2008

Survey of waterbird communities of the Living Murray icon sites -November 2007

THE UNIVERSITY OF NEW SOUTH WALES

MURRAY-DARLING BASIN COMMISSION

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Summary

1. Waterbird abundance and breeding was concentrated in the Lower Lakes, Coorong and Murray Mouth Icon site which supported a mean total of 249,146 waterbirds (92% of survey total) with high species richness (42), including Freckled Duck, Cape Barren Geese, Banded Stilt, Australian Shelduck, Great Cormorant and migratory shorebirds. Breeding was also mostly confined to this icon site with 96% of the survey total.

2. The northern Coorong supported high numbers of waterbirds (142,198), with significantly fewer birds in the southen Coorong (9,512). Lake Albert (30,276) and Alexandrina (67,169) also supported large numbers of waterbirds. Waterbird breeding abundance was low and restricted mainly to Lake Albert (3,951 mean breeding index), comprising two species (Straw-necked Ibis and Pied Cormorant).

3. Water levels in the southern Coorong were low (<40 % full by area) while the northern Coorong and lower lakes held considerably more water (>90% full by area)

4. Severe drought conditions continue to impact on waterbird communities and limit the availability of other wetland, floodplain and riverine habitats throughout the southern Murray-Darling basin.

5. Most floodplain or shallow Icon sites were dry or almost dry and supported few waterbirds. The main river channel held water but relatively few birds and with low species richness.

6. Wetland habitat in the Barmah-Millewa Forest icon site was mostly restricted to the main river channels and Moira Lake, and waterbird abundance was low.

7. Most shallow floodplain wetland habitat in Gunbower Koondrook Perricoota system was dry and few waterbirds were present

8. Hattah Lakes held water with high waterbird numbers recorded (16,097), comprising mainly Grey teal, Hardhead, Eurasian coot, Pacific black duck and Australasian shoveler. Within the icon wetland, two sites held most of the birds; Lake Lockie (12,200 mean total) and Lake Yerang (2,800 mean total),

9. Wetland habitat in the Chowilla & Lindsay Wallpolla icon site was mostly restricted to the main channels although a small number of deeper billabongs still held water. Low numbers of waterbirds were recorded at this site.

10. River Murray channel sites held water at all sections surveyed between Lake Hume and the Murray mouth but supported relatively low numbers and diversity of waterbirds

Introduction

Aerial surveys of waterbirds can be used to identify high conservation wetlands (Kingsford 1995, Kingsford & Porter 1994, Halse *et al.* 2005), estimate species' abundance (Kingsford et *al*. 1999) and monitor changes in wetland condition over large temporal and spatial scales (Kingsford *et al*. 2004, Porter *et al*. 2006). In November 2007 an aerial waterbird survey of The Living Murray (TLM) Icon Wetland Sites was successfully completed, the first survey of all Icon sites at one time. Previous waterbird surveys had been icon site specific using ground based assessments. This report presents summary results of the 2007 Icon Wetland survey.

Commencing in 2008, aerial waterbird surveys will be done annually in Spring to coincide with the Eastern Australian Waterbird Survey. Methods for surveying and reporting on waterbirds (Kingsford & Lee 2007) and terrestrial species of significance at each Icon site are being developed and implemented as part of Icon site Condition Monitoring work. Reporting proforma's will be developed, as will protocols for storing the data produced from the ground based surveys. The icon aerial survey program will link to these Icon site bird monitoring activities so that there will be complementarity between surveys. This will provide a more complete understanding of the condition of waterbird communities at each Icon Site.

Aims

1. Undertake annual aerial waterbird surveys of The Living Murray (TLM) Icon Wetland Sites (Barmah-Millewa; Gunbower-Koondrook-Pericoota; Hattah Lakes, Chowilla-Lindsay-Wallpolla; Lower Lakes-Coorong-Murray Mouth; River Murray Channel) in November 2007 to coincide with the annual Eastern Australian Waterbird Survey
2. Undertake the surveys at a scale to inform on water birds on water bodies and wetlands within Icon Sites.
3. Report on waterbird survey at the icon site and with reference to the current years Eastern Australian Waterbird Survey

Methods

Each Icon site was surveyed twice following standard methods established for aerial surveys of waterbirds in eastern Australia (Braithwaite *et al*. 1986, Kingsford 1999). The first survey was followed immediately by another to provide an estimate of counting error. For the River Murray Channel, a 5 km stretch was randomly selected between icon sites and surveyed twice to provide an unbiased estimate of waterbird use of the channel in different sections of the river. The sections were located as follows:

Murray 1	Barmah-Hume Dam	35^0 59.0 S 146^0 29.6 E	west of Cobram
Murray 2	Gunbower-Barmah	35^0 57.7 S 145^0 45.9 E	east of Echuca
Murray 3	Hattah-Gunbower	35^0 03.37 S 144^0 38.85 E	near Swan Hill
Murray 4	Wentworth-Hattah	34^0 11.58 S 143^0 27.3 E	south of Mildura
Murray 5	Coorong – Chowilla	34^0 17.5 S 139^0 38.0 E	north of Blanchetown

Waterbirds were counted in November 2007 from a Cessna 206 aircraft flown at a height of 30-46 m and a speed of 167-204 km/h (90-110 knots), within 150 m of the shoreline, where waterbirds usually congregate (Kingsford & Porter 1994; Kingsford 1999). An observer on each side of the aircraft counted all waterbirds sighted on their side of the aircraft. Waterbird species were identified and their numbers estimated and immediately recorded on digital audio recorders. Nesting birds and those with broods were also identified and counted. Some waterbird species could not reliably be identified to species level from the air and were grouped as follows: small grebes (Australian little grebe; Hoary headed grebe), large egrets (Intermediate Egret and Great Egret), terns (Crested tern; Lesser Crested tern; see Apppendix 1) and small and large migratory wading birds (Charadriformes; see Appendix 1). Wetland percent full (by area) was also estimated for each discrete wetland counted, enabling an an index of wetland area to be constructed.

Two count types were used: total and proportional counts. For total counts the whole wetland is circumnavigated while for proportion counts a portion of the wetland (usually > 50 %) is counted. Counts for each species are totalled for each observer to give either a total count for a wetland or a proportional count for the wetland. Counts on proportions of wetlands are then extrapolated to give an index of total waterbird numbers for the whole wetland (Kingsford *et al*. 2003).

Final choice of counting approach was flexible to enable variable waterbird distribution, abundance and wetland composition to be adequately sampled. Within each Icon site, selected waterbodies marked on 1:250 000 topographic maps and discrete bodies of open water >1 ha in size were counted seperately to allow distribution of waterbird community within the site to be described. Waterbird species were separated into five functional groups (ducks and grebes; herbivores; piscivores; large wading birds and shorebirds) designed to reflect diet and foraging habitat (modified from Kingsford & Porter 1994; see Appendix 1)

Analyses

Waterbird abundance and species richness were compared with ANOVA using SYSTAT v12 software (Systat Inc. 2007). Data were log transformed to stabilise variance and improve normality. Differences in waterbird communities among Icon sites, wetlands and replicate counts were compared using analysis of similartities (ANOSIM) (Clarke 1993) with PRIMER v6 software (Clarke & Gorley 2006). A one way global analysis was followed by pairwise comparisons to determine differences. The number of comparisons was generally small relative to the number of replicates, significantly reducing the risk of Type I error (Clarke 1993). A Bray-Curtis dissimilarity matrix of species abundance was calculated after log transformation to reduce heteroscedasticity and reduce the risk of Type I error.

Similarities and groupings among wetland species assemblages were analysed using hybrid non-metric multidimensional scaling (nMDS) (PRIMER v6 software; Clarke & Gorley 2006). Ordinations were done on a Bray-Curtis dissimilarity matrix (described above). Configurations were calculated in two dimensions after 50 random starts and Shepard diagrams examined for degenerate solutions (Legendre & Legendre 1998).

Species which discriminated most among survey regions were identified by similarity percentage (SIMPER) analysis (Clarke & Warwick 1994). Average Bray-Curtis dissimilarity ($\overline{\delta}$) between all pairs of inter group samples was calculated from a matrix (46 x 64) of mean wetland species abundance and then decomposed into the separate contributions from each species and expressed as a percentage of average dissimilarity ($\overline{\delta}$).

Results and discussion

The Living Murray (TLM) Icon Wetland Sites supported a mean total of more than 271,240 waterbirds, comprising 46 species. This represents almost double the total number of birds estimated by the Eastern Australian Waterbird Survey (EAWS) in 2007 (143,725), and considerably more than any year since 2001 (Porter *et al*. 2006; Kingsford & Porter 2007).

Differences in abundance and species richness among icon sites were highly significant ($F_{5,6}$=48.99, P<0.001 and $F_{5,6}$=17.71, P<0.002 respectively). The Lower Lakes, Coorong and Murray Mouth icon site held an order of magnitude more waterbirds than the other five icon sites combined (Table1; Fig. 1). Icon sites with high abundance also tended to have high species richness (Table 1).

Mean total counts (all icon sites combined) of five species exceeded 20,000; Banded Stilt (73,164), Grey Teal (40,572), Australian Shelduck (47,403), Great Cormorant (25,516) and terns (21,032) (Table 2). Other abundant species (>5,000 mean total) were Small waders (13,764), Australian Pelican (10,973), Silver Gull (9,729) and Black Swans (6,396). The 2007 EAWS identified ten species as abundant: Grey Teal (29,339), Pink-eared duck (18,197), Plumed Whistling duck (14,484), Hardhead (8,453), Pacific black duck (7,795), Red-necked avocet (5,967), Black Swan (5,695), Australian Pelican (5,188), Straw-necked Ibis (5,080) and Black-winged Stilt (5,054) (Kingsford & Porter 2007).

EAWS 2007 results indicate severe and widespread drought conditions continue to affect wetlands, floodplains and rivers throughout eastern Australia. Trend analyses indicate declines in waterbird abundance, wetland area, breeding abundance and breeding species richness are significant (Kingsford & Porter 2007). Below average wetland area was recorded by the EAWS throughout most of the survey area in 2007. The southern extremity of the Coorong within the EAWS band was almost dry. The Macquarie Marshes, Lowbidgee and Menindee Lakes were dry or almost dry. Most rivers in the Murray-Darling Basin were also low with little water on the floodplain (Kingsford & Porter 2007). Some of the Paroo overflow lakes also held water but relatively few birds (<4,100). Wetland area index for the 2007 EAWS was the lowest on record (Kingsford & Porter 2007).

Available wetland habitat detected by the EAWS was mostly (22%) distributed in the north (Band 10) and Bands 2 to 4 (see appendix 2, Fig A2.1). Band 2 contained 14% of total wetland area; Band 3 had 16% and Band 4 had 16% (Kingsford & Porter 2007). Total waterbird abundance was low (second lowest on record) and waterbirds were concentrated on a few wetlands (Kingsford & Porter 2007). Six Queensland wetland systems held 41% of total abundance; Lake Torquinnie (15%, Band 8), Lake Moondarra (6%, band 10), Coolmunda Dam (6%, Band 6), Lake Phillipi and Pippagitta Waterhole (10%, Band 8) and Lake Galilee (4%, Band 9) (Kingsford & Porter 2007).

For the Icon sites, total mean breeding (nests and broods) abundance of 4,119 comprised 5 species; Straw necked Ibis (2,500), Pied Cormorant (1,417), Australian Pelican (150), Royal Spoonbill (33) and Black Swan (19). This represents almost 10 times the total breeding index recorded by the EAWS in 2007 (Kingsford & Porter 2007). Total breeding index (469, all species combined) for the EAWS in October 2007 was below average, and concentrated (92%) in one location – Rhyll Swamp on Phillip Island, south of Melbourne. Breeding

species richness for the EAWS was the lowest on record, with only two non-game species, White Ibis and Black Swan recorded (Kingsford & Porter 2007). Breeding within all survey bands was also low. The EAWS recorded low numbers of waterbirds and breeding on key wetland systems including Cooper Creek, Paroo overflow, Menindee Lakes, Lowbidgee and Macquarie Marshes, extending a sequence of below average years (Kingsford & Porter 2007). A combination of severe drought and long term effects of river regulation, continues to impact on wetland area, waterbird abundance and breeding.

Table 1. Mean abundance and number of waterbird species on wetlands within The Living Murray Icon Sites and Lake Mulwala in November 2007"

Icon Wetland	Abundance		Number of species	
	mean	range	mean	range
Lower Lakes-Coorong & Murray Mouth	249,146	198,686-299,606	42	41-43
Hattah Lakes	16,097	15,680-16,513	23	22-24
Chowilla-Lindsay-Wallpolla	3,859	1,706-6,013	20.5	22-19
Lake Mulwala	1,520	-	8.5	-
Barmah-Millewa	1,368	1,146-1,589	14	14-14
River Murray	739	722-756	16.5	16-17
Gunbower-Perricoota	31	9-53	4	2-6

Severe drought conditions continue to impact on waterbird communities and limit the availability of other wetland, floodplain and riverine habitats throughout the southern Murray-Darling basin. Most floodplain or shallow Icon sites were dry or almost dry and supported few waterbirds. The main river channel held water but relatively few birds and with low species richness.

Relative abundance of waterbird functional groups varied among icon wetlands (Fig. 2). Hattah Lakes supported proportionally more ducks than other icon sites and shorebirds were most prominent on the Lower Lakes, Coorong and Murray Mouth icon site. Piscivores were important in the Barmah-Millewa and Gunbower-Perricoota sites, probably reflecting the relative abundance of fish compared to other food and habitat resources at these sites. Waterbirds species assemblages differed significantly among Icon sites (global R=0.667; P<0.001; Fig.3). There was no significant overall difference in the species abundances recorded in replicate counts of icon wetlands (global R=-0.144; P=0.998; Fig.3). This indicates that overall, survey methodology was consistent and waterbird mobility did not unduly bias results. Differences in replicate counts of icon stes was most pronounced where mean abundance was low (e.g. Gunbower-Koondrook-Perricoota; Table 1, Fig.3).

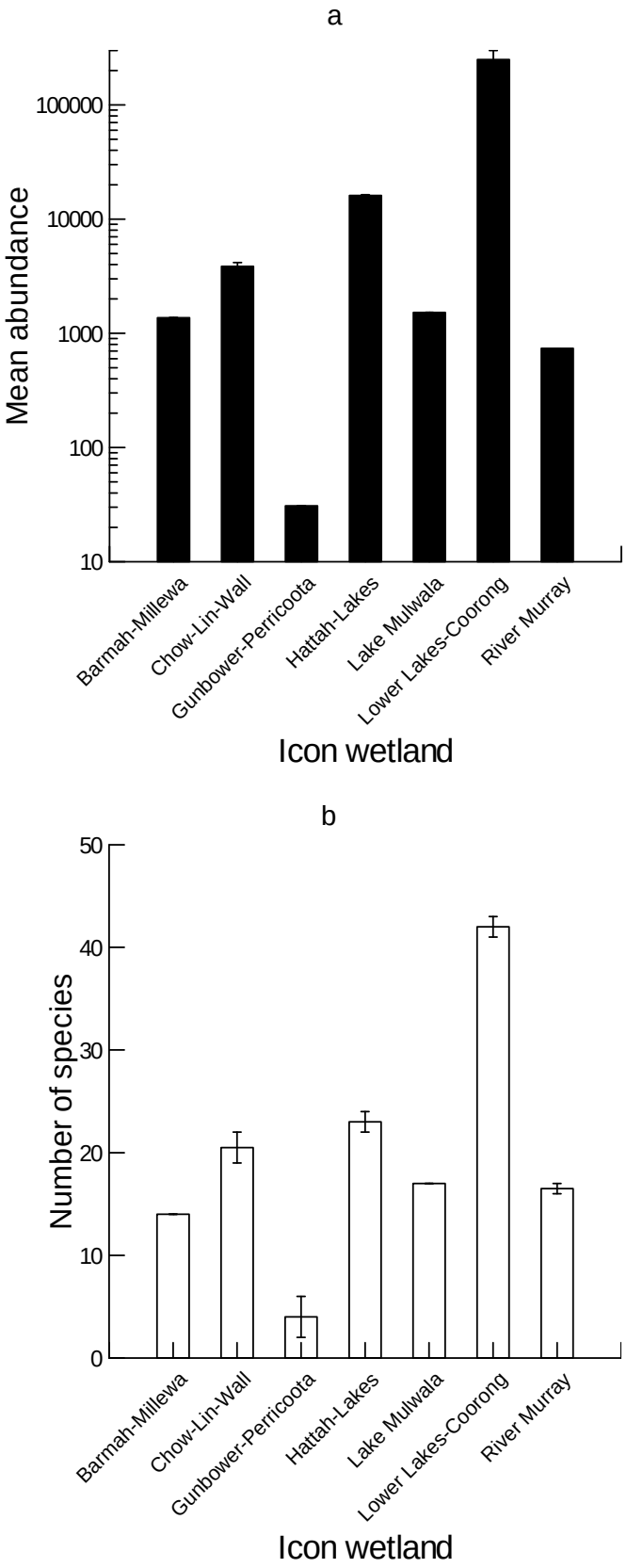

Figure 1. Mean (±se) waterbird abundance (a) and number of species (b) on Murray Icon wetlands and Lake Mulwala in November 2007

Table 2. Mean waterbird species abundance in TLM icon wetlands, November 2007

Species	Barmah-Millewa	Chowilla Lindsay Wallpolla	Gunbower-Perricoota	Hattah Lakes	Lower Lakes, Coorong, Murray Mouth	River Murray	total
Australasian shoveller	0	0	0	202	605	0	807
Australian Pelican	744	656	1	46	9408	118	10973
Australian shelduck	77	1042	0	50	36138	12	37318
Banded Stilt	0	0	0	0	73164	0	73164
Black duck	29	85	3	78	2664	47	2906
Black Swan	0	490	0	1	6396	154	7041
Black winged stilt	13	0	0	96	2263	0	2372
Black-tailed native hen	0	2	0	16	0	0	18
Cape Barren Geese	0	0	0	0	1111	0	1111
Caspian Tern	0	2	0	0	862	0	864
Chestnut teal	0	0	0	0	1271	0	1271
Darter	1	16	1	1	7	5	30
Dusky moorhen	0	0	0	0	21	0	21
Egrets	27	12	1	3	107	1	150
Eurasian coot	0	474	0	606	1901	0	2980
Freckled duck	0	0	0	0	49	0	49
Glossy Ibis	0	0	0	179	42	14	234
Great Cormorant	5	17	0	24	25443	27	25516
Great crested grebe	0	0	0	0	299	0	299
Grebes	0	0	0	0	12	0	12
Grey Teal	0	351	0	13669	26476	51	40547
Gull billed tern	0	0	0	0	353	0	353
Hardhead	0	3	0	202	204	0	408
Large egret	0	8	0	0	94	0	101
Large wader	0	0	0	0	1574	0	1574
Little black cormorant	45	358	21	7	81	21	531
Little pied cormorant	7	36	1	0	22	10	75
Masked Lapwing	1	3	0	26	180	0	211
Musk Duck	0	0	0	0	45	0	45
Pacific heron	0	1	0	24	0	2	26
Pied Cormorant	6	10	3	0	3845	4	3867
Pied ostercatcher	0	0	0	0	19	0	19
Pink-eared duck	0	0	0	337	13	0	350
Purple Swamphen	0	0	0	0	93	0	93
Red necked avocet	0	0	0	90	1463	0	1553
Royal spoonbill	94	4	0	0	78	5	181
Silver Gull	0	0	0	0	9729	0	9729
Small waders	0	0	0	265	13499	0	13764
Sooty Oystercatcher	0	0	0	0	8	0	8
Straw necked Ibis	0	0	0	0	3092	103	3195
Tern	0	0	0	0	21032	0	21032
Whiskered tern	147	0	0	2	3822	0	3971
White faced heron	21	5	0	7	36	25	92
White Ibis	60	15	0	1	1087	19	1181
Wood duck	12	257	1	21	25	121	437
Yellow billed spoonbill	80	17	0	149	514	2	762

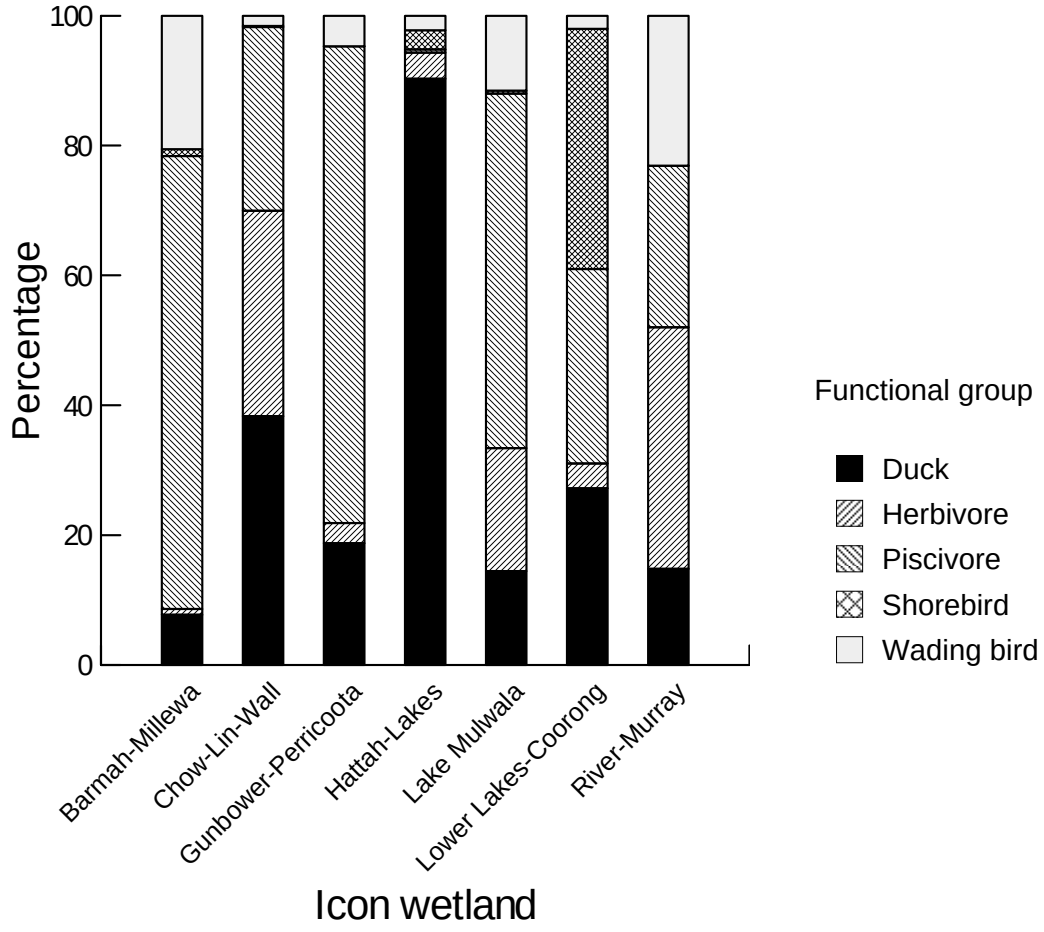

Figure 2. Relative abundance of five waterbird functional groups among icon wetlands and Lake Mulwala

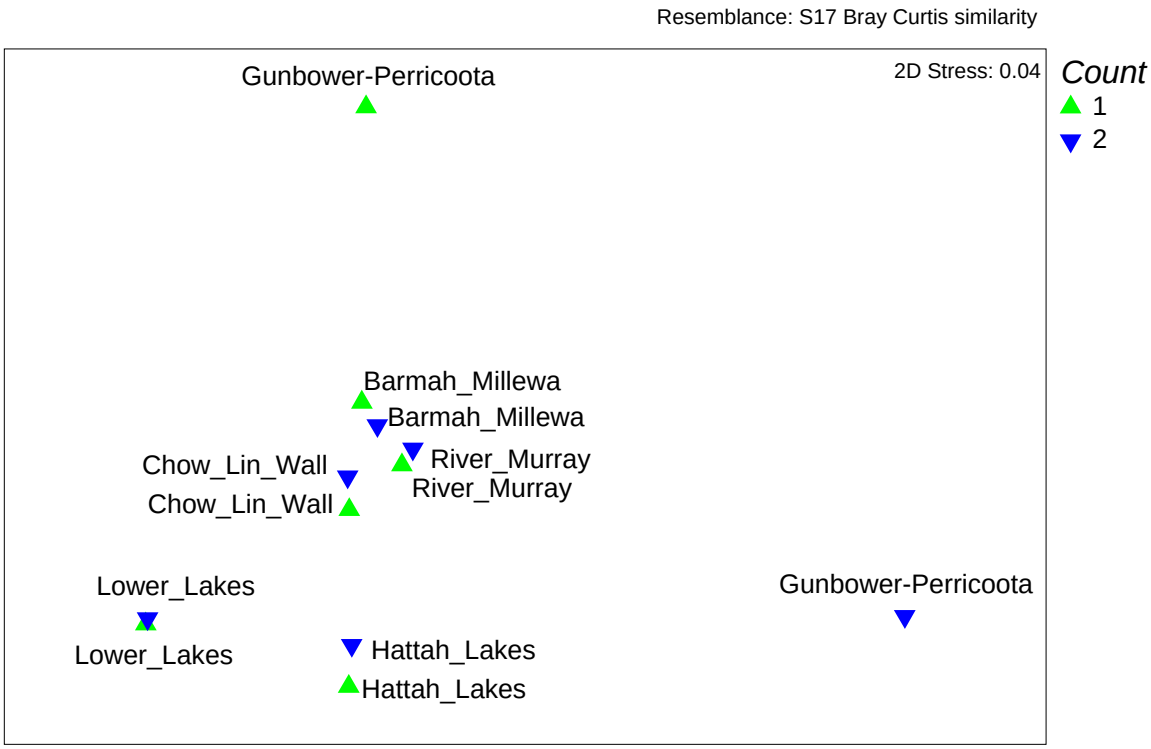

Figure 3. Ordination plot (nMDS) of Icon wetland species abundance in replicate counts

Lower Lakes, Coorong and the Murray Mouth Icon site

Waterbirds were strongly concentrated in the Lower Lakes, Coorong and Murray Mouth Icon site which supported more than 249,146 (92%) of waterbirds surveyed, (Table 1). The site had high species richness (42), supporting large numbers of Banded Stilt, Australian Shelduck, Great Cormorant, Grey Teal, Terns and migratory shorebirds (Table 2). Waterbird breeding was also concentrated within this site, mainly within Lake Albert with a breeding index of 3,951 (96% of survey total), comprising just two species (Straw necked Ibis and Pied Cormorant). Four discrete wetland sections which were counted within this site – Lake Alexandrina, Lake Albert, northern Coorong and southern Coorong (Table 3). The northern Coorong (142,198 mean total) supported more waterbirds than any other area counted (Fig. 4).

Water extent in Lakes Alexandrina and Albert was estimated at 90% full (by area). The northern coorong was 70% full while levels in the southern Coorong were low (<40 % full) and the area supported far fewer waterbirds (9,512 mean total) than the northern Coorong; Fig. 4).

Table 3. Mean waterbird abundance and number of species in wetland sections within Murray Icon wetlands

Icon Wetlands	Wetland section	Abundance		Number of species	
		mean	range	mean	range
Barmah Millewa	Barmah Millewa	23	19-26	6	6-6
Barmah Millewa	Barmah Millewa Sth	19	4-34	3	1-4
Barmah Millewa	Edward River	0	0	0	0
Chowilla-Lindsay-Wallpolla	Chowilla Billabong[a]	557		10	
Chowilla-Lindsay-Wallpolla	Chowilla Lock 5-6	235	224-247	14	13-15
Chowilla-Lindsay-Wallpolla	Chowilla Lock 6-7	366	297-435	12	8-16
Chowilla-Lindsay-Wallpolla	Chowilla Lock 7-8	90	55-125	8	6-9
Chowilla-Lindsay-Wallpolla	Chowilla Lock 8-10	2,600	989-4,210	16	14-18
Barmah-Millewa	Moira Lake	1,326	1,093-1,559	10	10-10
Chowilla-Lindsay-Wallpolla	Hattah-Chowilla	74	70-78	9	9-9
Gunbower-Perricoota	Gunbower-Perricoota	31	9-53	4	2-6
Lower Lakes-Coorong-Murray Mouth	Lake Albert	30,276	26,707-33,845	27	24-29
Lower Lakes-Coorong-Murray Mouth	Lake Alexandrina	67,169	62,092-72,247	33	26-39
Lower Lakes-Coorong-Murray Mouth	North Coorong	142,198	100,101-184,295	33	29-36
Lower Lakes-Coorong-Murray Mouth	South Coorong	9,512	9,236-9,787	7	7-7
Hattah Lakes	Lake Arawak	391	375-407	20	5-34
Hattah Lakes	Lake Brockie	17	11-22	5	1-8
Hattah Lakes	Lake Bullah	123	63-182	4	2-6
Hattah Lakes	Lake Hattah	498	436-559	7	7-7
Hattah Lakes	Lake Lockie	12,255	11,459-13,051	8	7-9
Hattah Lakes	Lake Yerang	2,814	2,545-3,083	14	14-14
Murray River	Murray 1	18	17	5	5-5
Murray River	Murray 2	9	16	2	1-3
Murray River	Murray 3	13	7	3	2-3
Murray River	Murray 4	250	176-324	10	8-12
Murray River	Murray 5	449	393-504	10	10-10
	Lake Mulwala[a]	1,520	-	17	-

[a] single count only

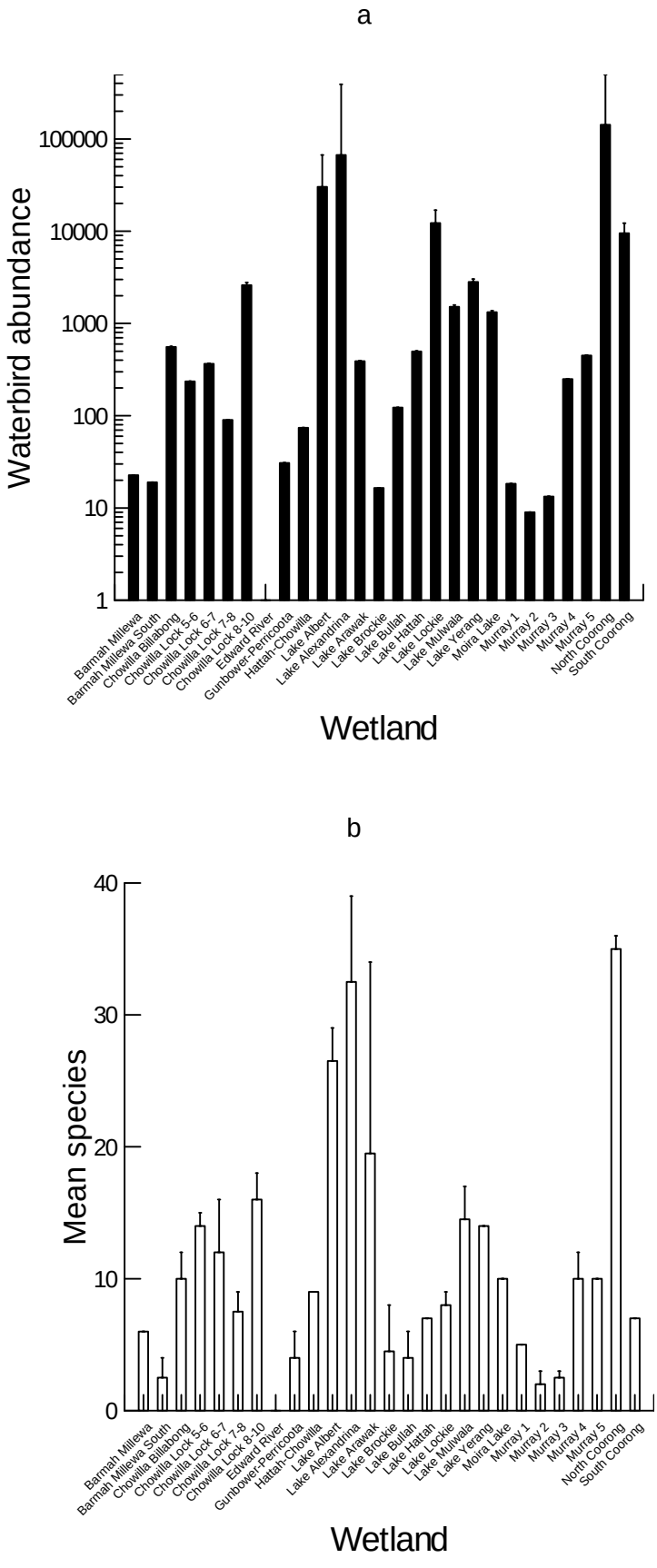

Figure 4. Mean (±se) waterbird abundance (a) and number of species (b) in wetland sections within Icon sites

Hattah Lakes Icon Site

Hattah Lakes held 40-80% water with high waterbird numbers recorded on Lake Lockie (12,255) and Lake Yerang (2,814; Table 3; Figure 4). Species comprised mainly Grey teal, Hardhead, Eurasian coot, Pink-eared duck, Pacific black duck and Australasian shoveler (Table 2).

Chowilla & Lindsay Wallpolla Islands Icon SIte

Wetland habitat in the Chowilla & Lindsay Wallpolla icon site was mostly restricted to the main channels although a small number of deeper billabongs still held water. Low numbers of waterbirds (3,859 mean total) were recorded at this site (Table 3) and these were mostly located in the wetland section Chowilla Lock 8-10 (34^0 7.85' S 141^0 51.2 E; Fig. 4).

Barmah-Millewa Forest Site

Wetland habitat in the Barmah-Millewa Forest icon site was mostly restricted to the main river channels and Moira Lake, and waterbird abundance was low (Table 3; Fig.4).

River Murray Channel Icon Site

River Murray channel sites held water at all sections surveyed between Lake Hume and the Murray mouth but supported relatively low numbers and diversity of waterbirds (Table 3; Fig.4).

Gunbower-Koondrook-Perricoota Icon Site

Most shallow floodplain wetland habitat in Gunbower Koondrook Perricoota system was dry and few waterbirds and species were present (Table 3; Fig.4).

Additional Site – Lake Mulawa

Lake Mulawala supported 1,520 waterbirds (only a single count was done on this wetland) and 17 species. A small breeding colony of around 150 Pelicans was recorded.

References

Braithwaite, L.W., Maher, M., Briggs, S.V. and Parker, B.S. (1986) An aerial survey of three game species of waterfowl (Family Anatidae) in eastern Australia. *Australian Wildlife Research* **13**, 213-23.

Caughley, G. (1979) Sampling techniques for aerial censuses. *Aerial surveys of fauna populations* Aust. Nat. Parks & Wildl. Serv. Spec. Publ. 1, 9-13.

Clarke, K. R. (1993). Non-parametric multivariate analysis of changes in community structure. *Australian Journal of Ecology* **18**, 117-143.

Clarke, K.R. and Gorley, R.N. (2006) PRIMER V6: User Manual/Tutorial. Plymouth, UK, Primer-E Ltd.

Clarke, K. R. and Warwick, R. M. (1994). 'Change in Marine Communities: an approach to statistical analysis and interpretation.' (Natural Environment Research Council: UK.)

Halse, S.A., Pearson, G.B., Hassell, C., Collins, P., Scanlon, M.D., and Minton, C.D.T. (2005). Mandora Marsh, north-western Australia, an arid-zone wetland maintaining continental populations of waterbirds. *Emu* **105**, 115-125.

Kingsford, R. T. (1995). Occurrence of high concentrations of waterbirds in arid Australia . *Journal of Arid Environments* **29**, 421-425.

Kingsford, R.T. (1999) Aerial survey of waterbirds on wetlands as a measure of river and floodplain health. *Freshwater Biology* **41**, 425-438.

Kingsford, R.T., Jenkins K.M., and Porter, J.L. (2004) Imposed hydrological stability on lakes in arid australia and effects on waterbirds . *Ecology* **85**, 2478-2492.

Kingsford, R. T. and Lee, E. (2007). Waterbirds and floodplain health within the Murray-Darling Basin at Icon site, valley zone and valley scales. 2007. Sydney Australia, University of New South Wales.

Kingsford, R.T. and Porter, J.L. (1994) Waterbirds on an Adjacent Freshwater Lake and Salt Lake in Arid Australia. *Biological Conservation* **69**, 219-228.

Kingsford, R.T. and Porter, J.L. (2007) Aerial Survey of Wetland Birds in Eastern Australia - October 2007 Annual Summary Report. (School of Biological Earth and Environmental Sciences, University of New South Wales. Unpublished report, 29pp. Sydney, Australia).

Kingsford, R.T., Wong, P.S., Braithwaite, L.W., and Maher, M.T. (1999) Waterbird abundance in eastern Australia, 1983-92. *Wildlife Research* **26**, 351-366.

Legendre, P. and Legendre, L. Numerical Ecology (1998) Amsterdam, Elsevier Science B.V. Developments in Environmental Modelling.

Porter, J.L., Kingsford, R.T., and Hunter, S.J. (2006). Aerial surveys of wetland birds in Eastern Australia - October 2003-2005. Department of Environment & Conservation (NSW) Occasional Paper No. 37 pp70.

Systat Inc. (2007). SYSTAT 12. San Jose, California USA.

Appendix 1. Waterbird species and functional groups identified during aerial surveys.

Table A1.

Waterbirds	Specific name	Waterbirds	Specific name
Great Crested Grebe (d)	*Podiceps cristatus*	Brolga (lw)	*Grus rubicundus*
[a]Small grebes (d)		Comb-crested Jacana	*Irediparra gallinacea*
Hoary-headed Grebe	*Poliocephalus poliocephalus*	Pied Oystercatcher (sh)	*Haematopus longirostris*
Australasian Grebe	*Tachybaptus novaehollandiae*	Masked Lapwing (sh)	*Vanellus miles*
Australian Pelican (p)	*Pelecanus conspicillatus*	Banded Lapwing (sh)	*Vanellus tricolor*
Darter (p)	*Anhinga melanogaster*	Black-winged Stilt (sh)	*Himantopus himantopus*
Great Cormorant (p)	*Phalacrocorax carbo*	Banded Stilt (sh)	*Cladorhynchus leucocephalus*
Pied Cormorant (p)	*Phalacrocorax varius*	Red-necked Avocet (sh)	*Recurvirostris novaehollandiae*
Little Black Cormorant (p)	*Phalacrocorax sulcirostris*	[a]Large waders (sh)	
Little Pied Cormorant (p)	*Phalacrocorax melanoleucos*	Eastern Curlew	*Numenius madagascariensis*
Pacific Heron (lw)	*Ardea pacifica*	Whimbrel	*Numenius phaeopus*
White-faced Heron (lw)	*Ardea novaehollandiae*	Little Curlew	*Numenius minutus*
Great Egret (lw)	*Ardea alba*	Bar-tailed Godwit	*Limosa lapponica*
[a]Small egrets (lw)		Black-tailed Godwit	*Limosa nebularia*
Intermediate Egret	*Ardea intermedia*	[a]Small waders (sh)	
Little Egret	*Ardea garzetta*	Grey Plover	*Pluvialis squatorola*
Cattle Egret	*Ardea ibis*	Lesser Golden Plover	*Pluvialis dominica*
Nankeen Night Heron (lw)	*Nycticorax caledonicus*	Mongolian Plover	*Charadrius mongolus*
Black-necked Stork (lw)	*Xenorhynchus asiaticus*	Double-banded Plover	*Charadrius bicinctus*
Glossy Ibis (lw)	*Plegadis falcinellus*	Black-fronted Plover	*Charadrius melanops*
Australian White Ibis (lw)	*Threskiornis aethiopica*	Red-capped Plover	*Charadrius ruficapillus*
Straw-necked Ibis (lw)	*Threskiornis spinicollis*	Ruddy Turnstone	*Arenaria interpres*
Royal Spoonbill (lw)	*Platalea regia*	Grey-tailed Tattler	*Tringa brevipes*
Yellow-billed Spoonbill (lw)	*Platalea flavipes*	Common Sandpiper	*Tringa hypoleucos*
Magpie Goose (h)	*Anseranas semipalmata*	Marsh Sandpiper	*Tringa stagnatilis*
Plumed Whistling-duck (d)	*Dendrocygna eytoni*	Terek Sandpiper	*Tringa terek*
Wandering Whistling-duck (d)	*Dendrocygna arcuata*	Greenshank	*Tringa nebularia*
Black Swan (h)	*Cygnus atratus*	Red Knot	*Calidris canutis*
Freckled Duck (d)	*Stictonetta naevosa*	Great Knot	*Calidris tenuirostris*
Cape Barren Goose (h)	*Cereopsis novaehollandiae*	Sharp-tailed Sandpiper	*Calidris acuminata*
Australian Shelduck (d)	*Tadorna tadornoides*	Red-necked Stint	*Calidris ruficollis*
Radjah Shelduck (d)	*Tadorna radjah*	Curlew Sandpiper	*Calidris ferruginea*
Pacific Black Duck (d)	*Anas superciliosa*	Broad-billed Sandpiper	*Limicola falcinellus*
Mallard (d)	*Anas platyrhynchos*	Red-kneed Dotterel	*Erthrogonys cintus*
Grey Teal (d)	*Anas gracilis*	Latham's snipe	*Gallinago hardwickii*
Chestnut Teal (d)	*Anas castanea*	Silver Gull (p)	*Larus novaehollandiae*
Australasian Shoveler (d)	*Anas rhynchotis*	Pacific Gull (p)	*Larus pacificus*
Pink-eared Duck (d)	*Malacorhynchus membranaceus*	Whiskered Tern (p)	*Sterna hybrida*
Hardhead (d)	*Aythya australis*	Gull-billed Tern (p)	*Sterna nilotica*
Australian Wood Duck (d)	*Chenonetta jubata*	Caspian Tern (p)	*Hydroprogne caspia*
Cotton Pygmy-goose (d)	*Nettapus coromandelianus*	[a]Terns (undifferentiated) (p)	
Green Pygmy-goose (d)	*Nettapus pulchellus*	Silver Gull	*Larus novaehollandiae*
Blue-billed Duck (d)	*Oxyura australis*	Pacific Gull	*Larus pacificus*
Musk Duck (d)	*Biziura lobata*	Whiskered Tern	*Sterna hybrida*
Black-tailed Native-hen (h)	*Gallinula ventralis*	Gull-billed Tern	*Sterna nilotica*
Dusky Moorhen (d)	*Gallinula tenebrosa*	Caspian Tern	*Hydroprogne caspia*
Purple Swamphen (h)	*Porphyrio porphyrio*	Crested Tern	*Sterna bergii*
Eurasian Coot (h)	*Fulica atra*	Lesser crested Tern	*Sterna bengalensis*
		White-winged black Tern	*Chlidonias leucopterus*

[a] Species that could not be separated during aerial surveys. Funtional groups are: ducks and grebes (d); herbivores (h); shorebirds (sh); piscivores (p) and large wading birds (lw).

Appendix 2. Eastern Australian Waterbird Survey - 2007 summary results (Kingsford & Porter 2007)

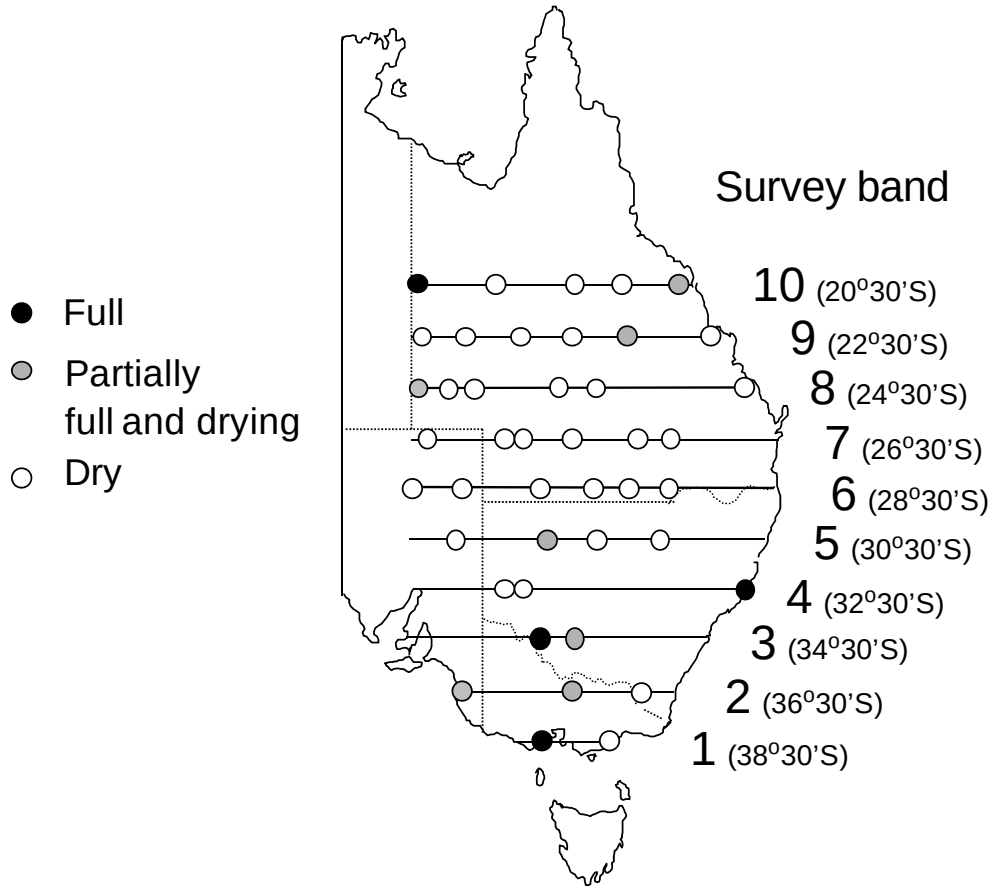

Fig. A2.1 Key to important wetlands in the 2007 EAWS from W-E, by band (1-10)

10 Lake Moondarra, Cloncurry River, Flinders River, Campaspe R, Burdekin R
9 Georgina R, Eyre Ck, Hamilton R, Diamantina R, Lake Galilee, Styx R
8 Mumbleberry-Torquinnie Lakes, Eyre Ck, Diamantina R, Thomson R, Barcoo R, various small coastal wetlands
7 Goyder Lagoon, Lake Yamma Yamma, Cooper Ck, Bulloo R, Paroo R, Warrego R
6 Lake Eyre, Lake Hope, Bulloo R, Paroo R, Warrego R, Balonne R,
5 Lake Frome, Paroo O'flow, Darling R, Macquarie Marshes
4 Menindee Lakes, Talyawalka Lakes, Myall Lakes
3 Murray River Lakes, Lowbidgee Swamp
2 Coorong, Cooper + Mokoan Lakes, Cooma-Monaro
1 Curdies Inlet, Jack Smith Lake