Cryptic and colonial-nesting waterbirds in the Coorong, Lower Lakes and Murray Mouth: distribution, abundance and habitat associations

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Project Summary

The Coorong, Lower Lakes and Murray Mouth (CLLMM) region is internationally recognised for its role in providing important wetland habitats for birds. Although there is a relatively good understanding of wetland birds and their habitat associations within the ecosystem, some groups of birds are considered to be cryptic because they are seldom observed and their habitat requirements are not well known. These 'cryptic' (mostly reed-dwelling) species, and colonial-nesting waterbirds are under-represented in the current body of scientific literature and monitoring data. This study used new methods to gain baseline information on the abundance and distribution of cryptic and colonial-nesting waterbirds that utilise CLLMM habitats.

The findings of this report can be summarised as follows:

- Lower Lakes wetlands provide significant habitat for cryptic bird species. 34-265 observations of 13 cryptic species were recorded within repeat surveys at 15 wetland sites.
- Analysis of wetland habitat features in relation to the occupancy and abundance of cryptic birds shows that habitat preferences are species-specific. Each species was correlated with unique combinations of wetland vegetation types and cover, topography or water features. Some species, such as the Australasian Bittern prefer large areas of homogenous habitat (i.e. large reed beds), whereas other species, such as the Australian Spotted Crake, prefer complex, heterogeneous habitats containing a mix of reeds, lignum and grasses.
- Coorong and Lower lakes habitats provide significant and regular nesting habitat for thousands of colonial-nesting waterbirds. Over 4000 active nests of 8 waterbird species were detected in aerial surveys from October 2012-February 2013. Most nesting activity was observed on reedy islands in the Lower Lakes and islands with little vegetation in the Southern Coorong.
- A comparison of historical and modern data shows that breeding activity for some species, such as the Australian Pelican, is relatively stable. Other species, such as the Fairy Tern and Glossy Ibis have either reduced or ceased breeding in the CLLMM.

The findings of this study highlight the importance of CLLMM habitats for cryptic and breeding waterbirds. This information increases our understanding of what drives the distribution and abundance of these birds within the system, and how the site should be managed to ensure their persistence in the future.

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Introduction

Background

The Coorong, and Lakes Alexandrina and Albert Ramsar site is internationally recognised for its role in providing important wetland habitats for birds (Eckert 2000; Phillips and Muller 2006; Rogers and Paton 2009). This Ramsar wetland lies within the Coorong, Lower Lakes and Murray Mouth (CLLMM) region. The CLLMM's dramatic salinity gradient (freshwater in the Lakes to hypersaline in the Southern Coorong), provides a diverse range of wetland habitats that support >200,000 waterbirds every summer and act as a drought refuge for many of South Australia's wetland bird populations (Paton 2010). Compared to the majority of other Australian wetlands, the CLLMM's birdlife communities are relatively well-studied; and we have some understanding of the habitat requirements and the ways in which many bird species respond to altered water regimes and drought (Paton 2010; Paton et al. 2011; Paton et al. 2009a; Paton and Rogers 2009; Rogers 2012; Wainwright and Christie 2008). However, some groups of birds, considered to be cryptic (mostly reed-dwelling) species, and colonial-nesting waterbirds are relatively under-represented in the current scientific literature, with little monitoring data available to inform an understanding of their habitat preferences and requirements (O'Connor et al. 2012). These birds can be difficult to detect using regular survey methods, because of their secretive behaviour, or preference for habitats that are difficult to access. In this study, a new survey method is used to gain baseline information on the abundance and distribution of cryptic and colonial-nesting waterbirds that use CLLMM habitats. This information will increase our understanding of the habitat requirements of these birds, and how the site could be managed to ensure their persistence in the future.

Cryptic birds

In this study, cryptic birds are defined as wetland-dependent species that display secretive behaviour and are generally difficult to detect. In the CLLMM, these bird species are generally dependent on emergent, littoral vegetation. This project focuses on cryptic species within the following broad groups: Bitterns, Snipe, Rails, Crakes and Passerines. Cryptic birds are particularly under-represented in current bird monitoring programs(O'Connor et al. 2012), because many of these species depend on thick vegetation, are rarely seen, vocalise infrequently (except for Passerines) and prefer inundated areas that are difficult to access. These birds may be particularly sensitive to hydrological change, particularly with regard to how water level impacts on the distribution or availability of habitat. Therefore, there is a need for greater understanding of the ways in which water delivery and drought may impact the distribution of habitat, and hence the persistence of these species at the site. Cryptic wetland birds such as the Australasian Bittern, *Botaurus poiciloptilus,* and Australian Painted Snipe, *Rostratula australis*, are considered endangered at an International scale (BirdLife International 2012a; 2012b), while other species such as the Little Bittern, *Ixobrychus dubius*, and Lewin's Rail, *Lewinia pectoralis*, are endangered

at a local scale (Gillam and Urban 2011). These ratings are most likely due to widespread wetland degradation and loss, which is estimated at >89% in South-eastern South Australia (Usback and James 1993). With perhaps less than 10% of SE South Australian wetlands left, remaining sites, such as Lakes Alexandrina and Albert, may be of high conservation value if they provide significant habitat for cryptic species. Data on the distribution, abundance and habitat requirements of cryptic bird species are generally lacking at a national scale; few published studies have systematically surveyed their abundance and habitat requirements within an Australian wetland system (but see Goodsell 1990; Pickering and Gole 2008; Todd 2000). These data will be valuable for both informing future risk assessments to determine conservation ratings for these species, and be of practical use to inform management plans.

Colonial-nesting waterbirds

Colonial-nesting waterbirds are highly dependent on sufficient water flows in order to commence and successfully complete their breeding cycle (Kingsford and Auld 2005; Murray et al. 2012; Stewart and Harper 2002). These birds are known to breed on relatively few wetlands in Australia, where the size and success of breeding responses are directly linked to local hydrological conditions (Kingsford and Johnson 1998; Scott 1997). The CLLMM region has historically supported breeding activity for a range of colonial-nesting bird species: from seabirds such as terns, gulls, pelican and cormorants, to freshwater species including Ibis, spoonbill and egrets. But only two species-specific monitoring programs currently collect data on CLLMM waterbird breeding activity: 1) the Fairy Tern program (annual sampling, University of Adelaide and DEWNR (DENR 2012; Paton and Rogers 2009), and, 2) the Beach-nesting Birds Project (biannual sampling, Birdlife Australia). In the past, sporadic monitoring has occurred for Pelicans in the Coorong (Chapman 1963; DENR 2011; Hitchcock 1937; Sutton 1933b) and cormorants, ibis, spoonbill and egrets in Lakes Albert and Alexandrina (Beruldsen 1963; Close et al. 1982), but no study has attempted to systematically capture the full spectrum of CLLMM waterbird breeding activity. In this study, aerial survey techniques were used to provide a ‘snapshot’ of waterbird breeding activity across the whole CLLMM wetland system within the peak breeding period for most species (October to February). A descriptive assessment of historical and modern waterbird breeding activity at the site is also provided in order to assess and discuss reasons for changes in the location, species identity or size of breeding events.

Aims and Objectives

Cryptic bird survey

Aims:

- Examine the distribution and local abundance of cryptic bird species at 15 Lower Lakes wetlands.

- Identify key habitat characteristics associated with the abundance and distribution of cryptic bird species.

Specific research questions

1. Do CLLMM habitats support cryptic bird species?
2. What cryptic species are present and at how many sites?
3. Which habitat features can be used to predict cryptic bird species occurrence/abundance?
4. Do cryptic birds utilise CLLMM habitats for nesting?

Colonial-nesting waterbird survey

Aim:

- Determine the extent to which waterbirds currently use the CLLMM site for breeding by comparing the current extent of waterbird breeding in the CLLMM with known historic breeding.

Specific research questions

1) Which habitats/sites are used by colonial-nesting waterbirds for breeding and where are they located?
2) Can available data be used to assess changes in the location and ecological characteristics of key waterbird breeding areas over the past 100 years?

Methodology

Cryptic birds

Study sites

This study was conducted at 15 wetland sites around the edges of Lakes Alexandrina, Albert and their tributaries (Figure 1). The 15 survey sites were chosen from over 40 potential wetland locations that were visited prior to commencing surveys. Sites were selected based on: 1) habitat characteristics, including water availability and vegetation cover and type, 2) predicted potential for supporting cryptic bird species. At each of the 15 study sites, two rectangular 2 ha plots were established for sampling (2ha plots were chosen based on the standard BirdLife Australia sampling method). All plots included wetland edges, which are defined as the maximum extent of water bodies in September (e.g. lake shoreline, river edge or other wetland border).

The final 15 sites fit into one of three broad categories:

1. High (>70%) reed cover (n=5); characterised by reed beds and open water
2. Medium (20-69%) reed cover (n=5); characterised by heterogeneous habitat including features such as reeds, open water, lignum, sedges and/or samphire species.
3. Low (<20%) reed cover (n=5); mainly inundated samphire, and other wetlands that did not include direct lake shoreline habitat.

Detailed descriptions of survey sites are given in Appendix 1.

Figure 1. Lakes Albert and Alexandrina and associated tributaries. The 15 sites surveyed for cryptic birds are shown as red points on the map. Reedy Island (shown in yellow) was only surveyed in September. Its replacement site: Goolwa, was surveyed from October to December.

Reedy Island was initially chosen and surveyed in September, but was excluded from further surveys because the site was too difficult to access. The Goolwa site replaced Reedy Island from October to December. Reedy island survey data are presented in the results as a record, but were excluded from further habitat analyses.

Study Species

This study focussed on 14 cryptic bird species, which are listed along with their conservation status in Table 1. Of note, a recent assessment indicates that for 6 of the 14 study species little population data are available (listed as 'Data Deficient'), and 4 are thought to be 'Declining' in the CLLMM region(Gillam and Urban 2011). This clearly highlights the need for more local information on the abundance and distribution of cryptic birds.

Table 1. Current conservation listing for focal cryptic bird species at an International (IUCN Redlist), National (EPBC Act), or State scale (NPWS Act), or at a regional SouthEast SA or CLLMM level (DEWNR Regional Species Conservation Assessments(Gillam and Urban 2011)).
Conservation status is shown as **CR** (Critically Endangered), **EN** (Endangered), **VU** (Vulnerable), **RA** (Rare), **LC** (Least Concern), or **DD** (Data Deficient). IUCN criteria for allocating categories of extinction risk are shown in parentheses. Where known, species population trend is shown as: '**0**' (Stable),'**–**'(probable or definite decline), '**+**'(increasing), or **DD** (Data Deficient) in the shaded columns.

Common Name	Scientific Name	International	Trend	National	State	South East SA	Trend	CLLMM	Trend
Australasian Bittern	*Botaurus poiciloptilus*	EN(C1)	-	EN	VU	EN	-	EN	-
Australian Painted Snipe	*Rostratula australis*	EN (C2a(ii))	-	EN	VU	CR	-	CR	-
Australian Reed-warbler	*Acrocephalus australis*	LC	0			RA	0	LC	0
Australian Spotted Crake	*Porzana fluminea*	LC	DD			RA	DD	RA	DD
Baillon's Crake	*Porzana pusilla*	LC	DD			DD	DD	DD	DD
Buff-banded Rail	*Gallirallus philippensis*	LC	0			RA	DD	RA	DD
Dusky Moorhen	*Gallinula tenebrosa*	LC	DD			RA	0	RA	DD
Golden-headed Cisticola	*Cisticola exilis*	LC	+			RA	-	VU	-
Latham's Snipe	*Gallinago hardwickii*	LC	-			RA	0	LC	0
Lewin's Rail	*Lewinia pectoralis*	LC	-		VU	EN	-	EN	-
Little Bittern	*Ixobrychus dubius*	LC	-		EN	CR	-	DD	DD
Little Grassbird	*Megalurus gramineus*	LC	+			RA	0	LC	0
Purple Swamphen	*Porphyrio porphyrio*	LC	DD			NT	0	NT	0
Spotless Crake	*Porzanata buensis*	LC	DD		RA	RA	DD	RA	DD

Survey Methods

Surveys were conducted over a 3-day period on a monthly basis between September and December 2012. Survey dates were as follows: September 17, 18 & 24, October 22-24, November 19-21, and December 17-19. To obtain survey data, observers searched one of the two2 ha plots at each site and recorded all birds (including non-target species) that were heard or seen within a 40 minute period. Each plot was systematically searched by one observer (Plots A and B were searched at the same time by one of the two observers), to increase the likelihood that each

individual bird was recorded once in each survey. GPS co-ordinates for all four corners of each 2 ha plot are provided in Appendix 2. Observers wore waders, which enabled them to access almost all areas of inundated wetlands. For each observation, the following information was recorded:

- Site ID, date and time
- Species identity
- Number of individuals
- Behaviour (e.g. roosting, foraging, swimming, calling)
- Substrate being used by bird (e.g. reeds, lignum, open water)
- Age (juvenile/adult)and sex of bird if possible
- Evidence of nesting/breeding behaviour

Surveys commenced at approximately 6am, and were completed by 8pm. In the case of inclement weather (strong winds or high temperatures), surveys were stopped until conditions improved. Over the four survey visits, each site was surveyed twice in the morning and twice in the afternoon. Every site was surveyed at least once in early morning (before 9am) or late afternoon (after 4pm), when bird activity was expected to be at its peak.

Habitat Surveys

In each of the monthly surveys, the following information was recorded at each site:

- Weather conditions (wind, temperature etc.)
- Minimum and maximum water depth at each 2 ha plot
- Estimated % cover of water at each 2 ha plot

To estimate the effects of local habitat variables on cryptic bird abundance, information was collected about the plant species and communities that were present within each 2 ha plot (these floristic data were collected only once for each plot, during the November bird survey as little change in floristic cover and composition was expected over the 4-month study period). These surveys recorded the percentage cover of dominant (>5% cover) vegetation species in a 2metre radius of the observer at 9 GPS points in each 2 ha plot. To confirm plant identification in the field, at least one specimen of each species was collected, and identified by State Herbarium of SA staff.

The vegetation dataset provided reference sites for subsequent mapping of habitat types. The mapping of vegetation types within each plot was achieved by visual interpretation of aerial imagery (taken in 2011 at 0.5m resolution), using GIS (ESRI ArcMap™) to define habitat boundaries. The proportion of each 2 ha plot that was comprised of each of the 16 major habitat features (Table 2)was then calculated from this mapping. This digitisation method was repeated within a 100m buffer of the border of each survey plot. The purpose of examining habitat features within the100m buffer zone was to identify whether species occupancy or abundance is predicted more strongly by

very localised habitat features (i.e. with 2 ha plot), or by features within a slightly broader context (i.e. within a 100m buffer zone of the central point).

Table 2. Habitat feature classes used to categorise raster images of survey plots

	Habitat class	Description/Genera/common name
1	Reeds >1m	*Phragmites, Typha, Eleocharis spacelata*
2	Sedges <1m	*Eleocharis acuta, Bulboschoenus, Baumea,*
3	Sedges >1m	*Juncus, Gahnia, Cyperus, Schoenoplectus*
4	Samphire	*Suaeda, Tecticornia*
5	Aquatic herbs>1m	*Triglochin striatum, Crotula, Myriophyllum, milfoil, water couch, Hydrocotyle*
6	Aquatic Herbs<1m	*Triglochin procerum*
7	Lignum	*Muehlenbeckia*
8	Open water	*Open water, not covered by floating or emergent vegetation*
9	Bare ground/litter (dry)	*Dry ground*
10	Mudflat (wet)	*Wet, open mudflat*
11	Aquatic ferns	*Azolla, duckweed/waterweed, Lemna*
12	Dry herbs	*Samoleus, Medicargo, Senecio*
13	Dry Shrubs >1m	*Blackberry, Grevillia, Callistemon (or similar)*
14	Tree>2m	*Melaeleuca*
15	Grasses <1m	*Paspalum, Distichilis, Erharta, Lolium, Lachnagrostis, Ammophila, Polypogon*
16	Roads, buildings	

Statistical Analyses

All statistical analyses were performed using R-project for statistical computing for windows version 2.15.1 for windows (R Development Core Team 2008).

Cryptic birds species-group classification

Some CLLMM cryptic bird species are recognised as being more abundant (e.g. Australian Reed-warbler) than others (e.g. Little Bittern), hence developing habitat associations for less common species is more difficult. As a surrogate measure, species group associations were identified in order to provide surrogate habitat associations for less common species. Cryptic bird species were classified into groups based on their patterns of co-occurrence. To accomplish this, hierarchical clustering with Ward's Algorithm method was applied in the 'hclust' function of the package 'maptree' (White 2010). This method creates clusters of objects by minimising the sum of squares at each level (Ward 1963). To identify the optimal number of species groups presented in hierarchical trees, the Kelley-Gardner-Sutcliffe penalty function was applied (Kelley 1996) in the 'kg' function of 'maptree'. This analysis simultaneously maximises differences between and maintains cohesiveness between clusters. These cluster analyses were performed on both the full dataset (13 species) and a reduced dataset (8 species), which excluded species that made up less than 5% of total detections (n=1,951).

Occupancy, abundance, and habitat variables

Generalized Linear Models (GLM) were used to identify which habitat variables were associated with cryptic bird occupancy and abundance. Occupancy data (binary presence/absence data) were analysed using a binomial distribution and a logit-link function. Abundance data were analysed using a Poisson distribution.The wetland habitat features used in these models are described in Table 3.Since the Little Bittern, Baillon's Crake, Buff-banded Rail, Dusky Moorhen and Lewin's Rail each made up less than 1% of overall cryptic bird detections (n=1-16 observations per species), they were not included in the habitat analyses.

To reduce the number of models to be considered for each species, two 'full' models were analysed with survey visit (Month) as an ordinal variable. Model 1 contained all 14 habitat variables (Table 3) at the local (2 ha) scale, whereas Model 2 contained all 14 habitat variables at a broader landscape scale (within a 100m buffer zone from the centre point of the 2 ha plot). The model outputs were inspected for non-significant terms, which were removed from further analyses (Step 1). Next, 10 different models were run: one null model, one model that considered local reed cover only, one 'full' model at the local scale, one "full" model at the broader landscape scale, and 6 models that included the most likely combinations of significant variables from Step 1(see discussion in Burnham and Anderson 2002 pages 333-334). Model selection was based on ΔAIC (Akaike Information Criteria) values that were calculated using corrected AIC values (AIC_C).
AIC_C was calculated using the equation below:

$AIC_C=AIC+\underline{2K(K+}$

ΔAIC is a measure of each model relative to the 'best' model and is calculated as:

$\Delta AIC=\Delta_i=AIC_i-minAIC.$

Only models within 2 units of the ΔAIC value were retained for further consideration (Burnham and Anderson 2002). Analyses of occupancy and abundance data were run separately.

Table 3. Details of habitat variables included in GLM analyses

Vegetation Characteristics	
RE	Reeds
SE <1m	Sedges <1m
SE >1m	Sedges >1m
SA	Samphire
AQ>1m	Aquatic herbs>1m
AQ<1m	Aquatic Herbs<1m
LI	Lignum
AF	Aquatic ferns
GR	Grasses
Physical features of the site	
MU	Mudflat (wet)
OW	Open water
WMI	Minimum water level in the 2 ha plot in October
WMA	Maximum water level in the 2 ha plot in October
%IN	% of the 2 ha plot that was inundated with water in October

Colonial-nesting waterbirds

Survey methods

The entire perimeter of the Lower Lakes and Coorong was surveyed for signs of waterbird breeding activity between October 2012 and February 2013. The lakes and tributaries (including Goolwa Channel and Barrages) were surveyed on the following dates: 18th Oct & 4th Dec 2012, and 15th Jan 2013. The Coorong was surveyed separately on the: 14th Nov and 27th Dec 2012, and 22nd Feb 2013. Each survey of either the Coorong or lakes was conducted >6 weeks apart to avoid duplicate counting of the same active nests (incubation periods).

Waterbird nests and young (if possible) were counted from a Cessna aircraft flown at a height of 500 feet at an airspeed of 90-110 knots. Two observers took part in each survey; each person observing activity from their side of the aircraft. When breeding colonies were located, one person recorded the species identity, estimated the number of birds present, and recorded the location using handheld GPS. The aircraft circled each location while the other observer took photographs of the colony. These photographs were later used to verify waterbird species identity, number of active nests, number of non-nesting adults, and number of young (pelicans only) at each colony. Young pelicans included ‘downies’ (smaller than adults with short grey-white down, generally forming a creche) or ‘chicks’(domestic fowl-sized or smaller, naked with no feathers) as described in DENR (2011).

Comparison of historic and modern waterbird breeding data

Waterbird breeding data was compared across three main time periods that were ecologically significant in terms of changes to the hydrology of the system

1911-1954: Period of relatively low total annual water diversions (<4500GL/Year)(MDBA 1995).

1955-1996: Substantial increase in the volume of water diverted from the Murray-Darling Basin (up to 12,500 GL/Year), mostly as a result of increased irrigation (MDBA 1995; MDBA 2011).

1997-2013: Decrease in volume of total diversions from a peak 13,000GL in 1997 to ~6200GL in 2011 after a 'cap' was introduced in July 1997 (MDBA 2011).

Breeding records were taken from available literature and datasets (Appendix 3). Only colonies of ≥10 birds were included in this summary, but some data for beach-nesting birds (non-colonial) are presented in order to demonstrate the importance of Younghusband Peninsula nesting habitats.

Results

Cryptic Birds

Detection and abundance

A total of 1,951 cryptic birds were recorded during this study (see Appendix 4 for a summary of the total number of observations of each species at each site). Over the four-month survey period, between 5-11 cryptic species were detected at each site. Table 4 shows the maximum number of each cryptic bird species observed at each site in any of the four survey months. These counts are likely to be most indicative of the highest number of individuals of each species using the site at a point in time. The highest number of species (11) were detected at Finniss River and 'Jacobs' (Figure 1;Table 4). More birds were detected at Pomanda Point than any other site (Appendix 4).

Table 4. Summary of the maximum number of each cryptic bird species (per month) detected at the 16 surveyed sites**.** The total number of species is also provided for each site.*****Reedy Island was only surveyed in September, and **Goolwa was only surveyed in October, November and December.

	Boggy Creek	Finniss River	Goolwa**	Jacobs	Kennedy Bay	Clayton Bay	Loveday Bay	Milang Snipe Sanctuary	Pomanda Point	Narrung Narrows	Poltalloch	Reedy Island*	Reedy Point	Tolderol	Tookayerta	Waltowa
Australasian Bittern		1		2		1	1		3	2				2		
Australian Reed-warbler	12	6	15	21	1	8	6	5	23	15	2	5	4	10	11	10
Australian Spotted Crake		2		8	5	2	1		12	4	3				1	19
Baillon's Crake															1	
Buff-banded Rail		1		1								1			2	2
Dusky Moorhen		1		2					1							2
Golden-headed Cisticola	6	19	3	7	16	28	5	7	7	4		1	9	29	4	15
Latham's Snipe	6				1	3		12					1			
Lewin's Rail		3		1	2							1		1	3	
Little Bittern		1		1		1						1				
Little Grassbird	15	6	21	12	8	10	6	3	26	14	11		5	14	15	20
Purple Swamphen	33	1	15	13	5	34	6	2	19	19	2			3	2	17
Spotless Crake	4	3	2	4	1	2		1	9	6	1		1	3	8	4
Total # species	**6**	**11**	**6**	**11**	**8**	**9**	**6**	**6**	**8**	**7**	**5**	**5**	**5**	**7**	**9**	**8**

All study species except the Australian Painted Snipe were detected at least once during the surveys. The three Passerine species (Australian Reed-warbler, Little Grassbird and Golden-headed Cisticola), and the Purple Swamphen were the most abundant species in these surveys, with records of 365-505 observations over the four month survey period (Table 5). The next most common group included the Australasian Bittern, Australian Spotted Crake, Latham's Snipe and Spotless Crake, with 20-89 records each (Table 5). Species that were rarely recorded (1-16 observations) in this study include Baillon's Crake, Buff-banded Rail, Dusky Moorhen, Lewin's Rail and Little Bittern (Table 5).

Table 5. Summary of monthly and total records of each focal cryptic bird species across the 15 surveyed sites.

Species	Sept	Oct	Nov	Dec	Total records per species
Australasian Bittern	3	8	4	5	**20**
Australian Reed-warbler	117	118	74	113	**422**
Australian Spotted Crake	1	25	20	34	**80**
Baillon's Crake	0	1	0	0	**1**
Buff-banded Rail	1	4	0	2	**7**
Dusky Moorhen	1	2	4	1	**8**
Golden-headed Cisticola	75	71	72	147	**365**
Latham's Snipe	11	10	21	10	**52**
Lewin's Rail	3	5	6	2	**16**
Little Bittern	0	1	0	2	**3**
Little Grassbird	153	149	122	81	**505**
Purple Swamphen	116	88	104	73	**381**
Spotless Crake	11	21	24	33	**89**
Total birds/month	**492**	**504**	**452**	**503**	

Of the 1862 records of cryptic birds, 30% were ‘seen’, and 70% were ‘heard’. Four species were only ever heard (and not seen) in this study (Baillon’s Crake, Lewin’s Rail, Little Bittern, and Spotless Crake). Nesting activity was only recorded for the Purple Swamphen (n=2 nests).However, all three Passerine species (Golden-headed Cisticola, Australian Reed-warbler and Little Grassbird) were observed to carry nesting material on various occasions.

Of note, 12 Mount Lofty Ranges Southern Emu-wrens, *Stipiturus malachurus intermedius,* were observed at the Finniss River site, a location at which they have not been recorded previously (M. Pickett (Conservation Council of South Australia) 2012, pers. comm.). This species is nationally listed under the *EPBC Act 1999*as ‘Endangered’.

Cluster analysis identified four major species groupings based on co-occurrence of the 13 species detected in the surveys (Figure 2). These four groups were similar between analyses that used the full dataset of 13 species, and the reduced dataset of 8 species (excluding species with detections<5% of total detections other than the Australasian Bittern). These species groupings can be used to infer probable habitat preferences of the 5 species with low (<18) observations: (Lewin’s Rail, Little Bittern, Baillon’s Crake, Buff-banded Rail and Dusky Moorhen), for which there were too few records to undertake quantitative habitat analyses.

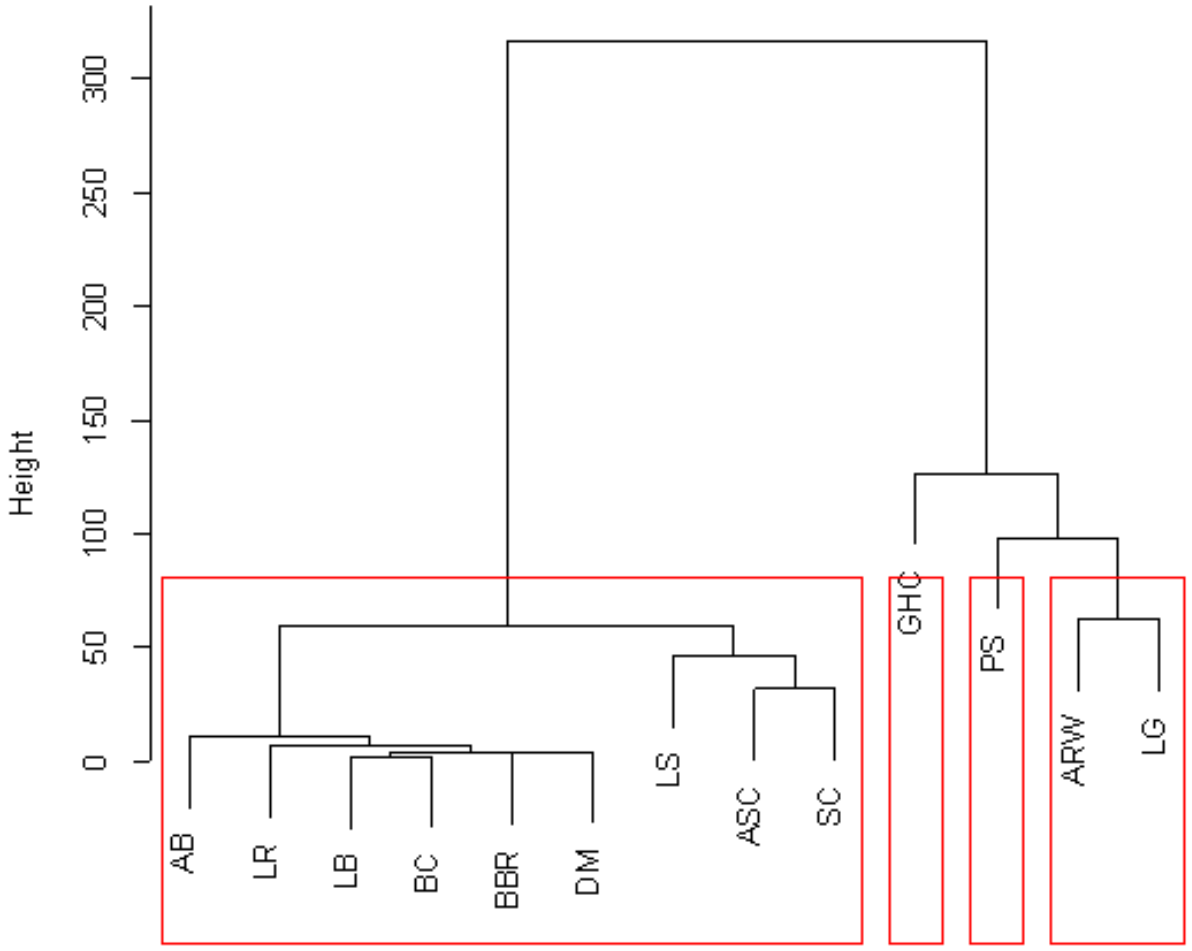


Figure 2. Dendrogram showing cryptic bird species groups based on co-occurrence. Red Boxes indicate the four species groups identified in cluster analyses. AB= Australasian Bittern, LR=Lewin's Rail, LB=Little Bittern, BC=Baillon's Crake, BBR=Buff-banded Rail, DM=Dusky Moorhen, LS=Latham's Snipe, ASC=Australian Spotted Crake, SC=Spotless Crake, GHC=Golden-headed Cisticola, PS=Purple Swamphen, ARW=Australian Reed-warbler, LG=Little Grassbird.

Relation of species occupancy/abundance to habitat variables

Based on model selection results, reed cover was a significant predictor of both occupancy and abundance in 75% of models (Table 6). Reed cover was positively associated with abundance for 6 of the 8 modelled species. Other habitat variables that were included in >50% of selected models included: Lignum, Aquatic Herbs, Aquatic Ferns, % of area inundated by water and Minimum and Maximum water depth.

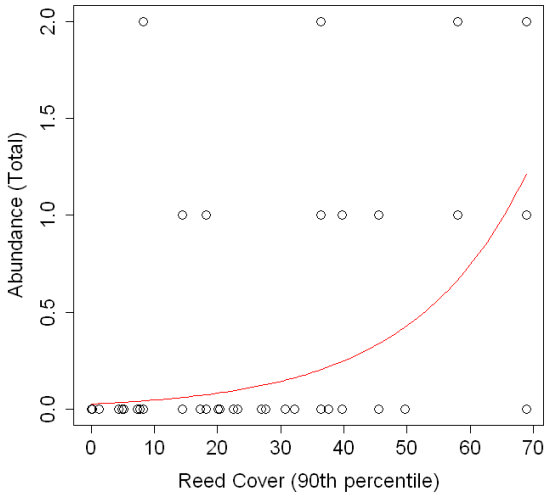
The 'best' models (ΔAIC = 0) for predicting occupancy and abundance contained different habitat variables for each species. Australasian Bittern occupancy and abundance models included only one parameter: reed cover (Figure 3a; Table 6), while abundance models for species such as the Purple swamphen and Golden-headed Cisticola contained 9 and 11 parameters respectively (Figures 3b,c;Table 6). These results suggest that Bitterns use relatively homogeneous, dense reed habitats, whereas Swamphens and Cisticolas use heterogeneous habitats with many different vegetation types. Conversely, increasing reed cover was found to have a negative effect on Latham's Snipe occupancy (Figure 3d), while samphire cover was the only parameter that was

positively associated with occupancy of this species (Figure 3e). No local habitat variables were significant predictors of Latham's Snipe abundance, possibly because this species was found at few sites that had very different characteristics (Table 4; Appendix 1). Samphire cover was also positively related to Australian Reed-warbler and Golden-headed Cisticola abundance, even though these species were rarely observed to forage or perch directly on Samphire. The presence of Samphire may indirectly influence the abundance of these species by increasing habitat complexity and therefore prey availability or access to other resources, or may simply reflect a position relative to the water line.

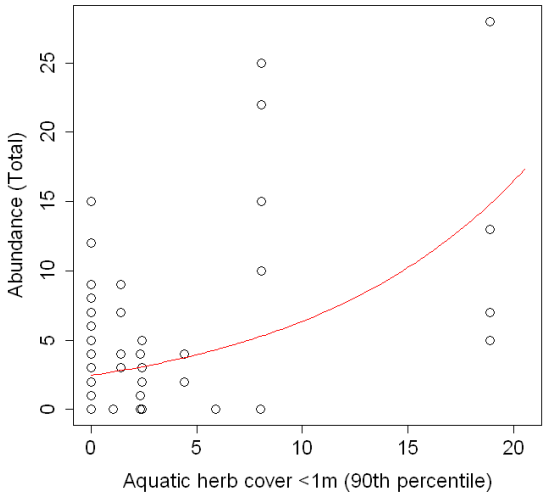
The GLMs that included habitat variables within the 100m buffer zone were chosen slightly more often than models that only included values from within 2 ha plots. For example, the Australian Reed-warbler responds to reed cover at a broader landscape scale, and Australian Spotted Crake abundance was positively associated with lignum cover at the landscape scale (Figures 3e,f; Table 6).

Table 6. Habitat relationship model results by species, in 2 ha plots (2 ha) or the 2 ha plot+ 100mbuffer zone (Buffer). *K*=number of parameters included in mode. See Table 3 for descriptions of variables. Abundance and occupancy data analyses are shown. Non-significant model parameters are indicated in parentheses (probability of inclusion >.05).Parameters in bold font have a positive effect on abundance or occupancy, whereas parameters in normal font have a negative effect. The number of alternative models (where ΔAIC_c=<2; change in Akaike's Information Criterion adjusted for small sample size) are indicated in the final column, with associated model details in Appendix 5.

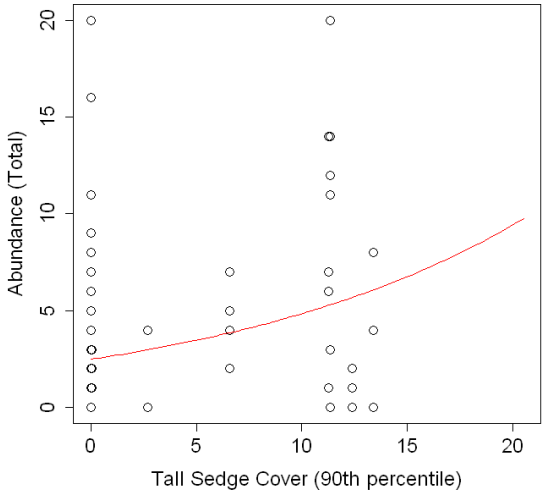
Species	Analysis	Area	Model parameters	*K*	# Alterative Models
Australasian Bittern	Abundance	Buffer	**Reeds**	1	2
	Occupancy	Buffer	**Reeds**	1	0
Australian Reed-warbler	Abundance	Buffer	**Reeds, Samphire, Aquatic Herbs>1m, Open Water, Mudflat, Aquatic Ferns**	6	0
	Occupancy	2 ha	**Reeds, (Aquatic Herbs>1m), Lignum, (Aquatic Ferns), (Max Water Level)**, Month	6	0
Australian Spotted Crake	Abundance	Buffer	**Reeds, Lignum, Open Water, Grasses, Month**	5	1
	Occupancy	Buffer	**Reeds, Lignum, Month**	3	1
Golden-headed Cisticola	Abundance	Buffer	**Sedges>1m, Samphire, Aquatic Herbs<1m**, Aquatic Herbs>1m, Lignum, Aquatic Ferns, % inundated, **Min Water Level, Month**	9	0
	Occupancy	Buffer	Aquatic Ferns	1	1
Little Grassbird	Abundance	2 ha	**Reeds, Lignum,% inundated,** Month	4	1
	Occupancy	2 ha	**Reeds, Aquatic Herbs<1m, Lignum,% inundated,** Month	5	1
Purple Swamphen	Abundance	2 ha	**Reeds, Sedges>1m, Aquatic Herbs<1m,** Aquatic Herbs>1m**, Lignum, Open Water, Mudflat, Aquatic Ferns, Grasses, % inundated,** Month	11	1
	Occupancy	Buffer	Sedges<1m**, Aquatic Ferns, Max Water Level**, Month	4	1
Spotless Crake	Abundance	Buffer	**Reeds, Aquatic Herbs>1m, % inundated,** Min Water Level**, Month**	5	0
	Occupancy	2 ha	**Reeds, Aquatic Herbs<1m, (Lignum), (Month)**	4	2
Latham's Snipe	Abundance	2 ha	*Full model, no significant parameters*	14	0
	Occupancy	2 ha	Reeds,**Samphire**	2	1



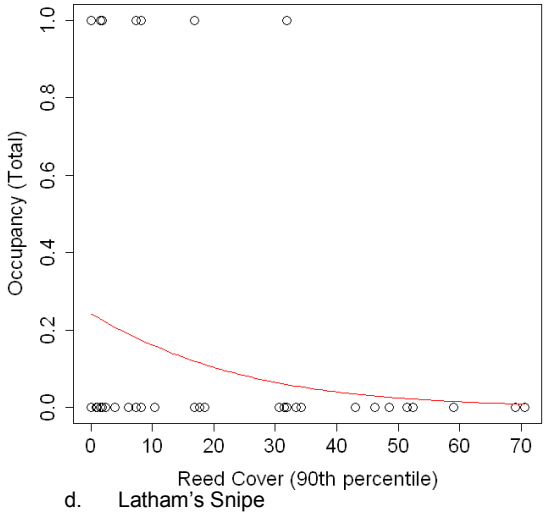
a. Australasian Bittern



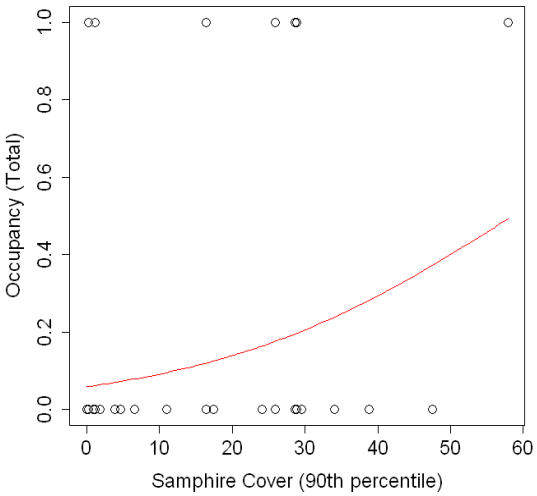
b. Purple Swamphen



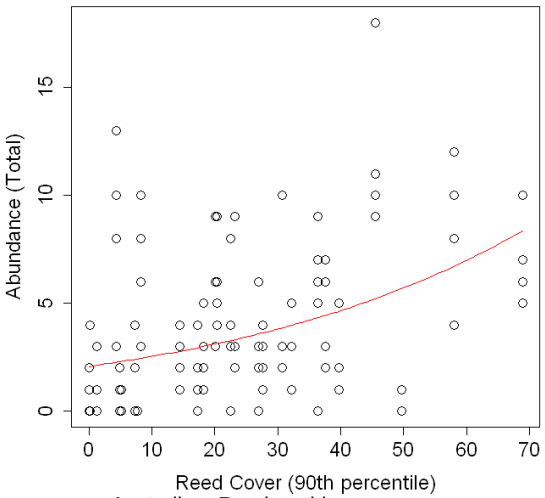
c. Golden-headed Cisticola



d. Latham's Snipe



e. Latham's Snipe



e. Australian Reed-warbler

Figure 3. The relationship between a) reed cover (buffer zone) and Australasian Bittern abundance, b)aquatic herb cover and Purple Swamphen abundance, c) tall sedge (>1m) cover and Golden-headed Cisticola abundance, d) reed cover (2 ha plot) and Latham's Snipe site occupancy, e) samphire cover and Latham's Snipe Occupancy, and f) reed cover (buffer zone) and Australian Reed-warbler abundance. Occupancy refers to whether a species was detected at the site at each visit (0=no, 1=yes), whereas Abundance refers to the total number of each species detected per site per visit.

Colonial-nesting waterbirds

2012-2013 Aerial Surveys

Colonial-nesting waterbirds were observed to breed at 7 main locations in the Lakes (Figure 2; Table 7) and on three different islands in the Southern Coorong(Figure 3; Table 7).Crested Terns had the largest breeding colony in the CLMM, with 4050 active nests recorded on Pelican Island (Coorong) between November and December (Table 7). Crested terns have been observed breeding in large numbers on Cattle Island in the years preceding this study (P. Gillen 2013 pers. comm.). More than 2000 active Australian Pelican nests were recorded across three islands in the 'Pelican Island' group of the Southern Coorong. Mellor and North Pelican Islands contained active Pelican colonies between November and February, whereas Pelican Island was only colonised after Crested and Caspian Terns had left (January or early February). Fairy Tern colonies were not detected using the aerial survey method, even when the aircraft flew over known (and currently active) nesting sites to search for evidence of activity. Silver Gull breeding colonies were also not observed in these surveys, although they regularly breed on islands in the Southern Coorong (Paton 2010). This species can breed outside of the Spring/Summer period surveyed in this study (D. Paton (University of Adelaide) 2013 pers. comm.).

Table 7. Location and number of active nests (nests with incubating/brooding parent), non-nesting birds and chicks/juveniles observed in the Lakes and Coorong from October 2012 to February 2013. Counts represent cumulative numbers observed over three surveys.

Species	Area	Wetland/island	Active nests	Non-nesting Birds	Chicks/ Juveniles
Crested Tern	Coorong	Pelican Island	4050	800	0
Australian Pelican	Coorong	Mellor Island	562	378	155
Australian Pelican	Coorong	North Pelican Island	1361	3505	700
Australian Pelican	Coorong	Pelican Island	247	57	0
Caspian Tern	Coorong	Pelican Island	40	5	0
Black Swan	Lakes	Lake Albert (East)	0	0	10
Black Swan	Lakes	Narrung Narrows (West)	1	0	0
Black Swan	Lakes	Low Point	1	0	0
Pied Cormorant	Lakes	Tolderol	916	430	3
Royal Spoonbill	Lakes	Lake Albert	10	0	0
Straw-necked Ibis	Lakes	Boggy Lake	606	9	0
Straw-necked Ibis	Lakes	Currency Creek	159	0	0
Straw-necked Ibis	Lakes	Lake Albert East	160	0	0
Straw-necked Ibis	Lakes	Tolderol	67	3	0
Straw-necked Ibis	Lakes	unnamed bay, west of Reedy Pt	1032	10	0
Australian White Ibis	Lakes	Boggy Lake	179	28	0
Australian White Ibis	Lakes	Currency Creek	119	0	0
Australian White Ibis	Lakes	Low Point	90	0	0
Australian White Ibis	Lakes	Narrung Narrows	115	0	0
Australian White Ibis	Lakes	Lake Albert East	120	0	0
Australian White Ibis	Lakes	Point Sturt	13	12	0
Australian White Ibis	Lakes	unnamed bay, west of Reedy Pt	64	5	0
		Total	**9912**	**5242**	**868**

More than 2000 active Straw-necked Ibis nests were recorded at five locations in Lakes Alexandrina and Albert. Many of these were ‘mixed’ colonies with Australian White Ibis. Ibis breeding was most prolific in October and December; no Ibis colonies were recorded in January (Appendix 6). Pied Cormorant were first observed with active nests in December, where they formed a large colony (>900 nests) on reedy islands near Tolderol. Swan and Royal Spoonbill were detected in low numbers ≤10 in the lakes (Table 7). However >100 cygnets were observed from the lake edges and barrages between September 2012 and January 2013 by J. O’Connor and G. Kerr, and it is likely that they had finished nesting before the commencement of aerial surveys.

A full description of aerial survey data by date and specific location is provided in Appendix 6.

Comparison of historical and modern waterbird breeding observations.

Aerial surveys detected 8 of the 23 colonial-nesting waterbird species that have been historically recorded breeding in the CLLMM. A summary of historic and modern breeding areas in the lakes and Coorong is shown in Figure 6 and Figure 7 respectively. A literature review of all known breeding records from the area shows that there are many ‘gaps’ in the data. The location, timing, and focal species of waterbird breeding surveys have been inconsistent since they began in 1911 (Table8; Table 9). Some species still appear to have been breeding in similar numbers and locations across all three time periods. For example, Australian Pelican have formed breeding colonies on the Coorong’s Pelican Islands since at least 1911. In all time periods, Pelicans have been observed with up to 1500-2000 active nests or young, which reflect good conditions in at least some of the survey years. Other species with seemingly stable breeding populations include the Caspian Tern, and Australian White Ibis (Table 8; Table 9).

Fairy terns continue to breed on islands and reefs in the Southern Coorong, but in much lower numbers than both the pre-1997 and pre-1955 study periods (Table 8). This likely reflects the reduced population size of the species: from >1300 birds in 1985 to 351 birds in 2012 (O’Connor et al. 2012; Paton and Bailey 2012; Paton and Rogers 2009).

Notably, the thousands of cormorants and ibis, and hundreds of spoonbill and egrets that nested in Pelican Lagoon and Salt Lagoon in the 1960s and 1970s have disappeared. Other species for which there is little information, but appear to have ceased or reduced their once-prolific breeding activity include: Musk Ducks, Pacific Black Ducks, and Black Swans (Table 8;Table 9). A full summary of historical and modern waterbird breeding events is provided in Appendix 3.

Birdlife Australia's Beach-nesting Bird monitoring data from 2010 shows that the entire Younghusband Peninsula beach (Figure 7) also provides important nesting habitat for the following four species: Hooded Plovers (13 nests), Red-capped Plovers (39 nests), Pied Oystercatchers (56 nests) and Sooty Oystercatchers (4 nests) (Appendix 7).Hooded Plovers, Red-capped Plovers and Pied Oystercatchers will also nest on islands and shorelines of the Coorong lagoon (Sutton 1933a; D. Paton Annual Waterbird Census; Sutton 1933b), where their breeding activity is not intensively surveyed.

Table 8.Summary of historical and modern breeding activity in the Coorong. Time periods are indicated as follows: 1=1911-1954, 2=1955-1996, 3=1997-2013. * includes data from this study, ** unusual breeding event in 2006. Minimum and maximum values of nests/breeding pairs or young represent data taken at a single site in a single year.

Species	Location	Time	Period Surveyed	# Years surveyed	Nests or breeding pairs	Young	References
Australian Pelican	Pelican Islands	1	1911-1950	11	48-390	some->2000	(Chapman 1963; Condon and Terrill 1948; Hanks 1929; Hitchcock 1937; Paton 1982; Sutton 1930; Sutton 1933b; White 1918)
Australian Pelican	Pelican Islands	2	1962-1981	4	50-350	>100-1500	(Chapman 1963; Eckert 1965; Marchant and Higgins 1990; Paton 1982)
Australian Pelican	Pelican Islands, Seagull Island and Teal Island	3	2009-2013	6	489-2170*	61-501*	(DENR 2010; D. Paton Annual Waterbird Census; DENR 2011)
Banded Stilt**	Coorong South Lagoon	3	1981-2013	17	>140	120-1,006	(Gosbell and Christie 2006; D. Paton Annual Waterbird Census)
Black Swan	Pelican Islands and Swan Island	1	1918-1935	5	14-233*	6-?	(Condon and Terrill 1948; Hanks 1929; Sutton 1930; Sutton 1933b; White 1918)
Caspian Tern	Wild Dog Islands	1	1932	1	48	?	(Sutton 1933b)
Caspian Tern	Stonywell Island, Teal Island	2	1964-1976	8	10-120	>9-116	(Copley 1996; Paton 1982)
Caspian Tern	Pelican Island, Teal Island, various unnamed reefs	3	2007-2013	2	6-40*	2-9	1997 Fairy Tern Survey (A. Partridge); D. Paton Annual Waterbird Census
Cormorant sp.	Pelican Islands	1	1935	1	12	?	(Condon and Terrill 1948)
Crested Tern	Halfway and.Stonywell Islands	2	1964-1992	32	500-3000	556-3865	(Copley 1996)
Crested Tern	North Pelican, West Cattle, Teal and Seagull Islands	3	1997-2013	14	914-4050*	704-3117	1997 Fairy Tern Survey (A. Partridge); D. Paton Annual Waterbird Census
Fairy Tern	Wild Dog Islands, Trevarrow's Island	1	1929-1937	3	25->372	?	(Hitchcock 1937; Paton 1982; Sutton 1930; Sutton 1933b)
Fairy Tern	Stonywell, Bluff, Halfway & Pelican Islands. Various unnamed islets & reefs, Murray Mouth.	2	1965-1986	11	20-200	42-221	(Paton 1982)
Fairy Tern	Teal Island, Unnamed Island near Cattle Island, various unnamed reefs, Murray Mouth	3	1997-2013	8	11-150	2-51	(DENR 2012; Paton 2003; C. Manning fairy Tern Survey; Paton and Bailey 2012; Paton and Rogers 2009)
Pied Cormorant	Pelican Islands, unnamed islet near Policeman's Point	1	1928-1937	5	17-125	Some-many	(Condon and Terrill 1948; Copley 1996; Hanks 1929; Hitchcock 1937; Sutton 1930; Sutton 1933b)
Red-necked Avocet	Coorong South Lagoon	3	2000-2013	13	20-120		D. Paton, Annual Waterbird census
Silver Gull	Pelican and Wild Dog Islands, Goat Island	1	1928-1932	6	22-579	Some	(Hanks 1929; Sutton 1930; Sutton 1931)

Species	Location	Time	Period Surveyed	# Years surveyed	Nests or breeding pairs	Young	References
Silver Gull	Seagull Island, Stonywell Island	2	1964-1968	5	300	Small number-933	(Copley 1996; Ottaway et al. 1988)
Silver Gull	Southern Coorong Islands	3			Hundreds		(Paton 2010; G. Herasingh (Southern Fisherman's Association) 2013 pers. comm.)

Table 9. Summary of historical and modern breeding activity in the Lower Lakes. Time periods are indicated as follows: 1=1911-1954, 2=1955-1996, 3=1997-2013. Values with an asterisk include data from the current study.

Species	Location	Time	Period Surveyed	# Years surveyed	Nests	Young	References
Australian Pelican	Reedy Point, South of Milang	2	1963	1	350	>150	(Chapman 1963; Eckert 1965)
Australian White Ibis	Salt Lagoon Islands and Pelican Lagoon	2	1962-1976	12	50->400	many	(Bonnin 1967; Close et al. 1982)
Australian White Ibis	Lakes Alexandrina and Albert	3	2012-2013	1	700*	-	
Black Swan	Between Milang and Tolderol, Boggy Lake, Tolderol Point, Snake Is.	1	Early 1900s until 1940s	?	Hundreds	?	(Eckert 2000)
Black Swan	Lake Albert, Alexandrina and Goolwa Channel	3	2011-2013	3	Hundreds	>500	(Paton and Bailey 2011)
Caspian Tern	Nalpa (Mulgundawa) Salt Lake, Mundoo Channel	2	1966-1968	2	12-40		(Copley 1996)
Glossy Ibis	Salt Lagoon	2	1962-1971	8	Some-400	?	(Beruldsen 1963; Close et al. 1982)
Great Black Cormorant	Salt Lagoon and Pelican Lagoon	2	1962-1979	1	10-10,000	>26->80	(Bonnin 1967; Close et al. 1982)
Great Egret	Salt Lagoon	2	1962-1974	8	>50-100	60->140	(Close et al. 1982)
Little Black Cormorant	Salt Lagoon and Pelican Lagoon	2	1962-1979	15	50-4000	>20->200	(Bonnin 1967; Close et al. 1982)
Little Pied Cormorant	Mundoo Island	1	1931	1	45	?	(Sutton 1932)
Little Pied Cormorant	Salt Lagoon and Pelican Lagoon	2	1962-1976	13	50-2000	>100->340	(Bonnin 1967; Close et al. 1982)
Musk Duck	Lake Alexandrina	1-2	Until 1960's	?	hundreds	?	(Paton et al. 2009b)
Nankeen Night Heron	Pelican Lagoon	2	1966	1	50	?	(Bonnin 1967)
Pacific Black Duck	Lake Alexandrina	1-2	Until 1960's	?	hundreds	?	(Eckert 2000)
Pied Cormorant	Salt Lagoon	2	1963-1979	12	50-6000	Many->34	(Bonnin 1967; Close et al. 1982)
Pied Cormorant	Lake Alexandrina	3	2011-2013	3	420-916*	?	(Paton et al. 2011)
Royal Spoonbill	Salt Lagoon	2	1962-1974	11	Few-100	?	(Bonnin 1967; Close et al. 1982)
Royal Spoonbill	Lake Albert	3	2013	1	10*	?	(Bonnin 1967; Close et al. 1982)
Silver Gull	Mulgundawa Salt Lake	2-3	?	?	hundreds		(Eckert 2000)
Straw-necked Ibis	Salt Lagoon and Pelican Lagoon	2	1962-1976+	10	Some-1000 or 'up to 10,000'	many	(Beruldsen 1963; Bonnin 1967; Close et al. 1982)
Straw-necked Ibis	Lake Alexadrina and Albert	3	2011-2013+	2	160-2162*	?	(Paton et al. 2011)
White Egret sp	Pelican Lagoon	2	1966	1	60	?	(Bonnin 1967)
White-faced Heron	Mundoo Island	1	1931	1	10	?	(Sutton 1932)
Yellow-billed Spoonbill	Salt Lagoon and Pelican Lagoon	2	1962-1979	11	20->100	some	(Beruldsen 1963; Bonnin 1967; Close et al. 1982)

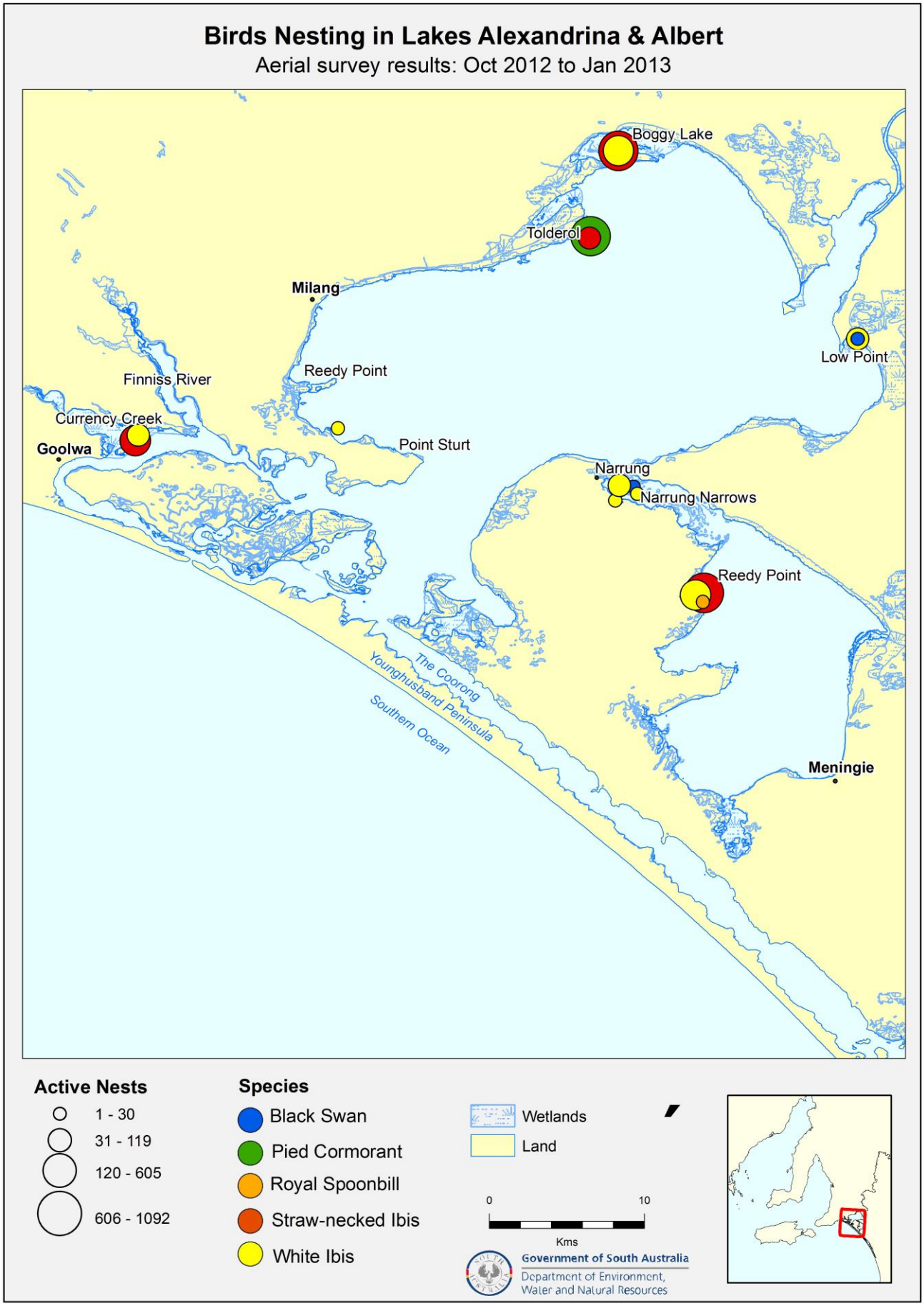


Figure 4. Distribution and abundance of waterbird breeding activity (active nests) in the Lower Lakes, October 2012- January 2013

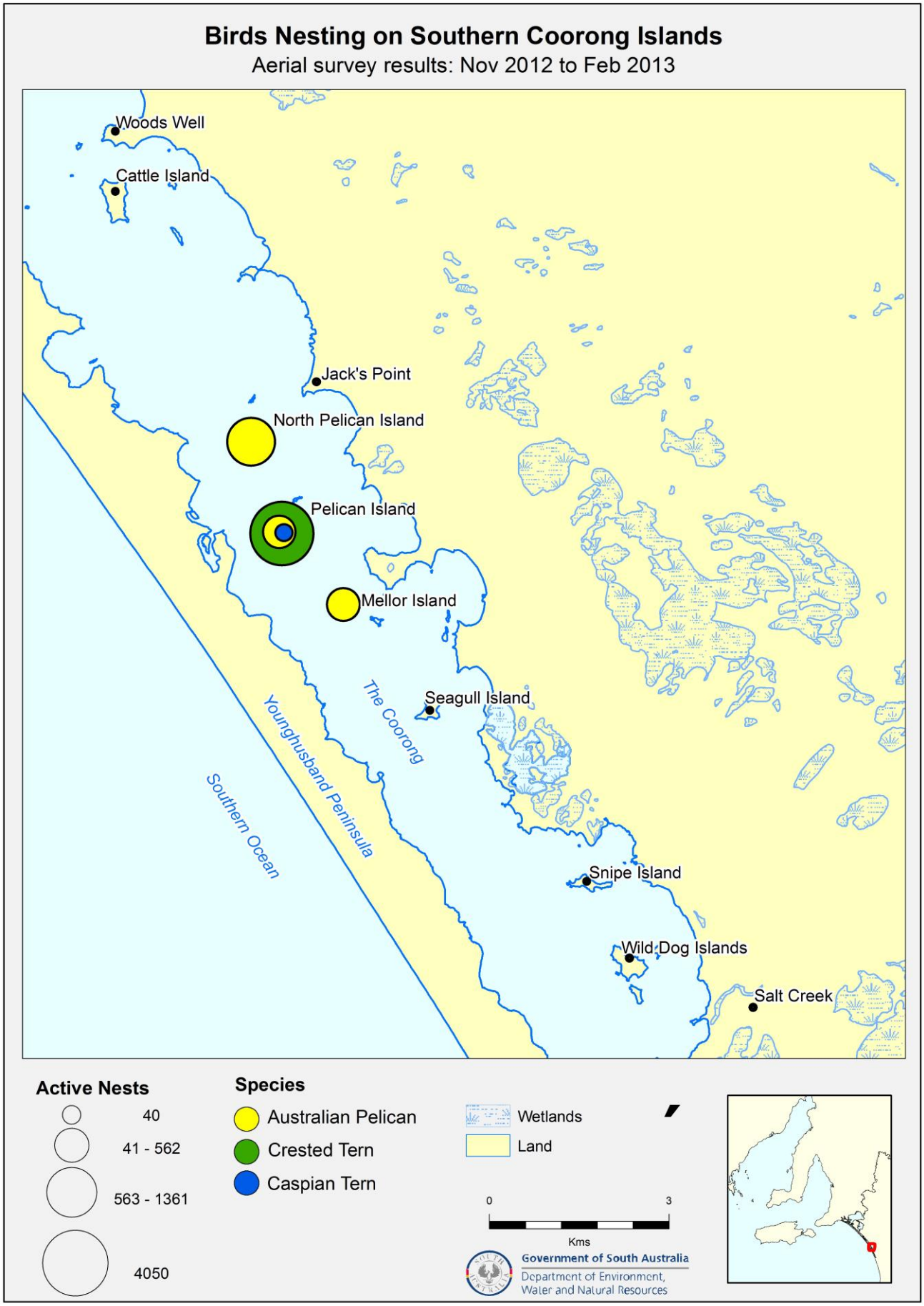


Figure 5. Distribution and abundance of waterbird breeding activity (active nests) in the Coorong, November 2012- February 2013

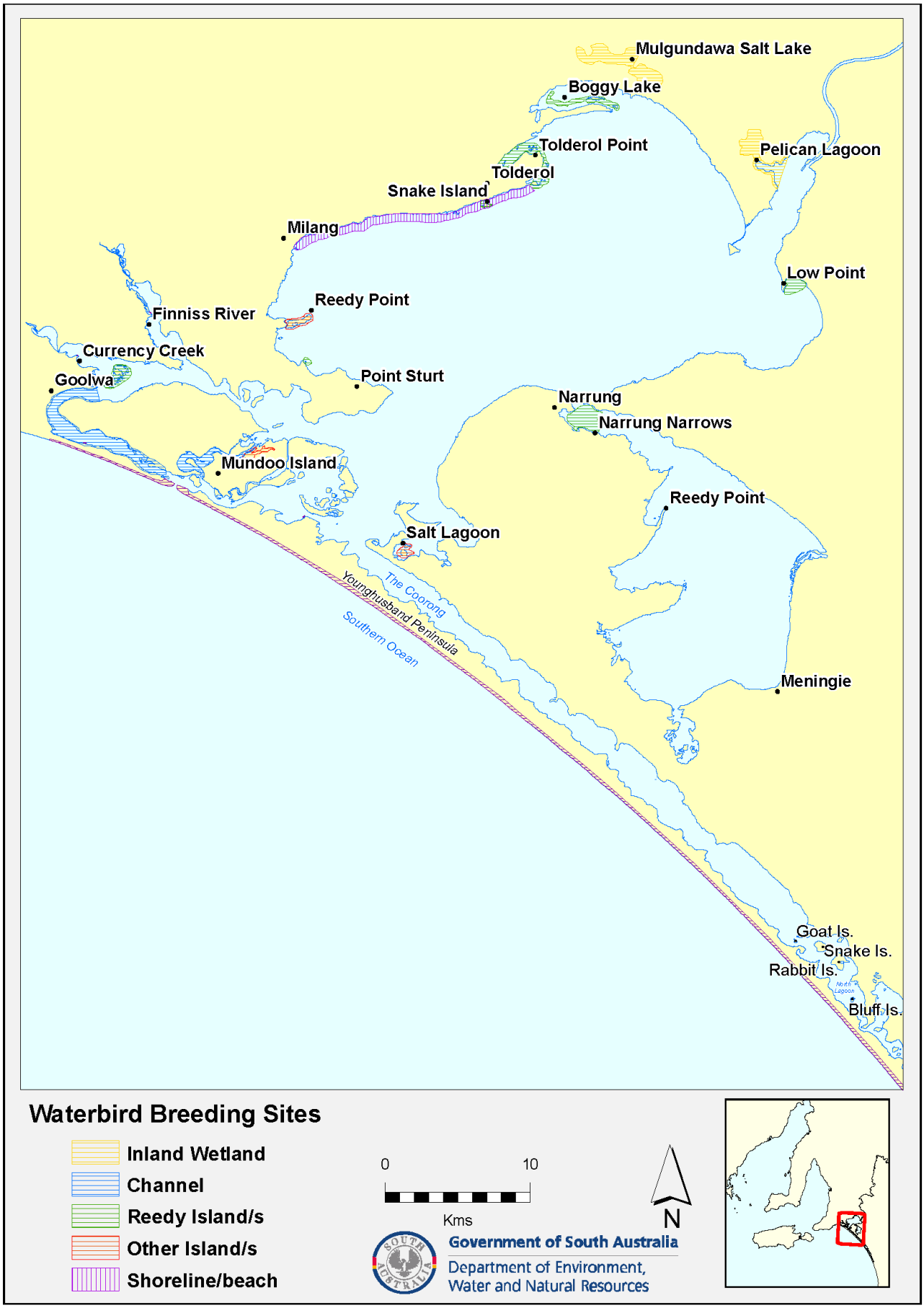


Figure 6. Areas identified as being historic or modern waterbird breeding locations in Lakes Alexandrina, Albert and surrounds

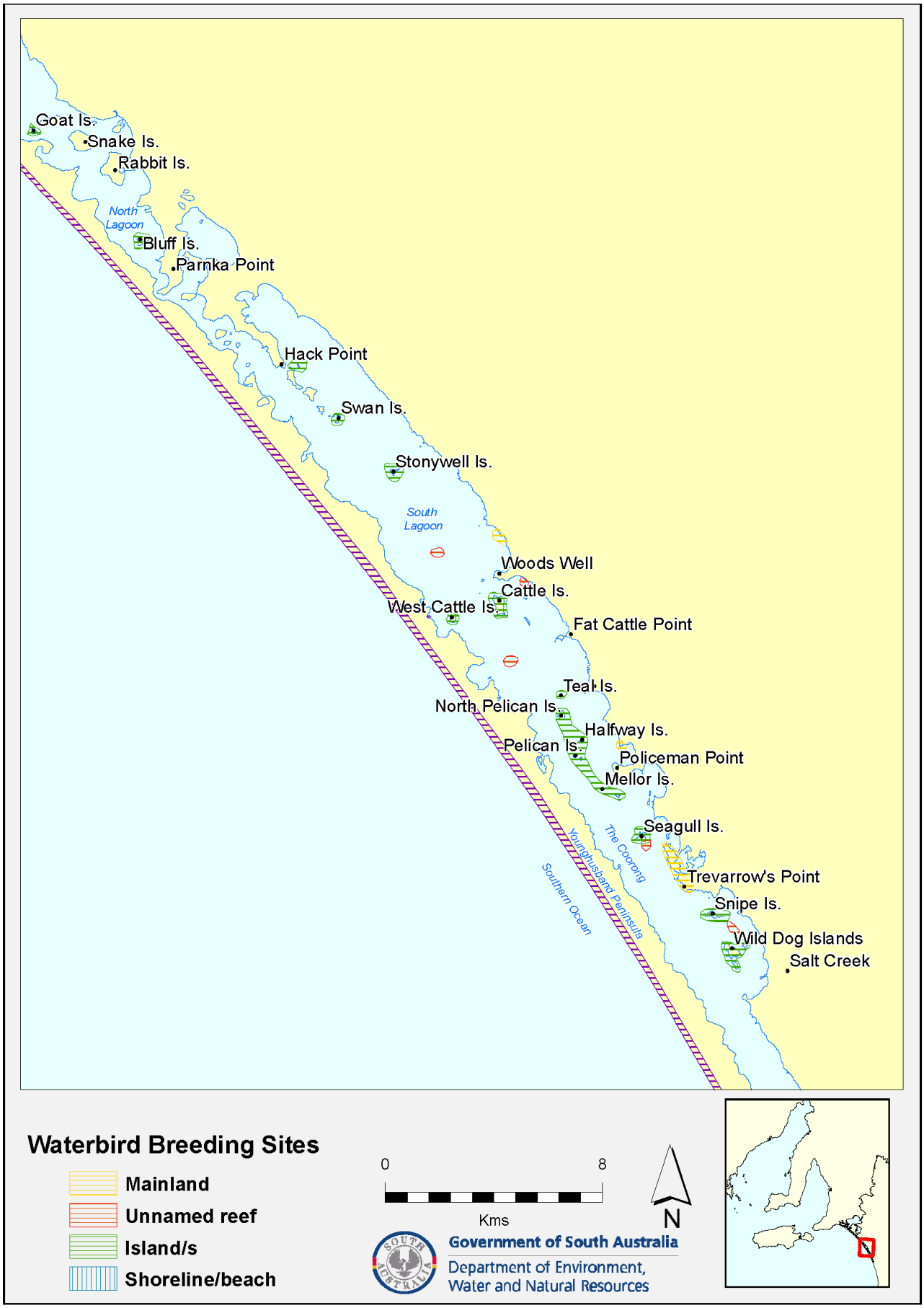


Figure 7. Areas identified as being historic or modern waterbird breeding locations in the Coorong

Discussion

Cryptic Birds

This study shows that the Lower Lakes provide significant habitat for cryptic bird species. Almost 2000 observations of 13 different cryptic bird species were recorded during this study. The occupancy and abundance of cryptic birds at the 15 surveyed sites followed species-specific patterns that reflect local habitat preferences.

Percentage reed cover had a positive effect on occupancy and abundance for nearly all species, including bitterns, crakes and reed-warblers (during the time period considered in this study). However, increasing reed cover had a negative effect on Latham's Snipe, a species that primarily utilises inundated samphire areas (habitat preferences also discussed in Higgins and Davies 1996; Todd 2000). Species-specific habitat preferences also differed in relation to the homogeneity or heterogeneity of wetland features. For example, the Australasian Bittern and Latham's Snipe appear to prefer relatively homogeneous habitats dominated by reeds or samphire respectively. Other species, such as Australian Reed-warblers, Australian Spotted Crakes and Purple Swamphens used more heterogeneous habitats that include reeds, but also other vegetation types such as sedges, samphire, aquatic herbs, lignum and grasses (the combinations of which differ depending on bird species). Importantly, the analyses show that no two species used the exact same combination of habitat features. Different cryptic species use different wetland types and many may require specific wetland features at a broader landscape scale. These and other species-specific patterns must be considered when interpreting the results of this study in the context of wetland conservation and rehabilitation. This study provides some information on habitat-use and conditions at a local scale, but a greater understanding of the role of CLLMM cryptic bird habitats in the context of the regional populations is still required to be certain about their management needs. Therefore it is recommended that these results be considered in relation to regional (South East South Australian) surveys of cryptic species if and when such data becomes available.

Five bird species were detected in very low numbers (<2% of overall observations), and could not be analysed in relation to site-specific habitat variables. However, cluster analyses of species co-occurrences grouped these species (Lewin's Rail, Little Bittern, Baillon's Crake, Buff-banded Rail and Dusky Moorhen), together with the Australasian Bittern. This grouping suggests that the 5 species may respond to habitat variables in a similar way to that of the Australasian Bittern, and are likely to be strongly associated with reedy habitats. However, these species are likely to be reliant on a broader range of wetland features, within and outside of the CLLMM, and further studies are required in order to identify specific habitat preferences.

Very little breeding activity was observed in this study, despite conducting the surveys in peak breeding season for most species. Many birds were detected by their advertising calls, so it is highly possible that these birds had nests that were too difficult to locate. Australasian Bitterns, for example, are presumed to breed locally, though no nest has ever been found (Eckert 2000). Very few nests of other species, such as the Spotless Crake, Australian Spotted Crake and Lewin's Rail have been recorded in the past 50 years (Eckert 2000). Another explanation for the low rates of nest detection may be that pairing success was low in 2012, possibly as a 'lag' effect of potentially low population numbers from the recent drought. Continued monitoring of these birds may help to detect nesting activity, and therefore the conditions that are required for successful breeding in these species.

Cryptic birds were detected in higher numbers in this survey that in previous surveys of bird distribution and abundance in the lower lakes (Paton and Bailey 2012; Paton et al. 2011; Rogers 2012; Thiessen 2011). It is recommended that the methods of this study be repeated in future cryptic bird surveys of the Lower Lakes. Intensive, repeat surveys of inundated wetland habitats increase the likelihood of detecting these species, and will be useful for detecting future changes in population numbers and/or distributions. Future surveys should be conducted by trained personnel that can competently identify cryptic species by their calls, as the secretive nature of these birds mean that they are rarely seen. Repeat surveys will allow for determination of the effects of changing environmental conditions (water availability and resulting impacts on fringing vegetation) on cryptic bird distribution and abundance. The current survey most likely reflects baseline patterns that may be observed in a relatively 'good' year, due to high lake levels in 2012. Of note, the 20 Australasian Bittern records confirm that CLLMM wetlands provide significant habitat for this endangered species, whose total South Australian population is currently estimated at 26–116 individuals (BirdLife International 2012a). However, considering the maximum number of Australasian Bitterns calling from each site per survey, it is estimated that 12 individual birds were recorded during this survey (some observed on multiple occasions). The three records for the Little Bittern are also significant, as the only other confirmed observation of this species in the CLLMM is from Tolderol in 1998 (Birdlife Atlas data, (but see Eckert 2000)). This survey focussed on cryptic bird distribution and abundance at 15 selected wetland sites and does not represent the total abundances or distributions of these species across the whole CLLMM region. Cryptic bird species are likely to utilise other Lower Lakes habitats in particular, where wetlands with similar hydrological and vegetation characteristics can be found.

The results of this study should also be considered in relation to discussions concerning the manipulation of water delivery to Lower Lakes wetlands. The data provides a snapshot of current numbers that can be used to assess future management actions. In particular, two of the surveyed sites: Milang Snipe Sanctuary and Tolderol, are current candidates for experimental trials of increased water delivery and/or manipulation of vegetation features. Water delivery experiments to

the Milang Snipe Sanctuary should consider the impacts of water levels on Latham's Snipe. This species was observed more frequently, and in higher numbers at this site than any of the other 14 surveyed wetlands. The current work indicates that Latham's Snipe prefer the Northern Basin of the Milang Snipe Sanctuary, which was inundated for longer than the Southern Basin. It is recommended that water should be experimentally delivered to the Southern Basin in order to investigate potential changes in the abundance and distribution of snipe across the whole wetland. The Southern Basin covers an area that is slightly larger than the 2 ha survey plot. On-site water levels should also not exceed those at which snipe are able to forage (Latham's Snipe can presumably forage in water that is up to 80mm deep based on bill size ranges of 61.0-80.0mm (Higgins and Davies 1996)). Current discussions around the manipulation of water delivery and vegetation at Tolderol should also consider the potential impacts of these management actions on rare and endangered species such as the Australasian Bittern, Lewin's Rail and the Spotless Crake, which were detected at the site. Proposed manipulation of reed cover at the site must consider the dependency of these species on reedy habitats. The endangered Australasian Bittern, in particular, was usually detected in dense reed beds, therefore some of this habitat must be retained in order to conserve bittern habitat at the site.

The results of this study suggest that habitat features used by cryptic birds differ from those of other wetland species such as waterfowl or migratory shorebirds. Thus management and restoration objectives for those species are likely to be inadequate for maintaining cryptic bird habitat. This highlights the need for diverse and complementary wetland habitats that support a range of different waterbird communities. Management plans for cryptic bird species should focus on the impacts of water delivery to wetlands dominated by vegetation such as reeds, sedges, samphire, aquatic herbs and lignum. Cryptic wetland birds are strongly associated with local wetland features, and are likely to be highly sensitive to changes in water levels that result in loss of fringing habitat. Revegetation plans should aim to improve the availability of these vegetation types for the purpose of maintaining important cryptic bird habitats in the Lower Lakes. However, revegetation programs should complement (and not replace) appropriate water delivery regimes. It is recommended that revegetation efforts be compared with control sites using manipulative (adaptive management) experiments that consider bird numbers and community composition at each site.

Colonial-nesting waterbirds

Coorong and Lower lakes habitats provide significant and regular nesting habitat for thousands of colonial-nesting waterbirds. Over 4000 active nests of 8 waterbird species were detected in aerial surveys. Most modern nesting activity were observed on reedy islands in the Lower Lakes and islands with little vegetation in the Southern Coorong.

Meaningful comparisons of historical and modern waterbird breeding activity were hindered by the lack of regular and consistently sampled monitoring data. For example, there are no known breeding records for common species such as the Straw-necked or Australian White Ibis before the 1960's. More than 2000 ibis nests were observed in 2012, and up to 10,000 ibis nests were recorded annually in the 1960's, so it is likely that these birds also used the system for breeding in the early 1900s. Similarly, 500-4000 Crested Terns have been recorded nesting in the Coorong since the 1960's, and the lack of data beforehand likely reflects the lack of monitoring rather than an absence of breeding. Furthermore, historical data (usually pre-1955) are often qualitative and difficult to interpret, with reports of 'great numbers' or 'many' birds nesting rather than actual count data. Despite these difficulties, some evaluation of the main trends of breeding activity for some species was possible.

Some species, such as the Crested Tern and Australian Pelican appear to have nested in similar numbers and locations for at least the past 50 to 100 years respectively. However, the size and success of each breeding attempt has undoubtedly been affected by natural variation and human impacts across years. For example, pelican fledging success may have been lower in the 1911-1955 time period due to regular 'massacres' of chicks and juveniles by fisherman who incorrectly saw the birds as predators of larger commercial fish (Chapman 1963). Breeding activity by Pelicans, Fairy Terns, and possibly Crested and Caspian Terns was affected by high salinities and reduction of small fish numbers during the drought of the 2000s (Paton 2005; Paton and Rogers 2009). Few, if any Pelicans were breeding in the Coorong between 2003-2005 (Paton 2005), and Fairy Terns had many unsuccessful breeding attempts on Murray Mouth Beaches.

For other species, the abundance and location of waterbird breeding activity has changed across the three time periods considered in this study. For example, hundreds of Glossy Ibis and Musk Duck bred in the lakes until the 1960's, but few if any of these birds have nested in the system since (Close et al. 1982; Eckert 2000; Paton et al. 2009b). Other species, such as Royal Spoonbill and Fairy Tern continue to use similar parts of the system, but in reduced numbers, which likely reflects their reduced population sizes within the system (Paton 2012; Paton et al. 2009a). Notably, the thousands of cormorants and ibis, and hundreds of spoonbill and egrets that nested in Pelican Lagoon and Salt Lagoon in the 1960s and 1970s have disappeared. The reasons for this are unclear, however a loss of suitable nesting trees (e.g. *Melaleuca halmaturorum*) may have reduced the quality of these nesting sites (Close et al. 1982). Similarly, Needles Island (Coorong) was once a regular nesting site for Silver Gulls, but is no longer used because of the proliferation of boxthorn, which now almost completely covers the island (G. Hera-Singh (Southern Fisherman's Association) 2013 pers. comm.). It is recommended that CLLMM revegetation and invasive species control programs consider these, and other, impacts of vegetation loss or invasion on waterbird nesting islands.

The Coorong has been assessed as ‘Critically Endangered’ under newly proposed IUCN ecosystem risk assessment guidelines (Keith et al. 2013). As a result, monitoring of birds that use the Coorong as breeding habitat, particularly southern islands, should be continued. It is only through the collection of long term monitoring datasets that it is possible to detect and respond to ecological changes that may have lasting, and possibly adverse impacts on an ecosystem (for example, the ecological ‘crisis’ caused by drought and over extraction of water in the 2000s (Kingsford et al. 2011; Lester and Fairweather 2009; Paton et al. 2009a). The Coorong is the only South Australian site where the Australian Pelican breeds on an annual basis. The Coorong therefore provides critical breeding habitat for this species when other wetland sites (such as inland salt lakes) are dry and not suitable for nesting. The IUCN red-listed and EPBC Act listed Fairy Tern, as well as Crested Terns and Caspian Terns also breed annually on Coorong Islands. Since the Fairy Tern cannot be easily detected from aerial surveys, it is recommended the continuation of targeted boat based surveys be conducted in order to monitor breeding activity and success.

Biannual surveys of Younghusband Peninsula (BirdLife Australia) show that this coastline also provides significant nesting habitat for beach-nesting birds (non-colonial). Species such as Hooded Plovers and Oystercatchers nest on these beaches (as well as Coorong shorelines and islands) between August and March. The Hooded Plover was recently up graded to “Endangered” on the IUCN RedList, due to its small population size and very low fledging success rates. The declining population trend of this species has resulted from high levels of human disturbance and nest predation (Buick and Paton 1989; Weston and Elgar 2005). The importance of Coorong beaches for the Hooded Plover, and other beach-nesting bird species should therefore be considered when devising management plans that include human use of the site (see also Buick and Paton 1989).

Colonial-nesting waterbirds respond strongly to hydrological conditions, and their breeding activity can be used as a key indicator of wetland status. Large and widespread breeding events typically reflect desirable wetland conditions including: suitable water levels, prey resources and nest site availability. Ongoing surveys of waterbird breeding activity could therefore be used within a larger suite of indicators to determine wetland status and whether management actions are required.

Conclusions

This study presents findings of the first detailed Lower Lakes cryptic bird survey and whole-of-system CLLMM waterbird breeding survey.

The results of the cryptic bird survey represent a significant contribution to our understanding of cryptic bird species, which is currently lacking at both a national and international scale. The CLLMM is well-recognised for its role in providing significant habitat for a diverse waterbird

community, but prior to this study, there was a poor understanding of habitat requirements of cryptic bird species at the site. Increased knowledge of the drivers (habitat features) that influence the abundance and distribution of cryptic birds will inform future management decisions such as water delivery and habitat rehabilitation. Cryptic birds were detected at higher frequency than in other CLLMM bird survey programs, which highlights the need for intensive, targeted searches for these species. Direct evidence of breeding activity (e.g. nests or chicks) was not detected for most cryptic species, however the presence of vocalising individuals (display calls) and nest-building behaviour (individuals seen carrying nesting material), suggests that some breeding activity may have gone undetected.

The results of the waterbird breeding survey show that the CLLMM provides significant breeding habitat for colonial-nesting and shorebird species. Comparisons of modern and historical breeding activity show that the location and intensity of breeding events has changed for some species, but not others. Aerial surveys have proven to be an efficient and cost-effective method to monitor almost all colonial-nesting waterbird activity across the whole CLLMM site, and should be continued in order to assess impacts of changing ecological conditions on waterbird breeding activity.

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Appendices

Appendix 1

Summary of habitat characteristics at each of the 30 survey plots (15 site). Values represent % cover of each habitat feature within the 2 ha plot. Data are also given for the minimum and maximum water depth recorded in each plot (cm) and the % of the 2 ha plot that was covered by water in October.

Site	Plot	Reeds	Sedges <1m	Sedges >1m	Samphire	Aquatic Herbs <1m	Aquatic Herbs >1m	Lignum	Open water	Mudflat (wet)	Aquatic ferns	Grasses <1m	Other	Water min (cm)	Water max (cm)	% inundated
Boggy Creek	A	6.1		10.9	1.8				13.3		28.7	39.1		0	80	40
Boggy Creek	B	31.8	0.7		0.3	18.9			25.3		0.4	22.6		0	80	95
Finniss	A	51.5		13.6	3.9							12.2	18.8	0	80	50
Finniss	B	34.2		32.1	0.9			0.5				7.7	24.6	0	5	60
Goolwa	A	59.1	2.4	0.1				0.5	27.9			10.2		50	125	100
Goolwa	B	52.4							42.1			7.1		0	100	95
Jacobs	A	43.0	0.5		11.0	4.4			8.2		7.0	25.8		0	80	60
Jacobs	B	10.3	0.4						64.6		9.2	15.1	0.4	0	80	90
Kennedy Bay	A	16.8	1.7		25.9				9.1			36.6	9.8	0	50	80
Kennedy Bay	B	17.7	1.0		17.4				36.0			25.3	2.7	0	60	80
Clayton Bay	A	8.2		21.7	16.5	1.4			17.0		1.6	33.8		0	100	95
Clayton Bay	B	7.4		25.0	1.2	8.1			44.7		5.0	9.8		0	100	95
Loveday Bay	A	2.4	0.1		24.1					21.5		42.9	8.8	0	5	30
Loveday Bay	B	18.5	12.0			2.3			19.5		7.0	38.5	2.2	0	20	50
Milang Snipe	A		4.5		57.9			0.7		9.6		18.2	9.1	0	10	20
Milang Snipe	B	1.8	13.2		28.9			5.5		7.2		20.2	23.1	0	5	5
Nalpa	A	70.5							16.3				13.2	50	120	100
Nalpa	B	69.1							28.3				2.7	50	180	100
Narrung Narrows	A	48.5			0.3				15.5		2.0	33.6	0.1	0	120	75
Narrung Narrows	B	30.6							65.4			4.0		10	80	100
Poltalloch	A				38.8			4.0	37.8	0.5		16.2	2.8	0	25	60
Poltalloch	B	1.0	8.3		29.5				23.4			28.0	9.7	0	60	50
Reedy Point	A	1.5	8.0		28.6	8.0			9.9	16.0		23.4	4.6	0	20	25
Reedy Point	B		3.3		0.3	5.9			86.7			2.6	1.2	0	80	60
Tolderol	A	3.9			47.5	1.1		6.6		18.4		0.1	22.5	0	25	80
Tolderol	B	46.1			34.1			2.2	17.4				0.2	0	100	50
Tookayerta Creek	A	31.5		41.5			3.9			1.5		5.2	16.3	0	80	90
Tookayerta Creek	B	33.4		25.5			7.5		4.0			15.9	13.7	1	30	100
Waltowa	A	0.8	0.6		6.5	2.4		36.4	2.2	1.2		49.8		0	10	5
Waltowa	B	8.2	4.6		4.7			26.0	26.1	4.4		25.9	0.1	0	10	30

Appendix 2

GPS co-ordinates for all corners of each 2 ha plot. Co-ordinate system: GDA 94, Zone: 54, Accuracy: ±4m.

Site	Plot	Easting	Northing	NAME
Boggy Creek	A	6067224	312215.1	BC-A1
Boggy Creek	A	6067178	312455.6	BC-A2
Boggy Creek	A	6067101	312442.7	BC-A3
Boggy Creek	A	6067151	312197.6	BC-A4
Boggy Creek	B	6067171	312040.2	BC-B1
Boggy Creek	B	6066973	312040.8	BC-B2
Boggy Creek	B	6066975	311941.8	BC-B3
Boggy Creek	B	6067175	311941.3	BC-B4
Clayton Bay (Knappsteins)	A	6071279	310016.8	KN-A1
Clayton Bay (Knappsteins)	A	6071111	309910.6	KN-A2
Clayton Bay (Knappsteins)	A	6071166	309827.7	KN-A3
Clayton Bay (Knappsteins)	A	6071331	309934.9	KN-A4
Clayton Bay (Knappsteins)	B	6071204	310132.8	KN-B1
Clayton Bay (Knappsteins)	B	6071034	310026.6	KN-B2
Clayton Bay (Knappsteins)	B	6071086	309944.7	KN-B3
Clayton Bay (Knappsteins)	B	6071255	310048.2	KN-B4
Finniss River	A	6077639	304962.1	FI-A1
Finniss River	A	6077499	305165	FI-A2
Finniss River	A	6077435	305120.1	FI-A3
Finniss River	A	6077576	304916.2	FI-A4
Finniss River	B	6077721	304857.7	FI-B1
Finniss River	B	6077530	304896.4	FI-B2
Finniss River	B	6077507	304798.8	FI-B3
Finniss River	B	6077701	304758.2	FI-B4
Goolwa	A	6066584	299801.6	GW-A1
Goolwa	A	6066760	299892.9	GW-A2
Goolwa	A	6066713	299980.1	GW-A3
Goolwa	A	6066537	299886.1	GW-A4
Goolwa	B	6066596	299788.6	GW-B1
Goolwa	B	6066642	299701.4	GW-B2
Goolwa	B	6066819	299790.9	GW-B3
Goolwa	B	6066771	299879.9	GW-B4
Jacobs	A	6066811	337858.9	JA-A1
Jacobs	A	6066914	338029.3	JA-A2
Jacobs	A	6066828	338078	JA-A3
Jacobs	A	6066726	337908.5	JA-A4
Jacobs	B	6066699	337430	JA-B1
Jacobs	B	6066699	337570.6	JA-B2
Jacobs	B	6066561	337569.5	JA-B3
Jacobs	B	6066559	337431.7	JA-B4
Kennedy Bay	A	6044874	343798.8	KB-A1
Kennedy Bay	A	6044998	343646.4	KB-A2
Kennedy Bay	A	6045074	343709.3	KB-A3
Kennedy Bay	A	6044947	343863.6	KB-A4

Site	Plot	Easting	Northing	NAME
Kennedy Bay	B	6044954	343595.6	KB-B1
Kennedy Bay	B	6045018	343519.4	KB-B2
Kennedy Bay	B	6045169	343646.1	KB-B3
Kennedy Bay	B	6045106	343722.3	KB-B4
Loveday Bay	A	6061774	326473	LB-A1
Loveday Bay	A	6061917	326336	LB-A2
Loveday Bay	A	6061985	326408.2	LB-A3
Loveday Bay	A	6061843	326544.2	LB-A4
Loveday Bay	B	6061637	326764	LB-B1
Loveday Bay	B	6061834	326764.7	LB-B2
Loveday Bay	B	6061834	326861.7	LB-B3
Loveday Bay	B	6061635	326864.6	LB-B4
Milang Snipe Sanctuary	A	6079851	315899.7	MS-A1
Milang Snipe Sanctuary	A	6079837	315976.3	MS-A2
Milang Snipe Sanctuary	A	6079593	315930.4	MS-A3
Milang Snipe Sanctuary	A	6079605	315853.9	MS-A4
Milang Snipe Sanctuary	B	6079596	315807.7	MS-B1
Milang Snipe Sanctuary	B	6079578	315884.4	MS-B2
Milang Snipe Sanctuary	B	6079336	315828.5	MS-B3
Milang Snipe Sanctuary	B	6079353	315753.7	MS-B4
Narrung Narrows	A	6064316	341842.3	NN-A1
Narrung Narrows	A	6064275	341546.5	NN-A2
Narrung Narrows	A	6064206	341559.5	NN-A3
Narrung Narrows	A	6064253	341851.6	NN-A4
Narrung Narrows	B	6064117	341903.8	NN-B1
Narrung Narrows	B	6064224	342067.9	NN-B2
Narrung Narrows	B	6064150	342120	NN-B3
Narrung Narrows	B	6064041	341955	NN-B4
Poltalloch	A	6071640	343348.9	PO-A1
Poltalloch	A	6071840	343335.4	PO-A2
Poltalloch	A	6071843	343430.6	PO-A3
Poltalloch	A	6071651	343443.1	PO-A4
Poltalloch	B	6071446	342824.1	PO-B1
Poltalloch	B	6071337	342663.6	PO-B2
Poltalloch	B	6071417	342606.8	PO-B3
Poltalloch	B	6071525	342771.9	PO-B4
Pomanda Point (Nalpa)	A	6080113	346706.9	NA-A1
Pomanda Point (Nalpa)	A	6080029	346755.6	NA-A2
Pomanda Point (Nalpa)	A	6079932	346581.9	NA-A3
Pomanda Point (Nalpa)	A	6080018	346534.2	NA-A4
Pomanda Point (Nalpa)	B	6079969	346549.5	NA-B1
Pomanda Point (Nalpa)	B	6079779	346608.2	NA-B2
Pomanda Point (Nalpa)	B	6079753	346513.2	NA-B3
Pomanda Point (Nalpa)	B	6079940	346454.6	NA-B4
Reedy Point	A	6074391	314521.7	RP-A1
Reedy Point	A	6074429	314588.1	RP-A2
Reedy Point	A	6074212	314708.9	RP-A3
Reedy Point	A	6074179	314639.6	RP-A4
Reedy Point	B	6074494	314319.9	RP-B1

Site	Plot	Easting	Northing	NAME
Reedy Point	B	6074719	314217.1	RP-B2
Reedy Point	B	6074752	314286.4	RP-B3
Reedy Point	B	6074526	314390	RP-B4
Tolderol	A	6083810	331855.6	TO-A1
Tolderol	A	6083827	331781.7	TO-A2
Tolderol	A	6084066	331835.4	TO-A3
Tolderol	A	6084051	331910.2	TO-A4
Tolderol	B	6083937	332071.3	TO-B1
Tolderol	B	6083938	332006.8	TO-B2
Tolderol	B	6084236	332006.7	TO-B3
Tolderol	B	6084236	332071.2	TO-B4
Tookayerta Creek	A	6078840	300305.1	TY-A1
Tookayerta Creek	A	6078753	300258.9	TY-A2
Tookayerta Creek	A	6078842	300084.3	TY-A3
Tookayerta Creek	A	6078930	300126.9	TY-A4
Tookayerta Creek	B	6078689	300481.1	TY-B1
Tookayerta Creek	B	6078617	300415.5	TY-B2
Tookayerta Creek	B	6078745	300270	TY-B3
Tookayerta Creek	B	6078821	300330.1	TY-B4
Waltowa	A	6058146	352705.2	WT-A1
Waltowa	A	6058083	352514.2	WT-A2
Waltowa	A	6058175	352487.3	WT-A3
Waltowa	A	6058237	352673.8	WT-A4
Waltowa	B	6058376	352908.9	WT-B1
Waltowa	B	6058438	352721.3	WT-B2
Waltowa	B	6058532	352754.1	WT-B3
Waltowa	B	6058467	352940	WT-B4

Appendix 3

Summary of waterbird breeding records in the Coorong and Lower Lakes (1911-2013). Time periods are indicated as follows: 1=1911-1954, 2=1955-1996, 3=1997-2013.

Time	Species	Area	Location	Year	# Nests	# Breeding pairs	# Young	Reference
1	Australian Pelican	Coorong (South)	Pelican Islands	1910 or 1911			2000	Paton 1982
1	Australian Pelican	Coorong (South)	Pelican Island	1911?		>1000	2000	Chapman 1963
1	Australian Pelican	Coorong (South)	Islands	1918	Many	Many	Hundreds	White, 1918
1	Australian Pelican	Coorong (South)	Pelican Islands	1920-21			700-800	Paton 1982
1	Australian Pelican	Coorong (South)	Pelican Islands	1927	great numbers			Paton 1982
1	Australian Pelican	Coorong (South)	Unknown Pelican Island	1928	200	268		Hanks, 1929
1	Australian Pelican	Coorong (South)	Unknown Pelican Island	1928	68			Hanks, 1929
1	Australian Pelican	Coorong (South)	Halfway or Pelican Island	1929	Scattered		some	Sutton 1930
1	Australian Pelican	Coorong (South)	Islands	1929	>200	>400	Some	Sutton 1930
1	Australian Pelican	Coorong (South)	North Pelican island?	1929	200			Sutton 1930
1	Australian Pelican	Coorong (South)	Islands	1932	300	300		Sutton, 1933a
1	Australian Pelican	Coorong (South)	Unknown Pelican Island 1	1935	390	778	>200	Condon & Terrill 1948
1	Australian Pelican	Coorong (South)	Unknown Pelican Island 2	1935	340		37	Condon & Terrill 1948
1	Australian Pelican	Coorong (South)	Unknown Pelican Island 3	1935	48		?	Condon & Terrill 1948
1	Australian Pelican	Coorong (South)	North Pelican island	1937	>300	>300	Many	Hitchcock, 1937
1	Australian Pelican	Coorong (South)	Mellor Island	1950	300	300	Many	Chapman 1963
2	Australian Pelican	Lake Alexandrina	3km south of Bremer River mouth	late 1950s	hundreds	hundreds		Eckert, 2000
2	Australian Pelican	Coorong (South)	Mellor Island	1958	100	100	?	Chapman 1963
2	Australian Pelican	Coorong (South)	Mellor Island	1962	200	250		Chapman 1963
2	Australian Pelican	Coorong (South)	Pelican Island	1962	50		>100	Chapman 1963
2	Australian Pelican	Lake Alexandrina	Reedy Point, South of Milang	1963	350	350	>150	Eckert, 1965
2	Australian Pelican	Lake Alexandrina		1963	300			Chapman 1963
2	Australian Pelican	Coorong (South)	Pelican Islands	1965			1500	Paton 1982
2	Australian Pelican	Coorong		1981	Many	Many		HANZAB
3	Australian Pelican	Coorong (South)	Pelican Islands	2006			100	DENR Pelican Monitoring
3	Australian Pelican	Coorong (South)	North Pelican Island	2009/10	>552	552	>61	DENR Pelican Monitoring
3	Australian Pelican	Coorong (South)	Teal Island	2010	26	26	19	DENR Pelican Monitoring

Time	Species	Area	Location	Year	# Nests	# Breeding pairs	# Young	Reference
3	Australian Pelican	Coorong (South)	North Pelican Island	2010/11	264	264	221	DENR Pelican Monitoring
3	Australian Pelican	Coorong (South)	Pelican Island	2010/11	47	47	72	DENR Pelican Monitoring
3	Australian Pelican	Coorong (South)	Pelican Islands	2010/11	264	264	>221	DENR Pelican Monitoring
3	Australian Pelican	Coorong (South)	Seagull Island	2010/11	152	152	189	DENR Pelican Monitoring
3	Australian Pelican	Coorong (South)	North Pelican Island	2013			1675	D. Paton Annual Waterbird Census
3	Australian Pelican	Coorong (South)	Pelican Island	2013			263	D. Paton Annual Waterbird Census
2	Australian White Ibis	Lake Alexandrina	Salt Lagoon Islands	1962	many			Close et al. 1982
2	Australian White Ibis	Lake Alexandrina	Salt Lagoon Islands	1963	>100		Observed	Beruldsen, 1963
2	Australian White Ibis	Lake Alexandrina	Salt Lagoon Islands	1964		80 pairs		Close et al. 1982
2	Australian White Ibis	Lake Alexandrina	Salt Lagoon Islands	1965	50			Close et al. 1982
2	Australian White Ibis	Lake Alexandrina	Pelican Lagoon	1966	100		?	Bonnin, 1967
2	Australian White Ibis	Lake Alexandrina	Salt Lagoon Islands	1966	50			Close et al. 1982
2	Australian White Ibis	Lake Alexandrina	Salt Lagoon Islands	1967			many	Close et al. 1982
2	Australian White Ibis	Lake Alexandrina	Salt Lagoon Islands	1969	many			Close et al. 1982
2	Australian White Ibis	Lake Alexandrina	Salt Lagoon Islands	1971	some			Close et al. 1982
2	Australian White Ibis	Lake Alexandrina	Salt Lagoon Islands	1972	>400			Close et al. 1982
2	Australian White Ibis	Lake Alexandrina	Salt Lagoon Islands	1973	some			Close et al. 1982
2	Australian White Ibis	Lake Alexandrina	Salt Lagoon Islands	1974	some			Close et al. 1982
2	Australian White Ibis	Lake Alexandrina	Salt Lagoon Islands	1976		50 pairs		Close et al. 1982
3	Banded Stilt	Coorong (South)		2006	>140		1006	Gosbell& Christie, 2006
3	Banded Stilt	Coorong (South)	South of Wood's Well	2006			120	D. Paton Annual Waterbird Census
3	Banded Stilt	Coorong (South)	Near Policeman's Point	2006			11	D. Paton Annual Waterbird Census
3	Banded Stilt	Coorong (South)	Seagull Island	2006			15	D. Paton Annual Waterbird Census
3	Banded Stilt	Coorong (South)	Reef South of Mellor Island	2006			100	D. Paton Annual Waterbird Census
2	Black Cormorant	Lake Alexandrina	Pelican Lagoon	1966	10000		Many	Bonnin, 1967
1	Black Swan	Lake Alexandrina	Between Milang and Tolderol	Early 1900s	hundreds			Eckert, 2000
1	Black Swan	Coorong (South)	Swan Island	1918	dozens	dozens		White, 1918
1	Black Swan	Coorong (South)	Unknown Pelican Island	1928	14	14		Hanks, 1929
1	Black Swan	Coorong (South)	Halfway or Pelican Island	1929	14	14	0	Sutton 1930
1	Black Swan	Coorong (South)	Swan and North Pelican Island.	1932	233	233		Sutton, 1933a Inspection…
1	Black Swan	Coorong (South)	Unknown Pelican Island 2	1935	43	43	6	Condon & Terrill 1948
1	Black Swan	Lake Alexandrina	Boggy Lake, Tolderol Point and Snake Island	until 1940s	hundreds			Eckert, 2000

Time	Species	Area	Location	Year	# Nests	# Breeding pairs	# Young	Reference
3	Black Swan	Lakes	Lake Alexandrina, Albert and Goolwa Channel	2011			>500	D. Paton Annual Waterbird Census
1	Caspian Tern	Coorong (South)	Islands	1932	48	48		Sutton, 1933a
1	Caspian Tern	Coorong (South)	Wild Dog Islands	1932	>30			Paton 1982
2	Caspian Tern	Goolwa	Mundoo Channel	1951		40		Copley 1996
2	Caspian Tern	Coorong (South)	Stonywell Island	1964			24	Paton 1982
2	Caspian Tern	Coorong (South)	Stonywell Island	1964		30		Copley 1996
2	Caspian Tern	Coorong (South)	Stonywell Island	1965			116	Paton 1982
2	Caspian Tern	Coorong (South)	Stonywell Island	1965		120		Copley 1996
2	Caspian Tern	Lake Alexandrina	Lake Mulgundawa/Nalpa Salt Lake	1966		12		Copley 1996
2	Caspian Tern	Coorong (South)	Stonywell Island	1966			38	Paton 1982
2	Caspian Tern	Coorong (South)	Stonywell Island	1966		20		Copley 1996
2	Caspian Tern	Coorong (South)	Stonywell Island	1967			30	Paton 1982
2	Caspian Tern	Coorong (South)	Stonywell Island	1967		40	some	Copley 1996
2	Caspian Tern	Lake Alexandrina	Lake Mulgundawa/Nalpa Salt Lake	1968		15		Copley 1996
2	Caspian Tern	Coorong (South)	Stonywell Island	1968			>10	Paton 1982
2	Caspian Tern	Coorong (South)	Stonywell Island	1968		10		Copley 1996
2	Caspian Tern	Coorong (South)	Stonywell Island	1969			>5	Paton 1982
2	Caspian Tern	Coorong (South)	Stonywell Island	1975			>50	Paton 1982
2	Caspian Tern	Coorong (South)	Stonywell Island	1975		75		Copley 1996
2	Caspian Tern	Coorong (South)	Stonywell Island	1976			>9	Paton 1982
2	Caspian Tern	Coorong (South)	Stonywell Island	1976		20		Copley 1996
3	Caspian Tern	Coorong (South)	Teal Island	1997	6		2	Fairy tern survey (1997, Angela Partridge)
3	Caspian Tern	Coorong (South)	Reef West of West Cattle Island	2013	5		2	D. Paton Annual Waterbird Census
3	Caspian Tern	Coorong (South)	Reef West of Fat Cattle Point	2013	1			D. Paton Annual Waterbird Census
3	Caspian Tern	Coorong (South)	Pelican Island	2013	22		9	D. Paton Annual Waterbird Census
1	Cormorant (unknown sp.)	Coorong (South)	Unknown Pelican Island 1	1935	12		0	Condon & Terrill 1948
2	Crested Tern	Coorong (South)	Stonywell Island	1964-1965		2500	2045	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1965-1966		2000	1608	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1966-1967		3000	1850	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1967-1968		2500-3000	2000	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1968-1969		2500	1275	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1969-1970			1237	Copley 1996

Time	Species	Area	Location	Year	# Nests	# Breeding pairs	# Young	Reference
2	Crested Tern	Coorong (South)	Stonywell Island	1970-1971			1200	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1971-1972			2191	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1973-1974			1346	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1974-1975			2610	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1975-1976			1950	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1976-1977			1760	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1978-1979			1600	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1979-1980			1200	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1981-1982			899	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1982-1983			1000	Copley 1996
2	Crested Tern	Coorong (South)	Stonywell Island	1983-1984			2676	Copley 1996
2	Crested Tern	Coorong (South)	Halfway Island	1985-86			3865	Copley 1996
3	Crested Tern	Coorong (South)	North Pelican Island	1997	414		0	Fairy tern survey (1997, Angela Partridge)
3	Crested Tern	Coorong (South)	North Pelican Island	1997	414			Fairy tern survey (1997, Angela Partridge)
3	Crested Tern	Coorong (South)	Seagull Island	1997	500	656	0	Fairy tern survey (1997, Angela Partridge)
3	Crested Tern	Coorong (South)	Seagull Island	1997	500		556	Fairy tern survey (1997, Angela Partridge)
3	Crested Tern	Coorong (South)	Pelican Island	2003			704	D. Paton Annual Waterbird Census
3	Crested Tern	Coorong (South)	West Cattle Island	2009			1680	D. Paton Annual Waterbird Census
3	Crested Tern	Coorong (South)	Teal Island	2009			1590	D. Paton Annual Waterbird Census
3	Crested Tern	Coorong (South)	West Cattle Island	2012		3330		D. Paton Annual Waterbird Census
3	Crested Tern	Coorong (South)	Pelican Island	2013	50		1100	D. Paton Annual Waterbird Census
1	Fairy Tern	Coorong (South)	Wild Dog Islands	1929	25			Sutton 1930
1	Fairy Tern	Coorong (South)	Wild Dog Islands	1932	195			Sutton, 1933a
1	Fairy Tern	Coorong (South)	Wild Dog Islands	1932	>167			Paton 1982
1	Fairy Tern	Coorong (South)	Trevarrow's Island	1937	62		24	Hitchcock, 1937
1	Fairy Tern	Coorong (South)	Trevarrow's Island	1937	25			Paton 1982
2	Fairy Tern	Coorong (South)	Bluff Island	1965		100	157	Copley 1996
2	Fairy Tern	Coorong (South)	Stonywell Island	1965			157	Paton 1982
2	Fairy Tern	Coorong (South)	Stonywell Island	1966		90	160	Copley 1998
2	Fairy Tern	Coorong (South)	Bluff Island	1967				Copley 1996
2	Fairy Tern	Coorong (South)	Stonywell Island	1968			221	Paton 1982
2	Fairy Tern	Coorong (South)	Island near Hack Point	1968-69	100			Paton 1982
2	Fairy Tern	Coorong (South)	Murray Mouth	1969		colony		Copley 1996

Time	Species	Area	Location	Year	# Nests	# Breeding pairs	# Young	Reference
2	Fairy Tern	Coorong (South)	Stonywell Island	1969		200	221	Copley 1996
2	Fairy Tern	Coorong (South)	Bluff Island	1974			174	Paton 1982
2	Fairy Tern	Coorong (South)	islet 4km NW Woods Well	1977	35			Copley 1996
2	Fairy Tern	Coorong (South)	Halfway Island	1985	2	60	42	Copley 1996
2	Fairy Tern	Coorong (South)	Pelican Island	1985		100	110	Copley 1996
2	Fairy Tern	Coorong (South)	Halfway Island	1986			42	Copley 1996
3	Fairy Tern	Coorong (South)	Seagull Island (reef south of)	1997	11		2	Fairy tern survey (1997, Angela Partridge)
3	Fairy Tern	Coorong (South)	Snipe Island (reef south of)	1997	112		2	Fairy tern survey (1997, Angela Partridge)
3	Fairy Tern	Coorong	Island west of Cattle Island	1998	colony			Paton 2003
3	Fairy Tern	Coorong	Cow Island	1999		150		Paton 2003
3	Fairy Tern	Coorong	Exposed reef North of Cattle Island	1999		20		Paton 2003
3	Fairy Tern	Coorong	Exposed reef South of Cattle Island	1999		20		Paton 2003
3	Fairy Tern	Coorong	Exposed reef West of Cattle Island	1999		20		Paton 2003
3	Fairy Tern	Coorong	Teal Island	2000		110-120		Paton 2003
3	Fairy Tern	Coorong	Goat Island (the Needles)	2008/2009		>50		Paton and Rogers 2009
3	Fairy Tern	Coorong	Murray Mouth	2008/2009	?			Paton and Rogers 2009
3	Fairy Tern	Coorong	Goat Island (the Needles)	2009/2010	52			Paton 2003
3	Fairy Tern	Coorong	Reef north of Wild Dog Islands	2010	30		17	C.Manning Fairy Tern Survey
3	Fairy Tern	Coorong	Murray Mouth	2010/11	128		51	C.Manning Fairy Tern Survey
3	Fairy Tern	Coorong (North)	Ocean Beach	2011/12	11			D. Paton Annual Waterbird Census
3	Fairy Tern	Coorong (South)	Teal Island	2011/12	>62		>20	D. Paton Annual Waterbird Census
3	Fairy Tern	Coorong (South)	Unnamed Island near Cattle Island	2011/12	>79		>27	D. Paton Annual Waterbird Census
3	Fairy Tern	Coorong (South)	Unnamed Island near Fat Cattle Point	2011/12	>45		>22	D. Paton Annual Waterbird Census
3	Fairy Tern	Coorong (South)	Reef South of Cattle Island	2013	8			D. Paton Annual Waterbird Census
3	Fairy Tern	Coorong (South)	Reef West of Fat Cattle Point	2013	7			D. Paton Annual Waterbird Census
3	Fairy Tern	Coorong (South)	Teal Island	2013	19		2	D. Paton Annual Waterbird Census
3	Fairy Tern	Coorong (South)	Reef Northwest of Wood's Well	2013	26		35	D. Paton Annual Waterbird Census
2	Glossy Ibis	Lake Alexandrina	Salt Lagoon Islands	1962	>250			Close et al. 1982
2	Glossy Ibis	Lake Alexandrina	Salt Lagoon Islands	1963	250-300			Beruldsen, 1963
2	Glossy Ibis	Lake Alexandrina	Salt Lagoon Islands	1964		12 pairs		Close et al. 1982
2	Glossy Ibis	Lake Alexandrina	Salt Lagoon Islands	1965	400			Close et al. 1982
2	Glossy Ibis	Lake Alexandrina	Salt Lagoon Islands	1966	270>370			Close et al. 1982
2	Glossy Ibis	Lake Alexandrina	Salt Lagoon Islands	1967		some		Close et al. 1982

Time	Species	Area	Location	Year	# Nests	# Breeding pairs	# Young	Reference
2	Glossy Ibis	Lake Alexandrina	Salt Lagoon Islands	1969	some			Close et al. 1982
2	Glossy Ibis	Lake Alexandrina	Salt Lagoon Islands	1971	>11			Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1963	100			Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1964	200			Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1965	50			Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1966	>1000			Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1970	?		>60	Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1971	>1320			Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1972	815			Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1973	10			Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1973	>630			Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1974	>60			Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1975	>19			Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1976	100		>80	Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1977	few			Close et al. 1982
2	Great Cormorant	Lake Alexandrina	Salt Lagoon Islands	1979	>25		>26	Close et al. 1982
2	Great Egret	Lake Alexandrina	Salt Lagoon Islands	1963	>50			Close et al. 1982
2	Great Egret	Lake Alexandrina	Salt Lagoon Islands	1964		50 pairs		Close et al. 1982
2	Great Egret	Lake Alexandrina	Salt Lagoon Islands	1965	>50			Close et al. 1982
2	Great Egret	Lake Alexandrina	Salt Lagoon Islands	1966	100			Close et al. 1982
2	Great Egret	Lake Alexandrina	Salt Lagoon Islands	1967		100 pairs	>140	Close et al. 1982
2	Great Egret	Lake Alexandrina	Salt Lagoon Islands	1968			60	Close et al. 1982
2	Great Egret	Lake Alexandrina	Salt Lagoon Islands	1971	numerous			Close et al. 1982
2	Great Egret	Lake Alexandrina	Salt Lagoon Islands	1974	>50			Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1962	50			Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1962	>50			Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1963	>200			Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1964	>1000			Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1965	50			Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Pelican Lagoon	1966	4000		?	Bonnin, 1967

Time	Species	Area	Location	Year	# Nests	# Breeding pairs	# Young	Reference
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1966	>1400			Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1967	>500			Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1968	?		>50	Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1970	?		>20	Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1971	>2220			Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1972	1400			Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1973	810			Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1974	>300			Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1975	?		>90	Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1976	>50		>200	Close et al. 1982
2	Little Black Cormorant	Lake Alexandrina	Salt Lagoon Islands	1979	>50		>50	Close et al. 1982
1	Little Pied Cormorant	Mundoo Island	Teatree	1931	56			Sutton, 1932
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1962	>200			Close et al. 1982
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1963	Hundreds		Many	Beruldsen, 1963
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1963	"breeding" NE			Close et al. 1982
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1964	100			Close et al. 1982
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1965	50			Close et al. 1982
2	Little Pied Cormorant	Lake Alexandrina	Pelican Lagoon	1966	2000		?	Bonnin, 1967
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1966	>1000			Close et al. 1982
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1967	>500		>100	Close et al. 1982
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1968	?		>340	Close et al. 1982
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1969	?		>185	Close et al. 1982
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1971	200			Close et al. 1982
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1972	100			Close et al. 1982
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1973	>450			Close et al. 1982
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1974	>40			Close et al. 1982
2	Little Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1976	>50			Close et al. 1982
1	Musk Dusk	Lake Alexandrina	Wetlands	Until 1960s	hundreds			Paton et al. 2009

Time	Species	Area	Location	Year	# Nests	# Breeding pairs	# Young	Reference
2	Nankeen Night Heron	Lake Alexandrina	Pelican Lagoon	1966	50		?	Bonnin, 1967
1	Pacific Black Duck	Lake Alexandrina	Wetlands	Until 1960s	hundreds			Eckert, 2000
1	Pied Cormorant	Coorong (South)	Unknown Pelican Island	1928	17			Hanks, 1929
1	Pied Cormorant	Coorong (South)	Halfway or Pelican Island	1929	105		Some	Sutton 1930
1	Pied Cormorant	Coorong (South)	island opposite Policeman's Point	1932	125			Copley 1996
1	Pied Cormorant	Coorong (South)	Islands	1932	24			Sutton, 1933a
1	Pied Cormorant	Coorong (South)	Unknown Pelican Island 2	1935	37		0	Condon & Terrill 1948
1	Pied Cormorant	Coorong (South)	Islet near North Pelican Island	1937	31		Many	Hitchcock, 1937
2	Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1963	"breeding" NE			Close et al. 1982
2	Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1964	50			Close et al. 1982
2	Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1965	50			Close et al. 1982
2	Pied Cormorant	Lake Alexandrina	Pelican Lagoon	1966	6000		Many	Bonnin, 1967
2	Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1966	>500			Close et al. 1982
2	Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1968	?		>34	Close et al. 1982
2	Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1971	>480			Close et al. 1982
2	Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1972	>590			Close et al. 1982
2	Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1973	>190			Close et al. 1982
2	Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1975	>300			Close et al. 1982
2	Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1976	>50		>200	Close et al. 1982
2	Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1977	few			Close et al. 1982
2	Pied Cormorant	Lake Alexandrina	Salt Lagoon Islands	1979	>25			Close et al. 1982
3	Pied Cormorant	Lake Alexandrina		2011	420			D. Paton Annual Waterbird Census
3	Red-necked Avocet	Coorong (South)	Reef West of Mellor Island	2006	69			D. Paton Annual Waterbird Census
3	Red-necked Avocet	Coorong (South)	Reef South of Mellor Island	2006	120			D. Paton Annual Waterbird Census
3	Red-necked Avocet	Coorong (South)	North of Woods Well	2010	20			D. Paton Annual Waterbird Census
2	Royal Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1962		50 pairs		Close et al. 1982
2	Royal Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1963		50 pairs		Close et al. 1982
2	Royal Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1964		50 pairs		Close et al. 1982
2	Royal Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1965		50 pairs		Close et al. 1982
2	Royal Spoonbill	Lake Alexandrina	Pelican Lagoon	1966	100		?	Bonnin, 1967
2	Royal Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1966		50 pairs		Close et al. 1982
2	Royal Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1967		>50 pairs		Close et al. 1982
2	Royal Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1969		>50 pairs		Close et al. 1982

Time	Species	Area	Location	Year	# Nests	# Breeding pairs	# Young	Reference
2	Royal Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1971	many			Close et al. 1982
2	Royal Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1972	few		few	Close et al. 1982
2	Royal Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1973			many	Close et al. 1982
2	Royal Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1974		50 pairs	many	Close et al. 1982
1	Silver Gull	Coorong (South)	Unknown Pelican Island	1928	53			Hanks, 1929
1	Silver Gull	Coorong (South)	Halfway or Pelican Island	1929	22		Some	Sutton 1930
1	Silver Gull	Coorong (South)	Wild Dog Islands	1929	116			Sutton 1930
1	Silver Gull	Coorong (South)	Wild Dog Islands	1929	97			Sutton 1930
1	Silver Gull	Coorong (North)	Goat Island (the Needles)	1930	19		2	Sutton 1931
1	Silver Gull	Coorong (South)	Islands	1932	579			Sutton, 1933a
2	Silver Gull	Coorong (South)	Stonywell Island	1964-67			small number	Copley 1996
2	Silver Gull	Lake Alexandrina	Mulgundawa Salt Lake	1967		1000	,	Ottaway, Carrick and Murray 1988
2	Silver Gull	Lake Alexandrina	Mulgundawa Salt Lake	1968		1000	933	Ottaway, Carrick and Murray 1988
2	Silver Gull	Coorong (South)	Seagull Island	1968		300	94	Ottaway, Carrick and Murray 1988
3	Silver Gull	Lake Alexandrina	Mulgundawa, Nalpa salt lake	annual	numbers			Eckert, 2000
2	Straw-necked Ibis	Lake Alexandrina	Salt Lagoon Islands	1963	>100		Observed	Beruldsen, 1963
2	Straw-necked Ibis	Lake Alexandrina	Salt Lagoon Islands	1964	40 pairs			Close et al. 1982
2	Straw-necked Ibis	Lake Alexandrina	Salt Lagoon Islands	1965	500			Close et al. 1982
2	Straw-necked Ibis	Lake Alexandrina	Pelican Lagoon	1966	1000		Many	Bonnin, 1967
2	Straw-necked Ibis	Lake Alexandrina	Salt Lagoon Islands	1966	numerous			Close et al. 1982
2	Straw-necked Ibis	Lake Alexandrina	Salt Lagoon Islands	1967	>500			Close et al. 1982
2	Straw-necked Ibis	Lake Alexandrina	Salt Lagoon Islands	1969	many			Close et al. 1982
2	Straw-necked Ibis	Lake Alexandrina	Salt Lagoon Islands	1971	many			Close et al. 1982
2	Straw-necked Ibis	Lake Alexandrina	Salt Lagoon Islands	1973	some			Close et al. 1982
2	Straw-necked Ibis	Lake Alexandrina	Salt Lagoon Islands	1974	some			Close et al. 1982
2	Straw-necked Ibis	Lake Alexandrina	Salt Lagoon Islands	1976	100			Close et al. 1982
3	Straw-necked Ibis	Lake Alexandrina		2011	160			D. Paton Annual Waterbird Census
3	Straw-necked Ibis	Lake Alexandrina	Snake Island		up to 10,000			Eckert, 2000
2	White Egret	Lake Alexandrina	Pelican Lagoon	1966	60			Bonnin, 1967
1	White-faced Heron	Mundoo Island	Teatree	1931	10			Sutton, 1932
2	Yellow-billed Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1962		50 pairs		Close et al. 1982

Time	Species	Area	Location	Year	# Nests	# Breeding pairs	# Young	Reference
2	Yellow-billed Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1963	>100		Observed	Beruldsen, 1963
2	Yellow-billed Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1963		50 pairs		Close et al. 1982
2	Yellow-billed Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1964		30 pairs		Close et al. 1982
2	Yellow-billed Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1965		40 pairs		Close et al. 1982
2	Yellow-billed Spoonbill	Lake Alexandrina	Pelican Lagoon	1966	50		0	Bonnin, 1967
2	Yellow-billed Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1966		some		Close et al. 1982
2	Yellow-billed Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1967		some		Close et al. 1982
2	Yellow-billed Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1971		many		Close et al. 1982
2	Yellow-billed Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1972		many		Close et al. 1982
2	Yellow-billed Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1974		some		Close et al. 1982
2	Yellow-billed Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1976		50 pairs	some	Close et al. 1982
2	Yellow-billed Spoonbill	Lake Alexandrina	Salt Lagoon Islands	1979	some			Close et al. 1982

Appendix 4

Summary of the number of each cryptic bird species detected at each of the 16 surveyed sites**.** The total number of species and observations are also provided for each site.*****Reedy Island was only surveyed in September, and **Goolwa was only surveyed in October, November and December.

	Boggy Creek	Finniss River	Goolwa**	Jacobs	Kennedy Bay	Clayton Bay	Loveday Bay	Milang Snipe Sanctuary	Pomanda Point	Narrung Narrows	Poltalloch	Reedy Island*	Reedy Point	Tolderol	Tookayerta	Waltowa
Australasian Bittern		1		6		1	1		5	4				2		
Australian Reed-warbler	35	15	24	68	1	21	18	8	76	51	4	5	9	31	33	21
Australian Spotted Crake		2	1	11	6	2	1		16	4	3				1	33
Baillon's Crake															1	
Buff-banded Rail		1		1								1			2	2
Dusky Moorhen		1		4					1							2
Golden-headed Cisticola	6	46	9	8	48	61	11	13	13	11		1	25	74	9	28
Latham's Snipe	8				2	6		35					1			
Lewin's Rail		4		2	3							1		2	4	
Little Bittern		1		1		1										
Little Grassbird	38	10	42	31	21	28	13	9	89	46	23	4	19	30	33	69
Purple Swamphen	70	2	34	31	10	95	11	3	54	33	3			6	3	26
Spotless Crake	4	4	4	6	1	2		1	11	13	1		1	5	22	9
Total # species	**6**	**11**	**6**	**11**	**8**	**9**	**6**	**6**	**8**	**7**	**5**	**5**	**5**	**7**	**9**	**8**
Total Observations	**161**	**87**	**114**	**169**	**92**	**217**	**55**	**69**	**265**	**162**	**34**	**12**	**55**	**150**	**108**	**190**

Appendix 5.

Alternative habitat relationship model results (ΔAIC_c=<2) by species, in 2 ha plots (2 ha) or the 2 ha plot+ 100mbuffer zone (Buffer). *K*=number of parameters included in mode. Abundance and occupancy data analyses are shown. Non-significant model parameters are indicated in parentheses (probability of inclusion >.05).Parameters in bold font have a positive effect on abundance or occupancy, whereas parameters in normal font have a negative effect.

Species	Analysis	Area	Model parameters	*K*
Australasian Bittern	Abundance	Buffer	**Reeds, (Lignum)**	2
	Abundance	Buffer	**Reeds, Lignum, (Grasses)**	3
Australian Spotted Crake	Abundance	Buffer	**Reeds, (Samphire), Lignum, Open Water, Grasses, Month**	6
	Occupancy	2 ha	**Reeds, (Lignum), Month**	3
Golden-headed Cisticola	Occupancy	Buffer	(Lignum), Aquatic Ferns	2
Little Grassbird	Abundance	2 ha	**Reeds, (Aquatic Herbs<1m), Lignum,% inundated,** Month	5
Purple Swamphen	Abundance	2 ha	**Reeds, Sedges>1m, Samphire, Aquatic Herbs<1m,** Aquatic Herbs>1m**, Lignum, Open Water, Mudflat, Aquatic Ferns, Grasses, % inundated,** Month	12
	Occupancy	Buffer	Reeds, Sedges<1m**, Aquatic Ferns, Max Water Level**, (Month)	5
Spotless Crake	Occupancy (1)	Buffer	**Reeds, Aquatic Herbs>1m, (Lignum),(**Min Water Level)**,(Month)**	5
	Occupancy (2)	2 ha	**Reeds, Aquatic Herbs>1m**	4
Latham's Snipe	Occupancy (1)	2 ha	Reeds	1
	Occupancy (2)	2 ha	**Samphire**	1

Appendix 6

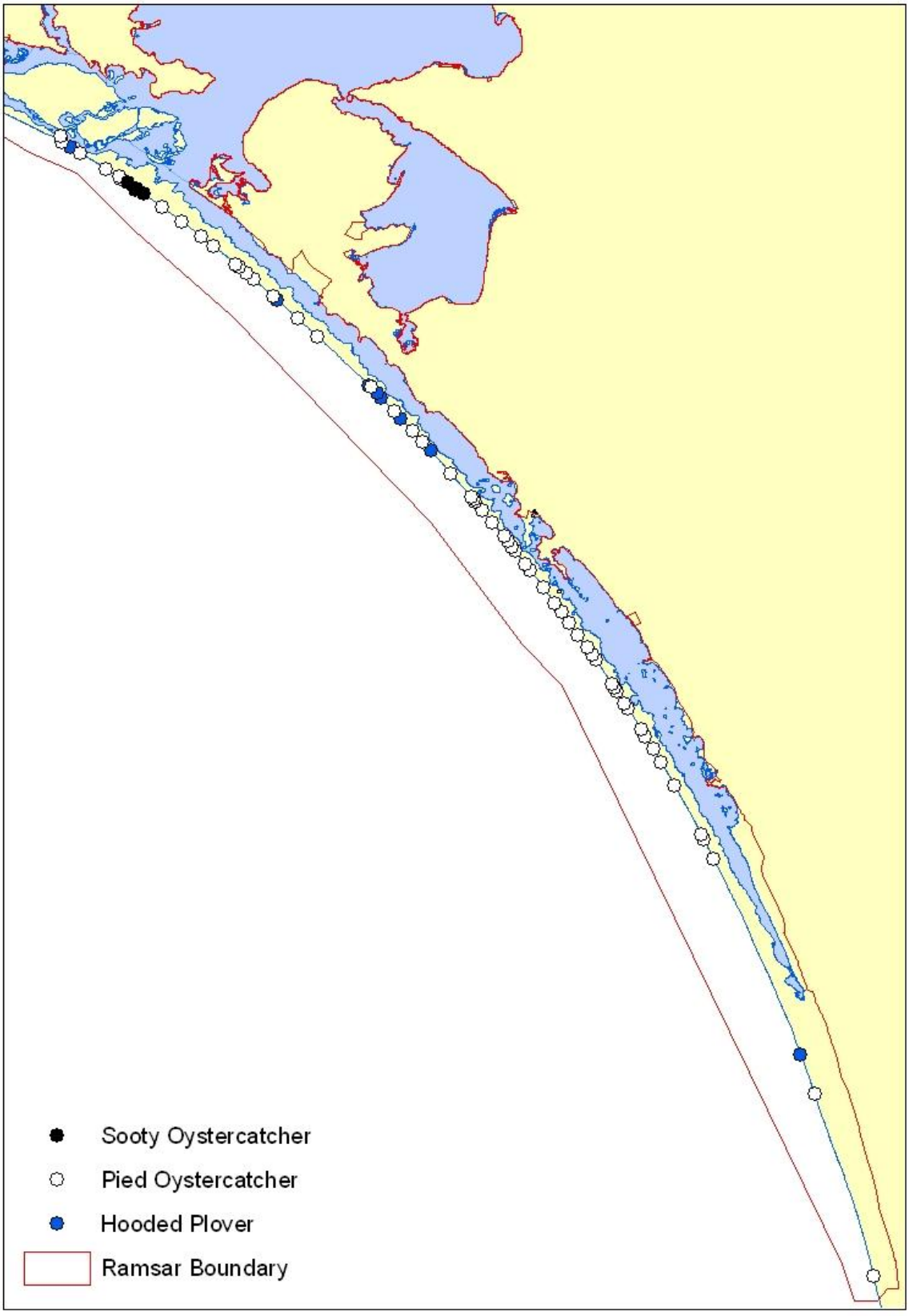
Summary of 2012/2013 waterbird breeding (aerial) survey results by location and date.

Year	Month	Day	Region	Wetland/island	Lat	Long	Species	Birds on nests	Non-nesting birds	Chicks /Juveniles	Colony nesting Stage	Details
2012	10	18	Lake Alexandrina	Boggy Lake	6088988	334753.1852	White Ibis	80			on nest	Nests scattered across islands in Boggy Lake
2012	10	18	Lake Alexandrina	Boggy Lake	6088988	334753.1852	Straw-necked Ibis	445			on nest	Nests scattered across islands in Boggy Lake
2012	10	18	Lake Alexandrina	Low Point	6077528	350909.9641	White Ibis	90			on nest	Grouped nests among very small reedy islands
2012	10	18	Lake Albert	Narrung Narrows (East)	6060395	340441.62	White Ibis	120			on nest	
2012	10	18	Lake Albert	Narrung Narrows (East)	6060395	340441.62	Straw-necked Ibis	160			on nest	
2012	10	18	Lake Albert	Lake Albert (East)	6060395	340441.62	Black Swan	10			fledged	Old nests, Cygnets present
2012	10	18	Lake Albert	Narrung Narrows (West)	6067514	336678.357	White Ibis	30			on nest	Patchy nests
2012	10	18	Lake Albert	Narrung Narrows (West)	6067972	336423.221	Black Swan	1			on nest/fledged	Patchy nests, Cygnets present
2012	10	18	Lake Albert	Rumply Point	6077528	350909.9641	Black Swan	1			on nest	
2012	11	14	Coorong	North Pelican Island	6010256	370116	Australian Pelican	390	1790	280	on nest/fledged	
2012	11	14	Coorong	North Pelican Island	6010256	370116	Crested Tern	700	220		on nest	
2012	11	14	Coorong	North Pelican Island	6010256	370116	Caspian Tern	10	5		on nest	
2012	12	4	Lake Alexandrina	Boggy Lake	6089683	335463.3781	Straw-necked Ibis	161	9		on nest	
2012	12	4	Lake Alexandrina	Boggy Lake	6089683	335463.3781	White Ibis	79	28		on nest	
2012	12	4	Lake Alexandrina	Boggy Lake	6089683	335463.3781	White Ibis	20	0		on nest	
2012	12	4	Tributaries	Currency Creek	6071294	304594.5562	White Ibis	47	0		on nest	
2012	12	4	Tributaries	Currency Creek	6070352	304626.9138	White Ibis	72	0		on nest	
2012	12	4	Tributaries	Currency Creek	6070352	304626.9138	Straw-necked Ibis	159	0		on nest	
2012	12	4	Lake Albert	Narrung Narrows	6067086	335242.3645	White Ibis	10	0		on nest	
2012	12	4	Lake Albert	Narrung Narrows	6068067	335506.4126	White Ibis	75	0		on nest	
2012	12	4	Lake Alexandrina	Point Sturt	6071753	317349.4603	White Ibis	13	12		on nest	
2012	12	4	Lake Alexandrina	Tolderol	6084024	333580.1862	Pied cormorant	340	250		on nest	

Year	Month	Day	Region	Wetland/island	Lat	Long	Species	Birds on nests	Non-nesting birds	Chicks /Juveniles	Colony nesting Stage	Details
2012	12	4	Lake Alexandrina	Tolderol	6084024	333580.1862	Straw-necked Ibis	67	3		on nest	
2012	12	4	Lake Albert	unnamed bay, west of Reedy Pt	6061115	340994.3618	Straw-necked Ibis	1032	10		on nest	
2012	12	4	Lake Albert	unnamed bay, west of Reedy Pt	6061115	340994.3618	White Ibis	64	5		on nest	
2012	12	27	Coorong	Mellor Island	6007537	371655	Australian Pelican	360	190		on nest	
2012	12	27	Coorong	North Pelican Island	6010256	370116	Australian Pelican	950	1180	280	on nest/fledged	4 nesting colonies, 1 creche of juvs
2012	12	27	Coorong	Pelican Island	6008715	370620	Crested Tern	3350	580		on nest	Mostly in centre of island
2012	12	27	Coorong	Pelican Island	6008715	370620	Caspian Tern	30			on nest	North-eastern corner of island, next to nesting Crested terns (<5m)
2013	1	15	Lake Albert	Lake Albert	6060780	340957.7263	Royal Spoonbill	10		0	On nest	
2013	1	15	Lake alexandrina	Tolderol	6084150	333652.3846	Pied cormorant	576	180	3	On nest, Eggs and chicks	
2013	2	23	Coorong	Mellor Island	6007537	371655	Australian Pelican	202	188	155	On nest/Fledged	
2013	2	23	Coorong	North Pelican Island	6010256	370116	Australian Pelican	21	535	140	On nest/fledged	
2013	2	23	Coorong	Pelican Island	6008715	370620	Australian Pelican	247	57	0	On nest, new colony	

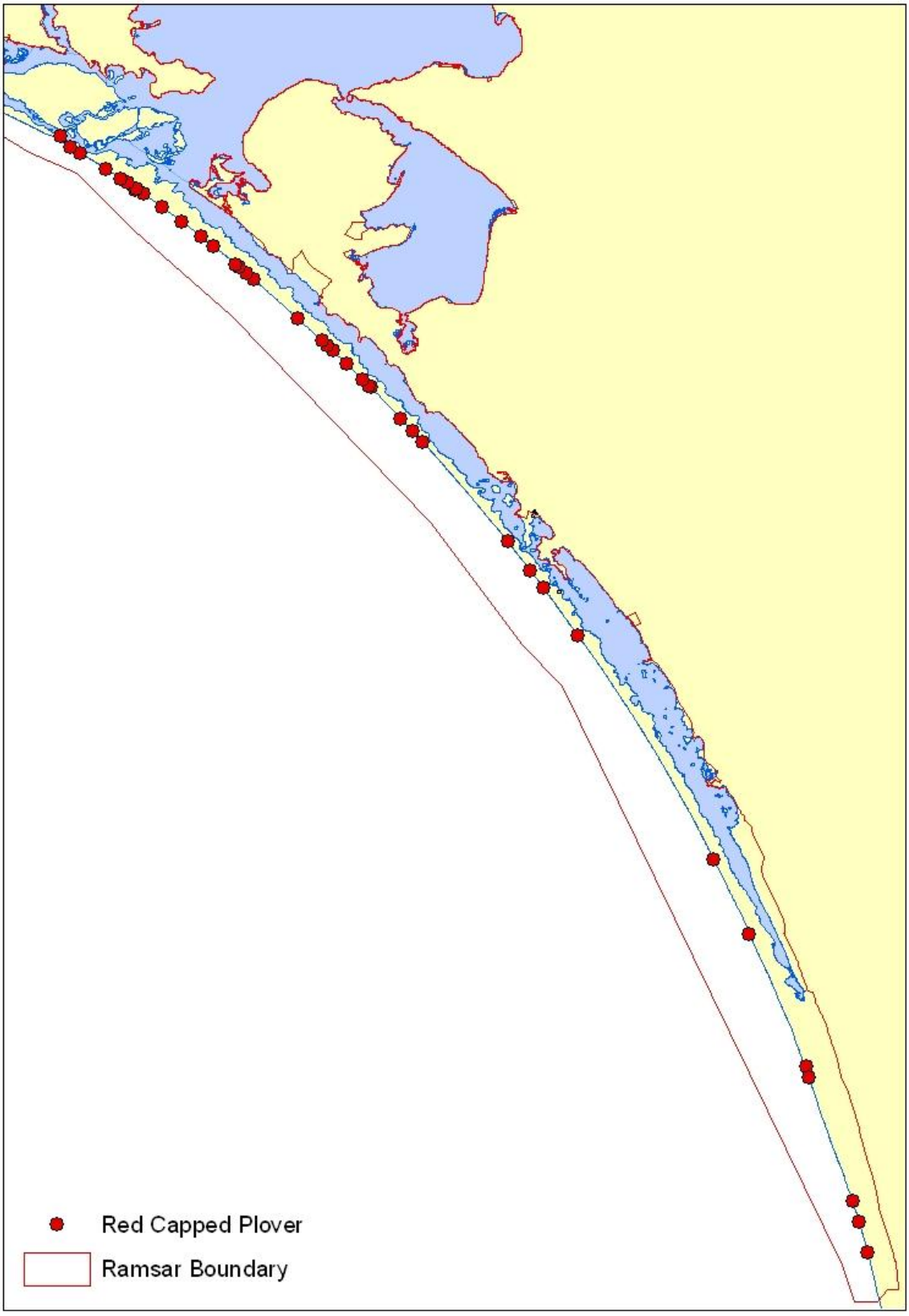
Appendix 7a)

Beach-nesting bird nests on the Younghusband Peninsula (summer, 2010): Hooded Plover, Pied Oystercatcher and Sooty Oystercatcher. Data source: Birdlife Australia



Appendix 7b)

Red-capped Plover nests on the Younghusband Peninsula (summer, 2010). Data source: Birdlife Australia



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Water and Natural Resources