Condition Monitoring of the Coorong, Lower Lakes and Murray Mouth Icon Site: Waterbirds in the Coorong and Lower Lakes 2017

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Cover Image: Little Pied Cormorant, Lake Alexandrina, January 2017. Photographer: Fiona Paton

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Executive Summary

Substantially fewer waterbirds were using the Coorong and Lower Lakes in January-February 2017 compared to the previous year. In January 2017, 76,207 waterbirds (46 species) were counted in the Coorong, compared with 185,000 waterbirds (57 species) in the previous January. Similarly, the numbers of waterbirds using the Lower Lakes in 2017 had dropped to a little over 61,000 birds (44 species), about 70% of the numbers counted in the previous year. Clearly target B-1 of the Lower Lakes, Coorong and Murray Mouth Icon Site Condition Monitoring Plan '*to maintain or improve water bird populations in the Lower Lakes, Coorong and Murray Mouth*' was not met.

Of the 40 species of waterbirds used to provide a Whole of Icon Site Score (WOISS) for waterbirds using the Coorong, 23 species were below their long-term (2000-2015) median abundances and some markedly so. Of concern was that all thirteen species of shorebirds were present in numbers below their long-term median abundances, including various stilts, sandpipers, and plovers. Three of these species, namely Banded Stilt (*Cladorhynchus leucocephalus*), Red-necked Stint (*Calidris ruficollis*) and Sharp-tailed Sandpipers (*Calidris acuminata*) were present in abundances that were the lowest on record, and a further three species (Black-winged Stilt (*Himantopus himantopus*), Curlew Sandpiper (*Calidris ferruginea*) and Red-capped Plover (*Charadrius ruficapillus*)) were at their second lowest abundances reported over the past 18 years. For Banded Stilt and Sharp-tailed Sandpiper, the abundances in the Coorong in 2017 were equivalent to just 1% of their long-term medians, while Red-necked Stints were at 22% of their long-term median. Extremely high water levels in January and widespread filamentous green algae (*Ulva* sp.) that blanketed the shallow mudflats and shorelines of the southern Coorong eliminated habitat and access to food for these birds in January 2017, effectively excluding them from much of the Coorong. Future management will need to limit the establishment of high water levels during summer, as well as limiting the environmental conditions that favour filamentous green algae. The previous unregulated flow of 2010-11 also resulted in high water levels excluding shorebirds from mud flats. The high water levels that establish in the southern Coorong during years of substantial flow are likely related to the extent to which the Murray Mouth becomes restricted during intervening years of low flows. Other species that were in much lower abundances in the Coorong than in previous years were Great Egret (*Ardea modesta*), Chestnut Teal (*Anas castanea*) and Musk Duck (*Biziura lobata*). For the first time ever no Musk Ducks were using the Coorong in 2017, while only 40% of the long-term median for Chestnut Teal were counted. Chestnut Teal, however, were breeding in the Coorong, suggesting the Coorong was providing suitable habitat for them in January 2017.

Of the 25 bird species used in calculating the waterbird WOISS for the Lower Lakes, 16 were in abundances below their median abundances for 2013-2015 in January-February 2017. Fifteen of these species were in abundances lower than their abundances in the previous year. Eleven of these were piscivorous species, including four species of cormorant, two species of terns, two species of grebes, the Australasian Darter (*Anhinga novaehollandiae*), Australian Pelican (*Pelecanus conspicillatus*) and Great Egret. In contrast, the prominent herbivorous waterfowl in the Lower Lakes (Black Swan (*Cygnus atratus*), Grey Teal (Anas gracilis), Australian Shelduck (*Tadorna tadornoides*) and Pacific Black Duck (*Anas superciliosa*)) were all in abundances above

their target abundances (i.e., above their 2013-2015 median abundance), as were the two species of ibis and Royal Spoonbill (*Platalea regia*).

For both the Coorong and the Lower Lakes, there were waterbird species that had increased in abundance since the 2016 count and others that had decreased. The current waterbird WOISS integrates these into a single score for the Coorong and a separate score for the Lower Lakes. In 2017, the WOISS for the Coorong and the WOISS for the Lower Lakes were both lower than in the previous year, but the change in score was small relative to the magnitude of some of the actual changes in abundances for many species. This occurs because current WOISS uses a conservative approach when assessing abundances by examining count data over the last three years, applying a negative value (-1) to abundances only if the abundances in two of the last three years fall below the long-term median. If all three fall below the long term median, then a score of -2 is assigned. As such it takes no account of the extent to which the numbers fall below the targeted median value in any one year and there may be value in reviewing the current scoring technique and providing a further penalty when abundances fall well below targets.

Interpreting changes in abundances and distributions of waterbirds using the Coorong and Lower Lakes is difficult because the birds are likely to be influenced not just by the conditions within this system at the time when the birds are counted but also by the conditions at other times in the year and elsewhere. In the long-term, an understanding of the temporal and spatial scales over which the birds operate will be needed to allow effective management of the Coorong and Lower Lakes for them.

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1 Preamble

This report builds on a series of annual reports on waterbirds in the Coorong and Lower Lakes. Substantial parts of previous annually-produced reports are reiterated so that relevant background and historical perspectives, as well as details of methods and monitoring targets, are provided within this report, reducing the need to revisit previous reports for those details. The discussions in these annual reports largely focus on waterbird-related matters that have arisen from the current year's monitoring outcomes. Previous reports, therefore, should be consulted for the summary findings and discussion specific for earlier years.

2 Introduction

The Lower Lakes, Coorong and Murray Mouth (LLCMM) region is a Wetland of International Importance under the Ramsar Convention and is one of the Living Murray's (TLM) icon sites within the Murray-Darling Basin. Large numbers of small migratory and non-migratory waders (sandpipers, plovers and stilts), piscivorous birds (pelicans, cormorants, grebes and terns) and waterfowl (swans and ducks) use components of this wetland system, particularly during summer (e.g., Paton 2010). This abundance and diversity of waterbirds was one of the prime reasons for the LLCMM region being listing as a Wetland of International Importance. Most waterbirds use the shallow but often highly productive margins of wetlands, and the permanent wetlands of the Coorong and Lower Lakes have historically provided extensive areas of shallow productive wetland habitat, even in droughts (Paton *et al.* 2015a).

Waterbird use of the Lower Lakes has been assessed annually since 2009, while the Coorong and Murray Mouth region has been assessed annually since 2000 with the counts taking place during summer when the extent of birds using these wetlands is highest (Paton 2010). These systematic counts are then used to document changes in the distributions and abundances of waterbirds within the different components of the LLCMM and in recent years this annual census has been used to assess various waterbird-related targets (e.g., Paton & Bailey 2012a,b; 2013) listed in the LLCMM Icon Site Condition Monitoring Plan (Maunsell 2009). Amongst these targets is target B-1 - *to maintain or improve water bird populations in the Lower Lakes, Coorong and Murray Mouth.* These targets and the associated annual monitoring programs were reviewed and new ecological targets set (e.g., Paton 2014; Robinson 2014; Paton *et al*. 2015b, Table 1). This report summarises the results of the 2017 summer waterbird census for the Coorong, Lower Lakes and Murray Mouth region against the new targets.

The annual counts of waterbirds within the LLCMM need to be placed in context, the context of a wetland system that has been recovering from severe perturbations that resulted in the quality of wetland habitats deteriorating for waterbirds. With these wetlands now recovering post drought, a key focus for the current waterbird monitoring has been to establish if the waterbird communities have also recovered. To appreciate any recovery requires an understanding of the extent to which these wetland systems were perturbed and the causes of those perturbations.

Over the last sixteen years, there have been dramatic changes to the hydrology of the LLCMM region. Within the Lower Lakes, water levels during 2009 and most of 2010 were consistently below sea-level (-0.5m AHD in Lake Albert; and -0.7 m to -0.9 m AHD in Lake Alexandrina). This resulted in the waterline disconnecting from the fringing vegetation, along with an increased risk of acid-sulfate soils being exposed to the air, leading to potential acidification. For the Coorong and Murray Mouth, there were no substantial River Murray flows over the barrages for almost eight years from 2002-2010. During this period, the Murray Mouth and associated channels had to be dredged to keep the Mouth open. The lack of flows also affected the ecology of the Coorong, disrupting seasonal patterns to water levels and resulting in the accumulation of excessive amounts of salt in the South Lagoon (Paton 2010). These hydrological changes led to changes in the distributions and abundances of key aquatic food resources (plants, invertebrates and fish) used by waterbirds in the Coorong. As the salinities increased, the distributions of the salt tolerant fish, the smallmouth hardyhead (*Atherinosoma microstoma*), and the salt-tolerant chironomid (*Tanytarsus barbitarsis*), that are prominent in the southern Coorong, retracted northwards. From 2007 onwards, both were absent from the South Lagoon, when salinities exceeded 150 gL^{-1}. However, brine shrimps (*Parartemia zietziana*) thrived in the South Lagoon and southern reaches of the North Lagoon during this period. The other major change to food resources was the loss of the key aquatic macrophyte *Ruppia tuberosa* from the southern Coorong during this period. These ecological changes in turn affected the distributions and abundances of waterbirds, with many piscivorous and herbivorous bird species forced to vacate the South Lagoon (Paton 2010). These changes have been attributed to an extensive drought within the Murray-Darling Basin during the 2000s, coupled with on-going over-extraction of water for human use.

During the latter half of 2010, extensive rains within the Murray-Darling Basin brought floods to the River Murray and flows returned to the Lower Lakes. Water levels in the Lower Lakes returned to the more typical managed water levels between 0.6 m and 0.8 m AHD in 2011 and have remained on or around this level since then. With these changes in water levels, there were dramatic changes in the waterbird communities using the Lower Lakes. For example, in 2009 and 2010, there were tens of thousands of stints and sandpipers foraging around the southern shorelines of the Lower Lakes, taking advantage of rarely exposed mudflats as levels dropped as low as -1 m AHD (e.g., Paton & Bailey 2010). However, in spring 2010, water levels in the lakes were re-instated to more typical levels, covering the extensive areas of mudflat that were covered with shallow water in 2009 and 2010 with deep water. This excluded wading birds like stints and sandpipers and, consequently, they had all but disappeared from the Lower Lakes when the counts were undertaken in January 2011 (e.g., Paton & Bailey 2011a). These shorebird species have remained in low abundances around the Lower Lakes ever since (e.g., Paton & Bailey 2012a, 2013, 2014, Paton *et al.* 2015c). However, the distributions and abundances of other species of waterbirds increased over the next 2-3 years and are now considered to have recovered from the severe drought (e.g., Paton & Bailey 2012a, 2013, 2014, Paton *et al.* 2015a,b; 2016d).

Table 1: Ecological targets for waterbirds using the Coorong and Lower Lakes. Table A1 (Appendix) lists the 40 species that are used in the assessment of waterbird populations in the Coorong (including Murray Mouth), and their long-term (2000-2015) median abundances, and long-term (2000-2015) average AOO and EOO, while Table A2 (Appendix) lists the 25 species that are used in the assessment of waterbird populations in the Lower Lakes, and their recent (2013-2015) median abundances, and recent (2013-2015) average AOO and EOO.

Ecological Objective	Maintain or improve water bird populations in the Lower Lakes, Coorong and Murray Mouth.
Definition of how objective is interpreted	Maintain means continuing to meet the long-term threshold ecological targets set for the abundances and distributions of selected species of waterbirds in the Coorong (40 species) and in the Lower Lakes (25 species). A simple index (negative) based on the number of species that failed to meet their threshold ecological targets is used to derive a Whole of Icon Site Score (WOISS) for the Coorong and for the Lower Lakes. Maintain means that the index calculated in a particular year is at or above the 2015 index. Improve means that the waterbird indices for the Coorong have exceeded the 2015 indices for three consecutive years.
Ecological target(s)	Coorong waterbirds 1. Exceed the long-term (2000-2015) median value for abundance of each of 40 selected waterbird species in the Coorong in two of the last three years. 2. Exceed the 75% threshold for the long-term (2000-2015) Area of Occupation (AOO) for each of 40 selected waterbird species in the Coorong. 3. Exceed the 75% threshold for the long-term (2000-2015) Extent of Occurrence (EOO) for each of 40 selected waterbird species in the Coorong. 4. All waterbird species to spend less than 70% of their time foraging.
	Lower Lakes waterbirds 1. Exceed the recent (2013-2015) median value for abundance of each of 25 selected waterbird species in the Lower Lakes in two of the last three years. 2. Exceed the lower 75% threshold for the recent (2013-2015) Area of Occupation (AOO) for each of 25 selected waterbird species in the Lower Lakes. 3. Exceed the 75% threshold for the recent (2013-2015) Extent of Occurrence (EOO) for each of 25 selected waterbird species in the Lower Lakes. 4. All waterbird species to spend less than 70% of their time foraging.

Once the Lower Lakes had re-filled in spring 2010, the barrage gates were opened, reinstating flows to the Murray Mouth in late September 2010. With this release, the northern channels of the Murray Estuary were quickly freshened, before flows continued down the Coorong, diluting the high salinities in the South Lagoon as well. The general consensus was that this freshening of the Coorong would be beneficial, allowing a wide range of different taxa, including plants, invertebrates, fish and birds, to rebuild their population sizes. In January 2011, chironomids had recolonised the South Lagoon and were abundant, yet only small numbers of smallmouth hardyheads were in the South Lagoon, and there was no detectable recovery of *R. tuberosa*. However, *R. tuberosa* and chironomids were still abundant in the middle and southern sections of the North Lagoon, where they had established during the previous five years (Paton & Bailey 2011b). Brine shrimps, however, continued to be abundant throughout the South Lagoon. The other key food resources, various polychaete worms (particularly *Capitella* sp.), were still mainly restricted to the northern sections of the North Lagoon and the Murray Estuary (Paton & Bailey 2011b). Despite some modest recovery, waterbird numbers for the Coorong and Lower Lakes were the lowest on record in January 2011 and lower than abundances during the drought. The low numbers were largely attributed to extremely high water levels in the Coorong in January, with the high water levels excluding most birds from accessing food resources around the shores of the Coorong lagoons (Paton & Bailey 2011b; Paton *et al.* 2015a). With the continuation of flows and the maintenance of lower salinities throughout 2011, there were further changes in the distributions and abundances of food resources. By July 2011, there were no brine shrimps detected in the Coorong, and by January 2012, smallmouth hardyhead were extremely abundant in the southern Coorong (Paton & Bailey 2012b). However there had been no recovery of *R. tuberosa*. In fact *R. tuberosa* had declined further by January 2012, as the extensive beds that were present in the North Lagoon in January 2011 were absent, having vanished by June 2011 (Paton & Bailey 2012c). *Ruppia tuberosa* has been slowly recovering throughout the southern Coorong since then. By the summers of 2015 and 2016, the species had recovered its former range but had not reached the same level of vigour (cover, productivity) as existed prior to the millennium drought (e.g., Paton *et al*. 2016a). The seed banks for this species were still to be replenished and so *R. tuberosa* continues to lack any long-term resilience in the Coorong (Paton *et al*. 2015d, 2016a,b).

This report provides a summary for the waterbird census that was conducted in the Coorong, Murray Mouth and Lower Lakes region in January 2017 and assesses the abundances against the proposed targets set for waterbirds in the revised Condition Monitoring Plan (Table 1). For the Coorong, the abundances and distributions of 40 species of waterbirds are used as the basis for assessing Target B-1: *To maintain or improve bird populations in the [Lower Lakes,] Coorong and Murray Mouth,* where the abundances of each of the 40 species should exceed the long-term (2000-2015) median abundance in two out of three years in the future (e.g., Paton *et al.* 2015b). For the Lower Lakes, the abundances and distributions of 25 species of waterbirds are used as the basis for assessing Target B-1: *To maintain or improve bird populations in the Lower Lakes, [Coorong and Murray Mouth],* where the abundances of each of the 25 species should exceed the recent (2013-2015) median abundance in two out of three years in the future. For the Lower Lakes, systematic counts of waterbirds did not commence until 2009 and the first two years of

Lakes' censuses coincided with a period when the Lakes were at unprecedented low water levels and the waterbird community was atypical, as many of the reed dependent species were excluded. For the next two years (2011, 2012) the waterbird populations recovered and since then have been reasonably consistent and typical of the waterbird community likely to have occupied the wetlands of the Lakes prior to the millennium drought (Paton *et al.* 2015a,b). Thus, the census data collected in 2013, 2014 and 2015 has been used to create the target for median abundance. The use of medians, and the requirement to exceed the median in two out of three years, takes into account the inherent variability that exists in waterbird count data and the goal of enhancing waterbird populations across the wetlands.

Most of the waterbirds using the Coorong use the wetland during the summer months when other wetlands are usually dry (Paton 2010, Paton *et al.* 2015a). Thus, the numbers of waterbirds counted in the Coorong and Lower Lakes in any one year is likely to be influenced by conditions of other wetlands that the birds use, including those used at other times of the year. Some care is therefore required in interpreting changes in abundances. The use of median values rather than means overcomes some of the variability that inevitably exists in counts. Two other targets consider the distribution of the birds: (1) the extent of occurrence (EOO) and (2) the area of occupation (AOO), with both of these needing to fall within 75% of the long-term (2000-2015) average values for those variables for the Coorong (Paton *et al.* 2015b) and within 75% of the recent (2013-2015) average values for those variables for the Lower Lakes.

A further index, namely the percent of birds that were foraging when counted during the census, provides a measure of the quality of the habitat or resources for different waterbird species. This index is independent of other wetlands and is likely to be more informative of the actual conditions in the Coorong and Lower Lakes for waterbirds. The percent of birds foraging reflects the amount of time a bird needs to allocate to foraging and so is a measure of how easily an individual of a species can harvest its food requirements (Paton *et al*. 2015a, 2015e). The quality of a habitat for foraging is higher when birds spend less time foraging compared to wetlands where the birds spend more time foraging. The interim target for foraging is to have fewer than 70% of the birds foraging when counted for each of the waterbird species. When more than 70% of the birds are foraging during the January counts, the quality of the habitat is poor for those species (Paton *et al*. 2015a, 2015e). Reporting of this index simply involves determining the number of species that are spending more than 70% of their time foraging.

3 Methods

All waterbird observations were made using either binoculars (8-10x magnification), or spotting scopes (20x-60x magnification). Birds were identified to species, counted, and their activity classified to one of four categories (foraging, resting, flying, breeding).

3.1 Counting birds in the Coorong

In order to census the waterbirds of the Coorong, the system was divided into 1-km sections, running approximately perpendicular to the direction of the wetlands. This sampling strategy was initially established in 1984-5 when the birds using the South Lagoon were first counted (Paton 2010) and the same sampling strategy was applied to the whole Coorong when complete counts commenced in 2000 to allow historical comparisons (e.g., Paton *et al.* 2009; Paton 2010). The Murray Estuary was, therefore, divided into 17 x1-km sections running from Pelican Point to Goolwa Barrage while the North Lagoon of the Coorong was divided into 45 x 1-km sections running from Parnka Point to Pelican Point. The South Lagoon consisted of 55 x 1-km sections running from Parnka Point to 42-Mile Crossing; however, the number of sections actually counted in summer in the South Lagoon has varied (between 43 and 54) with inter-annual variations in water levels (with the southernmost end being completely exposed in years with low water levels).

Within each 1-km section, counts of waterbirds were conducted both on foot, and by boat. In 2017, the eastern shorelines of each section were walked by at least two observers, while open water areas in the middle of the Coorong and other areas inaccessible by foot (such as islands) were counted from a boat, again by at least two observers. The western shorelines were either counted on foot or from a small boat, again with at least two observers. All waterbirds detected within each component (e.g., eastern shoreline, western shoreline, centre, islands) of each 1-km section were recorded. Each of these components is defined by a unique cell code, of the format SNNX, where S stands for the lagoon (either South (S) or North (N)), NN is the distance in kilometres from the junction of the two lagoons and X stands for the component of the 1-km section (either eastern (E) or western (W) shoreline, or centre (C)). For example, S38E represents the eastern shoreline in the South Lagoon, 38km south of the junction. This division of the data into cells allows for assessments of changes in distribution at a fine-scale through time, and allows AOO and EOO to be determined.

Within a census period, typically between 10 and 20 consecutive 1-km sections were counted per day, depending on the number of birds, their geographical location within each section, as well as other factors, such as weather conditions. Some variance thus occurs in the total duration (7-16 days) of the census from one year to the next. In 2017, the census of waterbirds in the Coorong was conducted between 6 and 15 January 2017 (10 days; eight days surveying), with the counts commencing at the southern end of the Coorong and moving northwards during the sampling period, as was the case in previous years. The North and South Lagoons were counted in the first six days of surveying, and the Murray Estuary was counted on the 12 and 15 January, with bad weather preventing counting on the 13 and 14 January.

3.2 Counting birds in the Lower Lakes

Similar methods were used to count waterbirds around the shores of the Lower Lakes between 16 January and 1 February 2017, with a total of eight survey days. The shorelines of each lake were divided into 1 km x 1 km grid cells (based on Transverse Mercator Projection, Map Grid of Australia (MGA94), Zone 54) and the numbers of birds present in each grid cell were recorded along with their activity (foraging, flying, resting, breeding), allowing both the abundance and the distribution of birds over the Lower Lakes to be determined. Grid cells, however, differed in the amount of shoreline present and also in the extent of shallow water but no adjustments of the numbers of birds was undertaken to account for any differences in grid cells. The time spent surveying each 1km x 1km grid also varied depending on the length of shoreline and aquatic habitat and the ease with which the cell could be covered. The time spent in each cell was set as the time required to cover all aquatic habitat and count all of the birds within the cell. Usually two or three observers worked collaboratively to cover each grid cell. In all, 496 grid cells (126 around Lake Albert, 293 around Lake Alexandrina and a further 77 which covered the Goolwa Channel and related tributaries) were counted during the census period, with all cells containing shoreline being surveyed.

Counts of waterbirds around the shores of the Lower Lakes were conducted either by foot, from a small boat or both, depending on the extent of backwaters and ease of access with a boat to the shoreline. During the counts, the location of observers was continuously verified using hand-held GPS units to ensure the integrity of data for each section of shoreline.

3.3 Behavioural surveys of waterbirds

In addition to recording the behaviour of waterbirds when detected during the counts, repeated counts of birds and their activities were undertaken throughout the day at selected sites (e.g., a bay) along the Coorong. This involved counting the numbers of birds in different activities (including foraging), typically at 2-5 minute intervals for 2-3 hours, and then repeating this for 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. In most years, the same sites (e.g., bays) of a subset of 10 sites that have been surveyed since 2007, and are spread along the length of the Coorong and Murray Estuary, were re-surveyed. However, differences in water levels and hence the shorelines caused some adjustments to the areas observed. Furthermore, in some years, fewer sites were surveyed (with no sites surveyed in 2010), due to restricted site access, lack of funding and skilled personnel, and/or lack of waterbirds. In January 2017, there were so few waterbirds using the Coorong and Murray Estuary that surveys were conducted at only one site (Villa dei Yumpa (S06E) in the South Lagoon), where there were sufficient numbers of waterbirds to warrant collection of this type of intensive behavioural data.

3.4 Data analysis

For the purposes of reporting against the ecological targets in Table 1, the overall abundances of waterbirds using the Coorong were determined by adding the counts for each 1-km section, while for the Lower Lakes, overall abundances were determined by adding the counts of the 1 km by 1 km grid cells.

For calculations of AOO and EOO, all birds that were flying when detected were excluded as these birds may not be using the particular 1-km section in the Coorong or the 1 km x 1 km grid cell in the Lower Lakes. The AOO for each species using the Coorong consisted of dividing each 1-km section into three subsections (eastern shore, centre and western shore) and reporting on the number of subsections where a particular species was resting, foraging or breeding in the Coorong, while the EOO for the Coorong was calculated as the number of 1-km sections between the most northerly and most southerly presence of the species. For the Lower Lakes, AOO for each species equated to the number of grid cells where a particular species was resting, foraging or breeding. The EOO for the Lower Lakes was reported as the area (in km^2) of the minimum convex polygon enclosing all 1 km x 1 km grid cells where a particular species was resting, foraging or breeding. This was specifically performed in ArcGIS 10.1 using the Minimum Bounding Geometry tool in the ArcGIS toolbox.

The assessment of foraging effort in the Coorong for January 2017 was expressed as a percentage of the total number of birds of a species foraging divided by the total number of birds of that species counted during the January 2017 census of the Coorong. The same method was also used for calculating foraging effort in the Lower Lakes. This technique, however, is likely to under-estimate the amount of time a species allocates to foraging because waterbirds are easily disturbed from foraging as people or boats approach them prior to those birds being counted.

The foraging effort for the Coorong was also supplemented by behavioural data collected at Villa dei Yumpa (S06E) in January 2017. This was the only accessible location in the Coorong where sufficient birds were present to warrant these additional observations in January 2017. For each species, observations made during this survey from the five three-hourly periods were amalgamated, with estimations of foraging effort for a particular species only used if counts of 100 or more birds of that species were made over the day. This removed species with only small and potentially unrepresentative sample sizes. Foraging effort for a species was then expressed as a percentage of the total number of birds foraging (that met the >100 bird count requirement) divided by the total number of birds of that species.

3.5 Assessing changes in the food resources for birds in the Coorong

Since 2001, the relative abundances of key food resources (small fish, aquatic benthic invertebrates, seeds, turions and plants) for waterbirds have been assessed in the Coorong at the same time as the bird counts. The same methods are used each year. In January 2017, four sets of 10-25 core samples (core size: 7.5 cm ø, 4 cm deep) of surface mud were collected at each of 17 monitoring sites spread along the Coorong. Additional assessments of resources were also conducted at eight sites on the western shoreline of the South Lagoon to confirm patterns detected for the eastern shoreline (see Table A2 and Figure A1 in the appendix for details of the locations). Each of the four sets of samples were collected at a different position relative to the waterline (i.e., dry mudflat mid-way between the current waterline and the shore line; mudflat at the water line, mudflat covered by 30 cm of water; and mudflat covered by 60 cm of water). All mud samples were then sifted *in situ* through an Endecott sieve (500 μm mesh size), and the abundance of plant (*Ruppia tuberosa*) propagules (seeds, turions) and shoots, chironomid larvae and pupae, and other aquatic invertebrates (e.g., polychaetes), were recorded. Twenty-five cores were taken from each of the sampled depths for sites with *R. tuberosa* in the southern Coorong, while ten samples from each depth were taken at other sites without *R. tuberosa* in the northern Coorong. The aquatic invertebrates (polychaetes) in the northern Coorong were more evenly distributed within a site and so only ten cores were required to provide an adequate measure of abundances, unlike the areas with *R. tuberosa,* where both the plants and invertebrates (chironomids) were patchily distributed.

Water quality measures were also taken at the time of assessing food resources, with turbidity recorded *in situ* using a Secchi disc, and water samples collected so that the conductivity could be measured with a TPS conductivity metre subsequently in the laboratory. Water samples were diluted when required to remain within the optimum range of the conductivity sensor being used. Conductivity was converted to salinities (gL^{-1}) using the equation developed by Webster (unpubl.) specifically for the Coorong. Previously, the equation developed by Williams (1986) was used to convert conductivities to concentration but this equation slightly under-estimates salinities, particularly at high conductivities. Estimates of fish abundance were collected by dragging a 7m seine net, a distance of 50 m, in water approximately 0.7 m deep. The seine net was dragged three times at each of the 17 eastern sites to provide replicate samples.

4 Results and Preliminary Discussion

4.1 Abundances of birds in the Coorong in January 2017 and relative to other years

In January 2017, 76,207 waterbirds (46 species) were counted in the Coorong (Table 2). This compares with 185,000 waterbirds (57 species) in the previous year (Paton *et al.* 2016d). In January 2017, only three species exceeded 10,000 individuals, namely Australian Shelduck (*Tandorna tadornoides*), Grey Teal (*Anas gracilis*) and Silver Gull (*Chroicocephalus novaehollandiae*). In January 2016, there were eight species present in abundances of greater than 10,000 individuals (Paton *et al.* 2016d). Those species that failed to reach abundances in excess of 10,000 individuals in January 2017 despite doing so in January 2016 were the Hoary-headed Grebe (*Poliocephalus poliocephalus*), Whiskered Tern (*Chlidonias hybridus*), Banded Stilt (*Cladorhynchus leucocephalus*), Red-necked Stint (*Calidris ruficollis*) and Sharp-tailed Sandpiper (*Calidris acuminata*). Three species were present in abundances of greater than 5,000 individuals in January 2017: Australian Pelican (*Pelecanus conspicillatus),* Crested Tern (*Thalasseus bergii*) and Red-necked Stint; while four species were present in abundances of more than 1,000 individuals, namely Black Swan (*Cygnus atratus*), Chestnut Teal (*Anas castanea*), Great Cormorant (*Phalacrocorax carbo*), and Red-necked Avocet (*Recurvirostra novaehollandiae)* (Table 2). In January 2017, the numbers of birds counted in the Murray Estuary, North Lagoon, and South Lagoon were in the range of 20,000-28,000 birds respectively (Table 2), between 30% and 60% of the abundances recorded for these regions in January 2016 (Paton *et al.* 2016d). The Murray Estuary continued to support the greatest diversity of bird species (43 species, Table 2), although many of those continued to be present in small numbers (Paton 2010; Paton *et al.* 2016a). The North and South Lagoons supported 38 and 34 species of birds, respectively (Table 2), all lower than in the previous year (Paton *et al.* 2016d).

Of the 40 species of waterbirds used to provide the waterbird WOISS for the Coorong, 23 species were below their long-term (2000-2015) median abundances and some markedly so (Table 3). Of concern was that all thirteen species of shorebirds used for the Coorong WOISS were present in numbers below their long-term median abundances, including various stilts, sandpipers, and plovers. Three of these species (Banded Stilt, Red-necked Stint and Sharp-tailed Sandpipers) were present in abundances that were the lowest on record, and a further three species (Black-winged Stilt (*Himantopus himantopus*), Curlew Sandpiper (*Calidris ferruginea*) and Red-capped Plover (*Charadrius ruficapillus*)) were at their second lowest abundances reported over the past 18 years. The abundances of Common Greenshanks (*Tringa nebularia*) in 2017 also continued to remain below those recorded prior to and throughout the millennium drought (i.e., 2000-2010), indicating that this species has not recovered numerically post the millennium drought. Several factors are likely to have contributed to the low abundances of shorebirds in the Coorong in January 2017, specifically high water levels and the prominence of filamentous green algae (*Ulva* sp.), in particular around the shorelines of the southern Coorong. In years when substantial (unregulated) flows are released over the barrages, water levels, particularly in the southern Coorong, are substantially higher than for years without such flows. Under these conditions, water levels

Table 2: Numbers of waterbirds counted in the Coorong in January 2017. The table shows the abundances of each species in each of three regions of the Coorong: South Lagoon; North Lagoon and Murray Estuary.

Species	Status* (SA, EPBC, IUCN)	Murray Estuary	North Lagoon	South Lagoon	Total
Black Swan		509	995	334	1838
Australian Shelduck		1206	2956	8589	12751
Australasian Shoveler	RA	80	4		84
Grey Teal		4567	8260	2692	15519
Chestnut Teal		72	1898	893	2863
Pacific Black Duck		246	3	16	265
Hardhead		4			4
Cape Barren Goose	RA	247	18		265
Hoary-headed Grebe			10	278	288
Great Crested Grebe	RA		43	7	50
Little Pied Cormorant		2	1		3
Great Cormorant		1727	2166		3893
Little Black Cormorant		44	501	21	566
Pied Cormorant		36	133	140	309
Black-faced Cormorant		80	3	182	265
Australian Pelican		681	1230	4130	6041
Fairy Tern	END,VUL,VUL	107	46	208	361
Little Tern	END			2	2
Caspian Tern		739	560	208	1507
Whiskered Tern		371	37	51	459
Common Tern	RA	4	5	11	20
Crested Tern		1926	882	3517	6325
Great Egret	MIG	4			4
White-faced Heron		49	92	81	222
Little Egret	RA	1	1	4	6
Australian White Ibis		274	74	1	349
Straw-necked Ibis		43	7		50
Royal Spoonbill		40		1	41
White-bellied Sea-eagle		1			1
Pacific Gull		8	1		9
Silver Gull		5181	3789	4158	13128
Eurasian Coot		3			3
Pied Oystercatcher	RA	37	33	40	110
Sooty Oystercatcher	RA	4			4
Black-winged Stilt		25	16	5	46
Red-necked Avocet		2		1333	1335
Banded Stilt	VUL		134	2	136
Pacific Golden Plover		25			25
Red-capped Plover		4	59	90	153
Hooded Plover	VUL, VUL, VUL			8	8
Masked Lapwing		105	147	200	452
Banded Lapwing				7	7

Table 2 continued

Species	Status* (SA, EPBC, IUCN)	Murray Estuary	North Lagoon	South Lagoon	Total
Black-tailed Godwit	RA, MIG, NT		30		30
Bar-tailed Godwit	RA, MIG, NT	29			29
Far Eastern Curlew	VUL, MIG, CR, END	7	1		8
Common Greenshank	MIG	139	163	31	333
Common Sandpiper	RA, MIG		1		1
Red Knot	MIG, END, NT	35			35
Red-necked Stint	MIG, NT	839	4392	436	5667
Sharp-tailed Sandpiper	MIG	99	28	2	129
Curlew Sandpiper	MIG, CR, NT	102	70	36	208
Grand Total		19704	28789	27714	76207

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

Table 3: Abundance, Area of Occupation (AOO) and Extent of Occurrence (EOO) for waterbirds counted in the Coorong in January 2017. The table lists all waterbird species recorded during January counts for 2017 and the two previous years. The median abundances and target values for AOO and EOO are also given for the 40 species of waterbirds regularly counted in the Coorong that are used to determine the whole of icon site score (WOISS), along with the contribution that each of these species made to the 2017 WOISS. Abundances that fall below the long-term median are indicated by red text, as are the AOOs and EOOs when these fall below the target value of 75% of the long-term average AOO and EOO. The WOISS scores for individual species were determined by assigning a value of-1 if two of the three counts over the last 3 years fell below the long-term median abundance, and -2 if all three counts fell below the median. An additional -1 was added to the individual species score if the AOO or EOO fell below the target value for these variables, and -2 if both targets for these variables were not met.

Species	**Abundance**				**AOO**		**EOO**		**WOISS**
	2015	**2016**	**2017**	**Median**	**2017**	**Target**	**2017**	**Target**	
Black Swan	3614	3834	1838	1633	92	45	106	72	0
Australian Shelduck	7597	13779	12751	8426	161	96	110	74	0
Pink-eared Duck	516	523	0						
Australasian Shoveler	1077	611	84		7		16		
Grey Teal	21748	33426	15519	11846	167	93	113	76	0
Chestnut Teal	4000	4690	2863	7216	117	82	103	72	-2
Pacific Black Duck	657	378	265	223	16	14	99	47	0
Hardhead	34	1026	4		1		1		
Freckled Duck	0	18	0						
Blue-billed Duck	23	0	0						
Musk Duck	263	142	0	171	0	14	0	62	-3
Cape Barren Goose	519	181	265	97	9	5	19	16	0
Hoary-headed Grebe	11907	14072	288	4218	40	50	53	70	-2
Great Crested Grebe	147	209	50	199	9	26	67	53	-2
Little Pied Cormorant	186	190	3	258	3	26	24	39	-4
Great Cormorant	2549	1696	3893	1287	51	30	57	47	0
Little Black Cormorant	3765	723	566	1253	26	26	97	49	-1
Pied Cormorant	766	765	309	271	44	34	96	49	0
Black-faced Cormorant	139	151	265	130	12	5	85	50	0
Australian Pelican	3616	4302	6041	3410	107	100	98	75	0

Table 3 continued

Species	Abundance				AOO		EOO		WOISS
	2015	2016	2017	Median	2017	Target	2017	Target	
Fairy Tern	406	410	361	337	15	26	84	57	-1
Little Tern	0	4	2		1		1		
Gull-billed Tern	29	13	0						
Caspian Tern	680	603	1507	598	86	52	105	63	0
Whiskered Tern	7850	10638	459	5360	23	120	90	73	-1
Common Tern	25	20	20		4		73		
Crested Tern	3697	4610	6325	3897	125	50	103	70	0
Great Egret	61	66	4	36	3	20	10	40	-2
White-faced Heron	160	156	222	156	65	45	114	75	0
Glossy Ibis	7	0	0						
Little Egret	24	40	6	7	4	4	112	35	-1
Australian White Ibis	709	813	349	300	43	22	55	27	0
Straw-necked Ibis	69	10	50	25	7	2	38	15	0
Royal Spoonbill	96	49	41	22	10	5	94	24	0
Yellow-billed Spoonbill	5	0	0						
White-bellied Sea-eagle	5	0	2		1		1		
Pacific Gull	4	4	9		4		33		
Silver Gull	8604	11370	13128	8274	219	151	114	78	0
Australian Spotted Crake	2	1	0						
Eurasian Coot	2753	1020	3	62	1	5	1	14	-2
Pied Oystercatcher	131	158	110	158	38	31	93	68	-1
Sooty Oystercatcher	8	10	4		2		2		
Black-winged Stilt	534	589	46	417	10	31	76	62	-1
Red-necked Avocet	9477	4507	1335	3007	18	49	97	63	-1
Banded Stilt	1300	13301	136	15092	4	46	51	64	-4
Pacific Golden Plover	46	0	25	36	2	3	3	18	-3
Red-capped Plover	1459	2695	153	1234	27	58	110	74	-1
Oriental Plover	1	0	0						
Hooded Plover	6	7	8	8	5	4	22	38	-2
Red-kneed Dotterel	0	10	0						
Masked Lapwing	512	460	452	466	114	73	106	77	-1
Banded Lapwing	0	26	7		1		1		
Black-tailed Godwit	47	25	30		3		4		
Bar-tailed Godwit	78	44	29		3		9		
Far Eastern Curlew	13	8	8	13	3	3	37	6	-1
Whimbrel	0	1	0						
Common Greenshank	355	443	333	430	70	66	106	75	-1
Common Sandpiper	2	1	1		1		1		
Marsh Sandpiper	2	0	0						
Red Knot	0	22	35		1		1		
Sanderling	448	41	0						
Red-necked Stint	54624	27498	5667	26286	37	88	106	77	-1
Sharp-tailed Sandpiper	14071	23366	129	13179	11	91	86	71	-1
Curlew Sandpiper	3943	1248	208	2252	8	26	82	61	-2
WOISS (total)									**-41**

encroach upon the terrestrial fringing habitat and greatly reduce the amount of suitable foraging habitat (mudflat covered by no more than a few centimetres of water) for shorebirds (Paton and Bailey 2011b). High water levels greatly restrict foraging opportunities for shorebirds, particularly shorter-legged species like sandpipers, stints and plovers. The second significant factor reducing habitat quality for waterbirds in January 2017, was the widespread appearance of filamentous green algae (*Ulva* sp.) around the shorelines of the southern Coorong (e.g. Paton *et al*. 2017). Filamentous algae were so prominent in the spring and summer of 2016-2017 that they blanketed all populations of *Ruppia tuberosa*. Furthermore, wind-induced wave action regularly washed mats of algae towards the shore where algae accumulated as thick blankets, several centimetres thick, both above the shoreline where it rotted, and over most of the mudflats covered with shallow water. This effectively eliminated easy access to the underlying food resources sought by shorebirds in the southern Coorong, even for longer-legged species, such as stilts and avocets. Furthermore, the algae prevented seed set for *Ruppia tuberosa* (Paton *et al*. 2017a) and floating mats were likely to restrict the emergence of adult chironomids (*Tanytarsus barbitarsis*), and hence the subsequent availability of chironomid larvae. Traditionally, these seeds and larvae have been key food resources for many shorebirds in the Coorong.

The water bird census conducted in January 2011 was also conducted during a similar period of unregulated flows and very high water levels in the Coorong (Paton and Bailey, 2011b). Low abundances of shorebirds and waterbirds comparable to those of January 2017 were reported in that year. The assumption is that in these wetter years with greater flows, there are alternative inland wetlands available for the Coorong birds to use. However, as yet, these other wetlands have not been identified. This remains a significant deficiency in our understanding of the biology and needs of these birds and limits our ability to manage wetlands for them. Importantly, one should not assume that in those years when the Coorong is unsuitable that there will be alternative productive wetlands available elsewhere for them. During dry periods, the Coorong will be one of the few wetlands available, and so maintaining the ecological character and productivity of this wetland from a waterbird perspective remains an important priority. The appearance of filamentous green algae in the southern Coorong is a recent phenomenon with little algae present prior to 2013. The widespread prominence of filamentous green algae throughout the southern Coorong in 2016-17 suggests that the southern Coorong is now eutrophic and that the ecological character has changed. Given this, problems associated with filamentous green algae are likely to recur in future years, including dry years, and the ability of the region to support large numbers of waterbirds, particularly shorebirds, is now likely to have been significantly diminished.

Of the remaining ten species that were below their long-term median abundances in the Coorong, seven were largely piscivorous bird species, including two species of grebes, two species of cormorants, two species of egret and Whiskered Tern. The ability of these species to forage in the shallows, at least around the southern Coorong, is also likely to have been affected by filamentous algae. However, other fish-eating species were in abundances above their long-term (2000-2015) median abundances, including Australian Pelican, Great Cormorant, Crested Tern, Caspian Tern (*Hydroprogne caspia*) and White-faced Heron (*Egretta novaehollandiae*). These differences suggest the responses of individual species varies irrespective of whether they share common resources. Caspian Terns and White-faced Herons were in their highest abundances on record for the Coorong, suggesting that some species have benefited from the changed conditions. The other three species present in abundances below their long-term median abundance were Chestnut Teal, Musk Duck (*Biziura lobata*) and Eurasian Coot (*Fulica atra*). For the first time in nearly 20 years, there were no Musk Ducks present anywhere in the Coorong (or the Lower Lakes). The abundance of Chestnut Teal, a species closely associated with the Coorong, rather than the Lower Lakes, was also the lowest on record. Filamentous algae might interfere with foraging for both species. Other waterfowl, including Black Swan, Australian Shelduck and Grey Teal, albeit present in lower numbers than in January 2016 (Table A4, Appendix A), were still present in numbers above their long-term median abundances. Interestingly, small numbers of Chestnut Teal had ducklings in attendance during the census, suggesting the Coorong was still suitable for them.

4.2 Abundances of birds in the Lower Lakes in January 2017 and relative to other years

A little over 61,000 birds (44 species) were counted in the Lower Lakes during the January-February 2017 census, about 70% of the numbers counted in the previous year (Paton *et al.* 2016d). Only one species exceeded 10,000 individuals, the Australian Shelduck, accounting for more than 25% of the birds counted (Table 4). Three other species exceeded 5,000 individuals: Grey Teal, Pied Cormorant (*Phalacrocorax varius*) and Pacific Black Duck (*Anas superciliosa*; Table 4). Seven species exceeded 1,000 individuals: Black Swan, Great Cormorant, Australian Pelican, Australian White Ibis (*Threskiornis molucca*), Straw-necked Ibis (*Threskiornis spinicollis*), Whiskered Tern and Silver Gull (Table 4). Over 60% of the birds that were counted were using Lake Alexandrina, a little more than 30% were counted in Lake Albert and the remaining 5% were present in the Goolwa Channel and related tributaries (Table 4). In January-February 2017, Lake Alexandrina also had the greatest species richness (40 species), whereas Lake Albert and the Goolwa Channel and related tributaries supported 27 and 28 species of birds, respectively.

In January-February 2017, 16 of the 25 bird species used in calculating the waterbird WOISS for the Lower Lakes were in abundances below their median abundances for 2013-2015 (Table 5), and 15 of these were in abundances lower than their abundances in January-February 2016 (Table A5). Eleven of these were piscivorous species, including four species of cormorant, two species of terns, two species of grebes, the Australasian Darter (*Anhinga novaehollandiae*), Australian Pelican and Great Egret (*Ardea modesta*). Lower abundances for this suite of species suggests that their typical food resources, smaller-bodied fish, may have diminished, particularly for Great Cormorants, where abundances had declined by over 10,000 birds over the last year. In contrast, the abundances of two other species of fish-eating birds, Crested Tern and White-faced Heron, were the highest on record in January-February 2017 (although their abundances were much lower than those of Great Cormorants). In contrast, the prominent herbivorous waterfowl in the Lower Lakes (Black Swan, Grey Teal, Australian Shelduck and Pacific Black Duck) were all in abundances above their target abundances (i.e., above their 2013-2015 median abundance), as were the two species of ibis and Royal Spoonbill (*Platalea regia*). Other species to be in lower abundances in January-February 2017 were Cape Barren Goose (*Cereopsis novaehollandiae*), Silver Gull, Purple Swamphen (*Porphyrio porphyrio*), Eurasian Coot and Masked Lapwing (*Vanellus miles*).

Table 4: Numbers of waterbirds counted in the Lower Lakes in January 2017. The table shows the abundances of each species in each of three regions of the Lower Lakes: Goolwa Channel & related tributaries; Lake Albert and Lake Alexandrina.

Species	Status* (SA, EPBC, IUCN)	Goolwa Channel	Lake Albert	Lake Alexandrina	Total
Black Swan		224	571	1772	2567
Australian Shelduck		680	8878	7765	17323
Pink-eared Duck				14	14
Australasian Shoveler	RA		58	122	180
Grey Teal		134	1899	3703	5736
Chestnut Teal		8	108	85	201
Pacific Black Duck		1000	3534	2600	7134
Hardhead		62	17	98	177
Freckled Duck	VUL			86	86
Australian Wood Duck		29	5	23	57
Cape Barren Goose	RA		331	543	874
Australasian Grebe		6			6
Hoary-headed Grebe		5	1	40	46
Australasian Darter	RA	1		30	31
Little Pied Cormorant				54	54
Great Cormorant		86	413	4377	4876
Little Black Cormorant		7	22	43	72
Pied Cormorant		17	884	6638	7539
Black-faced Cormorant				4	4
Australian Pelican		63	566	2015	2644
Caspian Tern		42	53	224	319
Whiskered Tern		1	50	2323	2374
Crested Tern		25	174	681	880
Great Egret	MIG		15	5	20
White-faced Heron		18	21	262	301
Australian White Ibis		118	254	1521	1893
Straw-necked Ibis		14	926	1690	2630
Royal Spoonbill		9	28	315	352
Yellow-billed Spoonbill				1	1
Pacific Gull		2			2
Silver Gull		192	302	952	1446
Dusky Moorhen		7		2	9
Purple Swamphen		95	72	102	269
Eurasian Coot		45	191	309	545
Black-tailed Native-hen		1			1

Table 4 continued

Species	Status* (SA, EPBC, IUCN)	Goolwa Channel	Lake Albert	Lake Alexandrina	Total
Black-winged Stilt				5	5
Red-capped Plover				36	36
Red-kneed Dotterel			2		1
Masked Lapwing		52	154	188	394
Common Greenshank	MIG			8	8
Marsh Sandpiper	MIG			2	2
Red-necked Stint	MIG, NT			11	11
Sharp-tailed Sandpiper	MIG			194	194
White-bellied Sea-eagle	END			1	1
Grand Total		2943	19529	38844	61316

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

Table 5: Abundance, Area of Occupation (AOO) and Extent of Occurrence (EOO) for waterbirds counted in the Lower Lakes in January 2017. The table lists all waterbird species recorded during January counts for 2017 and the two previous years. The median abundances and target values for AOO and EOO are also given for the 25 species of waterbirds regularly counted in the Lower Lakes that are used to determine the whole of icon site score (WOISS), along with the contribution that each of these species made to the 2017 WOISS. Abundances that fall below the recent median are indicated by red text, as are the AOOs and EOOs when these fall below the target value of 75% of the recent average AOO and EOO. The WOISS scores for individual species were determined by assigning a value of-1 if two of the three counts over the last 3 years fell below the long-term median abundance, and -2 if all three counts fell below the median. An additional -1 was added to the individual species score if the AOO or EOO fell below the target value for these variables, and -2 if both targets for these variables were not met.

Species	**Abundance**				**AOO**		**EOO**		**WOISS**
	2015	**2016**	**2017**	**Median**	**2017**	**Target**	**2017**	**Target**	
Black Swan	1692	3998	2567	1799	182	150	1584	1239	0
Australian Shelduck	13249	12909	17323	13249	205	137	1513	1186	0
Pink-eared Duck	30	235	14		2		2		
Australasian Shoveler	252	518	180		9		362		
Grey Teal	1023	6624	5736	3912	92	67	1599	1183	0
Chestnut Teal	56	297	201		18		930		
Pacific Black Duck	4538	5461	7134	4981	237	162	1721	1275	0
Hardhead	41	305	177		11		819		
Freckled Duck	56	347	86		2		2		
Blue-billed Duck	0	5	0						
Musk Duck	0	1	0						
Australian Wood Duck	7	282	57		10		926		
Cape Barren Goose	853	1124	874	1010	30	27	1041	781	-1
Australasian Grebe	0	0	6		1		2		
Hoary-headed Grebe	3	19	46	103	7	8	508	538	-4

Table 5 continued

Species	Abundance				AOO		EOO		WOISS
	2015	2016	2017	Median	2017	Target	2017	Target	
Great Crested Grebe	75	41	0	128	0	30	0	733	-4
Australasian Darter	73	55	31	73	12	22	404	643	-3
Little Pied Cormorant	53	146	54	84	10	31	449	1038	-3
Great Cormorant	14963	18840	4876	14963	282	228	1594	1285	0
Little Black Cormorant	412	333	72	907	15	63	803	1092	-4
Pied Cormorant	8759	11187	7539	8759	242	171	1309	1154	0
Black-faced Cormorant	0	0	4		1		1		
Australian Pelican	7203	6627	2644	6239	222	229	1389	1297	-1
Caspian Tern	583	976	319	609	99	82	1605	1131	-1
Whiskered Tern	3610	4622	2374	4497	110	268	1063	1291	-3
Common Tern	1	0	0						
Crested Tern	490	412	880	490	105	69	1436	1071	0
White-necked Heron	0	0	0						
Great Egret	51	215	20	133	11	73	516	961	-3
White-faced Heron	96	130	301	119	87	48	1511	1196	0
Nankeen Night Heron	5	17	0						
Glossy Ibis	22	0	0						
Australian White Ibis	508	946	1893	611	125	80	1466	1245	0
Straw-necked Ibis	239	1333	2630	1620	62	27	1350	992	-1
Royal Spoonbill	215	201	352	209	45	22	1112	1004	0
Yellow-billed Spoonbill	11	4	1		0		0		
White-bellied Sea-eagle	2	1	1		1		1		
Pacific Gull	0	1	2		1		1		
Silver Gull	1823	1901	1446	1823	87	74	1331	1133	0
Purple Swamphen	463	620	269	463	76	83	1575	1166	-1
Dusky Moorhen	32	25	9		5		22		
Eurasian Coot	2492	4151	545	3339	32	114	1212	1233	-3
Black-tailed Native Hen	0	11	1		1		1		
Pied Oystercatcher	0	1	0						
Black-winged Stilt	85	269	5		2		2		
Red-necked Avocet	0	133	0						
Red-capped Plover	15	3	36		4		131		
Red-kneed Dotterel	0	3	2		0		0		
Masked Lapwing	565	599	394	565	64	56	1506	1170	0
Black-tailed Godwit	1	1	0						
Common Greenshank	10	8	8		1		1		
Marsh Sandpiper	4	0	2		1		1		
Wood Sandpiper	1	0	0						
Red-necked Stint	30	115	11		3		1		
Sharp-tailed Sandpiper	214	581	194		5		37		
Curlew Sandpiper	52	0	0						
WOISS (total)									**-32**

4.3 Birds of listed conservation status in the Coorong and Lower Lakes in January 2017

Of birds listed as 'endangered' by the International Union for Conservation of Nature (IUCN), only the Far Eastern Curlew (*Numenius madagascariensis*) was found in the Coorong in January 2017, with only eight individuals observed (Table 2). The Fairy Tern (*Sternula nereis*) and Hooded Plover (*Thinornis rubricollis*), both listed as 'vulnerable' (IUCN), were found in the Coorong in January 2017, and while this included 361 Fairy Terns, only eight Hooded Plovers were observed using the South Lagoon (Table 2). However, 85 of the 361 Fairy Terns were immatures, believed to be recruits from the summer 2015-16 breeding attempts and about 1-year old (Fairy Terns first breed when 2-years old). Such a large cohort of immature birds is promising but it is concerning that adult abundances have decreased by some 100 individuals since January 2016 (Paton *et al.* 2016d).

Five 'near threatened' IUCN listed species were observed in the Coorong and Lower Lakes, namely Black-tailed Godwit (*Limosa limosa*), Bar-tailed Godwit (*Limosa lapponica*), Red Knot (*Calidris canutus*), Red-necked Stint and Curlew Sandpiper, with the two latter species exceeding 5,000 and 200 birds, respectively (Table 2; Table 4). However, the numbers of Red-necked Stint and Curlew Sandpiper in the Coorong were relatively low, only constituting 22% and 9% of their long-term median abundances, respectively (Table 3). Furthermore, under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999, the Far Eastern Curlew, Bar-tailed Godwit and Curlew Sandpiper are considered 'critically endangered', while the Red Knot is listed as 'endangered' (Table 2). With the exceptions of the Fairy Tern and Hooded Plover, the species listed above are considered 'migratory' under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 (Table 2; Table 4).

Of greatest concern under the South Australian National Parks and Wildlife (SANPW) Act 1972 are the Fairy Tern, Little Tern (*Sternula albifrons*) and White-bellied Sea-eagle (*Haliaeetus leucogaster*) (listed as endangered) and, albeit to a lesser extent, Freckled Duck (*Stictonetta naevosa*), Banded Stilt, Hooded Plover and Far Eastern Curlew (listed as vulnerable) (Table 2; Table 4).

Some species of conservation status that have been found in the Coorong and Lower Lakes in previous years were notably absent in January 2017: (a) there were no Blue-billed Duck (*Oxyura australis*), which are listed as near threatened (IUCN); (b) no Whimbrel (*Numenius phaeopus*) nor Sanderling (*Calidris alba*), which are 'migratory' birds (EPBC) and locally 'rare' (SANPW); and (c) no Musk Duck, which are also locally 'rare' (SANPW).

4.4 AOO and EOO for waterbirds using the Coorong and Lower Lakes in 2017

The areas of occupation (AOO) and extents of occurrence (EOO) for all of the waterbird species counted in the Coorong and Lower Lakes during the 2017 census are provided in Table 3 and Table 5, respectively.

AOOs and EOOs provide measures of the distribution of the different bird species within these two wetland systems and can also be used to assess the status and changes in status of species over time. The EOO measures the spread of a species while the AOO indicates the amount of area being used by a species. Species with a high EOO are widely distributed across a wetland, while those with a low EOO may have a restricted distribution which may indicate specific habitat requirements. A high AOO indicates that most of the wetland is being used by a species while a low AOO indicates that only a small portion of the wetland is being used, perhaps because specific habitat needs are rarely met. Alternatively, species with a low AOO may aggregate in flocks and so only occupy a few areas at any one time, or the species has a low abundance overall resulting in few areas being used.

For the Coorong, 26 species used all three wetland components (estuary, north and south lagoons) in January 2017 (Table 2) and so had high EOOs, with 25 species spread over at least 80 km of the Coorong (Table 3). For AOOs, three species were recorded at more than 150 locations (cells) within the Coorong, half the number of species in the previous year. A further six species were detected at 80 or more locations. More detailed analysis of the distributions of selected species, with greater than 1000 individuals counted in the Coorong, show distinct patterns between different groups of birds. For example, Red-necked Stints were largely associated with the northerly sections near the Murray Mouth and more predominantly at the junction between the two lagoons, while Red-necked Avocets were also abundant at this junction and further south, being largely restricted to the South Lagoon (Figure 1). In contrast, various herbivorous waterfowl (swans and ducks), were more evenly spread along the length of the Coorong (Figure 1). These patterns are likely to reflect the distribution and access to different food resources for the different groups of birds.

For the Lower Lakes, 19 species had EOOs in excess of 1000 km^2 (Table 5). These species were mainly waterfowl (e.g., ducks) and fish-eating species (e.g., cormorants) but also included Australian White Ibis, Straw-necked Ibis, Royal Spoonbill Silver Gull, Purple Swamphen, Eurasian Coot and Masked Lapwing. Waterbirds, however, only use the margins of the Lower Lakes and, as the EOO is calculated as the minimum convex polygon that includes all records, much of the area included in the EOO is not used. Nine of these 19 species were counted in at least 100 of the 1 km x 1 km cells, but none were counted in excess of 300 cells, unlike the previous year where there were three species (Paton *et al.* 2016d). Of the species with EOOs of less than 1000 km^2, none were detected in more than 25 of the 1 km x 1 km cells (Table 5).

Of the 40 species used to calculate the waterbird WOISS for the Coorong, 18 species failed to reach their target EOO, target AOO or both, suggesting significant reductions in distribution relative to their long-term (2000-2015) distributions within the Coorong. These species included seven largely piscivorous species (2 grebes, 2 terns, 2 egrets, 1 cormorant), nine species of shorebird, and Eurasian Coot and Musk Duck. Sixteen of these 18 species also failed to reach their abundance targets.

Of the 25 species used to calculate the waterbird WOISS for the Lower Lakes, eight species failed to reach their target EOO and AOO in January-February 2017, and two other species, Purple Swamphen and Australian Pelican, failed to reach their AOO target. These targets were set at 75% of their average EOOs and AOOs during 2013-2015 and indicate significant reductions in their distributions within the Lower Lakes. Eight of the ten species were fish-eating species; two species

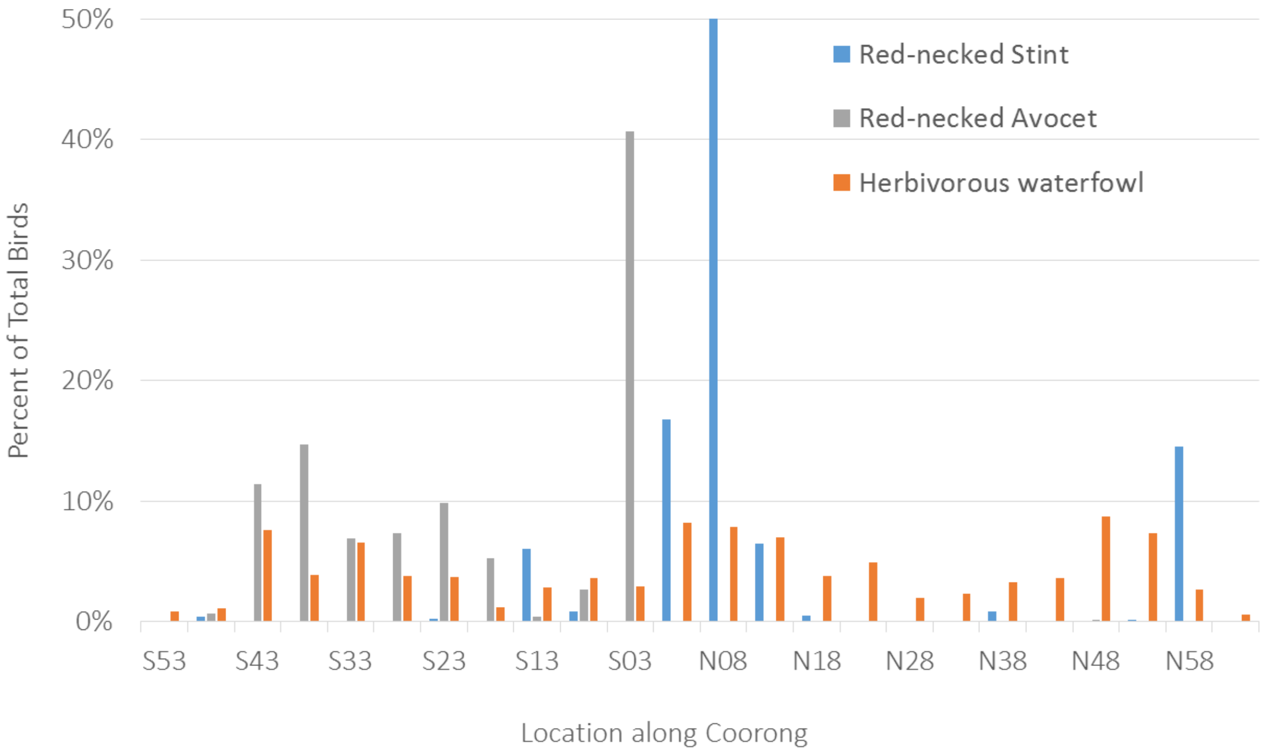

Figure 1: The percent of total birds counted in each 5-km section along the Coorong for January 2017 for Red-necked Stint, Red-necked Avocet and four species of herbivorous waterfowl, namely Australian Shelduck, Black Swan, Grey Teal and Chestnut Teal, combined.

of grebe, two species of cormorant, Australasian Darter, Australian Pelican, Whiskered Tern and Great Egret. All ten species also failed to reach their abundance targets.

4.5 Whole of Icon Site Score (WOISS) for waterbird populations in the Coorong for January 2017

The Whole of Icon Site Score (WOISS) for the Coorong in January 2017 was -41 (Table 3), a score considerably less than the WOISS of -26 in 2016, and lower than the previous four years (Figure 2). While the WOISS is still better than the WOISS during the nine years from 2004-2012 (inclusive) (Figure 2), the recent decline is of concern. Little Pied Cormorant (*Microcarbo melanoleucos*) and Banded Stilt both contributed -4 (the maximum deficit possible) to the WOISS, with Musk Duck and Pacific Golden Plover (*Pluvialis fulva*) contributing -3. Chestnut Teal, Hoary-headed Grebe, Great Crested Grebe (*Podiceps cristatus*), Great Egret, Hooded Plover, Common Greenshank, Sharp-tailed Sandpiper and Curlew Sandpiper all contributed -2, while a further 12 species also failed to meet one of their species' targets for abundance, AOO or EOO.

4.6 Whole of Icon Site Score (WOISS) for waterbird populations in the Lower Lakes for January 2017

The Whole of Icon Site Score (WOISS) for the Lower Lakes in January 2017 was -32, which is close to three times the WOISS for the previous two years (-11 in 2016 and -12 in 2015; see Paton *et al.* 2016d). As was the case in 2016, Hoary-headed Grebe, Great Crested Grebe and Little Black Cormorant (*Phalacrocorax sulcirostris*) contributed the maximum deficit of -4 to the WOISS (Paton *et al.* 2016d; Table 5). Consequently, these three species have failed to meet their abundance

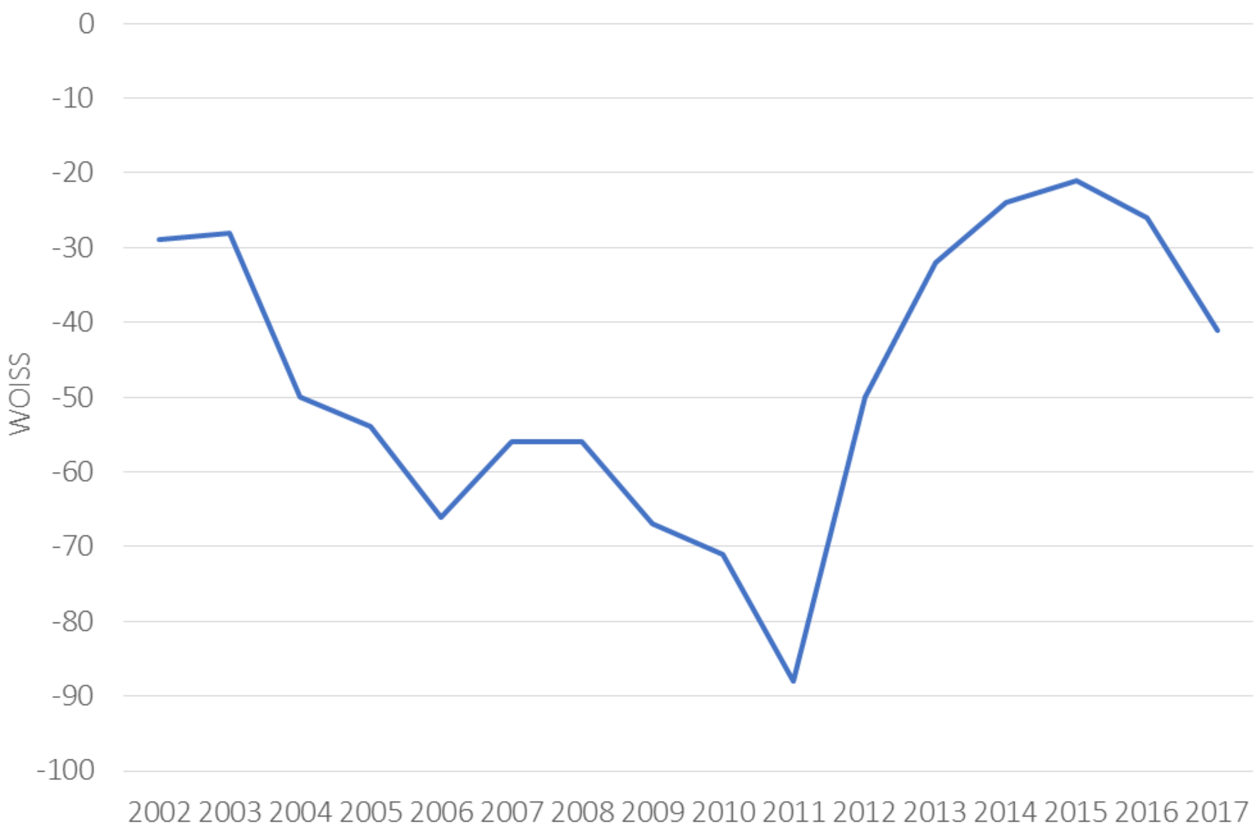

Figure 2: Changes in the whole of icon site score (WOISS) for waterbirds using the Coorong in January from 2002 to 2017. See Table 3 for the individual species and their scores used in calculating the WOISS in 2017.

targets in the last three years and their EOO and AOO targets in 2016 and 2017. These three species largely consume small fish, as do four other species that each contributed -3 to the WOISS of the Lower Lakes in 2017, namely Australasian Darter, Little Pied Cormorant, Whiskered Tern and Great Egret (Table 5). Furthermore, 12 of the 14 piscivores that are regularly counted in the Lower Lakes failed to reach their species' median abundance target in 2017, with many falling well short (e.g., in 2017, there were 20 Great Egret, equivalent to only 15% of their median abundance target). Failures of many of the piscivores to meet such targets may reflect a shift in the availability of small fish.

The WOISS calculated for waterbirds using the Lower Lakes is not comparable to the WOISS calculated for waterbirds using the Coorong because of differences in the range and number of species used in the calculations. The Coorong WOISS is based on 40 species while the WOISS for the Lower Lakes is based on 25 species. On a 'per species' basis, the average contribution of the 40 species contributing to the WOISS for the Coorong in 2017 was -1.03 compared to -1.28 for the 25 species contributing to the Lower Lakes WOISS in 2017, meaning that the WOISS score for the Lower Lakes was a littler poorer than for the Coorong.

4.7 Waterbird breeding in the Coorong and Lower Lakes in January 2017

The Coorong is an important breeding ground for colonies of Fairy Terns (listed as *Endangered* (SANPW Act 1972) and *Vulnerable* (EPBC and IUCN) – see Section 4.3) and supports other colonial nesting birds, such as Australian Pelican, Crested Tern and Caspian Tern. Some 3200 Australian

Pelicans, 2600 Crested Terns and 140 Caspian Terns were observed nesting in the South Lagoon during the January 2017 census, all more than observed in January 2016 (Paton and Paton 2016).

However, Fairy Terns, which tried to breed in two locations throughout December and January, had limited success in the 2016-17 breeding season. There were two breeding colonies of Fairy Terns in 2016-17: the first on Younghusband Peninsula around the Murray Mouth and the second on an islet close to the eastern shoreline in the South Lagoon. Throughout January, the former colony was disturbed and/or predated upon a couple of times, but 10 free-flying juveniles were observed in late January. The second colony was on an island in the South Lagoon and had about 75 nests with between one and three eggs in mid-January. However, due to the barrage closure in early January, resulting in a rapid 0.6m drop in water levels in the South Lagoon over January (Paton *et al.* 2017), the island was reconnected to the mainland by late January and the colony was destroyed by foxes before any chicks were even hatched. Breeding success was also hampered by (a) numerous storm events that resulted in birds abandoning their nests; and (b) by relatively high water levels throughout the southern Coorong compared with previous years (Paton *et al.* 2017) that kept their normal breeding islands used in recent years in the southern Coorong inundated with water.

In January 2017, there were also around 750 Silver Gulls (*Chroicocephalus novaehollandiae*) breeding on islands in the South Lagoon. Two dependent Hooded Plover chicks were seen near Salt Creek and two pairs of Pied Oystercatchers (*Haematopus longirostris*) were also seen with dependent chicks. Numerous Black Swan cygnets and Chestnut Teal ducklings were also observed.

The Lower Lakes also provided breeding grounds for some bird species (Figure 3). Notably during the census of the Lower Lakes in 2017, three colonies of Pied Cormorant were observed in Lake Alexandrina (Figure 3), with a total of 1540 free-flying juveniles and 840 nestlings. Straw-necked Ibis were also breeding in relatively large numbers, with around 500 nestlings and 200 nests with eggs observed in total over four breeding colonies (Figure 3). Compared with Pied Cormorant and Straw-necked Ibis, Australian White Ibis and Royal Spoonbill had more colonies but with fewer birds per colony, and were often found nesting in the same locations (Figure 3). In total, for the Australian White Ibis, there were four free-flying juveniles, about 30 nestlings and more than 15 nests with eggs. For the Royal Spoonbill, there were a total of two free-flying Juveniles, around 15 nestlings and at least 15 nests with eggs. There was a single colony of Little Pied Cormorant near Wellington in Lake Alexandrina (Figure 3), consisting of nests with eggs and close to 40 adults.

A single juvenile Australasian Grebe (*Tachybaptus novaehollandiae*) was observed at the sewage lakes west of Goolwa (Figure 3) and outside the Lower Lakes census area, while 13 juvenile Purple Swamphen, 23 juvenile Pacific Black Duck, 200 cygnets and 2 Black Swan nests were also observed throughout the Lower Lakes during the census in 2017 (Figure 3).

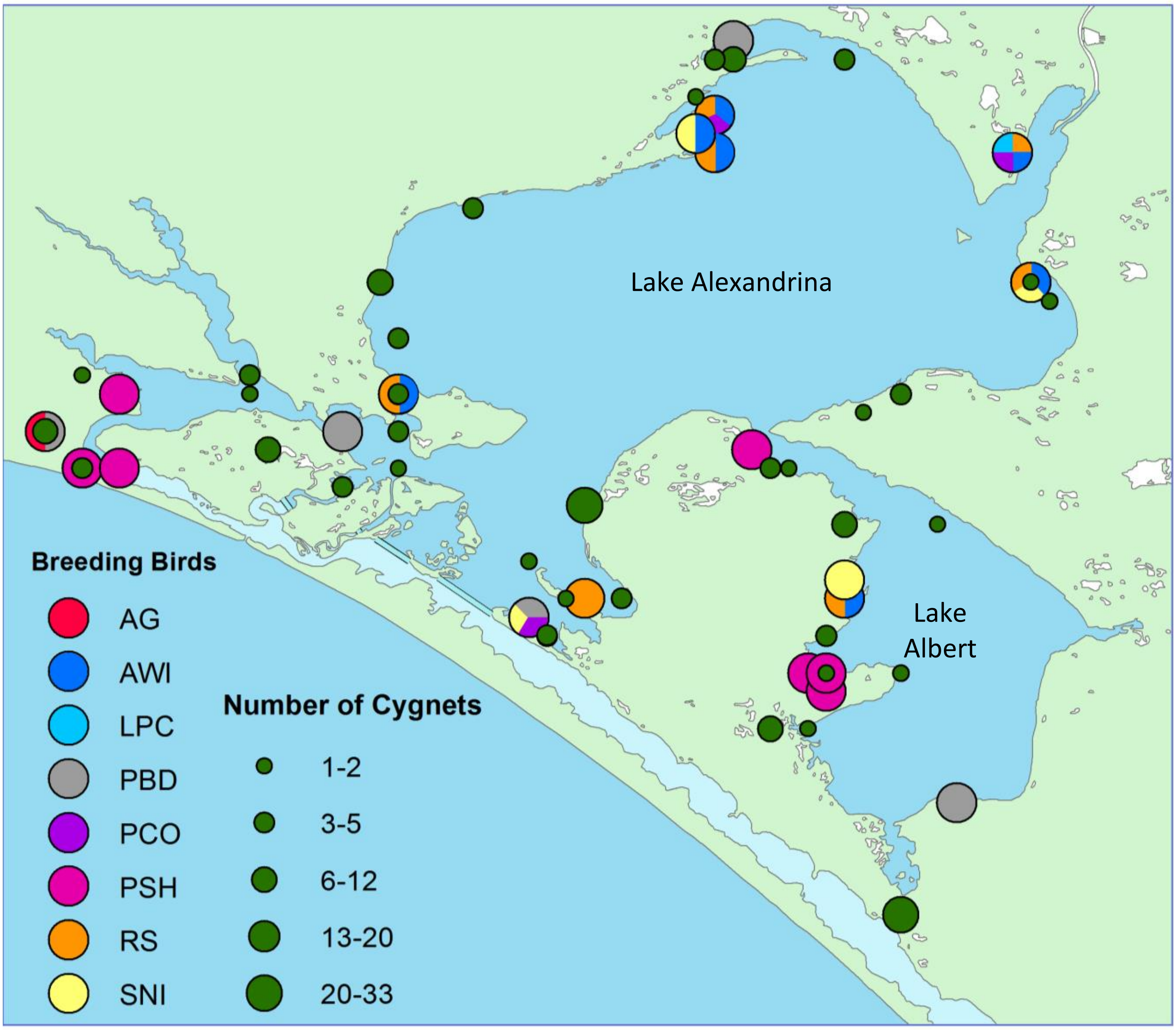

Figure 3: Locations of breeding birds (AG = Australasian Grebe, AWI = Australian White Ibis, LPC = Little Pied Cormorant, PBD = Pacific Black Duck, PCO = Pied Cormorant, PSH = Purple Swamphen, RS = Royal Spoonbill, SNI = Straw-necked Ibis) and sightings of Black Swan cygnets in the Lower Lakes in January 2017.

4.8 Waterbird foraging levels

The waterbird species that were using the Coorong in January 2017 differed with respect to the percentages of birds that were foraging when detected. In general, fish-eating species had low percentages of foraging birds (Table 6), indicating that little time was needed to harvest the food they needed and that food resources were easily harvested, as has been the case in previous years. That several fish-eating species (terns and Australian Pelican) were also breeding in the Coorong in January 2017 (Section 4.7) is consistent with an abundance of food. In contrast, most of the shorebirds were usually foraging when counted (Table 6), indicative of using food resources that were poorer or more difficult to harvest. In general, the proportion of birds that were foraging when counted during the waterbird census of the Coorong in January 2017 was lower than in previous years (Table 6). Some care, however, is required in interpreting these apparent lower foraging levels for waterbirds in the Coorong for January 2017. For many of the shorebirds in particular, the numbers of birds scored was much lower than in previous years. When the

Table 6: Percent of birds that were foraging when detected during the census of waterbirds in the Coorong in January from 2006 to 2017, for species where more than 100 individuals were detected and assigned a behavioural activity. Those species where 70% or more of the birds were foraging are shaded in dark pink (with white text), and those with 50-69% of the birds foraging are shaded in pale pink. The amount of foraging is likely to be related to the quality of the habitat, such that if 70% or more of the birds are foraging the habitat quality and associated food resources are poor.

Species	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Black Swan	35	30	46	57	24	17	21	30	20	26	20	14
Australian Shelduck	13	14	14	9	24	4	11	5	21	19	19	18
Grey Teal	11	22	7	7	30	0	18	24	14	14	19	13
Chestnut Teal	8	9	12	4	36	0	15	3	6	22	12	12
Pacific Black Duck	65	21	15	31	38	31	11	12	19	48	27	80
Musk Duck	25	10	95	52	44	38	57	58	77	19	27	
Hoary-headed Grebe	99	90	81	35	73		67	66	62	64	14	32
Great Crested Grebe	60	85	14	17	59	0	77	48	73	54	56	
Great Cormorant	7	1	13	2	1	18	13	14	1	3	3	2
Little Black Cormorant	65	1	5	22	0	1	38	2	2	9	3	3
Pied Cormorant	23	3	18	25	8	22	17	4	9	11	10	19
Australian Pelican	13	3	10	21	3	11	7	6	11	14	16	6
Fairy Tern	20	16	26	34	83	3	13	7	8	15	17	12
Caspian Tern	8	2	16	8	7	23	16	12	12	16	16	10
Whiskered Tern	47	33	36	42	29	0	40	33	34	33	28	23
Crested Tern	3	0	1	0	0	8	5	1	1	6	2	5
White-faced Heron	44	16	36	30	9	27	22	43	27	33	32	36
Australian White Ibis	58	64	57	32	29	19	59	57	58	68	76	65
Silver Gull	16	24	26	31	25	23	24	29	27	34	21	19
Eurasian Coot	2						21	33	19	57	6	
Black-winged Stilt	27	80	67	58	64	57	39	67	70	81	75	
Red-necked Avocet	31	46	48	14	22	25	30	51	61	78	37	16
Banded Stilt	65	53	72	98	82	68	79	89	78	75	81	4
Red-capped Plover	51	50	74	49	66	61	77	84	86	77	61	63
Masked Lapwing	11	7	18	12	20	7	6	16	14	17	44	21
Common Greenshank	62	58	64	46	27	16	48	51	57	63	64	49
Red-necked Stint	75	72	80	60	30	41	85	92	84	88	77	42
Sharp-tailed Sandpiper	60	67	72	62	47	47	73	90	89	72	87	95
Curlew Sandpiper	76	79	96	98	64	69	78	96	41	60	84	52

numbers are lower and there are fewer flocks, the behaviour of just a few flocks when detected can by chance influence the percentages, and so the scores for January 2017 may not be indicative of the actual foraging levels of the birds. A similar argument may account for the high proportion of Pacific Black Duck that were reported as foraging when counted as well. In January 2017, a higher proportion of the shorebirds that were detected were flying (for some species over 15%), which was much higher compared to previous years (usually 0-3%). Such a finding suggests the birds were finding it more difficult to find suitable foraging areas that allowed extended periods of foraging in the Coorong in January 2017 compared with previous years. This is consistent with the much higher water levels in January 2017 that largely eliminated suitable habitat for these birds, and with the widespread blanketing of shorelines with filamentous green algae *(Ulva* sp.) which would have prevented access to underlying food resources for shorebirds (Paton *et al.* 2017). Of the 8-10 sites that have been used in recent years to collect behavioural data throughout the day (e.g., Paton *et al.* 2016d), only one (Villa dei Yumpa, S06E) yielded sufficient birds (i.e., at least 100 records for individual species) to allow foraging percentages to be calculated in 2017, and then only for 11 species. Interestingly, none of these 11 species was present at this site throughout the entire day, indicating that even this site was unable to support the birds and their foraging throughout the day. Given this, percent foraging levels, which ranged from 14% for Silver Gulls to 87% for Sharp-tailed Sandpipers are unlikely to be reliable. The different species were also often present at different times of the day, for example the small shorebirds (namely Red-necked Stint, Sharp-tailed Sandpiper, Curlew Sandpiper and Red-capped Plover) were only present in the two morning sessions (of the five sessions).

A similar data set of foraging rates was also collected during the census of the Lower Lakes with only two species spending more than 50% of their time foraging in 2017: Purple Swamphen and Cape Barren Goose (Table 7). The other species were typically spending less than 40% of their time foraging, indicating that food resources were meeting their requirements. In general, the various bird species were spending similar amounts of time foraging in 2017 as they were in 2016 (Table 7), suggesting little change in resource levels for waterbirds between years. However, importantly, many of the species (e.g. Little Black Cormorant, Great Crested Grebe and Great Egret) that feed on small-bodied fish were either not present or in such small numbers that a legitimate estimate of their foraging levels could not be determined. However, Caspian Terns, which also feed on small-sized fish, were spending more time foraging in 2017 than in previous years. In combination with reduced abundances in 2017 for Caspian Tern (Table 5), this further suggests foraging opportunities had deteriorated for this group of birds.

4.9 Ecological conditions and food resources in the Coorong in January 2017

In January 2017, salinities of the Murray estuary of the Coorong ranged from 4-20 gL^{-1}, while for the North Lagoon salinities increased steadily southwards from 6 gL^{-1} at Pelican Point to 68 gL^{-1} at Magrath Flat (Figure 4). There was no gradient of salinities in the South Lagoon with salinities varying between 58 gL^{-1} and 83 gL^{-1} (Figure 4). These salinities were amongst the lowest recorded for the Coorong in January for the previous 18 years and similar to the salinities reported in January 2002 (Figure 4).

Polychaetes were the prominent benthic invertebrate across the North Lagoon and Murray Estuary (Figure 5), associated with the lower salinities. There were small, patchy influxes of polychaetes into the South Lagoon for the first time (Figure 5), reflecting the lower salinities in this lagoon in January 2017 (Figure 4). Generally, abundances of polychaetes within the Coorong were lower than they have been for the last five years (Figure 5).

Table 7: Percent of birds that were foraging when detected during the census of waterbirds in the Lower Lakes in January from 2009 to 2017, for species where more than 100 individuals were detected and assigned a behavioural activity. Those species where 70% or more of the birds were foraging are shaded in dark pink (with white text), and those with 50-69% of the birds foraging are shaded in pale pink. The amount of foraging is likely to be related to the quality of the habitat, such that if 70% or more of the birds are foraging the habitat quality and associated food resources are poor.

Species	2009	2010[#]	2011	2012	2013	2014	2015	2016	2017
Black Swan	46	0	38	16	20	8	20	24	23
Australian Shelduck	18	2	19	7	9	13	29	8	4
Grey Teal	33	2	1	3	17	20	7	13	17
Pacific Black Duck	11	0	3	14	21	13	17	10	4
Cape Barren Goose	20	0	19	41	58	54	66	44	52
Great Cormorant	1	0	24	27	3	8	21	20	10
Little Black Cormorant	4	0	4	14	12	2	12	6	
Pied Cormorant	7	0	6	13	12	11	13	13	16
Australian Pelican	22	0	11	6	13	5	14	11	5
Caspian Tern	11	0	40	29	12	27	19	16	46
Whiskered Tern	22	0		51	60	51	49	41	36
Crested Tern	17	0	23	38	9	31	38	36	16
Great Egret	39		22	27	37	16		38	
White-faced Heron			8	48	32	35		38	23
Australian White Ibis	40	0	14	37	55	25	55	60	48
Straw-necked Ibis	3	0	6	28	13	9	60	37	29
Royal Spoonbill	1	0	4	8	29	8	5	28	14
Silver Gull	26	1	6	3	4	6	9	5	3
Purple Swamphen				57	59	63	56	54	51
Eurasian Coot	77	0		34	53	40	45	52	49
Masked Lapwing	32	0	5	8	8	16	18	18	17

[#] In 2010, water levels were exceptionally low, so there was very limited opportunity for waterbirds to forage, accounting for the low foraging levels in 2010

The chironomid (*Tanytarsus barbitarsis*) was restricted to the southern Coorong (sites from 54 to 97 km from the Murray Mouth) (Figure 6). However, for much of the South Lagoon, abundances were much lower than in previous years, except in areas near the junction of the two lagoons (between N02 and S06, i.e., 54 to 62 km from the Murray Mouth) (Figure 6). Interestingly, those species that feed on chironomid larvae, e.g., Red-necked Stint, Red-necked Avocet, showed higher abundances within this region (Figure 1). The chironomids detected near the Murray Mouth (Figure 6) were a different species of chironomid (*Chironomus* sp.). Red-necked Stint abundances also peaked, albeit to a lesser extent, in this region (Figure 1).

Several other aquatic invertebrates, notably amphipods and small cockles, continue to be prominent in mud cores taken at some of the sites in the northern Coorong in January 2017 (Table 8).

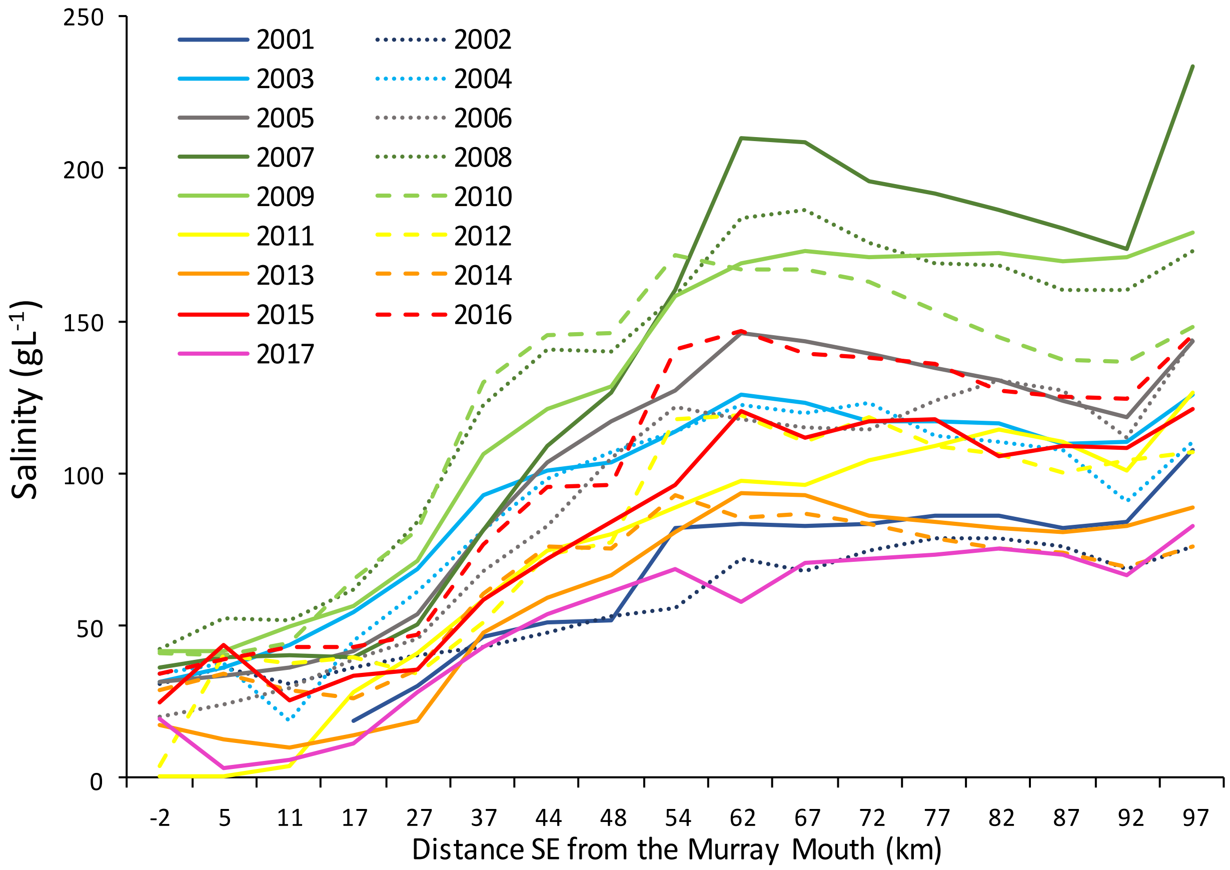

Figure 4: Salinities along the Coorong are shown for January from 2001 to 2017. Position along the Coorong is defined as the distance from the Murray Mouth, where negative values are NW of the mouth and positive values are SE. The junction of the two lagoons (Parnka Point) is at kilometre 59.

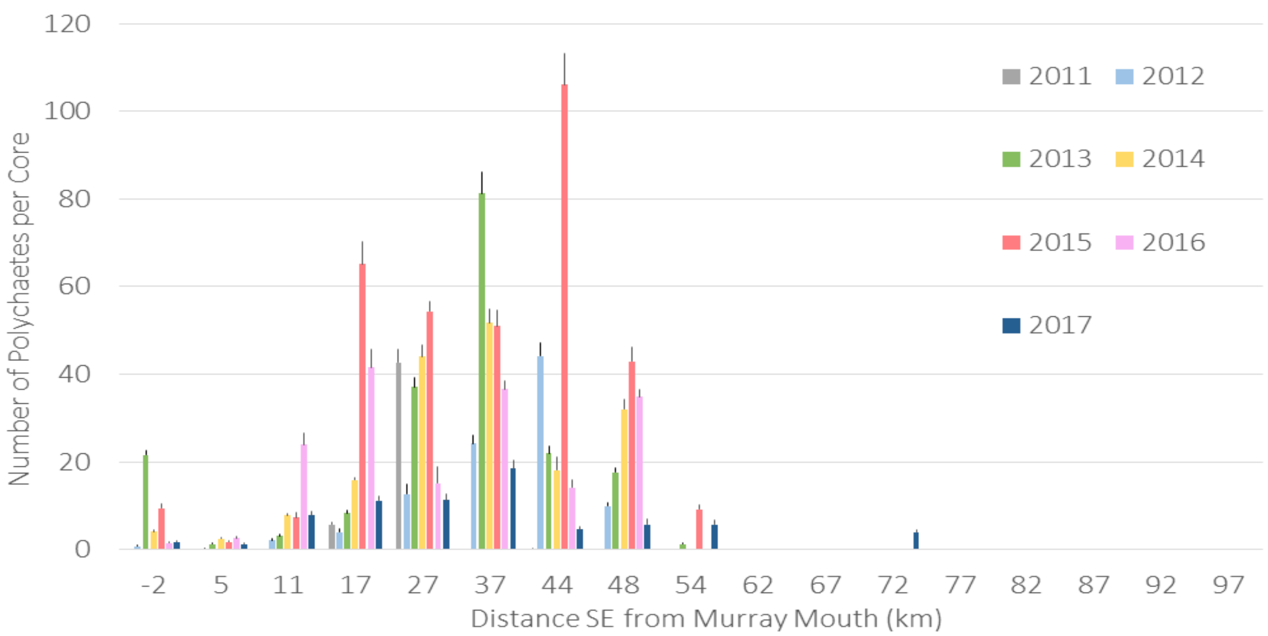

Figure 5: Mean number (+ s.e.) of polychaete worms found in 20-50 cores (10-25 samples taken in water 30cm deep and 10-25 samples at 60cm water depth) at 17 sites spread along the eastern shore of the Coorong (see Figure A1) in January from 2011 to 2017. Data can be converted to items/m^2 by multiplying by 226. Sites at -2, 5 and 11 km are in the region known as the Murray estuary; those at 17-54 km are in the North Lagoon; while those from 62-97 km are in the South Lagoon. Negative distances are NW of the Murray Mouth. Polychaetes include at least three species, of which the most abundant was a species of *Capitella*. In 2016, 60cm-deep samples could not be collected at sites at -2, 62, 82 and 97 km from Murray Mouth.

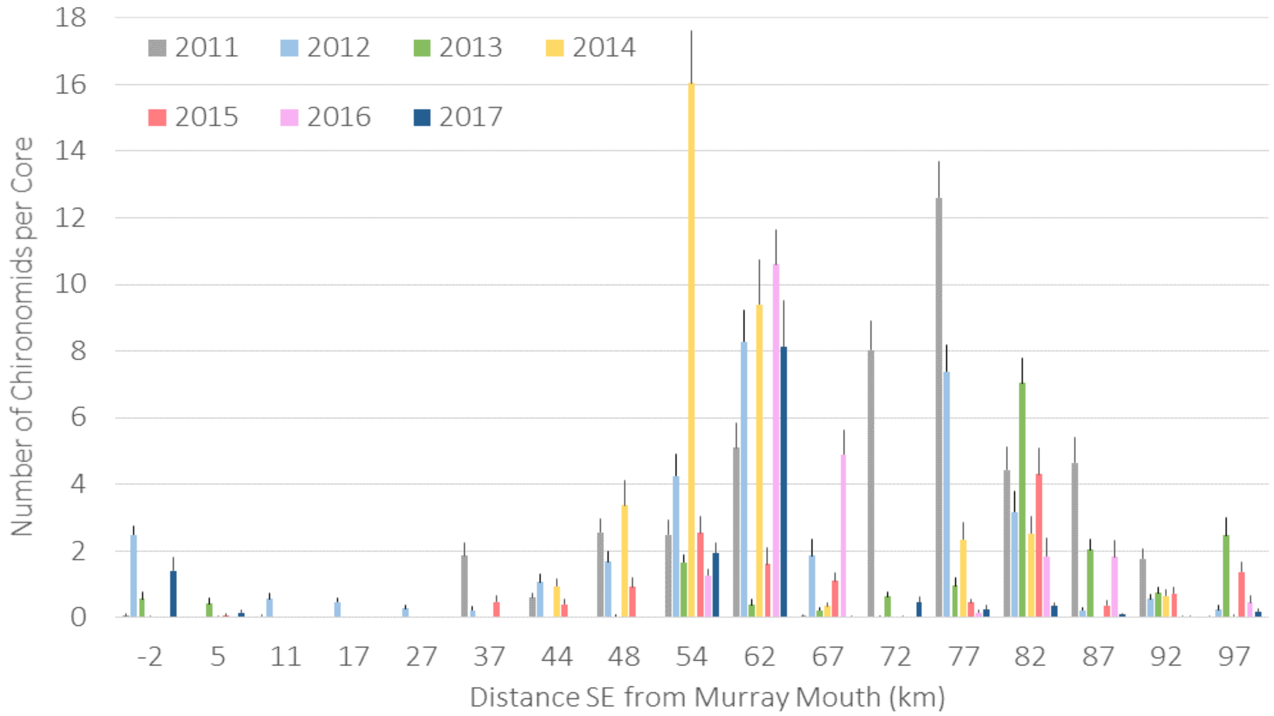

Figure 6: Mean number (+ s.e.) of chironomid larvae found in 20-50 cores (10-25 samples taken in water 30cm deep and 10-25 samples at 60cm water depth) at 17 sites spread along the eastern shore of the Coorong (see Figure A1) in January from 2011 to 2017. Data can be converted to items/m^2 by multiplying by 226. Sites at -2, 5 and 11 km are in the region known as the Murray estuary; those at 17-54 km are in the North Lagoon; while those from 62-97 km are in the South Lagoon. Negative distances are NW of the Murray Mouth. Note that the chironomids occupying the southern Coorong were *Tanytarsus barbitarsis,* while those near the Murray Mouth were another species (probably a species of *Chironomus*).

Table 8: Abundances of amphipods and small cockles in mud samples taken in the Coorong in January 2017. Data show means ± s.e. for 10 cores taken at each depth. Cockles were predominantly (>95%) < 5 mm across. To convert the means per core to mean abundance per m^2 multiply by 226. See Table A3 and Figure A1 in Appendix for site locations and a map of sites, respectively.

Site	Km from Mouth	Exposed	waterline	30 cm	60 cm
		Amphipods			
N58E	2	1.3 ± 0.7	1.4 ± 0.5	11.4 ± 1.3	12.6 ± 2.8
N52E	4	2.6 ± 0.7	5.4 ± 1.6	4.5 ± 1.6	17.0 ± 2.3
N45E	11		0.0 ± 0.0	2.2 ± 0.8	13.2 ± 2.6
N39E	17	0.0 ± 0.0	0.8 ± 0.6	7.9 ± 1.7	7.5 ± 1.2
N29E	27		0.1 ± 0.1	4.8 ± 0.9	6.1 ± 1.6
N19E	37		3.4 ± 1.8	6.6 ± 1.7	6.3 ± 1.3
N12E	42		0.0 ± 0.0	0.0 ± 0.0	0.5 ± 0.2
		Cockles			
N58E	2	0.9 ± 0.6	3.1 ± 0.7	0.1 ± 0.1	2.7 ± 0.6
N52E	4	0.0 ± 0.0	12.1 ± 2.9	6.7 ± 1.6	0.9 ± 0.3
N45E	11		0.8 ± 0.6	1.1 ± 0.5	8.2 ± 2.0
N39E	17	0.0 ± 0.0	0.1 ± 0.1	1.5 ± 0.6	4.1 ± 1.3
N29E	27		0.0 ± 0.0	1.1 ± 0.4	22.2 ± 4.0
N19E	37		0.0 ± 0.0	0.3 ± 0.3	0.1 ± 0.1

Smallmouth hardyhead continued to be distributed in the shallow waters around the margin of the Coorong, but predominantly in the more saline South Lagoon (Figure 7). Other species of small fish were caught in smaller numbers (overall) at most sites in January 2017, bar those in the Murray Estuary where they were most abundant (Figure 8).

The other key food resource used in the southern Coorong by a range of waterbirds is the aquatic plant *R. tuberosa*. In January 2017, *R. tuberosa* was substantially more prominent than in previous years but was still patchily distributed and in general was largely detected growing at the same sites where it was detected growing in previous years (Figure 9; Paton *et al.* 2017). Grazing pressure on these plants was moderate compared to previous years, with only 57% of shoots showing some level of grazing compared to over 80% in January 2016 (Paton *et al.* 2017).

In addition to consuming the foliage of *R. tuberosa*, many waterfowl (ducks, swan) will also consume the seeds and turions of *R. tuberosa*, and seeds and turions are also taken by some shorebirds, including sandpipers, stints, stilts, and plovers (e.g., Paton 1986, Paton 2010, Paton *et al.* 2015a). The abundances of these two food resources in the Coorong were still low during January 2017 (Table 9). For example, overall seed densities in the upper 4 cm of sediment within the normal extent of occurrence of *R. tuberosa* (Paton *et al.* 2016a,b) were 229 seeds.m^{-2} and comparable to previous years (Paton *et al.* 2016d). The densities for turions were 520 turions.m^{-2}, also comparable to previous years (Paton *et al.* 2016d). These densities compare to historical densities of around 20,000 seeds.m^{-2} and over 3,000 turions.m^{-2} in the South Lagoon in the early 1980s (Paton 1986). The maximum densities of seeds and turions at any site were 1335 seeds.m^{-2} and 1652 turions.m^{-2}, both from sites at the northern end of the South Lagoon, where many of the shorebirds, particularly Red-necked Stint, were aggregating in January 2017.

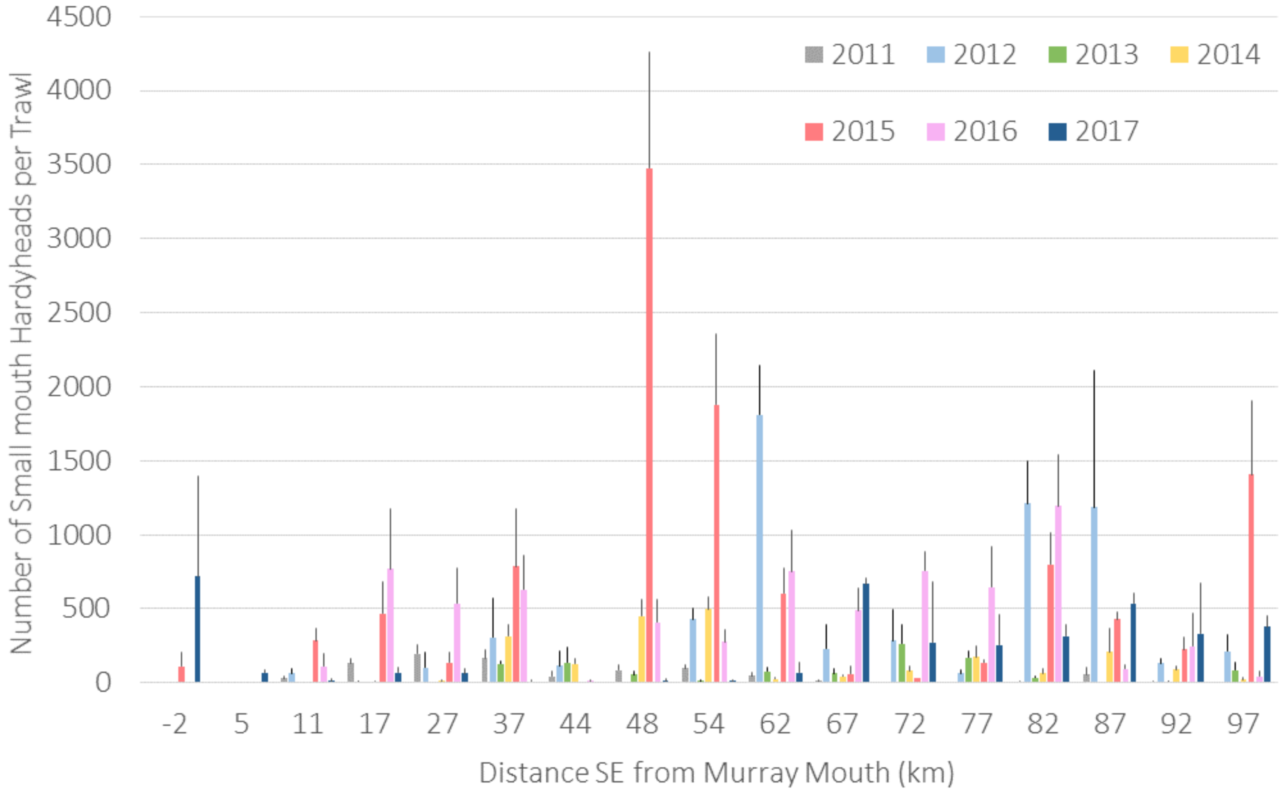

Figure 7: Mean number (+ s.e.) of smallmouth hardyheads found in three replicate 50 m long trawls of 7 m seine net at 17 sites spread along the eastern shore of the Coorong (see Figure A1) for January from 2011 to 2017. Sites at -2, 5 and 11 km are in the region known as the Murray estuary; those at 17-54 km are in the North Lagoon; while those from 62-97 km are in the South Lagoon. Negative distances are NW of the Murray Mouth.

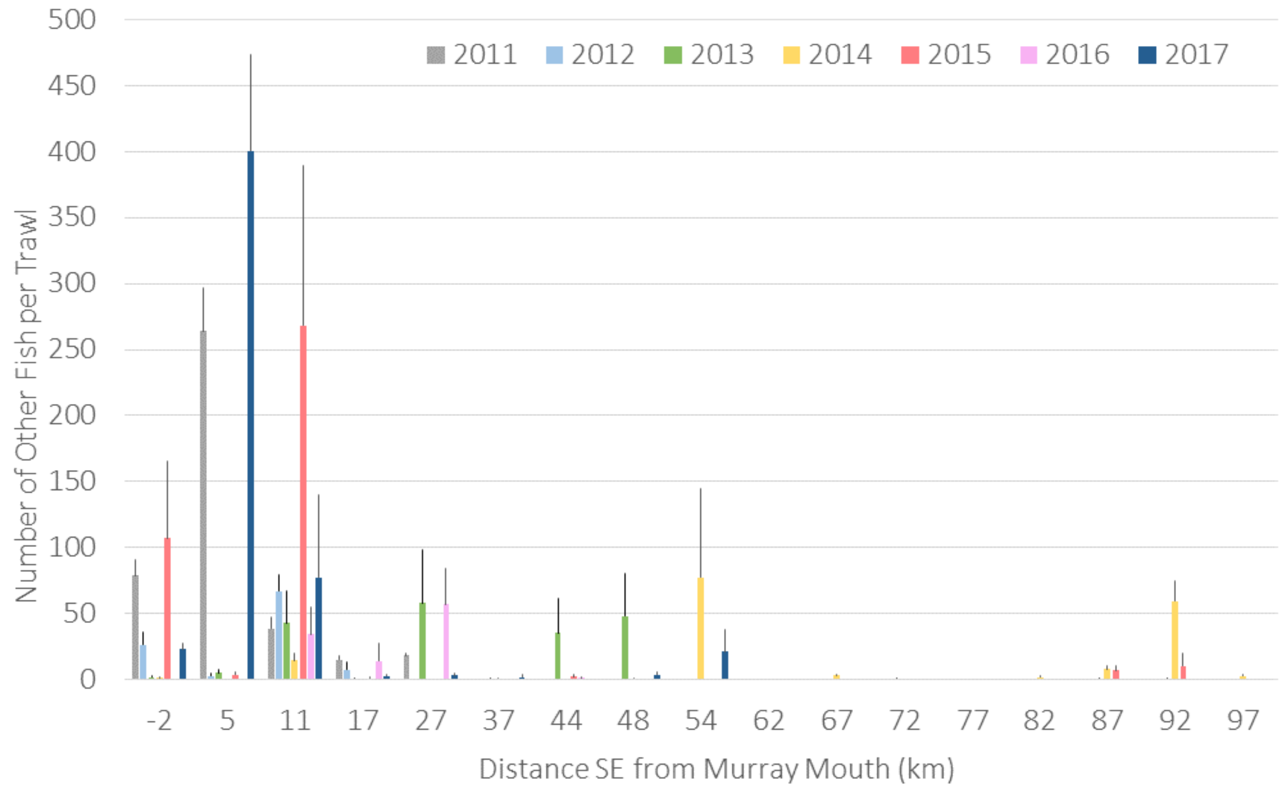

Figure 8: Mean number (+ s.e.) of fish (other than smallmouth hardyheads) found in three replicate 50 m long trawls of a 7 m seine net at 17 sites spread along the eastern shore of the Coorong (see Figure A1) for January from 2011 to 2017. Sites at -2, 5 and 11 km are in the region known as the Murray estuary; those at 17-54 km are in the North Lagoon; while those from 62-97 km are in the South Lagoon. Negative distances are NW of the Murray Mouth.

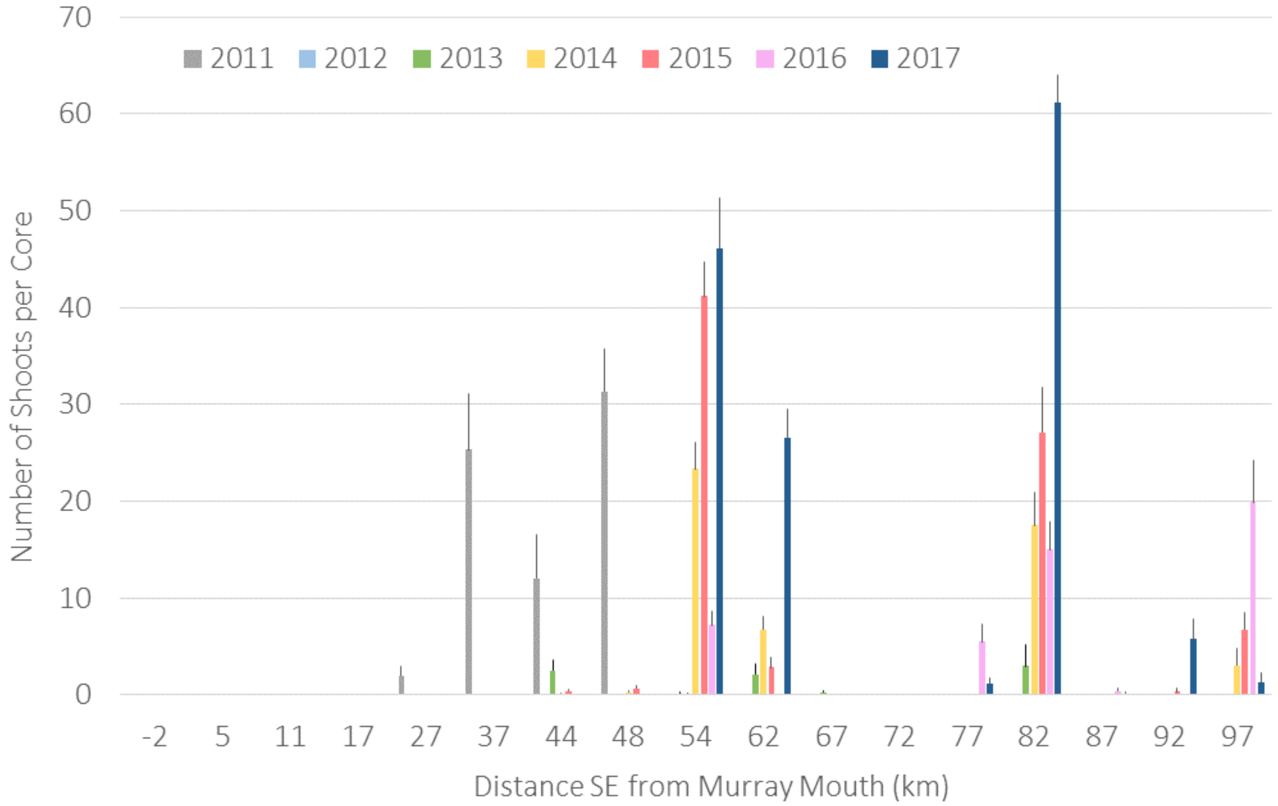

Figure 9: Mean number of *Ruppia tuberosa* shoots (+ s.e) present in 50 core samples (25 taken at each of two water depths (0.3m and 0.6m)) at 17 sites spread along the eastern shore of the Coorong in January from 2011 to 2016 (see Figure A1). Data can be converted to shoots/m^2 by multiplying by 226. Sites at -2, 5 and 11 km are in the region known as the Murray estuary; sites at 17-54 km are in the North Lagoon; while those from 62-97 km are in the South Lagoon. Negative distances are NW of the Murray Mouth.

Table 9: Densities of *Ruppia tuberosa* seeds and turions found in cores taken at sites along the Coorong in January 2017. The table shows the mean number of seeds (± s.e.) per core (75 mm diam x 4 cm deep) and mean number of turions at 21 sampling sites in the Coorong where *R. tuberosa* has been present (note the five most Northern sites had no *R. tuberosa* present and so are not shown). To calculate densities of seeds and turions multiply the mean numbers per core by 226. See Table A3 and Figure A1 in Appendix for site locations and a map of sites, respectively.

Site	Km from mouth	Seeds per core (mean ± s.e.)		Turions per core (mean ± s.e.)	
		Eastern shore	Western shore	Eastern shore	Western shore
N19	37	0.09 ± 0.04		0.00 ± 0.00	
N12	44	0.00 ± 0.00		0.00 ± 0.00	
N08	48	0.00 ± 0.00		0.00 ± 0.00	
N02	54	1.80 ± 0.52		1.21 ± 0.32	
S06	62	2.64 ± 0.46	5.91 ± 0.85	5.01 ± 0.97	5.57 ± 0.92
S11	67	0.10 ± 0.04	1.40 ± 0.25	0.00 ± 0.00	7.31 ± 1.26
S16	72	0.09 ± 0.05	1.00 ± 0.26	0.00 ± 0.00	2.40 ± 0.49
S21	77	0.43 ± 0.08	0.61 ± 0.18	0.00 ± 0.00	6.09 ± 0.81
S26	82	1.53 ± 0.20	0.16 ± 0.08	5.27 ± 0.69	2.03 ± 0.66
S31	87	0.02 ± 0.01	0.04 ± 0.02	0.00 ± 0.00	1.28 ± 0.53
S33	89	2.88 ± 0.42		6.28 ± 1.00	
S36	92	0.84 ± 0.21	0.00 ± 0.00	0.01 ± 0.01	0.47 ± 0.24
S41	97	0.35 ± 0.09	0.01 ± 0.01	0.03 ± 0.03	2.99 ± 0.65

5 General Discussion and Conclusions

The waterbird Whole of Icon Site Score (WOISS) integrates increases and decreases in abundances and distributions against stated targets for a suite of waterbird species that are regularly recorded using the Coorong, with a separate WOISS calculated for the Lower Lakes. In 2017, the WOISS for the Coorong and the WOISS for the Lower Lakes were both lower than in the previous year, clearly indicating that bird abundances and distributions had deteriorated in both areas since the previous 2016 assessment. Therefore, target B-1 of the LLCMM Icon Site Condition Monitoring Plan (Maunsell 2009), which is *to maintain or improve water bird populations in the Lower Lakes, Coorong and Murray Mouth,* has not been met.

For both the Coorong and the Lower Lakes, the numbers of waterbirds were much lower in January 2017 than in January 2016 and January 2015. A simple explanation, which is easily proffered, is that higher rainfall across south-eastern Australia in 2016-17 provided the birds with alternative wetlands, with the birds simply shifting to these other wetlands in favour of the Coorong and Lower Lakes. Such an explanation, however, deflects emphasis away from any potential deterioration in the conditions of the Coorong and Lower Lakes, either as an alternative explanation, or contributing explanation for the reductions in bird numbers. For 2016-17, despite the unregulated flows bringing much needed additional water to the region, conditions for waterbirds in the southern Coorong at least, had deteriorated from those of 2015-16 and 2014-15. The deterioration in the quality of the Coorong for waterbirds, particularly shorebirds, was due to very high water levels in summer, which prevented the birds from being able to forage on suitable mudflats because the water levels sitting above those mudflats were too deep for them. A similar situation occurred during the previous unregulated flow event of 2010-11, when shorebirds were also largely excluded from mud flats because water levels were too high. These high water levels may be related to the extent to which the Murray Mouth becomes restricted during intervening years with limited flows, even with dredging. A restricted Murray Mouth will slow the rate at which water can leave the northern Coorong, resulting in water backing up and the maintenance of higher water levels into the southern Coorong. The extent to which this water backs-up is likely to be related to the volumes being released over the barrages and the extent to which the Murray Mouth is restricted. Options to adjust the volumes being released, or the extent of dredging activities and hence the openness of the Mouth, should be explored to determine if the loss of access to suitable mudflats for shorebirds can be alleviated during future unregulated flow events.

The second factor that reduced the quality of the southern Coorong for waterbirds in 2016-17 was the widespread prominence of filamentous green algae (*Ulva* sp.). This is a recent issue that has developed over the last three or four years. In 2016-17, the algae was so prominent that it blanketed most of the shallow margins of the southern Coorong, largely preventing access for a variety of waterbirds to food resources underneath. The high flows and associated lower salinities of 2016-17 may have facilitated the growth and spread of algae throughout the southern Coorong in the last year. However, even though the salinities were lower than in recent years, the salinities were still largely within the targeted range of 60-100 gL^{-1} sought for the South Lagoon. The minimum to this salinity range was set largely because the algae was assumed to perform poorly at salinities above 60 gL^{-1}, allowing the key aquatic macrophyte in the southern Coorong, *Ruppia tuberosa*, to grow and reproduce without interference or competition from algae (Paton *et al*. 2017). In addition, the blankets of filamentous green algae may also disrupt key stages in the life cycle of the widespread chironomid *T. barbitarsus*, by preventing pupae from reaching the surface, where adults can emerge. Reductions in numbers of adult chironomids will reduce numbers of subsequent eggs that are laid and lead to lower numbers of chironomid larvae present on the sediment, as was detected in January 2017, further reducing the quality of the region as a foraging habitat for selected shorebirds.

Given that the algae was widespread throughout the South Lagoon of the Coorong in 2016-17, when salinities were between 58 and 82 gL^{-1} (Paton *et al*. 2017), the minimum salinity threshold may need to be adjusted upwards to about 80 gL^{-1}. Importantly, salinities in the southern Coorong can fall below 80 gL^{-1} even in years with limited flows. Thus, from a waterbird perspective, there is the potential for filamentous green algae to be prominent and interfere with their access to food, even in years when there has been no significant rains. In such years, alternative wetlands may not be readily available for waterbirds to use and their dependence on the wetlands of the Coorong and Lower Lakes is likely much greater. If the wetlands of the Coorong and Lower Lakes are in poor condition in those years, then the birds will suffer. That there were other wetlands potentially available for the birds in 2016-17 was perhaps fortuitous.

The numbers of waterbirds using the Coorong and Lower Lakes during summer fluctuates greatly from one year to the next, and some of these fluctuations can be attributed to changes in the availability of other wetlands and or changes in habitat quality in the Coorong and Lower Lakes. However, to fully understand the fluctuations in waterbird numbers requires more than just a focus on the numbers within a key wetland system like the Coorong and Lower Lakes. Until the availability of alternative wetlands has been properly documented, and the extent to which these are used by waterbirds from the Coorong determined, our understanding of changes in annual abundances of waterbirds using the Coorong and Lower Lakes will be limited. At present, the assumption is that the waterbirds and migratory shorebirds, for which the Coorong and Lower Lakes are listed as being internationally important, will simply return when these other wetlands are no longer available. There is some support for this in that waterbirds returned to the Coorong and Lower Lakes 1-2 years after the previous unregulated flow event of 2010-11. However, some had still not returned to pre-2010-11 abundances even by 2015-16 (e.g., Common Greenshank) suggesting that poor years in the Coorong may have a lasting impact, or that the alternative wetlands are not ideal for some species.

Adding further complexity to understanding changes in abundances is that not all species respond in the same way during a particular event, and the responses may differ from one event to the next. For example, the abundances of White-faced Herons increased substantially over the last year for both the Lower Lakes and the Coorong, while the ecologically similar Great and Little Egrets decreased. That White-faced Herons performed better might reflect their capacity to forage in terrestrial pastures for food, something that the two egrets rarely do. Similarly, Australian White Ibis and Straw-necked Ibis forage extensively in pastures for terrestrial invertebrates and showed increased abundances over the last year, while most other species declined. These ibis may simply be responding to improved foraging opportunities in terrestrial systems in wetter years.

In general, the waterbird species that had declined dramatically in the Lower Lakes, in addition to egrets, were small terns, grebes and the smaller species of cormorants, suggesting that the Lower Lakes no longer supported a ready supply of small fish or that the supply of such fish was low compared to what was available at other wetlands in wetter years. In contrast to these declines, some species of fish-eating birds found conditions suitable for breeding in summer 2016-17. This included Little Pied and Pied Cormorants in the Lower Lakes, and various terns and Australian Pelicans in the Coorong. Interestingly, Little Pied Cormorants, despite being present in low abundances, were breeding. Potentially, conditions in the Coorong and Lower Lakes at other times of the year might have influenced the birds, forcing many to leave such that there were few birds remaining by summer.

Similar issues may arise for some waterfowl. For example, Chestnut Teal were at their lowest abundances in the Coorong in 2016-17, yet young ducklings were present in the company of adults at many locations in the Coorong during the January 2017 census. That the birds were breeding suggests that the habitat quality of the Coorong was good for them at this time, despite the birds being in low abundances. Again, conditions at other times during the previous 12 months may have influenced the birds. For the southern Coorong, salinities were extremely high in the previous summer (e.g. Paton *et al.* 2016d), sufficient to trigger a short but widespread outbreak of brine shrimps (*Parartemia zietziana*) in the South Lagoon that lasted into spring (Paton *et al*. pers. obs.). Brine shrimps were last recorded in the Coorong during the high salinities of the millennium drought. Thus, the ecological conditions in the southern Coorong during the previous 12 months were approaching extremes, certainly as far as salinities were concerned, and the birds may have sought to avoid those extremes.

Without detailed knowledge of the ecological requirements of the birds and what drives their movements, our understanding of the importance of the Coorong and Lower Lakes to them remains rudimentary. In the absence of any detailed study, on-going monitoring of the abundances and reporting against targets should continue. At the very least, the monitoring data generate hypotheses that can be subsequently tested.

The current waterbird WOISS has been designed to account for fluctuations in abundances by integrating the count data over the last three years by applying a negative value (-1) to abundances, but only if the abundances in two of the last three years fall below the long-term median. If all three fall below the long term median, then a score of -2 is assigned. This is a conservative approach for assessing the changes in abundances, as it takes no account of the extent to which the numbers fall below the targeted median value. In 2017, five species had the lowest abundances on record for the Coorong (for the past 18 years), namely Chestnut Teal, Musk Duck, Banded Stilt, Red-necked Stint and Sharp-tailed Sandpiper. For Banded Stilt and Sharp-tailed Sandpiper, the abundances in the Coorong in 2017 were equivalent to just 1% of their long-term medians, while Red-necked Stints were at 22% of their long-term median. For the first time ever no Musk Ducks were using the Coorong in 2017, while only 40% of the long-term median for Chestnut Teal were counted. There were also another eight species for which the abundances in 2017 were relatively similar to the minimum abundances and in all cases the abundances were 12% or less of their respective long-term median abundances. Those species were Hoary-headed Grebe, Little Pied Cormorant, Whiskered Tern, Great Egret, Eurasian Coot, Black-winged Stilt, Red-capped Plover and Curlew Sandpiper. Furthermore, eight species, whose abundances in 2017 were 12% or less of their long-term medians, failed to have a negative score registered for their abundance when calculating the WOISS for the Coorong. This was because in the two previous years their abundances had exceeded their long-term medians. Those species were Hoary-headed Grebe, Whiskered Tern, Great Egret, Eurasian Coot, Black-winged Stilt, Red-capped Plover, Red-necked Stint and Sharp-tailed Sandpiper. There may be merit in reviewing how the WOISS is calculated to better capture extreme reductions in abundance in the year in which they occur. An added penalty for species with abundances of less than 10% of their long-term median abundances may be warranted. Under the current scheme, if the birds that are in low abundances in 2016-17 increase in 2017-18, but not up to or above their long-term medians, then the WOISS for the next year will likely be even lower than 2016-17, despite some recovery in numbers. The lower WOISS will suggest further deterioration, and that conditions were poorer in 2017-18 rather than in 2016-17, when the more extreme changes in abundances were detected.

Ultimately, a more refined approach to managing the wetlands of the Coorong and Lower Lakes is required to reliably deliver suitable habitat that can support the diversity of waterbirds that use the region. This is particularly true for the Coorong, which supports the majority of migratory shorebirds that visit the region annually. The current management levers are crude instruments that are limited to adjusting flows over the barrages when water is available and maintaining dredging to keep an open Murray Mouth. At present, water levels and salinities can vary substantially from one year to the next, affecting the quality of habitat being provided for different waterbird species. The Coorong and its waterbirds are likely to benefit if the extremes in water levels and salinities are avoided. Additional innovative management is likely to be needed to dampen the impact of filamentous green algae on the ecology of the southern Coorong. There is also a need to prevent rapid drops in water levels in spring as these result in the key aquatic plant in the southern Coorong, *R. tuberosa*, being exposed to desiccation before it has reproduced. These additional management actions are required largely because the flows reaching the region, even when the MDB Plan is fully implemented, are not enough on their own to secure a healthy Coorong. If innovative solutions cannot be implemented in a timely fashion, then waterbird populations will continue to decline, increasing the need to explore alternative solutions in other wetlands to compensate for the losses.

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8 Appendix

Table A1: Median abundances, Area of Occupation and Extent of Occurrence for 40 waterbird species in the Coorong. Medians were calculated for 16 years of data (2000-2015) collected in January and excluding birds counted in the creek at Salt Creek. The abundance data include birds scored as flying, while data for area of occupation (AOO) and extent of occurrence (EOO) do not include birds scored as flying over, as these may not have been using the actual area in which they were seen. The AOO were based on dividing the 1-km strips that were used for the bird census into 3 parts (eastern, centre, western) for 110 km of the Coorong. Data for EOO is expressed as the length (km) of the Coorong between the most northerly and most southerly records in each year. The lower value of the 95% confidence interval (CI) and the 75% value for AOO and EOO are given. The target median abundance, AOO and EOO are shaded.

SPECIES	Median abundance	Area of Occupation			Extent of Occurrence (km)		
		Mean ± s.e.	Lower 95% CI	75% AOO	Mean ± s.e.	Lower 95% CI	75% EOO
Black Swan	1633	61 ± 5	50	45	96 ± 4.2	87	72
Australian Shelduck	8426	128 ± 4	120	96	98 ± 1.6	95	74
Grey Teal	11846	124 ± 13	98	93	101 ± 1.2	98	76
Chestnut Teal	7216	109 ± 6	96	82	97 ± 0.9	95	72
Pacific Black Duck	223	19 ± 2	14	14	63 ± 7.2	48	47
Musk Duck	171	18 ± 2	14	14	82 ± 4.7	73	62
Cape Barren Goose	97	7 ± 1	6	5	22 ± 4.7	12	16
Hoary-headed Grebe	4218	67 ± 9	49	50	94 ± 0.6	93	70
Great Crested Grebe	199	35 ± 5	24	26	71 ± 8.4	54	53
Little Pied Cormorant	258	35 ± 4	28	26	52 ± 4.7	43	39
Great Cormorant	1287	41 ± 3	34	30	62 ± 6.4	49	47
Little Black Cormorant	1253	34 ± 6	22	26	66 ± 7.4	51	49
Pied Cormorant	271	45 ± 5	35	34	65 ± 6.1	53	49
Black-faced Cormorant	130	7 ± 1	6	5	67 ± 7.8	51	50
Australian Pelican	3410	134 ± 10	113	100	100 ± 1.1	97	75
Fairy Tern	337	35 ± 5	25	26	76 ± 5.5	65	57
Caspian Tern	598	69 ± 7	55	52	84 ± 4.3	75	63
Whiskered Tern	5360	160 ± 14	132	120	97 ± 4.3	88	73
Crested Tern	3897	66 ± 8	49	50	93 ± 1.5	90	70
Great Egret	36	26 ± 7	12	20	53 ± 8.6	36	40
White-faced Heron	156	61 ± 5	50	45	100 ± 1.1	97	75
Little Egret	7	6 ± 1	4	4	47 ± 7.2	33	35
Australian White Ibis	300	29 ± 3	22	22	36 ± 3.6	28	27
Straw-necked Ibis	25	3 ± 1	2	2	21 ± 3.8	13	15
Royal Spoonbill	22	7 ± 1	4	5	32 ± 5.0	22	24
Silver Gull	8274	201 ± 6	189	151	104 ± 0.5	103	78
Eurasian Coot	62	7 ± 3	1	5	19 ± 7.8	4	14
Pied Oystercatcher	158	41 ± 3	35	31	91 ± 1.4	88	68
Black-winged Stilt	417	41 ± 4	33	31	82 ± 3.1	76	62
Red-necked Avocet	3007	66 ± 10	46	49	85 ± 6.6	71	63

Table A1 continued

SPECIES	Median abundance	Area of Occupation			Extent of Occurrence (km)		
		Mean ± s.e.	Lower 95% CI	75% AOO	Mean ± s.e.	Lower 95% CI	75% EOO
Banded Stilt	15092	61 ± 11	40	46	85 ± 4.8	76	64
Pacific Golden Plover	36	4 ± 1	3	3	24 ± 4.0	16	18
Red-capped Plover	1234	77 ± 5	68	58	98 ± 2.4	94	74
Hooded Plover	8	6 ± 1	4	4	51 ± 8.1	35	38
Masked Lapwing	466	97 ± 3	91	73	103 ± 0.5	102	77
Far Eastern Curlew	13	4 ± 1	3	3	7 ± 2.2	3	6
Common Greenshank	430	88 ± 4	80	66	99 ± 0.6	98	75
Red-necked Stint	26286	118 ± 11	96	88	103 ± 0.7	101	77
Sharp-tailed Sandpiper	13179	121 ± 11	99	91	95 ± 2.8	89	71
Curlew Sandpiper	2252	35 ± 5	26	26	82 ± 5.3	71	61

Table A2: Median abundances, Area of Occupation and Extent of Occurrence for 25 waterbird species in the Lower Lakes. Medians were calculated for 3 years of data (2013-2015) collected in January. The abundance data include birds scored as flying, while data for area of occupation (AOO) and extent of occurrence (EOO) do not include birds scored as flying over, as these may not have been using the actual area in which they were seen. The AOO were based on dividing the 1-km strips that were used for the bird census into 3 parts (eastern, centre, western) for 110 km of the Coorong. Data for EOO is expressed as the length (km) of the Coorong between the most northerly and most southerly records in each year. The lower value of the 95% confidence interval (CI) and the 75% value for AOO and EOO are given. The target median abundance, AOO and EOO are shaded.

SPECIES	Median abundance	Area of Occupation (km²)			Extent of Occurrence (km²)		
		Mean ± s.e.	Lower 95% CI	75% AOO	Mean ± s.e.	Lower 95% CI	75% EOO
Black Swan	1799	200 ± 7	186	150	1652 ± 39	1575	1239
Australian Shelduck	13249	183 ± 4	175	137	1582 ± 50	1484	1186
Grey Teal	3912	89 ± 30	29	67	1577 ± 92	1396	1183
Pacific Black Duck	4981	216 ± 12	193	162	1700 ± 16	1669	1275
Cape Barren Goose	1010	36 ± 5	27	27	1041 ± 11	1019	781
Hoary-headed Grebe	103	10 ± 7	-4	8	717 ± 383	-34	538
Great Crested Grebe	128	39 ± 18	3	30	978 ± 227	533	733
Darter	73	29 ± 9	12	22	857 ± 267	334	643
Little Pied Cormorant	84	42 ± 12	19	31	1384 ± 116	1157	1038
Great Cormorant	14963	304 ± 18	270	228	1714 ± 13	1688	1285
Little Black Cormorant	907	83 ± 34	17	63	1456 ± 140	1181	1092
Pied Cormorant	8759	228 ± 17	194	171	1538 ± 75	1390	1154
Australian Pelican	6239	305 ± 8	290	229	1729 ± 8	1714	1297
Caspian Tern	609	110 ± 8	95	82	1508 ± 18	1472	1131
Whiskered Tern	4497	357 ± 27	303	268	1722 ± 15	1693	1291
Crested Tern	490	92 ± 17	59	69	1428 ± 77	1277	1071
Great Egret	133	98 ± 46	8	73	1281 ± 339	616	961
White-faced Heron	119	64 ± 3	58	48	1595 ± 8	1579	1196
Australian White Ibis	611	107 ± 6	95	80	1660 ± 10	1640	1245
Straw-necked Ibis	1620	36 ± 9	19	27	1322 ± 154	1021	992
Royal Spoonbill	209	29 ± 5	19	22	1338 ± 35	1270	1004
Silver Gull	1823	99 ± 15	69	74	1511 ± 15	1481	1133
Purple Swamphen	463	111 ± 8	95	83	1555 ± 62	1434	1166
Eurasian Coot	3339	152 ± 41	72	114	1644 ± 39	1569	1233
Masked Lapwing	565	74 ± 4	67	56	1560 ± 42	1478	1170

Table A3: Location details for sampling sites used for mud sampling to assess benthic food resources for birds during January 2016. Eastings and northings are Map Zone 54H in GDA94 units to the nearest 5m. The values given are the average of the easting and northings of the four depths at which mud sampling took place at each site. The individual locations for each of the depths are held with the data (not provided).

Site	Site name (Eastern shore)	Lagoon	Distance from Mouth (km)*	Eastern shore			Western shore		
				Zone	Easting	Northing	Zone	Easting	Northing
N58		Estuary	-2	54H	305462	6065378			
N52		Estuary	4	54H	313418	6063013			
N45	Pelican Point	North	11	54H	321098	6058904			
N39	Mark Point	North	17	54H	326273	6055286			
N29	Long Point	North	27	54H	333977	6048502			
N19	Noonameena	North	37	54H	342533	6042174			
N12		North	44	54H	347959	6037285			
N08		North	48	54H	350522	6034249			
N02	Magrath Flat	North	54	54H	354684	6029538			
S06	Villa dei Yuma	South	62	54H	360454	6024694	54H	358067	6024263
S11	Braeside	South	67	54H	363123	6022500	54H	360914	6020398
S16		South	72	54H	367049	6018086	54H	363817	6016002
S21		South	77	54H	370278	6013457	54H	367502	6012315
S26	Policeman's Point	South	82	54H	372526	6008937	54H	369874	6007766
S31		South	87	54H	374401	6004315	54H	372631	6003931
S33	Gemini Downs	South	89	54H	376381	6003588			
S36	Salt Creek	South	92	54H	377502	6000803	54H	375476	5999686
S41	Tea Tree Crossing	South	97	54H	378547	5996472	54H	377511	5995712

*distances are negative for sites NW of the Murray Mouth and positive for sites SE of the Murray Mouth

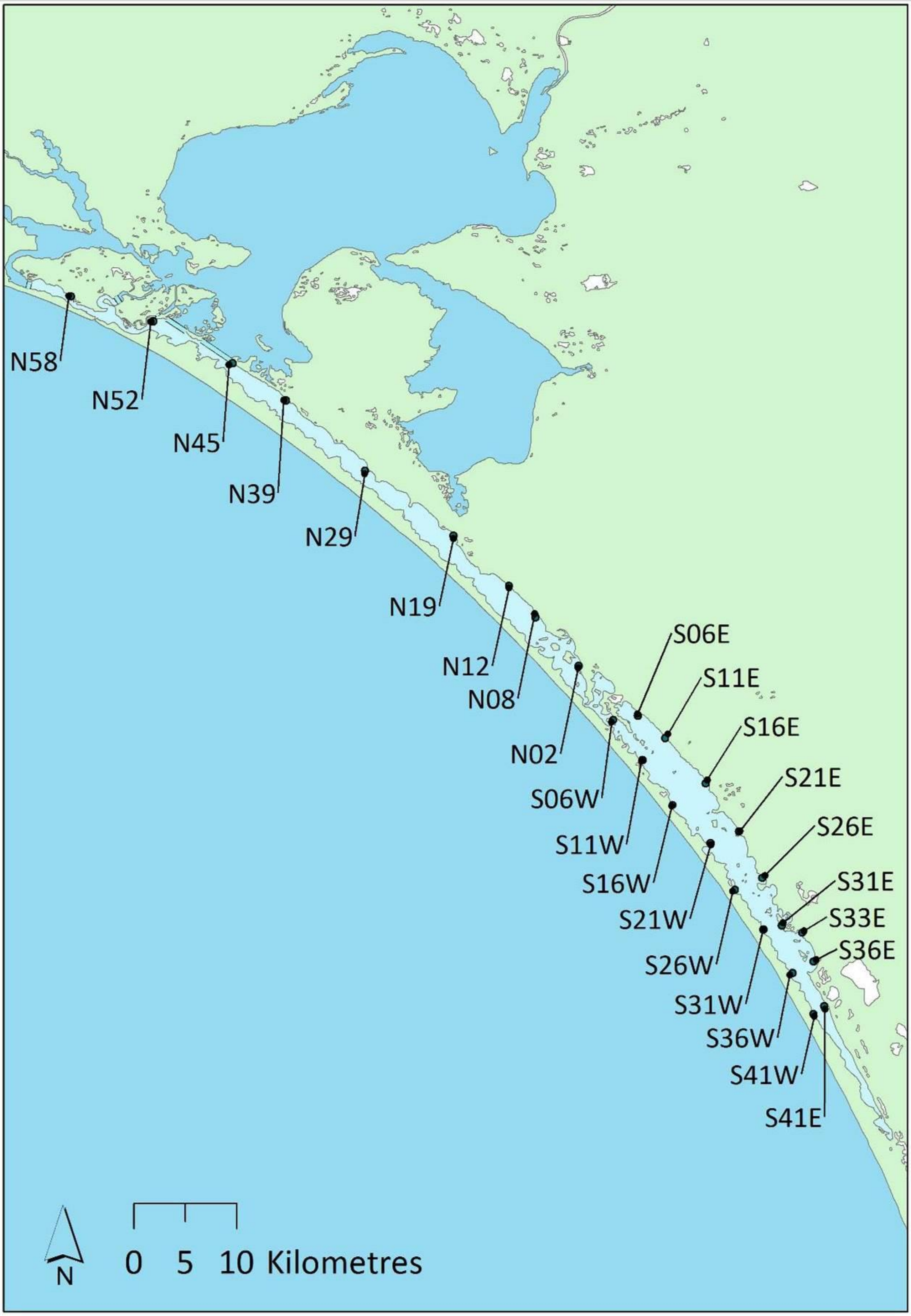

Figure A1: Map of the Coorong showing sites used for mud sampling to detect benthic food resources for birds during January 2017. Codes for sites have been indicated.

Table A4: Annual abundances in the Coorong from 2000 to 2017 for the 40 species used to calculate the WOISS for the Coorong. Each highlighted cell indicates the minimum abundance recorded for each species from 2000-2017.

SPECIES	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Black Swan	2595	2500	1227	3476	1012	699	1764	1501	1802	871	606	206	1427	2712	1966	3614	3834	1838
Australian Shelduck	4630	8581	2737	8201	8315	8536	20461	2609	6112	16457	25416	17507	7411	21527	13352	7597	13779	12751
Grey Teal	10811	17884	39510	30606	11431	12260	11077	5045	5439	8787	7525	194	41139	52541	87029	21748	33426	15519
Chestnut Teal	7302	15245	21221	13088	17107	7129	13314	2996	5242	6415	4741	4665	8577	8610	4880	4000	4690	2863
Pacific Black Duck	433	258	55	186	183	200	267	392	214	220	26	45	225	266	453	657	378	265
Musk Duck	388	66	143	230	441	335	171	345	170	111	300	13	157	171	61	263	142	0
Cape Barren Goose	135	179	15	402	41	76	51	29	81	46	218	80	113	290	678	519	181	265
Hoary-headed Grebe	8448	3039	2871	2273	2428	2629	4949	4410	4419	14935	9109	0	7333	922	4025	11907	14072	288
Great Crested Grebe	273	62	210	162	153	543	188	609	101	787	496	2	585	290	135	147	209	50
Little Pied Cormorant	778	221	557	663	189	294	123	431	487	310	6	0	333	190	114	186	190	3
Great Cormorant	383	1468	1860	266	559	304	513	4257	110	1105	172	2701	5961	1616	4703	2549	1696	3893
Little Black Cormorant	294	2934	1436	1753	452	446	1234	963	65	1271	722	756	24468	2581	2433	3765	723	566
Pied Cormorant	130	485	328	273	134	343	200	215	217	269	105	227	885	2193	760	766	765	309
Black-faced Cormorant	120	118	116	76	59	218	107	34	157	41	220	208	288	254	143	139	151	265
Australian Pelican	4672	5656	4071	2924	2915	2292	3203	3124	1574	1165	2929	4260	6205	9566	5122	3616	4302	6041
Fairy Tern	632	681	349	385	175	326	277	279	427	301	326	163	351	283	347	406	410	361
Caspian Tern	531	1362	782	664	227	415	856	359	153	267	219	375	1073	1086	973	680	603	1507
Whiskered Tern	4660	4603	3161	3592	3913	4552	17259	7527	5393	11177	5326	155	7808	6014	8966	7850	10638	459
Crested Tern	4941	4800	2783	1297	2767	5638	1908	8564	4016	7190	11631	3777	6827	2841	3075	3697	4610	6325
Great Egret	32	90	144	107	8	8	12	39	14	13	2	3	186	242	203	61	66	4
White-faced Heron	133	208	151	204	81	127	99	135	191	91	173	132	173	176	204	160	156	222
Little Egret	6	34	3	5	5	3	8	12	9	6	2	0	22	24	26	24	40	6
Australian White Ibis	267	625	360	362	129	246	160	424	306	157	198	151	293	395	1022	709	813	349
Straw-necked Ibis	45	14	23	107	24	111	3	0	26	652	18	4	10	31	340	69	10	50
Royal Spoonbill	11	161	28	15	10	9	14	108	70	0	5	33	14	79	100	96	49	41

Table A4 continued

SPECIES	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Silver Gull	7748	10300	7908	8449	5209	8099	16398	6465	5435	10267	10102	14803	8482	6294	6184	8604	11370	13128
Eurasian Coot	260	0	24	96	56	63	75	60	14	0	0	0	1350	10168	478	2753	1020	3
Pied Oystercatcher	115	164	157	216	159	168	220	113	145	206	186	131	130	86	188	131	158	110
Black-winged Stilt	491	258	276	696	298	343	680	662	676	530	337	44	103	318	493	534	589	46
Red-necked Avocet	163	717	3724	5341	2834	6030	4130	1672	149	333	869	162	3179	4482	6440	9477	4507	1335
Banded Stilt	2354	15413	14770	6760	6356	32305	74858	64552	23470	213013	49448	18054	11671	1758	1399	1300	13301	136
Pacific Golden Plover	21	20	67	69	6	85	124	59	18	26	50	0	0	45	21	46	0	25
Red-capped Plover	1223	1636	625	1576	769	474	1094	1245	1393	1088	434	71	1329	1408	3049	1459	2695	153
Hooded Plover	8	29	25	17	29	16	2	6	8	5	5	4	8	22	5	6	7	8
Masked Lapwing	429	760	623	721	371	452	415	440	407	479	515	398	368	554	660	512	460	452
Far Eastern Curlew	1	1	57	7	23	12	51	9	18	25	13	3	5	11	15	13	8	8
Common Greenshank	579	417	591	415	428	563	620	579	546	432	495	208	169	281	241	355	443	333
Red-necked Stint	25524	27047	28413	43300	33752	23606	37207	17476	13930	20323	17533	6505	21119	29502	41958	54624	27498	5667
Sharp-tailed Sandpiper	13022	4399	13335	17473	10135	11581	33897	9987	12065	16455	17836	146	5246	13382	23083	14071	23366	129
Curlew Sandpiper	8157	2315	3633	2364	1830	2188	4513	5073	1642	872	962	217	49	798	2652	3943	1248	208

Table A5: Annual abundances in the Lower Lakes from 2009 to 2017 for the 25 species used to calculate the WOISS for the Lower Lakes. Each highlighted cell indicates the minimum abundance recorded for each species from 2009-2017.

SPECIES	2009	2010	2011	2012	2013	2014	2015	2016	2017
Black Swan	896	2791	4171	1334	1799	2700	1692	3998	2567
Australian Shelduck	12022	15787	14298	22273	11847	20764	13249	12909	17323
Grey Teal	10854	13857	804	5780	7688	3912	1023	6624	5736
Pacific Black Duck	1187	2003	1707	5794	4981	7376	4538	5461	7134
Cape Barren Goose	1692	1207	1303	2585	1655	1010	853	1124	874
Hoary-headed Grebe	0	2	0	36	124	103	3	19	46
Great Crested Grebe	12	24	217	108	201	128	75	41	0
Australasian Darter	2	5	2	124	122	32	73	55	31
Little Pied Cormorant	166	96	81	398	195	84	53	146	54
Great Cormorant	2081	6124	4998	9375	25741	12828	14963	18840	4876
Little Black Cormorant	107	1298	826	2091	907	1025	412	333	72
Pied Cormorant	1342	982	1717	3955	11305	8463	8759	11187	7539
Australian Pelican	4259	4460	2996	2699	5566	6239	7203	6627	2644
Caspian Tern	283	236	186	458	1384	609	583	976	319
Whiskered Tern	3536	3744	80	4362	5697	4497	3610	4622	2374
Crested Tern	529	327	313	309	599	335	490	412	880
Great Egret	104	65	105	390	394	133	51	215	20
White-faced Heron	95	94	225	133	158	119	96	130	301
Australian White Ibis	463	178	1195	1092	611	899	508	946	1893
Straw-necked Ibis	181	387	532	2704	1620	2136	239	1333	2630
Royal Spoonbill	396	341	201	126	166	209	215	201	352
Silver Gull	3743	3484	2829	2748	3741	1172	1823	1901	1446
Purple Swamphen	9	32	47	446	794	448	463	620	269
Eurasian Coot	252	3308	39	3650	6062	3339	2492	4151	545
Masked Lapwing	998	800	309	451	552	587	565	599	394