Ecological Character Description for waterbirds of the Coorong and Lower Lakes

David C. Paton, Fiona L. Paton & Colin P. Bailey

School of Biological Sciences

June 2015

Overview

This report provides the Ecological Character Description for waterbirds of the Coorong and Lower Lakes at a broad level for use by managers. A series of summary statements are used as subheadings to this report to highlight the key characteristics of the waterbirds that inhabit the Coorong and Lower Lakes. These statements are:

1. **Recent events inform the description of the ecological character for waterbirds using the Coorong and Lower Lakes**
2. **Abundances of waterbirds in the Coorong and Lower Lakes vary seasonally**
3. **Waterbirds use the shallow margins of the Coorong and Lower Lakes**
4. **The Lower Lakes and Coorong provide complementary habitats for waterbirds**
5. **Substantial numbers of waterbirds use the Coorong and Lower Lakes over summer**
6. **The Coorong and Lower Lakes support different waterbird communities**
7. **High inter-annual variability in waterbird numbers, often caused by external influences, is a key ecological character of the Coorong and Lower Lakes**
8. **The Coorong and Lower Lakes easily meet the waterbird-related Ramsar criteria**
9. **Behavioural studies inform waterbird habitat quality in the Coorong and Lower Lakes**
10. **Limited resilience to disturbance and slow recovery of food chains and waterbird populations is a modern ecological characteristic of the Coorong and Lower Lakes**
11. **In recent decades, the ecological characteristics of the Coorong and Lower Lakes have changed from a waterbird perspective**

Commented [NW1]: Link directly to 4?

1. Recent events inform the description of the ecological character for waterbirds using the Coorong and Lower Lakes

The Coorong and Lower Lakes were listed as a Wetland of International Significance in 1985. At this time, there was an appreciation that large numbers of a wide variety of waterbirds used the region. The waterbirds included migratory and endemic shorebirds (sandpipers, plovers and stilts), waterfowl (ducks, swans and geese) and a range of fish-eating species (pelicans, cormorants, terns and grebes) but the numbers and extent to which each species used these wetlands was poorly documented for most species, particularly for the Lower Lakes. Most of the initial attention in the 1980s was focussed on shorebirds within the Coorong. Re-assessments of the numbers of shorebirds using the Coorong in the 2000s showed that most species had declined. There were also substantial changes in the composition, distribution and abundances of waterbirds in general between the 1980s and 2000s for parts of the Coorong where historical data existed for the 1980s (e.g., South Lagoon; Paton *et al.* 2009; Paton 2010). Given the lack of quantitative data for many species in the 1980s and that most of the recent surveys have taken place during a period in which both the Coorong and Lower Lakes have been severely stressed, some care is required in describing the ecological characteristics of the waterbirds using the Coorong and Lower Lakes.

The following character description is based largely on surveys of waterbirds for the Coorong and Lower Lakes that have been conducted annually in summer since January 2000 for the Coorong and since January 2009 for the Lower Lakes. These surveys are essentially a complete census except that (i) the methods used are unlikely to detect and adequately census cryptic

species (rails, crakes, snipe, bittern) that use the fringing vegetation around the freshwater wetlands of the Lower Lakes and (ii) have not been designed to census a range of reed-dwelling passerines (warblers, grassbirds, cisticola).

The Coorong and Lower Lakes experienced substantial and unprecedented perturbations during the 2000s. For the Lower Lakes, water levels dropped to well below sea level and all of the fringing wetland vegetation became disconnected from the water. Extensive areas of mudflats were exposed for the first time, which changed the waterbird community using the Lower Lakes substantially (e.g. Paton & Bailey 2011, 2012, 2013). When water returned and refilled the Lower Lakes from ca mid-2010 (2009 for the Goolwa Channel), the emergent and submerged aquatic vegetation re-established around the margins of the Lower Lakes. The waterbirds recovered and, over the next two years, the waterbird community that was assumed (expected) to have existed prior to the perturbation re-established. Given that the first four years of waterbird counts for the Lower Lakes were during the period of exceptionally low water levels and subsequent recovery, only the last three years of census data (January 2013-2015) have been used in providing an ecological character description for waterbirds using the Lower Lakes. This is justified given that the extremely dry conditions should not recur (given the intent of the Murray Darling Basin Plan). Although there have been changes to waterbird use of the Lower Lakes since the time of nomination, those changes are not easily quantifiable. The changes are probably related to managing the actual water levels of the Lakes a little higher since the 1980s.

The Coorong also suffered significant ecological changes during the millennium drought that resulted in extremely high salinities in the southern Coorong. There were also more extended periods of low water levels but because the Coorong is connected to the sea, water levels do not drop below sea level. The high salinities that established in the southern Coorong exceeded the salinity tolerances of the main fish species (small-mouthed hardyhead *Atherinosoma microstoma*) and main benthic invertebrate (the chironomid *Tanytarsus barbitarsis*). Both species were excluded from the southern part of the Coorong for several years (e.g., Paton 2010). However, brine shrimps *Parartemia zietziana* established in the southern Coorong in these high salinities and became extremely abundant. Various ostracods were also abundant in the water column. There were other changes in the distribution and abundance of *Ruppia tuberosa* in the Coorong, and in the northern Coorong many other benthic invertebrates decreased in abundance and distribution. These extreme ecological changes, like those in the Lower Lakes, also had no precedent. However, for the Coorong, food chains remained throughout the wetland, albeit reduced in extent or different in places. When significant flows returned to the Coorong in late spring 2010, excessive salinities dissipated, and the system slowly recovered, although some components like *Ruppia tuberosa* are still to recover to pre-drought levels. Although various bird species responded to these changes by shifting their distributions, the Coorong was still habitable throughout this period for birds.

A more serious perturbation, however, occurred when the flows returned to the Coorong in late spring 2010. These flows were substantial and the Coorong quickly filled such that most of the mudflats were covered by too much water during summer to allow wading birds access. Many waterbirds vacated the region during this time. These types of perturbations are likely to recur for the Coorong in the future particularly overfilling of the Coorong during years of high or unregulated flows. In assessing the ecological character of the waterbirds that use the

Coorong, some appreciation of their capacity to respond and recover to these types of changes is invaluable for interpreting resilience and thus defining ecological character. Thus, for the Coorong, the full set of data collected from January 2000 to 2015 is used as the basis for defining the ecological character of the waterbirds that use the Coorong.

2. Abundances of waterbirds in the Coorong and Lower Lakes vary seasonally

The wetlands of the Coorong and Lower Lakes play a significant role in supporting waterbirds within the Murray Darling Basin and, more generally, in south-eastern Australia. They are permanent wetlands that support populations of waterbirds throughout the year but the year-round residents are supplemented by a significant influx of birds, including additional species, from spring until autumn. The additional species include a suite of migratory shorebirds from the Palaearctic. Substantial influxes of Australian endemic waterbirds also occur (Paton 2010). Thus, a key characteristic of these wetlands is that the numbers and variety of water birds using the wetlands fluctuates seasonally and also over longer time periods. For example, during extended droughts, the wetlands of the Coorong and Lower Lakes were increasingly important as a waterbird refuge. During the severe millennium drought, these wetlands supported over 400,000 waterbirds at times.

Commented [JO2]: Might also be worth describing the typical range in waterbird abundance (100,000-250,000?), but that the wetland has supported >400,000 birds when banded stilt abundance was unusually high (>200,000 individuals) in 2009.

3. Waterbirds use the shallow margins of the Coorong and Lower Lakes

The vast majority of waterbirds using both the Coorong and Lower Lakes use the margins of the lakes and lagoons. The margins are the areas where water levels are typically less than 1 m, coinciding with the productive parts of these wetlands. The high turbidity of the water is assumed to prevent benthic submerged aquatic plants from securing sufficient light to grow in deeper water. For the Lower Lakes, the margins often support reeds and other emergent vegetation that provides resources, as well as cover for waterbirds. However, the margins of the Lower Lakes' wetlands are now often steep and so the availability of suitable habitat for waterbirds, particularly species that wade in shallow water while foraging, is narrow in width or non-existent in places. This limits the diversity of waterbirds that can use the Lower Lakes (see below). In the Coorong, provided water levels are not too high, there are extensive areas of gently-sloping shoreline suitable for waterbirds that wade in shallow water when foraging. The presence of extensive mudflats covered with shallow water at least during the warmer months of the year makes the Coorong particularly important for shorebirds (migratory and endemic waders).

Commented [JO3]: Would be useful to explain why/how the margins have become steep. It sounds like it wasn't always this way?

Commented [JO4]: Can you briefly explain how the shorebirds use the mudflat, and why the mudflat is important? i.e. foraging, provides habitat for macroinvertebrate prey

4. The Lower Lakes and Coorong provide complementary habitats for waterbirds

The Lower Lakes are freshwater systems, where the same habitat features are repeated around the margins of the two lakes. Reeds of various species (*Typha, Phragmites, Schoenoplectus*) are prominent around the shorelines but the density, composition and width of these varies. Amongst the reed beds, and between them and the shoreline, are often areas of open shallow water where submerged aquatic plants can be abundant. More generally, areas with reeds are interspersed with areas without reeds, and in these latter areas the margins of the Lower Lakes are usually grassy verges. Such areas tend to be more exposed and have steeper shorelines. Importantly there are very few areas around the Lower Lakes

Commented [JO5]: Cite SARDI veg monitoring refs? Let me know if you need a copy of these

that provide shallow mudflats suitable for wading birds, at least not under current management of lake water levels between 0.5-0.8 m AHD.

In contrast, the Coorong is an estuarine to hypermarine wetland with extensive areas of shallow, gently sloping shorelines without emergent reeds. The salinity of this system prevents reeds from establishing, except in a few isolated places where freshwater seeps into the Coorong off the dunes of Younghusband Peninsula. In the northern regions of the Coorong, the mudflats become variously exposed during the tidal cycle, while, in the southern Coorong, seasonal shifts in water level of up to 1 m expose the mudflats in summer. Importantly, with a few exceptions (e.g., Red-capped Plover), most shorebirds do not exploit mudflats that are fully exposed, but instead forage over mudflats that are covered with a few centimetres of water.

A key feature of the Coorong for the last 30-40 years (at least) has been the salinity gradient that increases southwards. In a typical year, salinities may range from 10-70 gL^{-1} in winter and spring to 30-110 gL^{-1} in autumn along the length of the Coorong. As a consequence of the salinity gradient, the Coorong supports different ecosystems and food chains along its length and these differ from the food chains of the Lower Lakes, although the food chains of the Lower Lakes are poorly documented. In general, the diversity of aquatic invertebrates and fish decreases along the salinity gradient in the Coorong, with fewer species at higher salinities (e.g., Paton 2010). For example, in northern estuarine regions of the Coorong, various species of polychaetes are prominent benthic invertebrates but in the higher salinities of the southern Coorong only the chironomid (*Tanytarsus barbitarsis*) is prominent. Similar patterns exist for fish, with many more species present in the estuarine regions and just one species, the small-mouthed hardyhead (*Atherinosoma microstoma*), prominent in the South Lagoon. This reduction in species richness with salinity, however, does not mean the overall production of resources is diminished at the higher salinities. The other key component of the aquatic ecosystems and food chains of the Coorong are submerged aquatic plants. There have been marked changes in the species composition, distribution and abundance of submerged aquatic plants in the Coorong over recent decades. Several species are now no longer present (e.g. *Ruppia megacarpa*, *Lamprothamnium papulosum*) and others are far less abundant than they have been historically. A key submerged aquatic plant in the southern Coorong is *Ruppia tuberosa,* one of the few plants that can tolerate hypermarine salinities and so occupies the southern Coorong. This species was largely eliminated from the southern Coorong during the millennium drought and is only slowly recovering its distribution and abundance. In the North Lagoon, a key species historically, *Ruppia megacarpa*, disappeared prior to the millennium drought. However, a red algae *Gracilaria chilensis* may now provide some substitute ecological functions in the predominantly estuarine areas of the Coorong.

5. Substantial numbers of waterbirds use the Coorong and Lower Lakes over summer

Systematic counts of waterbirds using the Coorong during summer commenced in January 2000 and for the Lower Lakes during January 2009. The Coorong generally supports twice as many birds as the Lower Lakes in summer. The numbers of waterbirds supported in the Coorong in January has averaged over 167,000 over the last 16 years, while the average numbers for the Lower Lakes has been a little over 79,000 for the last seven years. Although

Commented [DJR6]: also areas of Samphire and higher elevation fringing wetland

Commented [DJR7]: more specifically many species prefer to forage at or near the shoreline (Rogers and Paton 2009- CLLamm report)

Commented [DJR8]: smallmouth

Commented [JO9]: Cite Ruppia monitoring reports here and below.

Commented [JO10]: Would be good to expand on this a little. Is it just present in the Murray estuary or is it present in the north lagoon? Could you briefly describe the substitute ecological functions? Ie.. does it provide substrate for macros or consumed by birds? Knowledge gap?

Commented [DJR11]: cf winter?

more than 80 species of waterbirds have been detected using the Coorong and over 70 species using the Lower Lakes during these counts, more than half the species are only present in small numbers. Of the 72 species counted in the Lower Lakes since 2009, only 33 were detected in all seven years and only 22 of these had more than 100 individuals present. For the 82 species detected during counts in the Coorong, 35 species were present in all years, with another 5 species present in all but one year. Of these 33 species were in abundances of more than 100 birds.

Commented [DJR12]: Also higher numbers during continental dry periods?

6. The Coorong and Lower Lakes support different waterbird communities

The waterbird communities that use the Lower Lakes and Coorong are markedly different. The key differences are that the Coorong supports large numbers of waders, particularly Red-necked Stints, Banded Stilts, Sharp-tailed Sandpipers and to a lesser extent Red-necked Avocets, Curlew Sandpipers, and Red-capped Plovers (Table 1). These species are only in very small numbers in the Lower Lakes (typically <1% of the numbers in the Coorong). A range of other waders are also largely, if not entirely, restricted to the Coorong, including Black-winged Stilt, Greenshank, oystercatchers, godwits, Eastern Curlew, Hooded Plover and Sanderling.

However, waterfowl (ducks) and fishing-eating species are prominent in both wetland systems (Table 1).- In the Lower Lakes, Great Cormorants, Pied Cormorants, Australian Pelicans and Whiskered Terns are the most prominent piscivorous species, while Whiskered Terns, Hoary-headed Grebes and Australian Pelicans are abundant in the Coorong. Crested Terns are also prominent in the Coorong but this species also fishes in the adjacent ocean. Five species of cormorants use the Coorong, and Great Cormorants and Little Black Cormorants are the most abundant of these. Other fish-eating species using these wetlands include Caspian Terns, Great Crested Grebes, Great Egrets and White-faced Herons and these species use both wetlands to comparable extents. One other important fish-eating species is the Fairy Tern, which is restricted to the Coorong region.

Commented [NW13]: Only adjacent – or most Sth Aus coastline?

For the Coorong, Grey Teal, Australian Shelduck, Chestnut Teal and Black Swans are prominent species of waterfowl, while Australian Shelduck, Pacific Black Duck, Grey Teal, Eurasian Coot and Black Swan are the most abundant waterfowl using the Lower Lakes (Table 1). A key compositional difference between the two wetland systems is in the prominence of Chestnut Teal in the Coorong, and Pacific Black Duck in the Lower Lakes. Musk Duck are now present in relatively low numbers and are now predominantly found in the Coorong. Other waterfowl including Australasian Shoveler, Pink-eared Ducks and Hardheads use both wetland systems when present in the region, while Freckled Ducks mainly use the Lower Lakes.

The Coorong and Lower Lakes also support significant numbers of Royal Spoonbills, Australian White Ibis, Straw-necked Ibis and Silver Gulls. Silver Gulls are widespread in both the Coorong and Lower Lakes, while the spoonbills and ibis are more abundant around the margins of the Lower Lakes. Although present in small numbers, Yellow-billed Spoonbills are also present and primarily associated with the Lower Lakes.

The freshwater swamps and reeds of the Lower Lakes also support a suite of largely cryptic birds, including Australian Bittern, Latham Snipe, and various rails (crakes) and water hens. The most conspicuous of these is the Purple Swamphen. Little Grassbirds, Clamorous Reed

Warblers and Golden-headed Cisticolas are also associated with the emergent and fringing vegetation of these freshwater systems.

7. High inter-annual variability in waterbird numbers, often caused by external influences, is a key ecological character of the Coorong and Lower Lakes

A key ecological characteristic of the Coorong and Lower Lakes from a waterbird perspective is that the numbers of waterbirds using the wetlands varies from one year to the next. These variations in abundances can be substantial. An extreme example is the Banded Stilt. In January 2009, in excess of 210,000 Banded Stilts used the Coorong but in the last three years fewer than 2,000 have been present in January in any year. The factors influencing the numbers of various waterbirds using the Coorong and Lower Lakes in any one year are poorly understood. However, factors outside the Coorong and Lower Lakes, as well as factors within the wetlands themselves, are likely to be influential.

The variability in the abundances of many species of waterbirds using the Coorong and Lower Lakes reflects the nature of the use of these wetlands by birds. Most species of waterfowl (ducks, swans) do not breed to any extent in the Coorong or Lower Lakes and move away from the Coorong, and to a lesser extent the Lower Lakes, during winter and spring to breed. The likely breeding areas are freshwater swamps that dry out over summer but fill during winter. Before the barrages were constructed, the margins of the Lower Lakes were likely to have provided breeding opportunities for many waterfowl but the management and maintenance of water levels within a narrow range may no longer provide the stimulus for breeding. The numbers of waterfowl that return to the Coorong and Lower Lakes from these breeding areas for the following summer will depend on the extent of successful breeding, and the timing of their arrival will be influenced by the conditions in these other wetlands and when they start to dry out. For these birds, the permanent wetlands of the Coorong and Lower Lakes function as a critical "summer" refuge that increases in importance in dry years.

Commented [JO14]: In the south-east, or elsewhere?

Commented [JO15]: Because of greater availability of nesting substrate and food resources?

For the migratory shorebirds that use the Coorong over the summer months a similar argument holds. These birds breed in the northern hemisphere and migrate annually between their breeding areas and non-breeding areas, like the Coorong, in the southern hemisphere. The abundances of these species in any one year in the Coorong are likely to be influenced by the extent of breeding, successful migration and whether other potential ephemeral wetlands hold water and are available for them to use on arrival. The endemic Banded Stilt and Red-necked Avocet rarely breed in the Coorong and also move away from the Coorong to exploit inland saline wetlands for breeding when these fill with water. Black-winged Stilts too may shift to nearby freshwater swamps when these hold water to breed. Other species that do not breed in the Coorong and show dramatic reductions in abundances when inland wetlands flood include Hoary-headed Grebe, Whiskered Tern and Eurasian Coot.

Most of the waterbirds that regularly breed within the Coorong and Lower Lakes are piscivorous species. These include the Australian Pelican, Fairy Tern, Crested Tern and Caspian Tern, which breed on islands in the southern Coorong, and the Pied Cormorant in the Lower Lakes. Although Crested Terns breed in the southern Coorong and forage to an extent in the Coorong and Lower Lakes, they largely forage in the adjacent marine environment when breeding. Caspian Terns and Australian Pelicans also forage substantial distances (probably at

least 100 km) from their breeding colonies in the southern Coorong. Breeding for these species in the Coorong still occurred even when the South Lagoon supported no fish. Fairy Terns on the other hand vacated their breeding islands in the South Lagoon when fish were absent in the southern Coorong. Although this species attempted to breed near the Murray Mouth at these times, these breeding events were prone to human disturbance and predation by foxes.

Pied Cormorants build nests and regularly breed in reed-beds and other emergent vegetation particularly on several of the islands within the Lower Lakes. During the late 2000s, Pied Cormorants did not breed when exceptionally low water levels disconnected the reeds from the water line. Although Little Black Cormorants and Little Pied Cormorants have been recorded breeding historically in the Lower Lakes, they have not been detected breeding in the region in recent years, while the Great Cormorant, although abundant, has never been recorded breeding in the Lower Lakes. Thus, many of the cormorants using the Coorong and Lower Lakes must also move away to breed.

Only two other species are recorded breeding regularly in the Coorong and Lower Lakes: Silver Gulls on islands in the southern Coorong and Straw-necked Ibis in reed-beds around the Lower Lakes. Silver Gulls are adaptable and feed on a variety of foods and their breeding may be linked to the breeding of pelicans and terns, where they can scavenge food. Straw-necked Ibis largely feed on terrestrial invertebrates away from wetland areas and so their abundances in any one year are likely to be influenced by rainfall and the extent to which nearby areas are irrigated. A range of other species also exploit terrestrial sources of food (pasture, grain and invertebrates) while using the Coorong and Lower Lakes during summer. These include, at least to some extent, Australian Shelduck, Pacific Black Duck, Australian White Ibis, Whiskered Tern and White-faced Heron.

In summary, the key ecological services that the permanent wetlands of the Coorong and Lower Lakes provide are suitable habitats and food resources to support a wide range of waterbirds during the summer months when other areas that they use are not suitable for them.

8. The Coorong and Lower Lakes easily meet the waterbird-related Ramsar criteria

Much of the historical and current assessments of the importance of the Coorong and Lower Lakes for waterbirds are based on the abundances of various species using the wetlands and whether various Ramsar criteria are met. For example, the Coorong and Lower Lakes supports in excess of 1% of the global populations of 27 species or subspecies of waterbirds in most years and so clearly meets this criterion (and all other waterbird related criteria) for listing as a Wetland of International Significance (O'Connor *et al,*. 2012). For some taxa, the percentages of global populations that are supported are much higher than 1%. For example, the Coorong regularly supports more than 10% of the south-eastern Australian population of Fairy Terns and, in January 2009, supported in excess of 213,000 Banded Stilts, greater than the (immediately prior) estimated of global population at the time.

Commented [DJR16]: Although recruitment may have been impacted by the loss of local fish populations around these islands?

Commented [JO17]: I have data on this (and other species mentioned in this report) from the aerial breeding surveys. Let me know if you want/need the final report.

Commented [JO18]: Cite Close 1982 for past cormorant breeding records. Also, great cormorants have been recorded breeding on the Salt Lagoon islands (lakes) in the 1960s and 1970s. Let me know if you need a PDF of the close ref

Commented [JO19]: Is this right? Using the current estimates, 8 species are regularly (3/5 years) present in excess of 1% of flyway population. I'm not sure how these 27 species qualify. I see that there are 27 species listed in table 2 of the animal conservation paper, but these do not exceed 1% flyway population numbers. Sorry if I'm missing something! Let me know if you need the current 1% estimates (2012) by the way. I have a table that includes these estimates alongside your species IDs

Commented [DJR20]: I often use the sharpy example here, up to 25% of global population

9. Behavioural studies inform waterbird habitat quality in the Coorong and Lower Lakes

Numerical statistics draw attention away from the need to manage the region to provide suitable habitats and resources for the different species of waterbirds, irrespective of the numbers present in any one year. In most summers, the region is required to support significant numbers of a wide diversity of waterbirds particularly during droughts. At these times, the quantity and quality of the food resources and access to those resources is critical.

One method of assessing the quality of the habitats, and hence the capacity of the Coorong and Lower Lakes to service the needs of the birds, is by assessing the birds' behaviour. Birds allocate more time to foraging when food resources are thinly spread and difficult to harvest (Paton *et al.* 2015 in prep.). For the Coorong, where such data exist, a range of piscivorous species spend typically around 20-50% of the day foraging (Table 2). These species have no difficulty securing the food that they need. That a range of fish-eating species also breed in the Coorong and Lower Lakes is also consistent with an abundant and easily harvested food resource. However, some herbivorous species (e.g., Black Swans) and many of the shorebirds usually allocate over 50% of their day to foraging, and sometimes as much as 80%, or more in some years. This suggests that their food resources, various aquatic plants and aquatic invertebrates, are not as rich or as easily harvested as fish. For these species, small reductions in the productivity of the mudflats on which they forage could be critical for their survival. Future management needs to focus on maintaining, if not improving, those resources as a priority, since the foraging data collected in January suggest that migratory shorebirds will have difficulty increasing their food intake as autumn approaches and day lengths decline.

10. Limited resilience to disturbance and slow recovery of food chains and waterbird populations is a modern ecological characteristic of the Coorong and Lower Lakes

The millennium drought challenged the capacity of the Coorong and Lower Lakes to support waterbird populations but at the same time provided insights into the resilience of the wetlands, the food resources that they provide, and insights into the adaptability of the waterbird populations. Those dynamics form part of the ecological character of these systems.

During the millennium drought, there was negligible if any flows of freshwater over the Barrages for eight consecutive years. This was as much a consequence of over-extraction of water for human use rather than drought *per se* but the drought brought the issue of over-extraction into sharp focus (e.g., Paton 2010). Throughout this period, continuous dredging was needed to keep the Murray Mouth open and maintain a tidal prism in the northern Coorong. The major perturbation affecting the food chains that supported the birds were: (1) higher salinities that eliminated hardyhead fish and chironomids from the southern Coorong but allowed brine shrimps to establish; and (2) consistent low water levels in spring, coupled with high salinities, that eliminated *Ruppia tuberosa* from the southern Coorong although the plant established new populations over several years in the middle sections of the North Lagoon (e.g., Paton 2010). Other aquatic invertebrates and fish species using the northern Coorong also declined during this period.

Commented [NW21]: Reword?

Waterbird responses to these perturbations were varied. In the southern Coorong, some species switched to feeding on brine shrimps. These included Banded Stilts, Hoary-headed Grebes, Chestnut Teal, Whiskered Terns and Silver Gulls. Other species, like Fairy Terns and Black Swans, vacated the southern Coorong but were able to use the northern Coorong.

In the Lower Lakes, the major perturbation was extremely low water levels (-0.5-1 m AHD) that were unprecedented. This disconnected the fringing aquatic vegetation from water and exposed extensive areas of dry mudflats. Reed-dependent waterbirds were largely absent, and most species of waterbird were less abundant except for a range of shorebirds (sandpipers, plovers, stilts) that were drawn to and used the nearly exposed mudflats, particularly where these abutted the Coorong.

Ironically, the major changes in abundances of waterbirds across the Lower Lakes and Coorong came not during the drought but when flows first returned to the region. The flows when they returned in spring 2010 were substantial and quickly filled, before subsequently overfilling, the Coorong and Lower Lakes. The overfilling of the wetlands was to such an extent that many of the shorebirds and a range of other species that typically forage while wading in shallow water (e.g., egrets, herons and spoonbills) were excluded from their usual feeding niches because the water levels were too high to allow them access. The numbers of waterbirds using the Coorong and Lower Lakes during this period of high water levels were the lowest of the last 16 years (e.g. Figure 1). Many other wetlands carried water at this time because of extensive rains, and so the waterbird populations would have been able to use these alternative wetlands this year. However, these alternatives may not always exist in years when unregulated flows restrict access to productive mudflats in the Coorong and Lower Lakes. Managing water levels, both during periods of negligible flows and during periods of extensive flows, will be needed to secure suitable resources and make them accessible to waterbirds in the future.

Commented [NW22]: ...would have chosen to... perhaps

Commented [NW23]: ? Cache this section in terms of 'if waterbird habitat is the management goal' (I'm assuming that 'overfilling' [I read 'flood'] provides a range of other ecological services that only occur during such times

The recovery of the waterbird communities following these perturbations was not immediate. For example, Purple Swamphens took three years to re-occupy suitable habitat around the Lower Lakes. For the southern Coorong, there was a one-year time lag before hardyhead fish populations had recovered and Fairy Terns had returned to breed in the southern Coorong. The key aquatic plant *Ruppia tuberosa* is yet to fully recover, despite attempts to facilitate recovery by translocating seeds from outside sources onto former productive mudflats. Although chironomids quickly re-colonised the southern Coorong once salinities were suitable, other aquatic invertebrates in the northern Coorong have taken several years to build substantial population densities. From a waterbird perspective, all of the species are still present but the abundances for some species, like Common Greenshank, are still lower than they were in January 2010 at the end of the drought. Abundances of other species, particularly waterfowl, remain low in areas like the southern Coorong that have traditionally been used extensively in the past. So, most of the current components of these wetlands have the capacity to recover, albeit with time lags, and so can be considered to still have resilience. However, the failure of *Ruppia tuberosa* to re-establish, let alone re-establish quickly, is of concern. This poor recovery is due to water levels falling in spring and exposing plants to desiccation before they have reproduced (ref). Historically, flows to the Murray Mouth were substantial during spring and into summer and this kept the extensive *Ruppia tuberosa* beds covered with water and allowed ample time for the plants to produce seeds and turions and

Commented [JO24]: Macroinvertebrate monitoring ref?

Commented [NW25]:

so maintain their population densities (e.g., Paton 2010). The current water allocations, even when the Murray Darling Basin Plan is fully implemented, suggest the volumes of water will continue to be inadequate to facilitate much recovery. Thus, the status of *Ruppia tuberosa* in the Coorong remains precarious and, as a consequence, the capacity of the Coorong to meet the needs of waterbird populations during droughts has been significantly compromised and, with that, its ecological character diminished.

Formatted: Font: Italic

Commented [JO26]: Possible to describe the importance of Ruppia to birds in a little more detail somewhere in the report. E.g. refer to the Delroy 1974 duck gut analysis paper that shows Ruppia making up a significant proportion of the birds' diet. Can we explicitly show that waterbird populations increase/decrease in response to changes in Ruppia abundance/distribution yet?

11. In recent decades, the ecological characteristics of the Coorong and Lower Lakes have changed from a waterbird perspective

Although much of the focus has been on recent decades, the quality of the Coorong and Lower Lakes as habitat for waterbirds has probably been deteriorating over a longer period of time. This is reflected in the loss of a range of aquatic plants (e.g., *Ruppia megacarpa* in the North Lagoon and *Lamprothamnium papulosum* in the South Lagoon) that were abundant in the Coorong in the 1980s but were totally absent in the 2000s, if not before. Even some of the abundant invertebrates that were present in the mid-1980s and early 1990s (e.g., the gastropod *Coxiella striata*) have been absent from the Coorong for several decades now. There is ample evidence over that same period to show that a range of waterbirds, including species of shorebird, waterfowl and tern, have also declined. When the the Coorong and Lower Lakes were nominated as a Wetland of International Significance in 1985, the wetlands were already likely to be on a trajectory of decline. Since then, the subsequent management and increased use of water within the Murray Darling Basin has likely accelerated the rate of decline.

Summary

As a general rule, the ecological character of the Coorong and Lower Lakes region from a waterbird perspective is one of steady deterioration. This deterioration is likely to be on-going, primarily because of past inappropriate water management and an ongoing inability to manage water levels effectively to recover the system in a timely fashion. Climate change will also erode available water supplies further in the future.

References

O'Connor, J., Pisanu, P., Rogers, D. (2012), An Assessment of the birds of the Coorong, Lower Lakes and Murray Mouth, South Australian Department for Environment and Natural Resources, Adelaide

Paton DC, Bailey CP 2010. *Condition Monitoring of the Lower Lakes, Coorong and Murray Mouth Icon Site: Waterbirds using the Lower Lakes in 2010*. (University of Adelaide, Adelaide)

Paton DC, Bailey CP 2011. *Condition Monitoring of the Lower Lakes, Coorong and Murray Mouth Icon Site: Waterbirds using the Lower Lakes in 2011*. (University of Adelaide, Adelaide)

Paton DC, Bailey CP 2012. *Condition Monitoring of the Lower Lakes, Coorong and Murray Mouth Icon Site: Waterbirds*

Paton, D. C. (2010), *At the End of the River: The Coorong and Lower Lakes*, ATF Press, Adelaide.

Commented [JO27]: I think you were actually referring to this one: O'Connor, J., Rogers, D., Pisanu, P. (2012), Monitoring the Ramsar status of the Coorong, Lakes and Murray Mouth: a case study using birds. South Australian Department for Environment and Natural Resources, Adelaide

Paton, D. C., D. J. Rogers, B. M. Hill, C. P. Bailey and M. Ziembicki (2009), *Temporal changes to spatially stratified waterbird communities of the Coorong, South Australia: implications for the management of heterogenous wetlands.* Animal Conservation **12**(5): 408-417.

Table 1: Median abundances of major groups of waterbirds and selected individual species using the Coorong and Lower Lakes in January. Data for the Coorong are based on 16 annual counts from 2000 to 2015, while those for the Lower Lakes are based on three counts from 2013 to 2015. Species are arranged in order of median abundances within major groups.

	COORONG	LOWER LAKES
Shorebirds	***62,720***	***989***
	Red-necked Stint (26,286)	Masked Lapwing (565)
	Banded Stilt (15,125)	Sharp-tailed Sandpiper (214)
	Sharp-tailed Sandpiper (13,179)	Black-winged Stilt (85)
	Red-necked Avocet (3,007)	Red-kneed Dotterel (56)
	Curlew Sandpiper (2,256)	Red-necked Stint (30)
	Red-capped Plover (1,234)	+ 13 other species (39)
	Masked Lapwing (468)	
	Greenshank (434)	
	Black-winged Stilt (417)	
	Pied Oystercatcher (158)	
	+ 21 other species (156)	
Waterfowl		***28,715***
29,731		
	Grey Teal (11,848)	Australian Shelduck (13,249)
	Australian Shelduck (8,426)	Pacific Black Duck (4,981)
	Chestnut Teal (7,231)	Grey Teal (3,912)
	Black Swan (1,647)	Eurasian Coot (3,339)
	Pacific Black Duck (228)	Black Swan (1,799)
	Musk Duck (172)	Cape Barren Goose (1,010)
	Cape Barren Goose (97)	Hardhead (874)
	Eurasian Coot (75)	Australasian Shoveler (143)
	+ 7 other species (7)	Pink-eared Duck (84)
		Australian Wood Duck (70)
		Chestnut Teal (56)
		Freckled Duck (56)
		Musk Duck (9)
		+ 2 other species (7)
Fish-eaters		***37,613***
17,586		
	Great Cormorant (1,287)	Great Cormorant (14,963)
	Little Black Cormorant (1,253)	Pied Cormorant (8,759)
	Pied Cormorant (271)	Little Black Cormorant (907)
	Little Pied Cormorant (258)	Little Pied Cormorant (84)
	Black-faced Cormorant (130)	Darter (73)
	Darter (1)	
	Australian Pelican (3410)	Australian Pelican (6239)
	Hoary-headed Grebe (4222)	Great Crested Grebe (128)

	Great Crested Grebe (201)	Hoary-headed Grebe (103)
	COORONG	**LOWER LAKES**
Fish-eaters Continued		
	Whiskered Tern (5,371)	Whiskered Tern (4,497)
	Crested Tern (3,897)	Caspian Tern (609)
	Caspian Tern (598)	Crested Tern (490)
	Fairy Tern (337)	+ 2 other terns (2)
	+ 3 other terns (8)	
	White-faced Heron (157)	Great Egret (133)
	Great Egret (73)	White-faced Heron (119)
	Little Egret (7)	Little Egret (2)
	Nankeen Night Heron (1)	Nankeen Night Heron (12)
		+ 1 other species (1)
Other species 8,645		***4,274***
	Silver Gull (8,296)	Silver Gull (1,823)
	Australian White Ibis (300)	Straw-necked Ibis (1,620)
	Straw-necked Ibis (25)	Australian White Ibis (611)
	Royal Spoonbill (22)	Royal Spoonbill (209)
	Yellow-billed Spoonbill (1)	Yellow-billed Spoonbill (12)
	+ other species (1)	+ other species (1)

Table 2: The percentage of time selected species of waterbird allocated to foraging over the course of a day. Data were collected from up to 10 sites spread along the length of the Coorong from the Northern section of the Murray Estuary to Salt Creek in the South Lagoon, with at least seven of these sites sampled in any one year. Not all species were present at the sites sampled in each year and those that only occurred in low numbers were excluded to avoid having samples that were not representative.

	2007	2008	2011	2012	2013	2014	2015	***Mean***
Shorebirds								
Banded Stilt	89	89	70	76	76	77	82	***80***
Common Greenshank	49	74	52	77	73	68	68	***66***
Red-capped Plover	59	62		82	84	64	58	***68***
Red-necked Avocet	51		35	52	57	48	51	***49***
Red-necked Stint	72	70	43	88	89	83	70	***74***
Sharp-tailed Sandpiper	66	73		88	92	81	66	***78***
Waterfowl								
Australasian Shelduck	23	15	10	18	21	16	7	***16***
Black Swan	58	61	22	28	74	49	77	***53***
Chestnut Teal	43	33	16	40	35	61	35	***38***
Grey Teal	44	3	10	43	51	37	48	***34***
Fish-eaters								
Australian Pelican	9	18	11	18	12	24	27	***17***
Caspian Tern	2	5	56	30	18	17	36	***23***
Hoary-headed Grebe	42	32		51	58	71	58	***52***
Whiskered Tern	22	22		54	45	40	46	***38***

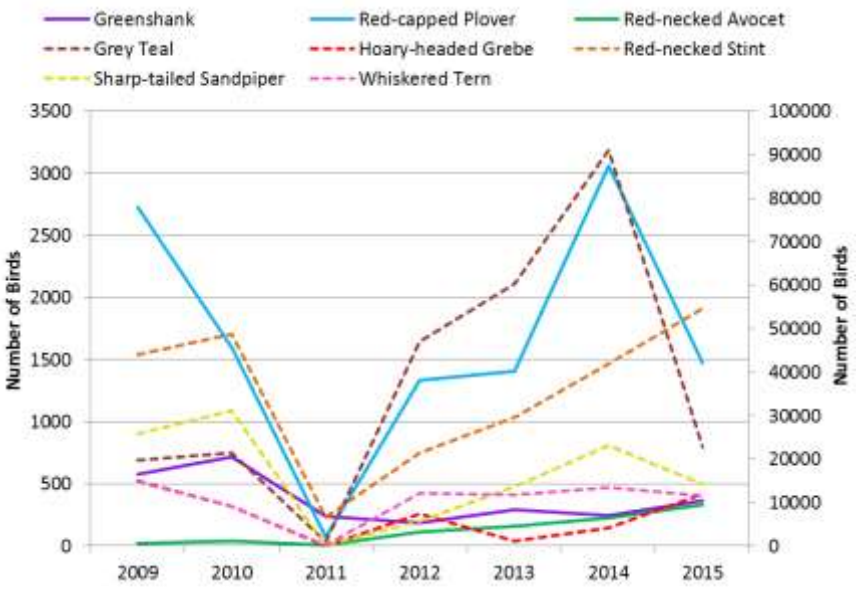

Figure 1: The total number of birds using the Coorong and Lower Lakes for a selection of species from 2009 to 2015. Numbers of birds for Greenshank, Red-capped Plover and Red-necked Avocet are plotted on the primary (left) axis and delineated using solid lines, while numbers of birds for all other species are plotted on the secondary (right) axis and are delineated using dashed lines.