River Murray wetlands baseline surveys of fish, water quality and acidification risk to inform drought planning

SARDI Publication Number RDO4/0245-5
SARDI Research report Series No: 197

[†]Ben Smith, [†]Anthony Conallin, [†]David Fleer,
[†]Karl Hillyard & [‡]Iain Ellis

[†]SARDI Aquatic Sciences,
PO Box 120, Henley Beach SA 5022

[‡]Murray Darling Freshwater Research Centre
PO Box 3428, Mildura, VIC 3502

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- March 2007 -

Government of South Australia
Primary Industries and Resources SA

This publication should be cited as:
Smith, B., Conallin, A., Fleer, D., Hillyard, K. and Ellis, E. (2007). River Murray wetlands baseline surveys of fish, water quality and acidification risk to inform drought planning. Primary Industries and Resources South Australia, SARDI Aquatic Sciences. Publication No RD04/0245-5. Research Report Series Number 197. 80 pages.

South Australian Research and Development Institute

SARDI Aquatic Sciences,
PO Box 120,
HENLEY BEACH, SA 5022.

Telephone: 8207 5400
Facsimile: 8207 5481
http://www.sardi.sa.gov.au

Authors:	Dr B. Smith, K. Hillyard, A. Conallin, D. Fleer & I. Ellis
Reviewers:	Lesley Alton (SARDI), Peter Waanders (SA MDB NRM Board), Sébasiten Lamontagne (CSIRO Land and Water).
Approved by:	Brenton Zampatti
Signed:	
Date:	22 March 2007
Distribution:	SARDI Aquatic Sciences, MDFRC, SA MDB NRM Board
Circulation:	Restricted

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ACKNOWLEDGEMENTS

The authors thank Dr. Darren Baldwin, Dr. Sébastien Lamontagne, Peter Waanders, Lesley Alton and Brenton Zampatti for commenting on the original manuscript and for providing technical advice, and the landholders and managers of all the surveyed wetlands for their cooperation in assisting with site access. The South Australian Murray-Darling Basin Natural Resources Management Board funded this work.

EXECUTIVE SUMMARY

The South Australian Murray-Darling Basin Natural Resources Management Board (SA MDB NRM Board) is considering blocking river connections to a number of wetlands along the South Australian River Murray, to prevent evaporative losses, as an emergency drought response. This survey was commissioned to gather some of the ecological data required to inform a risk assessment for 18 of these wetlands, and to contribute information to develop future wetland management plans and drought response strategies.

The wetlands sampled included four from the Riverland region (NSW/VIC/SA border to Overland Corner: Nelwood II, Horseshoe and Nelwart Swamps; and Tanyaca Creek) and 14 from the Murray Gorge region (Overland Corner to Mannum: Jaeschke Lagoon; Ross Lagoon; Donald Flat Lagoon; McBean Pound North; Reedy Island; Wombat's Rest Backwater; Big Bend; Bowhill; Craignook; Henley Park; Maidment Lagoon; Mark's Landing; Punyelroo; and Teal Flat). Each wetland was surveyed once over 24 hours for fish and water quality and to evaluate the risk of acidification associated with potential wetland drying. A further nine wetlands, for which Baseline ecological data had been collected previously (i.e. for fish, vegetation, macroinvertebrates, water quality, frogs and birds), were also evaluated for potential risk of acidification. These included Woolenook Bend, Gurra Gurra Lake, Lake Bonney, Yatco Lagoon, Pyap, Murbko South, Devon Downs North, North Purnong and Saltbush Flat (South Purnong). Surveys occurred during 15 December 2006 to 15 January 2007.

In total 33,506 fish from 15 species, including 10 native species and five invasive species were captured. Native species represented 85% of the total catch. The most abundant and widely distributed native fish taxa were carp gudgeons, unspecked hardyheads and bony herring (together comprising 74% of the total catch). Common carp and eastern gambusia were the most abundant and widespread invasive species, comprising 15% of the total catch. Two of the native species captured (silver perch and freshwater catfish) are currently protected under state (*South Australian Fisheries Act* 1982) or federal (*EPBC Act* 1999) legislation, and they were only sampled from one site (Tanyaca Creek).

The majority of wetlands surveyed had permanent connections with the River Murray, facilitating sufficient water exchange to maintain desirable water quality characteristics for fish: conductivity < 1000 µs cm^{-1}; pH > 7; dissolved oxygen > 6 mg L^{-1} (B. Smith, Unpub. Data). The highest mean conductivity reading (5993 µs cm^{-1}) was taken at Ross Lagoon, where the single shallow inlet has become choked with emergent reeds. The least turbid wetland was Maidment Lagoon (maximum recorded Secchi disc depth was 60 cm), which had abundant submerged and emergent aquatic vegetation.

Laboratory analyses of water samples highlighted that 70% (*n* = 19 of 27) of the wetlands surveyed may contain sulfidic sediments that are toxic to aquatic organisms and can produce noxious odours. Oxidation of reduced sulfidic sediments (e.g. through exposure to the air when the wetland is dried out) can also cause problems on re-wetting such as anoxia in the overlying water column (as oxygen is consumed to oxidise sediments), potential toxicity to aquatic plants and animals caused by the mobilisation of metals from the sediments and increased levels of acid. However, these wetlands also had soil pH levels greater than ~ 6, indicating a high buffering (or acid-neutralising) capacity, which would potentially preclude the majority of these wetlands from becoming acidic if they were dried (there is still a risk of sulphate toxicity and possible anoxia, however). Further comprehensive analyses are recommended (see Discussion in PART B).

Finally, the combined survey results from all of the River Murray Wetlands Baseline Surveys and from fish-habitat studies in the Chowilla region (B. Zampatti, Unpub. Data) indicate that native fishes, particularly the less abundant large bodied species, prefer habitat with flowing water, whereas invasive fishes prefer still waters. Thus, consideration should be given to the preservation of all wetlands with good connections with the river that facilitate relatively high velocity current flows within their inlet channels (in the range 0.2-0.7 $m\ s^{-1}$). This is especially relevant to wetlands in the region between the barrages in the Lower Lakes and Lock and Weir 1 at Blanchetown, where the prevailing north-south winds drive significant changes to river/wetland water levels (thus, high current velocities within the inlet channels). The importance of river flow *and* naturally-driven current flows (or even flows from irrigation pumps) to native aquatic fauna deserves more attention, particularly in heavily regulated systems such as the Murray-Darling Basin.

INTRODUCTION

The South Australian River Murray Wetlands Baseline Surveys (RMWBS) have been the most comprehensive wetlands surveys ever undertaken in the Murray-Darling Basin (Closs *et al.*, 2005). They have occurred each year since 2004, and have covered 68 wetlands. At each wetland, baseline data on the site characteristics, fish, water quality, groundwater, vegetation, birds, frogs and macroinvertebrates has been collected (Holt *et al.*, 2004; Smith, 2006a; Smith & Fleer, 2007). This information has already been used to derive wetland management plans for a number of wetlands, which include concise statements about local conservation values and planned management objectives. Importantly, the data provides a basis for evaluating the success of future management, to inform adaptive management strategies (see further, http://www.rivermurray.sa.gov.au/major/wetlands.html).

BACKGROUND

Given the severe and ongoing nature of the drought in South Australia, in late 2006, the South Australian Murray-Darling Basin Natural Resources Management Board (SA MDB NRM Board) undertook investigations regarding potential evaporative savings that could be achieved by blocking river connections on a number of wetlands, as an emergency drought response (Smith, 2006b). Blocking river connections will effectively isolate selected wetlands from the river thereby preventing the replacement of water lost through evaporation. A rigorous selection process identified nine wetlands as potentially suitable for immediate closure and a further 18 for which more information was required before an assessment on their suitability for closure could be made. This survey was commissioned to gather some of the ecological data required to inform a risk assessment for each wetland and to contribute information to develop future drought response strategies.

AIMS

This ecological survey had three aims:

1. Collect baseline data on the fish communities, water quality and potential risk of acidification for selected wetlands to inform ecological risk assessments regarding possible wetland closures for water savings during the 2006-2007 drought.
2. Provide a report on the survey's findings, paying particular attention to identifying threatened fish that may be at risk from wetland closures.
3. Provide data to inform the Board's future longer-term wetland management programs and development of material for Drought Response Strategies.

PART A – FISH AND WATER QUALITY

METHODS

1.1 FIELD SAMPLING

The 18 wetlands sampled for fish, water quality and acidification potential included (in geographical order, starting at the border):

RIVERLAND REGION
(SA/VIC/NSW Border to Overland Corner)

1. Nelwood Swamp	3. Nelwart Swamp
2. Horseshoe Swamp	4. Tanyaca Creek

MURRAY GORGE REGION
(Overland Corner to Mannum)

5. Jaeschke Lagoon	12. Bowhill
6. Ross Lagoon	13. Craignook
7. Donald Flat Lagoon	14. Henley Park
8. McBean Pound North	15. Maidment Lagoon
9. Reedy Island	16. Mark's Landing
10. Wombat's Rest Backwater	17. Punyelroo
11. Big Bend	18. Teal Flat

1.1.1 Site selection within wetlands

Within each wetland major habitat types (e.g. emergent littoral-, submerged- and overhanging vegetation, rocks, woody debris, open water, inlet channels and bare bank) and obvious variations in hydro-geography were identified. Five sites were selected based on these characteristics to optimise the diversity of fish species and life stages sampled.

1.1.2 Sampling gear and protocol

At each sampling site either three replicate fyke nets or three replicate gill nets were used, with three sets of fyke nets and two sets of gill nets being used at each wetland. Fyke nets are efficient at catching small-bodied fish (including juveniles of large-bodied species) whereas gills nets are more appropriate for catching large-bodied species. (Smith, 2007 Table 1). An attempt was made to standardise fishing effort across specific habitat types to maintain consistency such that local and regional comparisons between wetland fish communities could be made.

Nets were set in the mid-late afternoon and left overnight for approximately 24 h. Upon retrieval, total length (TL, mm) was measured for the first 20 fish of each species and the remainder were counted and visually inspected for rare/threatened species. All fish were released, including all invasive species.

NOTE: Although fyke nets will catch some larger fish and their young, gill netting is used because it is an important complementary method that specifically targets large-bodied species. Gill netting requires a license that is only available to commercial fishers and professional research organisations such as SARDI Aquatic Sciences, thus future community monitoring may be restricted.

Table 1. Summary of the fishing methods used in this River Murray Wetlands Baseline Survey.

Gear type	Mesh size and description
Fyke nets	single 6 m wing x 60 cm deep leader, 60 cm diameter entrance, 3 m funnel with 7 rings, 3 chambers and 8 mm stretched mesh
Gill nets	15 m long x 1 m deep, 3 x 5 m panels of 3, 4 and 5" stretched mesh (45, 75 and 115 mm) randomly positioned within the net.

1.1.3 Sub-sampling of fish within fyke nets

Fyke nets are very efficient at sampling small-bodied wetland fish. In some instances, they catch several hundred fish per net, per night (sometimes > 1000 fish per net). Thus, sub-sampling and extrapolation was required at some sites to minimise the stress on captured fish and to ensure the timely completion of sample processing. When sub-sampling was required, the catch was divided into halves (or thirds). One half (or third) of the total catch was processed as normal, whilst the other was inspected for rare/threatened species and returned to the water.

1.1.4 Water Quality:

Five water quality parameters were recorded at each fish sampling site: dissolved oxygen (DO, mg L^{-1}); electrical conductivity (concentration of soluble ions, µs cm^{-1}); pH; water temperature (°C); and turbidity (Secchi depth, cm). DO, conductivity, pH and temperature were recorded on a pre-calibrated water quality metre. This is the first year that the RMWBS have incorporated Secchi discs to measure turbidity. Previously, turbidity has been measured in Nephelometric Turbidity Units (NTU) using turbidity tubes. Secchi depth is considered more appropriate for community monitoring, as Secchi discs are easy to use and the results are more easily related to water clarity (turbidity refers to the scattering and absorption of light, rather than transmission, caused by suspended matter such as clay, dissolved organic material and microscopic organisms). Spot sampling like this is useful for detecting ‘extremes’ such as high conductivity or turbidity, or low DO.

RESULTS

1.2 FISH SURVEY

In total, 33,506 fish from 15 species were sampled (Table 2), including five invasive species and two protected native species: silver perch (*EPBC Act* 1999) and freshwater catfish (*South Australian Fisheries Act* 1982) (Smith, 2007; Table 2)[1]. These protected species were only sampled from one site (Tanyaca Creek).

Table 2 lists the total number of each species captured and provides details of their relative abundances and distribution, total length (TL, mm), and the conductivity-range of the water in which they were found. We captured the range of wetland species expected from the surveyed regions (Riverland and Murray Gorge), minus five that are thought to be locally extinct (Murray hardyhead, *Craterocephalus fluviatilis*; southern purple spotted gudgeon, *Mogurnda adspersa*; chanda perch, *Ambassis agassizii*; southern pygmy perch, *Nannoperca australis*; Yarra pygmy perch, *Nannoperca obscura*). There are also other estuarine and euryhaline (tolerant of a wide range of salinities) freshwater fish species common to the Lower Swamps (Mannum to Wellington) and Lower Lakes (Lakes Alexandrina and Albert) regions of the South Australian Murray-Darling Basin, and these are listed elsewhere (see further, Smith 2006).

Native species represented 85% of the total number of fish captured with the most abundant and widely distributed native fish taxa being carp gudgeons (a species complex of uncertain taxonomy; Bertozzi *et al.*, 2000), unspecked hardyheads and bony herring that together comprised 74% of the total catch. Common carp and eastern gambusia were the most abundant and widespread invasive species, comprising 15% of the total catch. Whilst the remaining native and invasive species were not abundant, they were generally widespread and occurred at > 60% of the wetlands surveyed.

[1] Three species: Murray rainbowfish (*Melanotaenia fluviatilis*), dwarf flathead gudgeon (*Philypnodon sp*.) and unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*) have been removed from the Draft Threatened Species Schedule for South Australia (DEH 2003) since the 2005 Baseline Survey (Smith 2006). This schedule is still under consideration.

Table 2. Summary of the fishes captured during the 2006 River Murray Wetlands Baseline Survey, including their total abundance (% of catch) and distribution (% of wetlands), conservation status (State, SA *Fisheries Act* 1982; National, *EPBC Act* 1999), a comparison of catches between regions*, and the conductivity and turbidity of the waters in which they were found. P = Protected, Vu = Vulnerable.

Common Name	Species Name	Total	Abundance (% of catch)	Distribution (% of wetlands)	Cons. Status		Number of Fish		Length (mm, TL)			Conductivity ($\mu S\ cm^{-1}$)		
					State	National	Murray Gorge	Riverland	Ave	Min	Max	Ave	Min	Max
Native Fish														
Australian smelt	*Retropinna semoni*	1096	3.27	83			1069	27	57	26	85	554	187	1311
bony herring	*Nematalosa erebi*	3573	10.66	100			2941	632	202	18	500	569	138	6410
golden perch	*Macquaria ambigua*	17	0.05	44			11	6	346	155	495	370	138	818
carp gudgeon complex	*Hypseleotris spp.*	15209	45.39	94			12652	2557	36	17	55	634	138	1311
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	6108	18.23	94			3683	2425	43	17	80	456	138	1311
dwarf flathead gudgeon	*Philypnodon sp.*	55	0.16	61			52	3	40	23	54	793	229	1311
Murray rainbowfish	*Melanotaenia fluviatilis*	84	0.25	72			74	10	56	35	72	470	174	818
flathead gudgeon	*Philypnodon grandiceps*	2262	6.75	83			2212	50	52	19	111	852	138	1311
freshwater catfish	*Tandanus tandanus*	4	0.01	6	P		0	4	148	110	258	187	187	187
silver perch	*Bidyanus bidyanus*	1	0.00	6		Vu	0	1	350	350	350	195	195	195
Exotic/Invasive Fish														
common carp	*Cyprinus carpio*	3769	11.25	100			3677	92	242	15	760	598	141	6410
eastern gambusia	*Gambusia holbrooki*	1203	3.59	83			754	449	32	15	55	893	138	6410
goldfish	*Carassius auratus*	52	0.16	67			38	14	185	34	400	514	138	1004
redfin perch	*Perca fluviatilis*	69	0.21	67			65	4	91	40	400	520	174	818
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)	4	0.01	22			4	0	370	342	405	634	406	1075
Total Fish		**33506**					**27232**	**6274**						
Total Species		**15**					**15**	**15**						

*Note difference in number of wetlands sampled per region (Murray Gorge, *n* = 14; Riverland, *n* = 4)

1.3 REGIONAL COMPARISON

In this survey, four wetlands from the Riverland region and 14 from the Murray Gorge region were sampled. No wetlands from the Lower Swamps and Lower Lakes region were included effectively precluding detailed regional comparisons. However, some broad scale comparisons between the regions are outlined below. These are in agreement with the conclusions of previous surveys (Holt *et al*., 2004; Smith, 2006, Smith, 2007).

Riverland Region

The four wetlands surveyed in the Riverland region included Nelwood II, Horseshoe and Nelwart Swamps, and Tanyaca Creek. A total of 6,274 individuals from 14 species were captured, including four invasive species and two protected native species: silver perch (*EPBC Act* 1999) and freshwater catfish (*South Australian Fisheries Act* 1982) (Table 2, Table 3). These protected species were only recorded at one site, Tanyaca Creek, highlighting the importance of protecting this off-stream anabranch creek and its associated wetland.

The remaining species are all widespread throughout the South Australian Murray. Whilst dwarf flathead gudgeons and Murray rainbowfish are not abundant, there is no evidence to suggest that their abundance has changed over time due to a lack of previous baseline data. However, there is evidence to suggest that overfishing, river regulation and other anthropogenic effects have led to a significant reduction in the abundance of golden perch (MDBC 2003). Nevertheless, golden perch are generally less abundant in still, shallow wetlands (which comprised the majority of surveyed wetlands). In this region's survey golden perch comprised < 0.1% of the total catch, similar abundances were documented in the 2004, 2005 and 2006 RMWBS, which examined the fish communities of 27, 22 and eight River Murray wetlands, respectively (Holt *et al*., 2004; Smith, 2006; Smith and Fleer, 2007).

Overall, carp gudgeons and unspecked hardyheads were the most abundant native species captured, followed by bony herring, flathead gudgeon and Australian smelt. Of the invasive species, eastern gambusia dominated the catch, followed by common carp, goldfish and redfin perch. Across wetlands and using standard methods, species richness varied from 12 species at Tanyaca Creek to nine species at Nelwart Swamp, and total abundances varied from 2131 at Nelwart to 1088 at Nelwood II (Table 3).

Table 3. Summary of the fishes captured at the wetlands in the Riverland region.

	Riverland Region			
Common Name	**Nelwood II**	**Horseshoe**	**Nelwart**	**Tanyaca**
Native Fish				
Australian smelt		1	22	4
bony herring	72	74	310	176
callop	4			2
carp gudgeon complex	450	460	1245	402
unspecked hardyhead	503	606	104	1212
dwarf-flathead gudgeon	1		2	
Murray rainbowfish	2	5		3
flathead gudgeon	7	28	15	
freshwater catfish				4
silver perch				1
Exotic/Invasive Fish				
common carp	20	13	39	20
eastern gambusia	22	3	393	31
goldfish	7	1		6
redfin perch		2	1	1
carp x goldfish hybrid				
Total Fish	**1088**	**1193**	**2131**	**1862**
Count of Species	**10**	**10**	**9**	**12**

Murray Gorge Region

The 14 wetlands surveyed in the Murray Gorge region included Jaeschke Lagoon, Ross Lagoon, Donald Flat Lagoon, McBean Pound North, Reedy Island, Wombat’s Rest Backwater, Big Bend, Bowhill, Craignook, Henley Park, Maidment Lagoon, Mark’s Landing, Punyelroo and Teal Flat. A total of 27,232 individuals from 13 species, including five invasive species were captured (Table 4). Variation in abundances among species from the different regions relates to the number of wetlands sampled per region (Riverland, n = 4; Murray Gorge, n = 14).

Wetlands in the Murray Gorge region contained a similar fish community (species composition) to those of the Riverland region, with the exception of Tanyaca Creek in the Riverland region where one silver perch and four freshwater catfish were captured (none of these fish were captured in the Murray Gorge region). Across wetlands, species richness varied from 12 species at Reedy Island, Maidment Lagoon, Mark’s Landing and Punyelroo to three species at Ross Lagoon (Waikerie). Total abundances varied from 4310 at Craignook to 95 at Ross Lagoon (Table 4).

Table 4. Summary of the fishes captured at the wetlands in the Murray Gorge region.

	Murray Gorge Region									
Common Name	**Jaeschke**	**Ross**	**Donald Flat**	**McBean Pound**	**Reedy Island**	**Wombat Rest**	**Big Bend**	**Bow Hill**	**Craignook**	**Henley Park**
Native Fish										
Australian smelt	85		37	1	5	30	31	4		149
bony herring	760	23	163	44	252	667	42	13	52	485
callop					1	1			2	
carp gudgeon complex	46		262	461	337	457	160	1418	3068	1470
unspecked hardyhead	415		196	61	1017	111	169	172	795	257
dwarf-flathead gudgeon				10	3		6	13	4	
Murray rainbowfish			2	1	23	13		4		4
flathead gudgeon	7		19		32	2	733	388	355	63
freshwater catfish										
silver perch										
Exotic/Invasive Fish										
common carp	131	33	24	62	15	12	14	30	19	180
eastern gambusia	377	39				17	141	49	13	7
goldfish			1	1	1	1		12		
redfin perch			12		18			1	2	12
carp x goldfish hybrid	1			1	1					1
Total Fish	**1822**	**95**	**716**	**642**	**1705**	**1311**	**1296**	**2104**	**4310**	**2628**
Count of Species	**8**	**3**	**9**	**9**	**12**	**10**	**8**	**11**	**9**	**10**

1.4 WATER QUALITY

Conductivity (µs cm^{-1}): Of the 18 wetlands sampled for fish and water quality, Ross Lagoon (Waikerie) recorded the highest mean conductivity (5993 µs cm^{-1}), likely due to evapo-concentration; the inlet is currently choked with reeds, preventing adequate water exchange with the river. Big Bend was also slightly saline (mean conductivity was 1195 µs cm^{-1}) as one of its inlets was choked with reeds; the other has been filled with dirt to allow vehicle access along the riverbank. The conductivity of the remaining wetlands (average, 200-800 µs cm^{-1}) was typical of River Murray wetlands in South Australia, which have permanent connections with the main channel (facilitating water exchange) and are unaffected by salty groundwater intrusion (Holt *et al.*, 2004; Table 5).

Turbidity (Secchi depth, cm): Secchi depth readings varied from a minimum of 5 cm at Nelwart Swamp (most turbid) to a maximum of 60 cm at Maidment Lagoon (least turbid). Mean Secchi depth recordings for the remaining wetlands were typically in the range 10-25 cm (Table 5). This is likely to be a result of the shallow nature of these wetlands, which leads to wind-induced turbulence and the subsequent disturbance of soft muddy substrates.

Water Temperature (°C): Water temperatures reflected the air temperatures at the time of sampling. They varied from 21.3°C at McBean Pound North, to 34.2°C at Ross Lagoon, but were mostly in the range 24-28°C (Table 5).

Dissolved Oxygen (DO, mg L^{-1}): The DO concentration for all wetlands sampled was high with the average DO content being > 8 mg L^{-1} (Table 5). The high DO concentration of these wetlands is likely to reflect their shallow nature (wind-assisted oxygenation of the water column occurs readily) and the time of day that measurements were recorded. In regards to the latter, sampling typically occurred during the mid-late afternoon after aquatic plants had been actively photosynthesizing (consuming carbon dioxide and producing oxygen) during the day. Regardless, DO is unlikely to pose a problem for aquatic fauna in the wetlands surveyed.

pH: Mean pH values ranged from 7.8 to 9.7 (Table 5). Whilst these figures are relatively alkaline, they reflect the underlying geology of the wetlands (Holt *et al.*, 2004), and are similar to those recorded from previous surveys (Smith, 2006; Smith and Fleer, 2007).

Table 5. Summary of water quality data for each wetland.

	Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Location	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**
Nelwood II	200	138	235	27.4	26.6	29.2	7.7	6.8	9.4	7.9	7.8	9.4	32	28	37
Horseshoe	219	157	279	32.3	30.2	32.8	8.0	4.5	11.4	8.5	7.0	9.0	26	20	47
Nelwart	700	689	709	27.5	26.5	27.9	5.9	5.8	7.3	7.8	7.6	7.9	6	5	8
Tanyaca	227	187	243	26.4	25.2	27.0	8.1	8.1	8.3	8.7	7.8	9.0	26	20	40
Jaeschke	615	524	643	25.9	22.0	28.3	n/a	n/a	n/a	9.0	7.6	9.5	11	6	13
Ross	5993	5670	6410	32.0	30.9	34.2	n/a	n/a	n/a	8.6	8.3	8.9	16	13	18
Donald Flat	436	429	444	25.3	23.6	28.4	8.4	8.1	9.0	8.2	8.0	8.6	20	20	22
McBean Pound	926	687	1097	25.3	21.3	30.0	n/a	n/a	n/a	8.1	7.8	8.5	27	24	31
Reedy Lagoon	414	380	424	26.7	25.7	27.0	8.3	7.2	8.7	7.8	7.7	8.2	38	35	46
Wombat's Rest	512	470	539	26.3	25.0	27.1	8.4	7.7	8.8	8.5	8.2	9.1	10	7	12
Big Bend	1195	909	1311	26.6	22.6	27.9	10.1	8.1	11.9	8.5	7.7	8.5	6	5	9
Bow Hill	837	576	980	26.6	24.2	27.0	10.2	9.2	11.2	9.7	9.5	9.9	38	25	55
Craignook	746	730	776	24.6	24.0	25.3	9.1	8.3	11.2	8.3	8.1	8.6	20	20	29
Henley Park	480	406	505	25.9	25.0	26.2	7.7	5.5	11.3	8.0	7.5	9.6	19	16	24
Maidment	485	298	1000	22.7	21.8	25.2	9.4	8.7	10.3	9.4	9.2	9.9	50	40	60
Mark's Landing	693	474	818	24.5	22.3	25.5	9.3	8.9	9.7	8.7	8.5	9.0	15	14	20
Punyelroo	457	376	698	24.0	23.2	25.2	8.3	8.1	8.4	8.3	7.9	9.2	12	9	15
Teal Flat	734	707	789	26.2	24.6	27.4	9.6	8.4	15.8	8.4	7.6	9.7	16	5	25

1.5 SITE SUMMARIES

1.5.1 Riverland Region

1.5.1.1 Nelwood Swamp (Nelwood II)

General information

NOTE: Due to a miscommunication, the wetland sampled was ~1.5 km downstream of Nelwood proper, and is hereafter named 'Nelwood II' for discrimination.

At Nelwood II, fish, water quality and acid-sulfate soil sampling were undertaken during 18-19 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 6.

Nelwood II is approximately 1 km long x 100 m wide. There are two inlets, each of 2-3 m wide and 1.5 m deep. The wetland operates as a flow through system, from upstream to downstream, although the upstream inlet is becoming chocked with emergent reeds. Within the wetland there was an abundance of submerged and emergent riparian vegetation, and the average depth was 1-1.5 m (appeared to be an excavated channel). There was no evidence of salty groundwater intrusion into the wetland and there were no obvious impacts from grazing. One large irrigation pump exists at the 'Brooklyn Bridge' crossing, towards the upstream end of the wetland.

A total of 1088 fish from 10 species were captured, including three invasive species (Table 7). Unspecked hardyheads, carp gudgeons and bony herring were the most abundant native fishes, whilst common carp and eastern gambusia were the most abundant invasive species captured. The remaining native (dwarf flathead gudgeons, Murray rainbowfish, golden perch) and invasive (goldfish) species were all recorded in low abundance. The capture of relatively small individuals of bony herring, carp gudgeons, unspecked hardyheads, common carp, eastern gambusia and goldfish may indicate relatively recent recruitment.

The above catch from Nelwood II was similar in species composition to that recorded from Nelwood proper during autumn and spring surveys in 2004 (M. Harper, Unpublished Data). In those surveys, sampling occurred over 24 hours using 3 x 2 sets of small-mesh fyke nets (no gill nets). However, Australian smelt was captured in Nelwood proper in 2004 but not in Nelwood II, and golden perch and dwarf flathead gudgeons were captured in Nelwood II in 2006 but not in Nelwood proper (Table 7). There was also some variation in abundances between locations but due to the difference in methods used and the times of sampling, the reasons for these differences are difficult to resolve.

Due to the wetland operating as a flow through system, recorded water quality parameters were similar to that in the river. The average conductivity, water temperature, DO concentration, pH and Secchi depth was 200 µs cm^{-1}, 27.4°C, 7.7 mg L^{-1}, 7.9 and 32 cm, respectively (Table 8). Thus, the water was relatively fresh, well oxygenated, basic in pH and relatively clear.

Implications for management

- No threatened fish species were sampled from Nelwood II, or have recently been recorded from nearby wetlands, i.e. Nelwood proper.
- Both Nelwood II and Nelwood proper had water column sulfate concentrations within proposed trigger levels (i.e. 10 mg SO_4 L^{-1}, Baldwin *et al*., 2007) indicating that they are unlikely to contain sulfidic sediments (see further, Part B).
- If these wetlands are to be disconnected from the river (leading to drying via evaporation), they should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if significant kills of native aquatic fauna are observed or if poor water quality develops.

Table 6. Summary of the habitat type and fishing method used at each site in Nelwood II.

Site #	Method	Habitat description	Latitude	Longitude
1	Gill Net	Fringing emergent reeds, 100-130 cm deep, muddy substrate, dense beds of submerged *Vallisneria* and *Potamogeton*, some flow apparent	-33.97183	140.93061
2	Fyke Net	Abundant *Potamogeton*, fringing emergent reeds, muddy substrate	-33.97197	140.92962
3	Gill Net	Abundant *Potamogeton* and *Vallisneria*, fringing emergent reeds, 100-120 cm deep, muddy substrate	-33.97265	140.92857
4	Fyke Net	Wetland inlet, abundant *Potamogeton*, *Vallisneria* and *Myriophillum*, fringing emergent reeds, 50-120 cm deep, muddy substrate	-33.97405	140.92520
5	Fyke Net	Abundant *Potamogeton*, fringing emergent reeds, 50-150 cm deep, muddy substrate	-33.97093	140.93443

Table 7. Summary of the number and length of species captured at Nelwood II (and Nelwood proper*).

			Total Length (mm)			*Nelwood Proper
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**	**Total**
Native Fish						
Australian smelt	*Retropinna semoni*					13
bony herring	*Nematalosa erebi*	72	257	30	412	458
golden perch	*Macquaria ambigua*	4	326	155	390	
carp gudgeon complex	*Hypseleotris spp.*	450	35	23	45	1887
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	503	36	27	62	223
dwarf flathead gudgeon	*Philypnodon sp.*	1	44	44	44	
Murray rainbowfish	*Melanotaenia fluviatilis*	2	66	66	66	67
flathead gudgeon	*Philypnodon grandiceps*	7	38	31	45	560
freshwater catfish	*Tandanus tandanus*					
silver perch	*Bidyanus bidyanus*					
Exotic/Invasive Fish						
common carp	*Cyprinus carpio*	20	270	22	720	15
eastern gambusia	*Gambusia holbrooki*	22	32	18	42	323
goldfish	*Carassius auratus*	7	159	41	246	1
redfin perch	*Perca fluviatilis*					
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)					
Total Fish		**1088**				**3547**
Total Species		**10**				**9**

Table 8. Summary of water quality data recorded at Nelwood II.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**
200	138	235	27.4	26.6	29.2	7.7	6.8	9.4	7.9	7.8	9.4	32	28	37

1.5.1.2 Horseshoe Swamp

General information

At Horseshoe Swamp, fish, water quality and acid-sulfate soil sampling were undertaken during 18-19 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in If this wetland is to be disconnected from the river (leading to drying via evaporation), it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if significant kills of native aquatic fauna are observed or if poor water quality develops.
Table 9.

Horseshoe Swamp is approximately 6 km long x 250 m wide and has three permanent connections with the main river channel providing continuous water exchange. These connections are all > 1.5 m deep but range from 2-20 m wide. The submerged and emergent vegetation appeared healthy, and the average water depth was 1 m. There was no evidence of salty groundwater intrusion into the wetland, and no grazing impacts or domestic/irrigation pumps were observed.

A total of 1193 fish from 10 species were captured, including four invasive species (Table 10). Unspecked hardyheads, carp gudgeons and bony herring were the most abundant native species, whilst common carp was the most abundant invasive species. The remaining native (Australian smelt, Murray rainbowfish, flathead gudgeon) and invasive (eastern gambusia, goldfish, redfin perch) species were all recorded in low abundance. The capture of relatively small individuals of bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons, common carp and goldfish may indicate relatively recent recruitment.

Wetland water quality was similar to that in the river due to the wetland's three connecting channels. The average conductivity, water temperature, DO concentration, pH and Secchi depth was 219 µs cm^{-1}, 32.3°C, 8.0 mg L^{-1}, 8.5 and 26 cm, respectively (Table 11). Thus, at the time of sampling, the water was relatively fresh, well oxygenated, basic in pH and clear.

Implications for management

- No threatened fish species were captured.
- Water column sulfate concentrations within proposed trigger levels (i.e. 10 mg SO_4 L^{-1}, Baldwin *et al*., 2007) indicating that it is unlikely to contain sulfidic sediments (see further, Part B).
- If this wetland is to be disconnected from the river (leading to drying via evaporation), it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if significant kills of native aquatic fauna are observed or if poor water quality develops.

Table 9. Summary of the habitat type and fishing method used at each site in Horseshoe Swamp.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	50 cm deep, muddy substrate, scattered submerged vegetation	-34.06334	140.79634
2	Fyke Net	Very silty/muddy substrate, dense submerged vegetation, adjacent stands of emergent *Typha*	-34.06042	140.79726
3	Gill Net	Adjacent bare bank between red gums, 50-100 cm deep, firm muddy substrate, scattered submerged vegetation	-34.06525	140.79767
4	Gill Net	Open water, muddy substrate, 120 cm deep, scattered submerged vegetation	-34.06712	140.80129
5	Fyke Net	Firm muddy bottom, adjacent bare bank with some macrophytes nearby, 70 cm deep	-34.06833	140.79554

Table 10. Summary of the number and length of species captured at Horseshoe Swamp.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	1	37	37	37
bony herring	*Nematalosa erebi*	74	205	35	388
golden perch	*Macquaria ambigua*				
carp gudgeon complex	*Hypseleotris spp.*	460	34	21	48
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	606	38	23	57
dwarf flathead gudgeon	*Philypnodon sp.*				
Murray rainbowfish	*Melanotaenia fluviatilis*	5	51	48	53
flathead gudgeon	*Philypnodon grandiceps*	28	34	22	50
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	13	359	96	690
eastern gambusia	*Gambusia holbrooki*	3	28	27	31
goldfish	*Carassius auratus*	1	62	62	62
redfin perch	*Perca fluviatilis*	2	119	118	120
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**1193**			
Total Species		**10**			

Table 11. Summary of water quality data recorded at Horseshoe Swamp.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
219	157	279	32.3	30.2	32.8	8.0	4.5	11.4	8.5	7.0	9.0	26	20	47

1.5.1.3 Nelwart Swamp

General information

At Nelwart Swamp, fish, water quality and acid-sulfate soil sampling were undertaken during 19-20 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in If this wetland is to be disconnected from the river (leading to drying via evaporation), it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if significant kills of native aquatic fauna are observed or if poor water quality develops.
Table 12.

Nelwart Swamp is approximately 1.6 km long x 150 m wide (max). The wetland has one permanent connection with the main river channel that is 20 m wide and approximately 50 cm deep. There appeared to be little water exchange with the main river, and submerged vegetation was sparsely distributed. The average water depth within the wetland was 50 cm, and the emergent riparian vegetation was dense and abundant. There was evidence of salty groundwater intrusion at the terminal end of the wetland but no grazing or irrigation pumps were observed.

A total of 2131 fish from nine species were sampled, including three invasive species, (Table 13). Carp gudgeons were by far the most abundant native species captured, followed by bony herring and unspecked hardyheads. Eastern gambusia and common carp were the most abundant invasive species captured. The remaining native (dwarf flathead gudgeons, flathead gudgeons and Australian smelt) and invasive (redfin perch) species were all recorded in low abundance. The capture of relatively small individuals of bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons, common carp, eastern gambusia and redfin perch may indicate relatively recent recruitment.

The average conductivity, water temperature, DO concentration, pH and Secchi depth was 700 µs cm^{-1}, 27.5°C, 5.9 mg L^{-1}, 7.8 and 6 cm, respectively (Table 14). Thus, due to poor water exchange with the river, the wetland was slightly saline and turbid but well oxygenated and basic in pH.

Implications for management

- No threatened fish species were sampled, and invasive species (particularly eastern gambusia) were abundant. Native fish might benefit from improved water quality and the ease of passage that would stem from increasing connectivity between the wetland and river. Furthermore, reduced turbidities would promote the establishment of submerged aquatic vegetation, which would provide fish with, *inter alia*, cover from predators and spawning and nursery habitat.
- Water column sulfate concentrations exceeded suggested trigger levels (i.e. 10 mg SO_4 L^{-1}, Baldwin *et al.*, 2007) indicating that this wetland is likely to contain sulfidic sediments, which, if dried, may lead to noxious odours, the poisoning of aquatic flora and fauna, and anoxic and/or acidic sediments upon re-wetting (see Part B).
- If this wetland is to be disconnected from the river (leading to drying via evaporation), it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if significant kills of native aquatic fauna are observed or if poor water quality develops.

Table 12. Summary of the habitat type and fishing method used at each site in Nelwart Swamp.

Site #	Method	Habitat description	Latitude	Longitude
1	Gill Net	Open water, 100 cm deep, soft muddy bottom	-34.21254	140.75038
2	Fyke Net	Adjacent to stands of *Juncus,* 50 cm deep, soft muddy bottom, scattered woody debris	-34.21402	140.75246
3	Gill Net	Adjacent dense stand of *Typha,* 70 cm deep, soft muddy substrate	-34.21419	140.74698
4	Fyke Net	Adjacent dense stand of *Typha,* 50 cm deep, soft muddy substrate	-34.21621	140.74656
5	Fyke Net	Open water, 100 cm deep, soft muddy substrate	-34.21686	140.74794

Table 13. Summary of the number and length of species captured at Nelwart Swamp.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	22	55	42	70
bony herring	*Nematalosa erebi*	310	191	38	465
golden perch	*Macquaria ambigua*				
carp gudgeon complex	*Hypseleotris spp.*	1245	37	27	50
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	104	44	32	80
dwarf flathead gudgeon	*Philypnodon sp.*	2	37	32	42
Murray rainbowfish	*Melanotaenia fluviatilis*				
flathead gudgeon	*Philypnodon grandiceps*	15	46	35	71
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	39	299	67	720
eastern gambusia	*Gambusia holbrooki*	393	31	18	53
goldfish	*Carassius auratus*				
redfin perch	*Perca fluviatilis*	1	70	70	70
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**2131**			
Total Species		**9**			

Table 14. Summary of water quality data recorded at Nelwart Swamp.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**
700	689	709	27.5	26.5	27.9	5.9	5.8	7.3	7.8	7.6	7.9	6	5	8

1.5.1.4 Tanyaca Creek

General information

At Tanyaca Creek, fish, water quality and acid-sulfate soil sampling were undertaken during 19-20 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 15.

Tanyaca Creek is a small anabranch system that is permanently connected to the River Murray to the north-west, to Rumpagunya Creek to the south-west, and occasionally connects to the Pike-Mundic system to the north-east during high river flows (A. Conallin, Pers. Comm.). The Creek has some flow and is approximately 3 km long and 150 m wide (max). There are three inlets, up to 2 m deep: two connect to the Murray River, and one connects to Rumpagunya Creek. Whilst there is abundant woody debris (making the upstream inlet impassable by boat), none are choked with reeds. The deeper (1.5-2 m) central areas of the wetland contained sparse patches of dense *Vallisneria* and *Myriophyllum*, and occasional areas of *Potamogeton* around the wetland's margins (< 60 cm deep). Emergent vegetation was patchy. Whilst there was no evidence of groundwater intrusion, there was evidence of grazing around the margins of the wetland (obvious pugging and cows observed in inlet). No irrigation pumps were seen. Importantly, this was the only site where threatened fish (silver perch and freshwater catfish) were sampled during this study (see below).

A total of 1862 fish from 12 species were recorded, including two threatened native species (silver perch and freshwater catfish) and four invasive species (Table 16). Unspecked hardyheads were by far the most abundant native species captured, followed by carp gudgeons and bony herring. Eastern gambusia and common carp were the most abundant invasive species captured. The remaining native (Australian smelt, golden perch and Murray rainbowfish) and invasive (goldfish and redfin perch) species were all recorded in low abundance, as were the two threatened species (silver perch, n = 1; freshwater catfish, n = 4). The capture of relatively small individuals of Australian smelt, bony herring, carp gudgeons, unspecked hardyheads, common carp, eastern gambusia, goldfish and redfin perch may indicate relatively recent recruitment.

Wetland water quality was similar to that in the river due to the wetland's connecting channels. The average conductivity, water temperature, DO concentration, pH and Secchi depth was 227 µs cm^{-1}, 26.4°C, 8.7 mg L^{-1}, 8.7 and 26 cm, respectively (Table 17). Thus, the water was relatively fresh, well oxygenated, basic in pH and clear.

Implications for management

- Tanyaca Creek was the only site where the threatened species, silver perch and freshwater catfish, were recorded highlighting the importance of protecting this off-stream anabranch creek and its associated wetland. Therefore, it is recommended that this wetland should not be disconnected from the river for water saving purposes.
- The current state of this wetland should be maintained and monitoring should continue to ensure its function as habitat for threatened species.

Table 15. Summary of the habitat type and fishing method used at each site in Tanyaca Creek.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	Edge habitat, scattered snags, patches of *Vallisneria* , *Myriophyllum* and sparse emergent reeds, 40-80cm deep, muddy substrate, wind-induced current flows	-34.23805	140.76619
2	Gill Net	Open water, patches of *Vallisneria* and *Myriophyllum* , 150-180 cm deep, muddy substrate, wind-induced current flows	-34.23843	140.76017
3	Fyke Net	Edge habitat, scattered snags, patches of *Vallisneria* and *Potamogeton* , dense patches of friging reeds, 30-60 cm deep, muddy substrate, wind-induced current flows	-34.23641	140.75584
4	Gill Net	Wetland edge, patches of *Vallisneria, Potamogeton* , 100-120 cm deep, muddy substrate.	-34.23432	140.75272
5	Fyke Net	Wetland inlet, some current flow, muddy/silty substrate, scattered small snags, 40-120 cm deep, patches of *Vallisneria*	-34.23309	140.75145

Table 16. Summary of the number and length of species captured at Tanyaca Creek.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	4	44	36	51
bony herring	*Nematalosa erebi*	176	284	35	410
golden perch	*Macquaria ambigua*	2	418	395	440
carp gudgeon complex	*Hypseleotris spp.*	402	36	26	50
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	1212	42	29	65
dwarf flathead gudgeon	*Philypnodon sp.*				
Murray rainbowfish	*Melanotaenia fluviatilis*	3	53	45	61
flathead gudgeon	*Philypnodon grandiceps*				
freshwater catfish	*Tandanus tandanus*	4	148	110	258
silver perch	*Bidyanus bidyanus*	1	350	350	350
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	20	242	25	670
eastern gambusia	*Gambusia holbrooki*	31	31	19	54
goldfish	*Carassius auratus*	6	150	40	195
redfin perch	*Perca fluviatilis*	1	45	45	45
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**1862**			
Total Species		**12**			

Table 17. Summary of water quality data recorded at Tanyaca Creek.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
227	187	243	26.4	25.2	27.0	8.1	8.1	8.3	8.7	7.8	9.0	26	20	40

1.5.2 Murray Gorge Region

1.5.2.1 Jaeschke Lagoon

General information

At Jaeschke Lagoon, fish, water quality and acid-sulfate soil sampling were undertaken during 9-10 Jan 2007. The fishing methods that were used at each site and a brief site description are indicated in Table 18.

Jaeschke Lagoon is approximately 800 m long x 400 m wide (max) with one narrow (5-6 m) and shallow (50 cm) inlet at the south-western corner. Whilst this inlet is partially choked with emergent reeds, there appears to be water exchange with the main river channel, as indicated by acceptable water quality (see below). Submerged beds of *Vallisneria* were extensively distributed throughout this shallow wetland (average depth < 40 cm), but emergent vegetation was scarce. There was no evidence of salty groundwater intrusion but the riparian zone was heavily impacted by cattle grazing (extensive pugging and consumption of emergent vegetation).

A total of 1822 fish from eight species were recorded, including three invasive species (Table 19). Bony herring and unspecked hardyheads were by far the most abundant native species captured, followed by Australian smelt and carp gudgeons. Eastern gambusia and common carp were the most abundant invasive species captured. The remaining native (flathead gudgeons) and invasive (carp x goldfish hybrid) species were all recorded in low abundance. The capture of relatively small individuals of Australian smelt, bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons, common carp and eastern gambusia may indicate relatively recent recruitment.

Wetland water quality was slightly reduced in comparison to that of the river, due to limited water exchange through the wetland's single connecting channel. The average conductivity, water temperature, pH and Secchi depth was 615 $\mu s\ cm^{-1}$, 25.9°C, 9.0 and 11 cm, respectively (N.B. DO concentration was not recorded at this site due to equipment failure, Table 20). At the time of sampling, the water was relatively fresh, basic in pH and moderately turbid. The shallow nature of the lagoon would facilitate significant wind-induced oxygenation.

Implications for management

- No threatened fish species were sampled.
- Preventing cattle grazing within the littoral/riparian zone will improve wetland health by enabling the persistence of ephemeral and permanent emergent vegetation. As well as providing good fish habitat, healthy riparian and littoral vegetation improves water quality and acts as a source of organic matter, shade and food.
- Water column sulfate concentrations exceeded suggested trigger levels (i.e. 10 mg SO_4 L^{-1}, Baldwin *et al.*, 2007) indicating that this wetland is likely to contain sulfidic sediments, which, if dried, may lead to noxious odours, the poisoning of aquatic flora and fauna, and anoxic and/or acidic sediments upon re-wetting (see Part B).
- If this wetland is to be disconnected from the river (leading to drying via evaporation), it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland.
- Consideration should be given to the possible impacts of drying and re-wetting on the extensive submerged vegetation community.
- Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.

Table 18. Summary of the habitat type and fishing method used at each site sampled in Jaeschke Lagoon.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	Wetland edge, exposed muddy substrate, 20 cm deep	-34.17526	139.99014
2	Gill Net	Open water, muddy substrate, 50 cm deep	-34.17638	139.99304
3	Fyke Net	Open water, muddy substrate, 35 cm deep	-34.17564	139.99414
4	Fyke Net	Wetland edge, dense emergent *Typha* , muddy substrate, 30 cm deep	-34.17789	139.99691
5	Gill Net	Wetland edge, dense emergent *Typha* , muddy substrate, 30 cm deep	-34.17817	139.99278

Table 19. Summary of the number and length of species captured at Jaeschke Lagoon.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	85	55	37	72
bony herring	*Nematalosa erebi*	760	121	18	435
golden perch	*Macquaria ambigua*				
carp gudgeon complex	*Hypseleotris spp.*	46	36	25	48
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	415	48	34	66
dwarf flathead gudgeon	*Philypnodon sp.*				
Murray rainbowfish	*Melanotaenia fluviatilis*				
flathead gudgeon	*Philypnodon grandiceps*	7	39	34	48
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	131	180	33	730
eastern gambusia	*Gambusia holbrooki*	377	33	23	55
goldfish	*Carassius auratus*				
redfin perch	*Perca fluviatilis*				
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)	1	368	368	368
Total Fish		**1822**			
Total Species		**8**			

Table 20. Summary of water quality data recorded at Jaeschke Lagoon.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
615	524	643	25.9	22.0	28.3	n/a	n/a	n/a	9.0	7.6	9.5	11	6	13

1.5.2.2 Ross Lagoon

General information

At Ross Lagoon, fish, water quality and acid-sulfate soil sampling were undertaken on 10-11 Jan 2007. The fishing methods that were used at each site and a brief site description are indicated in Table 21.

Ross Lagoon is approximately 1.3 km long x 800 m wide. It has one narrow (< 5 m) inlet that is currently choked with emergent reeds and does not facilitate any water exchange with the river. Overall, the wetland is extremely shallow (average depth is 30 cm), there is no submerged vegetation, and emergent vegetation is patchy (some stands of *Typha* were observed). In addition, salt scalds were observed and *Eucalyptus largiflorens* trees appeared to be in poor health indicating an intrusion of salty groundwater.

Ross Lagoon showed the lowest fish abundance and diversity of all wetlands surveyed with only 95 fish from three species (two of which were invasive) being captured (Table 22). Bony herring was the only native species captured and it was in low abundance (n = 23). Common carp and eastern gambusia were also relatively sparse. The capture of relatively small individuals of each of these species may indicate relatively recent recruitment.

The average conductivity, water temperature, pH and Secchi depth was 5993 µs cm^{-1}, 32°C, 8.68 and 16 cm, respectively (N.B. DO concentration was not recorded at this site due to equipment failure, Table 23). Thus, due to an absence of water exchange with the river, the wetland water was saline and moderately turbid but basic in pH. The shallow nature of the lagoon would facilitate significant wind-induced oxygenation.

Implications for management

- Ross Lagoon contained the least diverse and least abundant fish community of all surveyed wetlands. This is likely to be a result of the high salinity of the water (mean conductivity was 5993 µs cm^{-1}) stemming from a lack of water exchange with the river, an intrusion of salty groundwater, and extreme temperatures in the shallow water during summer. For the aquatic flora and fauna to recover, this wetland will need to be reconnected to the main river channel by dredging the inlet to reduce salinities to below 1000-1500 µS cm^{-1}.
- Water column sulfate (167 mg SO_4 L^{-1}) and conductivity (5998 µS cm^{-1}) concentrations were far in excess of suggested trigger levels (i.e. 10 mg SO_4 L^{-1} and 1750 µS cm^{-1}, respectively), indicating that it has a very high likelihood of containing sulfidic sediments (A. Baldwin, Pers. Comm.). Further comprehensive analyses are recommended before the wetland is considered for drying (Baldwin *et al*., 2007).

Table 21. Summary of the habitat type and fishing method used at each site in Ross Lagoon.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	Wetland edge, dense emergent *Typha* , muddy substrate, 20 cm deep	406382	6219677
2	Fyke Net	Open water, muddy substrate, 20 cm deep	406452	6219327
3	Gill Net	Open water, muddy substrate, 50 cm deep	406057	6219382
4	Fyke Net	Wetland edge, dense stand of *Phragmites* , muddy/rocky substrate, 30 cm deep	405742	6219412
5	Gill Net	Wetland edge, dense stand of *Typha,* 20 cm deep	405882	6219742

Table 22. Summary of the number and length of species captured at Ross Lagoon.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*				
bony herring	*Nematalosa erebi*	23	199	37	303
golden perch	*Macquaria ambigua*				
carp gudgeon complex	*Hypseleotris spp.*				
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*				
dwarf flathead gudgeon	*Philypnodon sp.*				
Murray rainbowfish	*Melanotaenia fluviatilis*				
flathead gudgeon	*Philypnodon grandiceps*				
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	33	571	60	760
eastern gambusia	*Gambusia holbrooki*	39	34	22	45
goldfish	*Carassius auratus*				
redfin perch	*Perca fluviatilis*				
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**95**			
Total Species		**3**			

Table 23. Summary of water quality data recorded at Ross Lagoon.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
5993	5670	6410	32.0	30.9	34.2	n/a	n/a	n/a	8.6	8.3	8.9	16	13	18

1.5.2.3 Wombat's Rest Backwater

General information

At Wombat's Rest Backwater, fish, water quality and acid-sulfate soil sampling were undertaken on 20-21 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 24.

Wombat's Rest Backwater is approximately 1 km long x 300 m wide (max). There is one short inlet at the downstream end, which is clear of emergent reeds, and around 100 m wide and 2 m deep. Water exchange between the river and wetland is therefore expected. Submerged vegetation was sparse, although emergent reeds surrounded the wetland, particularly on the eastern edge. The average depth of the wetland was 1-1.2 m, there was no evidence of groundwater intrusion and grazing did not appear to be an issue. A number of domestic- and one irrigation pump were seen near the wetland inlet.

A total of 1311 fish from 10 species were recorded, including three invasive species (Table 25). Bony herring, carp gudgeons and unspecked hardyheads were the most abundant native fishes, whilst eastern gambusia and common carp were the most abundant invasive species captured. The remaining native (Australian smelt, golden perch, Murray rainbowfish and flathead gudgeon) and invasive (goldfish) species were all recorded in low abundance. The capture of relatively small individuals of bony herring, carp gudgeons, unspecked hardyheads, common carp and eastern gambusia may indicate relatively recent recruitment.

Wetland water quality was similar to that in the river, due to water exchange through the wetland's wide connecting channel. The average conductivity, water temperature, DO concentration, pH and Secchi depth was 512 µs cm^{-1}, 26.3°C, 8.4 mg L^{-1}, 8.5 and 10 cm, respectively (Table 26). Thus, the water was relatively fresh, well oxygenated, basic in pH and moderately turbid.

Implications for management

- No threatened fish species were sampled.
- Water column sulfate concentrations were within proposed trigger levels (i.e. < 10 mg SO_4 L^{-1}, Baldwin *et al*., 2007) indicating that drying is unlikely to lead to the development of problems associated with acid-sulphate soils. Nevertheless, if this wetland is to be disconnected from the river, it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.

Table 24. Summary of the habitat type and fishing method used at each site in Wombat's Rest Backwater.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	Muddy substrate, dense stands of *Typha* in littoral zone, 80-100 cm deep, abundant woody debris (large and small)	-34.10590	139.66879
2	Gill Net	Abundant woody debris, no aquatic vegetation, 100-120 cm deep, muddy substrate	-34.10703	139.66894
3	Fyke Net	Wetland edge, muddy substrate, dense stands of *Typha*, 60 cm deep, abundant woody debris (large and small)	-34.10932	139.66737
4	Gill Net	Open water, muddy substrate, no aquatic vegetation, some scattered snags, 80-100 cm deep	-34.10976	139.66926
5	Fyke Net	Fringing *Typha*, muddy substrate, abundant woody debris (small and large), 80-100 cm deep	-34.11139	139.66963

Table 25. Summary of the number and length of species captured at Wombat's Rest Backwater.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	30	60	51	64
bony herring	*Nematalosa erebi*	667	143	26	310
golden perch	*Macquaria ambigua*	1			
carp gudgeon complex	*Hypseleotris spp.*	457	45	35	55
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	111	42	35	51
dwarf flathead gudgeon	*Philypnodon sp.*				
Murray rainbowfish	*Melanotaenia fluviatilis*	13			
flathead gudgeon	*Philypnodon grandiceps*	2			
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	12	140	76	248
eastern gambusia	*Gambusia holbrooki*	17	31	25	47
goldfish	*Carassius auratus*	1			
redfin perch	*Perca fluviatilis*				
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**1311**			
Total Species		**10**			

Table 26. Summary of water quality data recorded at Wombat's Rest Backwater.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
512	470	539	26.3	25.0	27.1	8.4	7.7	8.8	8.5	8.2	9.1	10	7	12

1.5.2.4 Donald Flat Lagoon

General information

At Donald Flat Lagoon, fish, water quality and acid-sulfate soil sampling were undertaken during 20-21 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 27.

Donald Flat Lagoon is approximately 3.4 km long x 800 m wide. There is one long (150 m), narrow (20 m) inlet on the eastern edge of the wetland, and a second wider (150 m) inlet at the southern end. Both inlets are ~1 m deep, free of emergent vegetation and allow continuous water exchange with the river. The submerged vegetation was sparsely distributed but the emergent riparian vegetation was dense and abundant. There was evidence of salty groundwater intrusion at the northern (terminal) end of the wetland, and cattle were observed grazing on the island between the wetland and river. Some water pumps were noted toward the northern inlet.

A total of 716 fish from nine species were recorded, including three invasive species, (Table 28). Carp gudgeons, unspecked hardyheads and bony herring were the most abundant native fishes, whilst common carp was the most abundant invasive species captured. The remaining native (Australian smelt, Murray rainbowfish and flathead gudgeon) and invasive (goldfish and redfin perch) species were all recorded in low abundance. The capture of relatively small individuals of Australian smelt, bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons and redfin perch may indicate relatively recent recruitment.

Wetland water quality was similar to that in the river, due to water exchange through the wetland's two connecting channels. The average conductivity, water temperature, DO concentration, pH and Secchi depth was 436 µs cm^{-1}, 25.3°C, 8.4 mg L^{-1}, 8.2 and 20 cm, respectively (Table 29). Thus, the water was relatively fresh, well oxygenated, basic in pH and moderately clear.

Implications for management

- No threatened fish species were sampled and the wetland water quality was within acceptable limits.
- Water column sulfate concentrations exceeded suggested trigger levels (i.e. 10 mg SO_4 L^{-1}, Baldwin *et al.*, 2007) indicating that this wetland is likely to contain sulfidic sediments, which, if dried, may lead to noxious odours, the poisoning of aquatic flora and fauna, and anoxic and/or acidic sediments upon re-wetting (see Part B).
- Groundwater intrusion at the wetland's terminus will lead to high salinities upon drying, with possible negative impacts on the floodplain's flora and fauna. Significant accumulations of salt may also impact riverine fauna, if salty water is washed from the wetland to the river upon re-filling.
- If this wetland is to be disconnected from the river, it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.

Table 27. Summary of the habitat type and fishing method used at each site in Donald Flat Lagoon.

Site #	Method	Habitat description	Latitude	Longitude
1	Gill Net	Open water, 100 cm deep, firm substrate	-34.23634	139.63286
2	Fyke Net	Adjacent dense stand of *Typha,* 50 cm deep, scattered submerged vegetation, firm substrate	-34.24117	139.63334
3	Gill Net	Adjacent dense stand of *Typha,* 50 cm deep, firm substrate	-34.24467	139.63081
4	Fyke Net	Adjacent stands of *Juncus* at base of cliff, 50 cm deep, soft mud/rock base	-34.25357	139.62205
5	Fyke Net	Open water, 100 cm deep, adjacent stands of *Typha,* soft muddy bottom	-34.24664	139.62379

Table 28. Summary of the number and length of species captured at Donald Flat Lagoon.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	37	49	37	63
bony herring	*Nematalosa erebi*	163	231	30	435
golden perch	*Macquaria ambigua*				
carp gudgeon complex	*Hypseleotris spp.*	262	34	25	46
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	196	38	28	58
dwarf flathead gudgeon	*Philypnodon sp.*				
Murray rainbowfish	*Melanotaenia fluviatilis*	2	56	55	57
flathead gudgeon	*Philypnodon grandiceps*	19	40	32	53
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	24	384	187	650
eastern gambusia	*Gambusia holbrooki*				
goldfish	*Carassius auratus*	1	290	290	290
redfin perch	*Perca fluviatilis*	12	59	40	72
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**716**			
Total Species		**9**			

Table 29. Summary of water quality data recorded at Donald Flat Lagoon.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
436	429	444	25.3	23.6	28.4	8.4	8.1	9.0	8.2	8.0	8.6	20	20	22

1.5.2.5 McBean Pound North

General information

At McBean Pound North, fish, water quality and acid-sulfate soil sampling were undertaken during 8-9 Jan 2007. The fishing methods that were used at each site and a brief site description are indicated in Table 30.

McBean Pound North is approximately 1 km long x 400 m wide (max). During floods, the wetland would connect to the river via numerous flood-runners but at standard operating levels there is only one connection at the northern end. This inlet is only 10 m wide, and whilst it was choked with reeds there may have been some water exchange (water exchange through the bank is also possible). Sparse submerged vegetation was noted but the emergent riparian vegetation, including stands of regenerating red gums, was dense and appeared healthy. The wetland is mostly shallow (0.5 m) but reached 1-1.5 m along the cliffs on the western edge. There were some sheep grazing around the wetland, and four water pumps were present (one commercial, three domestic).

A total of 642 fish from nine species were recorded, including three invasive species (Table 31). Carp gudgeons, unspecked hardyheads and bony herring were the most abundant native fishes, whilst common carp was the most abundant invasive species captured. The remaining native (Australian smelt, dwarf flathead gudgeon and Murray rainbowfish) and invasive (goldfish and carp x goldfish hybrid) species were all recorded in low abundance. The capture of relatively small individuals of bony herring, carp gudgeons, unspecked hardyheads, dwarf flathead gudgeons and common carp may indicate relatively recent recruitment.

Relatively high water conductivities (max 1097 µs cm^{-1}) were indicative of the wetland's poor connection with the river, facilitating minimal water exchange. The average conductivity, water temperature, pH and Secchi depth was 926 µs cm^{-1}, 25.3°C, n/a mg L^{-1}, 8.1 and 27 cm, respectively (N.B. DO concentration was not recorded at this site due to equipment failure, Table 32). Thus, at the time of sampling, the water was relatively salty but it was basic in pH and moderately clear. The shallow nature of the lagoon would facilitate significant wind-induced oxygenation.

Implications for management

- No threatened fish species were sampled.
- Water column sulfate concentrations exceeded suggested trigger levels (i.e. 10 mg SO_4 L^{-1}, Baldwin *et al.*, 2007) indicating that this wetland is likely to contain sulfidic sediments, which, if dried, may lead to noxious odours, the poisoning of aquatic flora and fauna, and anoxic and/or acidic sediments upon re-wetting (see Part B).
- If this wetland remains connected to the river, the flora and fauna would benefit from improved water quality that would result from dredging the inlet channel to enhance water exchange. Furthermore, reduced turbidities would promote the establishment of submerged aquatic vegetation, which provides freshwater fishes with, *inter alia*, cover from predators and spawning and nursery habitat.
- If this wetland is to be disconnected from the river, it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.

Table 30. Summary of the habitat type and fishing method used at each site in McBean Pound North.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	Wetland edge, muddy substrate, dense *Typha*, 75 cm deep	-34.28310	139.63071
2	Gill Net	Wetland edge, steep bank, *Typha* in littoral zone, 1 m deep	-34.27741	139.62813
3	Fyke Net	Wetland edge, large woody debris, *Typha*, 50 cm deep	-34.27774	139.62829
4	Gill Net	Open water, 75 cm deep	-34.28076	139.63093
5	Fyke Net	Open water, 75 cm deep	-34.28054	139.63307

Table 31. Summary of the number and length of species captured at McBean Pound North.

Common Name	Species Name	Total	Total Length (mm) Ave	Min	Max
Native Fish					
Australian smelt	*Retropinna semoni*	1	47	47	47
bony herring	*Nematalosa erebi*	44	267	28	500
golden perch	*Macquaria ambigua*				
carp gudgeon complex	*Hypseleotris spp.*	461	31	17	43
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	61	41	28	55
dwarf flathead gudgeon	*Philypnodon sp.*	10	29	23	40
Murray rainbowfish	*Melanotaenia fluviatilis*	1	35	35	35
flathead gudgeon	*Philypnodon grandiceps*				
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	62	410	25	665
eastern gambusia	*Gambusia holbrooki*				
goldfish	*Carassius auratus*	1	258	258	258
redfin perch	*Perca fluviatilis*				
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)	1	405	405	405
Total Fish		**642**			
Total Species		**9**			

Table 32. Summary of water quality data recorded at McBean Pound North.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
926	687	1097	25.3	21.3	30.0	n/a	n/a	n/a	8.1	7.8	8.5	27	24	31

1.5.2.6 Reedy Island

General information

At Reedy Island, fish, water quality and acid-sulfate soil sampling were undertaken during 21-22 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 33.

Reedy Island is approximately 1.5 km long x 0.5 km wide (max) with two inlets. The upstream inlet is around 15 m wide and > 2 m deep with a levee and pipe culvert. The downstream inlet is a narrow channel of 2-3 m wide and > 2 m deep. Both inlets are free of emergent reeds and the wetland operates as a flow through system from upstream to downstream. The wetland is obviously popular for recreational pursuits including water skiing, as there are navigation buoys, ski jumps and a club-house established on site. Submerged vegetation was patchy and limited to the shallow/protected areas of the wetland and there was dense emergent/littoral vegetation. The average depth in the centre of the wetland is beyond 2 m, although it is 0.5-1.5 m around the margins. There was no evidence of salty groundwater intrusion into the wetland but there may be some grazing on Reedy Island proper. No irrigation pumps were seen.

A total of 1705 fish from 12 species, including eight native species was captured (Table 34). Unspecked hardyheads, carp gudgeons and bony herring were the most abundant native fishes, whilst redfin perch and common carp and eastern gambusia were the most abundant invasive species captured. The remaining native (Australian smelt, golden perch, dwarf flathead gudgeon, Murray rainbowfish and flathead gudgeon) and invasive (goldfish and carp x goldfish hybrid) species were all recorded in low abundance. The capture of relatively small individuals of bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons and redfin perch may indicate relatively recent recruitment.

Due to the wetland operating as a flow through system, from upstream to downstream, recorded water quality parameters were similar to that in the river (Table 35). The average conductivity, water temperature, DO concentration, pH and Secchi depth was 414 µs cm^{-1}, 26.7°C, 8.3 mg L^{-1}, 7.8 and 38 cm, respectively. Thus, the water is relatively fresh, well oxygenated, basic in pH and clear.

Implications for management

- No threatened fish species were sampled.
- This wetland is generally > 1 m depth, has good water quality and continuous current flow, which is rare for the region. The inlets and the main lagoon contain excellent riparian, littoral and structural habitat for large-bodied fishes such as golden perch, but also abundant habitat for small-bodied fishes.
- As well as providing good fish habitat, healthy riparian and littoral vegetation improves water quality, and acts as a source of organic matter, shade and food. It also provides shelter from predators such as redfin perch, which were moderately abundant within this wetland.
- Reedy Island had water column sulfate concentrations within proposed trigger levels (i.e. 10 mg SO_4 L^{-1}, Baldwin *et al.*, 2007) (see Part B).
- If this wetland is to be disconnected from the river, it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.

Table 33. Summary of the habitat type and fishing method used at each site in Reedy Island.

Site #	Method	Habitat description	Latitude	Longitude
1	Gill Net	Wetland inlet, some slow flow, emegent *Phragmites* on both banks, 200-250 cm deep, muddy bottom	-34.28641	139.64408
2	Fyke Net	Abundant emergent vegetation, muddy bottom, scattered woody debris, 100-120 cm deep	-34.28914	139.64331
3	Fyke Net	Wetland inlet, 130-160 cm deep, abundant *Phragmites*, some *Myriophyllum*, muddy bottom	-34.29486	139.64569
4	Gil Net	Wind-induced flow, emergent *Typha* stands, scattered woody debris, muddy substrate, 150-200 cm deep, sparse submerged *Vallisneria*	-34.29101	139.64504
5	Fyke Net	Some scattered woody debris, firm muddy bottom, fringing *Phragmites* and *Typha*	-34.29623	139.64330

Table 34. Summary of the number and length of species captured at Reedy Island.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	5	54	41	61
bony herring	*Nematalosa erebi*	252	217	37	418
golden perch	*Macquaria ambigua*	1	362	362	362
carp gudgeon complex	*Hypseleotris spp.*	337	33	25	47
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	1017	38	28	62
dwarf flathead gudgeon	*Philypnodon sp.*	3	40	38	42
Murray rainbowfish	*Melanotaenia fluviatilis*	23	55	45	68
flathead gudgeon	*Philypnodon grandiceps*	32	38	30	65
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	15	422	335	575
eastern gambusia	*Gambusia holbrooki*				
goldfish	*Carassius auratus*	1	254	254	254
redfin perch	*Perca fluviatilis*	18	98	40	400
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)	1	364	364	364
Total Fish		**1705**			
Total Species		**12**			

Table 35. Summary of water quality data recorded at Reedy Island.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
414	380	424	26.7	25.7	27.0	8.3	7.2	8.7	7.8	7.7	8.2	38	35	46

1.5.2.7 Mark's Landing

General information

At Mark's Landing, fish, water quality and acid-sulfate soil sampling were undertaken during 12-13 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 36.

Mark's Landing is approximately 4.5 km long x 0.8 km wide (max). Two inlets were observed, which appeared to allow continuous water exchange with the river. The northern upstream inlet is long (500 m) and narrow (< 5 m) and adjacent to the Swam Reach caravan park. It has a regulator and carp screens. The southern downstream inlet is around 30 m wide and only 50 m long. Due to access restrictions (i.e. the wetland is divided by a levee), only the southern portion of the wetland was sampled. There were patches of submerged *Vallisneria* in the deeper sections (1-2 m) and dense emergent *Typha* in the littoral/riparian zone, although this was patchy along the eastern bank (adjacent cliffs). The mean depth was 0.5-1 m and the maximum depth was > 2 m along the eastern bank. There was no evidence of salty groundwater intrusion, but there was some cattle grazing around southern portion of the wetland. There was one large irrigation pump in the southern wetland and numerous domestic/irrigation pumps on the northern wetland.

A total of 2123 fish from 12 species, including eight native species, was captured (Table 37). Carp gudgeons, Australian smelt, bony herring, unspecked hardyheads and flathead gudgeons were the most abundant native fishes, whilst common carp and eastern gambusia were the most abundant invasive species captured. The remaining native (golden perch, dwarf flathead gudgeons and Murray rainbowfish) and invasive (goldfish and redfin perch) species were all recorded in low abundance. The capture of relatively small individuals of Australian smelt, bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons, common carp, eastern gambusia, goldfish and redfin perch may indicate relatively recent recruitment.

Due to the wetland's two connections with the main river channel, recorded water quality parameters were similar to that in the river (Table 38). The average conductivity, water temperature, DO concentration, pH and Secchi depth was 693 $\mu s\ cm^{-1}$, 24.5°C, 9.3 $mg\ L^{-1}$, 8.7 and 15 cm, respectively. Thus, the water was relatively fresh, well oxygenated, basic in pH and moderately clear.

Implications for management

- Whilst this wetland contained among the most diverse and abundant fish community of any wetland sampled during this survey, no threatened fish species were sampled.
- The wetland water quality was within acceptable limits.
- Water column sulfate concentrations were within proposed trigger levels (i.e. 10 mg SO_4 L^{-1}, Baldwin *et al*., 2007, PART B).
- If this wetland is to be disconnected from the river, it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.

Table 36. Summary of the habitat type and fishing method used at each site in Mark's Landing.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	Scattered *Vallisneria* beds, some small snags, open water, 50 cm deep	-34.59898	139.60772
2	Gill Net	Open water, submerged *Vallisneria*, 150 cm deep	-34.59119	139.60800
3	Fyke Net	Gravel substrate, up to 100 cm deep, emergent littoral/riparian vegetation (*Typha* and *Juncus*)	-34.58599	139.60611
4	Fyke Net	Scattered woody debris, 50-100 cm deep, *Juncus*	-34.58382	139.60153
5	Gill Net	Open water, 150 cm depth, muddy substrate	-34.58854	139.60760

Table 37. Summary of the number length of species captured at Mark's Landing.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	330	57	30	71
bony herring	*Nematalosa erebi*	267	196	30	410
golden perch	*Macquaria ambigua*	1	305	305	305
carp gudgeon complex	*Hypseleotris spp.*	1134	37	27	49
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	171	46	21	61
dwarf flathead gudgeon	*Philypnodon sp.*	1	42	42	42
Murray rainbowfish	*Melanotaenia fluviatilis*	11	61	51	72
flathead gudgeon	*Philypnodon grandiceps*	102	48	26	111
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	67	181	33	750
eastern gambusia	*Gambusia holbrooki*	22	30	19	46
goldfish	*Carassius auratus*	4	77	34	170
redfin perch	*Perca fluviatilis*	13	88	77	100
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**2123**			
Total Species		**12**			

Table 38. Summary of water quality data recorded at Mark's Landing.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
693	474	818	24.5	22.3	25.5	9.3	8.9	9.7	8.7	8.5	9.0	15	14	20

1.5.2.8 Punyelroo

General information

At Punyelroo, fish, water quality and acid-sulfate soil sampling were undertaken on 11-12 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 39.

Punyelroo is approximately 3.7 km long x 400 m wide. There is one main inlet, 10 m wide x 1.5 m deep x 200 m long adjacent to a causeway that divides the wetland. There is continuous water exchange through this inlet and current velocities may reach approximately 0.5 m s^{-1} (Unpublished Data) due to wind effects on riverine surface waters. River water enters the northern section of the wetland from this channel and enters the southern section through a single large pipe culvert that traverses the causeway. A second inlet at the southern end of the wetland connects via a marshy channel and pipe culverts that are mostly choked with reeds. Submerged *Vallisneria* beds are sparsely distributed, and emergent riparian vegetation is patchy along the banks but thick along the causeway. On average, the depth of the wetland is uniform (0.5-1 m), but depth may vary by as much as 10-30 cm on a daily basis and depends on the direction and intensity of the prevailing winds. There was no evidence of salty groundwater intrusion and at least two large irrigation pumps were present.

A total of 878 fish from 12 species, including eight native species, was captured (Table 40). Australian smelt, carp gudgeons, bony herring, flathead gudgeons and unspecked hardyheads were the most abundant native fishes, whilst common carp and eastern gambusia were the most abundant invasive species captured. The remaining native (golden perch, dwarf flathead gudgeons and Murray rainbowfish) and invasive (goldfish and redfin perch) species were all recorded in low abundance. The capture of relatively small individuals of Australian smelt, bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons, common carp, eastern gambusia, goldfish and redfin perch may indicate relatively recent recruitment.

Due to the wetland's two connections with the main river channel, recorded water quality parameters were similar to that in the river (Table 41). The average conductivity, water temperature, DO concentration, pH and Secchi depth was 457 μs cm^{-1}, 24.0°C, 8.3 mg L^{-1}, 8.3 and 12 cm, respectively. Thus, the water was relatively fresh, well oxygenated, basic in pH and moderately turbid.

Implications for management

- No threatened fish species were sampled and the wetland water quality was within acceptable limits.
- All of the golden perch and Murray rainbowfish, and the majority of the Australian smelt and flathead gudgeons were captured from within close proximity to the central inlet channel, which receives significant flow. In comparison, the majority of common carp and eastern gambusia were captured from within the wetland proper, where there was little flow. This is a regular finding from similar wetlands in the region indicating the importance of river flow *and* naturally driven current flows (arising from wind effects on riverine surface waters), particularly in heavily regulated systems such as the Murray-Darling Basin. For this reason, consideration should be given to the preservation of this wetland and all permanent/unmanaged wetlands with good connections to the main channel, which facilitate high velocity current flows within their inlet channels. This is especially relevant to wetlands in the region between the barrages in the Lower Lakes and upstream to Lock and Weir 1 at Blanchetown, where the prevailing north-south winds drive significant changes to river/wetland water levels thus generating high current velocities within inlet channels.
- Punyelroo had water column sulfate concentrations marginally exceeding proposed trigger levels (by ≤ 0.7 mg $SO_4.L^{-1}$, see PART B) indicating that whilst it is unlikely to contain sulfidic sediments, caution should prevail.
- If this wetland is to be disconnected from the river, it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.

Table 39. Summary of the habitat type and fishing method used at each site in Punyelroo.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	Wind-induced water flow, emergent *Typha* & *Phragmites* , no submerged veg, abundant floating fragments of *Myriofillum* , muddy substrate, no snags, 10-50 cm deep	-34.61733	139.60524
2	Gill Net	40-120 cm deep, scattered large snags, scattered *Typha* , muddy substrate	-34.37417	139.36533
3	Gill Net	Open water, 100 cm deep, no emergent/submerged vegetation, scattered woody debris, muddy bottom	-34.63334	139.60635
4	Fyke Net	Medium-large sized woody debris, some littoral/riparian vegetation (none submerged), 20-100 cm deep, muddy substrate, floating fragments of *Vallisneria* and *Myriophyllum*	-34.63415	139.60901
5	Fyke Net	Muddy substrate, littoral grasses, wind-induced water flow, 20-30 cm deep, submerged *Vallisneria* and floating *Azolla* present	-34.38317	139.36688

Table 40. Summary of the number and length of species captured at Punyelroo.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	309	57	32	72
bony herring	*Nematalosa erebi*	113	178	27	354
golden perch	*Macquaria ambigua*	5	307	220	400
carp gudgeon complex	*Hypseleotris spp.*	191	37	24	50
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	40	47	36	60
dwarf flathead gudgeon	*Philypnodon sp.*	1	40	40	40
Murray rainbowfish	*Melanotaenia fluviatilis*	3	56	51	62
flathead gudgeon	*Philypnodon grandiceps*	98	48	25	78
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	65	366	15	745
eastern gambusia	*Gambusia holbrooki*	40	34	20	52
goldfish	*Carassius auratus*	10	153	35	400
redfin perch	*Perca fluviatilis*	3	64	62	66
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**878**			
Total Species		**12**			

Table 41. Summary of water quality data recorded at Punyelroo.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
457	376	698	24.0	23.2	25.2	8.3	8.1	8.4	8.3	7.9	9.2	12	9	15

1.5.2.9 Big Bend

General information

At Big Bend, fish, water quality and acid-sulfate soil sampling were undertaken on 12-13 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 42.

Big Bend is approximately 2.6 km long x 300 m wide (max). Towards the north-eastern end is a constructed inlet channel that has been filled with dirt and no longer allows water exchange with the river. A second inlet channel exists towards the south-eastern end of the wetland and this is choked with emergent reeds for the majority of its length (~120 m). Consequently, there was no obvious water exchange with the river, but wetland water levels and river levels co-varied. Given the proximity of the wetland's entire eastern bank to the river and the narrow width of the bank (100 m), water exchange across the bank is possible. This is most likely at the southern end where the water was least salty (see water quality results below), but salty groundwater intrusion at the northern end may have also contributed to this difference.

A total of 1296 fish from 8 species, including six native species, was captured (Table 43). Flathead gudgeons, unspecked hardyheads and carp gudgeons were the most abundant native species captured, whilst eastern gambusia was the most abundant invasive species captured. The remaining native (Australian smelt, bony herring and dwarf flathead gudgeons) and invasive (common carp) species were all recorded in low abundance. The capture of relatively small individuals of Australian smelt, bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons and eastern gambusia may indicate relatively recent recruitment.

The average conductivity, water temperature, DO concentration, pH and Secchi depth was 1195 µs cm^{-1}, 26.6°C, 10.1 mg L^{-1}, 8.5 and 6 cm, respectively (Table 44). Thus, due to an absence of water exchange with the river, the wetland water was slightly saline and turbid but was basic in pH and well oxygenated.

Implications for management

- The majority of native fish species in Big Bend were not abundant with the exception of flathead gudgeons (733 individuals were captured). Their low abundance may be linked with the higher salinity of the water (mean conductivity was 1195 µs cm^{-1}) caused by an intrusion of salty groundwater at the northern end and an absence water exchange between the river and wetland. The absence of water exchange between the river and wetland may also impede fish passage enhancing the low abundance of fish in the wetland. Thus, this wetland should be reconnected with the main channel by dredging the upstream inlet and removing the fill from the downstream inlet. Installation of box/pipe culverts to maintain vehicle access should be considered if the downstream inlet is re-opened.
- No threatened fish species were sampled.
- Water column sulfate concentrations exceeded suggested trigger levels (i.e. 10 mg SO_4 L^{-1}, Baldwin *et al*., 2007) indicating that this wetland is likely to contain sulfidic sediments, which, if dried, may lead to noxious odours, the poisoning of aquatic flora and fauna, and anoxic and/or acidic sediments upon re-wetting (see Part B).
- Although this wetland appears to be disconnected from the main channel, its water level co-varies with that of the adjacent river suggesting that water exchange occurs via the bank. Consequently, it may not be possible to dry this wetland. If it is, however, the wetland should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.

Table 42. Summary of the habitat type and fishing method used at each site in Big Bend.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	Adjacent littoral stands *Juncus* and *Typha*, firm substrate, 25 cm deep	-34.62641	139.63905
2	Gill Net	Open water, muddy substrate, 100 cm deep	-34.62381	139.63997
3	Fyke Net	Open water, 50 cm deep, firm substrate	-34.62330	139.64130
4	Gill Net	Adjacent stands of *Juncus* and *Typha*, 150 cm deep, soft muddy substrate	-34.63712	139.63289
5	Fyke Net	Adjacent stands of *Juncus* and *Typha*, 100-120 cm deep, soft muddy substrate	-34.63426	139.63482

Table 43. Summary of the number and length of species captured at Big Bend.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	31	69	35	85
bony herring	*Nematalosa erebi*	42	169	84	274
golden perch	*Macquaria ambigua*				
carp gudgeon complex	*Hypseleotris spp.*	160	41	32	53
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	169	51	32	68
dwarf flathead gudgeon	*Philypnodon sp.*	6	41	30	54
Murray rainbowfish	*Melanotaenia fluviatilis*				
flathead gudgeon	*Philypnodon grandiceps*	733	68	38	85
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	14	439	223	680
eastern gambusia	*Gambusia holbrooki*	141	35	16	50
goldfish	*Carassius auratus*				
redfin perch	*Perca fluviatilis*				
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**1296**			
Total Species		**8**			

Table 44. Summary of water quality data recorded at Big Bend.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
1195	909	1311	26.6	22.6	27.9	10.1	8.1	11.9	8.5	7.7	8.5	6	5	9

1.5.2.10 Henley Park

General information

At Henley Park, fish, water quality and acid-sulfate soil sampling were undertaken on 11-12 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 45.

Henley Park is approximately 1.2 km long x 300 m wide (max). It has one inlet at the north-east corner, which is around 120 m long but only 2-10 m wide near the river. This inlet is free of emergent reeds, and there is continuous water exchange between the river and wetland. Submerged and emergent vegetation was abundant and the average water depth was 1 m. There was no evidence of salty groundwater intrusion and grazing did not appear to be an issue. An irrigation pump(s) provides water for domestic and commercial use.

A total of 2628 fish from 10 species, including six native species, was captured (Table 46). Carp gudgeons, bony herring, unspecked hardyheads, Australian smelt, and flathead gudgeons were the most abundant native fishes, whilst common carp was the most abundant invasive species captured. The remaining native (Murray rainbowfish) and invasive (eastern gambusia, redfin perch and carp x goldfish hybrid) species were all recorded in low abundance. The capture of relatively small individuals of Australian smelt, bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons, common carp, eastern gambusia and redfin perch may indicate relatively recent recruitment.

Due to the wetland's connection with the main river channel, recorded water quality parameters were similar to that in the river (Table 47). The average conductivity, water temperature, DO concentration, pH and Secchi depth was 480 $\mu s\ cm^{-1}$, 25.9°C, 7.7 $mg\ L^{-1}$, 8.0 and 19 cm, respectively. Thus, the water was relatively fresh, well oxygenated, basic in pH and moderately clear.

Implications for management

- No threatened fish species were sampled and the wetland water quality was within acceptable limits.
- Consideration should be given to the preservation of this wetland, which has a good connection with the main channel that facilitates high velocity current flows within its inlet channel. Native fishes are typically more abundant, and invasive fishes less abundant in habitats with flow, and these habitats are now rare, particularly given the highly regulated conditions that prevail in the lower Murray.
- Henley Park had water column sulfate concentrations within proposed trigger levels i.e. < 10 mg SO_4 L^{-1}, Baldwin *et al*., 2007) indicating that it is unlikely to contain sulfidic sediments (see further, Part B).
- If this wetland is to be disconnected from the river, it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.
- The potential effects of drying on the extensive submerged vegetation community and on other wetland flora and fauna should also be considered.

Table 45. Summary of the habitat type and fishing method used at each site in Henley Park.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	Wetland edge, adjacent dense bed of emergent *Typha* , clay/silt substrate	-34.62943	139.64526
2	Fyke Net	Sandy substrate, adjacent to *Juncus* stands	-34.62688	139.64814
3	Gill Net	Wetland edge, adjacent to stands of dense emergent *Phragmites*	-34.62452	139.65041
4	Gill Net	Open water, ajacent to submerged vegetation, 120 cm deep, muddy substrate	-34.62580	139.65256
5	Fyke Net	Open water, muddy substrate, 50 cm deep	-34.62461	139.65344

Table 46. Summary of the number and length of species captured at Henley Park.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	149	58	30	72
bony herring	*Nematalosa erebi*	485	158	26	390
golden perch	*Macquaria ambigua*				
carp gudgeon complex	*Hypseleotris spp.*	1470	36	27	50
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	257	44	33	67
dwarf flathead gudgeon	*Philypnodon sp.*				
Murray rainbowfish	*Melanotaenia fluviatilis*	4	55	52	57
flathead gudgeon	*Philypnodon grandiceps*	63	55	29	68
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	180	132	25	668
eastern gambusia	*Gambusia holbrooki*	7	37	22	50
goldfish	*Carassius auratus*				
redfin perch	*Perca fluviatilis*	12	100	53	272
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)	1	342	342	342
Total Fish		**2628**			
Total Species		**10**			

Table 47. Summary of water quality data recorded at Henley Park.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
480	406	505	25.9	25.0	26.2	7.7	5.5	11.3	8.0	7.5	9.6	19	16	24

1.5.2.11 Bow Hill

General information

At Bow Hill, fish, water quality and acid-sulfate soil sampling were undertaken on 13-14 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 48.

Bow Hill is approximately 2.3 km long x 0.5 km wide (max). There were no physical connections with the main river channel, yet the wetland water level co-varied with river height. This indicates leakage through the bank, particularly at the south-western end, where the bank is only 30 m wide. Within the wetland, submerged vegetation including *Myriophyllum* and *Vallisneria* were abundant, as was emergent *Typha* in the littoral zone surrounding the wetland. The average depth of the wetland was 0.6-1 m, although it was up to 1.5 m along the cliffs to the south. There was evidence of salty groundwater intrusion along the north-eastern margin and cattle were observed grazing along the edge of the wetland.

A total of 2104 fish from 11 species, including seven native species, was captured (Table 49). Carp gudgeons, flathead gudgeons and unspecked hardyheads were the most abundant native species captured, whilst eastern gambusia and common carp were the most abundant invasive species captured. The remaining native (Australian smelt, bony herring, dwarf flathead gudgeons and Murray rainbowfish) and invasive (goldfish and redfin perch) species were all recorded in low abundance. The capture of relatively small individuals of Australian smelt, bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons, common carp, eastern gambusia and redfin perch may indicate relatively recent recruitment.

The average conductivity, water temperature, DO concentration, pH and Secchi depth was 837 µs cm^{-1}, 26.6°C, 10.2 mg L^{-1}, 9.7 and 38 cm, respectively (Table 50). Thus, due to an absence of water exchange with the river, the wetland water was slightly saline but quite clear, basic in pH and well oxygenated.

Implications for management

- No threatened fish species were sampled.
- Water column sulfate concentrations exceeded suggested trigger levels (i.e. 10 mg SO_4 L^{-1}, Baldwin *et al*., 2007) indicating that this wetland is likely to contain sulfidic sediments, which, if dried, may lead to noxious odours, the poisoning of aquatic flora and fauna, and anoxic and/or acidic sediments upon re-wetting (see Part B).
- This wetland already appears to be disconnected from the main channel but its water level co-varies with that in the adjacent river, suggesting through-the-bank transfer. Consequently, it may not be possible to dry this wetland but if it is, the wetland should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.

Table 48. Summary of the habitat type and fishing method used at each site in Bow Hill.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	50-80 cm deep, dense *Typha*, abundant submerged *Myriophyllum*, some fallen trees and fence posts	-34.89610	139.60823
2	Gill Net	Open water, 100-130 cm deep, submerged *Myriophyllum*	-34.89805	139.60865
3	Fyke Net	20-40 cm deep, submerged *Vallisneria*, some *Myriophyllum*, no snags	-34.89948	139.60621
4	Gill Net	Submerged *Myriophyllum*, 150 cm depth, open water	-34.90036	139.60805
5	Fyke Net	No description provided	-34.89890	139.60987

Table 49. Summary of the number and length of species captured at Bow Hill.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	4	60	35	70
bony herring	*Nematalosa erebi*	13	301	100	410
golden perch	*Macquaria ambigua*				
carp gudgeon complex	*Hypseleotris spp.*	1418	38	24	55
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	172	49	17	74
dwarf flathead gudgeon	*Philypnodon sp.*	13	46	42	50
Murray rainbowfish	*Melanotaenia fluviatilis*	4	58	54	60
flathead gudgeon	*Philypnodon grandiceps*	388	59	27	82
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	30	458	22	700
eastern gambusia	*Gambusia holbrooki*	49	31	22	48
goldfish	*Carassius auratus*	12	237	53	385
redfin perch	*Perca fluviatilis*	1	230	230	230
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**2104**			
Total Species		**11**			

Table 50. Summary of water quality data recorded at Bow Hill.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
837	576	980	26.6	24.2	27.0	10.2	9.2	11.2	9.7	9.5	9.9	38	25	55

1.5.2.12 Craignook

General information

At Craignook, fish, water quality and acid-sulfate soil sampling were undertaken on 14-15 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 51.

Craignook is approximately 1.6 km long x 300 m wide (max). One connection with the river existed opposite a pump house (the water pump is currently unused), but this was choked with dense emergent reeds and there appeared to be no water flow through the channel. There may be a narrow inlet channel at the eastern end of the wetland (along the cliffs) but this could not be verified. Wetland water levels co-varied with river levels, suggesting a possible alternate linkage, although underground water exchange cannot be discounted. Submerged vegetation was abundant at the eastern end of the wetland adjacent to the pump house, and emergent riparian vegetation was abundant around the entire circumference of the wetland and appeared in good condition. The average water depth was 1 m. There was no evidence of salty groundwater intrusion and grazing did not appear to be an issue (although historically, the floodplain has been grazed).

A total of 4310 fish from 9 species, including six native species, was captured (Table 52). Carp gudgeons were the most abundant native species by far, followed by unspecked hardyheads, flathead gudgeons and bony herring. Common carp and eastern gambusia were the most abundant invasive species captured. The remaining native (golden perch and dwarf flathead gudgeons) and invasive (redfin perch) species were all recorded in low abundance. The capture of relatively small individuals of bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons and eastern gambusia may indicate relatively recent recruitment.

The average conductivity, water temperature, DO concentration, pH and Secchi depth was 746 µs cm^{-1}, 24.6°C, 9.1 mg L^{-1}, 8.3 and 20 cm, respectively. (Table 53). Thus, due to a speculated absence of water exchange with the river, the wetland water was slightly saline but moderately clear, basic in pH and well oxygenated.

Implications for management

- No threatened fish species were sampled.
- Water column sulfate concentrations exceeded suggested trigger levels (i.e. 10 mg SO_4 L^{-1}, Baldwin *et al.*, 2007) indicating that this wetland is likely to contain sulfidic sediments, which, if dried, may lead to noxious odours, the poisoning of aquatic flora and fauna, and anoxic and/or acidic sediments upon re-wetting (see Part B).
- This wetland already appears to be disconnected from the main channel but its water level co-varies with that in the adjacent river, suggesting through-the-bank transfer. However, the wetland is > 100 m from the river and we were unable to verify the existence of a possible secondary inlet channel at the downstream end. Consequently, it may or may not be possible to dry this wetland but if an attempt is made to do so, the wetland should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.
- Once flows to South Australia return to 'baseline' levels, consideration should be given to dredging the inlet channel to reconnect the wetland with the river.

Table 51. Summary of the habitat type and fishing method used at each site in Craignook.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	Limestone rocks with some mud near base of cliffs, 70-90 cm deep, littoral emergent reeds	-34.87812	139.61645
2	Gill Net	Mud over hard substrate, > 1 m deep, littoral emergent reeds near base of cliff	-34.88038	139.60996
3	Gill Net	Open water, 1.5 m deep	-34.87977	139.61939
4	Fyke Net	Open water, muddy substrate, 80 cm deep	-34.88059	139.62160
5	Fyke Net	adjascent littoral emergent reeds, *Vallisneria* , 40 cm deep, muddy substrate	-34.88171	139.62454

Table 52. Summary of the number and length of species captured at Craignook.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*				
bony herring	*Nematalosa erebi*	52	314	119	432
golden perch	*Macquaria ambigua*	2	252	252	252
carp gudgeon complex	*Hypseleotris spp.*	3068	34	21	45
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	795	45	32	61
dwarf flathead gudgeon	*Philypnodon sp.*	4	38	38	38
Murray rainbowfish	*Melanotaenia fluviatilis*				
flathead gudgeon	*Philypnodon grandiceps*	355	45	29	77
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	19	457	350	674
eastern gambusia	*Gambusia holbrooki*	13	25	15	44
goldfish	*Carassius auratus*				
redfin perch	*Perca fluviatilis*	2			
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**4310**			
Total Species		**9**			

Table 53. Summary of water quality data recorded at Craignook.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
746	730	776	24.6	24.0	25.3	9.1	8.3	11.2	8.3	8.1	8.6	20	20	29

1.5.2.13 Maidment Lagoon

General information

At Maidment Lagoon, fish, water quality and acid-sulfate soil sampling were undertaken on 14-15 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 54.

Maidment Lagoon is approximately 1.3 km long x 1 km wide (max). There is one permanent inlet at the north-east end that is free of emergent reeds and is around 15 m wide and 100 m long. Continuous water exchange between the wetland and river was apparent through this channel. At the southern end, there was a 2 m wide culvert (road crossing) that appeared to be filled with dirt, thereby preventing water exchange. Submerged aquatic vegetation was abundant (*Myriophyllum* and *Vallisneria*), as was emergent littoral/riparian vegetation (except along portions of the northern bank, which had been cleared). The average depth was ~50 cm, although sections along the northern bank reached 1.2 m. There was no evidence of salty groundwater intrusion, but cattle were observed grazing along the southern and eastern edges of the wetland.

A total of 4119 fish from 12 species, including eight native species, was captured (Table 55). Carp gudgeons, unspecked hardyheads, Australian smelt, flathead gudgeons and bony herring were the most abundant native fishes, whilst common carp were the most abundant invasive species captured by far. The remaining native (golden perch, dwarf flathead gudgeons and Murray rainbowfish) and invasive (eastern gambusia, goldfish and redfin perch) species were all recorded in low abundance. The capture of relatively small individuals of bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons, common carp, eastern gambusia and redfin perch may indicate relatively recent recruitment.

Due to the wetland's connection with the main river channel, recorded water quality parameters were similar to that in the river. The average conductivity, water temperature, DO concentration, pH and Secchi depth was 485 $\mu s\ cm^{-1}$, 22.7°C, 9.4 $mg\ L^{-1}$, 9.4 and 50 cm, respectively (Table 56). Thus, the water was relatively fresh, well oxygenated, basic in pH and very clear.

Implications for management

- The highest abundance of carp (n = 3011, adults and juveniles, average total length = 119 mm) ever recorded from a River Murray Wetlands Baseline Survey wetland was sampled from Maidment Lagoon. Drying this wetland therefore presents an excellent opportunity to remove carp, but evaporation and lowered river levels may be enough to dry the majority of the wetland, without intervention. The re-entry of carp in the future could be prevented using carp exclusion screens or carp separation cages.
- The connection between this wetland and the main river channel facilitates high velocity current flows. Native fishes are typically more abundant, and invasive fishes less abundant in habitats with flow, and these habitats are now rare, particularly given the highly regulated conditions that prevail in the lower Murray. Therefore, the inlet to Maidment Lagoon should be preserved, especially if the wetland is likely to dry naturally (as above).
- Given the proximity of this wetland to the river and its narrow banks, underground water exchange is probable. Thus if this wetland is chosen for closure, water exchange may persist, effectively preventing the wetland from drying.
- Water column sulfate concentrations marginally exceeded proposed trigger levels (by ≤ 0.7 mg $SO_4.L^{-1}$, see Part B) indicating that whilst it is unlikely to contain sulfidic sediments. Nevertheless, caution should prevail and the wetland should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.
- The potential effects of drying on the extensive submerged vegetation community and on other wetland flora and fauna should also be considered.

Table 54. Summary of the habitat type and fishing method used at each site in Maidment Lagoon.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	Submerged *Myriophyllum*, 30-50 cm deep, sandy substrate, wind-induced current flows	-34.90039	139.59618
2	Fyke Net	Algae over muddy substrate, 20-40 cm deep, emergent stands of *Juncus* at wetland edge	-34.89940	139.59172
3	Gill Net	Open water, 60-80 cm deep, submerged *Myrioophyllum,* muddy substrate, wind-induced flow	-34.89767	139.59521
4	Gill Net	Open water, sparse beds of *Myriophyllum*, 40-80 cm deep	-34.89657	139.59748
5	Fyke Net	Submerged beds of *Myriophyllum*, muddy substrate, 30-50cm depth, emergent stands of *Juncus* at wetland edge	-34.89569	139.59941

Table 55. Summary of the number and length of species captured at Maidment Lagoon.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	56	61	52	70
bony herring	*Nematalosa erebi*	38	281	85	390
golden perch	*Macquaria ambigua*	1	448	448	448
carp gudgeon complex	*Hypseleotris spp.*	685	37	24	53
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	210	46	32	67
dwarf flathead gudgeon	*Philypnodon sp.*	4	43	41	48
Murray rainbowfish	*Melanotaenia fluviatilis*	10	57	45	66
flathead gudgeon	*Philypnodon grandiceps*	78	56	28	76
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	3011	119	24	695
eastern gambusia	*Gambusia holbrooki*	19	28	19	51
goldfish	*Carassius auratus*	5	234	210	265
redfin perch	*Perca fluviatilis*	2	76	71	80
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**4119**			
Total Species		**12**			

Table 56. Summary of water quality data recorded at Maidment Lagoon.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
485	298	1000	22.7	21.8	25.2	9.4	8.7	10.3	9.4	9.2	9.9	50	40	60

1.5.2.14 Teal Flat

General information

At Teal Flat, fish, water quality and acid-sulfate soil sampling were undertaken on 13-14 Dec 2006. The fishing methods that were used at each site and a brief site description are indicated in Table 57.

Teal Flat is approximately 1.8 km long x 600 m wide. There are two inlets, one at either end. Both inlets have regulator structures installed and there appeared to be continuous water exchange with the river. There was sparse submerged vegetation but dense emergent riparian vegetation, and the average water depth was 1 m. There was no evidence of salty groundwater intrusion or cattle grazing. One large irrigation pump is sited at the north-east corner of the wetland.

A total of 3483 fish from 11 species, including seven native species, was captured (Table 58). Carp gudgeons were the most abundant native species sampled by far, followed by flathead gudgeons and unspecked hardyheads. Eastern gambusia and common carp were the most abundant invasive species captured. The remaining native (Australian smelt, bony herring, dwarf flathead gudgeons and Murray rainbowfish) and invasive (goldfish and redfin perch) species were all recorded in relatively low abundance. The capture of relatively small individuals of Australian smelt, bony herring, carp gudgeons, unspecked hardyheads, flathead gudgeons, common carp, eastern gambusia and redfin perch may indicate relatively recent recruitment.

Due to the wetland's dual connections with the main river channel, recorded water quality parameters were similar to that in the river. The average conductivity, water temperature, DO concentration, pH and Secchi depth was 734 $\mu s\ cm^{-1}$, 26.2°C, 9.6 mg L^{-1}, 8.4 and 16 cm, respectively (Table 59). Thus, the water was slightly saline, well oxygenated, basic in pH and moderately turbid.

Implications for management

- No threatened fish species were sampled and the wetland water quality was within acceptable limits for fish.
- Water column sulfate concentrations exceeded suggested trigger levels (i.e. 10 mg SO_4 L^{-1}, Baldwin *et al*., 2007) indicating that this wetland is likely to contain sulfidic sediments, which, if dried, may lead to noxious odours, the poisoning of aquatic flora and fauna, and anoxic and/or acidic sediments upon re-wetting (see Part B).
- If this wetland is to be disconnected from the river, it should be regularly monitored for water quality, sediment pH, fish kills and other adverse impacts. This monitoring should continue during the drying phase and beyond the re-wetting of the wetland. Contingency plans need to be implemented if kills of native aquatic fauna or significant differences between the observed and expected results of post-disconnection monitoring are observed, or if poor water quality develops.

Table 57. Summary of the habitat type and fishing method used at each site in Teal Flat.

Site #	Method	Habitat description	Latitude	Longitude
1	Fyke Net	Adjacent stands of *Juncus* and *Typha* , 40 cm deep, firm sandy substrate	-34.88714	139.55896
2	Fyke Net	Adjacent stands of *Juncus* and *Typha* , 40 cm deep, hard sandy substrate	-34.89331	139.56159
3	Fyke Net	Open water, 100 cm deep, firm mud/sand substrate	-34.88913	139.55789
4	Gill Net	Open water, 70-90 cm deep, firm mud/sand substrate	-34.88610	139.55601
5	Gill Net	Adjacent stands of *Juncus* and *Typha* , 30-40 cm deep, soft muddy substrate	-34.88306	139.55444

Table 58 Summary of the number and length of species captured at Teal Flat.

			Total Length (mm)		
Common Name	**Species Name**	**Total**	**Ave**	**Min**	**Max**
Native Fish					
Australian smelt	*Retropinna semoni*	32	46	26	69
bony herring	*Nematalosa erebi*	22	224	83	334
golden perch	*Macquaria ambigua*				
carp gudgeon complex	*Hypseleotris spp.*	2963	35	21	51
unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	69	47	36	62
dwarf flathead gudgeon	*Philypnodon sp.*	10	43	35	50
Murray rainbowfish	*Melanotaenia fluviatilis*	3	69	68	69
flathead gudgeon	*Philypnodon grandiceps*	335	48	19	85
freshwater catfish	*Tandanus tandanus*				
silver perch	*Bidyanus bidyanus*				
Exotic/Invasive Fish					
common carp	*Cyprinus carpio*	14	485	28	715
eastern gambusia	*Gambusia holbrooki*	30	29	17	44
goldfish	*Carassius auratus*	3	228	216	234
redfin perch	*Perca fluviatilis*	2	182	85	278
carp x goldfish hybrid	*Cyprinus hybrid* (undescribed)				
Total Fish		**3483**			
Total Species		**11**			

Table 59. Summary of water quality data recorded at Teal Flat.

Conductivity (µS cm^{-1})			Water Temp (°C)			Dissolved Oxygen (mg L^{-1})			pH			Secchi Depth (cm)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
734	707	789	26.2	24.6	27.4	9.6	8.4	15.8	8.4	7.6	9.7	16	5	25

PART B – ACIDIFICATION RISK

BACKGROUND

The following two paragraphs are extracts from Hall *et al*. (2006) (see references in that paper), with permission:

Sulfidic sediments form when sulfur compounds are reduced to sulfide by anoxic bacteria in the presence of organic carbon, and the sulfide reacts with metals in the sediment (predominantly iron) to form sulfidic minerals such as iron pyrite (Roden and Edmonds, 1997). Sulfidic sediments can adversely affect aquatic ecosystems because dissolved sulfides are toxic to aquatic organisms (e.g. Postgate, 1984), and high levels of sulfate reduction can produce noxious odours (Lamontagne *et al.*, 2004). Furthermore, oxidation of reduced sulfidic sediments (e.g. through exposure to the air) can produce anoxia and increased levels of acid, which can be flushed into the water body and cause harm to aquatic organisms (Sammut *et al.*, 1993). In a recent survey of 81 wetlands in the Murray-Darling Basin, more than 20% had evidence for the presence of sulfidic sediments at levels that could lead to ecological damage.

Implementing a drying phase in wetland management is increasingly common (Casanova and Brock 2000), but if sulfidic sediments are present, drying can oxidise sulfidic minerals and generate acid (actual acid sulfate soils). For example, the partial drawdown of a wetland in western NSW resulted in an extensive fish kill because of exposure and oxidation of sulfidic sediments leading to acidification (McCarthy et al. 2006). Many of the wetlands identified with sulfidic sediments had been inundated for extended periods of time, either because of river regulation, elevated groundwater levels and/or because they are used as disposal basins for water of poor quality. Conversely, reduced sulfur species tend not to build up to harmful levels in wetlands that have frequent (annual) wetting and drying cycles.

METHODS

In this study, water and sediment samples were taken from wetlands along the South Australian Murray (from the SA/NSW/VIC border to Mannum), to evaluate the risk of acidification associated with potential wetland drying. All wetlands sampled for fish and water quality (above) were sampled for acidification risk, plus an additional nine wetlands for which Baseline Surveys had been undertaken previously but potential risk of acidification analyses had not:

RIVERLAND REGION
(SA/VIC/NSW Border to Overland Corner)

1. Nelwood Lagoon
2. Woolenook Bend
3. Gurra Gurra Lake
4. Yatco Lagoon
5. Lake Bonney

MURRAY GORGE REGION
(Overland Corner to Mannum)

6. Murbko South
7. Devon Downs North
8. North Purnong
9. Saltbush Flat (South Purnong)

1.5.3 Field and Laboratory Protocols[2]

At random locations within each wetland, one sediment sample and three water quality samples were collected and processed using the following methods (after Baldwin *et al*. 2007):

1.5.3.1 Water quality

The colour and appearance of the wetland water was noted, as was the presence of floating debris or biological films on the water's surface (in particular, those of rust- or orange colouration). Three 500 mL surface water samples, preserved with the addition of 10 mL zinc acetate, were collected for sulfate analyses and placed on ice in an esky. In the laboratory, samples were refrigerated until processing using the turbidimetric method at the Wodonga MDFRC (NATA accredited) laboratory (following, Rayment and Higginson 1992).

Averaged water quality data from previous replicate measurements of water temperature (°C), conductivity ($\mu S\ cm^{-1}$), pH, turbidity (secchi depth, cm) and DO ($mg\ L^{-1}$) were used (see PART A). These parameters had been recorded at each fish-sampling site within each wetland, at approximately 50 cm depth, using a pre-calibrated Horiba, Quanta-Hydrolab or TPS water quality meter.

1.5.3.2 Sediment

Using a shovel, at approximately 50 cm from the water's edge, a clean 30 cm deep sample of the soil profile was collected and placed into a zip lock bag (to prevent contamination) and put on ice before freezing. At the MDFRC Albury Laboratory, soil samples were thawed overnight and thoroughly mixed before processing for sediment conductivity and pH:

[2] There is still no agreed upon method among "experts" for how to assess the acidification risk of wetlands, particularly wetlands in South Australia, and especially the other risks associated with sediments rich in reduced sulphur in the Murray-Darling Basin. Alternative laboratory and field protocols are available, and a debate to clarify these issues is needed (S. Lamontagne, CSIRO, Pers. Comm.).

The determination of sediment was made with a conductivity cell and probe (calibrated with 0.001 M and 0.01 M KCl solutions), by measuring the electrical resistance of a 1:5 soil:water suspension. This suspension was made by thoroughly mixing a 5 g sediment sample (dried at 80-85°C in an oven to constant weight and ground in a mortar and pestle to pass through a 1 mm sieve) and 25 ml of de-ionised water in a small beaker. In this case, the supernatant directly over the slurry was measured, after the mix was allowed to settle for 10 minutes.

The determination of sediment pH (i.e. evaluating the activity of the negative log of the hydrogen ion in a suspension) of 1:5 soil:water, was also made from the above suspension, but with a pH meter and probe (calibrated with pH 4 and pH 7 buffer solutions).

RESULTS

Using the Decision-Support Scheme from Baldwin *et al*. (2007) (Figure 1, from that paper) water column conductivity (µS cm^{-1}), pH and sulfate concentration (mg SO_4 L^{-1}), along with sediment conductivity (µS cm^{-1}) and pH was used to identify wetlands demonstrating a likelihood of containing sulfidic sediments (Table 60).

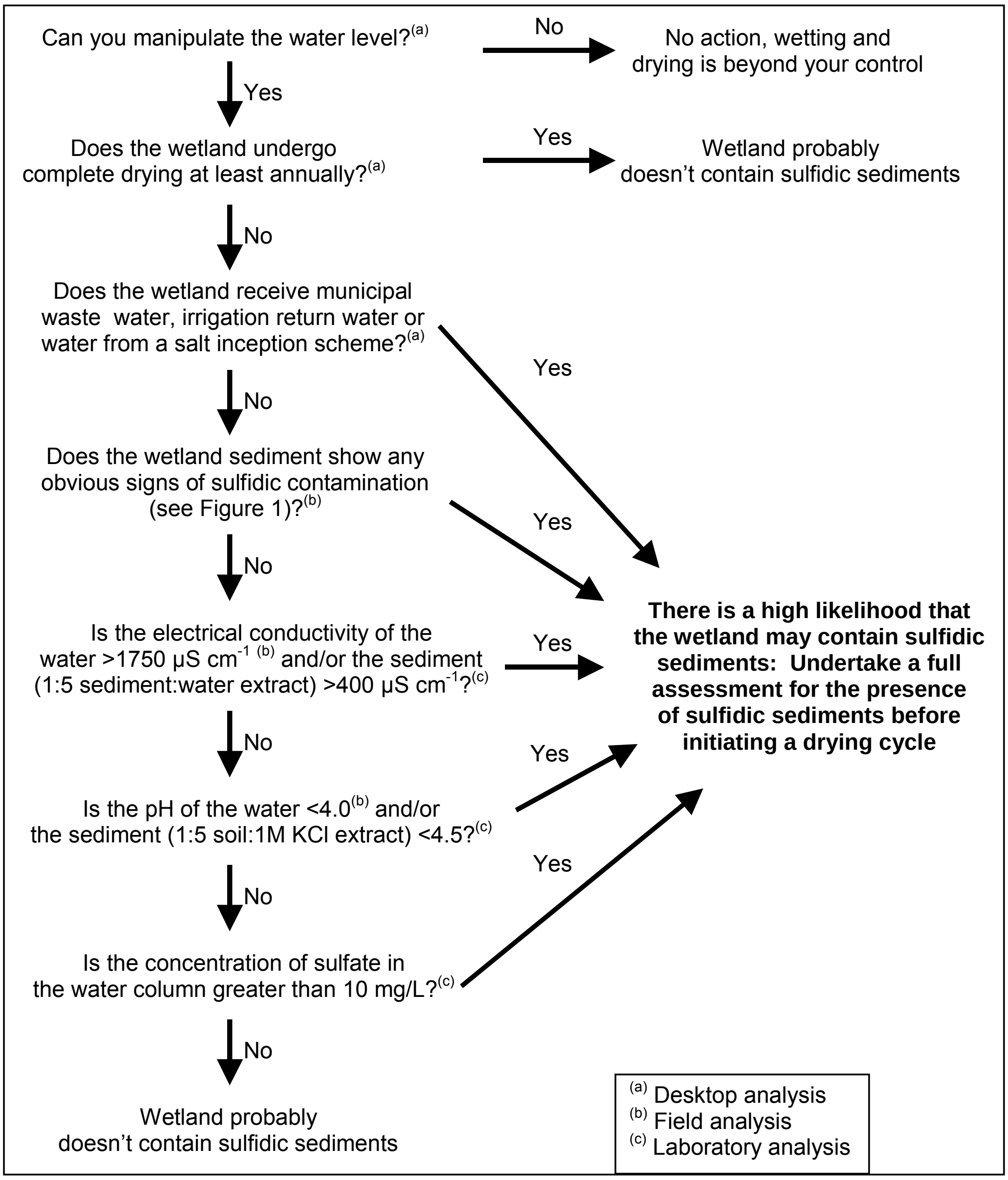

Figure 1. Decision-support scheme developed by Baldwin *et al.* (2007) for initial assessment of the likelihood that an inland wetland contains sulfidic sediments at levels that could cause ecological damage.

Table 60. Analysis of mean water column conductivity (µS cm^{-1}), pH and sulfate concentration (mg SO_4 L^{-1}); EC of sediment (1:5 sediment: water extract) and pH of the sediment (1:5 sediment:water extract).

Wetland	Sulfate (mg $SO_4.L^{-1}$)	Water column EC (µS.cm^{-1})	Water column pH	Sediment EC (µS.cm^{-1})	Sediment pH	Does sediment show any obvious signs of sulfidic contamination?	Does the wetland dry at least annually?	Does wetland receive wastewater, irrigation water or water from a salt inception scheme?
Nelwood (proper)	4.8	179.6	8	553.5	5.4	no	no	no
Nelwood II	6.1	189.2	8.6	139.9	5.7	no	no	no
Tanyaca Creek	7	215.8	8.6	83.1	7.9	no	no	no
Horseshoe Swamp	7.2	207.7	8.2	60.6	5.9	no	no	no
Reedy Island	7.7	404	7.9	659.5	7.5	no	no	no
Woolenook	8.7	294	8.8	80.7	6	no	no	no
Mark's Landing	9	693.2	8.6	157.9	6.4	no	no	no
Wombat's Rest Backwater	9.1	512.4	8.5	1466	6.6	no	no	no
Henley Park	9.5	464	8.5	144.9	6.6	no	no	no
Maidment Lagoon	10.3	632.4	9.5	231	8.2	no	no	no
Punyelroo	10.7	462.8	8.4	71.1	6.8	no	no	no
McBean Pound North	17.7	989	8.1	339.5	7.2	no	no	no
Craignook	18.8	756.6	8.4	153.1	6.6	no	no	no
Donald Flat Lagoon	20	436.2	8.4	115.4	8.6	no	no	no
Bow Hill	20.8	754.6	9.7	263	9	no	no	no
Pyap	21	706	9.5	129.9	6.7	no	no	no
Saltbush Flat	21.7	2600	8.8	495.5	8.8	no	no	no
Devon Downs North	23	1340	9	124.8	6.2	no	no	no
Teal Flat	25.2	738.4	8.5	441	5.9	no	no	no
Big Bend	26.3	1181.4	8.2	198.8	7.6	no	no	no
Nelwart Swamp	26.5	696.6	7.8	262.5	6.8	no	no	no
Murbko South	26.7	1225	9.2	315.5	6.6	no	no	no
North Purnong	28.3	2353	9.4	243	7.2	no	no	no
Jaeschke Lagoon	28.7	583.5	8.4	144.3	6.4	no	no	no
Yatco	34.3	1158	8.4	301.5	8.4	no	no	no
Ross Lagoon	161.7	5928	8.6	686.5	8.5	yes	no	no
Gurra Gurra Lake	348.3	6738	9.4	3810	8.7	yes	no	no
Lake Bonney	623.3	7342	8.8	3290	8.8	yes	no	historically

Seventy percent of the wetlands surveyed (n = 19 of 27) contained water column sulfate concentrations that exceed proposed trigger levels (i.e 10 mg SO_4 L^{-1}; Baldwin *et al.*, 2007,), indicating a high likelihood that they contain sulfidic sediments.

The wetlands with water column sulfate concentrations < 10 mg SO_4 L^{-1} included:

- Nelwood II
- Nelwood Proper
- Woollenook
- Horsehoe Swamp
- Tanyaca Creek
- Wombat's Rest
- Reedy Island
- Mark's Landing
- Henley Park

The wetlands with water column sulfate concentrations > 10 mg SO_4 L^{-1} included:

- Nelwart
- Gurra Gurra Lake**
- Pyap
- Yatco
- Lake Bonney**
- Jaeschke Lagoon
- Ross Lagoon**
- Murbko South
- Donald Flat Lagoon
- McBean Pound North
- Punyelroo*
- Big Bend
- Devon Downs North
- North Purnong**
- Saltbush Flat**
- Craignook
- Maidment Lagoon*
- Bowhill
- Teal Flat

* Marginally exceeded water column sulfate trigger levels (by ≤ 0.7 mg SO_4 L^{-1})

** Contained water column sulfate and EC concentrations far in excess of suggested trigger levels (> 10 mg SO_4 L^{-1} and > 1750 µS cm^{-1}, respectively), indicating that they have a very high likelihood of containing sulfidic sediments (A. Baldwin, Pers. Comm.).

All of the 19 wetlands with elevated water sulfate concentrations had soil pH levels greater than approximately 6-6.5 indicating a high buffering (or acid-neutralising) capacity, meaning that they may not become acidic if they were dried. However, oxidation of sulfidic sediments can also cause problems such as anoxia in the overlying water column (as oxygen is consumed to oxidise sediments), the mobilisation of metals from the sediments (Sullivan *et al.*, 2002 cited in Baldwin *et al.*, 2007) and potential toxicity to aquatic plants and animals (Postgate, 1984).

DISCUSSION

Based on the above results, we conclude that the full suite of analytical tests for water and sediment samples recommended in Baldwin *et al*. (2007) should be performed on each of the 19 wetlands demonstrating elevated sulfate concentrations (>10 mg SO4.L-1). These tests are particularly critical for Gurra Gurra Lake, Lake Bonney, North Purnong, Ross Lagoon and Saltbush Flat, which all exhibited water column sulfate concentrations and conductivity recordings that were well above the recommended threshold values. We also suggest a monitoring program for sulfate concentrations and sediment pH within all wetlands that are dried, and this monitoring should continue upon re-wetting the wetlands.

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