Waterbird responses to Goolwa Channel water-level management and Barrage releases, and developing habitat suitability models for waterbirds in the Coorong and Lower Lakes

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Summary

The distributions and abundances of waterbirds across the Lower Lakes and Coorong were determined in January 2011 and compared with similar data collected in previous years to assess the broad response of waterbirds to the return of freshwater flows to the Lower Lakes and Coorong. The majority of bird species decreased in overall abundance following the return of freshwater. Overall the abundances of waterbirds in the Lower Lakes and Coorong were about 30% of the overall abundances recorded in the previous year before flows returned. Those species showing the greatest declines included migratory shorebirds such as Red-necked Stints and Sharp-tailed Sandpipers, endemic shorebirds such as Red-capped Plovers, and other waterbirds such Grey Teal and Whiskered Terns. The fate of these birds is not known. A common assumption is that some of these species may have shifted to inland wetlands that had also recently filled, but if so the wetlands that are being used remain unknown. Australian Pelicans are often assumed to move to inland wetlands to exploit the abundances of fish, but no reduction in their numbers was detected across the Lower Lakes and Coorong in January 2011 compared to previous years. Clearly there are differences in the responses of different species to flooding or refilling events and factors driving those changes remain largely unknown. Management of waterbird populations within the Coorong and Lower Lake region continues to be disadvantaged by a lack of specific information on the scale of any movements for water bird populations in this region. High water levels in both the Lower Lakes and Coorong are likely to have excluded access to normally productive mudflats for many of the waders, notably sandpipers and plovers, but also potentially longer legged species like stilts and spoonbills, and is a potential explanatory factor in the reductions of bird numbers in January 2011. Some species of waterbird maintained their abundances and or increased in abundance slightly. These included Black Swans, Australian White Ibis, Straw-necked Ibis and two species of water hen: Purple Swamphen and Dusky Moorhen. Although there are no long-term historical data the numerical responses of these species are relatively small suggesting that the recovery of abundances and distributions for some species may take many years. A few waterbird species responded to the return of water to the Goolwa Channel in 2009 and the Lower Lakes in 2010 by breeding, notably Black Swan but also four colonial-nesting species (Pied Cormorant, Straw-necked Ibis, Royal Spoonbill and Australian White Ibis).

Additional observations aimed at establishing whether there were any localised concentrations of fish-eating birds near Barrages revealed no consistent patterns, but these data were collected several months after water was first released over the barrages by which time the freshening effects and distributions of potential fish prey were more diffuse.

There is a requirement to build habitat suitability models to allow the habitat requirements of waterbirds to be incorporated into future decision-making around the management of water in the Lower Lakes and Coorong. To this end broad habitat features along the shorelines of the Lower lakes and Coorong were collected while conducting the annual census; and additional detailed data on habitat features, water depths and bird behaviour were collected for 14 sites as the initial basis for developing these habitat suitability models. The report outlines the nature of these data sets.

Introduction

The wetlands of the Lower Lakes and Coorong have experienced extreme conditions over the last decade that has led to historically low water levels in the Lower Lakes, and historically high salinities in the Coorong, during the latter half of the first decade of the 21st century. Low water levels and high salinities have caused changes to the food resources and habitats for most waterbirds that frequent this region. Despite these ecological changes, and despite changes in the distribution and abundance of many species within these wetlands, large numbers of waterbirds continued to use the Lower lakes and Coorong, and these wetlands remained the key drought refuge within the Murray Darling Basin, accounting for over 95% of the waterbirds counted across the icon sites over the last 2-3 years (e.g. Paton 2010).

The arrival of substantial river flows into the Lower Lakes during 2010 has allowed the lakes to refill and then spill through the Barrages to the Murray Mouth and Coorong region. The initial volumes of water to be released over the Barrages were estimated to be around 100GL but because of extensive rains during spring and summer in eastern Australia the volumes actually released have been much greater than this with substantial volumes continuing to flow to the Murray Mouth at least until June 2011. Further the extensive rains have not only returned significant flows to the river, they have also flooded key wetlands like the Macquarie Marshes within the Murray-Darling Basin, as well as flooding many inland wetlands.

Waterbirds using the Lower Lakes and Coorong are likely to respond to these changed conditions in a number of ways: (1) dispersing to inland wetlands to take advantage of highly productive often short-lived systems where they may breed; or (2) responding to the local conditions, adjusting their distribution, abundance or behaviour to changes in the distribution of suitable habitat and or food within the Lower Lakes and Coorong wetlands. In the latter case some species may benefit by the changed conditions while others may be disadvantaged. The ecological conditions of the Coorong and Lower Lakes wetlands and circumstances prior to the return of this water to the Lower Lakes and Coorong are likely to be unique, and consequently the responses of the birds may also be unique to this event and circumstances. For example, the response of birds to flows over the Barrages may differ when flows have occurred annually and the ecological conditions of the wetlands are typical compared to when a flow returns after a long absence and ecological conditions are depressed when the flows return. There may also be temporal delays in their responses because of the time required for key aquatic food resources to recover. Similarly birds using the Lower Lakes may also respond differently when water levels have been maintained at higher and more consistent levels compared to when they have reached extremely low levels prior to a flow event. Measured responses might also differ between years when inland wetlands have water compared with years when they do not hold water. Thus some caution is required in interpreting avian responses to the return of water to the Lower Lakes and Coorong region based on this one event.

There were three areas of activity sought from the bird intervention monitoring:

(1) an assessment of the avian responses to regulator construction that allowed water levels in the Goolwa Channel to be elevated (relative to the rest of Lake Alexandrina) and maintained at levels typical of this region for the second year;
(2) an assessment of the avian responses to barrage releases; and
(3) provision of data on habitat features from a waterbird perspective at fine and coarse scales within Coorong and Lower Lakes in a form that can be integrated into a GIS, along with preliminary data on habitat use for selected water bird species.

These three components are inter-related, and ultimately can be combined to provide the basis for developing habitat suitability models for different waterbirds, which in turn allows the availability of suitable habitat within the Coorong and Lower Lakes region for individual species under different water regimes (ostensibly water levels) to be determined.

<u>Avian responses to the return of water levels and maintenance of water levels in the Goolwa Channel</u>

Waterbird abundances in the Goolwa Channel and Lower Lakes in January 2010

During spring 2009 more typical water levels were returned to the Goolwa Channel as a consequence of the Clayton regulator containing the flows from the Finniss River and Currency Creek to the Goolwa Channel, coupled with some pumping of water across the regulator. Although the numbers of waterbirds using the Goolwa Channel in January 2010 were higher than in January 2009 when the water levels were exceptionally low, increases for some species were also detected in the remaining areas of the Lower Lakes that remained at low levels (Table 1). The species showing marked increases in abundances within the Goolwa Channel between 2009 and 2010 were: Australian Pelican, Great Cormorant, Little Black Cormorant, Black Swan and Eurasian Coot. Of these, the first three species had increased in other areas of the Lower Lakes. The other major changes in abundances were markedly fewer Australian Shelduck and Grey Teal using the Goolwa Channel in January 2010 compared to January 2009. Importantly one of the key differences was that two waterbird species (at least) bred in the Goolwa Channel in spring 2009 (Black Swan and Pacific Black Duck) while there was no evidence of breeding in the previous year in the Goolwa Channel or elsewhere across the Lower Lakes in both years. The lifting of water levels in the Goolwa Channel in spring 2010 reconnected water levels to the fringing aquatic vegetation, providing suitable habitat for those species to breed, which was not provided elsewhere across the Lower Lakes.

Unfortunately there have been no systematic counts of waterbirds for the Goolwa Channel or the Lower Lakes prior to January 2009, and so there are no baseline measures for the numbers and types of birds that the Lower Lakes and Goolwa Channel typically supported. Thus it is not possible to state that the Goolwa Channel section of the Lower Lakes had recovered its bird populations following the return of water. Furthermore the responses detected in January 2010 need to be placed in the context of a greatly altered Lake and Coorong environment, that sat well outside any historical conditions for this region. Similarly the return of water to more typical levels across the remainder of the Lower Lakes in spring 2010 has no precedent and the distribution and abundances of birds in Goolwa Channel in the second year are likely to be influenced by these changes to wetland habitats and not represent an actual response to the maintenance of water levels or quality within the Goolwa Channel, nor necessarily reflect the original or typical waterbird community that might use this area.

Waterbird abundances in the Goolwa Channel and Lower Lakes in January 2011

Compared to the previous two years the numbers of waterbirds counted using the Goolwa Channel region and the Lower Lakes were substantially lower overall in January 2011 than the previous two years despite the return of flows to the Lower Lakes. In general the numbers of birds counted in January 2011 were about 30% of the numbers counted in the previous year (Table 1). The key species showing marked declines were the migratory waders, notably Red-necked Stints and Sharp-tailed Sandpipers. These migratory waders accounted for more than 30,000 of the birds counted in the Lower Lakes in January 2009 and over 40,000 in January 2010. In comparison there were fewer than 2,000 migratory waders detected around the shores of the Lower Lakes in January 2011. The other migratory waders to show a marked reduction in abundances were the Common Greenshank and Curlew Sandpiper. These dramatic declines were not unexpected since the water levels around the shores of the Lower Lakes and Goolwa Channel were very high and those high water levels largely eliminated areas of mudflat covered with shallow water. In January 2009 and January 2010 there were extensive areas of shallow mudflat and sandy shorelines particularly around the southern margins of the Lower Lakes and these were used extensively by these small migratory waders (Paton and Bailey 2010). The very low water levels across the Lower Lakes in January 2009 and 2010 are likely to have allowed these species access to suitable habitat, not available when the more typical higher water levels exist. Sadly similar reductions in the abundances of these small migratory shorebirds were also detected across the Coorong, where opportunities for migratory waders were also limited in January 2011 (see below).

Changes in the abundances of endemic non-migratory shorebirds mirrored the reductions in the migratory waders. For example Red-capped Plovers, Black-winged Stilts and Red-necked Avocets, although present in smaller numbers than the migratory waders, were virtually absent from the shores of the Lower Lakes in January 2011 (Table 1). Their absence is again consistent with suitable habitat being largely eliminated for these species by the high water levels present in January 2011.

Migratory and non-migratory shorebirds, however, have not been prominent in the Goolwa Channel region, not even in January 2009 when water levels were extremely low, and so the reductions in overall bird numbers within the Goolwa Channel are due to changes in the abundances of other species. Amongst the species that were in much lower numbers within the Goolwa Channel in January 2011 than the previous year were Great Cormorants and Eurasian Coots, both of which had aggregated in the Goolwa Channel in January 2010. Reductions in the numbers of Great Cormorants in the Goolwa Channel however were offset to a large extent by an increase in the numbers in the rest of the Lower Lakes, but Eurasian Coots were largely absent from the Lower Lakes in all three years. Eurasian Coots may have dispersed further away in response to other more inland wetlands holding water from mid- to late-2010 onwards. Several other species showed substantial declines between 2009-10 and 2011, particularly Whiskered Terns and Grey Teal (Table 1). Both of these species may have moved to inland wetlands. Other species that were less abundant in January 2011 around the shores of the Lower Lakes and Goolwa Channel were the Masked Lapwing, Royal Spoonbill and Yellow-billed Spoonbill. The latter two species forage in relatively shallow water and may have also been disadvantaged by the rapid return of water and then maintenance of high water levels across the lakes and channel. Equally though they may have left prior to the return of flows because of deteriorating conditions and found suitable foraging habitat elsewhere.

Only a few species increased in abundances across the Lower Lakes in January 2011, including Pied Cormorants and the two species of ibis, but the increases in numbers for these species were relatively small compared to some of the declines for other species. Black Swans appear to be the one species to have benefitted substantially with the initial return of water to the wetlands. Within the Goolwa Channel region Black Swan numbers increased in January 2010 following the return of water to the Goolwa Channel, and similar numbers were detected in the following January, when swans accounted for over 70% of all waterbirds counted within this reach (Table 1). Although some swans were present across the rest of the Lower Lakes in January 2009 and January 2010 when water levels were low, the numbers jumped three-fold in January 2011 following the re-flooding of the rest of the Lower Lakes. Not only did their numbers increase with the return of water but they also bred extensively across the region in January 2011. In January 2010 breeding by water birds was limited to Black Swans, Pacific Black Ducks and Little Pied Cormorants all of them nesting within the Goolwa Channel region. In this year 53 Black Swan cygnets were detected during the counts, 10 Pacific Black Duck nestlings and 7 Little Pied Cormorant nestlings. In the previous January (2009) there was no evidence of any waterbirds breeding. In comparison, in January 2011 not only were there many swans continuing to breed in the Goolwa Channel region, but they were also breeding across the Lower Lakes, with more than 500 cygnets counted (Table 2). Nine other species were also detected breeding in the reed beds and in the re-flooded fringing wetlands around the Lower Lakes, including four species of colonial-nesting waterbirds (Table 2), Dusky Moorhen and Purple Swamphen. Dusky Moorhens and Purple Swamphens were originally widespread around the shores of the Lower Lakes (e.g. Paton *et al*. 1994) but were largely absent from the whole region in January 2009 and January 2010. Both species are likely to be associated with wetlands where the water laps against fringing vegetation or there is emergent aquatic vegetation, and so both were likely to be excluded from most of the Lower Lakes when water levels were low and the fringing vegetation disconnected from the water. The numbers of both increased, but were still small, in January 2011, suggesting that the recovery of these species may take many years.

Table 1. Changes in the abundances of waterbirds within the Goolwa Channel and the remainder of the Lower Lakes in January for 2009-2011.

Species	2009 Goolwa	2010 Goolwa	2011 Goolwa	2009 L'Lakes	2010 L'Lakes	2011 L'Lakes
Australian Pelican	186	544	158	4073	4036	3129
Darter	0	0	0	2	5	2
Black-faced Cormorant	0	0	1	35	0	0
Pied Cormorant	1	4	5	1341	978	1708
Little Pied Cormorant	72	90	15	94	6	67
Great Cormorant	567	2508	234	1514	3493	4964
Little Black Cormorant	17	603	42	90	695	784
Great Crested Grebe	2	21	0	10	3	217
Hoary-headed Grebe	0	0	0	0	2	0
Black Swan	517	2095	2188	379	696	2227
Cape Barren Goose	0	0	0	1692	1215	1303
Domestic Goose	0	0	0	0	13	36
Domestic Fowl	0	0	0	0	0	6
Australian Wood Duck			0	0	0	9
Australian Shelduck	1432	3	12	10590	15446	14628
Pacific Black Duck	308	139	59	879	1864	1625
Mallard	5	0	0	8	0	1
Khaki C'bell (dom duck)	0	1	0	0	15	0
Grey Teal	1022	6	1	9832	13509	1145
Chestnut Teal	104	0	3	550	302	427
Australasian Shoveler	0	2	7	5	15	1
Hardhead	2	44	0	0	0	1
Musk Duck	2	0	3	0	4	9
Blue-billed Duck	0	0	1	0	1	0
White-bellied Sea Eagle	0	0	0	0	1	0
Australian Spotted Crake	0	2	0	0	0	0
Black-tailed Native-hen	0	0	0	1	0	0
Dusky Moorhen	0	0	9	13	0	21
Purple Swamphen	1	8	13	8	23	35
Lewins Rail	0	0	0	0	0	1
Eurasian Coot	252	3307	39	0	1	0
White-faced Heron	7	10	26	88	84	196
White-necked Heron	0	1	0	0	0	0
Nankeen Night Heron	0	0	0	0	0	6
Great Egret	19	15	0	85	47	108
Little Egret	8	1	0	8	1	4
Intermediate Egret	0	0	0	0	0	2
Australian White Ibis	111	13	13	352	165	1182
Straw-necked Ibis	4	0	2	177	387	531
Royal Spoonbill	49	74	1	347	267	200
Yellow-billed Spoonbill	6	10	4	49	48	13

Eastern Curlew	0	0	0	5	2	0
Common Greenshank	0	6	0	146	213	29
Marsh Sandpiper	0	0	0	0	6	0
Wood Sandpiper	0	3	0	0	4	0
Sharp-tailed Sandpiper	2	300	0	9236	11887	1097
Red-necked Stint	72	0	0	23655	31049	268
Curlew Sandpiper	0	0	0	66	1026	0
small wader (unidentified)	0	0	0	0	2500	0
Masked Lapwing	50	5	2	948	893	309
Banded Lapwing	0	0	0	178	424	0
Latham's Snipe	0	4	0	0	0	0
Red-kneed Dotterel	0	20	0	3	0	1
Red-capped Plover	5	0	0	1636	1162	2
Lesser Sand Plover	0	0	0	2	0	0
Black-fronted Dotterel	0	0	0	1	0	2
Black-winged Stilt	0	10	0	197	76	7
Banded Stilt	7	0	0	89	0	0
Red-necked Avocet	13	0	0	128	324	0
Silver Gull	1067	369	173	2676	3118	2707
Pacific Gull	0	0	0	0	0	1
Whiskered Tern	131	108	0	3405	3669	102
Caspian Tern	27	62	7	256	174	179
Gull-billed Tern	0	0	0	2	0	0
Crested Tern	78	17	83	451	310	233
Fairy Tern	0	0	0	0	0	4
Little Grassbird	0	0	0	0	0	15
Clamorous Reed Warbler	0	0	4	0	0	63
Golden-headed Cisticola	0	0	4	0	0	17
TOTAL	6146	10405	3099	75303	99757	37333

Table 2. Evidence of breeding by waterbirds in January 2011 in different parts of the Lower Lakes

Species	Goolwa Channel	Lake Alexandrina	Lake Albert
Number young birds detected			
Black Swan	376	139	47
Black-winged Stilt		3	
Chestnut Teal		6	
Dusky Moorhen		3	
Grey Teal		8	
Pacific Black Duck		10	
Purple Swamphen		3	
Colonial nesting species (nests or # large nestlings)			
Royal Spoonbill		nests	
Australian White Ibis		nests	

Pied Cormorant	420
Straw-necked Ibis	160

Building response models for water-birds using the Lower Lakes

Some caution is required in interpreting the responses of water birds to the re-filling of the Lower Lakes and Goolwa Channel. These assets experienced a substantial draw down of water levels for several years before water returned. Thus the counts taken in January 2009 and January 2010 may be exceptional because of the severity and widespread drought across the Murray Darling Basin. Unfortunately there are no historical systematic counts of waterbird use of the Lower Lakes and Goolwa Channel, and so no benchmarks of the typical numbers of waterbirds using this region, against which recent changes that have been recorded over the last three years can be compared. The actual changes in abundances recorded over the last three years for many species may fit within the normal variation of abundances, but may equally represent extreme changes in abundances due to the exceptional circumstances of the last three years. There is clearly a need to maintain the current annual monitoring program for an extended period of years to build the knowledge base on which to build response models. This monitoring is currently supported by *The Living Murray* program established and funded by the Murray Darling Basin Authority but that monitoring alone is unlikely to be sufficient to build an understanding of waterbird needs and responses to help in managing these wetlands from an avian perspective.

There are several components to building this understanding and they relate to the scales at which water birds operate and the scales at which wetlands are managed. Many waterbirds have great mobility and respond to the filling and drying of wetlands at sub-continental scales (in the case of migratory waders the scales are intercontinental) shifting readily from one wetland system to another depending on local and regional conditions in either a regular temporal pattern or irregularly. This mobility and flexibility impedes or at least challenges the development of effective management programs that centre on individual species or guilds of mobile species, and can cloud interpretations of responses to management actions implemented at the local wetland scale. Not all waterbirds, however, will move to the same extent and respond to the same variables, and so different species and even populations within a species are likely to differ in the spatial scales at which they operate. The relevance of scale for understanding waterbird use of the Lower Lakes is best illustrated by the dramatic reductions in the numbers of Grey Teal, Whiskered Terns, Red-capped Plovers, Red-necked Stints and Sharp-tailed Sandpipers in January 2011 compared with previous years and not having any knowledge of the fate of those birds. The usual interpretation is that they have moved to other wetlands that now contain water but the identity of those other wetlands remains unknown. However, they have not simply shifted to the adjacent Coorong (see below).

The second scale at which an understanding of waterbird use is required is the scale of individual wetland systems. In Australia much of the research on waterbirds has been conducted in the upper reaches of the Murray Darling Basin and over inland wetlands, with a strong focus on extensive wetland systems that are flooded intermittently. The Lower Lakes and Coorong are permanent wetland systems that are key drought refuges in south-eastern Australia, yet the use and management of this wetland system has to date been largely driven by the needs to meet water quality and quantity issues to serve human needs, and not from a bird or even broader biodiversity perspective. Within this wetland system waterbirds are not evenly distributed. This can be seen at the broad scale of wetland components (e.g. Goolwa Channel, Lakes, Coorong) where the bird communities, and component species vary spatially and temporally (Tables 1, 2 and also in sections of this report that follow). Those differences highlight differences in the habitat needs of different species which need to be taken into account in future management programs for this wetland complex. Changes in water levels, salinity levels and connectivity with fringing vegetation are all likely to influence habitat suitability, and hence the distribution and abundance of suitable habitat for different species. An understanding of what constitutes suitable habitat for different species and the quantity and location of suitable habitat for different species under different water regimes is now critical for developing and implementing an adaptive management program for these wetlands that takes into account the requirements of waterbirds. The first step in developing that understanding is to build habitat suitability models for a range of key species that use the Lower Lakes and Coorong.

The monitoring that has been conducted in each of the last three summers (in January) provides the basis for developing initial habitat suitability models at a coarse scale. Over the last three years all waterbirds in at least 300 1kmx 1km grid squares around the margins of the Lower Lakes and Goolwa Channel have been counted (381 grid cells in January 2011), along with recording the activity of the birds at the time of the count (flying, foraging, resting, breeding). In addition in January 2011 habitat features of the shoreline in most of these grid squares were also recorded. This involved estimating the percentage of the shoreline that was lined with reeds, lignum, flooded pasture or consisted of sand or mud flat devoid of vegetation (summarized in Table 3). Individual grid squares differ markedly in the composition of the habitat along their shorelines and these features are likely to influence the abundances of different water bird species in different areas. These habitat features, however, are not constant and will change over time (particularly with changes in lake water levels) and so are context specific: they can only be used to explore for patterns in bird abundances and distributions with shoreline features for the 2011 waterbird data. The scoring of habitat features at the scale of individual grid squares will need to be repeated at regular intervals but the intention with these data is to identify key areas and key habitat features that explain the broad distributions of different species within the Lower lakes, Goolwa Channel and Coorong (see below). In due course with knowledge of the relationships of birds with certain coarse habitat features will allow water resources to be managed to secure suitable habitat for different species under different conditions, with the added knowledge of where these key suitable habitats will exist for different species across this wetland system.

Note that the vast majority of all birds in this region use the margins of the Lower Lakes, so these counts and habitat assessments effectively target the area that will be used by waterbirds. The grid cells are based on the 1km grid lines for the GDA94 maps (horizontally consistent with satellite datum WGS84), and the data for each grid cell is stored using the central point of that grid square (easting, northing), with a GPS used to check on locations during counts. These bird data not only allow the distributions and abundances within different regions of the wetland (e.g. Goolwa Channel, Lake Alexandrina, Lake Albert; Table 1, 2) to be documented, compared and mapped (within a suitable GIS framework) but also allows the distributions and abundances of each of the species to be explored at a much finer resolution than simply the scale of a reach or lake.

Table 3. Summary of the habitats along the shorelines for 335 1km x 1km grid squares used for recording the counts of waterbirds in the Lower Lakes and Goolwa Channel in January 2011. The table shows the number of grid cells with different percent composition of different habitat features.

Habitat Feature	# grid cells with different percentages of shoreline habitat features					
% shoreline	0	1-10	11-30	31-70	71-90	91-100
Reeds	57	33	27	49	41	128
Sedges/rushes	310	5	0	11	0	9
Lignum	309	18	5	3	0	0
Pasture (flooded)	194	34	20	47	26	14
Rocks / rocky shoreline	298	14	11	8	4	0
Sand / mud shore(no veget)	257	32	17	12	12	5
Samphire	330	0	2	1	0	2
Man-made structures	324	2	4	4	1	0

The scale of this data collection also allows other analyses, for example comparisons of the area of occupation (number of grid cells in which a species is counted) and extent of occurrence (the distributional spread of a species across a wetland) that provides additional methods for assessing changes in distribution and abundance. Importantly over time these data will identify key areas (at the resolution scale of the 1km x 1km cells) that are consistently used for different key activities (foraging, breeding) by species, as well as providing the basis for coarse habitat suitability modelling with the capability of predicting species distributions within these wetland systems under different management regimes (and see below).

Avian responses to the return of releases of water over the Barrages to the Murray Mouth and Coorong

The return of freshwater flows to the northern Coorong will result in abiotic and biotic changes to the Coorong environment both of which alter habitat suitability for waterbirds in the Coorong that in turn will influence the distribution and abundances of birds within the Coorong. The abiotic changes include reductions in salinity, increases in water levels and increases in turbidity, and the biotic changes include shifts in the distribution and abundance and types of food resources available for waterbirds. Although the abiotic changes can be more or less immediate, changes in levels of certain food resources may be delayed because of the time required by aquatic flora and fauna to respond. As such the ecological responses to releases of freshwater over the Barrages are likely to be ongoing and not limited to the time of the initial releases.

There is likely to be a sequence of responses from birds as the water first returns and then additional responses over time as water spreads more generally over the Coorong. The initial responses to flows may include a short-term response to releases of water over the Barrages by piscivorous birds taking advantage of fish attracted to the return of freshwater flows, particularly when these are concentrated at a few gates on a barrage or at a fishway, but with more substantial releases of water and widespread freshening of the water around the barrages in the northern Coorong the bird responses may be more diffuse and or focus at different locations away from the release points (various barrages).

In making assessments of waterbird responses to the return of flows to the Coorong, two types of comparisons have been made: (i) changes in the abundances of birds within the Coorong relative to previous years; and (ii) changes in the local distributions of birds near barrages during periods of limited flow, no flow and the return of flow.

Changes in abundances of birds using the Coorong in January 2011 relative to the previous decade

Since January 2000, an annual census of all waterbirds using the Coorong has taken place in January. To do these counts the Coorong has been divided into 118 1-km wide strips from the southern tip of the South Lagoon to the Goolwa Barrage. These kilometre-wide strips are based on the original kilometre-wide strips that were established along the South Lagoon in 1984-5, and simply involved extending these as a series of parallel strips along the length of the North Lagoon (in 2000). Each 1-km wide strip has been divided into an 'eastern', 'western' and 'central' section. The central section usually consisted only of open water except where the 1km-strip contained islands, a peninsula or exposed reefs. The majority of the birds using the Coorong were associated with the shallow waters around the shorelines (e.g. Paton *et al.* 2009). Birds were systematically counted in each sector of each strip by counting birds from the shoreline and or from boats. The activity of the birds was also recorded for counts conducted from January 2006 onwards, and some specific foraging data collected in most years. These data have been compiled into an Access data-base where the individual count data for each sector of each strip is assigned a centrally-located easting and northing, so that the data can be incorporated easily into a GIS.

There were marked changes in the abundances of waterbirds using the Coorong in January 2011 compared with previous years (Figs 1-4). Of fifteen predominantly fish-eating species, four were absent from the Coorong in January 2011 (Hoary-headed Grebe, Great Crested Grebe, Little Pied Cormorant, Whiskered Tern) despite being abundant over the previous decade, two others were substantially less abundant in January 2011compared to previous years (Common Greenshank, Fairy Tern) and two others (Great Egret, Little Egret) continued a declining trend (Figs 1-4). In contrast the abundances of Australian Pelican and Crested Tern were similar to previous years. Both these species feed extensively outside the Coorong and so should be uncoupled to some extent from changes in the Coorong. The abundances of Pied, Great and Little Black Cormorants in January 2011 were comparable to previous years and contrasted with those of Little Pied Cormorants which declined. Similarly the numbers of White-faced Herons were similar in 2011 to average counts in previous years, while the smaller numbers of Great Egrets and Little Egrets declined between 2000-07 and 2008-10 and were lower again in January 2011. White-faced Herons were often recorded foraging in adjacent terrestrial habitats in the Coorong in the latter half of the last decade and this may have allowed this species to maintain numbers despite significant ecological changes to the Coorong.

Overall there was no increase in any predominantly fish-eating species in the Coorong despite the releases of water over the barrages. Furthermore the abundances of different species are not all synchronous in the direction of their response. Knowing this is important because it identifies potential species that may have dispersed to inland or distant wetlands and Hoary-headed and Great Crested Grebes and Whiskered Terns would appear to be such species. Others like Australian Pelicans and cormorants that often aggregate on inland waterways when these are flooded with water, however do not appear to have left the Coorong for these other wetlands, except possibly Little Pied Cormorants. Clearly different piscivorous birds have different ecological responses and hence different habitat requirements, and their responses may vary spatially and temporally. As a consequence habitat suitability models need to be developed at the individual species level and not for a collective of species in one guild. Furthermore the models may need to be both spatially and temporally explicit.

Other species of birds have also shown dramatic changes in abundance in the Coorong following the release of freshwater over the Barrages in spring 2010 (Figs 5 & 6). Of 12 additional waterbird species shown in Figures 5 and 6, only 3 species have maintained numbers comparable to counts in preceding years. These were Pied Oystercatcher, Australian Shelduck and Chestnut Teal. A range of other species largely vacated the Coorong or the species were at very low abundance relative to counts in previous years. These species included waterfowl such as Grey Teal, Black Swan, and Musk Duck, and various migratory and resident waders including Red-necked Stint, Sharp-tailed Sandpiper, Curlew Sandpiper, Black-winged Stilt, Red-necked Avocet and Red-capped Plover (Figs 5 & 6).

There are potentially a suite of different factors that may have led to these species decreasing in abundances in January 2011 compared with previous years rather than responding positively to the return of flows. First the Coorong changed dramatically during the second half of the last decade, leading to reductions and changes in the distribution and abundances of food resources (e.g. see Paton 2010). Many waterbird species had declined in abundance and distribution in recent years prior to the return of freshwater flows to the region (e.g. Paton 2010). For some species the recent return of flows may not have allowed those species to respond (as yet) and their numbers have remained low and or declined further because of the poor conditions of the Coorong. For others extremely high water levels in January 2011 across the Coorong may have prevented them from accessing food. The high water levels flooded adjacent samphire habitats and even terrestrial vegetation in places (see below) and largely eliminated access to extensive fringing mudflats around the Coorong for many waders including plovers, sandpipers, greenshanks, and even stilts and possibly longer-legged species like egrets and herons. The usual mudflats used by these species in previous years were covered by more than 30cm of water in January 2011, while in previous years they were covered by shallow water less than 30cm deep, often less than 10 cm deep (e.g. see below). Thus very low numbers of sandpipers, plovers, and greenshanks could be due to an absence of feeding areas. Some of these species may have dispersed to inland wetlands. That dispersal away from the Coorong may have been forced on the birds through lack of habitat or be a proactive move to exploit the potentially highly productive habitats that characterize these ephemeral wetlands in the few years that they contain water. Grey Teal and Black Swans may have also responded to the flooding of wetlands elsewhere, but equally they may have largely been excluded from the Coorong because the limited beds of *Ruppia tuberosa* were now covered by too much water that meant they could no longer easily access these plants while foraging from the surface. Other species may have been forced to depart because the higher turbidity of the fresh water entering the Coorong disrupted their foraging abilities. For example extremely turbid water may limit the ability of egrets and herons to detect fish in shallow water and so reduce their foraging abilities.

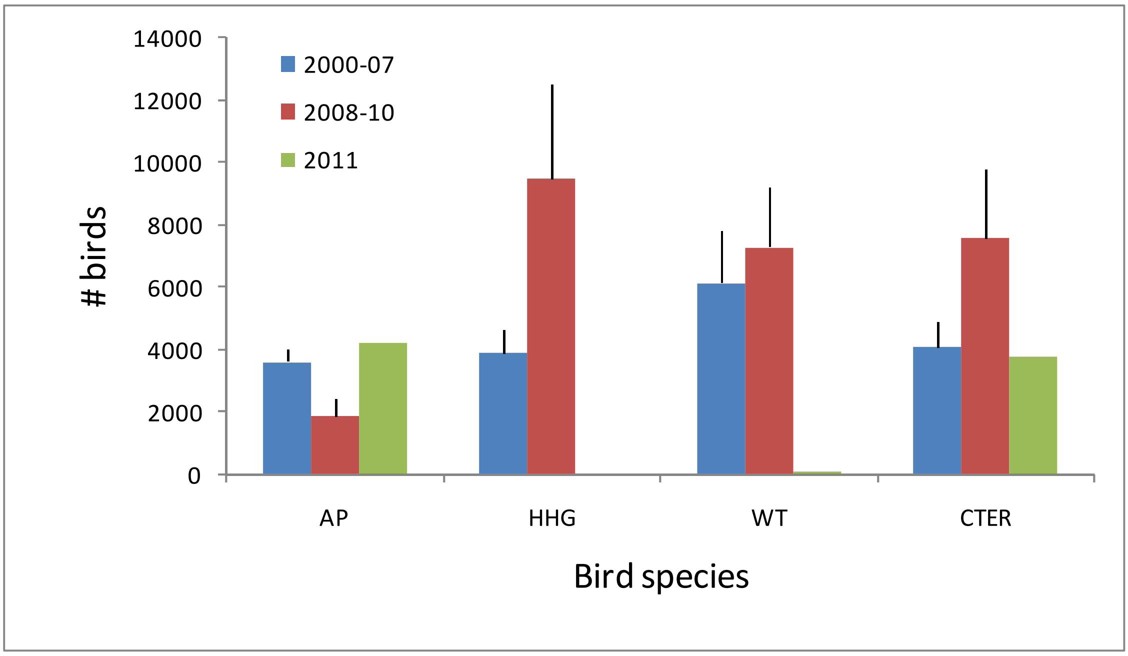


Figure 1. Abundances of four piscivorous bird species counted in January in the Coorong from 2000 to 2011. Data are means ± s.e for the eight years 2000-2007 inclusive (blue) and for the three years 2008-2010 inclusive (red). Data for January 2011 are shown in green. AP = Australian Pelican, HHG = Hoary-headed Grebe, WT = Whiskered Tern, and CTER = Crested Tern

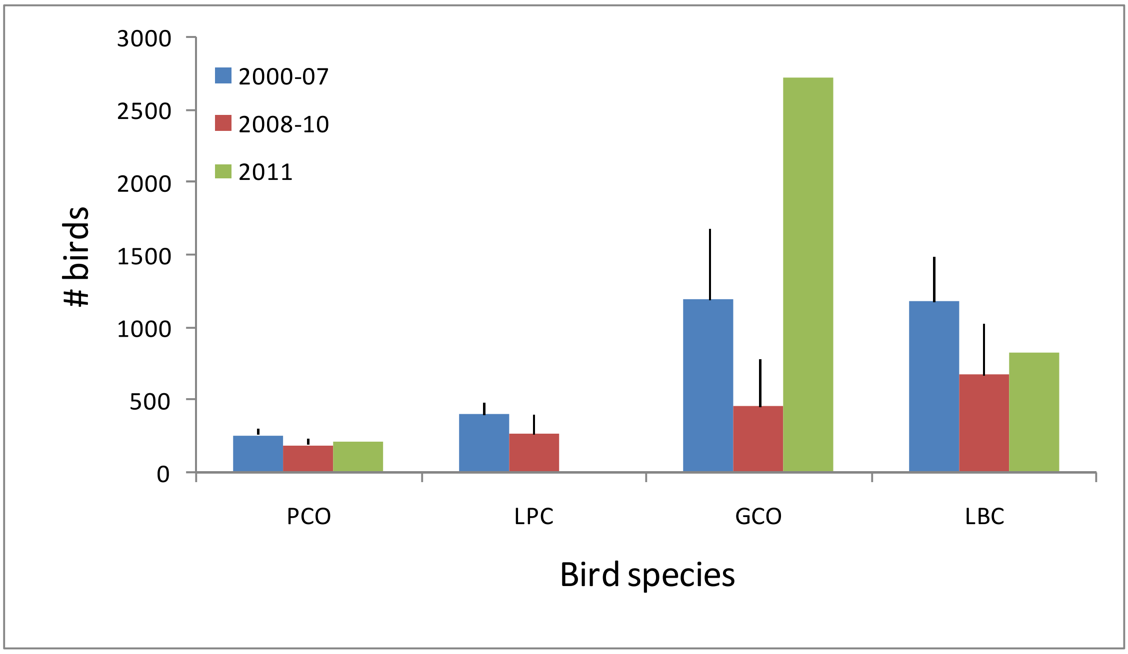


Figure 2. Abundances of four species of cormorant counted in January in the Coorong from 2000 to 2011. Data are means ± s.e for the eight years 2000-2007 inclusive (blue) and for the three years 2008-2010 inclusive (red). Data for January 2011 are shown in green. PCO = Pied Cormorant, LPC = Little Pied Cormorant, GCO = Great Cormorant, and LBC = Little Black Cormorant

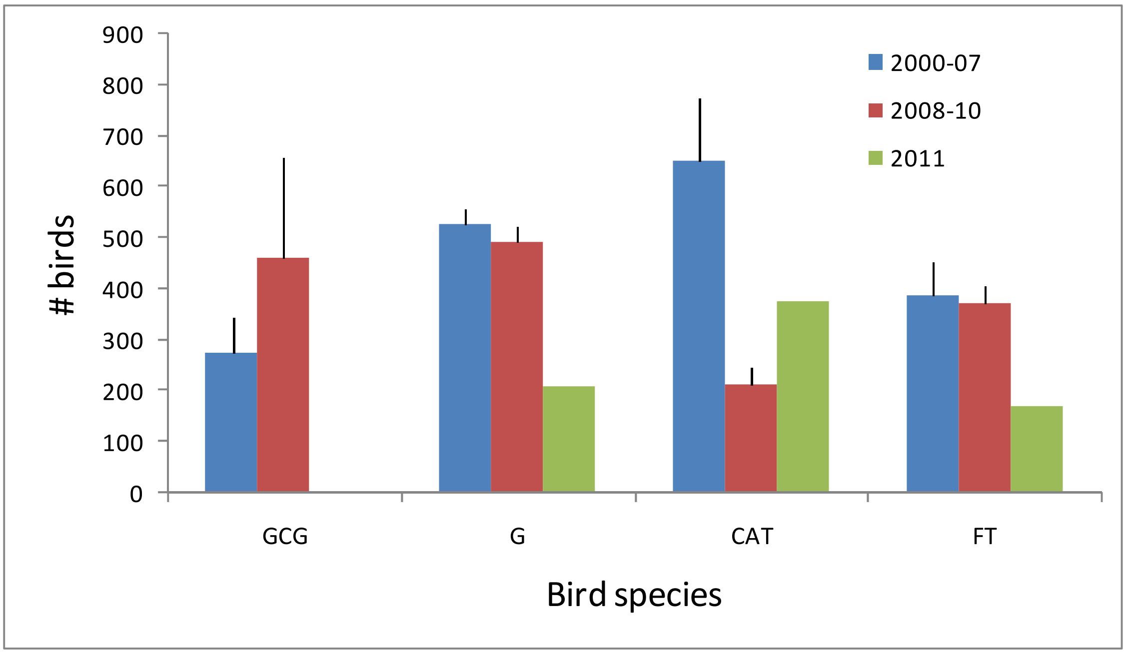


Figure 3 Abundances of four piscivorous bird species counted in January in the Coorong from 2000 to 2011. Data are means ± s.e for the eight years 2000-2007 inclusive (blue) and for the three years 2008-2010 inclusive (red). Data for January 2011 are shown in green. GCG = Great Crested Grebe, G = Common Greenshank, CAT = Caspian Tern, and FT = Fairy Tern

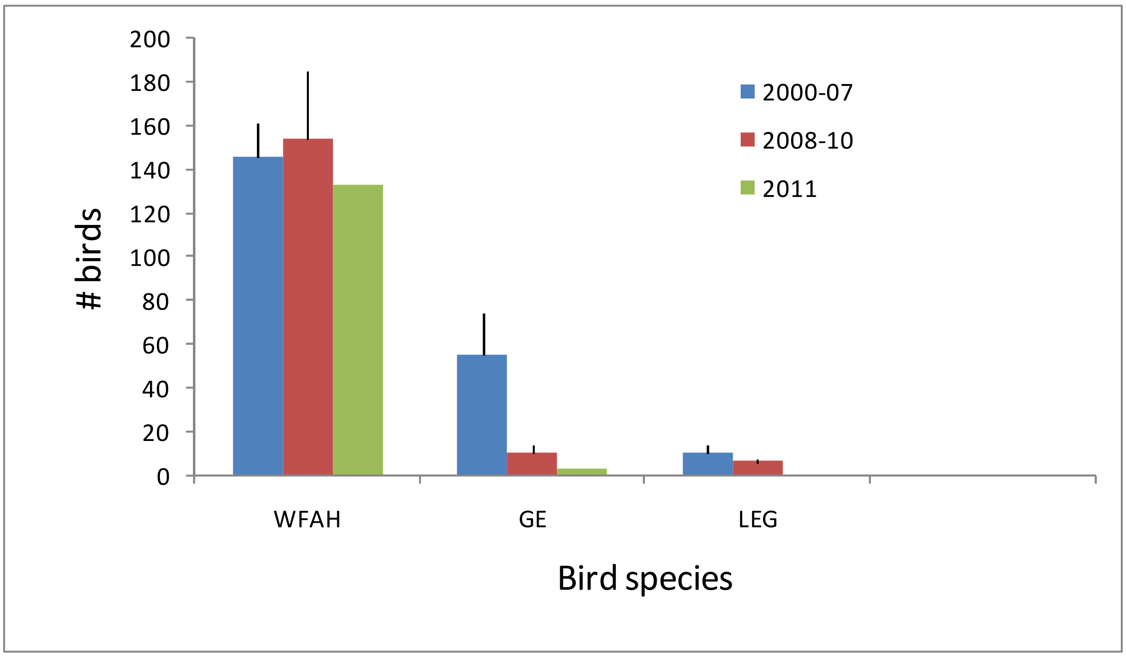


Figure 4. Abundances of three piscivorous bird species counted in January in the Coorong from 2000 to 2011. Data are means ± s.e for the eight years 2000-2007 inclusive (blue) and for the three years 2008-2010 inclusive (red). Data for January 2011 are shown in green. WFAH = White-faced Heron, GE = Great Egret and LEG = Little Egret

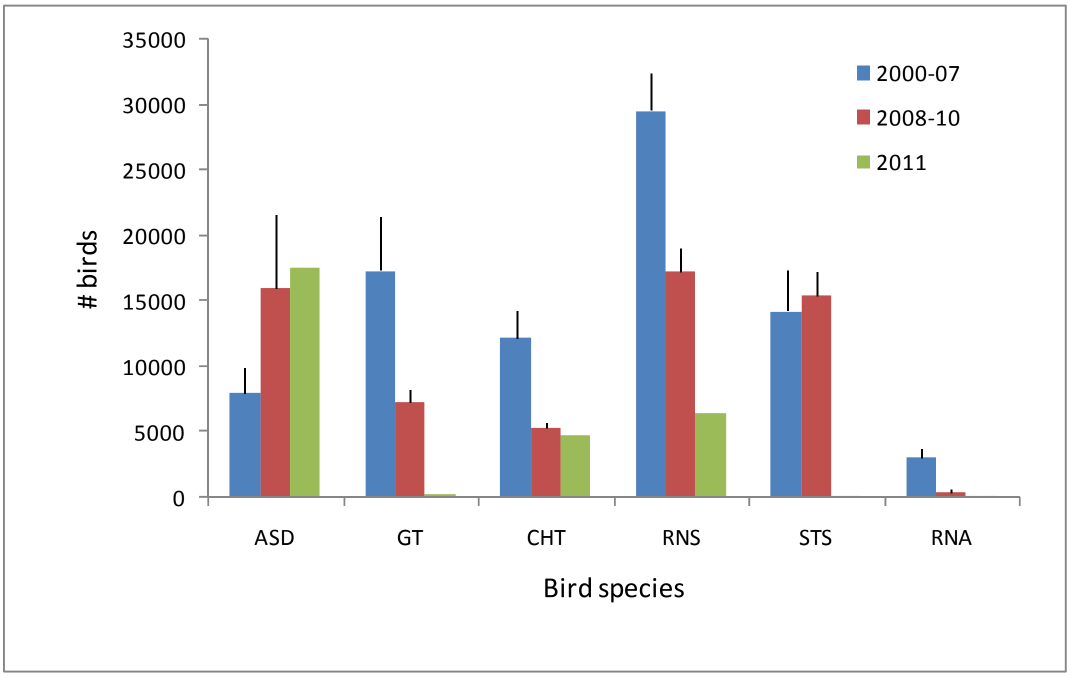


Figure 5. Abundances of six waterbird species counted in January in the Coorong from 2000 to 2011. Data are means ± s.e for the eight years 2000-2007 inclusive (blue) and for the three years 2008-2010 inclusive (red). Data for January 2011 are shown in green. ASD = Australian Shelduck, GT = Grey Teal, CHT = Chestnut Teal, RNS = Red-necked Stint, STS = Sharp-tailed Sandpiper, RNA = Red-necked Avocet.

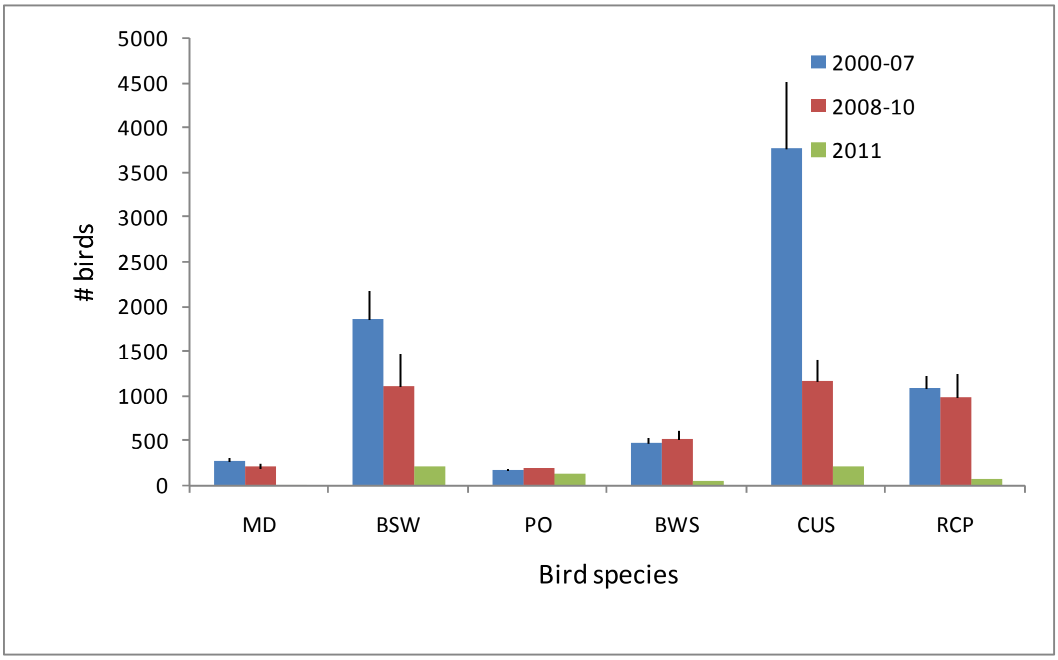


Figure 6. Abundances of six waterbird species counted in January in the Coorong from 2000 to 2011. Data are means ± s.e for the eight years 2000-2007 inclusive (blue) and for the three years 2008-2010 inclusive (red). Data for January 2011 are shown in green. MD = Musk Duck, BSW = Black

Swan, PO = Pied Oystercatcher, BWS = Black-winged Stilt, CUS = Curlew Sandpiper, RCP = Red-capped Plover

Amongst the twelve species shown in Figures 5 and 6, the three species that have maintained their numbers in the Coorong in January 2011 are worth highlighting for further discussion. Pied Oystercatchers are a coastal species that do not move away from the coast and their abundances in 2011 were comparable to those in previous years. The other two species that maintained their abundances were two species of waterfowl – Australian Shelduck and Chestnut Teal. In the Coorong region Australian Shelducks largely forage on pastures in adjacent areas and largely use the Coorong and Lower Lakes to rest (although some birds do feed), so this species would not be expected to respond to flows and might be expected to maintain reasonably stable population sizes in the region. Chestnut Teals may also have strong fidelity to local areas adjacent to the Coorong where they regularly breed and so not disperse as widely because of this.

Only two other species were prominent in the Coorong in January 2011, Banded Stilt and Silver Gull, Both species exceeded 10,000 birds (Sliver Gull 14,839; Banded Stilt 18,054) and both were largely found in the southern Coorong (81% and >99% of birds respectively). The numbers of Silver Gulls were comparable to previous years, while the numbers of Banded Stilts was somewhat lower, but their numbers fluctuate enormously. Banded Stilts are known to breed in inland wetlands when these fill with water and a large colony is currently breeding on Lake Torrens, so many of the birds that were counted in recent dry years may have moved to Lake Torrens. However not all the Banded Stilts had left the Coorong and significant numbers remained in January 2011. This perhaps highlights that movements to inland wetlands may not involve all birds within a population, and so requires non-breeding habitats to be managed wisely irrespective of whether inland wetlands carry water.

Overall, one of the important findings from the census data that compares abundances of birds in January 2011 with abundances over the last decade is that no waterbird species has shown a marked increase in abundance in the Coorong following the initial return of flows over the Barrages. If anything many species have shown a marked decrease in abundance that may be related to conditions in the Coorong or to birds dispersing away from the Coorong to other wetlands that now contain water. Importantly not all species respond, let alone respond in the same direction to environmental changes within the region, and so the ecological needs of each species needs to be considered in managing this system in the future.

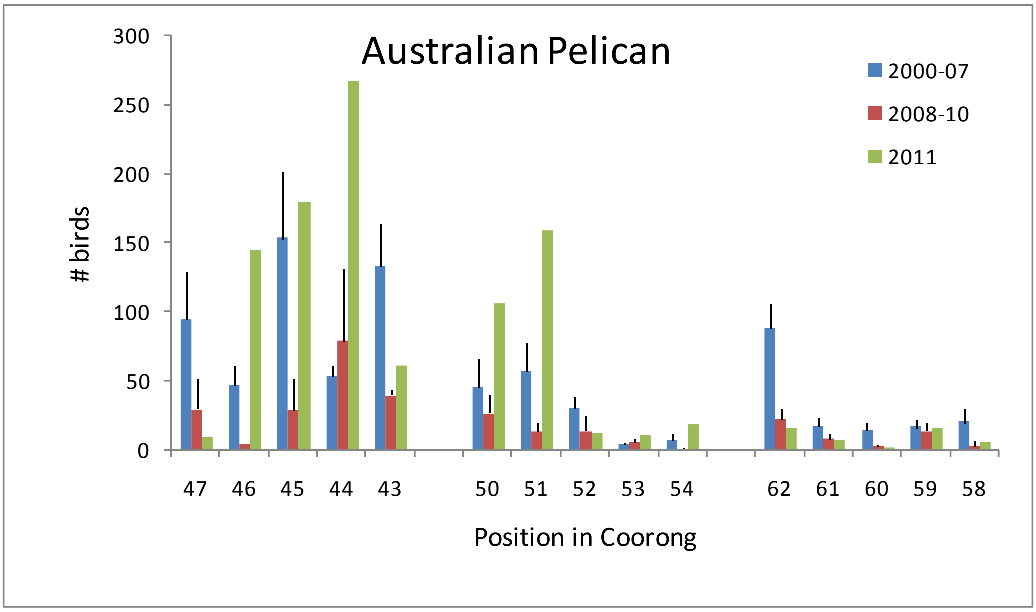
Changes in the local distributions and abundances of selected waterbirds near the Barrages

There were no consistent aggregations of various species of waterbirds immediately downstream of the barrages in January 2011 (Figs 7-12). Four species (Australian Pelican, Pied Cormorant, Great Cormorant, and Little Black Cormorant) showed some aggregation within 1-2km of the Ewe Island Barrage, but did not show comparable responses at the Tauwitchere or Goolwa Barrages (Figs 7, 9, 10). These different responses may reflect differences in other environmental features downstream of the three barrages, such as water depths and bathymetry that may influence fish abundance and or the ease with which these species can forage. Caspian Terns were generally less abundant close to the barrages in January 2011 compared with previous years (when no or only slight flows were taking place). Three factors may influence the performances of terns foraging immediately downstream of the barrages: the turbidity and or turbulence of the water may limit their ability to detect prey; suitable prey may not be present; and or other piscivorous species may influence where they forage. Other terns showed different responses with Whiskered Terns largely vacating the Coorong (Fig. 1) and areas close to the barrages (Fig. 8), and Crested Terns maintaining their abundances in the vicinity of the barrages when flows returned (Fig. 8). Other species of waterbird including Musk Duck and Hoary-headed Grebe had largely vacated the Coorong in January 2011 (Figs 1, 6) including areas near the Barrages (Fig. 11). Other species that were prominent in areas near the barrages in previous years, such as Great Crested Grebe, Red-necked Stint and Sharp-tailed Sandpiper, were also absent from the barrage area (details not provided) in January 2011, and if present in the Coorong were in greatly reduced abundances throughout. Two other potentially piscivorous species, Common Greenshank and White-faced Heron, maintained a presence near all three barrages in January 2011. For Common Greenshanks the numbers were generally lower across the five 1-km wide survey strips, but White-faced Herons showed an increase in abundance four-five kilometres south-east of the Tauwitchere Barrage. These birds were foraging against the western shoreline of the Coorong (i.e. Younghusband Peninsula) in flooded samphire or on the shoreline where water movement and turbulence was reduced.

Building response models for water-birds using the Coorong

As was the case with waterbirds using the Lower Lakes, assessing the responses of birds to the return of flows to the Coorong region is not straight forward, in that different species are likely to have different ecological requirements and so will respond differently. That the species have different ecological requirements, both with respect to preferences and tolerances, are well illustrated by the different patterns shown by the abundances and distributions of a range of species at both the broad (whole wetland) scale and also the finer resolution of individual 1 km sections (Figs 1-12). Clearly other habitat features, not just the return of flows and hence salinities, are influencing the distributions and abundances of waterbirds across this wetland. A greater understanding of the habitat requirements of a range of waterbird species that use this region is now required.

In January 2011, while conducting the annual census of both the Coorong and Lower Lakes, the relative proportions of different habitat features along the shoreline within a grid cell (Lower Lakes) or section (Coorong) were estimated and expressed as a percentage. Key features included whether the water lapped against a rocky or sandy shore or against aquatic or terrestrial vegetation and where possible the vegetation type (e.g. samphire, lignum, reeds, rushes or terrestrial vegetation). Although notes were kept on the width of the beach (invariably narrow) when sandy beaches occurred, additional features such as the width of vegetation features was not scored, and this may be required in future years. Because of the high water levels in January 2011 habitat assessments will need to be repeated in subsequent years because the shoreline habitats will differ depending on water levels. The 2011 data are likely to represent habitat conditions close to one end of the spectrum i.e. shoreline habitats under extremely high water levels but based on recent water marks left on fringing vegetation in January 2011 maximum water depths were approximately 20cm higher than they were in January.



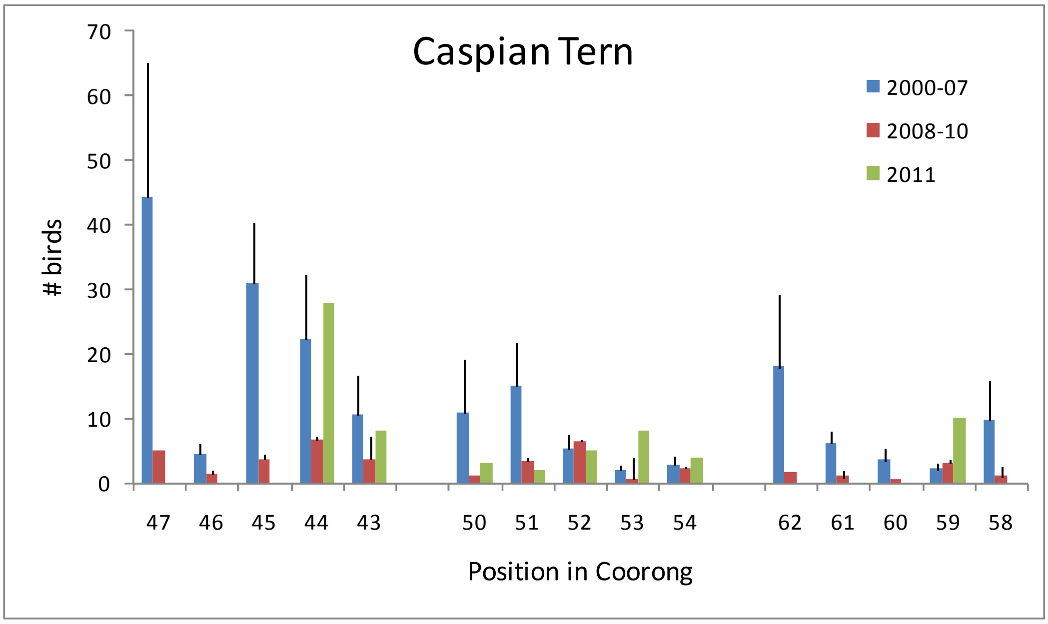
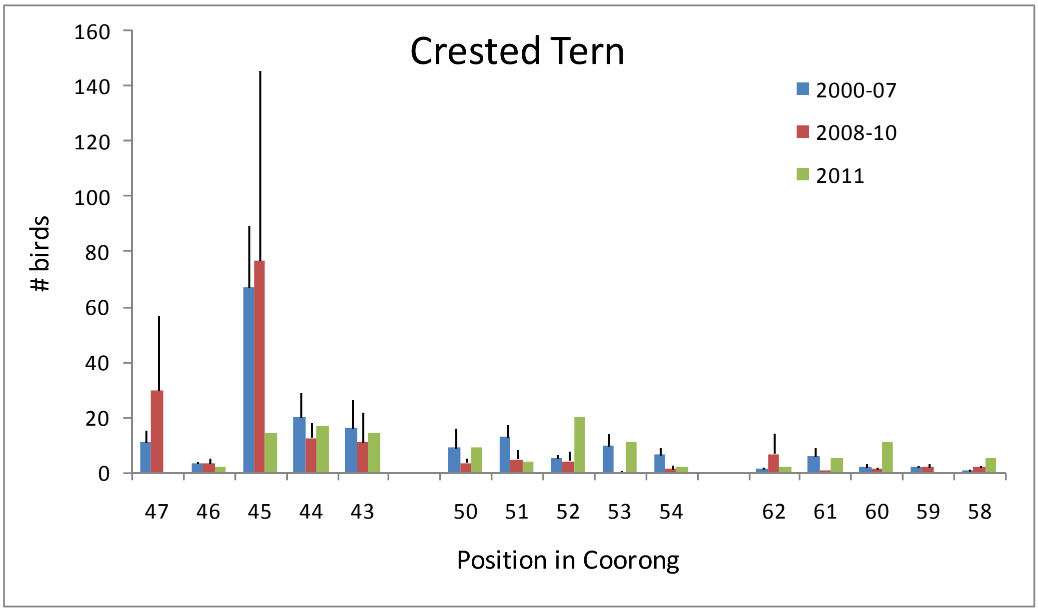


Figure 7. Abundances of Australian Pelican and Caspian Tern in January from 2000 to 2011 near each of three barrages. Numbers of birds counted in each of five consecutive 1-km strips from the Tauwitchere Barrage south-eastwards (47-43), from the Ewe Island Barrage north-westwards (50-54) and from the Goolwa Barrage south-eastwards (62-58). Mean abundance ± s.e. is shown for the eight years (2000-07, blue) prior to exceptionally low water levels in the Lower Lakes, for the three years (2008-10, red) when water levels in the Lower Lakes were exceptionally low, and for January 2011 (green).



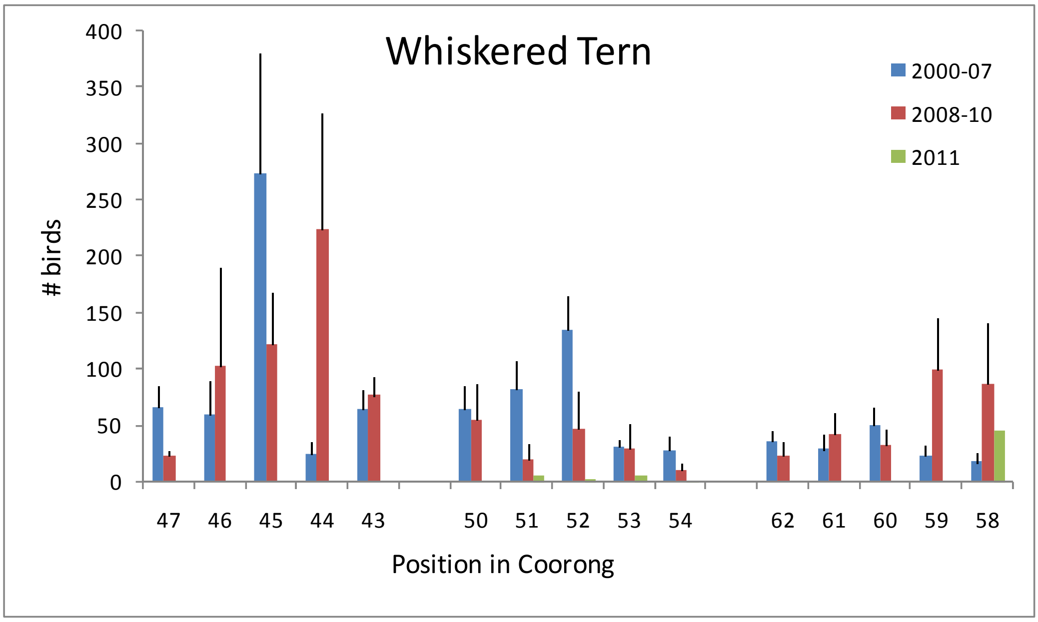
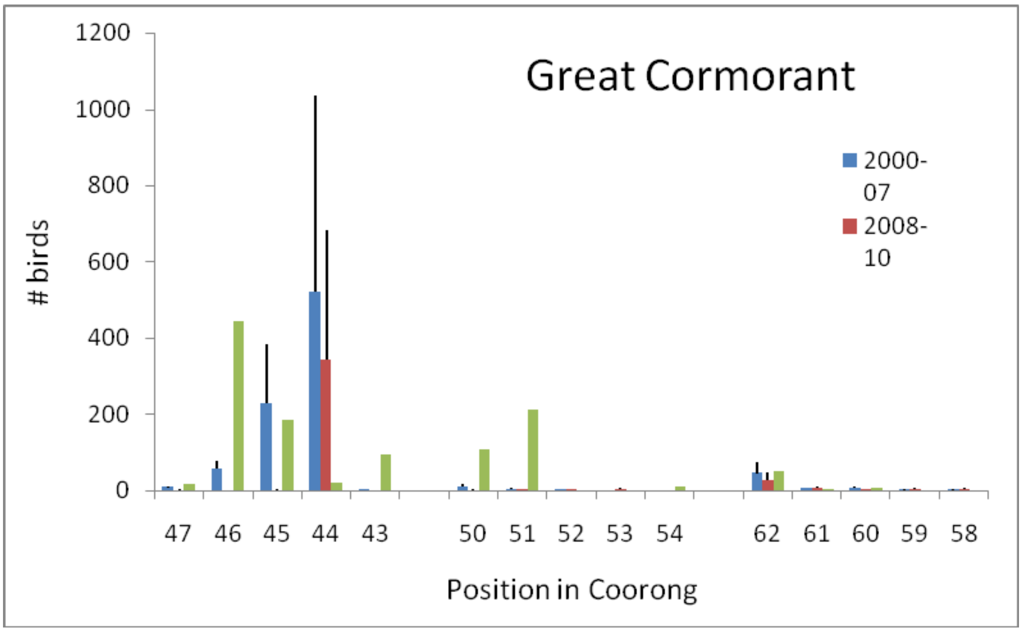


Figure 8. Abundances of Crested Tern and Whiskered Tern in January from 2000 to 2011 near each of three barrages. Numbers of birds counted in each of five consecutive 1-km strips from the Tauwitchere Barrage south-eastwards (47-43), from the Ewe Island Barrage north-westwards (50-54) and from the Goolwa Barrage south-eastwards (62-58). Mean abundance ± s.e. is shown for the eight years (2000-07, blue) prior to exceptionally low water levels in the Lower Lakes, for the three years (2008-10, red) when water levels in the Lower Lakes were exceptionally low, and for January 2011 (green).



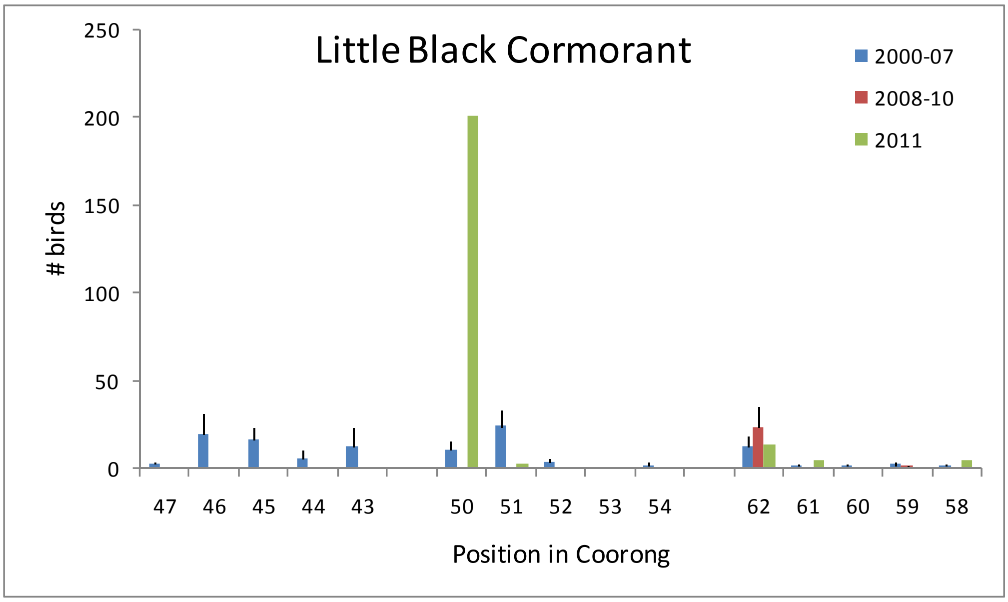
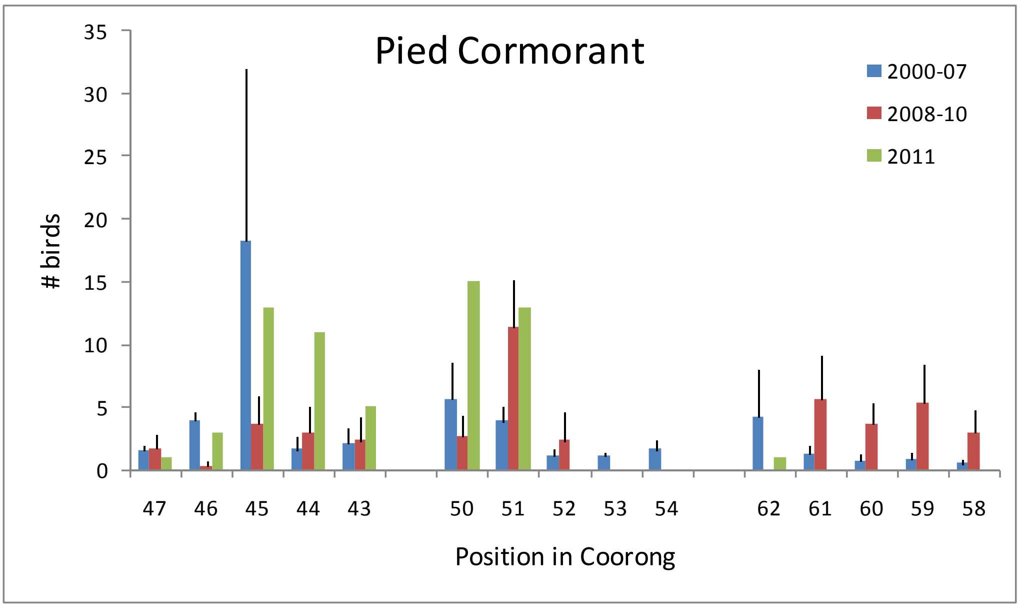


Figure 9. Abundances of Great Cormorant and Little Black Cormorant in January from 2000 to 2011 near each of three barrages. Numbers of birds counted in each of five consecutive 1-km strips from the Tauwitchere Barrage south-eastwards (47-43), from the Ewe Island Barrage north-westwards (50-54) and from the Goolwa Barrage south-eastwards (62-58). Mean abundance ± s.e. is shown for the eight years (2000-07, blue) prior to exceptionally low water levels in the Lower Lakes, for the three years (2008-10, red) when water levels in the Lower Lakes were exceptionally low, and for January 2011 (green).



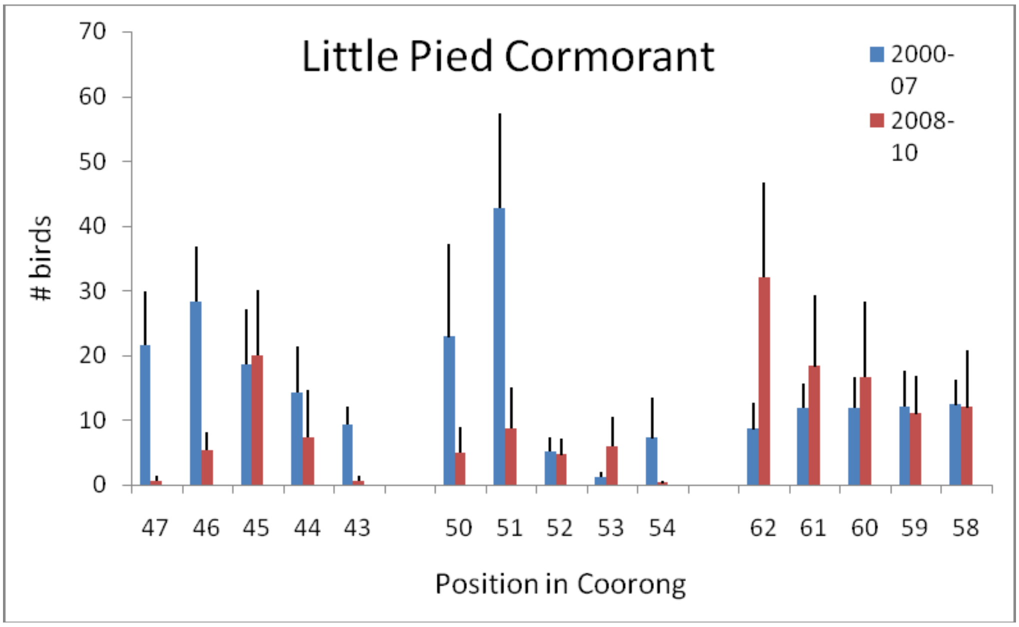


Figure 10. Abundances of Pied Cormorant and Little Pied Cormorant in January from 2000 to 2011 near each of three barrages. Numbers of birds counted in each of five consecutive 1-km strips from the Tauwitchere Barrage south-eastwards (47-43), from the Ewe Island Barrage north-westwards (50-54) and from the Goolwa Barrage south-eastwards (62-58). Mean abundance ± s.e. is shown for the eight years (2000-07, blue) prior to exceptionally low water levels in the Lower Lakes, for the three years (2008-10, red) when water levels in the Lower Lakes were exceptionally low, and for January 2011 (green).

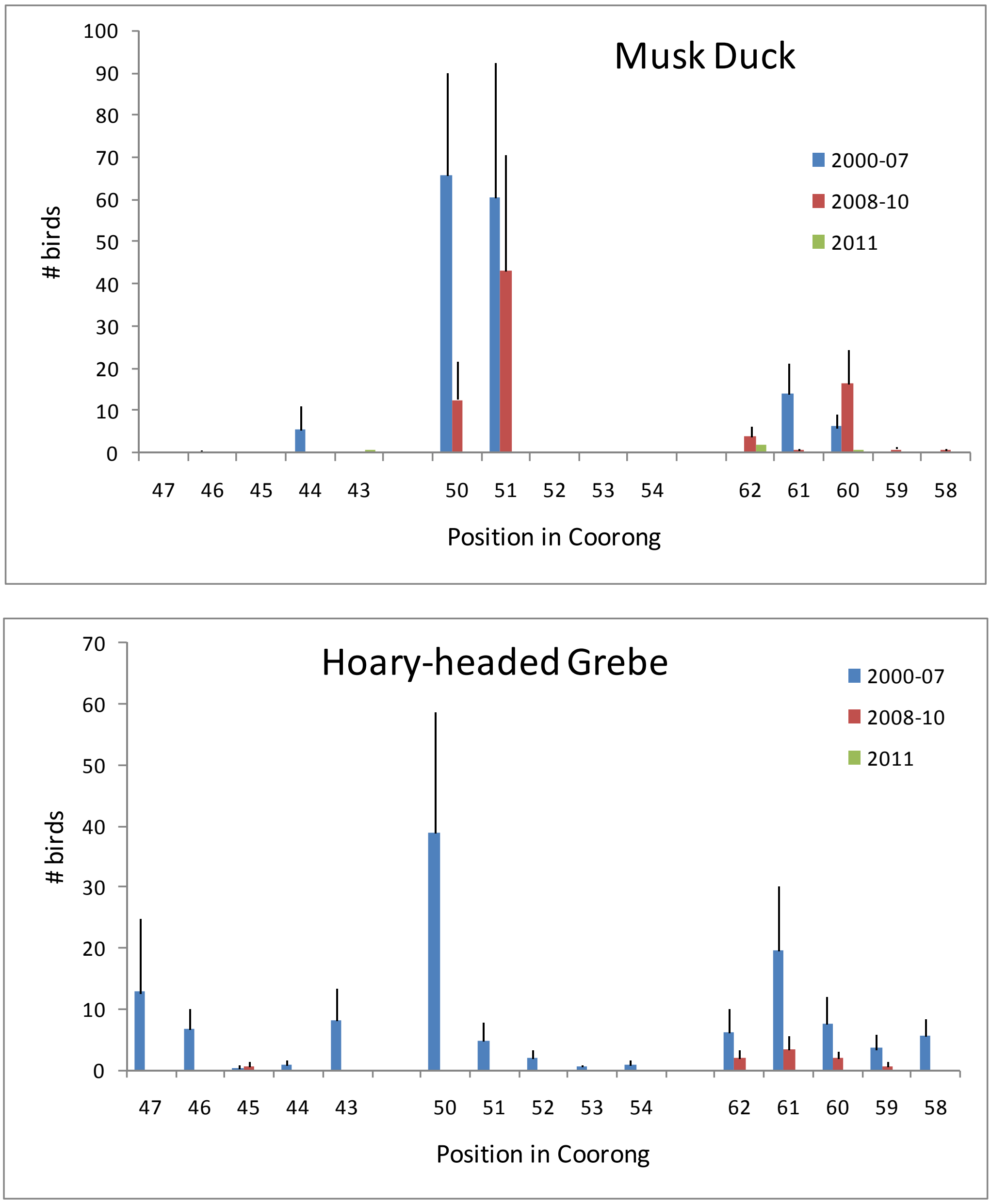
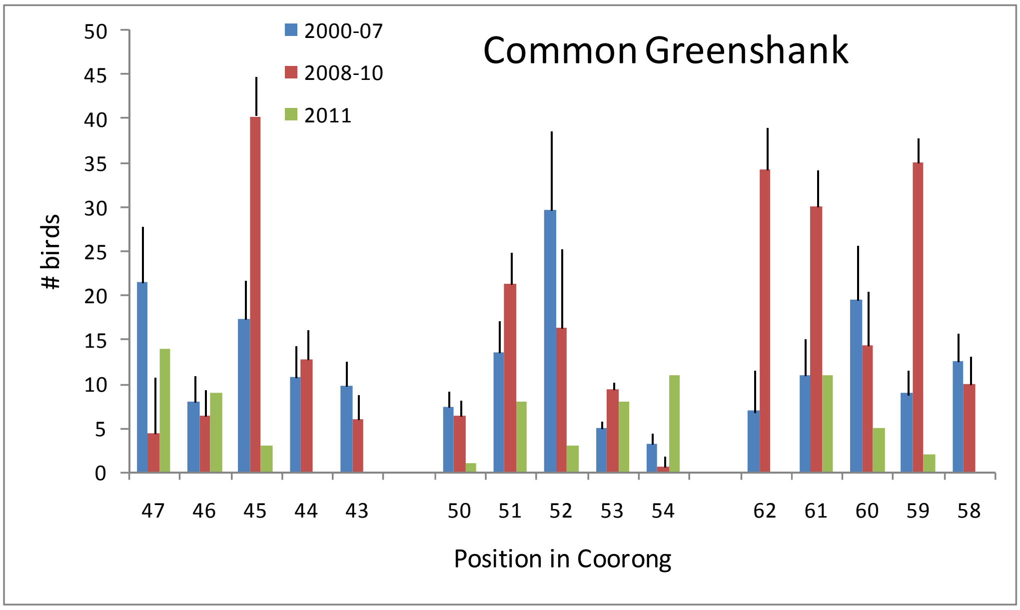


Figure 11. Abundances of Musk Duck and Hoary-headed Grebe in January from 2000 to 2011 near each of three barrages. Numbers of birds counted in each of five consecutive 1-km strips from the Tauwitchere Barrage south-eastwards (47-43), from the Ewe Island Barrage north-westwards (50-54) and from the Goolwa Barrage south-eastwards (62-58). Mean abundance ± s.e. is shown for the eight years (2000-07, blue) prior to exceptionally low water levels in the Lower Lakes, for the three years (2008-10, red) when water levels in the Lower Lakes were exceptionally low, and for January 2011 (green).



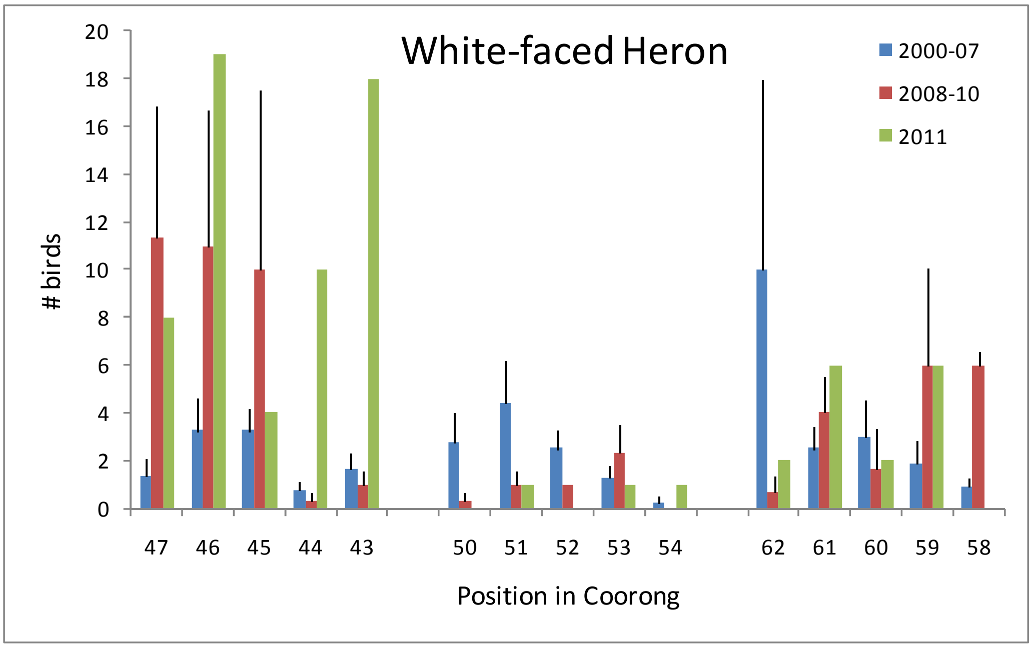


Figure 12. Abundances of Common Greenshank and White-faced Heron in January from 2000 to 2011 near each of three barrages. Numbers of birds counted in each of five consecutive 1-km strips from the Tauwitchere Barrage south-eastwards (47-43), from the Ewe Island Barrage north-westwards (50-54) and from the Goolwa Barrage south-eastwards (62-58). Mean abundance ± s.e. is shown for the eight years (2000-07, blue) prior to exceptionally low water levels in the Lower Lakes, for the three years (2008-10, red) when water levels in the Lower Lakes were exceptionally low, and for January 2011 (green).

There was considerable variability in the amounts of different habitat features from one section to another for both the North and South Lagoons (Table 4) similar to the extent of variability in shoreline features for the Lower Lakes, but with a different array of features. That there are differences between sections in their shoreline features is important because without those differences exploring for relationships (correlations) between habitat features and patterns to the distributions and abundances of waterbirds at the scale of the 1km sectors (or subsections within these) would not be possible. In its simplest form this modelling would consist of determining the extent to which the measured shoreline habitat features can explain the variability in numbers of different species at the scale of the 1 km wide sectors for January 2011. This modelling can be built within a GIS framework in that the habitat features can be mapped using the same central co-ordinates used for mapping the bird distributions and it is on that basis that the correlations between bird numbers and habitat features would be based. A range of other topographical features (e.g. level of exposure to winds from different directions, extent of open water offshore, steepness of the shoreline) as well as salinity and or types of food resources may need to be incorporated into this modelling in due course. Some of these additional features can be extracted from existing GIS layers and incorporated into the initial modelling without additional specific fieldwork, but other features may require additional fieldwork. Further adjustments to this modelling can be done by only considering the numbers of birds that are settled or foraging within the cells (i.e. excluding birds that were only flying over).

Table 4. Number of locations with different amounts of key habitats in the Coorong in January 2011.

Feature	Lagoon	# of sites with different % of each habitat						n
		0	1-10	11-50	51-89	90-99	100	
Fine sandy shore	North	28	25	25	15	8	13	114
	South	18	21	28	20	7	14	108
Coarse sandy shore	North	81	14	11	6	2	0	114
	South	73	16	15	4	0	0	108
Rocky shore	North	53	13	37	6	5	0	114
	South	45	17	18	19	6	3	108
Flooded terrestrial plants	North	64	11	23	14	1	1	114
	South	76	12	14	3	2	1	108
Flooded low samphire	North	77	14	16	5	2	0	114
	South	76	11	13	6	1	1	108
Flooded tall samphire	North	101	5	7	1	0	0	114
	South	94	7	6	1	0	0	108
Reeds	North	99	2	12	3	0	0	114
	South	107	0	1	0	0	0	108

The goal of the current body of work on habitat features was to collect habitat information at the same time as collecting information on the abundances and behaviour of the birds to allow this initial modelling to commence. As was the case for the assessment of habitats around the Lower

Lakes, the habitat assessments of the Coorong are context specific and relate to the conditions that existed in January 2011. In other years when water levels are lower and more typical, the shoreline features along the Coorong will differ, and the habitat features will need to be re-scored at regular intervals to capture temporal variation. As such, the data collected on habitat features in January 2011 are likely to represent one extreme end of habitat availability within the Coorong, a time of very high water levels.

Table 5 provides a summary of the habitat features at a lagoon scale to illustrate the extent of high water levels. In all previous years (2000-2010) no areas of samphire and no areas of terrestrial vegetation were inundated or even abutted the shoreline. In January 2011 around 22% and 28% of the shorelines for the South and North Lagoons respectively consisted of this type of habitat. Note that in making these calculations each individual location that was assessed was assumed to have an equal quantity of shoreline. This is however not the case and so these statistics should be used as a guide and have been calculated for illustrative purposes only.

Table 5. Summary of different habitat features for the North and South Lagoons in January 2011. The data show the mean percentage of different habitats from114 habitat assessments in the North Lagoon and 108 assessments of habitat in the South Lagoon

Habitat feature	Mean percent of shoreline	
	North Lagoon	South Lagoon
Fine sandy shore	35	43
Coarse sandy shore	9	7
Rocky shore	19	20
Reeds	5	0
Flooded low samphire	9	10
Flooded tall samphire	2	2
Flooded terrestrial plants	17	10
Other	4	8

Building habitat suitability models for waterbird species

Modelling patterns to the distribution and abundance of waterbirds with habitat features scored at the 1km scale provides a relatively coarse resolution for developing models of habitat use for waterbirds in the Coorong and Lower Lakes. Such modelling helps build understanding of waterbird use across the region but the approach is largely correlative and so does not define the factors causing the patterns with any certainty, but will identify habitat features that deserve further investigation. Furthermore this modelling, as outlined, largely ignores the behaviour and performances of waterbirds when exposed to different habitat features. A second independent way of building knowledge of the habitat requirements of waterbirds is to build habitat use and performance models at a much finer scale that takes into account the behaviour and performances of the birds themselves. This section of the report outlines this fine scale approach, and illustrates and audits the data that have been collected for this purpose. The contractual requirements were to collect suitable data on the foraging behaviour of waterbirds along with the availability of fine-scale habitat features at a series of sites as the first step in developing habitat suitability models. Building actual habitat suitability models, however, was outside the contractual requirements.

Documenting foraging behaviours of waterbirds

Three types of data on the foraging behaviour of birds have been collected: (i) measures of the amount of day-time spent by birds foraging at a site; (ii) measures of where birds were foraging at a site with a particular focus on the depth of water in which the birds were foraging and or the distance that the birds were foraging from the shoreline (both above and below the waterline); and (iii) measures of the rates at which the birds made foraging manoeuvres (e.g. pecks per minute) and their success rates (food items harvested per unit time) also linked to water depths and distances from the shore. Foraging rates and success rates are sometimes difficult to document because of the nature of the food items (small) or the nature of the foraging behaviour (e.g. pecking manoeuvres are not always easy to discern.

The rationale for collecting each of these sets of data was as follows. The amount of daytime a bird spends foraging through the day provides a measure of habitat quality. Those areas or times in the year when the birds spend large amounts of the daylight hours foraging are likely to indicate poor quality habitats that force the birds to spend much of their time foraging and not in other activities. These data are best collected on individual birds that are tracked throughout the day, but can also be collected by sampling the activity of birds throughout the day, and assuming that the same birds are being re-scored throughout the day. So when the amounts of time allocated to foraging accounts for only a small part of the day then the habitat is likely to be of high quality compared to sites and times when foraging accounts for a large amount of the observation time. The approach taken to collect these data on waterbirds has involved selecting sites and then recording the behaviour of all the birds within the observation area at frequent intervals (1 to 5 minutes) throughout the daylight hours. This involves scanning the observation area with a spotting scope and recording for each bird within the observation area whether it was foraging, resting, flying, calling, chasing etc. Three statistics are drawn from these data: (i) the average number of birds present during a scan, the greater the number of birds present the better the habitat; (ii) the extent to which a species was present at a site throughout the day (% of scans in which the species was present), the greater the extent (%) the better the habitat; and (iii) percent of the birds scored that were foraging, the lower the percentage the better the habitat provided (i) is also high. This latter condition is required because birds could visit briefly, attempt to forage and then depart. A further correction may also be required to account for birds that were only recorded as flying over the site and not settled. In general poorer habitats will have a higher percent of birds flying over them and not settling in them. Assessments of foraging effort may need to be corrected to only consider those birds that settle within the observation area. To illustrate the nature of the data that have been collected, foraging statistics and abundances of waterbirds are compared for two sites in Tables 6 and 7. The two sites were at Monument Rd on Hindmarsh Island and nearby at Beacon 19 on the opposite side of the Goolwa Channel downstream of the Goolwa Barrage. The Monument Rd site attracted more Australian White Ibis, Black Swans, Crested Terns, Pacific Black Duck and Whiskered Terns and allowed more foraging by those species to take place than the Beacon 19 site (Table 6). The Beacon 19 site, on the other hand supported more Royal Spoonbills, Silver Gulls and White-faced Herons with more foraging by those species than the Monument Rd site (Table 6). Neither site attracted much foraging activity from Australian Pelicans, Great Cormorants, Little Egrets or Musk Ducks.

Table 6. Average numbers of selected bird species, and average numbers of foraging birds, counted during scans taken at 5 minute intervals throughout the day for two sites downstream of the Goolwa Barrage: Monument Rd (Mon) and Beacon 19 (Beac) in April 2011.

Species	total birds		foraging birds	
	Mon	Beac	Mon	Beac
Australian Pelican	0.6	1.1	0	0.02
Australian White Ibis	2.6	0.6	2.4	0.2
Black Swan	2.0	0.2	0.6	0
Caspian Tern	0.3	0.1	0.1	0.03
Crested Tern	4.3	0.4	0.3	0.09
Great Cormorant	0.1	0.03	0	0
Little Egret	0	0.1	0	0.07
Musk Duck	0.3	0.03	0	0
Pacific Black Duck	2.3	0.2	0.6	0.01
Royal Spoonbill	0.1	0.5	0	0.3
Silver Gull	1.8	8.9	0.1	1.2
White-faced Heron	0.5	1.7	0.3	0.7
Whiskered Tern	1.2	0.2	1.2	0.02

The behaviour of the birds also differed between these two sites, with marked differences in the extent to which different species were present throughout the day. Most species of birds were only present at either of these sites for less half of the counts, with only four species present at either site for more than half the scans. This suggests that these sites are not providing all of the needs of the birds. Based on % presence, the Beacon 19 site provided better habitat than Monument Rd, while the Monument Rd site was used more consistently by Australian White Ibis, Black Swan, Crested Tern, Musk Duck and Pacific Black Duck (Table 7). Many of the birds detected during the 5 minute counts were flying over these sites, potentially indicative of poor quality habitats at the two sites. Differences also existed in the percent of birds that were foraging irrespective of whether birds that were flying over were included or excluded (Table 7). In many cases the percent of foraging amongst the activities scored was high (>50%) suggesting that habitats are poor for some species at one or both sites. For other species the percent of the birds foraging was low, suggesting these areas may provide good habitat. For these two sites some care is required in interpreting these behavioural data because the %presence was also low.

Table 7. Extent to which different bird species were present throughout the day and percent of birds doing different activities for two sites (Monument Rd (Mon) and Beacon 19 (Beac)) in April 2011. Extent of presence is the percentage of 5 minute scans (spread continuously throughout the day) when a species was present. % of birds that were foraging is given as a percentage of all birds counted and as a percentage of all birds excluding birds flying over

Species	%presence		% flyover		% forage (a)		%forage (b)	
	Mon	Beac	Mon	Beac	Mon	Beac	Mon	Beac
Australian Pelican	37	39	83	54	0	2	0	4
Australian White Ibis	73	14	3	60	92	35	95	88
Black Swan	41	7	2	0	32	0	33	0
Caspian Tern	21	11	63	69	34	25	92	80
Crested Tern	81	24	72	70	7	23	25	77
Great Cormorant	9	4	80	100	0	0	0	0
Little Egret	0	12		7		71		76
Musk Duck	27	3	0	0	0	0	0	0
Pacific Black Duck	34	5	59	79	27	7	66	33
Royal Spoonbill	42	45	100	4	0	68	0	71
Silver Gull	55	98	92	47	5	14	63	26
White-faced Heron	37	94	23	4	63	43	82	45
Whiskered Tern	10	3	4	84	96	11	100	69

The other behavioural data being collected includes more detailed information on the locations used by different species for foraging, relative to water depths and distance from the shore. The nature of these data is illustrated for some of the data collected in the Coorong in Tables 8 and 9. Waterbird species clearly differ with respect to the water depths in which they will forage (e.g. Table 8) and also in where they forage relative to the shoreline (Table 9). In general most water birds species that wade are largely restricted to foraging in shallow water near the edge of the water, while those that swim or fly while foraging are not restricted and may avoid very shallow areas. In some of the later sampling the actual locations of the birds were also recorded on a map of the survey area, to estimate spatial co-ordinates (i.e. Eastings and Northings) so that some of the locations of foraging birds could be more precisely related to detailed maps of habitat features.

Table 8. Water depths used for foraging by a range of waterbirds in the Coorong in January 2011. The percentage of birds foraging at different depths is provided. Water depths were determined by noting the extent to which the legs were covered with water (ankle to belly). Those relative measures will be converted to actual depths from measurements of the birds' legs in due course. Foraging above the water line is indicated as either foraging on damp substrates or dry substrates. Water depths cannot be determined for those species that swim or fly while foraging, but the approximate locations for these species can be estimated as a distance from the shoreline (see Table 9). Note that some species have limited data.

Species	Relative depth or foraging mode (% observations)									Total
	0 dry	0 damp	ankle	half knee	knee	thigh	belly	swim	fly	
Masked Lapwing	39	42	18	2						127
Straw-necked Ibis	19	81								16
Australian White Ibis	10	75			15					20
Pied Oystercatcher	7	92	1							162
Red-capped Plover	8	44	48							25
Red-necked Stint	13	17	45	15	9					3021
Silver Gull	3	10	46	3	9	1	0.1	17	10	4174
White-faced Heron	3	15		12	70					33
Common Greenshank	1	8	12	18	53	2	6			409
Sharp-tailed Sandpiper		33	47	15						34
Red-necked Avocet		9	6	20	17	14	6	29		35
Australian Shelduck		4	11	1	1			83		998
Chestnut Teal		5	2		0.6	2	0.4	91		504
Royal Spoonbill					100					7
Yellow-billed Spoonbill					100					1
Little Egret					100					2
Banded Stilt			2	2	1	9		85		1457
Australian Pelican								100		515
Black Swan								100		1365
Great Cormorant								100		297
Little Black Cormorant								100		144
Pied Cormorant								100		47
Caspian Tern									100	611
Crested Tern									100	420

Table 9. Location of foraging birds in the Coorong as a function of the distance from the waterline (0). Positive values show distance out into the Coorong and negative values show distance inland from the waterline. Foraging positions of birds were estimated by eye. Data are shown as percent of total observations given in the right-hand column. Note that for some species there are few observations.

Species	Distance from water line (m)											Total
	-6 - -20	-1--5	0--1	0	0-1	1-5	6-10	11-20	21-50	51-100	>100	
Black Swan						0.3		0.1	11		88	1365
Crested Tern			0.7			1.7	4	6	6	9	73	420
Pied Cormorant								6	4	21	68	47
Australian Pelican						19	13	2	3	5	58	515
Whiskered Tern											100	1
Black-faced Cormorant										100		1
Fairy Tern							21		32	21	26	19
Musk Duck										100		1
Banded Stilt					1	5	9		2	83		1457
Caspian Tern			0.1			4	18	19	28	11	20	611
Little Black Cormorant						43			14	21	22	144
Great Cormorant							81	0.7	15	1	2	297
Grey Teal						67	33					6
Australian Shelduck		1	1	8	8	6	15	13	40		9	998
Chestnut Teal		4	0.6	0.6	13	75	5	0.6	0.4	1		504
Black-winged Stilt					100							6
Little Egret					100							2
Yellow-billed Spoonbill					100							1
Silver Gull	3	1	3	18	35	18	2	5	4	2	10	4174
White-faced Heron		6	6	6	64	18						33
Red-necked Avocet				9	9	63	9	11				35
Royal Spoonbill					100							7
Common Greenshank		0.2	2	7	71	20						409
Sharp-tailed Sandpiper				62	38							34
Red-necked Stint	13		3	38	31	15						3021
Masked Lapwing	2	7	43	35	13							127
Red-capped Plover		20	20	28	32							25
Pied Oystercatcher	2	86	6	5		1						162
Australian White Ibis	10	50	25	0	10	5						20
Straw-necked Ibis		100										16

In conjunction with recording the behaviour of the birds fine scale measurements of habitat have involved recording changes in water depths and habitat features (sediment type; presence of submerged and emergent plants) along a series of parallel line transects, 50m apart. These habitat surveys were conducted over the same areas used to score the birds' behaviour and were generally linked to a 1 km section of coastline. For convenience the direction was either along the Northing or Easting line that was closest to being perpendicular to the shoreline, with the measurements extending out to depth of at least 60 and up to 80cm. Along each transect a waypoint was taken with a hand-held GPS whenever (i) there was a change in water depths of 10cm or more; (ii) a change in sediment type or sediment compaction; (iii) a change in vegetation type or density; and (iv) every 10m . Characteristics of the vegetation were estimated within a 1 m radius of the waypoint (determined by the distance between two outstretched arms over the waypoint location). For aquatic vegetation, percent cover for each species was estimated and for emergent plants this also included the number of stems and maximum height. For terrestrial vegetation, the percent cover was estimated for each species within a 1 m radius of the waypoint. These data allow changes in the bathymetry and habitat features across the sites to be mapped and incorporated into a GIS layer for that site.

Each of the sites measured differed with respect to its bathymetry and other habitat features and those are likely to influence the quantity of potentially useable habitat for different bird species at each site. Furthermore the quantities of different habitat changes with changes in water levels, and those changes are different for different sites. For example, Figure 13 shows the relative amounts of different depths of water at three sites in the Coorong (Gemini Downs, Parnka Point & Noonameena). With the high water levels present in January 2011, the site at Gemini Downs had relatively more mudflats covered by less than 10cm of water than either Parnka Point or Noonameena. Since most of the waders that use the Coorong forage on mudflats covered by less than 10cm of water (if not less than 5cm; e.g. Paton 2010) little suitable habitat for those species was present in January 2011. If, however, water levels were 30 cm lower then there would be extensive areas of mudflat covered by shallow water at Noonameena, while the other two sites would have similar amounts to those present in January 2011 (Fig. 13). These data then illustrate some of the changes to the availability of different habitats that come with changes in water levels. The data also form a baseline assessment of the vegetation and so will allow changes in the composition, spread and density of the fringing, emergent and submerged vegetation to be documented as well.

In summary, data documenting bird use and detailed habitat features have been collected for 14 sites spread around the shores of Lake Albert (2), Lake Alexandrina (6), Goolwa Channel (3) and the Coorong (3) during the period of April to June 2011. Each of these sites included up to a kilometre length of shoreline with all of the coastlines within a 1 km x 1km grid square being covered for all but one of these sites. The scale of these detailed assessments was deliberate to allow these data to be also linked to the census data collected at the scale of the 1km x 1km grid squares. Additional data on bird behaviour and habitats have also been collected from another eight sites in the Coorong prior to this and at several different times over the summer period. These additional data provide greater spatial spread for the data as well as temporal perspectives but these other observations were collected at a scale smaller than the 1km x 1km grid squares, and in the vast majority of cases since the return of flows to the region. Additional sets of data will need to be collected when water levels are lower and more typical of the region to facilitate the incorporation of temporal variability into the habitat suitability models that are to be developed.

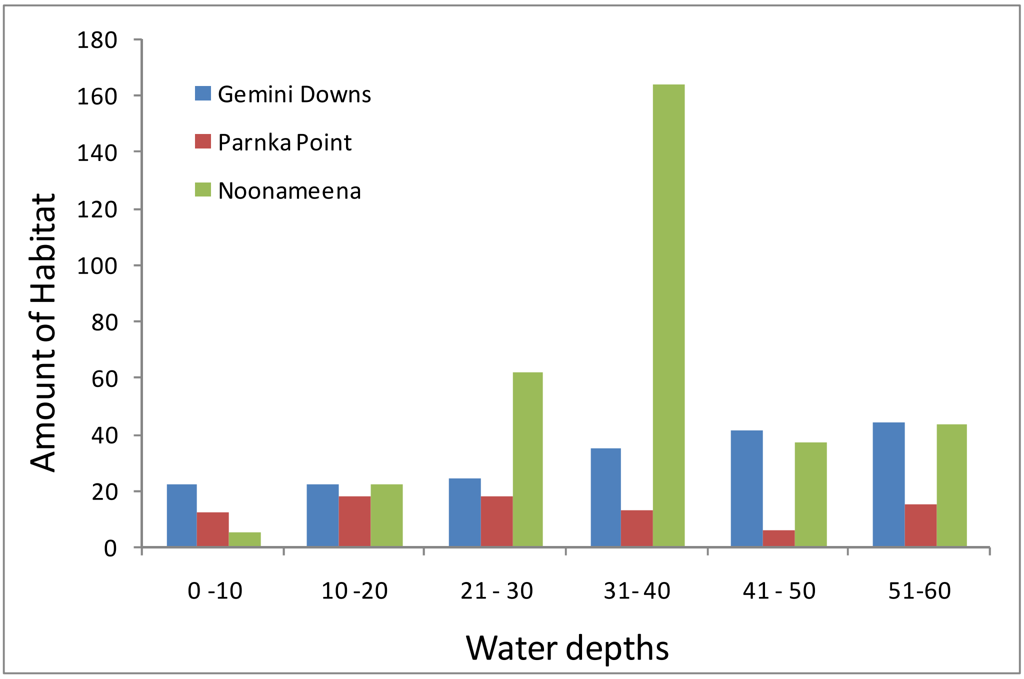


Figure 13. Relative amounts of different water depths (cm) at three sites in the Coorong in January 2011. Estimates are based on a series of parallel transects at each site along which water depths were measured to the nearest centimetre. The data plots the average length (m) of transects where the water depth was 0-10cm, 11-20cm, 21-30cm... 51-60cm. These three areas have different bathymetries and so offer different amounts of habitat (water depths) at different water levels.

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