Condition Monitoring of the Lower Lakes, Coorong and Murray Mouth Icon

Site: Waterbirds 2014

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Cover Image: Black Swans foraging on *Ruppia tuberosa*, Gemini Downs Bay, Coorong.
Image courtesy of David Paton

Photographer: David Paton

Executive Summary

Over 309,000 waterbirds were counted using the Coorong and Lower Lakes in summer 2014 with the Coorong supporting 230,000 waterbirds (70 species), three times the number of birds that were using the Lower Lakes (79,000; 58 species). Seven species of waterbird had abundances in excess of 10,000 birds: Grey Teal (*Anas gracilis*), Red-necked Stint (*Calidris ruficollis*), Australian Shelduck (*Tadorna tadornoides*), Sharp-tailed Sandpiper (*Calidris acuminata*), Great Cormorant (*Phalacrocorax carbo*), Whiskered Tern (*Chlidonias hybridus*), and Australian Pelican (*Pelecanus conspicillatus).* Except for the two cormorants, these species were more prominent in the Coorong than they were in the Lower Lakes. Three other species exceeded 5000 individuals: Pacific Black Duck (*Anas superciliosa*) Silver Gull (*Chroicocephalus novaehollandiae*), and Red-necked Avocet (*Recurvirostra novaehollandiae*).

Of the 77 species recorded across the Coorong and Lower Lakes during the counts in January-February 2014, 21 species (including two domesticated species) were found primarily in the freshwater wetlands of the Lower Lakes, and 32 species were found primarily in the saline wetlands of the Coorong, with 24 species using both wetlands to a reasonable extent. The two wetlands continue to provide complementary resources that support different waterbird communities. The waterbirds using the Coorong, however, were unique, as they included a range of migratory and endemic shorebirds and coastal species not prominent elsewhere within the Murray Darling Basin.

Overall, the numbers of waterbirds using the Coorong and Lower Lakes were higher in summer 2014 compared with the previous year. Three species largely contributed to the increased numbers of waterbirds over the last year: Grey Teal, Red-necked Stint and Sharp-tailed Sandpiper with increases of around 10,000 birds or more over the last year. The other numerically prominent shorebirds: the migratory Curlew Sandpiper (*Calidris ferruginea*) and the non-migratory Red-capped Plover (*Charadrius ruficapillus*) were also more abundant in January 2014 than in the previous three years. In contrast Great Cormorants and Eurasian Coots (*Fulica atra*) although increasing in abundance in recent years have shown declines of around 10,000 birds over the last year. Two other formerly abundant species have declined steadily in recent years. These are Banded Stilt (*Cladorhynchus leucocephalus*) and Silver Gull.

The water levels and salinities in the Coorong in January 2014 were typical of the conditions in the previous two years with salinities being typical of the historical, pre-drought salinities. The distributions and abundances of key food resources (aquatic invertebrates, small fish) were similar to the previous year as well but the key aquatic plant, *Ruppia tuberosa* was more abundant. This was matched by marked increases in the numbers of birds using the Coorong from around 187,000 to 230,000 over the last year. In contrast there was a reduction in the numbers of birds using the Lower Lakes during the same period from 98,000 in January-February 2013 to 79,000 in January-February 2014. These patterns suggest the Coorong may still be recovering while the Lower Lakes now may be slowly deteriorating as far as providing suitable habitat and resources for waterbirds.

In general, the abundances of waterbirds using the Coorong and Lower Lakes have increased or been maintained over the last year with a few notable exceptions. Given this, the Condition Monitoring Target B-1 - *to maintain or improve bird populations in the Lower Lakes, Coorong and Murray Mouth* – has been met.

Although numbers of waterbirds using a wetland are largely used to indicate the importance of a wetland for a particular species, numbers alone may be misleading. First the numbers of birds using a wetland in any one year may be influenced by the availability and condition of other wetlands within a region or even beyond. Thus low abundances in anyone year may indicate other wetlands are supporting a species, while high abundances may indicate that other wetlands are not available. The numbers of waterbirds, then, is an indication of importance in that year, while low abundances may not be overly informative. Second, and importantly the quality of a wetland may also depend on the ease with which various species of waterbirds can harvest resources, and so some assessment of the behaviour of birds using a wetland is also required to assess the quality of an area. For the Coorong and Lower Lakes, the effort required by different species to harvest food differed greatly. Most fish-eating species were only spending a small proportion of their time foraging consistent with good abundances of suitable prey. These contrasted with the effort required by some of the abundant shorebirds. For example, more than 80% of the Red-necked Stints, Sharp-tailed Sandpipers and Red-capped Plovers counted in 2014 were foraging suggesting the available habitats for them were still not of high quality.

Reporting changes in waterbird abundances at the wetland scale ignores the fine details in how the birds have responded and adjusted their distributions and abundances within the Coorong and Lower Lakes through time. No bird species were evenly distributed over the wetlands with most species patchily distributed in time and space suggesting that certain parts of these wetlands were more suitable than others and that this suitability changed through time. These patterns are illustrated for two species: Red-necked Stint and Fairy Tern (*Sternula nereis*). Furthermore even within a guild of similar species (cormorants, ducks, terns), the individual species often differed in their distributions and how these distributions and abundances changed through time. Each species appears to be responding to different features or to the same features differently. As a consequence of these individual differences, the requirements of each species will need be considered in developing management programs for these wetlands, as opposed to the requirements of guilds of species.

Two factors appear important in determining the distributions and abundances of these birds within the wetlands: the distribution of suitable habitat and the distribution and abundance of key food resources for the different species. High water levels (about 0.4m higher than normal) in summer 2011 appear to have had a major influence on various species that forage by wading over mudflats covered with shallow water. In summer 2011 most wading birds were excluded from the Coorong because these habitat features were all but excluded by high water levels. Although most species have recovered their abundances since then, some species like the Common Greenshank (*Tringa nebularia*) have shown little to no recovery. Managers will need to avoid conditions that are likely to result in excessive water levels at least for the Coorong over the summer months.

The variability in the numbers of birds counted from one year to the next and in their distributions remains a challenge for assessing the status of waterbirds within the Coorong and Lower Lakes. Ultimately the various factors that cause changes in numbers and distributions of different species using the wetlands of the Coorong and Lower Lakes need to be understood if the wetlands and hence waterbirds are to be effectively managed in the future. This will require: (i) the maintenance of counts of waterbirds using the Coorong and Lower Lakes in summer, as well as counts at other times of the year; (ii) counts of waterbirds using other wetland systems in south-eastern Australia; (iii) targeted autecological studies on key species of waterbirds; and (iv) incorporation of behavioural data with census data, food resources and habitat features to allow habitat suitability models to be developed for a range of species. Each species even within a guild of similar species is likely to differ ecologically and so have slightly different requirements. The absence of these specific details currently limits our ability to manage the Coorong and Lower Lakes proactively and effectively for waterbirds.

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 The Living Murray's (TLM) icon sites within the Murray-Darling Basin. Large numbers of small migratory and non-migratory waders (sandpipers, plovers, stilts), piscivorous birds (pelicans, cormorants, grebes, terns) and waterfowl (swans, 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.

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 bird populations in the Lower Lakes, Coorong and Murray Mouth.* This report summarizes the results of the 2014 summer waterbird census for the LLCMM region as a whole. Up until 2012 separate reports on waterbird use were provided for the two major systems, one on waterbird use of the freshwater wetlands of the Lower Lakes (e.g. Paton & Bailey 2012a) and a separate report for the estuarine to hypersaline wetlands of the Coorong (Paton & Bailey 2012b). These two wetland systems are complementary in terms of the wetland systems that they provide but also because they are likely to exchange waterbirds on a regular basis. For these reasons the counts from both monitoring areas have been combined in this 2014 report, as they were in 2013 (Paton & Bailey 2013a).

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 was to establish if the waterbird communities had 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 decade, there were dramatic changes to the hydrology of the LLCMM region. These changes have been attributed to an extensive drought within the Murray-Darling Basin during most of this period, coupled with on-going over-extraction of water for human use. Within the Lower Lakes, water levels during 2009 and most of 2010 were consistently below sea-level (-0.5m AHD in Lake Albert; and -0.7m to -0.9m 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 between 2002-2010. During this period the Mouth and associated channels had to be dredged to keep the Murray Mouth open. The lack of environmental 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. As the salinities increased the distributions of the salt tolerant fish, the small-mouthed hardyhead

(*Atherinosoma microstoma*) and the salt-tolerant chironomid (*Tanytarsus barbitarsis*) retracted to the North Lagoon. 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*. 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).

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 returned to the more typical managed water levels between 0.6 m and 0.8 m AHD in 2011 and have remained on or about 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). In January 2011, slightly fewer than 40,000 waterbirds were using the Lower Lakes, compared to 80,000-110,000 in the previous two years; with many species having declined in abundance (Paton & Bailey 2011a). A few species, however, were increasing in abundance and distribution in January 2011 and many of these and other species have increased further in abundance and distribution since 2011 (Paton & Bailey 2013). These increases in distribution and abundance were attributed to these waterbird populations recovering from the drought. However the current management of maintaining water levels in the Lower Lakes at or above 0.65 m AHD has resulted in few, if any, sandpipers, stints and plovers using the shorelines of the Lower Lakes in January 2012 and January 2013 (Paton & Bailey 2012a, 2013a).

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 hardyheads were in the South Lagoon, and there was no detectable recovery of *Ruppia tuberosa*. However *Ruppia* 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 resource, various polychaete worms (particularly *Capitella* spp.) 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, with the high water levels excluding most birds from accessing food resources around the shores of the Coorong lagoons (Paton & Bailey 2011b). 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 small mouth hardyhead were extremely abundant in the southern Coorong (Paton & Bailey 2012b). However there had been no recovery of *Ruppia tuberosa*. In fact *Ruppia 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). Given that the seed bank for this species was almost non-existent in the Coorong, the recovery of *Ruppia tuberosa* to its former range and abundance seems highly unlikely without intervention (Paton & Bailey 2012c, Paton & Bailey 2013b). The recovery of components of the waterbird communities that once used the Coorong are likely to be compromised by the lack of recovery of this aquatic plant.

In this report we focus on overall abundances of the different waterbird species using the LLCMM region in January-February 2014. These overall abundances are compared with similar data collected in previous years. The January-February 2014 abundances are also given for the major components of the Coorong and Lower Lakes, namely the Murray Estuary, Coorong North Lagoon, Coorong South Lagoon, Goolwa Channel, Lake Alexandrina, and Lake Albert. This is a coarse scale relative to the 1 km scale used to collect the data. In presenting the data at this coarse scale local variability and patchiness in abundances and distribution within the different wetland components are missed. Understanding local patterns to distribution and abundance in time and space is likely to provide important cues for eventual management of individual species. In this report several examples are shown to illustrate the nature of those data. However, exploring the data at this higher resolution falls outside the current contractual requirements.

Methods

<u>Counting birds in the Coorong</u>

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 48) 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 2014 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. This division of the data into 1-km sections allows for assessments of changes in distribution through time, at a fine-scale. For the purpose of this report details to this level were not required.

In addition, since 2006, birds were grouped according to their general behaviour (e.g. foraging, roosting, flying, and nesting). These behavioural data provided some information on the functional reasons for the distribution of waterbirds. For example, some species are abundant in relatively small areas of the South Lagoon, which reflects the distribution of suitable nest sites (rocky islands), rather than food resources.

Within a census period, 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 2014, the census of waterbirds in the Coorong was conducted between the 8^{th} and 19^{th} January 2014 (12 days; 9 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 slightly longer period taken to complete the census in January 2014 reflected some extreme temperatures (>40°C) that limited the counting to mornings.

Counting birds in the Lower Lakes

Similar methods were used to count waterbirds around the shores of the Lower Lakes between 24^{th} January and 8^{th} February 2014, with a total of 9 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, 474 grid cells (117 around Lake Albert, 280 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.

Within each section, shoreline counts of waterbirds were conducted either by foot or 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.

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-over or breeding).

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 2014, four sets of 25 core samples (core size: 7.5cm ø, 4cm deep) of surface mud were collected at each of 17 monitoring sites spread along the Coorong (see the appendix for details of the locations). Each of the four sets was collected at a different position relative to the waterline. In January 2011 three sampling positions were used because of very high water levels (the waterline, in water 30cm deep and in water 60 cm deep). Since then with lower water levels (ca 40-50cm lower) an additional 25 core samples have been taken from dry mud mid-way between the waterline and the high-water mark (shoreline), as well as the samples at the waterline and in water that was 30cm and 60cm deep. All mud samples were then sifted *in situ* through an Endecott sieve (500 μm mesh size), and the abundance of plant (*Ruppia* spp.) propagules (seeds, turions) and shoots, chironomid larvae and pupae, and other aquatic invertebrates (e.g. polychaetes) were recorded. Water quality measures were also taken at this time, with turbidity recorded *in situ* using a Secchi disc, and water samples collected and conductivity subsequently measured with a TPS conductivity metre in the laboratory, with samples being 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 (1988) 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 50m, in water approximately 0.7m deep. The seine net was dragged three times at each of the 17 sites to provide replicate samples.

Results and Preliminary Discussion

Abundances of birds in the Coorong and Lower Lakes in 2014

Over 230,000 waterbirds from 70 species were counted in the Coorong in January 2014 (Table 1). The Australian Shelduck (*Tadorna tadornoides*), Grey Teal (*Anas gracilis*), Red-necked Stint (*Calidris ruficollis*) and Sharp-tailed Sandpiper (*Calidris acuminata*) were present in abundances that exceeded 10,000 individuals. These four species each accounted for more than 5% of the birds counted, and collectively over 70% of the birds counted. Four other species were present in abundances that approached or exceeded 5,000 individuals (Chestnut Teal (*Anas castanea*), Australian Pelican (*Pelecanus conspicillatus*), Whiskered Tern (*Chlidonias hybridus*), Silver Gull (*Chroicocephalus novaehollandiae*) and Red-necked Avocet (*Recurvirostra novaehollandiae*; Table 1). The North Lagoon had 116,000 waterbirds present in January 2014, compared with a little over 48,000 using the Estuary and a little over 66,000 using the South Lagoon.

Table 1. Numbers of waterbirds counted in the Coorong in January 2014. The table shows the abundances of each species in each section of the Coorong: South Lagoon; North Lagoon and Murray Estuary

Species	Status* (SA, EPBC, IUCN)	South Lagoon	North Lagoon	Murray Estuary	Total
Black Swan		544	802	619	1965
Australian Shelduck		1690	11450	212	13352
Blue-billed Duck	RA	20	7		27
Pink-eared Duck			131		131
Australasian Shoveler	RA		38	10	48
Grey Teal		29449	44430	13158	87037
Chestnut Teal		928	3845	107	4880
Pacific Black Duck			98	355	453
Mallard hybrid or derivative			1		1
Hardhead		6	347	1217	1570
Musk Duck	RA	2	26	33	61
Freckled Duck	RA			1	1
Cape Barren Goose			36	642	678
Hoary-headed Grebe		2451	1433	141	4025
Great Crested Grebe	RA	25	43	67	135
Little Pied Cormorant		3	77	34	114
Great Cormorant		1	3016	1686	4703
Little Black Cormorant		757	667	1009	2433

continued

Table 1 Continued

Species	Status* (SA, EPBC, IUCN)	South	North	Estuary	Total
Pied Cormorant		138	547	75	760
Black-faced Cormorant		133	6	4	143
Australian Pelican		1570	2425	1127	5122
Little Tern	END, MIG	2			2
Fairy Tern	END,VUL,VUL	136	211		347
Gull-billed Tern		1	5	11	17
Caspian Tern		117	423	433	973
Whiskered Tern		3441	3859	1666	8966
Common Tern		60	6		66
Crested Tern		2307	297	471	3075
Great Egret	MIG	20	159	24	203
White-faced Heron		59	85	61	205
Little Egret	RA	2	18	6	26
Nankeen Night Heron			4	1	5
Australian White Ibis			277	745	1022
Straw-necked Ibis			179	161	340
Royal Spoonbill			43	57	100
Yellow-billed Spoonbill				2	2
Pacific Gull				9	9
Silver Gull		2091	2787	1307	6185
Purple Swamphen				3	3
Black-tailed Native Hen		3	28	87	118
Eurasian Coot		1	301	176	478
Pied Oystercatcher	RA	67	84	37	188
Sooty Oystercatcher	RA		1	3	4
Black-winged Stilt		25	151	317	493
Red-necked Avocet		2080	2463	1897	6440
Banded Stilt	VUL	191	1182	26	1399
Oriental Plover	MIG		5		5
Pacific Golden Plover	RA, MIG		8	13	21
Red-capped Plover		925	1895	229	3049
Hooded Plover		5			5
Red-kneed Dotterel			31	107	138
Grey Plover	MIG			4	4
Banded Lapwing			138	2	140
Masked Lapwing		171	384	106	661
Bar-tailed Godwit	MIG			78	78
Eastern Curlew	RA, MIG			15	15
Common Greenshank	MIG	42	84	115	241
Common Sandpiper	MIG	2			2

continued

Table 1. Continued

Species	Status* (SA, EPBC, IUCN)	South	North	Estuary	Total
Marsh Sandpiper	MIG			1	1
Sanderling	MIG		166	31	197
Red-necked Stint	MIG	12656	21359	7947	41962
Sharp-tailed Sandpiper	MIG	3674	8054	11360	23088
Curlew Sandpiper	MIG	451	1925	276	2652
Ruff	MIG		2		2
Ruddy Turnstone	MIG	6			6
White-breasted Sea Eagle	END, MIG		1	1	2
Clamorous Reed-Warbler			2	2	4
Little Grassbird		9	1	1	11
Grand Total		**66261**	**116043**	**48285**	**230589**

**State NPW Act listed species where END=endangered; VUL = Vulnerable; RA = Rare
EPBC listed species where END= endangered; VUL = Vulnerable; MIG = Migratory
IUCN listed species where END = endangered; VUL =Vulnerable

Fewer than 79,000 waterbirds (58 species) were counted using the Lower Lakes in 2014 (Table 2). Six species accounted for over 70% of the birds that were counted. For two species more than10,000 individuals were counted in the Lower Lakes in January 2014: Australian Shelduck and Great Cormorant (*Phalacrocorax carbo*). The other four species all exceed 4,000 individuals, with each accounting for more than 5% of the birds present (Table 2). These species were: Pacific Black Duck (*Anas superciliosa*), Pied Cormorant (*P. varius*), Australian Pelican and Whiskered Tern. Over 41,000 birds were counted using Lake Alexandrina compared to over 25,000 for Lake Albert and around 11,000 for the Goolwa Channel (Table 2).

Overall the Coorong and Lower Lakes were supporting in excess of 309,000 waterbirds in January 2014 with the Coorong supporting about three times as many birds as the Lower Lakes (Table 3). The bird communities were markedly different between the two wetland systems. Of the 77 species recorded, 21 species (including two domesticated species) were found primarily in the freshwater wetlands of Lower Lakes, and 32 species were found primarily in the saline wetlands of the Coorong, with 24 species using both wetlands to a reasonable extent (Table 3).

Of the species of waterfowl using the Coorong and Lower Lakes region, Grey Teal, Chestnut Teal, Pink-eared Duck (*Malacorhynchus membranaceus*), and Blue-billed Duck (*Oxyura australis*) mainly used the Coorong while Pacific Black Duck, Freckled Duck and Australian Wood Duck mainly used the freshwater habitats of the Lower Lakes (Table 3). Black Swan (*Cygnus atratus*), Australian Shelduck, Australasian Shovelers (*Anas rhynchotis*) Hardhead (*Aythya australis*) and Musk Duck (Biziura lobata) used both wetland systems.

Of the fish-eating species Hoary-headed Grebes (*Poliocephalus poliocephalus*) largely used the Coorong, while the larger Great Crested Grebe (*Podiceps cristatus*) used both the Coorong and Lower Lakes (Table 3). Only a single Australasian Grebe (*Tachybaptus novaehollandiae*) was detected in 2014 in freshwater habitat. Darters (*Anhinga melanogaster*) and Pied Cormorants (*Phalacrocorax varius*) were using the Lower Lakes predominantly while Great Cormorants (*Phalacrocorax carbo*) were abundant in both the Coorong and Lower Lakes. Little Black

Table 2. Numbers of waterbirds using the Lower Lakes in 2013. The abundances are shown for each of three components of the Lower Lakes: Lake Albert, Lake Alexandrina and the Goolwa Channel.

Species	Status* (SA, EPBC, IUCN)	Lake Albert	Lake Alexandrina	Goolwa Channel	Total
Black Swan		424	1818	403	2645
Australian Shelduck		13220	4806	734	18760
Australian Wood Duck			38	30	68
Pink-eared Duck		1	12		13
Australasian Shoveler	RA	72	63	7	142
Grey Teal		756	2617	469	3842
Chestnut Teal		2	31	18	51
Mallard hybrid or derivative				13	13
Pacific Black Duck		2133	3056	2024	7213
Hardhead		18	2138	14	2170
Musk Duck	RA	30	9	2	41
Freckled Duck	RA	100	29		129
Cape Barren Goose	RA	247	758	2	1007
Domestic Goose			18		18
Australasian Grebe		1			1
Hoary-headed Grebe		4	1	2	7
Great Crested Grebe	RA	24	104		128
Darter	RA		31	1	32
Little Pied Cormorant		10	24	43	77
Great Cormorant		1090	8806	2955	12851
Little Black Cormorant		90	484	451	1025
Pied Cormorant		1680	6688	68	8436
Australian Pelican		1400	3712	1125	6237
Caspian Tern		137	426	45	608
Whiskered Tern		894	3081	514	4489
Crested Tern		57	179	99	335
Eastern Great Egret	MIG	45	50	34	129
White-faced Heron		18	67	33	118
White-necked Heron			1		1
Little Egret	RA			2	2
Nankeen Night Heron		4	4	4	12
Australian White Ibis		520	268	79	867
Straw-necked Ibis		842	320	256	1418
Royal Spoonbill		67	116	19	202
Yellow-billed Spoonbill		2	11	12	25
Silver Gull		564	222	386	1172
Purple Swamphen		89	138	215	442

continued

Table 2 Continued

Species	Status* (SA, EPBC, IUCN)	Lake Albert	Lake Alexandrina	Goolwa Channel	Total
Australian Spotted Crake			1	1	2
Black-tailed Native-hen		2	68	8	78
Dusky Moorhen			2	21	23
Eurasian Coot		639	1256	1261	3156
Black-winged Stilt		17	42	6	65
Banded Stilt	VUL	8			8
Red-capped Plover		2	5		7
Red-kneed Dotterel		1	79	12	92
Black-fronted Dotterel				1	1
Banded Lapwing		41	4		45
Masked Lapwing		288	237	55	580
Latham's Snipe	RA, MIG		1		1
Common Greenshank	MIG	1		2	3
Marsh Sandpiper	MIG	8	2		10
Wood Sandpiper	MIG			9	9
Red-necked Stint	MIG		6		6
Sharp-tailed Sandpiper	MIG	37	50	1	88
White-bellied Sea-Eagle	END, MIG		1		1
Clamorous Reed-Warbler		11	18	4	33
Little Grassbird		2	8		10
Golden-headed Cisticola		1	4		5
Total		**25599**	**41910**	**11440**	**78949**

**State NPW Act listed species where END=endangered; VUL = Vulnerable; RA = Rare
EPBC listed species where END= endangered; VUL = Vulnerable; MIG = Migratory
IUCN listed species where END = endangered; VUL =Vulnerable

Cormorants (*Phalacrocorax sulcirostris*) and Little Pied Cormorants (*Phalacrocorax melanoleucos*) used both the freshwater habitats of the Lower Lakes and the salty waters of the Coorong to similar extents, while small numbers of the essentially marine Black-faced Cormorant (*Phalacrocorax fuscescens*) were restricted to the Coorong (Table 3). Caspian Terns (*Sterna caspia*) and Whiskered Terns used both the Coorong and the Lower Lakes extensively, while other terns (Crested Tern *Thalasseus bergii*, Fairy Tern *Sternula nereis*, Common Tern *Sterna hirundo*) used the Coorong to a much greater extent, if not exclusively.

In general, herons, egrets, ibis and spoonbills used both wetlands to similar extents although Straw-necked Ibis (*Threskiornis spinicollis*) and Yellow-billed Spoonbills (*Platalea flavipes*) were more abundant across the freshwater habits, while Little Egrets (*Egretta garzetta*) were mainly using the Coorong. The Purple Swamphen (*Porphyrio porphyrio*), Eurasian Coot (*Fulica atra*) and Dusky Moorhen (*Gallinula tenebrosa*) were largely using the Lower Lakes.

Lastly, but significantly, almost all of the shorebirds (sandpipers, plovers, stilts, oystercatchers) were strongly associated with the Coorong (Table 3). Lapwings (*Vanellus* spp) and Red-kneed Dotterels (*Erythogonys cinctus*), however, used both the Lower Lakes and Coorong, and although only present in small numbers during the census in 2014, Latham's Snipe (*Gallinago hardwicki*), Marsh Sandpiper (*Tringa stagnatilis*) and Wood Sandpiper (*Tringa glareola*) were predominantly associated with freshwater habitats.

Assessing the importance of these wetlands for waterbirds should not be based just on abundances. How the birds are using these wetlands is also very important. In Table 3 the percentage of birds that were foraging when counted is given. This percentage provides a measure of the effort or time a species needs to allocate to foraging. Those species with low percentages of birds that were foraging were either foraging on rich food sources that were easily gathered and or were foraging away from the Coorong and Lower Lakes. However, those species that have high percentages of birds foraging indicate species that have to spend significant amounts of time to harvest sufficient food, and if that is the case then the food resources and quality of the habitats are poor. Within the Coorong and Lower Lakes there were suites of birds that were only spending modest amounts of their time foraging (<50%) while there were others that were spending significant amounts of their time foraging (> 75%; Table 3). The species that were spending significant amounts of their time foraging in January 2014 were the shorebirds, notably Red-necked Stints, Sharp-tailed Sandpipers, Red-capped Plovers and Banded Stilts (*Cladorhynchus leucocephalus*), where typically more than 80% of the birds counted were foraging. This suggests that the quantity and quality of the food resources was poor for these species. Black-winged Stilts (*Himantopus himantopus*) and Red-necked Avocets were also spending more than 60% of their time foraging.

The behaviour of most of the fish-eating species (e.g. cormorants, terns, egrets, herons and pelicans) contrasted strongly with the behaviours of shorebirds. For fish-eating species usually less than 30% of the birds counted were foraging (Table 3). The exceptions to this include the grebes and Whiskered Terns that had relatively high numbers of foraging birds. However for grebes it is more difficult to ascertain when birds are foraging because they dive to escape disturbance as well as dive to forage, and so foraging for grebes may be over-estimated. Whiskered Terns are also likely to take invertebrates from the surface of the water, and this may account for a higher proportion of this species foraging. Typically less than 30% of the waterfowl (ducks, swan) counted were foraging (Table 3) suggesting that they were not limited by their food supply. However, some of the low counts for these species need to be treated with care because wetland areas can be used as safe refuges and or places to undergo moult rather than being significant foraging habitat. For example, many of the Australian Shelducks counted on or near the wetlands in January 2014 were flying off the wetlands to forage on terrestrial vegetation (irrigated Lucerne, spilt barley grain) for periods of time during the day, suggesting that they were obtaining most of their food from these sources. Furthermore, some of the shelducks were also moulting and so unable to easily leave the water for 2-3 weeks. These birds would have depended on aquatic food resources within Coorong or the Lower Lakes during these times. Other species that foraged away from the wetlands were Cape Barren Geese (*Cereopsis novaehollandiae*), Straw-necked Ibis (*Threskiornis spinicollis*) and Australian White Ibis (*Threskiornis molucca*). Another potential explanation for the low levels of foraging behaviour recorded for some waterfowl might be that they were simply resting before flying on to other wetlands.

<u>Changes in the abundances of birds using the Coorong and Lower Lakes</u>

The abundances of most waterbirds using the Coorong and Lower Lakes were higher in January 2014 compared with previous years (Table 4). This was particularly true for the prominent migratory shorebirds: Red-necked Stint, Sharp-tailed Sandpiper and Curlew Sandpiper (*Calidris ferruginea*). The numbers of these species have increased steadily over the last 4 years since historically low abundances of January 2011 when high water levels in both the Coorong and Lower Lakes would have limited their access to productive mudflats. The abundances of these three species in January 2014 were similar to their abundances at the end of the drought (i.e. January 2009, 2010; Table 4). The other numerically prominent shorebird, the non-migratory Red-capped

Plover was also in higher abundances in January 2014 than in the previous three years and similar to abundances in January 2009. These increased abundances contrast with those of the Common Greenshank which have remained low. In January 2009 and January 2010, well in excess of 500 greenshanks were counted in the Coorong and Lower Lakes, but the numbers fell around 50% in January 2011, and since then have not recovered. Most the other migratory shorebirds using the Coorong and Lower Lakes occur in small numbers (<10 individuals for most species) and are not detected every year and so there is no merit in considering changes in abundances for these species.

Table 3. Overall abundances of different waterbird species counted in the Coorong and Lower Lakes in 2014, and the relative use of the Lower Lakes and Coorong by different species. Birds were assigned to either the Lower Lakes or Coorong system if >80% of the birds were counted in the Lower Lakes or Coorong respectively. If a species was more evenly spread across both wetlands that species was assigned to both. The percentage of birds that were foraging when counted is also given for birds using the different wetlands.

Species	Lower Lakes	Coorong	Total	System (%)	Lakes % forage	Coorong % forage
Black Swan	2645	1965	4610	Both (57)	8.2	20.0
Australian Shelduck	18760	13352	32112	Both (58)	3.6	20.8
Australian Wood Duck	68		68	Lakes (100)		
Blue-billed Duck		27	27	Coor(100)		7.4
Pink-eared Duck	13	131	144	Coor (91)	15.4	
Australasian Shoveler	142	48	190	Both (75)	24.5	4.2
Grey Teal	3842	87037	90879	Coor (96)	20.4	14.4
Chestnut Teal	51	4880	4931	Coor (99)	25.5	5.7
Mallard hybrids etc	13	1	14	Lakes (86)		
Pacific Black Duck	7213	453	7666	Lakes (94)	13.1	18.8
Hardhead	2170	1570	3740	Both (58)	4.7	7.5
Musk Duck	41	61	102	Both (40)		77.0
Freckled Duck	129	1	130	Lakes (99)	1.6	
Cape Barren Goose	1007	678	1685	Both (60)	54.5	63.0
Domestic goose	18		18	Lakes (100)		
Australasian Grebe	1		1	Lakes (100)		
Hoary-headed Grebe	7	4025	4032	Coor (99)	57.1	62.0
Great Crested Grebe	128	135	263	Both (49)	36.7	73.3
Darter	32		32	Lakes (100)	12.5	
Little Pied Cormorant	77	114	191	Both (40)	7.1	10.5
Great Cormorant	12851	4703	17554	Both (73)	8.2	0.6
Little Black Cormorant	1025	2433	3458	Both (30)	1.8	1.8
Pied Cormorant	8436	760	9196	Lakes (92)	11.2	8.7
Black-faced Cormorant		143	143	Coor (100)		
Australian Pelican	6237	5122	11359	Both (55)	5.2	11.1
Little Tern		2	2	Coor (100)		
Fairy Tern		347	347	Coor (100)		8.1
Gull-billed Tern		17	17	Coor (100)		17.6
Caspian Tern	608	973	1581	Both (38)	27.3	12.0
Common Tern		66	66	Coor (100)		4.5
Whiskered Tern	4489	8966	13455	Both (33)	51.5	34.4
Crested Tern	335	3075	3410	Coor (90)	31.3	1.0
Eastern Great Egret	129	203	332	Both (40)	16.3	21.2
White-faced Heron	118	205	323	Both (37)	34.7	26.8
White-necked Heron	1		1	Lakes (100)		

continued

Table 3 cont

Species	Lower Lakes	Coorong	Total	System (%)	Lakes % forage	Coorong % forage
Little Egret	2	26	28	Coor (93)		57.7
Nankeen Night Heron	12	5	17	Both (71)		
Australian White Ibis	867	1022	1889	Both (46)	26.4	57.8
Straw-necked Ibis	1418	340	1758	Lakes (81)	6.9	41.8
Royal Spoonbill	202	100	302	Both (67)	7.2	9.0
Yellow-billed Spoonbill	25	2	27	Lakes (92)	48.0	
Pacific Gull		9	9	Coor (100)		
Silver Gull	1172	6185	7357	Coor (84)	6.4	26.8
Purple Swamphen	442	3	445	Lakes (99)	62.9	66.7
Australian Spotted Crake	2		2	Lakes (100)	50.0	
Black-tailed Native-hen	78	118	196	Both (40)	87.2	
Dusky Moorhen	23		23	Lakes (100)	56.0	
Eurasian Coot	3156	478	3634	Lakes (87)	42.0	19.2
Pied Oystercatcher		188	188	Coor (100)		22.3
Sooty Oystercatcher		4	4	Coor (100)		50.0
Black-winged Stilt	65	493	558	Coor (88)	92.3	69.8
Red-necked Avocet		6440	6440	Coor (100)		60.9
Banded Stilt	8	1399	1407	Coor (99)	87.5	77.6
Oriental Plover		5	5	Coor (100)		20.0
Pacific Golden Plover		21	21	Coor (100)		33.3
Red-capped Plover	7	3049	3056	Coor (100)	71.4	86.3
Hooded Plover		5	5	Coor (100)		20.0
Red-kneed Dotterel	92	138	230	Both (40)	96.8	47.1
Black-fronted Dotterel	1		1	Lakes (100)	50.0	
Grey Plover		4	4	Coor (100)		
Banded Lapwing	45	140	185	Both (24)		25.7
Masked Lapwing	580	661	1241	Both (47)	15.3	13.8
Bar-tailed Godwit		78	78	Coor (100)		55.1
Eastern Curlew		15	15	Coor (100)		46.7
Latham's Snipe	1		1	Lakes (100)		
Common Greenshank	3	241	244	Coor (99)	33.3	57.3
Common Sandpiper		2	2	Coor (100)		
Marsh Sandpiper	10	1	11	Lakes (91)	90.0	100.0
Sanderling		197	197	Coor (100)		10.7
Wood Sandpiper	9		9	Lakes (100)	100.0	
Red-necked Stint	6	41962	41968	Coor (100)	100.0	83.9
Sharp-tailed Sandpiper	88	23088	23176	Coor (100)	54.5	89.0
Curlew Sandpiper		2652	2652	Coor (100)		41.2
Ruff		2	2	Coor (100)		
Ruddy Turnstone		6	6	Coor (100)		100.0

Continued

Table 3 cont.

Species	Lower Lakes	Coorong	Total	System (%)	Lakes % forage	Coorong % forage
White-bellied Sea-Eagle	1	2	3	Both (33)		
Clamorous Reed-Warbler	33	4	37	Lakes (89)		
Little Grassbird	10	11	21	Both (48)		
Golden-headed Cisticola	5		5	Lakes (100)		
Total	**78949**	**230589**	**309538**			

However Black-tailed Godwits were present in moderate numbers in January 2009 and January 2010 at the end of the drought and have not been detected since the return of flows. Instead modest numbers of Bar-tailed Godwits have been present since January 2011 (Table 4).

Changes in the abundances of stilts and avocets using the Coorong differ. The abundances of Banded Stilts have been extremely low in recent years compared to their abundances in January 2009 when a high a proportion of the global population used the Coorong. The general absence of this species in recent years reflects the opportunities for breeding on ephemeral wetlands in inland Australia, but may also indicate that the Coorong has been a poor non-breeding location in recent years, and since the disappearance of brine shrimps. In contrast the numbers of Red-necked Avocets have increased in recent years to historically high abundances, while those of Black-winged Stilts have also increased but at a much slower rate since January 2011. Abundances of Pied Oystercatchers although low for the first three years following the return of freshwater flows to the region had recovered to more typical historical abundances in January 2014.

Most of the fish-eating species were still more abundant in January 2014 than at the end of the drought (January 2009, January 2010; Table 4). However the four non-marine cormorants were all less abundant in January 2014, than they were in either January 2012 or January 2013, one to two years after the return of flows suggesting that these wetlands (at least relative to other wetlands that might be available) were less suitable for them, than they were a year or two ago. A similar pattern is seen in the abundances of pelicans (Table 4). Eastern Great Egrets (*Ardea alba*) and Caspian Terns (*Sterna caspia*) although still more abundant than at the end of the drought had also declined in abundance over the last year. The abundances of Hoary-headed (*Poliocephalus poliocephalus*) and Great Crested (*Podiceps cristatus*) Grebes have fluctuated over the last four years and in January 2014 were in abundances lower than those at the end of the drought. The numbers of Fairy Terns and White-faced Herons (*Ardea novaehollandiae*) have been similar for the last 3-4 years and have shown no substantial increase since the return of flows to the Murray Mouth region. In contrast, the numbers of Crested Terns using the Coorong and Lower Lakes has been lower over the last two years, compared to the four years prior to this.

The waterfowl, the other numerically prominent birds in the Coorong and Lower Lakes show differences in changes in abundances. Grey Teal have increased dramatically over the last two years, while the similar Chestnut Teal if anything declined over the last year (Table 4). Abundances of Australian Shelduck although fluctuating have been reasonably consistent over the last six years, while Black Swans, Pacific Black Ducks and Hardheads have been more abundant from January 2011 onwards following the return of flows to the region. Other species of duck although more abundant in recent years have been present only in small numbers. Musk Ducks continue to be in low numbers across this wetland system.

Table 4. Changes in the abundances of waterbirds counted in the Coorong and Lower Lakes in summer (Jan-Feb) from 2009 to 2014.

Species	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Black Swan	1782	3400	4376	2767	4515	4610
Australian Shelduck	28484	40865	31847	29389	33379	32112
Australian Wood Duck	2	0	9	54	153	68
Pink-eared Duck	2	0	0	266	621	144
Australasian Shoveller	6	17	8	19	107	190
Grey Teal	19644	21046	1026	46919	60229	90879
Chestnut Teal	7073	5051	5209	8697	8757	4931
Mallard (hybrid& derivatives)	13	16	1	10	36	14
Pacific Black Duck	1416	2033	1729	5978	5254	7666
Hardhead	12	44	1	342	4659	3740
Blue-billed Duck	0	1	1	4	0	27
Musk Duck	113	304	25	159	182	102
Freckled Duck	0	0	0	9	5	130
Cape Barren Goose	1738	1433	1383	2320	1945	1685
Domestic Goose	4	13	36	27	15	18
Australasian Grebe	0	0	0	71	20	1
Hoary-headed Grebe	14961	9120	0	7403	1081	4032
Great Crested Grebe	799	520	219	694	492	263
Darter	2	5	2	124	123	32
Little Pied Cormorant	477	103	81	730	385	191
Great Cormorant	3186	6173	7723	15332	27357	17554
Little Black Cormorant	1378	2020	1659	26563	3490	3458
Pied Cormorant	1611	1087	1944	4840	13498	9196
Black-faced Cormorant	76	220	209	291	254	143
Australian Pelican	5425	7509	7260	8903	13335	11359
Little Tern	0	0	0	0	4	2
Fairy Tern	347	326	168	362	284	347
Gull-billed Tern	4	8	4	5	7	17
Caspian Tern	550	455	561	1531	2470	1581
Whiskered Tern	14718	9103	235	12159	11720	13455
Common Tern	2	1	0	0	26	66
Crested Tern	7719	11958	4090	7141	2340	3410
Australasian Bittern	0	0	0	1	0	0
Great Egret	117	64	108	575	637	332
Intermediate Egret	0	0	2	0	0	0
Cattle Egret	0	0	0	8	2	0
White-faced Heron	189	270	355	310	337	323
White-necked Heron	0	1	0	0	0	1
Little Egret	22	4	4	28	31	28
Nankeen Night Heron	0	0	6	9	26	17
Glossy Ibis	0	0	0	61	0	0
Australian White Ibis	620	376	1346	1366	1006	1889

continued

Table 4 cont.

Species	2009	2010	2011	2012	2013	2014
Straw-necked Ibis	835	405	536	2591	1651	1758
Royal Spoonbill	396	346	234	139	245	302
Yellow-billed Spoonbill	55	58	18	24	12	27
Pacific Gull	2	9	1	11	9	9
Silver Gull	14017	13621	17658	11236	10038	7357
Purple Swamphen	9	0	47	446	796	445
Lewin's Rail	1	0	1	0	0	0
Buff-banded Rail	0	0	0	0	1	0
Baillon's Crake	0	0	0	0	2	0
Australian Spotted Crake	2	3	0	29	20	2
Spotless Crake	0	0	0	3	0	0
Black-tailed Native-hen	7	31	0	135	1525	196
Dusky Moorhen	13	0	30	44	44	23
Eurasian Coot	284	3321	41	5075	16297	3634
Pied Oystercatcher	206	186	131	130	86	188
Sooty Oystercatcher	0	1	5	4	2	4
Black-winged Stilt	732	621	51	367	473	558
Red-necked Avocet	474	1193	162	3189	4490	6440
Banded Stilt	213109	49448	18054	11700	1780	1407
Pacific Golden Plover	26	50	0	0	45	21
Grey Plover	1	2	0	0	0	4
Red-capped Plover	2729	1596	73	1331	1409	3056
Lesser Sand Plover	2	0	0	0	0	0
Greater Sand Plover	3	0	0	0	0	0
Oriental Plover	0	0	0	0	0	5
Black-fronted Dotterel	1	0	2	0	2	1
Hooded Plover	5	5	4	8	24	5
Red-kneed Dotterel	5	31	1	88	106	230
Banded Lapwing	178	1092	2	0	44	185
Masked Lapwing	1481	1325	710	815	1107	1241
Latham's Snipe	0	4	0	7	1	1
Black-tailed Godwit	89	174	0	0	0	0
Bar-tailed Godwit	2	0	32	50	56	78
Whimbrel	0	1	1	0	0	0
Eastern Curlew	30	15	3	9	11	15
Terek Sandpiper	1	0	0	0	0	0
Common Sandpiper	1	0	0	0	0	2
Common Greenshank	578	714	237	182	293	244
Marsh Sandpiper	10	11	0	14	2	11
Wood Sandpiper	0	7	0	0	3	9
Ruff	0	0	0	0	0	2
Ruddy Turnstone	0	4	0	0	0	6
Great Knot	1	0	0	0	0	0

continued

Table 4 cont.

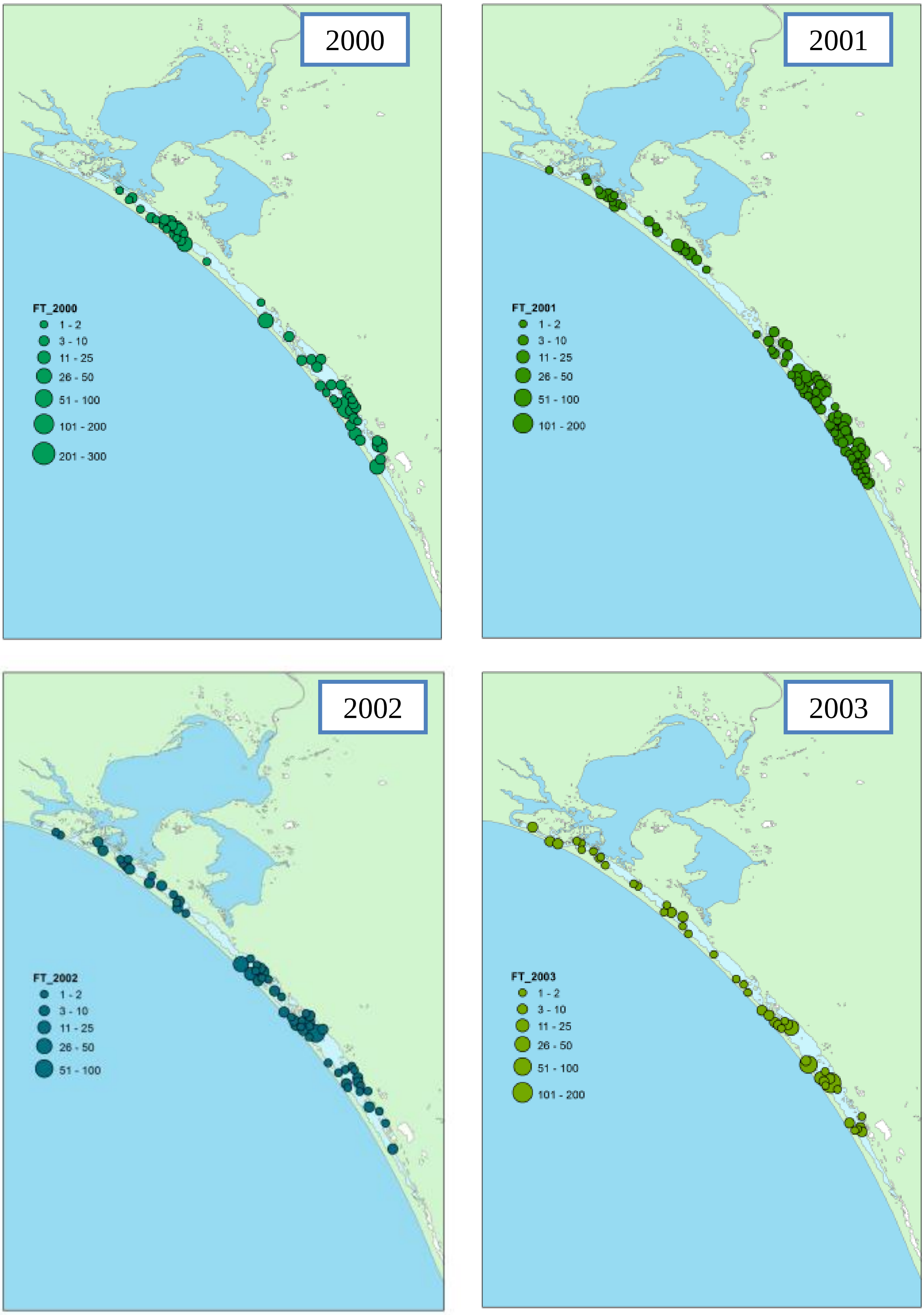
Species	2009	2010	2011	2012	2013	2014
Red Knot	0	1	0	0	0	0
Sanderling	0	515	0	0	120	197
Red-necked Stint	44050	48582	6605	21120	29582	41968
Sharp-tailed Sandpiper	25693	30023	37	5702	13688	23176
Curlew Sandpiper	938	1988	217	350	798	2652
unident small waders	0	2500	0	0	0	0
Total	**418458**	**281429**	**116526**	**250271**	**283717**	**309538**

In general the abundances of both Straw-necked and Australian White Ibises have continued to increase. In recent years both species have been more abundant than they were at the end of the drought. In contrast, both species of spoonbills remain in lower abundances than they were at the end of the drought (Table 4).

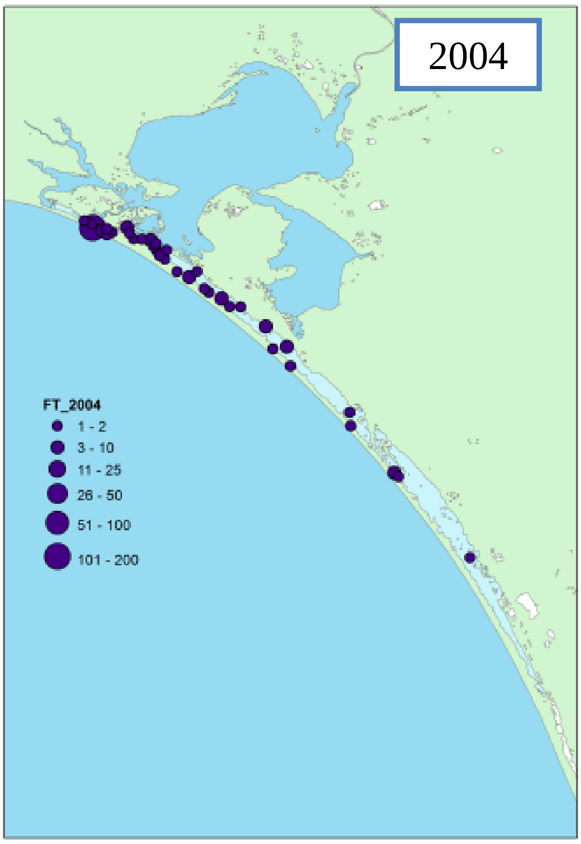
The two other species warranting comment are Silver Gulls and Purple Swamphens. Silver Gulls have steadily declined since January 2011, and abundances in January 2014 were approximately half their abundances at the end of the drought. Purple Swamphens were all but absent during the extreme drought years (January 2009; January 2010) but recolonised the reed beds around the Lower Lakes with numbers peaking in January 2013 (Table 4). However, their numbers dropped in January 2014, suggesting that the Lower Lakes may have become less suitable for them over the last year.

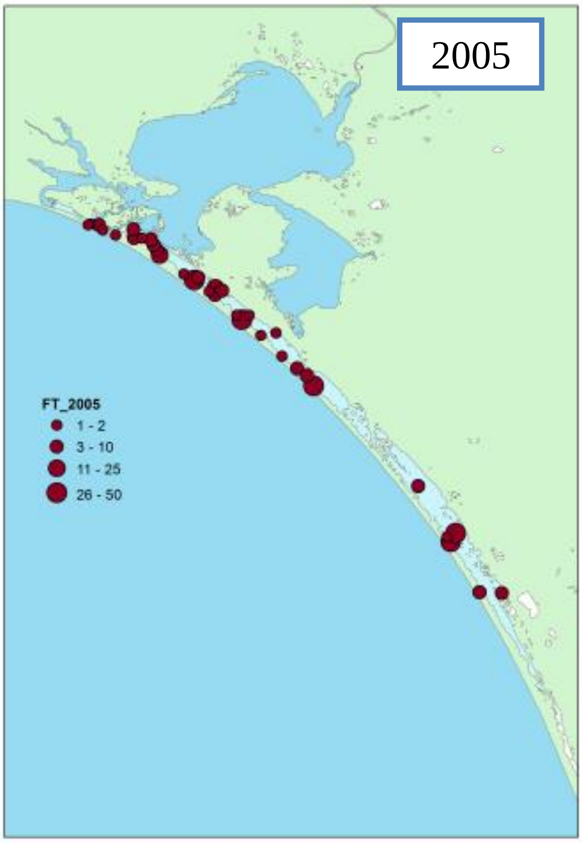
<u>Changes in distribution of waterbirds using the Coorong and Lower Lakes</u>

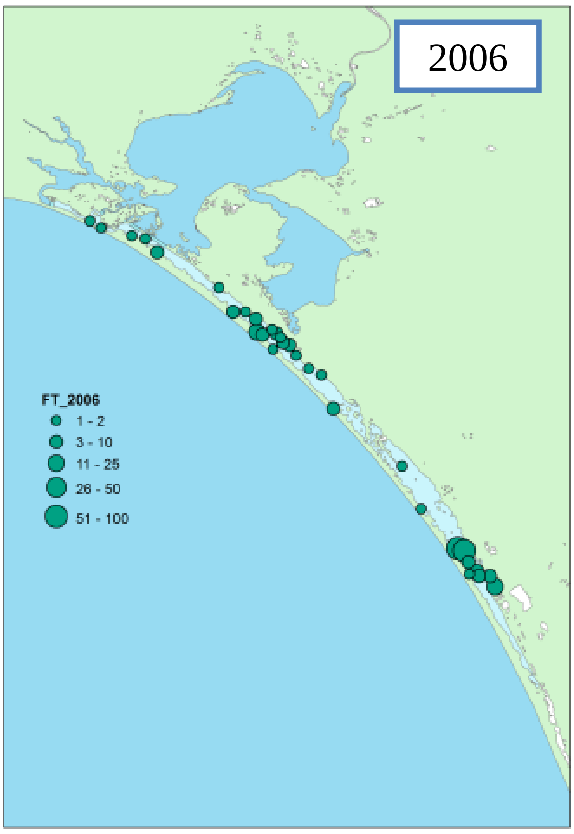
The changes in overall abundances of different species of waterbird, as outlined above, ignore the complexity of these wetlands in time and space, particularly the Coorong, and complexities of the avian responses. For example, few if any waterbird species are evenly distributed over these wetlands and their distributions often change from one year to the next. Those changes are likely to reflect changes in the distribution and abundance of ambient conditions (salinity, water levels), food resources and habitat features. Thus the logical extension of census work is to model changes in distribution and abundance of birds against the distribution and abundance of different habitat features, salinity, water levels and food resources. Ultimately understanding how these features influence the distributions and abundances of different species of waterbird will allow these wetlands to be managed for waterbird outcomes. Although doing this is beyond the scope of the current work, two examples of the changes in distribution for waterbirds are given in Figures 1 and 2 to illustrate the nature of the bird census data. In Figure 1 the distribution and abundance of Fairy Terns is shown for each January since 2000. In the initial years (2000-2003) of this sequence Fairy Terns were using both the North and South Lagoons. However from 2007-2011 they used the North Lagoon and areas around the Murray Mouth to a much greater extent than the South Lagoon, consistent with the absence of fish over most of the South Lagoon. In 2012-14, with small-mouthed hardyhead fish (*Atherinosoma microstoma*) once again abundant in the southern Coorong, Fairy Terns largely used the southern half of the Coorong and were absent from the northern 30-40 km of the Coorong (Fig. 1). Figure 2 plots the distribution and abundances of Red-necked Stints using the Coorong in January over the last 15 years from 2000 to 2014, and in the Lower Lakes from 2009 to 2014. As a general rule, Red-necked Stints were broadly spread along the Coorong during 2000-2003, but from 2004-2011 the distribution of birds in the southern Coorong was increasingly patchy, with Red-necked Stints using the exposed shorelines of the Lower Lakes when water levels were exceptionally low (below sea level for both lakes). For 2012-2014 with more typical water levels in both the Coorong and Lower Lakes, Red-necked Stints were largely restricted to the Coorong where they were once again broadly distributed except for the northern and middle sections of the North Lagoon (largely between Robs Point and Pelican Point), where they were less prominent, if not absent. In most years over the last 15 years the highest numbers of Red-necked Stints have been using the southernmost sections of the North Lagoon (Fig. 2).

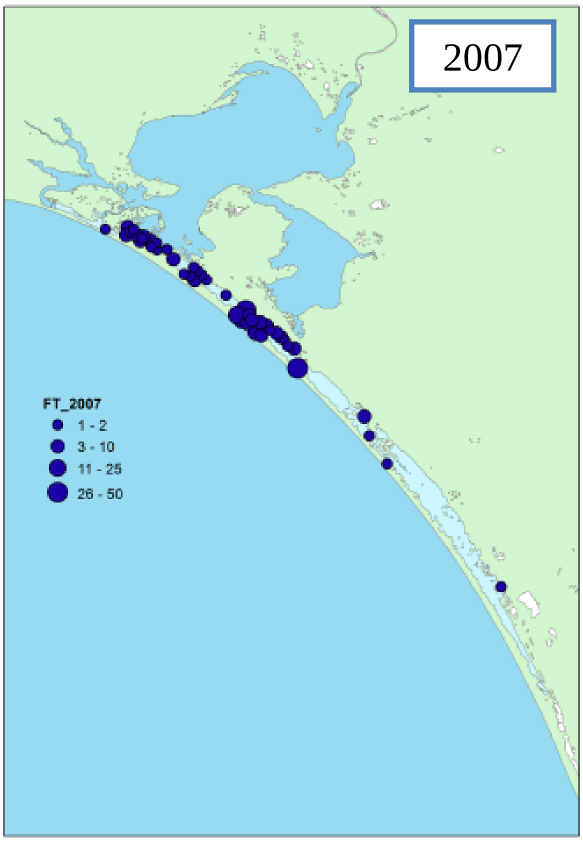


Fairy Tern distributions and abundances

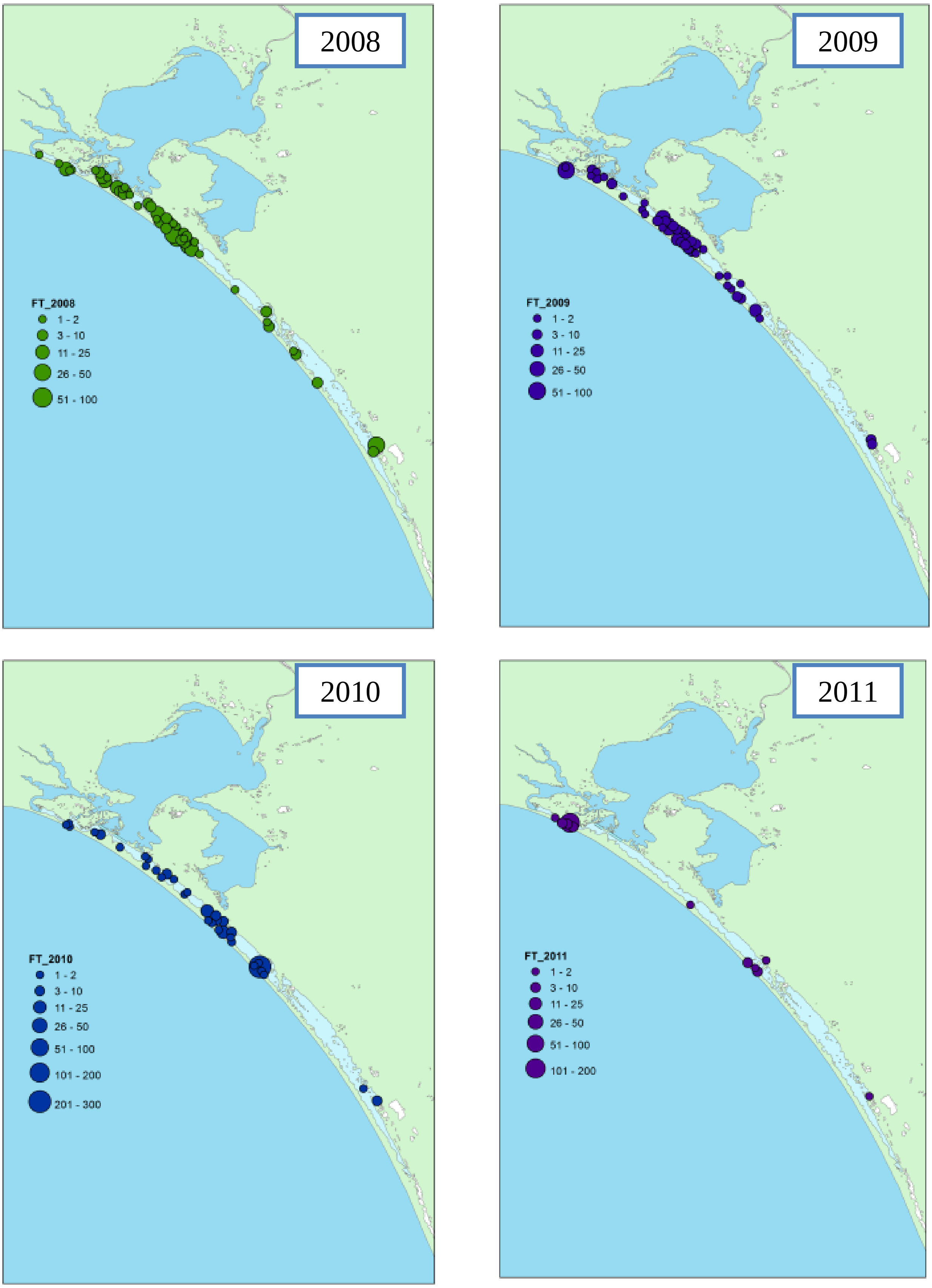




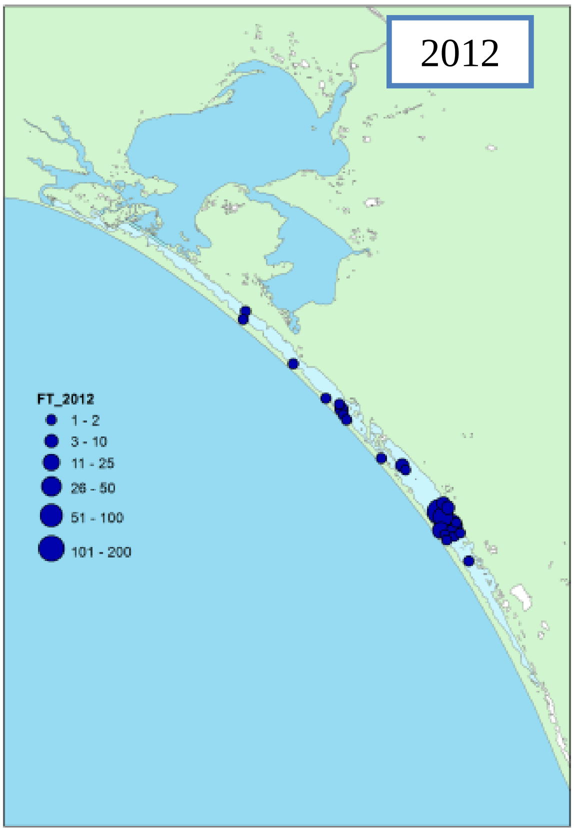


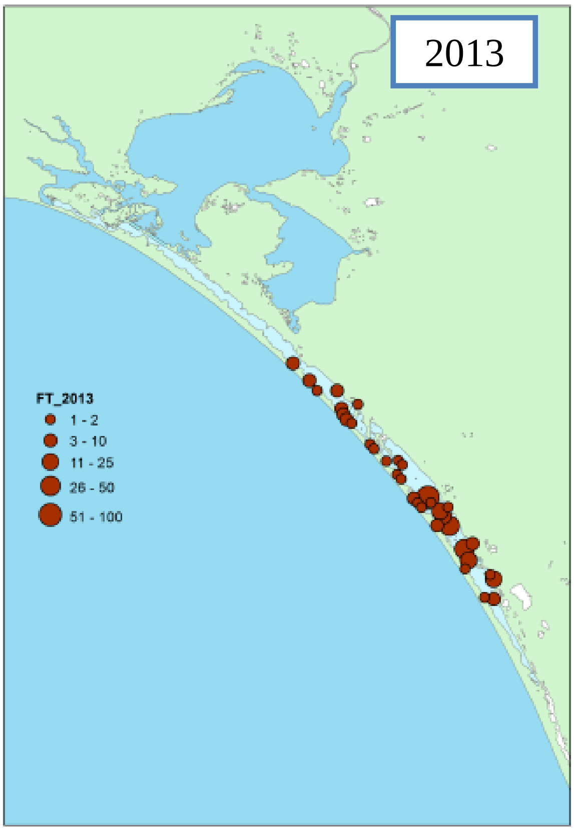


Fairy Tern distributions and abundances



Fairy Tern distributions and abundances





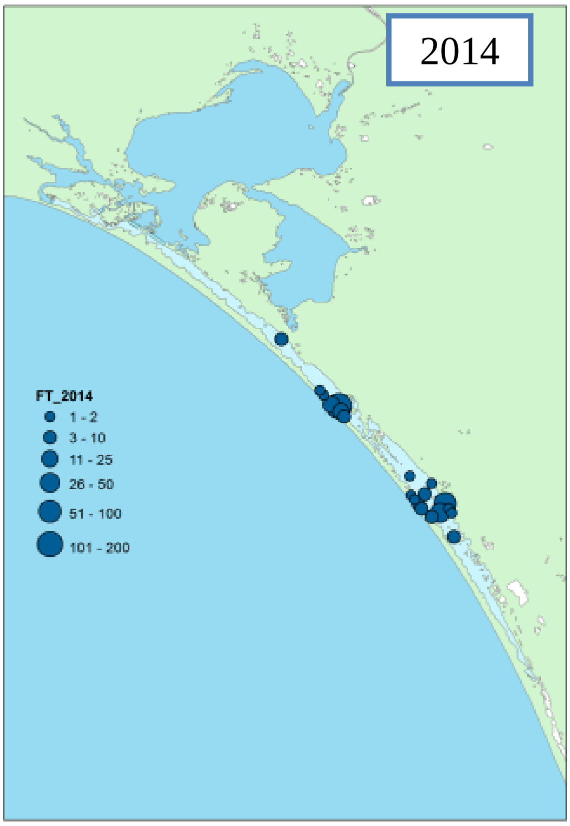
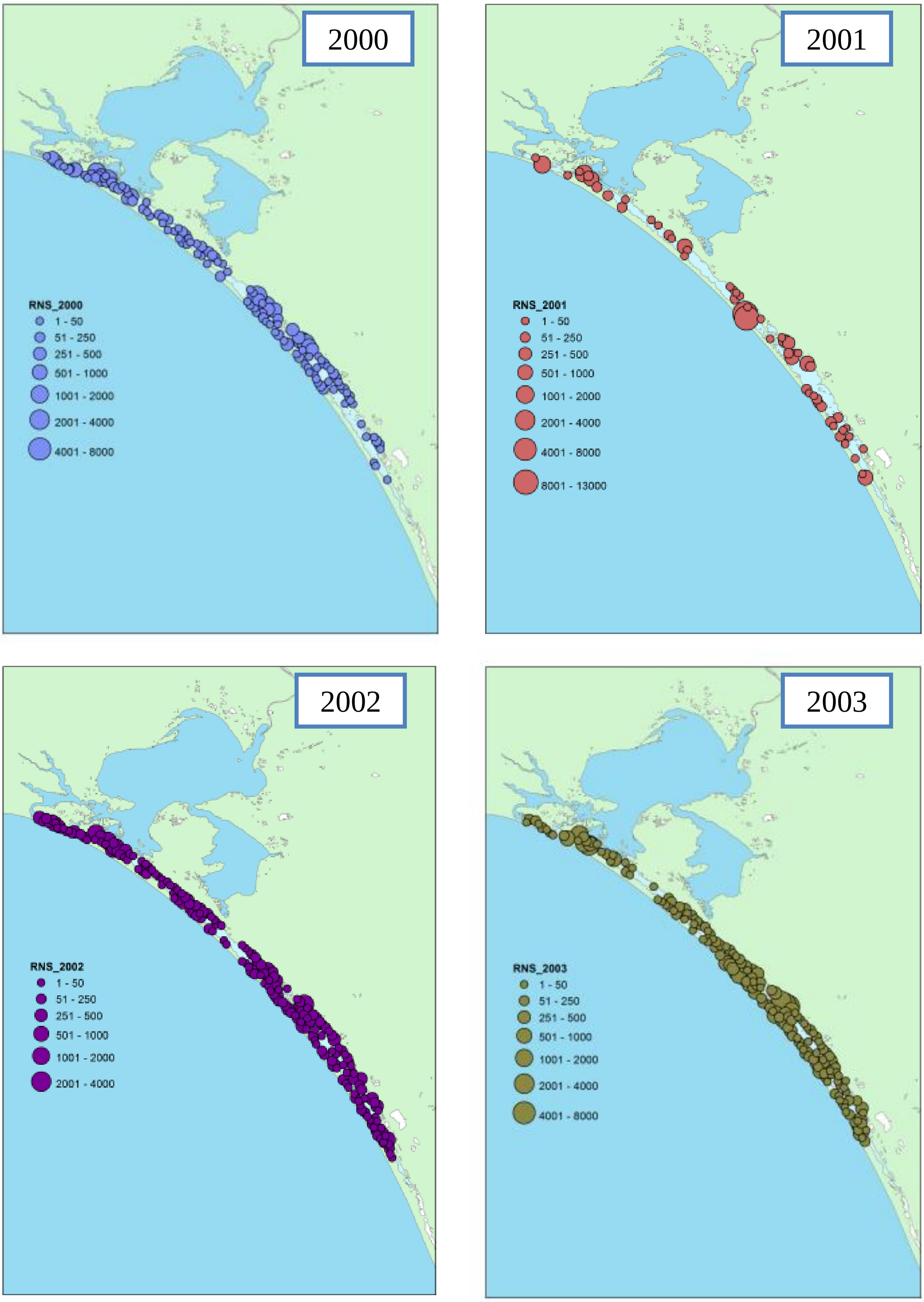
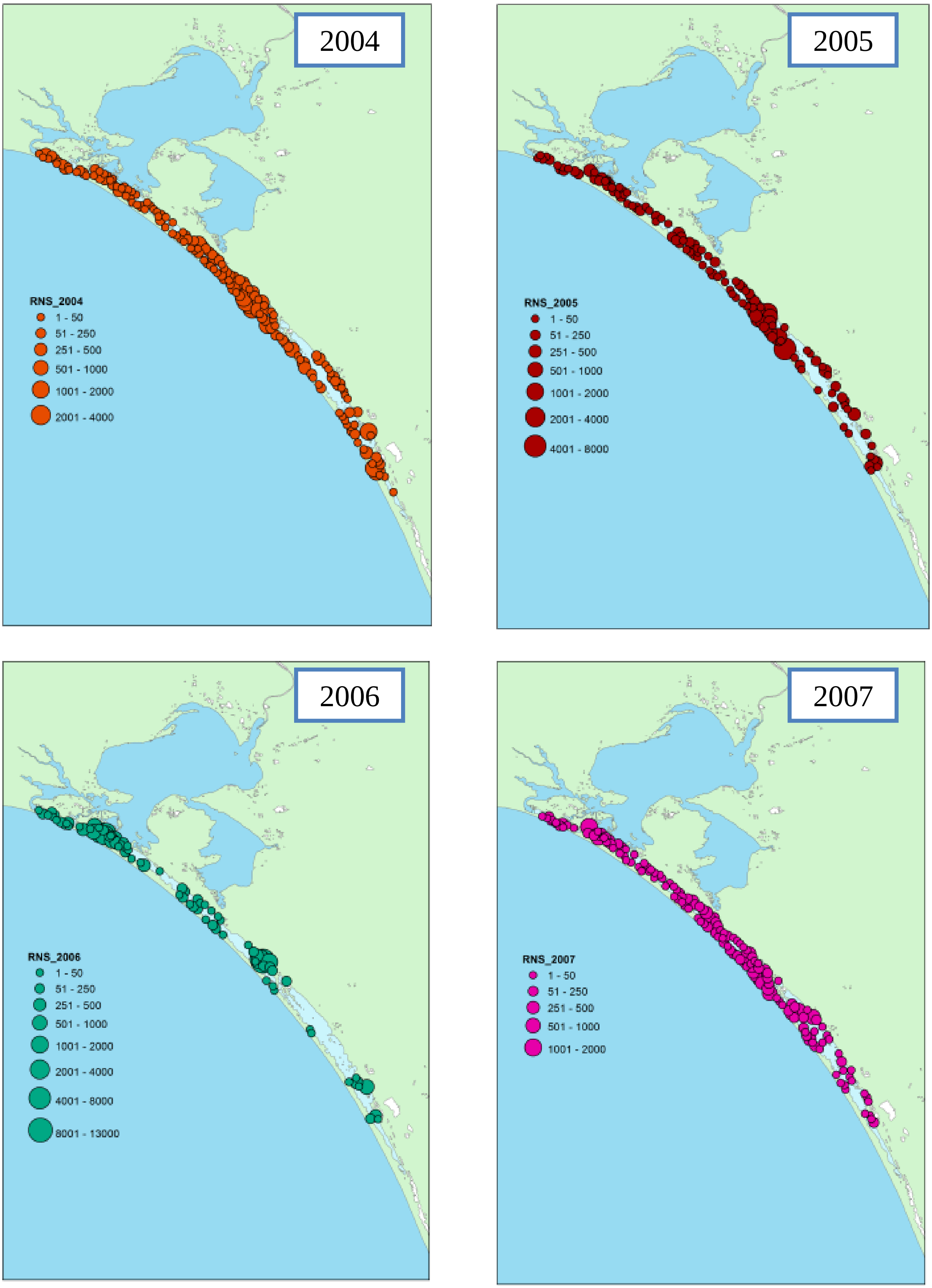


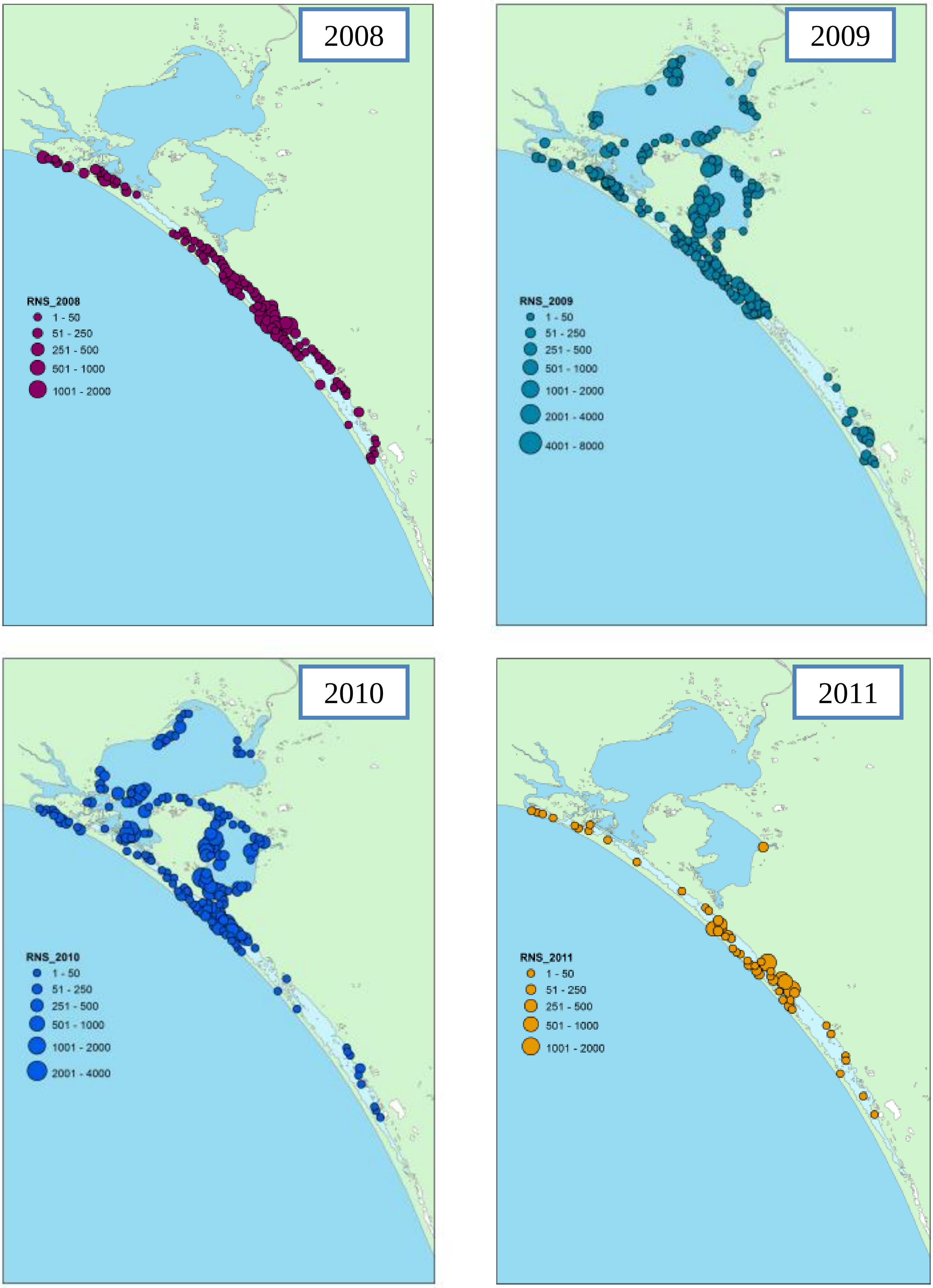
Figure 1: The distributions and abundances of Fairy Terns along the Coorong in January from 2000 to 2014.



Red-necked Stint distributions and abundances



Red-necked Stint distributions and abundances



Red-necked Stint distributions and abundances

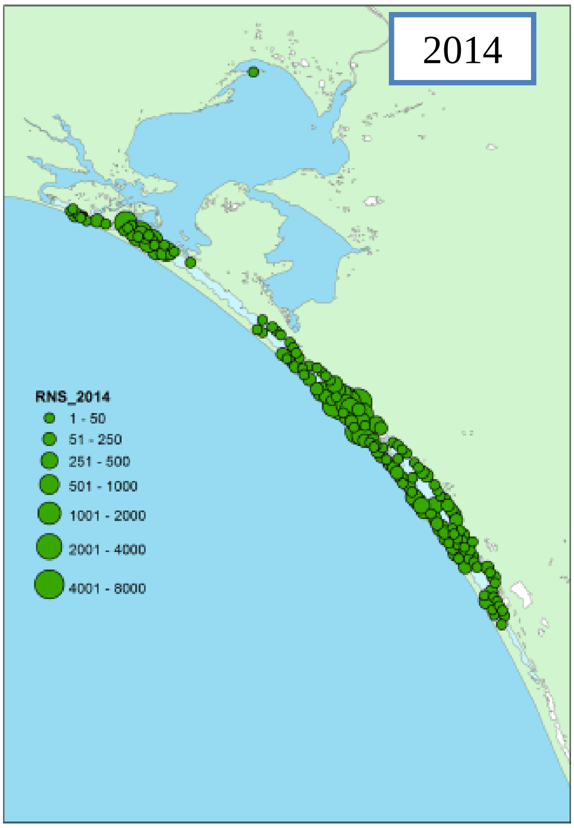


Figure 2: Distributions and abundances of Red-necked Stints in January along the Coorong over the last 15 years (2000-2014) and for the Lower Lakes from 2009-2014. No counts of waterbirds using the Lower Lakes from 2000-2008. However, few Red-necked Stints were likely to be using the Lower Lakes during this period given that the maintenance of higher water levels in the Lakes would have effectively excluded this species from the shorelines of the Lakes.

Changes in conditions and resources in the Coorong

The Coorong has undergone significant changes over the last six years. In 2009 and 2010 the salinities across the southern Coorong were extremely high and around 150 gL^{-1}(Fig. 3). With the return of freshwater flows to the Murray Mouth in late 2010 the salinities dropped and in the South Lagoon averaged around 110 gL^{-1} in both January 2011 and January 2012. In January 2013 and January 2014 the salinities had dropped further across the Coorong and were similar to the salinities that existed in January 2001 and January 2002 before the millennium drought (Fig. 3). The average salinity for the South Lagoon in January 2013 was 86 gL^{-1}, the first time that the average January salinity had been below 100gL^{-1} in the South Lagoon for more than a decade. In January 2014 the average salinity in the South Lagoon was 78 gL^{-1}.These changes in salinity influence the distributions and abundances of aquatic organisms that provide food resources for birds (Figs 4-6). In 2009 and 2010 there were no fish in the South Lagoon and very few chironomids because of the high salinities, but with the lower salinities in 2011 both began to recolonise the southern Coorong. Figure 4 shows the distributions and abundances of chironomid larvae along the Coorong over the last four years. In general, chironomids were widespread along the Coorong in January 2013 but not as abundant at many sites as in the previous year. In January 2014 chironomid larvae were particularly abundant at the southern end of the North Lagoon and northern end of the South Lagoon (Fig. 4) an area where there were high abundances of Red-necked Stints (Fig. 2). Polychaetes showed a similar distribution to previous years and were restricted to the northern Coorong where they were abundant, particularly along the middle and northern sections of the North Lagoon.

Small-mouthed hardyheads (*Atherinosoma microstoma*) were excluded from the South Lagoon of the Coorong by extremely high salinities from 2007-2010. In January 2011 shortly after the return of freshwater flows to the Murray Mouth hardyheads were mainly found in the North Lagoon (Fig. 5), despite salinities being suitable in the southern Coorong. In the subsequent year (2012) large numbers of hardyhead fish were caught in seine nets in the southern Coorong, suggesting a 1 year lag in the recovery of these fish. Since then hardyhead fish have been detected throughout the southern Coorong, but the areas with the largest catches have shifted from the middle sections of the South Lagoon in January 2013 to the southern end of the North Lagoon in January 2014 (Fig. 5). Given that hardyhead fish school these apparent shifts in distribution need to be treated cautiously as they may be caused by chance events while sampling. Fairy Terns however were largely detected in the areas with the higher fish abundances, shifting their distribution perhaps to take advantage of increased fish abundances in the southernmost sections of the North Lagoon. In addition to hardyheads, reasonable numbers of other fish were also caught in the seines in January 2014. These other species have generally been limited to the northern areas of the Coorong where the salinities are lower, but in January 2014 large numbers of other fish (primarily Congolli *Pseudaphritis urvillii*) were caught in seines at Salt Creek near the southern end of South Lagoon (Fig. 5). Salinities around Salt Creek were much lower (69 gL^{-1}) in January 2014 compared to other parts of the South Lagoon (Fig. 3). These other fish may have entered the Coorong when large volumes of freshwater from the SE drainage scheme were released into the Coorong at Salt Creek in spring 2013. At these times salinities at Salt Creek would have been even lower. Alternatively these other fish species have been drawn to the area because of the lower salinities. However, large numbers of Congolli were also caught at Magrath Flat at the southern end of the North Lagoon where the highest salinities (93 gL^{-1}) were recorded in January 2014.

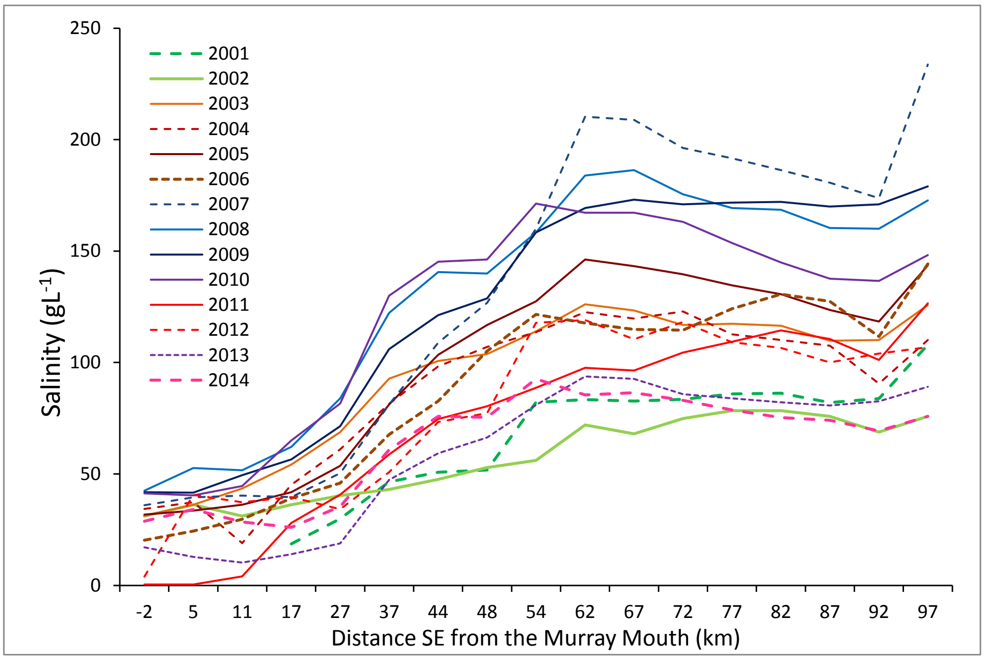
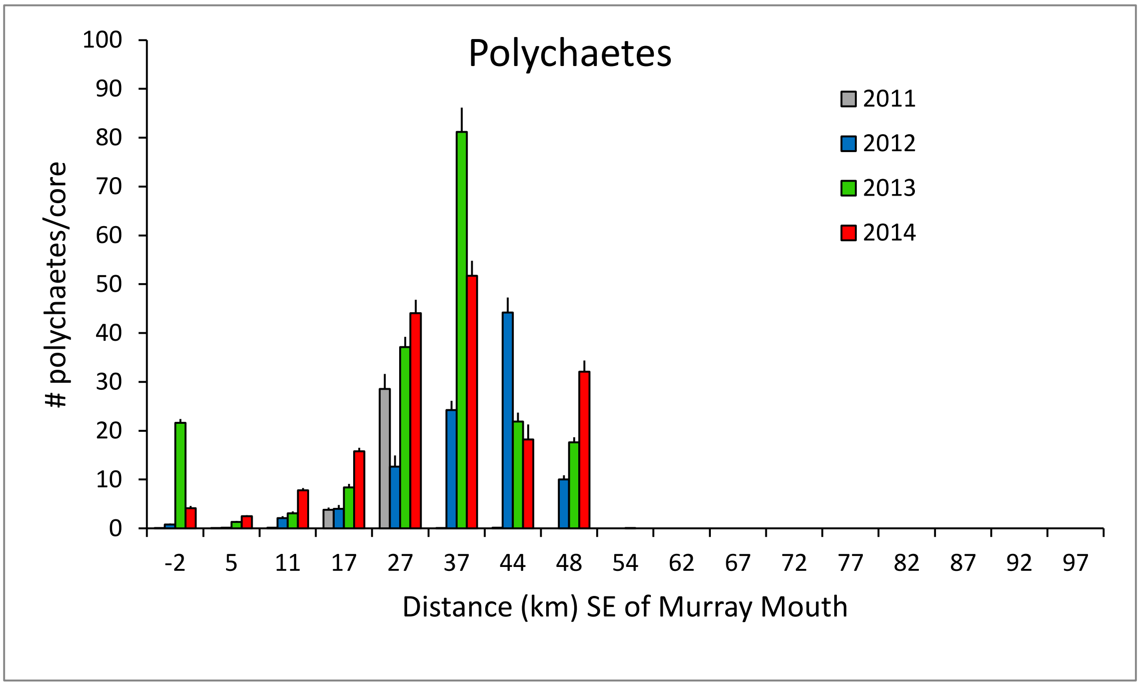


Figure 3. Salinities along the Coorong are shown for January from 2001 to 2014. Position along the Coorong is defined as the distance from the Murray Mouth, where negative values are NW of the mouth and positive values are SE. The junction of the two lagoons (Parnka Point) is at kilometre 59. The salinities shown for 2001 and 2002 and for 2013 and 2014 were typical of the salinities recorded during summer over the previous 30-40 years (Paton 2010).



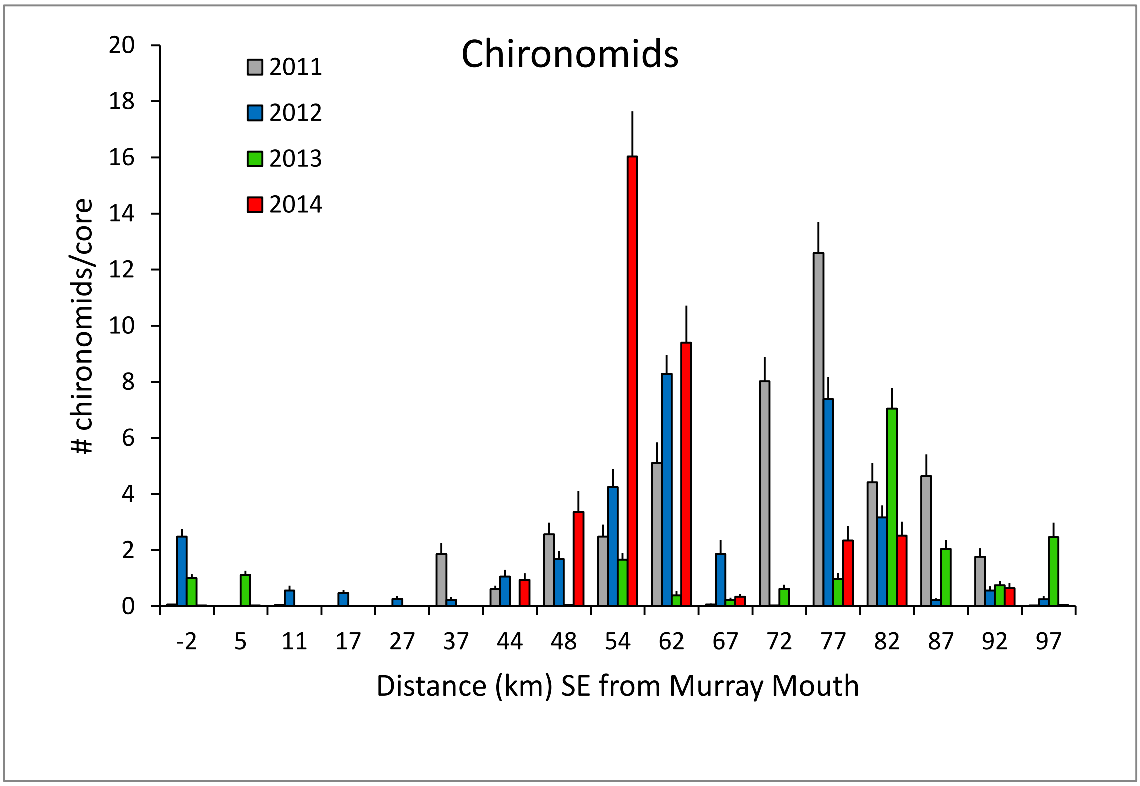


Figure 3. Mean number (+ s.e.) of polychaete worms and chironomid larvae found in 50 cores (25 samples taken in water 30cm deep and 25 samples at 60cm water depth) at 17 sites spread along the eastern shore of the Coorong in January from 2011 to 2014. Data can be converted to items/m^2 by multiplying by 226. Note that the scales on the y-axis differ for the two types of invertebrates. 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*), while the polychaetes include at least 3 species of which the most abundant was a species of *Capitella*.

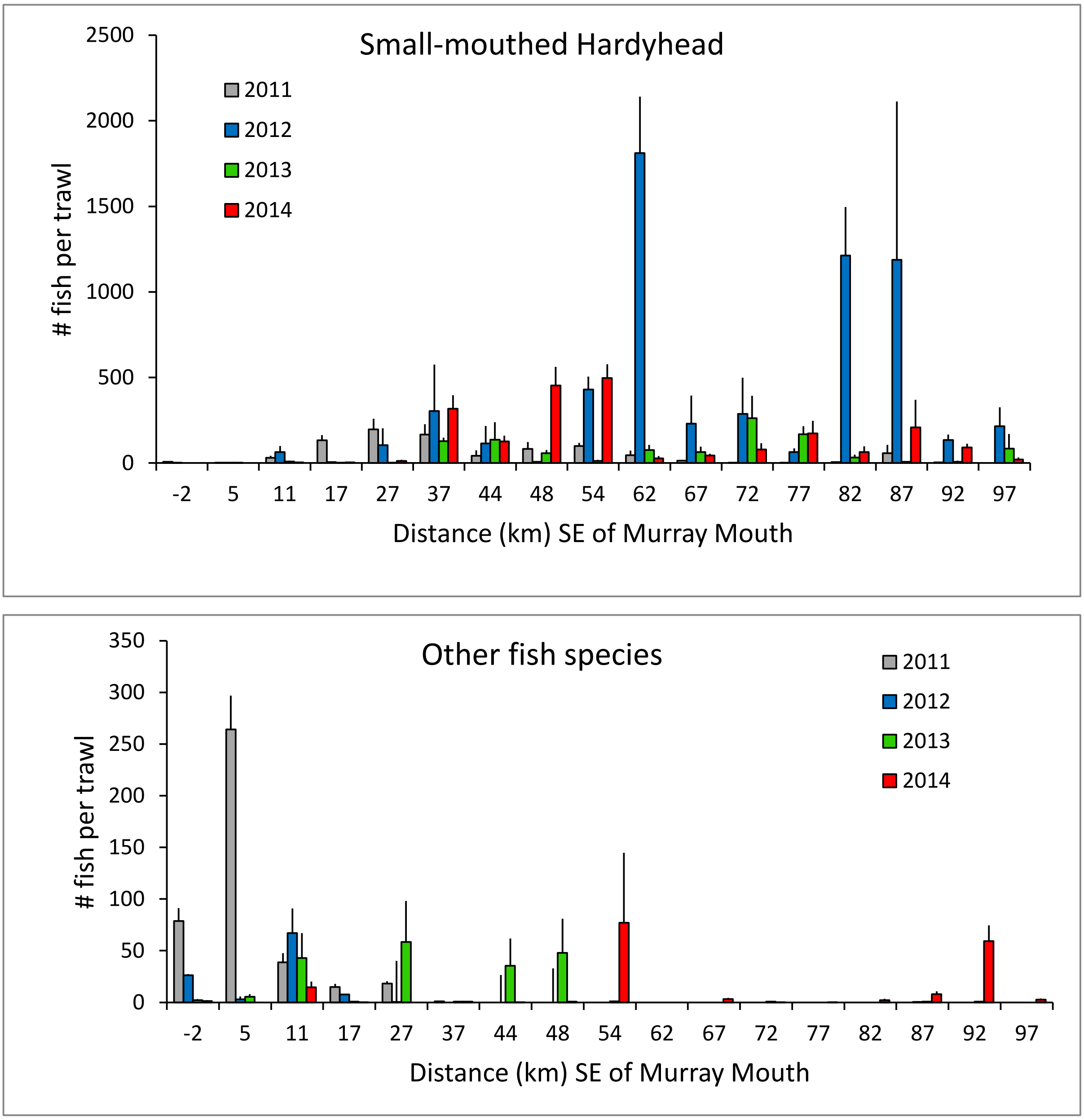


Figure 4. The distribution and abundance of small fish along the Coorong are shown for January from 2011 to 2014. Data are means (+s.e.) of three replicate 50m long trawls with a 7m seine net. Note that the scales on the y-axis differ for the two types of fish. Sites at -2, 5 and 11 km are in the region 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.

The other key food resource used in the Coorong by a range of waterbirds is *Ruppia tuberosa*. Despite favourable salinities since 2011, the populations of *Ruppia tuberosa* that were once abundant and widespread across the southern Coorong prior to the millennium drought have struggled to recover, with just small populations present at some sites in January 2013 (Fig. 6). However, there was a marked increase in the prominence of *Ruppia tuberosa* in the southern Coorong in January 2014 (Fig. 6). This distribution was still patchy with the species absent from more than half of the long-term monitoring sites in the South Lagoon in January 2014. *Ruppia tuberosa* was particularly prominent at the junction of the two lagoons between Villa dei Yumpa and Magrath Flat (54-62 km from the Murray Mouth) where the highest salinities occurred, and at Policeman's Point where recent translocation of *Ruppia tuberosa* seeds from Lake Cantara may have contributed.

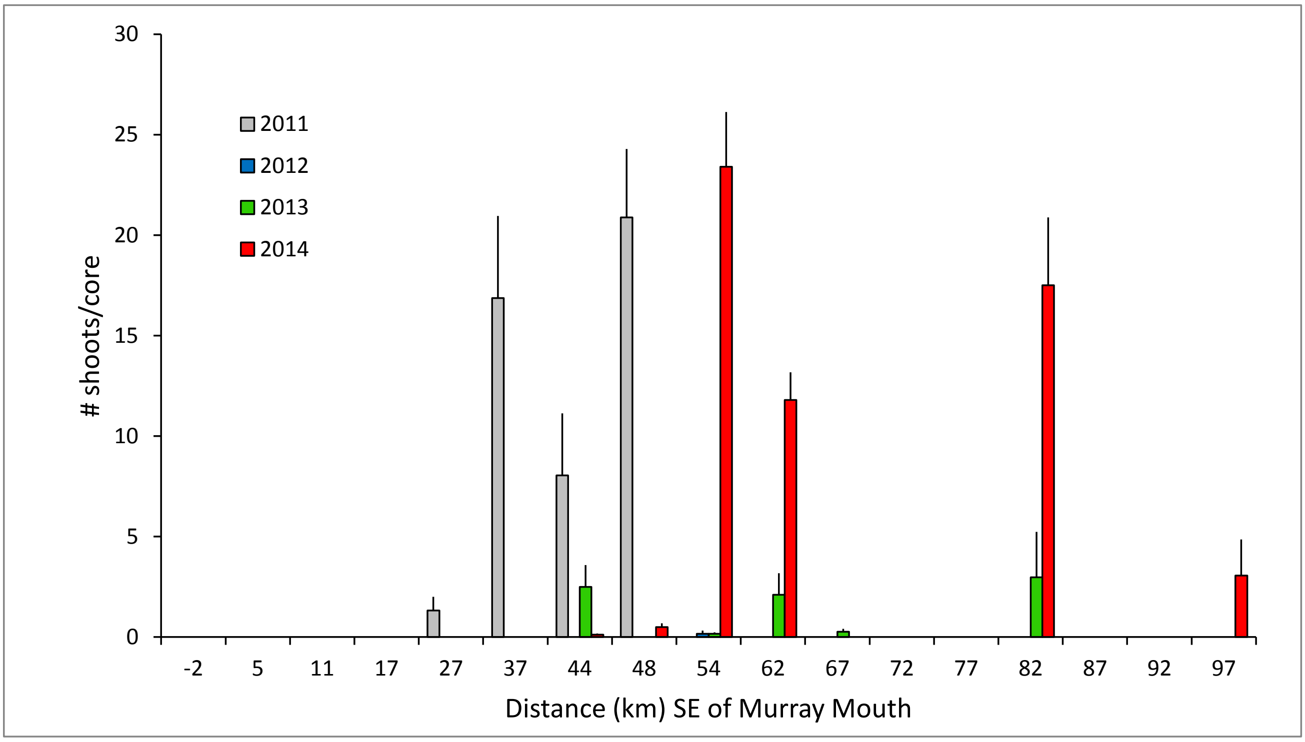


Figure 5. Mean number of *Ruppia tuberosa* shoots (+ s.e) present in 50 core samples (25 taken at each of two water depths (0.3m and 0.6m)) at 17 sites spread along the eastern shore of the Coorong in January from 2011 to 2014. Data can be converted to shoots/m^2 by multiplying by 226. Sites at -2, 5 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.

General Discussion and Conclusions

In general, the abundances of waterbirds using the Coorong and Lower Lakes have increased or been maintained over the last year with a few notable exceptions. Given this, the Condition Monitoring Target B-1 - *to maintain or improve bird populations in the Lower Lakes, Coorong and Murray Mouth* – has been met. However the abundances of a few species were higher in January 2009 and January 2010 than in January 2014 prior to the flows returning to the Murray Mouth. This suggests those species may still be recovering from the low numbers recorded in January 2011.

The Coorong and Lower Lakes supported in excess of 309,000 waterbirds in January 2014 up from 283,000 in January 2013. Given these abundances the Coorong and Lower Lakes clearly continue to meet the criteria expected of a Wetland of International Importance. The Coorong supported almost three times the numbers of birds compared to the Lower Lakes in January 2014. This is consistent with previous years when the Coorong typically supported at least twice as many birds as the Lower Lakes (Paton & Bailey 2013a). This highlights the importance of the Coorong from a bird perspective numerically. Furthermore, many species of waterbirds, particularly the endemic and migratory shorebirds (stilts, sandpipers, plovers and allies) were largely confined to the Coorong adding further support for the importance of this component of the wetland system. As many of the species using the Coorong are not prominent elsewhere along the Murray Darling system, the Coorong in particular warrants management to secure the resources needed by those species. The Lower Lakes, in turn support a number of waterbird species that rarely use the Coorong, but there are some species (various ducks, cormorants, terns) that readily use both wetland systems. The majority of the bird species currently using the Lower Lakes, however, use other freshwater wetlands elsewhere within the Murray Darling Basin and so are not as unique as the bird communities using the Coorong. From a bird perspective, however, the variously salty wetland systems of the Coorong complement those of the freshwater systems of the Lower Lakes allowing a greater diversity of waterbird species to exist within the region. Having the Coorong and Lower Lakes wetlands juxtaposed increases the range of wetland habitats in close proximity to each other and provides wider foraging opportunities for at least some species.

Three species have largely contributed to the increased numbers of waterbirds in the Coorong and Lower Lakes in January 2014 compared to January 2013: Grey Teal, Red-necked Stint and Sharp-tailed Sandpiper. While these species have shown increases of around 10,000 birds or more, Great Cormorants and Eurasian Coots have shown declines of around 10,000 birds, suggesting that the quality of wetland habitats for these species may have declined over the last year. Two other formerly abundant species have declined steadily in recent years. These are Banded Stilt and Silver Gull. In the case of Banded Stilts there have been multiple breeding attempts at ephemeral wetlands in inland South Australia and Western Australia over the last 3-4 years (R. Pedler pers. comm.). This may account for that species being much less abundant in the Coorong in the last 3-4 years, but equally food resources within the Coorong may not be as adequate now for this species as they were when brine shrimps were present. Numbers of Silver Gulls have more than halved in recent years (Table 4) and declines in this species might also be related to the absence of brine shrimps. Silver Gulls largely scavenge prey along the shorelines of the Coorong and their numbers may have built up during the latter years of the drought when large numbers of brine shrimps were being washed ashore. A reduction in the numbers of gulls using the Coorong may be beneficial in reducing potential nest predation for colonially-nesting pelicans and terns.

In general there has been a marked increase in the numbers of birds using the Coorong from around 187,000 to 230,000 over the last year, and a reduction in the numbers of birds using the Lower Lakes during the same period from 98,000 in January 2013 to 79,000 in January 2014. These patterns suggest the Coorong may still be recovering while the Lower Lakes may be slowly deteriorating as far as providing suitable habitat and resources for waterbirds. The maintenance of relatively high and stable water levels in the Lower Lakes for most of the year may reduce productivity and in turn reduce the capacity of the Lower Lakes to support wildlife. Unfortunately there is no information being collected on the availability of food resources at the same time as the bird census in the Lower Lakes to consider this. In the Coorong, however, the food resources were being maintained or had increased in January 2014 compared to similar data collected during the waterbird census in 2013, continuing a general trend for improving conditions over the last 3-4 years.

Reporting changes in waterbird abundances at the wetland scale ignores the fine details in how the birds may be responding and adjusting their distributions and abundances within the Coorong and Lower Lakes through time. No bird species were evenly distributed over the wetlands (e.g. see Figs 1 & 2). Instead most species were patchily distributed in time and space suggesting that certain parts of these wetlands were more suitable than others and that this suitability changed through time. Furthermore even within a guild of similar species (cormorants, ducks, terns), the individual species often differed in their distributions and how these distributions and abundances changed through time. Each species appears to be responding to different features or to the same features differently. As a consequence of these individual differences, the requirements of each species will need be considered in developing management programs for these wetlands.

Two factors are likely to influence the distributions and abundances of waterbirds using the Coorong and Lower Lakes. The first of these are changes in the distribution of suitable habitats for different species of waterbirds. At the end of the drought and prior to water returning to the Lower Lakes in late 2010, there were extensive mudflats around the Lower Lakes and the fringing aquatic vegetation was disconnected from the water. Those conditions offered foraging opportunities for many shorebirds (stints, sandpipers and plovers) and the birds used these areas under those conditions (e.g. Fig. 2). However, low water levels eliminated habitat for reed-dependent species like Purple Swamphens and this species had largely disappeared from the region in 2009 and 2010. They have subsequently returned albeit with a lag period of a year, once the fringing aquatic vegetation was reconnected with the water with the return of flows to the region in late 2010. With the Lakes refilled water was released over the barrages to the Coorong and the Coorong also quickly filled to water levels that were much higher in January 2011 compared to years before and after this year (Fig. 6). In fact, water levels in the Coorong in January 2012, 2013 and 2014 were similar to those of January 2009 and 2010 during the drought. The higher water levels in January 2011 eliminated or greatly reduced the foraging opportunities for shorebirds and they had largely vacated the shorelines of the Lower Lakes and the Coorong in January 2011 (e.g. Table 4, Figure 2). Future management will need to avoid excessively high water levels, at least for the Coorong, during summer, to avoid eliminating most of the migratory waders.

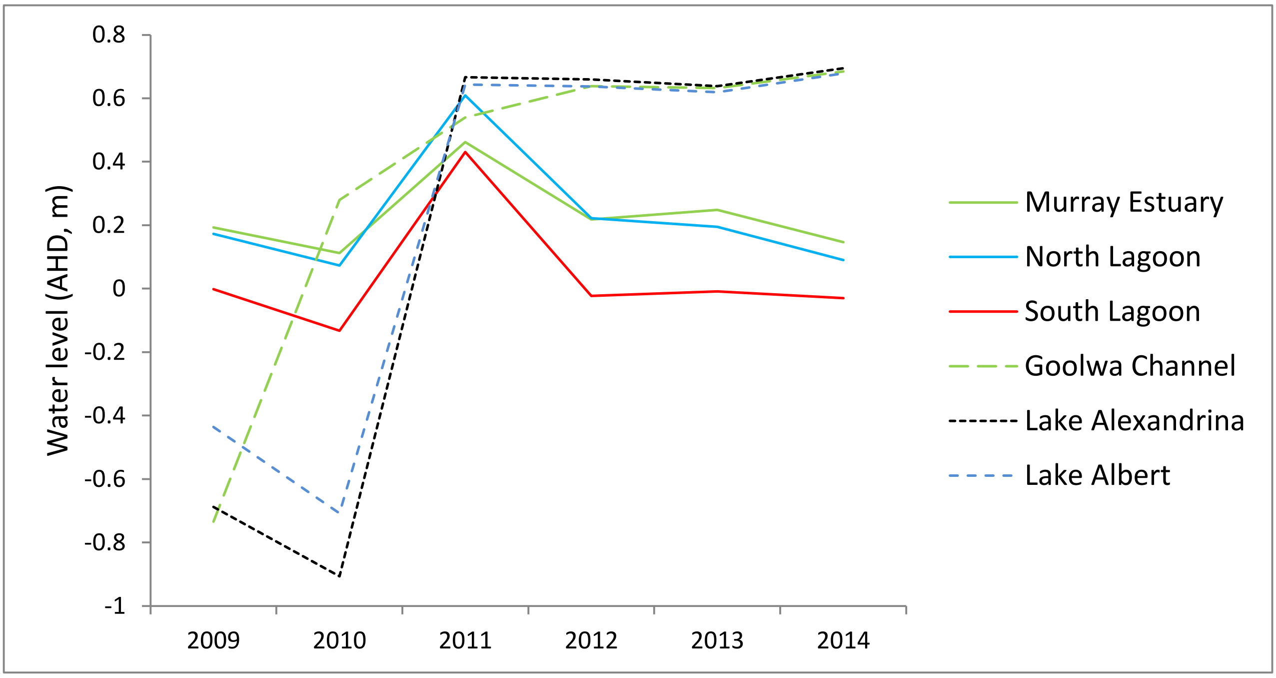


Figure 7. Changes in water levels in different sections of the Coorong and Lower Lakes in January from 2009 to 2014. Data are based on 2-3 telemetred stations in each water body.

The second factor likely to influence the distributions and abundances of waterbirds in the Coorong will be the availability of suitable food resources. Food resources used by birds are more dynamic than some of the physical or habitat parameters (salinities, water levels, mudflats covered with shallow water). This is because distributions and abundances of food resources are influenced by abiotic and biotic factors that are taking place through the year, and not just the periods when the birds are present. Some of these resources may not have fully recovered since the end of the drought conditions of 2010, such as *Ruppia tuberosa*, although the recent trends are encouraging. Ultimately understanding the factors that influence food resources will be needed to manage waterbird populations effectively in the Coorong. However, based on monitoring of waterbirds over the last six years, avoiding periods of excessively high water levels over summer when most waterbirds use the Coorong (Paton 2010) is important. High water levels in January 2011 were associated with major releases of water over the Barrages but these levels may have been exacerbated by an extended period of no flows prior to this that allowed incursions of marine sands into the Coorong channels to consolidate. Those consolidated sandbars can restrict the passage of freshwater released from the Barrages to the sea and cause water levels to rise higher than normal. In future there may be merit in dredging these channels after extended periods of no flow and to reduce the extent to which excessively high water levels can establish. This might require disturbing areas of consolidated sands when the flows are taking place, simply lifting the sand into the water column to facilitate sand egress out of the Mouth. However, higher water levels particularly in spring and early summer in the Coorong compared to recent years are likely to assist the recovery of *Ruppia tuberosa*. A balance between the higher water levels needed by *Ruppia* while avoiding extremely high water levels that exclude birds is required. There is clearly a need to have a greater focus on managing water levels in the Coorong.

Of the species of birds that have not yet recovered to the abundances that existed immediately prior to the return of freshwater flows to the region in late 2010 are the Common Greenshank and both species of spoonbill. Why these species have not recovered numerically is not known. Common Greenshanks feed mainly on small fish caught in shallow water within the southern Coorong and small fish have been abundant and widespread for the last three years so food resources would not seem to be limiting recovery. Other factors, perhaps off site may be involved. Given the limited recovery of these species since 2011, further targeted work on these species in particular is warranted.

Increases or decreases in abundances of species from one year to the next or relative to a pre-determined baseline are unlikely to provide an adequate assessment of the capacity of a wetland to service the needs of the various waterbirds. A further assessment of the quality of the wetlands should also be considered. One method of making such an assessment is from the behaviour of the birds. If birds need to spend large amounts of time foraging then their food resources are more likely to be limiting. Most fish-eating species and most herbivorous waterfowl (ducks, swans) in the Coorong appear to be spending around 20% or less of their daylight hours foraging (Table 3) suggesting that food resources were more than adequate for these species. In comparison most species of shorebirds (sandpipers, stints, stilts, plovers) were spending 70-90% of their time foraging based on the activity of the birds when counted (Table 3). This suggests that food resources for these species are more likely to be limiting, and any small reduction in the abundances of their food resources might be critical. The available behavioural data suggest the Coorong is still a poor quality habitat for shorebirds. Further work is required to understand the relationships between the foraging behaviour of the birds and the quality of the wetlands in the Coorong and Lower Lakes.

Using the percentage of birds that were foraging when counted as a measure of the ease with which birds can harvest the food they need could be imprecise, in part because many waterbirds are often in flocks where all the individuals forage at the same time or rest at the same time. Thus a large flock might be detected foraging or resting by chance during a count and so influence the estimate of the percent time spent foraging. However for abundant species that are widespread (e.g. Red-necked Stints), estimating daily foraging efforts from such data are reasonable because many hundreds of flocks are scored. Interestingly, the percentages of Red-necked Stints and Sharp-tailed Sandpipers that were foraging when counted in January 2014 (<90%) were a little lower than in January 2013 (>90%), suggesting a small improvement in resources for these birds over the last year. Furthermore, targeted and repeated observations of birds made throughout the day at a variety of locations along the Coorong provide similar estimates with typically over 90% of the time spent foraging (Paton *et al.* unpubl. data) even in January 2014.

Clearly any attempt to understand relationships between food availability, foraging performances (rates of prey capture) and the effort required by birds to harvest sufficient food (amount of time allocated to foraging) should focus on those species that are spending most of their time foraging to better determine the factors that influence habitat quality for them. With this information management programs can aim to target those factors that influence habitat quality.

The primary purpose of most monitoring programs, including this one on waterbirds is to detect changes in abundances and distributions that indicate a change in key assets that warrants management. For the bird populations that use the Coorong and Lower Lakes there are no clearly defined baselines or benchmarks, nor any targets or expected abundances that have been identified against which the counts in any one year could be compared. This is particularly true for the Lower Lakes where there have been no systematic assessments of overall abundances of waterbirds in the region prior to 2009. In 2009 and 2010 water levels in the Lower Lakes were at unprecedentedly low levels (below sea level) and so it is unlikely that the bird abundances using the Lower Lakes in those years were typical of the bird abundances in years prior to this. As such the 2009 and 2010 counts do not provide a suitable baseline. Although there is some historical information on the distributions of waterbirds using the lakes and their local abundances in some years, most of these date back prior to the 1970s and to times before the arrival of the European Carp (*Cyprinus carpio*) and its associated effects on waterbird habitat (Paton 2010). These were also times when water levels in the Lakes were not surcharged to the same extent as they are today (Paton 2010). So, even if there were complete historical data sets on bird use, those data are unlikely to be representative of the conditions that existed in more recent times immediately prior to the millennium drought, and that are likely to be re-established in the future. Thus, there is no simple baseline or benchmark against which to judge the current distributions and abundances of waterbirds in the Lower Lakes. The expectation is that the numbers of various waterbirds will stabilize around some sustainable number with some annual variation in abundances. The decline in overall abundances for at least some of the common species in the last year suggests that the current abundances might have stabilized around the typical abundances of species expected to use the Lower Lakes, at least under the current management regime. Additional monitoring of waterbirds using the Lower Lakes will be required to determine if the waterbird populations have stabilized.

For the Coorong there has been an ongoing increase in the overall abundances of many species since January 2011, and at least one key food resource (*Ruppia tuberosa*) is still to fully recover. Given this the eventual capacity of the Coorong to support waterbirds may increase further. Thus, for the Coorong there is also a need to continue to assess the distributions and abundances of waterbirds and their food resources in future years. These assessments of waterbirds are also needed at the scale of the whole wetland and not by subsampling a few sites and extrapolating from those to the whole wetland. This is because most species are patchily distributed in both space and time (e.g. Figs 1, 2).

The variability in the numbers of birds counted from one year to the next and in their distributions remains a challenge for assessing the status of waterbirds within the Coorong and Lower Lakes. Ultimately the various factors that cause changes in numbers and distributions of different species using the wetlands of the Coorong and Lower Lakes need to be understood if the wetlands and hence waterbirds are to be effectively managed in the future. This will require: (i) the maintenance of counts of waterbirds using the Coorong and Lower Lakes in summer, as well as counts at other times of the year; (ii) counts of waterbirds using other wetland systems; (iii) targeted autecological studies on key species of waterbirds; and (iv) incorporation of behavioural data with census data, food resources and habitat features to allow habitat suitability models to be developed for a range of species. Each species even within a guild of similar species is likely to differ ecologically and so have slightly different requirements. The absence of these specific details currently limits our ability to manage the Coorong and Lower Lakes proactively and effectively for waterbirds.

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Appendix

Table A1. Locations of monitoring sites used for assessing benthic food resources for birds along the Coorong. Eastings and northings are Map Zone 54H in GDA94 units to the nearest 5m. These locations give the shoreline at the sites where monitoring took place, with plankton, fish-trawls and mud samples taken out into the water beyond the shoreline.

Code	Site name	Lagoon	Distance from Mouth (km)*	Easting	Northing
N58		Estuary	-2	305485	6065430
N51		Estuary	5	314235	6063230
N45	Pelican Point	North	11	321110	6058955
N39	Marks Point	North	17	326235	6055395
N29	Long Point	North	27	333980	6048395
N19	Noonameena	North	37	342625	6042195
N12		North	44	347990	6037310
N08		North	48	350595	6034405
N02	Magrath Flat	North	54	354895	6029500
S06	Villa dei Yumpa	South	62	360455	6024900
S11	Braeside	South	67	363125	6022560
S16		South	72	367175	6018210
S21		South	77	370405	6013460
S26	Policemans Point	South	82	372680	6009030
S31	Gemini Downs	South	87	377445	6004300
S36	Salt Creek	South	92	377730	6000930
S41	Tea Tree Crossing	South	97	378780	5996640

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