to support most of the key shorebird species. Individual shorebird species did not have a fixed water depth preference when using Tolderol GR, as most shifted the water depths of their foraging across the five-month period (Table 7). For example, Red-necked Stint largely foraged in water at least 0.1 cm deep in February and March, while in April and May foraging was primarily on damp mud surfaces and by June the birds were once again foraging predominantly on mud flats covered by shallow water. Other species showed similar patterns of shifting the depths at which they foraged over the season. Those shifts in foraging sites and depths are consistent with shifts in the types and locations of prey that were available in any month for the birds to take.

3.3.3 PECKING RATES

The number of pecks that key shorebird species made per minute also varied seasonally, being lower in February and March than later in the year (Table 8). This is likely to reflect differences in both the availability and the sizes of food resources being exploited. For example, lower pecking rates in February and March are likely to indicate larger prey were being taken, while the higher pecking rates of around two pecks per second in May and June are likely to indicate that minute prey were being taken. However, these high pecking rates may indicate harvesting of biofilms (see Kuwae *et al.* 2012) and require further study. As the types, distribution and abundance of prey varied across the season at Tolderol GR and the actual food being taken by foraging birds was often hard to discern, pecking rates cannot be used as measures of food intake rates without further work.

Table 7: Percentage of waterbirds foraging at different water depths over an entire day for each of the five months from February to June 2019 for key species at Tolderol GR. Water depths are based on the bird's leg lengths. The numbers highlighted in pale blue with white text are the total number of birds for each species for each month on which the data is based.

		Percentage of birds that were foraging in different months				
Species	Water depth (cm)	February	March	April	May	June
Curlew Sandpiper		1	1101			
	0.9		13			
	1.7		26			
	3.3	100	32			
	4.9		18			
	6.5		13			
Red-necked Stint		141	752	395	391	504
	0	3	28	88	95	37
	0.1	71	25	8	5	63
	1.05	26	17	4		
	2.1		31			
Sharp-tailed Sandpiper		249	299	79	50	
	0	4	9	43	10	
	0.2	35	48	30	66	
	1.5	45	35	6		
	3	16	8	3	24	
	4.3			18		
Black-winged Stilt		785	161	88	44	1
	0			2	5	
	0.5	42	33	98	80	100
	6	46	57		16	
	12	12	11			
Red-capped Plover		177				248
	0	13				89
	0.3	33				11
	1.4	54				

Table 8: Average pecking rates expressed as pecks per minute ± standard error, with sample size indicated in brackets, for select species for February through June 2019 at Tolderol GR.

Species	Average pecking rate (pecks per minute) ± SE in different months				
	February	March	April	May	June
Curlew Sandpiper	54.8 ± 2.5 (19)	56.0 ± 3.0 (36)			
Red-necked Stint	59.2 ± 5.3 (30)	60.8 ± 3.8 (34)	96.3 ± 3.2 (120)	153.0 ± 6.6 (110)	105.1 ± 3.5 (109)
Sharp-tailed Sandpiper	39.4 ± 4.0 (33)	39.4 ± 2.2 (16)	60.7 ± 3.2 (37)	115.3 ± 7.0 (30)	
Black-winged Stilt	14.6 ± 1.2 (18)	31.2 ± 4.8 (10)	50.5 ± 4.2 (5)		
Red-capped Plover	43.3 ± 12.4 (4)				41.9 ± 1.8 (6)

4 Discussion

Tolderol GR supported modest numbers of a diversity of waterbird species during autumn 2019, including some of the species likely to be disadvantaged by deteriorating conditions in the southern Coorong, namely Curlew Sandpiper, Sharp-tailed Sandpiper, Red-necked Stint, Red-capped Plover and Black-winged Stilt (Paton *et al.* 2019; Table 1). This provides evidence that constructed wetlands can be managed in ways to provide foraging opportunities for key waterbird species and is consistent with the fact that constructed wetlands, from sewage ponds to salt evaporation pans, are well known globally for their capacity to provide waterbird habitat (e.g., Brusati *et al*. 2001; Lehnen and Krementz 2013; Orlowski 2013; Green *et al.* 2015; Lei *et al.* 2018). In some cases, these artificial wetlands provide better foraging outcomes for some species of shorebirds than adjacent natural tidal mudflats (Masero 2003).

The preliminary surveys undertaken in this study are likely to underestimate the extent of use of Tolderol GR, since, during autumn, most of the migratory shorebirds depart for the northern hemisphere to breed. Thus, their numbers may have already diminished before the counts commenced in late February, with substantially more shorebirds using Tolderol GR during summer. In fact, in January of the previous year, 2400 Curlew Sandpipers and over 4000 Sharp-tailed Sandpipers were using Tolderol GR (Peter Koch, Tolderol GR Wetlands Working Group, pers. comm., 2019), the latter being in excess of 1% of the global population (Bamford *et al.* 2008). Consequently, surveys at other times of the year, but particularly over summer, would likely reveal greater use of Tolderol GR than during this study. Therefore, the observations made in this study should be placed in that seasonal context. Nevertheless, the numbers of some of the shorebird species using Tolderol GR in autumn 2019 compared favourably to the numbers detected in the southern Coorong in January 2019. For example, the numbers of critically endangered Curlew Sandpipers using the artificial basins of Tolderol GR were relatively high, with up to 434 birds, compared to 199 birds in the southern Coorong in January 2019 (Table 1).

Not all the basins at Tolderol GR are operational at present (Figure 1) and thus there is considerable potential to significantly expand (approximately double) the area of suitable wetland habitat. The expectation is that management of these other basins will attract and support birds additional to those being supported currently. Furthermore, there is scope to upgrade and modify some of the infrastructure (pumps, channels) to allow individual basins to be watered independently of other basins. More efficient and effective management of all the basins at Tolderol GR should allow more areas of suitable habitat to be provided at one time. Furthermore, with knowledge of the conditions that favour key food sources for shorebirds, such as chironomids, potentially better-quality habitats and a succession of suitable habitats can be provided over summer and into autumn. This will further enhance the capacity of Tolderol GR to support the birds of greatest concern. From a small shorebird perspective, the key habitats to provide are damp mudflats and areas of mudflat covered with shallow water (<5 cm deep; Table 7 and Paton 2010). The current management of Tolderol GR involves pumping water into basins and then allowing water levels to drop through evaporation. As the water recedes, mudflats around the margins of each basin are gradually exposed, providing the birds with suitable substrates to search for food. The challenge will be to stagger the times when different basins are filled and allowed to draw-down. This is not possible with the current infrastructure, but upgrading the infrastructure would allow more of the basins at Tolderol GR to be filled independently and more efficient, effective and responsive management to maximise the waterbird outcomes.

Despite the extent to which some small shorebirds used Tolderol GR, some other key species were not detected or were detected only in small numbers, for example Banded Stilt, Red-necked Avocet, Common Greenshank and Chestnut Teal. This suggests that not all key species benefit from current wetland management at Tolderol GR. With more knowledge of the food resources used by these species and how to deliver them, one or more of the basins at Tolderol GR could be managed to help support them. Thus, a mosaic of habitat features and food resources could be provided at Tolderol GR to cater for a wider diversity of waterbirds. Alternatively, other wetland systems could be managed to provide resources for some of these species, delivering a mosaic of suitable habitats over a broader spatial scale. Elsewhere, the varied habitat characteristics of multiple restored sites allowed different shorebird assemblages to be catered for and this network of restored sites was considered important in sustaining regional populations of birds (Armitage *et* *al.* 2007). However, Tolderol GR provides freshwater habitats and these may not be overly attractive for some species, such as the Banded Stilt which has a predilection for more saline wetlands (e.g. Paton 2010; Paton *et al*. 2018) or Fairy Tern (see Hunt *et al.* 2019).

Tolderol GR is still relatively small compared to the southern Coorong. In most summers and autumns, there are extensive areas of mudflats covered with shallow water along the shores on both sides of the southern Coorong and around the many small islands. Given the southern Coorong is around 50 km in length, then more than 100 km of shallow shorelines are provided for shorebirds in the southern Coorong. Tolderol GR, in comparison, is only about 3 km in length and 1 km wide when fully operational. However, Tolderol GR consists of a series of basins and not a single wetland, which substantially increases the length of shoreline provided. Nevertheless, the amount of additional mudflat covered with shallow water will still be well short of the amount provided by the southern Coorong. Thus, additional areas of managed wetlands will be required elsewhere within the broader landscape to help offset the loss of productive shorelines in the southern Coorong, at least until the southern Coorong has recovered.

Even if suitable areas existed, the potential for re-establishing sufficient habitat in the short-term to compensate for the area of habitat likely to be lost across the southern Coorong is remote. As such, any new wetlands that are provided should aim to provide habitats of high quality. Defining what constitutes high quality habitat for the diversity of bird species being displaced from the Coorong is important, however, this is beyond the scope of this initial study. Many factors are likely to influence the quality of a habitat from a bird's perspective, with the ease with which a bird can obtain food likely to be a key determinant of habitat quality (Piersma *et al.* 1993), particularly outside the breeding season.

The amount of time that birds allocate to foraging may provide a guide to habitat quality at Tolderol GR. In the Coorong, key species of shorebirds, like Curlew Sandpiper, Sharp-tailed Sandpiper and Red-necked Stint, frequently spend more than 80% of the day foraging in the Coorong in January when there is at least 15 hours of daylight (e.g., Paton *et al.* 2019). This high allocation of time to foraging is indicative of food resources being difficult to harvest. Under these circumstances, small reductions in the size, abundances or accessibility of their foods is likely to challenge these birds because they have little additional time to allocate to foraging to secure the food that they need. That dead, emaciated shorebirds are found in the southern Coorong in summer (e.g., Paton *et al.* 2016), is consistent with habitats in this wetland system being of low quality. In comparison, those same shorebird species were spending much less time foraging (7-50%) when using basins within Tolderol GR, at least in February. Not only is day length shorter in February and March but this is also a time when migratory shorebirds undertake pre-migratory fattening, so their demands for food are likely higher than earlier in summer. This finding of less time allocated to foraging may be indicative that the shallow habitats being provided at Tolderol GR are providing foraging opportunities that are better than those of the southern Coorong, from a small shorebird perspective. Other species of shorebirds, like the Little Stint (*Calidris minuta*) also reduce the time they allocate to foraging when they can harvest food more readily, even immediately prior to migration (Masero 2003). Small prey size, high pecking rates and an inability to determine the numbers of prey being harvested by shorebirds at Tolderol GR limits our ability to compare areas based on food intake rates and so determine the quality of the habitats being provided from a foraging perspective. Importantly though, Tolderol GR is clearly able to support some of the key species disadvantaged by deteriorating conditions in the southern Coorong. Consequently, investment in increasing and enhancing the area of wetlands at Tolderol GR and improving the ease with which these man-made wetlands can be managed is warranted.

Assessments of habitat quality based on the time that birds allocate to foraging, needs to be tempered in one important respect. Even when the birds need to allocate more than 80% of the day to foraging, this only indicates that the foraging opportunities being provided may be of poor quality and not that the foraging opportunities were inadequate. Thus, the presence of various shorebirds using Tolderol GR, including some of the species likely to be displaced by deteriorating conditions in the southern Coorong, indicates that Tolderol GR is providing resources that are adequate for them. Spending large amounts of time foraging is not unusual for shorebirds (e.g., Puttick 1979; Morrier and McNeil 1991; Davis and Smith 1998; Masero 2003). For example, Curlew Sandpipers are reported spending as much as 80% of the day foraging in southern Africa (Puttick 1979) and as much as 11 hours foraging in southwest Spain (Masero 2003) and so are clearly capable of allocating large amounts of time to foraging and surviving. However, when birds allocate large amounts of time to foraging, they may have little capacity to buffer against subsequent reductions in their food resources. When food resources are more readily harvested and the birds are allocating less time to foraging, there is much greater capacity to cope with diminished food resources because the birds can readily increase the amount of time spent foraging to compensate for this.

The densities of microinvertebrates in some basins at Tolderol GR were also extremely high in February and March, as great as some of the highest densities measured throughout the Murray-Darling Basin (Shiel *et al.* 1982; Shiel and Aldridge 2011; Shiel and Tan, 2013a,b). This indicates that highly productive basins can be constructed. Abundances of chironomids, a key food resource used by shorebirds in the southern Coorong (e.g., Paton 2010) were also higher at Tolderol GR in February and March than they have been in summer in the southern Coorong in recent years (Paton *et al.* 2019). This is in line with the inference that Tolderol GR was providing suitable foraging opportunities for key shorebird species that may have been better than those currently being provided in the southern Coorong.

Two additional pieces of information are required to improve the management of wetlands in the Coorong region from a waterbird perspective. The first is an understanding of the temporal patterns of food resources within key wetlands and the second is an understanding of the movements of waterbirds within the region.

Historically, most waterbirds use the Coorong from sometime in spring until sometime in autumn (Paton 2010). The food resources used by the birds, or access to those food resources, are likely to change during this period. For example, filamentous green algae become increasingly prominent over spring, progressively interfering with the ability of the birds to access food on the mudflats and dampening the abundance of critical prey, like chironomids (Paton *et al.* 2019). Knowledge of how the food resources change over this spring-autumn period within the southern Coorong will allow the provision of other wetlands to be timed for when the birds are likely to seek alternatives. Equally, knowledge of the temporal changes to food resources within these alternative wetlands, including Tolderol GR, will allow management to be tailored to guarantee that suitable habitats are secured at those critical times.

One of the key assumptions with the provision of alternative habitats is that birds unable to use the southern Coorong will be able to locate them. There is as yet no information that birds from the Coorong can and will do this. Understanding how some of the key species move within the region is critical for determining the placement of artificial wetlands, so that any additional habitats that are provided have a reasonable prospect of being found by the birds. Decisions about where to invest in providing additional habitat ultimately depends on understanding the movements of key species. The numbers of most waterbird species using Tolderol GR varies not just from one month to the next (Table 2) but also from one day to the next. This suggests that there is a continuous flux in the birds using this wetland. Further to the notion of a flux, these wetlands in autumn may be used as ‘stepping stones’ along the migratory route for some species. For example, a Red-necked Stint and a Curlew Sandpiper carrying leg flags placed on the birds in Victoria were observed at Tolderol GR during this study. Thus, there is a reasonable prospect that birds displaced from the Coorong or in the process of migrating will find and use some of these alternative wetlands, including Tolderol GR. However, documenting and understanding these movements is critical if key species of waterbirds are to be managed effectively. This will require use of modern technologies, such as satellite tracking.

4.2 Building the knowledge to enable Tolderol Game Reserve to be managed for waterbird outcomes

At present there is insufficient understanding of how the various basins at Tolderol GR could be managed to optimise the waterbird outcomes. This in part reflects the nature of the management levers that are being used. Three management levers are available:

(1) the management of largely terrestrial vegetation that establishes when the basins are not holding water by ploughing, slashing or grazing and/or burning of reeds;
(2) the provision of water in spring to fill the basins; and
(3) topping up of water levels in some of the basins in summer and/or autumn (individual basins may take several days to weeks to fill, depending on their size).

The initial flooding of basins may result in a short period of time when terrestrial invertebrates become available as they escape the rising water. Initial flooding will also trigger propagule banks of aquatic organisms to emerge with a potential succession of different aquatic biota appearing over time. The timelines and sequence of aquatic biota involved is not known for these basins. Nor do we know how ploughing, slashing, grazing or burning influence the magnitudes and timings of the responses of the different biota. Our observations from late summer through autumn show substantial changes in the food resources available and being used by some of the small shorebirds at Tolderol GR. However, these do not document the full seasonal pattern to the aquatic food resources present in the basins, or whether these are influenced by the timing of when a basin is filled in spring. If there is a distinct temporal pattern related to time of watering, then staggering the times when individual basins are filled may provide a simple mechanism for providing good quality foraging opportunities at different times over summer, for example. Treatment of terrestrial vegetation by ploughing, grazing, slashing or burning prior to filling may have little influence on the aquatic responses, but instead may facilitate access to aquatic foods for some species, should drowned terrestrial vegetation interfere with the foraging efficiencies of some of the key waterbirds. Unfortunately, no basins were ploughed in spring 2018 and so there was no opportunity to examine this management action in our study.

Current management requires the first of a sequence of basins to be filled before the next basin is filled. This requires filling basins to a level where the water is lapping against the steep levee banks which results in little suitable foraging habitat for the small shorebirds, since at these times there is little mudflat exposed or covered with <5 cm of water within a basin. This in turn results in a delay between the filling of a basin and the subsequent provision of suitable foraging habitat for these birds, as the water levels have to drop sufficiently. Filling some basins to a lower level initially may provide suitable foraging habitat for these birds a little earlier. Although the basins will continue to provide suitable foraging habitat for shorebirds as the water continues to draw down, the level of evaporation of around a centimetre per day (Webster 2005) will mean the position and area of suitable foraging habitat will shift almost daily. This dynamic, coupled with changes in food resources, needs to be documented to be able to cater for and manage Tolderol GR in an optimal manner for these, and other, bird species. The trajectories and hence capacities of individual basins to provision suitable foraging opportunities is also likely to be influenced by the timing and extent of any top-ups of water levels during summer and autumn, adding a further dimension that needs to be understood to manage Tolderol GR. Equally important is the development of similar knowledge of seasonal changes in the capacity of the southern Coorong and other nearby wetland systems in provisioning suitable foraging opportunities, so that a truly integrated regional management program can be developed to best serve the birds. However, the lack of fine details should not prevent initial management trials from commencing. An important further consideration is that the goals of any integrated management program are well defined, with expected outcomes against which management actions can be judged and adjusted.

The current management of Tolderol GR is based primarily on previous experience of a team of committed volunteers that predominantly form the Tolderol GR Wetlands Working Group. Within the constraints of the infrastructure and limited funding, this voluntary management has been effective in providing some capacity to support key waterbird species of the Coorong. It would be prudent for any future management to work in partnership with the Tolderol GR Wetlands Working Group, with due consideration given to their experience and intimate knowledge of Tolderol GR. However, the ability to improve the management of the existing basins, and expand the numbers of basins that can be watered in an integrated manner with other wetlands in the region, requires significant investment in:

(a) upgrading the infrastructure at Tolderol GR to allow an expanded number of basins to be watered independently;
(b) research to determine the best watering regimes (timing, length of time inundated, length of time left dry) for the basins to produce a succession of suitable foraging opportunities for key species of waterbirds across the summer-autumn period and/or at critical times when other wetlands, including the Coorong, are unable to provide such habitats;
(c) research to identify the extent to which Tolderol GR basins are used at other critical times of the year, such as late spring and summer; and

(d) research to determine what benefits, if any, other actions like ploughing and burning (of encroaching reeds) and top-ups may have in provisioning or extending productive habitats for key species of birds likely to be disadvantaged from poor conditions in the southern Coorong.

In advancing the research needs listed above, an adaptive management approach should be taken, where some of the physical features, such as water levels and areas of suitable foraging habitat, food resources and bird responses to these, are monitored in conjunction with different watering regimes. This should include not just a focus on waterbirds, but also on the development and long-term maintenance of the food chains that support those birds, such as the micro- and macro-invertebrates. Given the additional area that could be watered, current baseline measures of bird use can be used to determine the likely expected net increase in bird use as a consequence of investing in upgrading and expanding infrastructure and improving the management of Tolderol GR. An important part is understanding how Tolderol GR contributes to the maintenance of waterbird populations in the region, particularly key species of the southern Coorong. This will require investment to allow comparable assessments of other wetland systems in the region, particularly seasonal patterns.

An important consideration is that Tolderol GR already has a reputation amongst birdwatchers as an accessible and valuable habitat for waterbirds. Investing and upgrading Tolderol GR and its management value-adds to that existing interest, increasing the connectivity between society and the environment. In this way, any investments are conspicuous to the general public, as well as providing some economic return to local communities through increased visitation.

5 Summary

In summary, the key goal of this research was to illustrate "proof-of-concept" that managed constructed wetlands can support some of the key waterbird species that are disadvantaged by a deteriorating southern Coorong. This preliminary investigation demonstrates the capacity of artificial wetlands to provide suitable habitats and resources for some of the key species of shorebirds, albeit limited by scale relative to the area of suitable habitat that was once provided by the southern Coorong.

Further targeted research is needed to manage Tolderol GR for the best outcomes for waterbirds. However, in the interim and for outcomes for the key small shorebird species, we recommend that Tolderol GR provide:

1) mudflats that are either damp or covered by water that is typically no more than 5 cm in depth, and
2) a diverse macro-invertebrate community to provide food at different times of the year for these birds.

Ultimately, management in the region should aim to establish a network of wetlands that not only provide resources at certain times of the year but, collectively, provide the resources needed by the birds at least for the spring to autumn period, if not all year round.

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Appendix A

Table A 1: Area (in hectares) of each basin at Tolderol GR (Kate Mason, DEW, pers. comm., 2019).

Basin	Area (ha)
0	9.2
1	6.0
2	8.5
3	2.4
4	11.3
5	6.2
6	10.1
7	12.0
8	1.1
9	4.7
10	6.1
11	15.3
12 & 13 *	26.7
14	29.5
15	19.9
16	16.3
17	17.6
Total	202.8

*Currently joined; being separated through earthworks as of June 2019.

Table A 2: Summary of Tolderol Game Reserve water allocation and usage. Annual permitted amount against the Tolderol Game Reserve water licence is 1030ML (Kate Mason, DEW, pers. comm., 2019).

Year	Water used (ML)	Area watered (ha)	Number of Basins	Electricity cost to pump ($)
2014/15	415.7	28.4	3	$ 4,824.17
2015/16	361.5	28.4	3	$ 3,724.91
2016/17	586.2	84.4	9	$ 3,335.00*
2017/18	1124.2	84.4	9	$ 9,361.00

Table A 3: Abundance of waterbirds counted in each basin of Tolderol GR for February 2019. Note that all Basins were counted but only those with birds are presented here.

	Basin number													
Species	1	2	4	5	6	7	8	9	10	11	12	13	17	18
Australasian Shoveler	0	0	0	0	1	0	0	0	0	2	0	0	26	0
Australian Pelican	0	0	0	0	1	4	1	0	0	3	0	0	6	0
Australian Shelduck	0	0	0	0	1	0	0	0	0	0	0	0	2	2
Australian Spotted Crake	0	0	0	2	0	0	0	2	0	0	0	0	0	0
Australian White Ibis	1	7	1	0	2	2	5	0	4	27	1	0	0	0
Black Swan	0	0	0	2	78	20	0	0	0	0	0	0	43	37
Black-tailed Native-hen	0	13	0	0	0	0	30	77	5	0	0	0	66	18
Black-winged Stilt	0	0	19	17	0	1	0	0	25	0	0	0	3	3
Caspian Tern	0	2	1	0	0	0	0	0	0	0	0	0	57	0
Common Greenshank	0	0	0	1	1	0	0	1	0	0	0	0	2	0
Crested Tern	0	0	5	0	0	0	0	0	0	0	0	0	95	0
Curlew Sandpiper	0	0	105	0	0	0	0	0	0	0	0	0	31	0
Eurasian Coot	0	0	0	0	0	42	0	0	0	0	0	0	0	0
Glossy Ibis	0	0	0	0	0	0	0	0	0	14	0	0	0	0
Grey Teal	4	0	241	0	39	0	0	0	0	58	0	0	485	5
Hoary-headed Grebe	0	0	2	0	0	1	0	0	0	0	0	0	0	0
Little Pied Cormorant	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Marsh Sandpiper	0	0	3	3	0	0	0	0	4	0	0	0	1	0
Masked Lapwing	0	0	32	14	0	0	0	2	0	0	0	0	4	1
Pacific Black Duck	0	0	6	0	33	0	0	0	0	2	0	0	18	0
Pink-eared Duck	0	0	0	0	0	0	0	0	0	0	0	0	35	0
Purple Swamphen	0	1	5	18	2	7	0	0	3	4	0	0	3	0
Red-capped Plover	0	0	71	4	0	0	0	0	0	0	0	0	24	0
Red-kneed Dotterel	0	0	2	4	0	0	0	7	9	0	0	0	0	0
Red-necked Stint	0	0	1	17	0	0	0	0	7	0	0	0	0	0
Royal Spoonbill	0	0	0	1	1	0	1	3	3	2	0	0	0	0
Sharp-tailed Sandpiper	0	1	216	58	0	0	0	6	41	0	0	0	82	0
Silver Gull	0	0	1	0	1	0	0	0	0	0	0	0	2	0
Straw-necked Ibis	0	0	0	0	0	6	0	0	0	0	0	6	0	0
Whiskered Tern	3	18	7	5	60	2	2	0	1	26	0	0	25	10
White-faced Heron	22	4	1	1	2	0	0	1	0	5	0	0	1	0
Yellow-billed Spoonbill	0	0	0	0	0	0	0	8	0	0	0	0	0	4

Table A 4: Abundance of waterbirds counted in each basin of Tolderol GR for March 2019. Note that all Basins were counted but only those with birds are presented here.

	Basin number													
Species	1	2	4	5	6	7	8	9	10	11	12	15	17	18
Australasian Shoveler	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Australian Pelican	0	0	0	0	0	0	0	1	0	0	0	0	7	0
Australian Shelduck	0	0	6	0	0	26	0	0	0	0	0	0	10	0
Australian White Ibis	2	10	0	8	1	1	3	0	0	0	4	0	4	0
Black Swan	0	0	0	0	27	15	0	0	0	0	0	0	54	4
Black-tailed Native-hen	0	31	2	0	0	0	18	120	0	0	0	0	32	0
Black-winged Stilt	0	66	7	11	1	1	0	18	27	15	0	0	17	11
Caspian Tern	0	1	0	0	0	0	0	0	0	0	0	0	16	0
Chestnut Teal	0	0	0	0	0	0	0	0	0	2	0	0	14	0
Common Greenshank	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Crested Tern	0	0	0	0	0	0	0	0	0	2	0	0	70	0
Curlew Sandpiper	0	10	0	0	0	0	0	32	24	0	0	0	133	0
Eurasian Coot	0	0	0	0	0	89	0	0	0	0	0	0	0	0
Great Cormorant	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Grey Teal	2	110	349	0	2	36	0	38	0	33	0	0	559	1
Hoary-headed Grebe	0	0	0	0	0	1	0	0	0	4	0	0	15	0
Little Pied Cormorant	0	0	0	0	1	0	0	0	0	0	0	0	1	0
Marsh Sandpiper	0	4	2	3	0	0	0	0	4	0	0	0	0	0
Masked Lapwing	7	2	9	8	0	0	2	0	2	0	0	2	4	5
Pacific Black Duck	31	4	8	0	6	37	0	0	0	22	0	0	15	12
Pacific Golden Plover	0	0	9	0	0	0	0	0	0	0	0	0	0	0
Pink-eared Duck	0	0	0	0	0	0	0	0	0	0	0	0	37	0
Purple Swamphen	0	15	0	11	6	15	1	0	1	11	0	0	10	0
Red-capped Plover	0	0	95	3	0	0	0	0	16	0	0	0	0	0
Red-kneed Dotterel	0	0	5	0	0	0	0	52	4	0	0	0	4	0
Red-necked Avocet	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Red-necked Stint	0	0	16	21	40	0	0	113	192	38	0	0	97	48
Royal Spoonbill	0	0	1	1	0	1	1	1	0	0	0	0	3	0
Sharp-tailed Sandpiper	0	31	7	3	0	0	0	50	0	12	0	0	83	0
Silver Gull	0	0	0	0	0	0	0	0	0	11	0	0	0	0
Whiskered Tern	0	0	1	0	22	0	0	1	1	18	0	0	239	0
White-faced Heron	0	1	0	0	2	1	0	2	0	3	0	0	0	0
Yellow-billed Spoonbill	0	0	0	0	0	0	0	1	0	0	0	0	0	0

Table A 5: Abundance of waterbirds counted in each basin of Tolderol GR for April 2019. Note that all Basins were counted but only those with birds are presented here.

	Basin number										
Species	2	4	5	6	7	8	9	10	11	17	18
Australasian Shoveler	0	0	0	3	10	0	0	0	0	18	1
Australian Pelican	0	0	0	0	3	1	0	0	0	1	0
Australian Shelduck	0	0	0	0	13	0	0	0	0	0	0
Australian Spotted Crake	0	0	1	0	0	0	0	0	1	0	0
Australian White Ibis	0	0	0	7	1	2	0	0	0	1	0
Black Swan	0	0	0	3	0	0	0	0	0	9	0
Black-fronted Dotterel	8	0	0	0	0	0	0	0	0	0	0
Black-tailed Native-hen	4	0	0	0	0	23	34	21	0	25	0
Black-winged Stilt	27	8	38	18	2	0	9	27	2	10	7
Caspian Tern	0	0	0	0	0	0	0	0	0	32	0
Chestnut Teal	0	0	0	18	5	0	0	0	0	2	0
Common Greenshank	0	0	2	0	0	0	0	0	0	1	0
Crested Tern	0	0	0	0	0	0	0	0	0	5	0
Curlew Sandpiper	0	0	0	0	0	0	0	0	0	0	10
Eurasian Coot	0	0	0	0	23	0	0	0	0	0	0
Great Cormorant	0	0	0	1	1	0	0	0	0	0	0
Grey Teal	0	187	4	235	97	0	23	0	56	290	20
Hoary-headed Grebe	0	0	0	1	0	0	0	0	29	0	0
Marsh Sandpiper	0	0	2	0	0	0	1	1	0	2	0
Masked Lapwing	36	2	2	4	0	0	0	0	1	8	2
Pacific Black Duck	0	4	0	4	0	0	2	0	0	5	0
Pink-eared Duck	0	0	0	0	0	0	0	0	0	89	0
Purple Swamphen	0	2	9	9	14	0	14	0	2	4	0
Red-capped Plover	0	44	5	0	5	0	0	14	0	0	0
Red-kneed Dotterel	7	2	7	6	5	1	5	94	13	0	0
Red-necked Stint	84	0	2	2	9	0	0	104	9	0	0
Royal Spoonbill	0	0	0	5	2	5	0	0	0	0	0
Sharp-tailed Sandpiper	41	1	0	28	0	0	1	1	0	0	1
Silver Gull	0	0	0	1	0	0	0	0	0	0	0
Whiskered Tern	0	0	0	0	0	0	0	0	0	15	0
White-faced Heron	0	1	0	6	2	1	2	0	2	0	0
Wood Sandpiper	1	0	0	2	0	0	0	2	0	2	0
Yellow-billed Spoonbill	0	0	0	5	10	3	1	0	0	0	0

Table A 6: Abundance of waterbirds counted in each basin of Tolderol GR for May 2019. Note that all Basins were counted but only those with birds are presented here.

	Basin number								
Species	4	5	6	7	8	10	11	17	18
Australasian Shoveler	0	0	0	0	0	0	0	36	0
Australian Pelican	0	0	1	4	0	0	0	0	0
Black Swan	0	0	2	0	0	0	0	10	0
Black-fronted Dotterel	0	0	21	1	0	0	0	0	0
Black-tailed Native-hen	0	0	0	0	16	1	0	25	0
Black-winged Stilt	0	2	10	3	0	0	3	22	18
Caspian Tern	0	0	0	0	0	0	0	19	0
Chestnut Teal	0	0	0	0	0	0	0	10	0
Common Greenshank	0	0	0	1	0	0	2	0	0
Crested Tern	0	0	0	0	0	0	0	3	0
Great Cormorant	0	0	0	0	0	68	0	0	0
Grey Teal	280	0	6	0	0	0	0	260	0
Hoary-headed Grebe	2	0	0	0	13	0	1	0	0
Masked Lapwing	11	0	2	0	0	0	0	2	0
Pacific Black Duck	0	0	0	0	0	3	0	0	0
Pink-eared Duck	100	0	0	0	0	0	0	167	0
Purple Swamphen	0	0	13	1	0	0	0	13	0
Red-capped Plover	0	12	0	0	0	95	0	0	0
Red-kneed Dotterel	0	0	37	1	0	38	0	0	0
Red-necked Stint	0	52	21	0	0	19	0	0	0
Royal Spoonbill	0	0	2	0	0	0	0	0	0
Sharp-tailed Sandpiper	0	0	3	0	0	0	0	0	0
White-faced Heron	1	1	0	0	0	0	0	0	0
Yellow-billed Spoonbill	0	0	2	0	0	0	0	0	0

Table A 7: Abundance of waterbirds counted in each basin of Tolderol GR for June 2019. Note that all Basins were counted but only those with birds are presented here.

	Basin number												
Species	4	5	6	7	8	9	10	11	12	14	15	17	18
Australasian Shoveler	0	0	0	0	0	0	0	0	0	0	0	3	0
Australian Spotted Crake	0	2	0	0	0	0	0	0	0	0	0	0	0
Black Swan	0	0	0	0	0	2	0	0	0	0	0	26	5
Black-fronted Dotterel	0	4	3	9	0	0	0	0	0	0	0	0	0
Black-tailed Godwit	1	0	0	0	0	0	0	0	0	0	0	0	0
Black-tailed Native-hen	0	0	0	0	32	0	12	0	0	0	0	0	0
Black-winged Stilt	1	21	62	2	0	2	0	4	0	0	0	18	8
Caspian Tern	0	0	0	0	0	0	0	0	0	0	0	10	0
Chestnut Teal	6	0	0	0	0	0	0	0	0	0	0	10	0
Crested Tern	0	0	0	0	0	0	0	0	0	0	0	11	0
Curlew Sandpiper	0	0	11	0	0	0	0	0	0	0	0	0	0
Grey Teal	216	0	122	0	0	0	0	0	0	0	0	277	49
Hoary-headed Grebe	2	0	0	0	1	0	0	0	0	0	0	1	0
Little Pied Cormorant	0	0	0	0	0	0	0	1	0	0	0	0	0
Marsh Sandpiper	1	0	0	0	0	0	1	0	0	0	0	0	0
Masked Lapwing	6	2	3	0	0	0	0	0	0	2	0	2	0
Pacific Black Duck	5	0	0	0	0	0	0	0	0	0	0	0	0
Pink-eared Duck	408	0	0	0	0	0	0	0	0	0	0	83	0
Purple Swamphen	0	0	17	3	0	0	0	0	0	0	0	9	2
Red-capped Plover	0	7	0	3	0	0	16	0	0	0	0	0	0
Red-kneed Dotterel	0	3	28	6	0	0	61	6	0	0	0	0	0
Red-necked Avocet	0	0	0	0	0	0	0	0	0	0	0	51	0
Red-necked Stint	0	5	0	0	0	0	138	0	0	0	0	0	0
Sharp-tailed Sandpiper	1	0	23	0	0	0	0	1	0	0	0	2	0
Spotless Crake	0	2	0	0	0	0	0	0	0	0	0	0	0
White-faced Heron	0	0	1	0	0	0	0	0	1	0	1	0	0
Yellow-billed Spoonbill	0	0	4	0	0	0	0	0	0	0	0	0	0

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