LOWER LAKES, COORONG AND MURRAY MOUTH ICON SITE

2012-13 Synthesis Report

JULY 2014

Government of South Australia
Department of Environment, Water and Natural Resources

Lower Lakes, Coorong and Murray Mouth Icon Site 2012-13 Synthesis Report

Partnerships and Stewardships

River Murray Operations and Major Projects Branch

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EXECUTIVE SUMMARY

The Department of Environment, Water and Natural Resources (DEWNR) is responsible for the delivery of The Living Murray (TLM) program in South Australia (SA), focusing on the Lower Lakes, Coorong and Murray Mouth (LLCMM) icon site and the Chowilla Floodplain icon site. Core activities include developing environmental watering proposals and delivery of environmental water, development and implementation of condition and intervention monitoring programs and engaging various community and indigenous stakeholders in the management of both icon sites.

During 2012-13, the LLCMM icon site was considered the highest priority site for receiving environmental water amongst the six TLM icon sites (MDBA, 2012a), based on the TLM ranking criteria.). This was based on the development of the SA Environmental Watering Proposal and overarching Annual Environmental Watering Plan which documented the ecological needs of both the River Murray channel, Chowilla Floodplain, and the LLCMM icon sites against different climate availability scenarios. The priority action for the LLCMM focused on the delivery of water through the barrages in late spring, summer and early autumn to maintain connectivity between the Lower Lakes and Coorong Estuary and ensure an open Murray Mouth, while reducing salinity levels in the lakes and Coorong. A focus on maintaining water levels in the Coorong South Lagoon to facilitate growth and reproduction of the species *Ruppia tuberosa* was considered an important ecological objective.

The 2012-13 year was the third consecutive year of high barrage outflows and was characterised by high flows to the Lakes and Coorong, particularly during late winter and spring. The LLCMM icon site continued to show signs of ecological recovery in response to increased water levels. All barrage fishways were operational for 365 days, with attractant flow, and the Murray Mouth remained open without the need to dredge. Murray hardyhead was the only threatened fish species to show obvious signs of recruitment in the Lower Lakes in 2012/13. Black bream also showed a gradual increase in abundance and an expansion of distributional range from the Estuary during the drought years into the North Lagoon post 2010 flows. Conversely, there was limited evidence of recruitment for Yarra pygmy perch and southern pygmy perch in the Lower Lakes. Despite the varied hydrological changes that have occurred throughout the five year monitoring period, abundances of waterbirds using the Coorong and Lower Lakes have generally increased or been maintained for at least the last three years. The 2012-13 monitoring has also revealed improvements in invertebrate populations in mudflats throughout most of the Murray Mouth and North Lagoon of the Coorong compared to the drought years.

In 2011-12, ten ecological targets out of a total of 16 were achieved, five were not achieved and for one target there was insufficient data to make an assessment. By comparison, in 2012-13, 11 ecological targets out of a total 16 were achieved (albeit two only partially), two were not achieved, and for four targets there were insufficient data to draw a definite conclusion. The additional targets achieved in 2012-13 related to endangered fish species populations in the Lower Lakes and populations of black bream, greenback flounder and mulloway in the Coorong. The results from the 2011-12 and 2012-13 years display a marked improvement from drought years (e.g. 2008-09) where only two targets were achieved, twelve were not achieved and three targets had insufficient data.

The successful colonisation and reproduction of *Ruppia tuberosa* continues to pose a challenge for site managers and although waterbird populations have been maintained or improved, their continued recovery will be affected by the distribution and abundance of *Ruppia tuberosa*. The length in recovery time for many species post-drought is evident in the similarity between the 2011-12 and 2012-13 monitoring year results and achievement of targets. Although there was a significant improvement immediately post-drought, ongoing consecutive years of higher flow into the future are required to ensure recovery can be completed. Overall, the 2012-13 monitoring results represent a continued improvement in the condition of the LLCMM icon site. A more detailed comparison between the 2012-13 monitoring year and preceding monitoring years is presented in Section 4.5.

The LLCMM Synthesis Report 2012-13 provides detailed information on the monitoring results taken from individual condition and intervention Monitoring reports while further elaborating on the status of the ecological targets to ascertain whether they were met for 2012-13 and identifies future priorities. The report summarises the management actions undertaken throughout the watering year and concludes with lessons learnt and recommendations to improve the annual environmental water planning and delivery process. This will help to ensure that environmental water is delivered to the LLCMM icon site in the way which will achieve maximum ecological outcomes in the future.

1. INTRODUCTION

To assess the overall condition of the LLCMM icon site, sixteen ecological / physical targets were assessed using data from annual monitoring undertaken for bird, fish, vegetation, and invertebrate communities (Table 1). Associated water quality and hydrological conditions (including connectivity) were also assessed in order to provide context and quantify changes in the condition of the LLCMM. Condition and intervention monitoring programs delivered through the TLM program (and other programs within DEWNR) aim to assess whether targets have been achieved. A summary of these targets and whether they were achieved in 2012-13 is presented and discussed in this report.

Since September 2010, significant flows have occurred in the Murray-Darling Basin resulting in substantial barrage releases to the Coorong. At the start of the 2012-13, the water availability outlook looked promising and South Australia was already receiving unregulated flows. Following the flow peak of 60,000 megalitres per day (ML/day) into South Australia in April 2012, flows receded to 20,000 ML/day by July 2012. As unregulated flow increased throughout July, flow at the SA border was maintained at around 45,000 ML/day and continued into October 2012 with the peak flow reaching 50,000 ML/day (refer to Figure 6). It was anticipated that environmental water would be provided on the tail of the unregulated flow peak to achieve positive ecological responses, however a rapid drop in flow at the SA border from 50,000 ML/day to 20,000 ML/day over a two week period meant this action was not feasible. In December 2012 a flow pulse was created with environmental water to increase flows at the SA border from 7,000 ML/day to 20,000 ML/day for a duration of 16 days to encourage spawning of Golden Perch in the channel and for *Ruppia tuberosa* reproduction in the LLCMM.

While large volumes of water delivered to the LLCMM in 2012-13 ensured salinity thresholds were maintained below the specified thresholds for the Coorong, Lake Albert salinities remained high, and reverse-head events at the barrages lead to short-term salinity spikes in Lake Alexandrina. No managed lake level 'cycling' events were implemented due to a lack of available re-fill volume in the latter part of the year, and due to a need to maintain lake levels to facilitate the removal of the Currency Creek regulator.

1.1 Objectives of the Synthesis Report

The LLCMM Icon Site Synthesis Report 2012-13 documents the results of monitoring programs implemented during 2012-13 and reports on the achievements of icon site ecological objectives and targets. The synthesis report also aims to discuss the relationship between the delivery of environmental water to the icon site and ecological responses.

The following key points summarise the main objectives of the Synthesis Report:

- Summarise the key findings of the LLCMM icon site Condition and Intervention Monitoring reports;
- Assess the achievements of specific icon site ecological objectives and targets and how this influences the overall status / condition of the icon site;
- Link ecological responses to climatic conditions (e.g. tide, wind, salinity, temperature, rainfall) within the icon site;
- Discuss environmental responses in relation to the delivery of environmental water to the LLCMM icon site; and
- Provide icon site specific information that will inform the development of an overarching TLM System Scale Synthesis Report.

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2. BACKGROUND

2.1 The Living Murray Initiative

The Living Murray (TLM) Initiative is one of Australia's most significant river restoration programs. Established in 2002, TLM is a partnership of the New South Wales, Victorian, South Australian, Australian Capital Territory and the Commonwealth Governments. It is coordinated by the Murray – Darling Basin Authority (MDBA). The long-term goal of this program is to achieve a healthy working River Murray system for the benefit of all Australians. The Department of Environment, Water and Natural Resources (DEWNR) in South Australia is responsible for the on-ground delivery and management of the Lower Lakes, Coorong and Murray Mouth (LLCMM) and Chowilla Floodplain icon sites.

TLM aims to improve the environmental health of six icon sites (Figure 1) that were chosen for their significant ecological, cultural, recreational, heritage and economic values. These icon sites include:

- Barmah–Millewa Forest;
- Gunbower–Koondrook–Perricoota Forest;
- Hattah Lakes;
- Chowilla Floodplain and Lindsay-Wallpolla Islands (including Mulcra Island);
- River Murray Channel; and
- Lower Lakes, Coorong and Murray Mouth

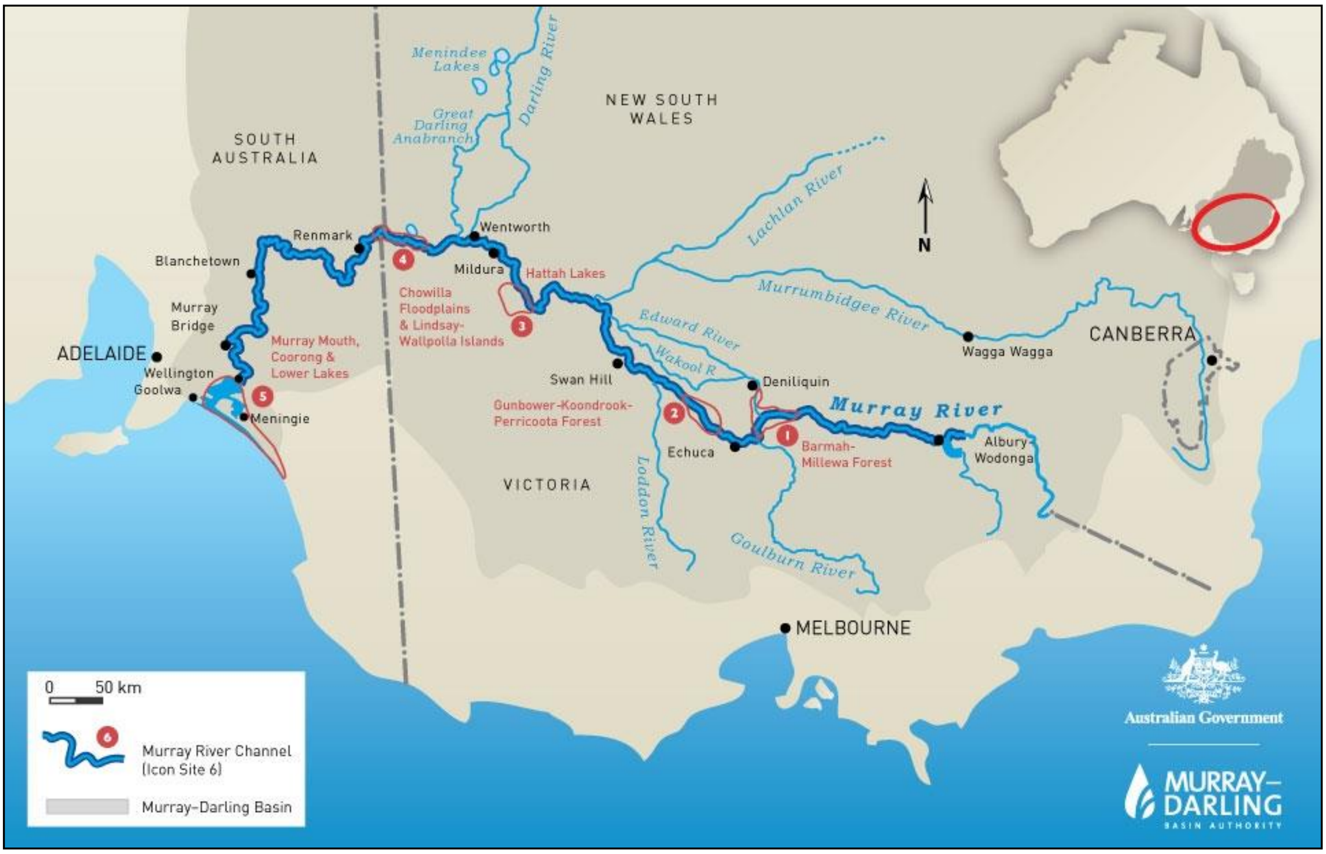

Figure 1 - Location of The Living Murray Icon Sites (map: MDBA)

2.2 The Lower Lakes, Coorong and Murray Mouth Icon Site

Lakes Alexandrina and Albert ('Lower Lakes'), the Coorong and Murray Mouth (LLCMM) have been identified as an ecologically and culturally important icon site. The LLCMM region (Figure 2,

Figure 3, Figure 4 and Figure 5) covers an area of approximately 140,000 hectares; it is a Ramsar-listed wetland of international importance and is also one of eighteen key indicator sites of the Murray–Darling Basin (MDB). The site has a unique mosaic of twenty three individual wetlands and provides habitat for nationally and internationally significant species. The icon site, which contains the Meeting of the Waters registered Ngarrindjeri heritage site, is central to the life and culture of the Ngarrindjeri people, who continue to live on their traditional country. The ecological health of the icon site has been severely degraded by river regulation, over-extraction, and to a lesser extent, a reduction in the diversion of drainage water from the South East of South Australia into the Coorong South Lagoon. These impacts have been exacerbated in recent times by a prolonged period of drought spanning nearly a decade.

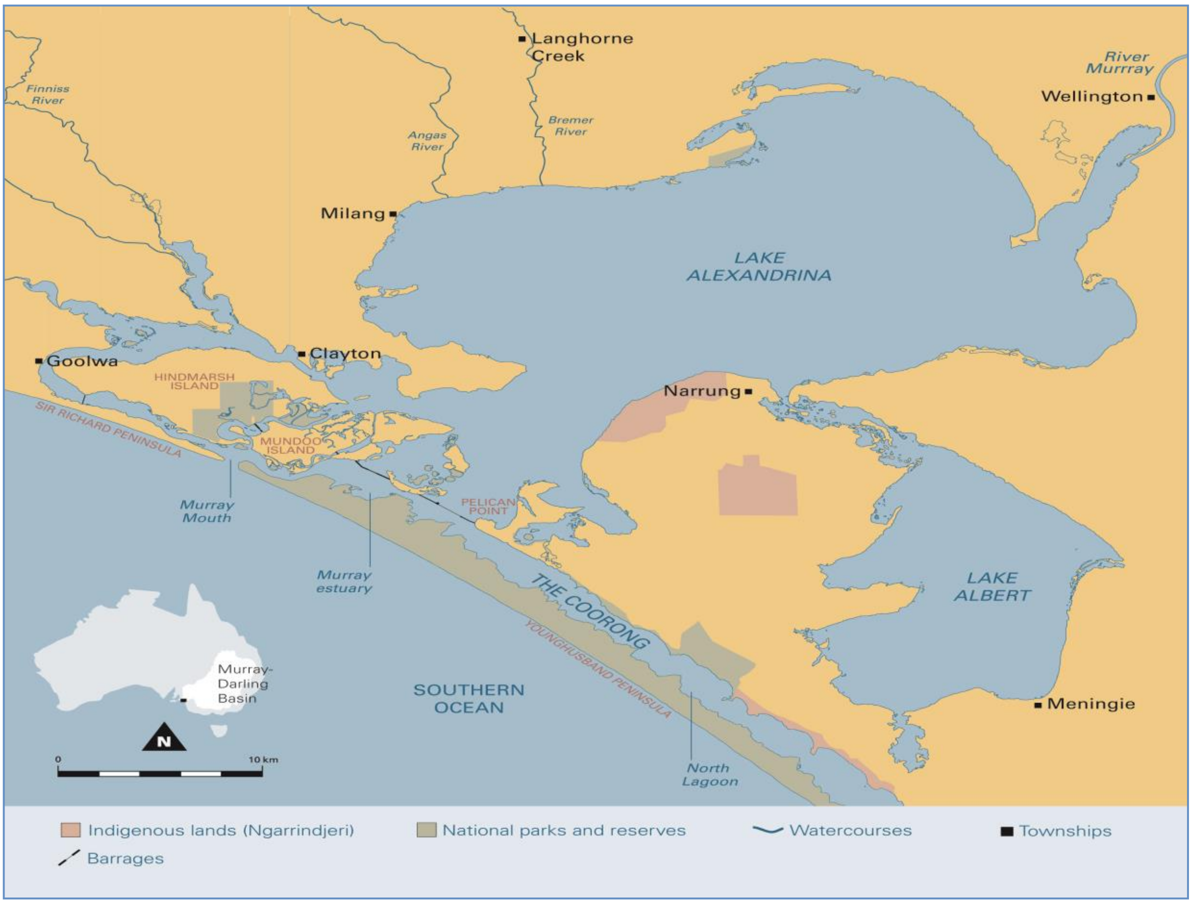

Figure 2 - Map of the Lower Lakes, Coorong and Murray Mouth Icon Site (map: Ecocreative)

Figure 3 - The Coorong Estuary (photo: Kirsty Wedge)

Figure 4 - The Lower Lakes (photo: Scotte Wedderburn)

Figure 5 - The Murray Mouth located at Goolwa (photo: Kirsty Wedge)

2.3 Ecological Objectives

The Living Murray interim ecological objectives were developed and approved by the Murray–Darling Basin Ministerial Council (MDBMC) in 2003, based on an understanding of the LLCMM icon site's characteristics and ecological requirements.

These ecological objectives are:

- an open Murray Mouth;
- more frequent estuarine fish spawning and recruitment; and
- enhanced migratory waterbird habitat in the Lower Lakes and Coorong.

2.4 Ecological Targets

Since the MDBMC objectives were approved, jurisdictions have continued to review and refine supporting ecological targets specific for each icon site. These refined ecological targets reflect years of lessons learnt from the delivery of environmental water combined with scientific research and monitoring, modelling analysis, and community consultation activities. This has enabled a clearer, more effective evaluation of environmental condition and responses to water availability. The Lower Lakes, Coorong and Murray Mouth Environmental Water Management Plan (MDBA, 2013) contains detailed information on both the MDBMC objectives and refined ecological targets. This Plan is revised periodically to reflect any significant changes.

Ecological targets for the LLCMM icon site have been developed and subsequently revised by a panel of scientific experts through the LLCMM Scientific Advisory Group, in conjunction with natural resource managers and other key stakeholders. Revision has seen targets clarified, the incorporation of knowledge gained throughout the ongoing Condition Monitoring process, and consideration of the changing environmental conditions in the icon site. Each of the revised ecological targets for the LLCMM contributes to at least one environmental objective of the LLCMM icon site (Table 1). The relationships between ecological targets and icon site objectives can be either direct and/or indirect. The purpose of establishing these targets is to enable ongoing assessment of specific bird, fish, vegetation and invertebrate communities of the LLCMM icon site, and the water quality and connectivity conditions which affect the biotic condition. These assessments inform the level of achievement of the icon site objectives. Measurable changes to some of the targets can be specifically associated with TLM management actions while others may only be inferred.

Table 1 - Summary of ecological targets and their connection to LLCMM Icon Site objectives

Target ID#	Ecological Target	Icon Site Objective		
		Open Mouth	Fish Recruitment	Bird Habitat
B1	Maintain or improve bird populations in the Lower Lakes, Coorong and Murray Mouth	✓		✓
F1	Maintain or improve recruitment success of diadromous fish in the Lower Lakes and Coorong	✓	✓	
F2	Maintain or improve recruitment success of endangered fish species in the Lower Lakes		✓	
F3	Provide optimum conditions to improve recruitment success of small-mouthed hardyhead in the South Lagoon		✓	
F4	Maintain or improve populations of black bream, greenback flounder and mulloway in the Coorong	✓	✓	
I1	Maintain or improve invertebrate populations in mudflats (both exposed and submerged)	✓	✓	✓
I2	Provide freshwater flows that provide food sources for Goolwa cockles	✓		
M1	Facilitate frequent changes in exposure and submergence of mudflats	✓		✓
M2	Maintain habitable sediment conditions in mudflats			✓
V1	Maintain or improve *Ruppia megacarpa* colonisation and reproduction		✓	✓
V2	Maintain or improve *Ruppia tuberosa* colonisation and reproduction		✓	✓
V3	Maintain or improve aquatic and littoral vegetation in the Lower Lakes		✓	✓
W1	Establish and maintain variable salinity regime with >30% of area below sea water salinity concentrations in estuary and North Lagoon		✓	✓
W2	Maintain a permanent Murray Mouth opening through freshwater outflows with adequate tidal variations to improve water quality and maximise connectivity	✓	✓	✓
W3	Maximise fish passage connectivity between the Lower Lakes and Coorong		✓	
W4	Maximise fish passage connectivity between the Coorong and the sea	✓	✓	

MDBMC Icon Site Objectives: – Open Mouth: an open Murray Mouth; Fish Recruitment: more frequent estuarine fish recruitment; Bird Habitat: enhanced migratory wader bird habitat in the Lower Lakes. Target ID – B: bird-related target; F: fish-related targets; I: invertebrate-related targets; M: mudflat-related targets; V: vegetation-related targets; W: water-related targets.

3. ENVIRONMENTAL WATER DELIVERY AND MANAGEMENT

3.1 Planned Environmental Watering

The annual environmental water planning process for 2012-13 commenced in February 2012 when consultation with various stakeholders including scientific experts, representatives of environmental water holders (MDBA and Commonwealth Environmental Water Holder (CEWH)), river operators, and community reference groups was undertaken. For the LLCMM icon site, consultation was specifically targeted at the Scientific Advisory Group (SAG), Community Advisory Panel (CAP) and the Ngarrindjeri Regional Authority (NRA). The engagement of these groups enabled effective discussions around watering scenarios and objectives, required volumes, preferred timing of environmental water delivery, and the review of modelling outputs. This information was then used in the development of a detailed Environmental Watering Proposal submitted to the MDBA and CEWH, which was later incorporated into the overarching TLM Annual Environmental Watering Plan (2012-13) (MDBA, 2012) for all six icon sites within the MDB.

Environmental Watering Proposals were developed by icon site managers and were focused around four climate availability scenarios using annual exceedance probabilities (AEP) (see Table 2). These scenarios have inbuilt assumptions regarding inflows from the Snowy River Scheme, unregulated flows into Hume Reservoir, inflows from Dartmouth Reservoir, inflows from major tributaries, conveyance and storage losses and usage patterns; and relate to specific annual inflow volumes that range from 2,900 GL QSA in a dry scenario to 18,100 GL QSA in a wet scenario (MDBA, 2012).

Table 2 - Climate scenarios used in annual environmental water planning in 2012-13

Scenario	AEP %	Flow Band
Dry/Median	75% and 90%	Entitlement to 20,000 ML/day
Median	50%	20,000 to 45,000 ML/day
Median/Wet	25%	45,000 to 60,000 ML/day
Wet	10%	60,000 to 80,000 ML/day

Specific annual ecological objectives were developed to justify the watering needs of the icon site and described for the range of flow conditions that could be encountered under each climate availability scenario. Antecedent conditions, constraints, and risks associated with delivery of environmental water were also considered when aligning ecological objectives to each scenario. The potential watering actions under each scenario are outlined in Table 3. It is worth noting that the LLCMM icon site watering actions were developed in conjunction with the watering needs of the River Murray Channel icon site.

The proposed watering actions for each icon site were prioritised by the MDBA Environmental Watering Group (EWG) based on TLM criteria. The LLCMM icon site was ranked the highest priority across all four climate scenarios due to the system-wide environmental benefits including large-scale fish and bird breeding events in wetter scenarios. The site also offered salinity and acidification reduction potential as a result of environmental water application, which would further assist recovery after the drought (MDBA, 2012).

3.1.1 Specific 2012-13 ecological objectives for the LLCMM icon site

In 2012-13, specific icon site objectives were developed as part of the Environmental Watering Proposal to guide delivery of environmental water to the LLCMM icon site. These objectives included:

- Twelve months of continuous barrage releases to maintain an open Murray Mouth; maintain/improve recruitment in diadromous fish; maintain/improve recruitment and distribution of Coorong commercial fish; and enhance feeding and nesting habitat for Fairy Terns.
- Maintain salinity levels) in Lake Alexandrina below 1,000 µS/cm from July 2012 to June 2013 to increase submerged aquatic plant abundance and diversity; increase recruitment and population size of small-bodied threatened fish; prevent tubeworm colonisation in the lakes; and increase Southern Bell Frog distribution and abundance in the lakes.
- Reduce salinity levels in Lake Albert with the aim of achieving a target of an average of 2,000 µS/cm by the end of June 2013.
- Maintain Coorong South Lagoon salinity levels <100 parts per thousand from July 2012 to June 2013 to maintain/improve Small-mouthed hardyhead populations; maintain/improve benthic invertebrate distribution and abundance and maintain/improve the abundance and diversity of piscivorous and insectivorous waterbirds.
- Maintain Coorong South Lagoon water levels between 0.0 and 0.2 m AHD over summer (December 2012 to February 2013) to increase the distribution and cover of *Ruppia tuberosa* and increase the density of the seed bank and maintain/improve the abundance and diversity of herbivorous waterbirds.

Table 3 - Environmental objectives and associated watering needs for the LLCMM Icon Site under each climate scenario

Climate Scenarios	Dry	Median	Median/Wet	Wet
Environmental objectives	**LLCMM**- maintain connectivity between lakes and estuary, maintain open Murray Mouth, maintain salinity in Lake Alexandrina <1,000 µS/cm	**LLCMM**- maintain connectivity between lakes and estuary, maintain open Murray Mouth, maintain salinity in Lake Alexandrina <1,000 µS/cm, salinity benefits in Coorong, South Lagoon	**LLCMM**- maintain connectivity between lakes and estuary, maintain open Murray Mouth, maintain salinity in Lake Alexandrina <1,000 µS/cm, salinity benefits in Coorong, South Lagoon	**LLCMM**- maintain connectivity between lakes and estuary, maintain open Murray Mouth, maintain salinity in Lake Alexandrina <1,000 µS/cm, salinity benefits in Coorong, South Lagoon
Priority watering actions	Flow to SA (QSA) of 20,000 ML/day	Flow to SA (QSA) of 20,000 to 45,000 ML/day	Flow to SA (QSA) of 45,000 to 60,000 ML/day to enhance, extend or manage the recession of natural high flow events where feasible to increase and/or prolong the inundation of floodplains and wetlands	Flow to SA (QSA) of 60,000 to 80,000 ML/day to enhance, extend or manage the recession of natural high flow events where feasible to increase and/or prolong the inundation of floodplains and wetlands
Estimated vols.	1,209 GL	1,360 GL	1,129 GL	1,379 GL

3.2 Actual Flow and Climatic Conditions

The 2012-13 water year commenced with a good water availability outlook as South Australia was receiving unregulated flows. Following the flow peak of 60,000 megalitres per day (ML/day) into South Australia in April 2012, flows receded to 20,000 ML/day by July 2012 (Figure 6) .As unregulated flow increased throughout July, flows were maintained at the South Australian border at around 45,000 ML/day. The unregulated flow continued into late October 2012,

Unregulated flows across the South Australian border lead to flows peaking just below 50,000 ML/day on 2 October 2012. At this time South Australia sought the release of environmental water to extend and maintain water levels and flow to enable completion of fauna breeding cycles. It was anticipated that environmental water would be provided on the tail of the unregulated flow peak to achieve this outcome. However, a rapid drop in flow of 30,000 ML/day from approximately 50,000 ML/day to 20,000 ML/day over a two week period meant that this action was no longer feasible (DEWNR, 2013a).

Barrage outflows peaked between late July and early October 2012, as a result of the unregulated flows. Flows then reduced significantly across the rest of the year, but were supplemented by environmental water (
Figure 7, Figure 8 and Figure 9). Fishways were in operation for the entire year, and flows were generally prioritised through Tauwitchere barrage to facilitate freshening in the Coorong (with the exception of June 2013 where flows were split between Goolwa and Tauwitchere to facilitate Murray Mouth openness and diadromous fish passage). Goolwa barrage was also carefully operated to minimise the impact of reverse flows during high tide/swell events. The 'average' barrage outflow of 2,000 ML/d required to maintain an open Murray Mouth (an agreed target between SA and the MDBA) was not achieved from January to April 2013, leading to some constriction in channels. Diurnal tide ratios remained within target levels, which are set to provide an indication of whether dredging is likely to be required.

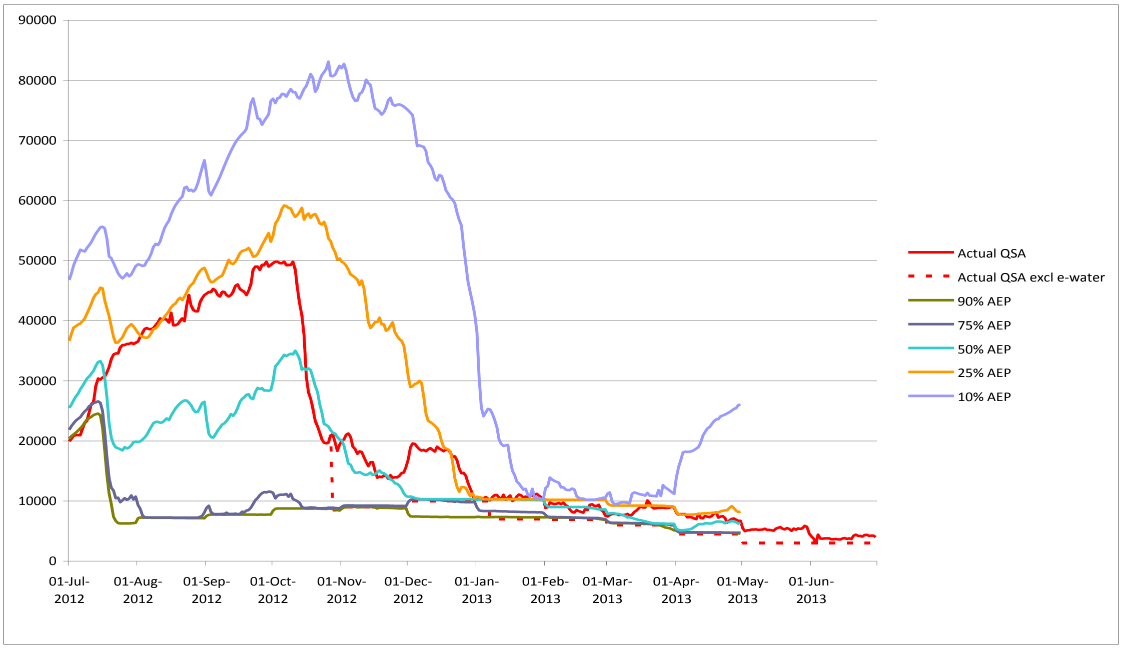

Figure 6 - Actual flow to South Australia in 2012-13 compared to annual exceedance probability data used to develop environmental watering priorities

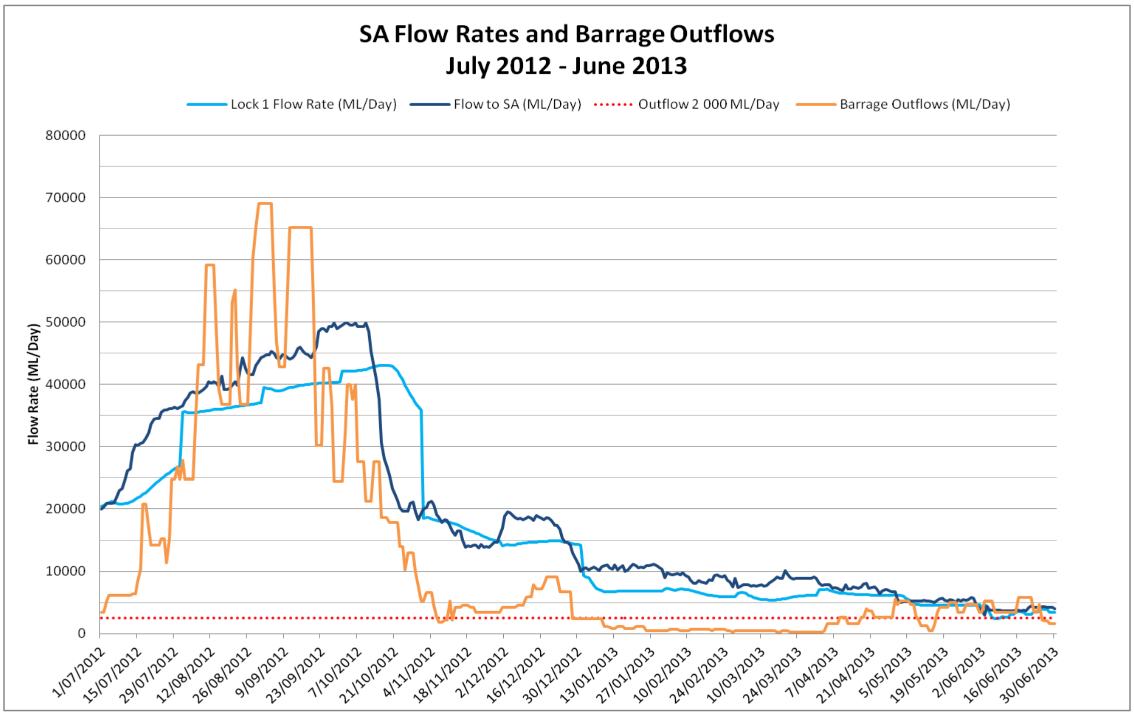

Figure 7 - Flow rates and barrage outflows 2012-13 (note that barrage outflow is estimated using the SA Water method)[1]

[1] The SA Water method for estimating barrage outflows is calculated using the number of open bays at each barrage and flow based on past gauging data.

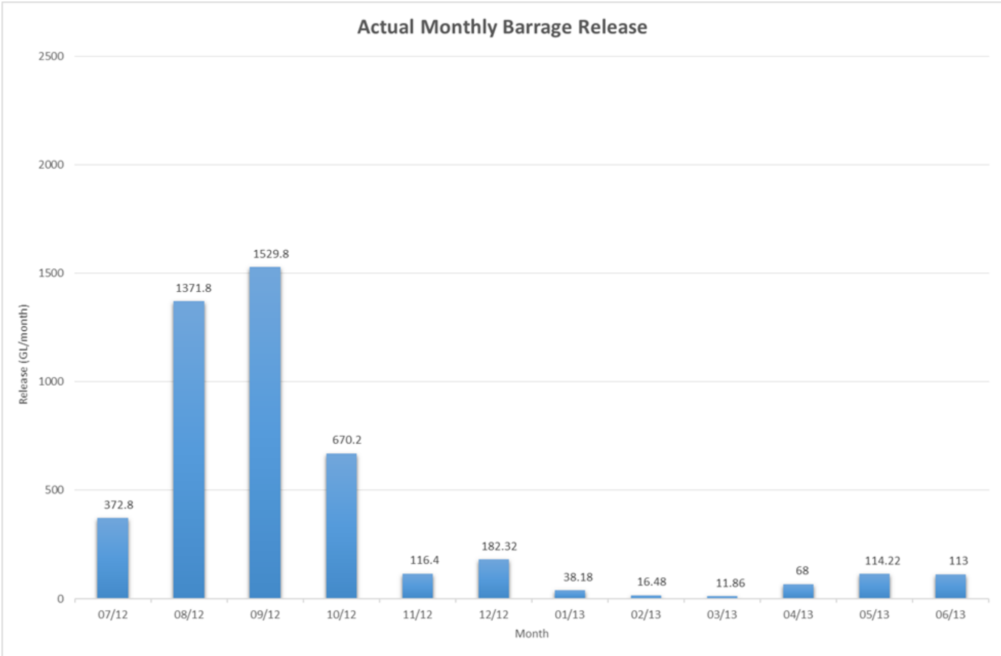

Figure 8 - Actual monthly barrage release 2012-13 (estimated using the SA Water method)

3.3 Environmental Water Delivery

In December 2012, a flow pulse that increased flows from 7,000 ML/day to 20,000 ML/day for 16 days was created with environmental water to encourage flow-cued spawning fish, such as Golden Perch, to move and breed, and to provide sufficient water for *Ruppia tuberosa* reproduction in the Coorong.

A total of 1,087,456 ML of environmental water was delivered to the River Murray Channel and LLCMM icon sites (DEWNR 2013a) for the entire year. This figure consisted of 785,952 ML of environmental water from the CEWH, 289,004 ML from TLM and 12,500 ML from the South Australian Minister for the River Murray Water Licence (DEWNR 2013a). In 2012-13 the LLCMM icon site received a total barrage outflow of 4,605,060 ML which enabled barrage and fishway releases to be undertaken throughout the whole year (Figure 10 and Figure 11, DEWNR 2013a).

3.4 Comparison of Planned and Actual Environmental Water Delivery

The actual flow to South Australia (excluding environmental water) in 2012-13 was compared to the four main climate scenarios and their corresponding environmental watering objectives developed as part of the environmental water planning process. In assessing the actual flow data it was found that from mid July 2012 to early October 2012 actual flow most closely resembled the 25% AEP (median/wet scenario). From October 2012 there was a rapid drop in flow (>30,000ML/day decrease over two weeks) which did not align with any of the planned climate scenarios. This represented a transition between scenarios (Steggles, 2013). On 27 October 2012 unregulated flow to South Australia ceased and environmental water delivery to South Australia commenced. From late October until the end of the water year flow to South Australia most closely resembled the 90% AEP (dry/median scenario).

Under the median/wet scenario during the mid-July to early October timeframe, triggers relating to a flow of 60,000 ML/d were met for three environmental watering actions for the SA River Murray channel and floodplain.

These environmental watering actions complimented proposed LLCMM actions and no additional environmental water was sought for the LLCMM in this timeframe (Steggles, 2013). However, these actions were not implemented due to a combination of factors which included; feasibility issues with the reduction in flow, delays in providing access to water holdings, an inability to add environmental water to the top of unregulated flows, and upstream river operations causing a rapid change in flow rates (Steggles, 2013). Under the dry/median scenario in the late October to late June timeframe, relevant triggers for the SA River Murray channel and floodplain were met and the corresponding watering actions were implemented. The watering action at the LLCMM also proceeded although no triggers were specified for this site.

The LLCMM icon site received a significant volume of environmental water throughout 2012-13, however the actual monthly delivery pattern differed significantly from those planned (Table 4). Water requirements in early spring may have been provided through unregulated flows. However, when the unregulated flows ceased, much lower volumes of environmental water were delivered between November and February than planned and much greater volumes were instead delivered between March and June. The variation from planned environmental delivery can be attributed to a range of factors including; delayed action from water holders, inability to boost unregulated flows, channel constraint issues limiting environmental water to approximately 50 GL in February, and the CEWH undertaking a watering action in the Goulburn River which resulted in return flows arriving in SA in autumn.

Table 4 - Comparison of planned versus actual environmental water delivery in the LLCMM (from Steggles 2013)

Month	Planned volumes based on hypothetical hydrographs (GL)				Approximate volume delivered (GL)			Difference between planned and delivered
	90% AEP-Baseline	Floodplain/ channel + LLCMM	LLCMM	Total planned	Actual delivered (traded)	Delivered as part of entitlement	Total e-water delivered	
Jun-12	372	0	0	0	0.0			
Jul-12	217	0	0	0	0.0	8.4	8.4	**8.4**
Aug-12	217	0	0	0	0.0	9.6	9.6	**9.6**
Sep-12	227	0	81	81	0.0	10.5	10.5	**-70.5**
Oct-12	265	152	99	251	44.5	13.3	57.7	**-193.3**
Nov-12	272	328	0	328	221.7	14.0	235.7	**-92.3**
Dec-12	310	310	0	310	218.0	16.9	234.9	**-75.1**
Jan-13	315	85	100	185	95.0	16.9	111.8	**-73.2**
Feb-13	253	0	156	156	55.2	15.1	70.3	**-85.7**
Mar-13	355	0	69	69	76.0	14.5	90.4	**21.4**
Apr-13	550	0	0	0	84.8	10.5	95.3	**95.3**
May-13	93	0	0	0	71.1	7.2	78.4	**78.4**
Jun-13	*[2]	0	0	0	27.3	7.0	34.3	**34.3**
Total	**3,446**	**875**	**505**	**1380**	**893.5**	**143.9**	**1037.4**	**-342.6**

[2] * This information was not available at the time when AEP curves were being developed.

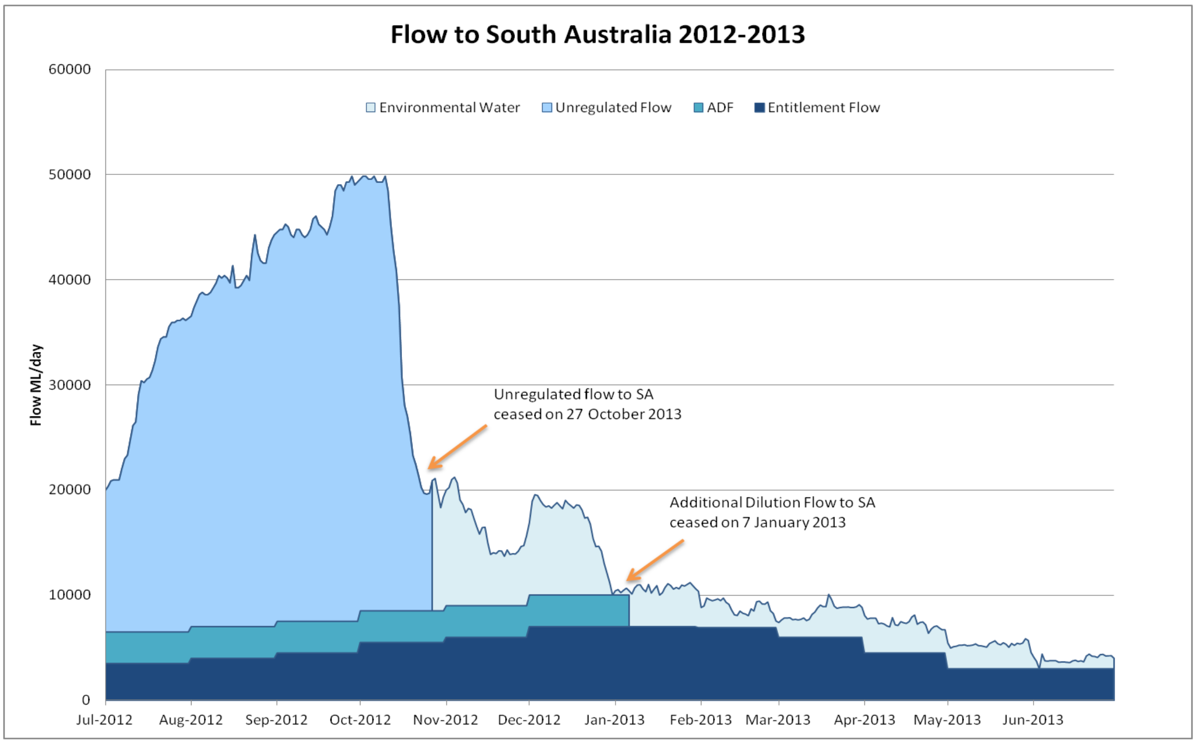

Figure 9 - Flow to South Australia 2012-13

3.5 Management Actions

During 2012-13 the LLCMM icon site was managed to maximise environmental water delivery through the barrages and in turn, to ensure connectivity between the Lower Lakes, Coorong Estuary and Murray Mouth. Key management actions included the following:

- Development of the Short-term Barrage Operating Plan (SBOP) to coordinate management decisions around barrage operations and lake level management.

- Prioritising barrage releases and delivery of environmental water during spring/summer months predominately through Tauwitchere Barrage to enhance recruitment and recovery of *Ruppia tuberosa* and reduction of salinity in the Coorong South Lagoon (Figure 14).

- Maintaining barrage releases and delivery of environmental water during autumn/winter months predominately through Goolwa Barrage (Figure 10) to assist lamprey (short-headed and pouched) migration upstream to complete their lifecycle, whilst maintaining the openness of the Murray Mouth.

- Surcharging Lake Alexandrina at appropriate times of the year allows for inundation of fringing lakeshore vegetation and storage of water for delivery over summer (Figure 12). The higher lake level allows more freshwater to be released through the barrages in support of ecological needs of the Coorong Estuary (particularly the South Lagoon).

- Managing barrage releases in the event of reverse head conditions associated with high tides and swells.

- Ensuring that all fishways located on the barrages remained open and functional all year round. Figure 11 shows the small vertical slot fishway in operation at Tauwitchere Barrage.

Figure 10 - Environmental water being released from Goolwa Barrage

Figure 11 - Small vertical slot fishway in operation at Tauwitchere Barrage

4. MONITORING RESULTS

The environmental and ecological information presented below was obtained from the full monitoring report prepared for each component by the respective service providers. For a full summary of longer term trends, including graphical presentations, please refer to the original reports, referenced in each of the following subsections.

4.1 Environmental Condition

4.1.1 Water Levels

Environmental water was focused on delivery to the Coorong in 2012-13 to maintain water levels in the South Lagoon between 0.0 – 0.2 m AHD over summer (December-February) (see Figure 11). This objective was only met during December 2012 when the overall volume of water flowing to South Australia was between 15,000 and 20,000 ML/day and corresponding flows over the barrages varied from 4,000 to 6,000 ML/day. The flows into South Australia dropped below 10,000 ML/day in January 2013, with the subsequent flow over the barrages dropping to around 1,000 ML/day when the additional dilution flow to South Australia ceased and the volume of environmental water released also declined. Water levels in the South Lagoon at these times were below 0.0 m AHD and reached - 0.2 m AHD in March 2013. This followed a peak water level of 1.0 m AHD in September 2012 (Figure 14). Water levels in the North Lagoon ranged from 0.1 – 0.7 m AHD, and were lowest in summer.

4.1.2 Salinity

<u>Lakes Alexandrina and Albert</u>

Average salinity in Lake Alexandrina, as per telemetered surface water station data remained between 400 and 700 EC with the exception of short-term spikes experienced in the Goolwa channel region between August and September 2012. Average salinity in Lake Albert remained around 3,400 EC until March 2013, after which salinity dropped to around 2,800 EC by the end of June 2013. During this time, levels in Lake Albert were higher than Lake Alexandrina (likely due to wind) which contributed to increased exchanges and mixing between the lakes. In general, lake levels were highly variable between July and September 2012 due to difficulties in passing large volumes through the barrages during periods of high tides and swells. From November 2012 to February 2013, levels were reduced from just over 0.80 to 0.60 m AHD (Australian Height Datum), and remained between 0.60 and 0.65 m AHD until the end of the year to facilitate removal of the Currency Creek regulator. Figure 12 and Figure 13 below show the average salinity and water levels in Lake Alexandrina and Lake Albert during the 2012-13 year, respectively.

<u>Coorong and Murray Mouth</u>

There were substantial reductions in mean salinity at all sampled sites during barrage releases from 2010 to 2013. In the Coorong North Lagoon, average salinity ranged from 5-35 parts per thousand (ppt), peaking in March 2013 when barrage outflows were lowest. In the South Lagoon, average salinity remained below the threshold of 100 ppt for the entire year, peaking at around 93 ppt in early April 2013 (Figure 14). It is worth noting that salinity levels in 2012-13 increased in the Murray Estuary compared with previous (post drought) years.

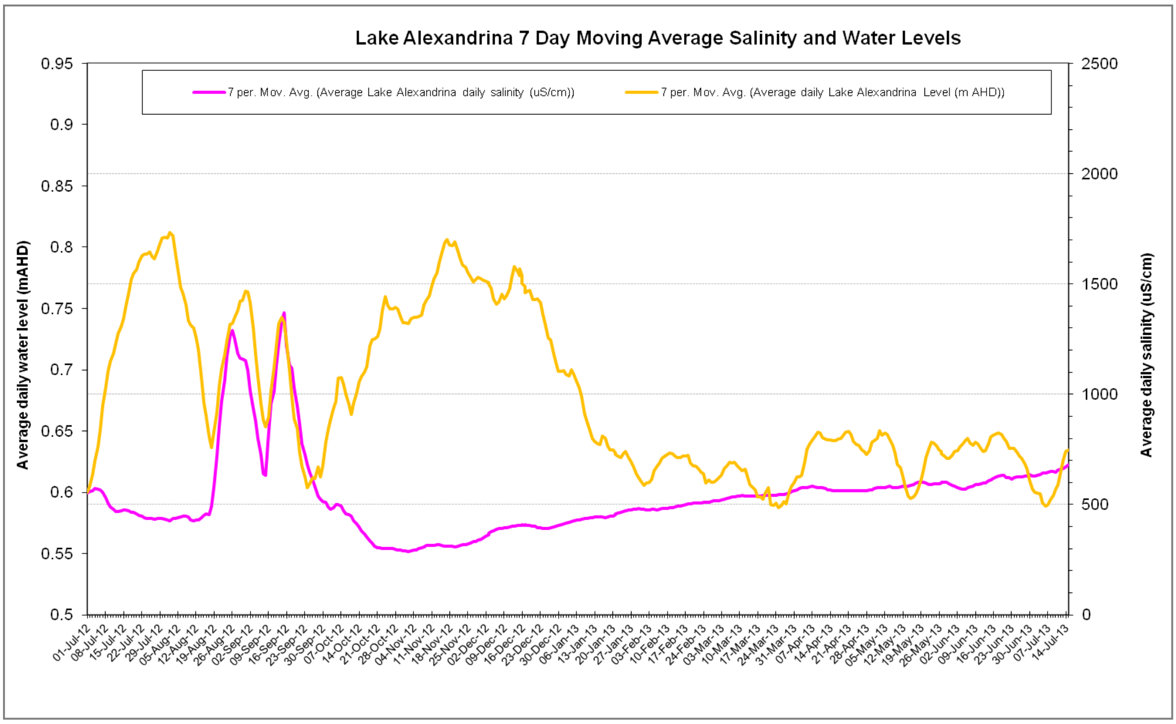

Figure 12 - Average salinity and water levels in Lake Alexandrina during 2012-13

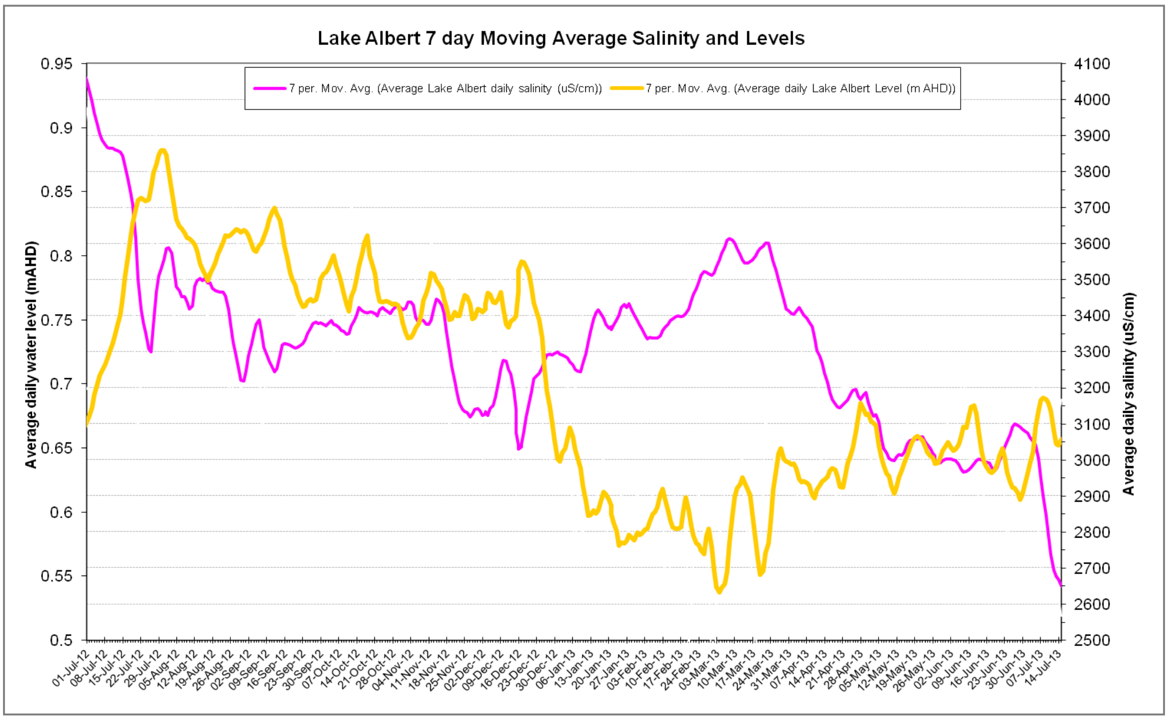

Figure 13 - Average salinity and water levels in Lake Albert during 2012-13

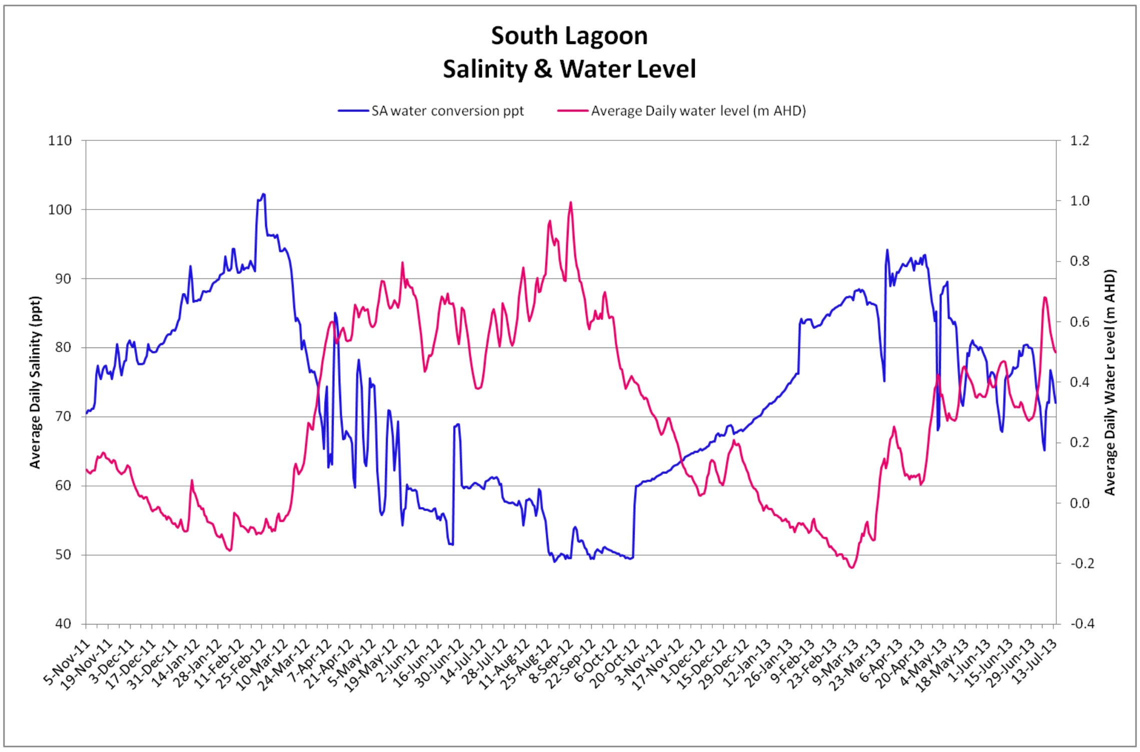

Figure 14 - Average salinity and water levels in the Coorong South Lagoon during 2012-13 (Salinity is measured in EC at telemetered sites and converted to ppt for analysis and comparison)

4.2 Ecological Monitoring

The following sections summarise the reports prepared by the respective service providers who undertook monitoring in the Coorong and Lower Lakes during 2012-13. The chapter is divided into the following sections: Fish Monitoring, Waterbird Monitoring, Vegetation Monitoring, and Invertebrate Monitoring. The relevant ecological targets from the Condition Monitoring Plan are presented for each study to establish the objective(s) of the monitoring undertaken. These targets are discussed in greater detail in Sections 4.4 and 4.5.

Presently, the LLCMM Condition Monitoring Plan (CMP) components do not have established baselines as monitoring under TLM program commenced during the drought. Instead, environmental and ecological monitoring results are typically compared to those documented in recent years and qualitatively describe a process of recovery, post-drought. At the time of writing, the LLCMM CMP was under review and service providers were in the process of developing revised quantitative targets, including relevant definitions and baselines for their respective components. The revised targets will allow statements to be made about whether there has been a change in Icon Site condition relative to the established baseline, and from year to year.

4.2.1 Fish Monitoring

<u>Coorong Fish Condition Monitoring 2012-13</u>

Ecological Targets:

F3 - Provide optimum conditions to improve recruitment success of small-mouthed hardyhead in the South Lagoon
F4 - Maintain or improve populations of black bream, greenback flounder and mulloway in the Coorong

Information presented below is obtained from the Condition Monitoring report "Coorong Fish Condition Monitoring 2008-2013: Black bream *(Acanthopagrus butcheri),* greenback flounder *(Rhombosolea tapirina*) and smallmouthed hardyhead *(Atherinosoma microstoma)* populations" (Ye, Q., Bucater, L., and Short, D. (2013)).

Small-mouthed hardyhead

Following the barrage releases from 2010-13 after a period of no inflow to the Coorong Estuary, there were significant increases in the recruitment, abundance and distribution of small-mouthed hardyhead populations. The overall abundance of small-mouthed hardyhead in 2012-13 remained similar to 2011-12. Spatiotemporal patterns varied between 2011-12 and 2012-13. The main spatial difference was attributed to significantly lower catch at Marks Point, the most northern site, than at southern sites in the Coorong. In 2012/13, there appeared to be a general reduction in catch in the North Lagoon, with an increase in the South Lagoon, when compared to 2011/12. In the North Lagoon, the presence of smaller fish (<39 mm) throughout the sampling months suggested recruitment success and a protracted spawning season. Although this species is highly salt tolerant, the elevated salinity levels experienced during 2008-09 and 2009-10 respectively, reduced its southerly distribution. In 2009-10 there were some improvements in abundance and recruitment, with a localised recovery in the southern end of the Coorong following small volumes of freshwater inflows from Salt Creek. Barrage releases and other sources of freshwater flows have decreased salinities further since 2010-11 which has led to a substantial increase in population abundance, distributional range and recruitment in the species, especially in the southern part of the Coorong.

There has been a general increase in recruitment of small-mouthed hardyhead in the Coorong since 2009-10. In particular, there was a substantial increase in the number of new recruits throughout an extensive area of the North and South Lagoons after significant flow events in 2010-11 and 2011-12. Seasonal reduction of salinity due to freshwater inflows is suggested to be a partial cue to spawning in small-mouthed hardyhead, while also providing sources of nutrients and organic matter to the Coorong. During 2012/13, the abundance of new recruits further increased in some South Lagoon sites. However, a general decline occurred in the North Lagoon, which may have been due to increased predation pressure given the increased abundance of piscivorous fish. Given that the small-mouthed hardyhead is a keystone species in the region, this possible predation is of particular ecological significance. Overall, the response of small-mouthed hardyhead to flows provides insight into population recovery when favourable conditions (i.e. salinity < 100 psu) are restored and shows the resilience of the population in the Coorong.

Black bream

Following significant barrage releases since 2010-11, there was an increase in annual commercial catch to 2.3 t and 3 t in 2010-11 and 2011-12, respectively, although those remained below the average of the previous ten years

($5.5 \ t \ y^{-1}$). In the last five years the highest catch has been between July and September with the peak monthly catch occurring in September. The barrage discharges in 2010-11 coincided with a southward range expansion into the North and South Lagoons compared to previous drought years and an increase in the proportional catch of black bream in the North Lagoon. Conversely, there had been no reported catches from the South Lagoon since 2001/02 until 2010/11.

Abundance of juvenile black bream exhibited a general decline from 2008-09 to 2011-12 and an increase in 2012-13. Despite the positive signs in the species following 2-3 years of high flows, it should be noted that the population level of black bream still remained low in the Coorong considering the substantial decline in abundance since the mid-1980s. Fish sampling in 2012-13 was subject to the effects of reduced sampling efficiency during high flows which may explain the low catches of juvenile black bream. A heavily truncated age structure of this long-lived species suggested reduced population resilience in the Coorong.

Greenback flounder

The relative abundance of juvenile greenback flounder varied greatly across sites and amongst years (2008-09 – 2012-13) in the Murray Estuary and Coorong. The presence of small juvenile flounder in each year indicated that recruitment has occurred annually in the Coorong over the study period and in the years post-flood (since 2010-11) and is likely influenced by freshwater flows to estuaries. The size distribution in January 2013 was dominated by larger fish compared to the preceding drought years. As this species spawns during autumn/winter before the typical high flow season, larval and juvenile growth may be enhanced by increased biological productivity (i.e. food availability) related to freshwater flows to estuaries, resulting in higher levels of recruitment success. Freshwater inflows also affect the Coorong salinity regime which in turn affects the reproductive biology of greenback flounder.

In summary, the 2012-13 monitoring showed that conditions resulted in the successful recruitment of small-mouthed hardyhead and therefore Target F-3 was achieved. However, black bream populations remained low in the Coorong and the age structure of the sample suggests reduced population resilience. This, combined with the dominance of larger fish in the Greenback flounder population means that Target F-4 was only partly achieved.

Small-bodied Threatened Fish Monitoring 2012-13

Ecological Target:

F2 - Maintain or improve recruitment success of endangered fish species in the Lower Lakes

Information presented below is obtained from the Condition Monitoring report "Condition Monitoring of Threatened Fish Species at Lake Alexandrina and Lake Albert (2012-2013)" (Wedderburn, S. and Barnes, T. (2013)).

Monitoring in November 2012 in the Lower Lakes recorded 5530 fish represented by 20 species. Alien fish constituted 24% of the total catch which in turn was comprised of carp (12% of total catch), redfin (7%), goldfish (3%) and Gambusia (3%). Common galaxias (32%), flathead gudgeon (10%) and lagoon goby (9%) were the most numerous of the native fishes. Notably, the diadromous congollis made up almost 6% of the total catch. In March 2013, monitoring at the same sites recorded 7514 fish represented by 24 species. The proportions of carp (2%) and goldfish (1%) in the total catch were substantially lower than in the November 2012 sampling. The proportions of both redfin and flathead gudgeon were similar in March whereas the proportion of common galaxias had declined and the proportion of Gambusia has increased. Overall, the number of fish captured in March 2013 was higher than in the March 2012 monitoring. Both the common galaxias and congollis had substantially higher abundances in March 2013 relative to previous years.

In 2012–13, all three threatened fish species were recorded for the first time since 2008. The Murray hardyhead population appears to be re-establishing as indicated by the capture of relatively high numbers in March 2013 compared to November 2012. It will remain unknown whether this is due entirely to natural means, or to the influences of re-stocking. There was strong evidence of recruitment of Murray hardyhead in the Finniss River and Goolwa Channel region but despite re-stocking efforts, it is yet to re-establish in habitat on Mundoo Island and Hindmarsh Island, and in Lake Albert, where it formerly occurred.

Southern pygmy perch and Yarra pygmy perch were captured in low numbers in November 2012 and March 2013. The low numbers and limited evidence of recruitment in southern pygmy perch and Yarra pygmy perch suggest unknown factors (e.g. predation, lack of prey) have hindered their population recovery. Fluorometer readings for Yarra pygmy perch showed they were mostly re-stocked fish, but a few are likely young-of-the-year. Similarly, most of the captured southern pygmy perch gave positive readings for calcein. Length-frequency distributions for all southern pygmy perch captured at the Lower Lakes during monitoring were too small to conclusively indicate the level of recruitment success in the Lower Lakes population. Similarly, the length-frequency distributions for all Yarra pygmy perch captured were from an extremely low number of fish, so limited conclusions could be drawn regarding the level of recruitment success.

Although all three threatened fish species were recorded for the first time since 2008 in the 2012-13 monitoring, the low numbers and limited evidence of recruitment in southern pygmy perch and Yarra pygmy perch mean that Target F-2 was only partly achieved.

Lamprey Intervention Monitoring at the Barrages

Ecological Target:

F1 - Maintain or improve recruitment success of diadromous fish in the Lower Lakes and Coorong

The usual spring/summer barrage fishway monitoring program was not funded in 2012-13, however, funding was secured for a winter lamprey monitoring program and the findings of this monitoring are summarised below.

Information presented below is obtained from the Intervention Monitoring report "Monitoring Upstream Movement of Lamprey at the Murray Barrages in Winter 2013" (Bice, C.M. and Zampatti, B.P., (2013)).

The main focus of the study was to capture lampreys (pouched and short-headed) migrating upstream through the fishways as they seek freshwater environments to complete their lifecycle. Both species are native to the Murray–Darling Basin, yet are quite rare and limited knowledge exists about their behaviours. Previous studies undertaken by Bice *et al*. (2012) in 2006, recorded moderate numbers (40 individuals) of adult short-headed lamprey and a single adult pouched lamprey migrating upstream through the barrages between September and November 2006 during low freshwater discharge. However, in subsequent sampling efforts between March 2007 and 2011, when freshwater discharge continued at very low levels, no adult lampreys were recorded. In a further sampling effort between July and November 2011, when freshwater flow returned in high volumes, low numbers (9 individuals) of pouched lampreys and a single short-headed lamprey were caught. Six individuals were implanted with passive integrated transponder (PIT) tags and one of these individuals was then detected migrating through the vertical-slot fishway at Lock and Weir 1 in October 2011.

The objective of the 2012-13 study was to further investigate the upstream migration of both pouched and short-headed lamprey at the Murray barrages. The fishways were used as the sampling tool and surgically implanted PIT tags allowed further detection of individuals as they migrated upstream in the lower River Murray. Knowledge of general fish movement at the Murray barrages in winter is poor, with previous investigations predominantly focusing on monitoring in spring and early autumn (Zampatti *et al*. 2010, Bice *et al.* 2012, Zampatti *et al.* 2012).

Monitoring for 2012-13 was undertaken over a two week period (24 June to 5 July 2013) and was targeted at three vertical slot-fishways on the following barrages; Tauwitchere Barrage (small vertical-slot fishway), Goolwa Barrage (large vertical-slot fishway) and Hunters Creek (small vertical-slot fishway). A total of two adult pouched lamprey were sampled from the Goolwa vertical-slot, but no short-headed lamprey were sampled. Common galaxias and Australian smelt were the two most abundant fish species sampled. Common galaxias were captured at each fishway but were most abundant at Hunters Creek, whilst Australian smelt were only sampled at Tauwitchere and Goolwa, and were equally abundant at both locations. Based on size and body condition, the vast majority of common galaxias sampled were adult fish in spawning or post-spawning condition.

As a result of this monitoring, the following observations were made:

- Pouched lamprey were sampled in low abundance, whilst short-headed lamprey were absent from the catch. Sampling over a greater temporal period is needed to determine the extent of the migration period for pouched and short-headed lamprey at the Murray barrages.

- Pouched lamprey were implanted with PIT tags so movements through the Murray Fishways may be detected in the future, providing information on upstream migration in the River Murray.

- Substantial numbers of adult common galaxias were collected at all fishways and appeared to be in reproductive condition. Upstream migrating juvenile common galaxias captured during spring/summer at the Murray Barrage fishways have been shown to be derived, in part, from spawning activity in June/July.

The 2012-13 monitoring project has provided significant new information on fish movement at the Murray barrage fishways during winter. Based on the data collected, Target F-1 was partly achieved. This study compliments data on fish movement at the Murray barrages during spring-summer, which was collected from 2006–2012 (Bice *et al.* 2012). Together these data highlight seasonal variation in fish movement and support the year round release of freshwater through the Murray barrages to facilitate movement.

4.2.2 Waterbird Monitoring

<u>Coorong and Lower Lakes Bird Census Monitoring in 2013</u>

Ecological Target:

B1 - Maintain or improve bird populations in the Lower Lakes, Coorong and Murray Mouth

Information presented below is obtained from the Condition Monitoring report "Condition Monitoring of the Lower Lakes, Coorong and Murray Mouth Icon Site: Waterbirds 2013" (Paton, DC, Bailey, CP. 2013a)

As discussed above, variable salinity has influenced the distributions and abundances of aquatic organisms that provide food resources for birds throughout the Lower Lakes and Coorong. Therefore, many of the bird populations within the Coorong and Lower Lakes were variable in 2012-13, with some species increasing in abundance, others decreasing, and some comparable to recent years.

The waterbird census in the Coorong over 2012-13 was undertaken during the period 9 – 17 January 2013 and monitoring around the shores of the Lower Lakes occurred between the 16 January – 5 February 2013. Counts of birds were recorded via transects along with their general behaviour (e.g. foraging, roosting, flying and nesting). The addition of behavioural data is very important as it provides an indication of the effort or time a species needs to allocate for foraging. Low percentage scores for foraging indicate that the species were either foraging on rich food sources or were foraging at other locations. In comparison, those species with high percentages of foraging behaviour indicate that the species has to spend significant amounts of time to harvest adequate food. This suggests that food resources and the quality of the habitat are poor.

A total of 283,000 waterbirds were recorded during a fixed area search in both the Coorong and Lower lakes in 2012-13 with the Coorong supporting twice as many birds compared to the Lower Lakes. Over 186,000 waterbirds from 66 species were recorded in the Coorong in January 2013. The Australian Shelduck (*Tadorna tadornoides*), Grey Teal (*Anas gracilis*), Eurasian Coot (*Fulica atra*), Red-necked Stint (*Calidris ruficollis*) and Sharp-tailed Sandpiper (*Calidris acuminata*) were all present in abundances that exceeded 10,000 individuals. These species accounted for over 65% of the birds that were counted. Four other species were present in abundances exceeding 5,000 individuals: (Chestnut Teal (*Anas castanea*), Australian Pelican (*Pelecanus conspicillatus*), Whiskered Tern (*Chlidonias hybridus*) and Silver Gull (*Chroicocephalus novaehollandiae*). The North Lagoon had nearly 93,000 waterbirds present in January 2013, compared with a little over 50,000 recorded in the Coorong Estuary and a little over 45,000 recorded in the South Lagoon.

Nearly 98,000 waterbirds (60 species) were counted using the Lower Lakes in January 2013. Seven species accounted for over 70% of the birds that were counted. For three species more than 10,000 individuals were counted in the Lower Lakes in January 2013: Australian Shelduck, Great Cormorant (*Phalacrocorax carbo*) and Pied Cormorant (*P. varius*). More than 5,000 Grey Teal, Australian Pelican, Whiskered Tern and Eurasian Coot were also present for each species. Over 59,000 birds were counted at Lake Alexandrina compared to nearly 28,000 for Lake Albert and over 10,000 for the Goolwa Channel.

The bird communities between the Lower Lakes and Coorong were very different with 19 species of the total 73 recorded found primarily in the freshwater of the Lower Lakes compared with 29 species found primarily in the saline wetlands of the Coorong. A further 25 species were recorded using both wetlands. Changes in the abundances of various waterbirds in the Coorong over the last two years have shown some dramatic increases for some species, for example Grey Teal (7,688), Black Swan (1,799), Caspian Tern (1,384), Eastern Great Egret (*Egretta alba)* (394), and Australian Pelican (5,566). A range of shorebirds including Red-necked Avocet (*Recurvirostra novaehollandiae*) (8), Red-capped Plover (1), Red-necked Stint (80) and Sharp-tailed Sandpipers (297) have also increased over the last three years from the low abundances recorded in January 2011 when high water levels excluded many shorebirds from the Coorong. However, four species; Common Greenshank (*Tringa nebularia*), Fairy Tern, Pied Oystercatcher (*Haematopus longirostris*) and Black-winged Stilt have not shown any substantial increase in abundance and distribution over the last three years. In January 2013 only 86 Pied Oystercatchers were detected in the Coorong, the first time in 14 years that fewer than 100 individuals were detected. In addition, none of these birds were breeding. The numbers of Fairy Terns also dropped from the previous year despite successful breeding in 2012. The numbers of this species recorded in recent years remain well below the numbers recorded in 2000-2001 when more than 600 individuals were counted. For Common Greenshanks more than 400 individuals were counted in each year from 2000-2010, but for the last three years this species has remained in numbers below 200. This species feeds predominantly on small fish caught in shallow water around the edges of the Coorong. The decline in abundance for Common Greenshanks was substantial in 2011 and appears to be linked to the extremely high water levels that established in both the Coorong and the Lower Lakes in that year.

One of the striking patterns in the abundances of waterbirds within the region has been the low numbers of many species of birds using the Coorong and Lower Lakes in 2011. Although many of these birds may have moved to other inland flooded wetlands in response to widespread rains during 2010, the lack of suitable shallow wetland areas around the margins of both the Coorong and the Lower Lakes in 2011 may have also contributed. These high water levels would have excluded many shorebirds and waders that rely on mudflats covered by shallow water for foraging. Two years on from 2011, the expectation would be that the majority of species would have increased in abundance and distribution in both the Lower Lakes and Coorong. The majority, but not all, species have shown a steady increase since 2011.

In general the fish-eating species (pelicans, most cormorants, several terns, egrets) have increased over the last five years. However, two of the fish-eating bird species selected for condition monitoring have not shown any substantial recovery: the Fairy Tern and Common Greenshank. The abundances of migratory waders (Curlew Sandpiper, Sharp-tailed Sandpiper and Red-necked Stint) have also increased since 2011, but have not yet reached pre-2011 abundances. A similar pattern has been detected for resident shorebirds such as the Red-capped Plover, Black-winged Stilt and Masked Lapwing. In recent years their abundances have been increasing but they are still to reach pre-2011 abundances. In contrast, the numbers of Red-necked Avocets have increased steadily over the last 5 years, while Banded Stilts were in low abundances in January 2013.

Responses of Waterbirds to Environmental Change (Monthly Fixed-Site Waterbird Monitoring)

Ecological Target:

B1 - Maintain or improve bird populations in the Lower Lakes, Coorong and Murray Mouth

Information presented below is obtained from the DEWNR Technical report "Response of Waterbirds to Environmental Change in the Lower Lakes, Coorong and Murray Mouth Icon Site" (O'Connor, JA and Rogers, DJ 2013). The data that has been analysed for this report has been collected on a monthly basis at fixed sites in the Lower Lakes and Coorong by Coorong Nature Tours (David Dadd).

Patterns of reporting rate and relative abundance of selected species have shown some general patterns of waterbird recovery in 2012/13. However, some species have continued to decline or persist in small numbers within the site or particular subregion. Species such as the Australian Pelican, Chestnut Teal, Red-necked Avocet and Banded Stilt have responded positively to the return of water flows, and are now recorded at rates and relative abundances comparable to those observed pre-drought.

Australian Pelicans were reported in declining numbers during the drought period but have been reported in increasing, and now stable (up to May 2013) numbers throughout the LLCMM since the return of water flows. Fairy Terns have been reported in relatively stable numbers in the Murray Estuary and Coorong South Lagoon since 2010. Recent declining numbers are a function of shifting ecological conditions, most notably, the distribution of their key food source (small-mouthed hardyhead). Although the reporting rate of the Common Greenshank in the Coorong Lagoons and Murray Estuary has increased post-drought, abundances are still very low compared to pre-drought.

In the Lakes and Coorong subregions, the reporting rate for Black Swans declined between 2001-2009 when the water levels were low. Since then, population trends have differed between regions and a recent positive trend in Black Swan reporting rate has been recorded in the Coorong South Lagoon. This was unexpected given the depleted nature of their key food source, *Ruppia tuberosa* in the Lagoon. However, a previous study by Paton and Bailey (2012) noted that few Black Swans were using the area for foraging. In contrast to the previous 3 years, the 2012/13 monitoring showed a decline in Black Swan abundances in the Murray Estuary and Coorong North Lagoon. Chestnut Teal continue to be reported at relatively stable rates across the Coorong and Lakes subregions.

The reporting rate of the four most widespread shorebird species (Curlew Sandpiper, Red-necked Stint, Sharp-tailed Sandpiper and Red-capped plover) showed a general decline in the Coorong from 2001-2009. Despite the return of water, a corresponding recovery in shorebird populations did not begin until 2011. All four species have since shown consistent increases in reporting rate in the Coorong and now appear to be approaching pre-drought levels. Conversely, the reporting rate of shorebirds in the Lakes region has decreased now that water flows have returned to pre-drought levels and the availability of mudflats for foraging has declined. The Sanderling has only ever been recorded in the Murray Estuary subregion and continues to be recorded at very low rates. None were recorded between 2010-2012.

Two of the three species of large endemic wader (Red-necked Avocet and Banded Stilt) selected for reporting showed consistent patterns of interannual change in reporting rate. Owing to a preference for saline environments, the species were infrequently recorded in the (usually freshwater) Lakes. For this reason, both species were more frequently reported in the hypersaline South Lagoon. The Banded Stilt were one of the only LLCMM waterbird species to be reported at higher rates during the peak of the drought, which may reflect an increased tolerance to hypersaline conditions, and in turn food sources with high salt content. Both the Red-necked Avocet and Banded Stilt have continued to be recorded at increasing rates in all subregions of the Coorong following the recovery of water levels to the wetlands. It should be noted that species such as these will respond to changes in habitat availability at a regional or national scale and therefore relative abundances may reflect comparatively better conditions elsewhere rather than ‘poor’ conditions in the LLCMM region. The Australian Pied Oystercatcher was reported in relatively stable rates across the entire period, with a sudden decline and recovery between 2010 and 2013. The return of water flows reduced the availability of marine mudflat habitats which the species relies on.

In summary, waterbird populations improved in both the Lower Lakes and the Coorong in 2012-13 with few species experiencing declines. Notably, a number of species recorded dramatic increases in abundances which contributed to the achievement of Target B-1.

4.2.3 Vegetation Monitoring

Lower Lakes Vegetation Condition Monitoring 2012-13

Ecological Target:

V3 - Maintain or improve aquatic and littoral vegetation in the Lower Lakes

Information presented below is obtained from the Condition Monitoring report "Lower Lakes Vegetation Condition Monitoring 2012-13" (Frahn, K.A., Gehrig, S. L., Nicol, J.M., and Marsland K.B. 2013).

During 2012-13, water level management in the Lower Lakes involved two drawdown and refilling cycles (between +0.6 and +0.8 m AHD) with the aim to reduce salinity in Lake Albert. The managed water level fluctuations in the Lower Lakes periodically exposed the fringes of lakeshores and wetlands, which provided opportunities for species requiring exposure to germinate (e.g. *Persicaria lapathifolia, Ludwigia peploides, Juncus* spp.) (Nicol, 2004). However, in the Lower Lakes there is limited opportunity for recruitment of species that require exposure to germinate due to most fringing areas being densely vegetated with emergent species such as *Typha domingensis* or *Phragmites australis*. Generally, shorelines that are not densely vegetated are subjected to wave action which can prevent seedlings from establishing (e.g. Foote and Kadlec, 1988). Nevertheless, water level fluctuations between +0.8 and +0.4 m AHD are recommended because areas of submergent vegetation are then maintained, the establishment of amphibious taxa in areas protected from wave action is facilitated (e.g. shorelines planted with *Schoenoplectus validus*), and salinity in Lake Albert is reduced.

During the monitoring period (spring 2012 to autumn 2013) water levels and salinity in Lake Alexandrina, the Goolwa Channel, the lower Finniss River and lower Currency Creek remained similar to the previous monitoring year. Salinity levels had also decreased in Lake Albert but not to the extent that it significantly affected any plant species.

Monitoring undertaken in 2012-13 is a continuation of data collected between 2008 and 2012 and provides information regarding the change in plant communities over this time. During the survey period the Lower Lakes has been subjected to a period of low water levels in Lake Alexandrina, several engineering interventions (e.g. Clayton and Currency Creek regulators), periods of unregulated flow, two in channel flow pulses, and entitlement flows. This monitoring program therefore aims to collect information regarding the change in wetland plant communities in response to drawdown, desiccation, and increased water levels due to regulated watering and natural flooding events. It further aims to quantify the understorey aquatic and littoral vegetation in the Lower Lakes to ascertain if plant species have maintained or improved in condition since monitoring began in 2008. Monitoring of understorey vegetation was conducted at 11 wetland and 25 lakeshore sites in spring and autumn from October 2008 to March 2013 (for sites established in 2008 or earlier) and every spring and autumn from October 2009 to March 2013 (for sites established in 2009). A total of 127 taxa consisting of 62 exotics (including two weeds of national significance, seven South Australian listed pest plants and one species listed as rare in SA) were recorded for all wetland sites between spring 2008 and autumn 2013. In all the wetlands changes in floristic composition through time were not consistent between elevations.

A total of 106 taxa consisting of 63 exotics (including one weed of national significance, three South Australian listed pest plants and one species listed as rare in SA) were recorded at shoreline sites in Lake Alexandrina, Lake Albert and the Goolwa Channel (including Finniss River and Currency Creek) from spring 2008 to autumn 2013. Lake

Alexandrina had the highest species richness (87 taxa across 10 sites) followed by Goolwa Channel (70 taxa across 10 sites) with Lake Albert exhibiting the lowest species richness (58 taxa across 5 sites). Lake Albert had the highest proportion of exotics (58.62%) compared to Lake Alexandrina (49.54%) and Goolwa Channel (42.85%).

In each location the plant community changed through time, varied over elevation, and there was a significant interaction between the two factors. Furthermore, the species (and hydrological processes) that caused the changes differed between locations.

Whilst there has been a significant increase in the abundance of submergent, amphibious, floating and emergent species since water levels returned to historical levels (average of 0.75 m AHD), the abundances of species from these functional groups is now likely much lower than in 2004 (Holt *et al.* 2005) or 2005 (Nicol *et al.* 2006). For example, the diverse submergent plant communities that covered extensive areas in Clayton Bay, Dunn's Lagoon, Narrung, Milang (Holt *et al.* 2005), Loveday Bay, Hunters Creek, Point Sturt and Poltalloch (Nicol *et al.* 2006) had not re-established by autumn 2013. In addition, extensive areas of *Myriophyllum salsugineum* were present upstream of the Hindmarsh Island Bridge in shallow areas of Goolwa Channel prior to the drawdown of lake levels (Nicol, pers. obs.) but were not present in autumn 2012. Furthermore, two species (*Lepilaena cylindrocarpa* and *Ranunculus trichoplyllus*) recorded in the 2004 (Holt *et al.* 2005) and 2005 (Nicol *et al.* 2006) baseline surveys were not present in wetlands or lakeshores. However, extensive beds (468 ha) of *Myriophyllum salsugineum* had established in the lower Finniss River and lower Currency Creek, and the emergent plant community throughout Lake Alexandrina and Goolwa Channel showed signs of improved condition after water levels were reinstated. These plant communities were present throughout 2011-12 and whilst not measured directly likely increased in extent, albeit not to the level observed before the drought.

All but two plant species (*Ranunculus trichoplyllus* and *Lepilaena cylindrocarpa*) of the 46 species recorded in 2004 and 2005, lost when water levels decreased, were recorded in the spring 2010 or autumn 2011 survey and were present in 2012-13. Results showed that the plant community shifted from being dominated by terrestrial taxa to submergent, emergent, floating and amphibious taxa. Finally, most aquatic species are capable of rapid colonisation by asexual reproduction once mature (Grace 1993); and despite Target V-3 not being achieved in 2012-13, it is likely that aquatic taxa will continue to increase in abundance providing water levels remain at current levels.

Ruppia tuberosa Intervention Monitoring in the Coorong South Lagoon 2012-13

Ecological Target:

V2 - Maintain or improve *Ruppia tuberosa* colonisation and reproduction

Information presented below is obtained from the Intervention Monitoring Report "Response of Ruppia tuberosa in the Coorong South Lagoon to Environmental Water Delivery over Summer 2012-13" (Paton, D.C & Bailey, C.P. (2013b)).

Since the return of freshwater flows to the LLCMM region in spring 2010, there has been little if any recovery of *Ruppia tuberosa* in the South Lagoon (Paton & Bailey 2012, 2013c). The extensive beds that had gradually established in the North Lagoon between 2006 and 2010 were also quickly lost, resulting in *Ruppia tuberosa* becoming less abundant following the return of freshwater flows to the Murray Mouth, than immediately prior to the end of the drought. There has been no improvement since (Paton & Bailey 2013c). Two factors have contributed to this poor recovery. Firstly, the quantities of propagules (seeds) remaining in the sediments are extremely low and on their own, unlikely to facilitate the rapid recovery of *Ruppia tuberosa* throughout most of the South Lagoon (Paton & Bailey 2012, 2013c). Secondly, although flows returned to the LLCMM region in spring 2010, the following two years brought diminished flows particularly in spring, resulting in water levels once again falling at critical times. This intervention monitoring project aimed to monitor the influence of additional releases of water over the barrages on the remnant populations of *Ruppia tuberosa* in the southern Coorong. The majority of the water was released over the Tauwitcherie Barrage to push water down to the South Lagoon to extend the period of time that remnant *Ruppia tuberosa* beds were covered with water with the aim that this would allow them to complete their reproductive cycle.

Based on historical and on-going monitoring most of the beds of *Ruppia tuberosa* are found on mudflats at elevations of around -0.2 m AHD to 0.2 m AHD in the southern Coorong. This elevation range can be used to provide an estimate of the water levels needed through spring to allow the plants to reproduce. *Ruppia tuberosa* is sensitive to desiccation and because wind-induced changes in water level in the Coorong are around 0.3 m, water levels over these beds need to be at least 0.3 m. This equates to having a water level of at least 0.5 m AHD if all of the beds are to be adequately covered with water. Water levels over the beds should also not exceed 0.9 m, as *Ruppia tuberosa* generally does not grow in water deeper than about 0.9 m in the Coorong because the high turbidity of the water reduces light penetration to the sediment bed (Paton & Bailey 2010). Thus the maintenance of water levels at around 0.5-0.7 m AHD provides the ideal depths for the existing beds of *Ruppia tuberosa* to flourish. This provides a basis to assess the effectiveness of supplementing flows with environmental water. If water levels drop below 0.5 m AHD, then some of the higher elevation areas of the *Ruppia tuberosa* beds risk periodic exposure. If the water levels drop below 0.1 m AHD then most of the lower elevation areas of the beds also risk exposure. Given this, the use of environmental water to maintain water levels at 0 - 0.2 m AHD in 2012-13 is only likely to protect *Ruppia tuberosa* growing at lower elevations.

In November and December 2012 when water levels were in the range of 0.0 – 0.2 m AHD, the high elevation components of the *Ruppia tuberosa* beds were exposed to desiccation, and only plants growing at lower elevations were covered with adequate water. There was no evidence of successful flowering at these higher elevation sites. There were, however, occasional snapped floral stalks likely a result of interference from filamentous green algae. The exposed *Ruppia* beds, however, had succeeded in producing type II turions prior to being exposed and where those desiccated plants existed, there were average numbers of type II turions of 24, 27 and 22 per core at Magrath Flat, Parnka Point and Villa dei Yumpa, respectively. However, these type II turions once exposed have a short life span.

For the mud flats that were still covered with water, there were *Ruppia tuberosa* plants primarily in the shallower depths but many of the shoots covered by less than 30 cm of water were browning as a result of exposure to the air or high temperatures. There were no flower-heads associated with these plants but there were some type II turions being produced. The differences between sites in terms of percentage of cores with *Ruppi*a was consistent with the Villa dei Yumpa site having higher cover in winter (Paton & Bailey 2013b). In December, the water levels had dropped further to around 0 m AHD so additional areas of *Ruppia tuberosa* were exposed. There were, however, plants present (in low numbers) at lower elevations that were still covered in water, that without the allocation of environmental water would have been exposed to desiccation from November onwards. Thus the allocation of environmental water had some benefit in allowing low elevation *Ruppia tuberosa* to survive, grow and potentially reproduce in late spring and early summer. However, with low cover and subsequent drops in water level in early January, little or no subsequent successful reproduction was detected. The only site where *Ruppia tuberosa* performed well was at Gemini Downs Bay where water levels did not drop to the same extent as in other areas of the Coorong. This was due to the presence of a sand bar disconnecting the bay from the rest of the Coorong which prevented the same rapid decline of water levels in spring. In this location *Ruppia tuberosa* was still covered with 20-30cm of water. The small population was sampled in January 2013 which indicated that plants had flowered in spring and there were at least 3 seeds per core found in sediments in areas still covered with water. All core samples taken at the site revealed shoots, seeds and type II turions and hundreds of waterfowl were recorded foraging over these beds.

Overall *Ruppia tuberosa* failed to complete its lifecycle and produce an adequate seed bank and Target V-2 was not achieved in 2012-13. This is comparable with previous years and therefore the survival of the species remains precarious. Observations from this monitoring indicate that to protect the full extent of the *Ruppia tuberosa* beds, water levels in the South Lagoon need to be maintained during late spring and early summer at a higher level, ideally around 0.5 m AHD. Based on flows over the barrages in 2012-13, the volume required is probably around 30,000 ML/day. This is equivalent to about a 1,000 GL of water being released over the barrages per month and compares with around 300 GL of environmental water being allocated over three months in 2012-13.

4.2.4 Invertebrate Monitoring

<u>Macrobenthic Invertebrate Condition Monitoring 2012-13</u>

Ecological Targets:

I1 - Maintain or improve invertebrate populations in mudflats (both exposed and submerged);
M1 - Facilitate frequent changes in exposure and submergence of mudflats;
M2 - Maintain sediment size range in mudflats; and
M3 - Maintain organic content for mudflats.
W1 - Establish and maintain variable salinity regime with >30% of area below sea water salinity concentration in the Murray Mouth Estuary and North Lagoon.

Information presented below is obtained from the Condition Monitoring report "Benthic Macroinvertebrate Survey 2012-13: Lower Lakes, Coorong and Murray Mouth Icon Site" (Dittmann, S., Ramsdale, T., Navong, N., Cummings, C., Baggalley, S. and Keuning, J. 2013)).

Benthic macroinvertebrates have been monitored under TLM since 2004. During this time changes in environmental condition have been extremely variable and comparisons to a reference state are difficult given the lack of quantitative historical data. To assess whether condition monitoring objectives and targets have been met for the LLCMM, the monitoring data has been categorised into three periods, each characterised by different flow conditions: 2004-2006 no to small flow, 2007-2009 extreme drought without barrage releases, and 2010-2012 return of flow which commenced in spring 2010. The analysis of monitoring data has also been separated into two regional areas – Murray Mouth and Coorong, and Goolwa Channel and Lower Lakes.

The Murray Mouth and Coorong continued to be characterised by a salinity gradient during the 2012-13 survey which recorded fresh to brackish water in the Murray Mouth and northern reaches of the Coorong North Lagoon leading into marine and hypersaline conditions into the Coorong South Lagoon. Environmental water was delivered to the icon site after the unregulated flow event ceased on 27 October 2012. However, the rate of recession from the flow event was steep (50,000 ML/d down to 20,000 ML/d) at the SA border, resulting in a reduction in barrage releases over late spring and summer.

Water levels in the Murray Mouth were lower in the 2012-13 survey compared to the previous year, exposing mudflats both in the Murray Mouth and Coorong. In the Coorong North Lagoon, the area of mudflats were narrower with 1-10 m of sediments exposed from the shore. Water levels in the North Lagoon were much more variable as they are subject to inflow of water from barrages along with wind and tidal influences. In the Lower Lakes, water levels had receded in January to below 0.65m AHD, but no sediments were exposed. Environmental conditions at all study sites around the Lower Lakes, Coorong and Murray Mouth were favourable and showed an improvement compared to previous years. While the gradient from brackish conditions in the Murray Mouth to hypersaline conditions in the Coorong continued, salinities were the lowest throughout the system since monitoring started in 2004. Salinities at sites around the Lower Lakes were also lower compared to the previous five years of monitoring. Dissolved oxygen was still below the ANZECC guidelines trigger value at several sites. Grain size compositions and organic matter content in the sediments has remained unchanged over the years. However, microphytobenthic biomass (indicated by chlorophyll – a) was higher than during the previous two years at sites in the Murray Mouth, Coorong North Lagoon and around the Lower Lakes.

Observations over consecutive sampling days did indicate a higher frequency of submergence and emergence of mudflats in the Murray Mouth and northern reaches of the Coorong North Lagoon which provided accessible foraging ground and adequate prey for shorebirds. Some sites in the Murray Mouth (Hunters Creek, Ewe Island and Pelican Point) had a higher proportion of finer particles. The samples from Pelican Point indicated muddier sediments than in previous years, yet the site was fairly sandy in the North Lagoon. Sediments at Mulbin and Yerrok were much coarser than previously observed. It is worth noting that some variation in grain size can occur given that sampling at the exact same location is not always possible given water levels changes, sediment movements, silting or erosion. While some of these variations are apparent in a multivariate analysis of grain size compositions across all sites and years, the sediment size remained predominantly fine to medium in size.

The continued river flow since spring 2010 led to an increase in the water level, thus inundating the large areas of mudflats which had been exposed when the water level had dropped far below sea level. While water level and salinity data revealed short term fluctuations in recent years as well (monthly or seasonal, also subject to water management measures), the sediments around the lake shores have remained permanently submerged since spring 2010 and are not accessible as foraging habitat for waders. However, the submergence will allow re-colonisation of sediments by aquatic invertebrates.

Sediments were primarily classed as fine sands, and were only coarser around the central region of Lake Alexandrina, at Milang (site L4), Poltalloch (site L5), Narrung (site L9) and Loveday (site L11), which was also noted in the field. Sediment at sites in Lake Albert (Seacombes (site L13), Waltowa (site L8) and Vanderbrink (site L12)) as well as Boggy Lake (site L18) and Clayton (site L2) had a higher contribution of clay and mud in the sediment than other sites, but most sediments were classified as fine or very fine sand and well to moderately well sorted. Differences in sediment were also site-specific.

A multivariate analysis of changes in grain size composition over the years indicated some shift between years, although no significant differences were detected. When water levels were low (2008 and 2009), sediments were mainly medium to coarse sand, becoming finer as the lakes refilled with water. Median grain sizes of sediments varied little over the years at sites in Goolwa Channel and closer to the barrages, while greater variation occurred near Lake Albert (sites L13, L8 and L12) and at Narrung (site L9). The coarse sediment encountered at Loveday (site L11) and Milang (site L4) could be due to some variation in location of sampling sites compared to previous years as dictated by water level changes and access to sampling sites.

The sediment organic matter content was low (average of 0.7 ± 0.1 % dry weight) for most of the lake sites, with outliers of >5 % dry weight at Clayton (site L2) and Waltowa, causing significant differences between sites. However, in the longer term comparison of sediment organic matter in the lake sediments, the values were within the range, or at the lower end of, sediment organic matter determined in previous monitoring years. Given the frequent outliers and high level of variation, further analysis into small scale patchiness and biogeochemistry is needed to determine whether these are artefacts or true patterns. The pollution indicator species *Capitella capitata* had contracted its distribution and was not found in the Murray Mouth, but is extending its occurrence into the South Lagoon. *Australonereis ehlersi* shifted into the North Lagoon, whereas the other nereidid species, *Simplisetia equisetis,* became more abundant in the Murray Mouth. The environmental results presented above confirm that Targets M1-M3 were all achieved, as was Target W-1 which resulted in the key macroinvertebrate species being more widely distributed in the 2012-13 monitoring survey.

Field sampling of benthic macroinvertebrates was undertaken during the period of late November 2012 to January 2013 when water levels were still relatively high in both the Lower Lakes and Coorong. Some larger mudflat areas were exposed and samples were taken using hand held corers. Where water levels were high, an Ekman grab was used. Both methods applied were the same as in previous years with the exception of five sites being discontinued in the Lower Lakes to allow more in-depth sampling at remaining sites. Apart from this change, the methodology has remained intact and in accordance with the LLCMM Icon Site Condition Monitoring Plan (Maunsell, 2009).

Most of the key macroinvertebrate species were more widely distributed in the 2012-13 monitoring survey compared to previous years; a direct result of increased flows and inundation of mudflats. Since the drought and subsequent compaction of their distribution range, macroinvertebrates are now spreading again throughout the area. Diversity has continued to increase at sites in the Murray Mouth and Coorong North Lagoon especially at Pelican Point and Mark Point, and the highest species diversity was recorded between Monument Road and Noonameena. Diversity continued to remain low at Parnka Point and at sites in the Coorong South Lagoon.

Abundances and biomass were either comparable or higher than in previous monitoring years at most sites in the Murray Mouth and Coorong North Lagoon but not in the Coorong South Lagoon. Therefore Target I-1 was only partly achieved. The majority of benthic macroinvertebrates were recorded in the surface sediment layer providing an accessible food source for short-billed waders. In the Murray Mouth, larger polychaete worms occurred in deeper sediment layers and were recorded in high abundance and biomass, providing prey for shorebirds with longer beaks. Molluscs were rarely recorded during this monitoring.

Macroinvertebrate communities in the Murray Mouth, Coorong North and South Lagoons continued to be distinct from one another with salinity, sediment organic matter, and Chorophyll-a contributing to this differentiation. Environmental change between drought and return flow years has directly contributed to the difference in macroinvertebrate communities (diversity, abundance and biomass) of each region. Communities have not yet fully returned to those present pre-drought.

In the Lower Lakes, species diversity of benthic macroinvertebrates has increased compared to the previous year, with the exception of the following sites: Milang, Tolderol, Poltalloch and Narrung which are located around the central reaches of Lake Alexandrina. These four sites had coarser sediment with low organic matter content and recorded very low abundances and biomass. The macroinvertebrate communities were distinct from all other sites in the Lower Lakes and Amphipods, chironomid larvae and oligochaetes were the most abundant. Sites in the lower reaches of Lake Alexandrina and Boggy Lake had higher abundances and biomass of macroinvertebrates compared to the previous two years of monitoring. Site specific variability was high at the sampling sites yet no regional differentiation in diversity, abundances or biomass could be detected.

Dip net sampling obtained a high diversity and abundance of aquatic macroinvertebrates in the Lower Lakes, including at the sites which recorded low abundances of macroinvertebrates in the sediment. Amphipods, freshwater shrimp, chironomids and various larval or adult insect taxa were abundant and distinct between Lake Albert and Lake Alexandrina. Macroinvertebrate recovery became apparent in the 2011-12 monitoring and has continued through to the 2012-13 monitoring, particularly in the Murray Mouth and Coorong North Lagoon. A return to a possible reference (i.e. pre-drought) condition has not yet been achieved, indicating that recovery after a prolonged drought period takes several years.

4.3 Achievement of Long-Term Environmental Water Requirements and Objectives

The following tables (Table 5 and Table 6) confirm that all long-term environmental water requirements for the LLCMM icon site were achieved in 2012-13. Similarly, all annual environmental watering objectives for the LLCMM icon site were achieved in 2012-13 with the exception of the reduction of salinity levels in Lake Albert below 2,000 EC. As reported above, average salinity in Lake Albert remained around 3,400 EC until March 2013, after which salinity dropped to around 2,800 EC by the end of June 2013. Salinity in Lake Albert is a function of QSA and the corresponding lake levels.

Table 5 - Achievement of long-term environmental water requirements for the LLCMM Icon Site in 2012-13

Environmental Water Requirement	Achieved	Not Achieved
Maintain lake levels above 0 m AHD to prevent ASS exposure	✓	
Maintain lake levels within a seasonal operating envelope (0.35 – 0.8 m AHD)	✓	
Ensure fishways are operated year-round	✓	
Ensure attractant flow is maintained to support fishways	✓	
Maintain Lake Alexandrina salinity <1000 EC for 95% of all years as part of a three year rolling average	✓	
Maintain Lake Alexandrina salinity <1500 EC for all years	✓	
Maintain flows to keep the Murray Mouth open	✓	
Maintain flows of at least 2,500 GL/yr over 2 years to prevent the Coorong existing in a degraded ecosystem state	✓	
Provide barrage outflow of 6,000 GL/yr, 1 in 3 years and 10,000 GL/yr, 1 in 7 years	✓	

Table 6 - Achievement of annual environmental watering objectives for the LLCMM Icon Site in 2012-13

Annual Environmental Water Objective (2012-13)	Achieved	Not Achieved
Twelve months of continuous barrage releases (prioritising fishways and attractant flows)	✓	
Maintain salinity levels in Lake Alexandrina <1,000 EC from July 2012 to June 2013	✓	
Reduce salinity levels in Lake Albert with the aim of achieving a target of an average of 2,000 EC by the end of June 2013.		✓
Maintain Coorong South Lagoon salinity levels <100 parts per thousand from July 2012 to June 2013	✓	
Maintain Coorong South Lagoon water levels between 0.0 and 0.2m AHD over summer (Dec 2012-Feb 2013)		✓

4.4 Status of Icon Site Condition and Progress Toward Meeting Ecological Objectives and Targets

The 2012-13 year was the third consecutive year of high barrage outflows and the LLCMM icon site continued to show signs of ecological recovery in response to increased water levels. All barrage fishways were operational for 365 days, with attractant flow and the Murray Mouth remained open without the need to dredge. Table 7 identifies the specific ecological targets that were met.

The 2012/13 monitoring period was characterised by high flows to the Lakes and Coorong, particularly during late winter and spring. Water levels in the Lakes have stabilised at 0.58-0.84 AHD since the return of flows to the system in 2010. Coorong water levels were variable, partially as a function of the volume of water released through the barrages, but below 0 m AHD in the South Lagoon in summer 2012. Salinities recorded at study sites during the monitoring year were the lowest measured since monitoring began in 2004. The reduction in salinities is most likely a result of continued flow over the barrages into the Murray Mouth and Coorong which has continued since spring 2010.

Murray hardyhead was the only threatened fish species to show obvious signs of recruitment in the Lower Lakes in 2012/13. There were significant increases in recruitment, abundance and distribution relative to the drought years (2008/09 and 2009/10) in this species. Black bream also showed a gradual increase in abundance and an expansion of distributional range from the Estuary during the drought years into the North Lagoon post 2010 flows. A significant increase of new recruit abundance was recorded compared to the previous two years. Conversely, there was limited evidence of recruitment for Yarra pygmy perch and southern pygmy perch in the Lower Lakes, so their population recovery appears to be hindered. While pouched lamprey were found in low abundance, and short-headed lamprey not at all, the re-connection of the Lower Lakes with the estuary has benefited the congollis population. Similarly, the relative abundance of common galaxias was substantially higher in 2012-13. These results highlight the ecological significance of the barrage releases and the critical role freshwater plays in facilitating successful spawning and recruitment in key estuarine and diadromous fish species and in restoring/maintaining estuarine habitat with a favourable salinity gradient.

Despite the varied hydrological changes that have occurred throughout the five year monitoring period, abundances of waterbirds using the Coorong and Lower Lakes have generally increased or been maintained for at least the last three years. Recovery of many waterbird species are likely to be affected by the distribution and abundance of *Ruppia tuberosa*, a key food resource in the Coorong with specific hydrological requirements which necessitates ongoing management. The 2012-13 monitoring has also revealed improvements in invertebrate populations in mudflats throughout most of the Murray Mouth and North Lagoon of the Coorong compared to the drought years. There have been improvements in diversity, abundances and biomass detected within the Murray Mouth and Coorong over the last three years and at several sites around the Lower Lakes. However, abundances and diversity have not yet returned to pre-drought levels. These invertebrates are also a key food resource for waterbirds and their distribution and abundance has a corresponding influence on waterbird communities, particularly migratory waders.

Despite environmental water delivery over summer, levels in the South Lagoon could not be maintained within the critical range needed for *Ruppia tuberosa* recruitment (specified as 0.0 – 0.20 m AHD). This affected the recovery and reproduction of *Ruppia tuberosa* across the Coorong South Lagoon for a second consecutive year. While the allocation of environmental water had some benefit in allowing low elevation *Ruppia tuberosa* to survive, grow and potentially reproduce in late spring and early summer, the low cover and subsequent drops in water level in early January meant little or no successful reproduction was detected.

Table 7 – Condition status of LLCMM ecological targets 2012-13

Target ID	Ecological Target	Partly Achieved	Achieved	Not Achieved
B1	Maintain or improve bird populations in the Lower Lakes, Coorong and Murray Mouth		✓	
F1	Maintain or improve recruitment success of diadromous fish in the Lower Lakes and Coorong	✓		
F2	Maintain or improve recruitment success of endangered fish species in the Lower Lakes	✓		
F3	Provide optimum conditions to improve recruitment success of small-mouthed hardyhead in the South Lagoon		✓	
F4	Maintain or improve populations of black bream, greenback flounder and mulloway in the Coorong	✓		
I1	Maintain or improve invertebrate populations in mudflats (both exposed and submerged)	✓		
I2	Provide freshwater flows that provide food sources for Goolwa cockles		✓	
M1	Facilitate frequent changes in exposure and submergence of mudflats		✓	
M2	Maintain sediment size range in mudflats		✓	
M3	Maintain organic content for mudflats		✓	
V1	Maintain or improve *Ruppia megacarpa* colonisation and reproduction			✗
V2	Maintain or improve *Ruppia tuberosa* colonisation and reproduction			✗
V3	Maintain or improve aquatic and littoral vegetation in the Lower Lakes			✗
W1	Establish and maintain variable salinity regime with >30% of area below sea water salinity concentrations in estuary and North Lagoon		✓	
W2	Maintain a permanent Murray Mouth opening through freshwater outflows with adequate tidal variations to improve water quality and maximise connectivity		✓	
W3	Maximise fish passage connectivity between the Lower Lakes and Coorong		✓	
W4	Maximise fish passage connectivity between the Coorong and the sea		✓	

4.5 Comparison of 2012-13 and 2011-12 results

During 2011-12, the LLCMM was South Australia's highest priority site for receiving environmental water. Significant unregulated flow events in the Murray-Darling Basin catchment resulted in the LLCMM icon site receiving a total annual barrage discharge of around 7,500 GL; and provided the second consecutive year of high flows following many years of drought. While this ensured Lake Alexandrina salinity levels remained below 1000 Electrical Conductivity (EC) and Lake Albert salinity levels were reduced by around 2000 EC over the course of the year, the timing of the unregulated flow was not optimal for some key species, particularly *Ruppia tuberosa*. The rapid reduction in flows in late spring, leading to a rapid drop in water levels in the Coorong South Lagoon during the critical period of reproduction for *Ruppia tuberosa* had perhaps the most detrimental effect on the ecology. This resulted in a failed recruitment event, meaning that the seedbank and long-term resilience of this species was reduced even further.

However, waterbird and estuarine fish numbers improved and invertebrate populations showed early signs of recolonisation in mudflat sediments. Within the Lower Lakes aquatic vegetation communities were reported to be in the process of recovery, albeit not to pre-drought scale and diversity. Despite the efforts of a wide spread re-stocking program, low abundances and diversity were noted for the small-bodied threatened fish monitoring program.

Table 8 presents a direct comparison of whether the ecological targets for the LLCMM icon site were achieved (completely or partly), not achieved, or unknown in the 2011-12 and 2012-13 monitoring years. In 2011-12, ten ecological targets out of a total of sixteen were achieved, five were not achieved and for one target there were insufficient data to make an assessment. By comparison, in 2012-13, 11 ecological targets out of a total sixteen were achieved (albeit two only partially), 2 were not achieved, and for four targets there was insufficient data to draw a definite conclusion. The additional targets achieved in 2012-13 related to endangered fish species populations in the Lower Lakes and populations of black bream, greenback flounder and mulloway in the Coorong. The results from the 2011-12 and 2012-13 years display a marked improvement from drought years (e.g. 2008-09) where only two targets were achieved, twelve were not achieved and three targets had insufficient data.

In 2012-13, the successful colonisation and reproduction of *Ruppia tuberosa* continues to pose a challenge for site managers and although waterbird populations have been maintained or improved, their continued recovery will be affected by the distribution and abundance of *Ruppia tuberosa*. The length in recovery time for many species post-drought is evident in the similarity between the 2011-12 and 2012-13 monitoring year results and achievement of targets. Although there was a significant improvement immediately post-drought, ongoing consecutive years of higher flow into the future are required to ensure recovery can be completed. The continuation of monitoring programs such as the Condition Monitoring program under TLM is vital to understanding the changing dynamics of the LLCMM ecosystem and how it will continue to recover and adapt post drought

Table 8 – Comparison of condition status of LLCMM ecological targets in 2011-12 and 2012-13

Target ID#	Ecological Target	2012-13	2011-12
B1	Maintain or improve bird populations in the Lower Lakes, Coorong and Murray Mouth	Achieved	Achieved
F1	Maintain or improve recruitment success of diadromous fish in the Lower Lakes and Coorong	Partly Achieved	Achieved
F2	Maintain or improve recruitment success of endangered fish species in the Lower Lakes	Achieved	Not achieved
F3	Provide optimum conditions to improve recruitment success of small-mouthed hardyhead in the South Lagoon	Achieved	Achieved
F4	Maintain or improve populations of black bream, greenback flounder and mulloway in the Coorong	Partly achieved	Not achieved
I1	Maintain or improve invertebrate populations in mudflats (both exposed and submerged)	Partly achieved	Achieved
I2	Provide freshwater flows that provide food sources for Goolwa cockles	Achieved	Unknown
M1	Facilitate frequent changes in exposure and submergence of mudflats	Achieved	Achieved
M2	Maintain habitable sediment conditions in mudflats	Achieved	Achieved
V1	Maintain or improve *Ruppia megacarpa* colonisation and reproduction	Not Achieved	Not achieved
V2	Maintain or improve *Ruppia tuberosa* colonisation and reproduction	Not achieved	Not achieved
V3	Maintain or improve aquatic and littoral vegetation in the Lower Lakes	Not achieved	Not achieved
W1	Establish and maintain variable salinity regime with >30% of area below sea water salinity concentrations in estuary and North Lagoon	Achieved	Achieved
W2	Maintain a permanent Murray Mouth opening through freshwater outflows with adequate tidal variations to improve water quality and maximise connectivity	Achieved	Achieved
W3	Maximise fish passage connectivity between the Lower Lakes and Coorong	Achieved	Achieved
W4	Maximise fish passage connectivity between the Coorong and the sea	Achieved	Achieved

5. CONCLUSIONS AND LEARNINGS

The following learnings have been gathered from operational decisions undertaken during 2012-13 and these will be used to inform future management of the icon site:

- Continue to target barrage releases predominantly through Tauwitchere Barrage during spring/summer to reduce salinity in the Coorong South Lagoon.
- Continue to inform real time management decisions with the aid of hydrologic modelling.
- Look for watering opportunities for lake-level 'cycling' to facilitate flushing of salt from Lake Albert.
- Avoid steep recessions in unregulated flow conditions by ensuring environmental water can be added to the tail end of the high flow period, allowing for a more gradual reduction in flow, therefore enhancing ecological outcomes.
- Work to address/resolve/manage issues caused by significant system constraints to the delivery of environmental water to South Australia in January and February.
- Continue the preparation of the Short Term Barrage Operating Plan (introduced in March 2013) to better inform management decisions around barrage operations and lake level management.
- Continue to manage barrages in times of high tides, high swell and reverse head conditions.
- Maintain fishway openings at all times along with supplementary attract flow from adjacent barrage bays.

6. REFERENCES

Beheregaray, L. Unpublished Data

Bice, C.M., Zampatti, B.P., (2013). Monitoring upstream movement of lamprey at the Murray barrages in Winter 2013. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Unpublished.

Bice, C. M., B. P. Zampatti, P. R. Jennings and P. Wilson (2012). Fish assemblage structure, movement and recruitment in the Coorong and Lower Lakes in 2011/12. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2011/000186-3. SARDI Research Report Series No. 680. 53pp.

DEWNR (2013a) South Australia's River Murray Environmental Watering Report 2012-13. Department of Environment, Water and Natural Resources, South Australia.

DEWNR (2013b) South Australia's Environmental Watering Plan 2012-13: Watering Action Proposal, Department of Environment, Water and Natural Resources, South Australia.

Dittmann, S., Ramsdale, T., Navong, N., Cummings, C., Baggalley, S. and Keuning, J. 2013: Benthic macroinvertebrate survey 2012-13: Lower Lakes, Coorong and Murray Mouth Icon Site. Report for the Department of Environment, Water and Natural Resources and the Murray-Darling Basin Authority. Flinders University of South Australia.

Foote, A.L. and Kadlec, J.A. (1988). Effects of wave energy on plant establishemnt in shallow lacustrine wetlands. *Journal of Freshwater Ecology* 4: 523-532.

Frahn, K.A., Gehrig, S. L., Nicol, J.M., and Marsland K.B. (2013). Lower Lakes vegetation condition monitoring – 2012/2013. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, SARDI Publication Number F2009/000370-5. SARDI Research Report Series No. 707. 69pp.

Grace, J.B. (1993). The adaptive significance of clonal reproduction in angiosperms: an aquatic perspective. Aquatic Botany 44: 159-180.

Hammer, M., S. Wedderburn & S. Westergaard, 2002. Freshwater fishes. In Brandle, R. (ed) A Biological Survey of the Murray Mouth Reserves, South Australia. Department for Environment and Heritage, Adelaide, 54-61.

Hirst, A. 2004. Broad-scale environmental gradients among estuarine benthic macrofaunal assemblages of south-eastern Australia: implications for monitoring estuaries. Marine and Freshwater Research 55:79-92.

Holt, M., Swingler, K., O'Donnell, E., Shirley, M., Lake, M., Conallin, A., Meredith, S., Ho, S., Prider, J., Poulsen, D., Richardson, S. and Cooling, M. (2005). River Murray Wetlands Baseline Survey. River Murray Catchment Water Management Board, Berri.

Maunsell Pty Ltd (2009) Lower Lakes, Coorong and Murray Mouth Icon Site Condition Monitoring Plan. Report for the South Australian Murray-Darling Basin Natural Resources Management Board, Adelaide.

MDBA (2012a) 2012-13 Murray-Darling Basin Environmental Watering Priorities. Murray-Darling Basin Authority, Canberra.

MDBA (2012b) The Living Murray Annual Environmental Watering Plan 2012-13. Murray –Darling Basin Authority, Canberra.

MDBA (2013) The Lower Lakes, Coorong and Murray Mouth Icon Site Environmental Water Management Plan 2013. Murray –Darling Basin Authority, Canberra.

Nicol, J.M. (2004). Vegetation Dynamics of the Menindee Lakes with Reference to the Seed Bank. PhD thesis, The University of Adelaide.

Nicol, J.M., Weedon, J.T. and Doonan, A. (2006). Vegetation Surveys. In 'River Murray Wetlands Baseline Survey – 2005'. (Eds Simpson, D., Holt, M., Champion, T., Horan, A. and Shirley, M.). (South Australian Murray Darling Basin Natural Resources Management Board: Berri).

O'Connor, JA, Rogers DJ (2013), Response of Waterbirds to Environmental Change in the Lower Lakes, Coorong and Murray Mouth Icon Site. South Australian Department of Environment, Water and Natural Resources, Adelaide.

Paton, DC 2010. At the end of the River. The Coorong and Lower Lakes. ATF Press, Hindmarsh.

Paton, D.C. & Bailey C. P. 2012. Annual monitoring of Ruppia tuberosa in the Coorong region of South Australia, July 2011. Report for the Department of Environment, Water and Natural Resources. (University of Adelaide, Adelaide).

Paton, DC, Bailey, CP. (2013a) Condition monitoring of the Lower Lakes, Coorong and Murray Mouth Icon Site: Waterbirds 2013. (Report for the Department of Environment Water and Natural Resources, University of Adelaide, Adelaide).

Paton, DC, Bailey, CP. (2013b) Response of Ruppia tuberosa in the Coorong South Lagoon to environmental water delivery over summer 2012-13 (Report for the Department of Environment, Water and Natural Resources, University of Adelaide, Adelaide)

Paton, D.C. & Bailey C. P. (2013c). Annual monitoring of Ruppia tuberosa in the Coorong region of South Australia, July 2012. Report for the Department of Environment, Water and Natural Resources. (University of Adelaide, Adelaide).

Steggles, T (2013), Evaluation of environmental watering in 2012-13. Department of Environment, Water and Natural Reources, South Australia.

Wedderburn, S. and Barnes, T. (2013). Condition Monitoring of Threatened Fish Species at Lake Alexandrina and Lake Albert (2012–2013). The University of Adelaide, Adelaide, 64.

Ye, Q., Bucater, L. and Short, D. (2013). Coorong fish condition monitoring 2008–2013: Black bream *(Acanthopagrus butcheri),* greenback flounder *(Rhombosolea tapirina)* and smallmouth hardyhead *(Atherinosoma microstoma)* populations. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2011/000471-3. SARDI Research Report Series No. 748. 91pp.

Zampatti, B. P., C. M. Bice and P. R. Jennings (2010). Temporal variability in fish assemblage structure and recruitment in a freshwater deprived estuary: The Coorong, Australia. Marine and Freshwater Research 61: 1298-1312.

Zampatti, B. P., C. M. Bice and P. R. Jennings (2012). Fish assemblage response and fishway effectiveness at Goolwa, Tauwitchere and Hunters Creek Barrages in 2010/11. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2011/000186-2. SARDI Research Report Series No. 605. 66pp.

7. GLOSSARY, ACRONYMS AND ABBREVIATIONS

Ambient — The background level of an environmental parameter (e.g. a measure of water quality such as salinity)

Ambient water monitoring — All forms of monitoring conducted beyond the immediate influence of a discharge pipe or injection well, and may include sampling of sediments and living resources

Ambient water quality — The overall quality of water when all the effects that may impact upon the water quality are taken into consideration

Anabranch — A branch of a river that leaves the main channel

Aquatic community — An association of interacting populations of aquatic organisms in a given water body or habitat

Aquatic ecosystem — The stream channel, lake or estuary bed, water and/or biotic communities and the habitat features that occur therein

Aquatic habitat — Environments characterised by the presence of standing or flowing water

Aquatic macrophytes — Any non-microscopic plant that requires the presence of water to grow and reproduce

Barrage — Specifically any of the five low weirs at the mouth of the River Murray constructed to exclude seawater from the Lower Lakes

Baseflow — The water in a stream that results from groundwater discharge to the stream; often maintains flows during seasonal dry periods and has important ecological functions

Basin — The area drained by a major river and its tributaries

Benchmark condition — Points of reference from which change can be measured

Benthic zone — The lowest level of a body of water, such as an ocean or a lake; inhabited mostly by organisms that tolerate cool temperatures and low oxygen levels, called benthos or benthic organisms

Biodiversity — (1) The number and variety of organisms found within a specified geographic region. (2) The variability among living organisms on the earth, including the variability within and between species and within and between ecosystems

Biological diversity — See 'biodiversity'

Biological integrity — Functionally defined as the condition of the aquatic community that inhabits unimpaired water bodies of a specified habitat as measured by community structure and function

Biota — All of the organisms at a particular locality

CAP – Community Advisory Panel

Catchment — That area of land determined by topographic features within which rainfall will contribute to run-off at a particular point

CFH - Critical Fish Habitat

CLLMM - Coorong Lower Lakes Murray Mouth

CPUE - Catch Per Unit Effort

Critical habitat — Those areas designated as critical for the survival and recovery of threatened or endangered species

CSIRO — Commonwealth Scientific and Industrial Research Organisation

DEWNR — Department of Environment, Water and Natural Resources (Government of South Australia)

Diversity — The distribution and abundance of different kinds of plant and animal species and communities in a specified area

DO — Dissolved Oxygen

DOC — Dissolved Organic Carbon

d/s — Downstream

EC — Electrical conductivity; 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C; commonly used as a measure of water salinity as it is quicker and easier than measurement by TDS

Ecological processes — All biological, physical or chemical processes that maintain an ecosystem

Ecological values — The habitats, natural ecological processes and biodiversity of ecosystems

Ecology — The study of the relationships between living organisms and their environment

Ecosystem — Any system in which there is an interdependence upon, and interaction between, living organisms and their immediate physical, chemical and biological environment

Endangered species — (1) Any species in danger of extinction throughout all or a significant portion of its range

Endemic — A plant or animal restricted to a certain locality or region

Entitlement flows — Minimum monthly River Murray flows to South Australia agreed in to the Murray-Darling Basin Agreement 1992

Environmental values — The uses of the environment that are recognised as being of value to the community. This concept is used in setting water quality objectives under the Environment Protection (Water Quality) Policy, which recognises five environmental values — protection of aquatic ecosystems, recreational water use and aesthetics, potable (drinking water) use, agricultural and aquaculture use, and industrial use. It is not the same as ecological values, which are about the elements and functions of ecosystems.

Environmental water provisions — That part of environmental water requirements that can be met; what can be provided at a particular time after consideration of existing users' rights, and social and economic impacts

Environmental water requirements — The water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk

EPA — Environment Protection Authority (Government of South Australia)

EPBC Act - Environment Protection and Biodiversity Conservation Act (1999)

Ephemeral streams or wetlands — Those streams or wetlands that usually contain water only on an occasional basis after rainfall events. Many arid zone streams and wetlands are ephemeral.

Estuaries — Semi-enclosed water bodies at the lower end of a freshwater stream that are subject to marine, freshwater and terrestrial influences, and experience periodic fluctuations and gradients in salinity

Estuarine habitat — Tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater run-off from the land

Eutrophication — Degradation of water quality due to enrichment by nutrients (primarily nitrogen and phosphorus), causing excessive plant growth and decay. See also algal bloom

Evapotranspiration — The total loss of water as a result of transpiration from plants and evaporation from land, and surface water bodies

Fishway — A generic term describing all mechanisms that allow the passage of fish along a waterway. Specific structures include fish ladders (gentle sloping channels with baffles that reduce the velocity of water and provide resting places for fish as they 'climb' over a weir) and fishlifts (chambers, rather like lift-wells, that are flooded and emptied to enable fish to move across a barrier).

Floodplain — Of a watercourse means: (1) floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under the Act; or (2) where (1) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the *Development (SA) Act 1993*; or (3) where neither (1) nor (2) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse

Flow bands — Flows of different frequency, volume and duration

Flow regime — The character of the timing and amount of flow in a stream

Fresh — A short duration, small volume pulse of streamflow generated by a rainfall event that temporarily, but noticeably, increases stream discharge above ambient levels

FSD - First Step Decision

Groundwater — Water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground; see also 'underground water'

Habitat — The natural place or type of site in which an animal or plant, or communities of plants and animals, live

Heavy metal — Any metal with a high atomic weight (usually, although not exclusively, greater than 100), for example mercury, lead and chromium. Heavy metals have widespread industrial uses, and many are released into the biosphere via air, water and solids pollution. Usually these metals are toxic at low concentrations to most plant and animal life.

Hydraulic conductivity (K) — A measure of the ease of flow through aquifer material: high K indicates low resistance, or high flow conditions; measured in metres per day

Hydrology — The study of the characteristics, occurrence, movement and utilisation of water on and below the Earth's surface and within its atmosphere; see also 'hydrogeology'

Hydrometric — Literally relating to water measurement, from the Greek words 'hydro' (water) and metrikos (measurement)

Impact — A change in the chemical, physical, or biological quality or condition of a water body caused by external sources

Indigenous species — A species that occurs naturally in a region

Infrastructure — Artificial lakes; dams or reservoirs; embankments, walls, channels or other works; buildings or structures; or pipes, machinery or other equipment

Integrated catchment management — Natural resources management that considers in an integrated manner the total long-term effect of land and water management practices on a catchment basis, from production and environmental viewpoints

Irrigation — Watering land by any means for the purpose of growing plants

Irrigation season — The period in which major irrigation diversions occur, usually starting in August–September and ending in April–May

KNYA - Kungun Ngarrindjeri Yunnan Agreement

Lake — A natural lake, pond, lagoon, wetland or spring (whether modified or not) that includes part of a lake and a body of water declared by regulation to be a lake. A reference to a lake is a reference to either the bed, banks and shores of the lake or the water for the time being held by the bed, banks and shores of the lake, or both, depending on the context.

Land — Whether under water or not, and includes an interest in land and any building or structure fixed to the land

Land capability — The ability of the land to accept a type and intensity of use without sustaining long-term damage

LLCMM - Lower Lakes, Coorong and Murray Mouth

Macro-invertebrates — Aquatic invertebrates visible to the naked eye including insects, crustaceans, molluscs and worms that inhabit a river channel, pond, lake, wetland or ocean

m AHD — Defines elevation in metres (m) according to the Australian Height Datum (AHD)

MDBA — Murray-Darling Basin Authority

MDBC — former Murray-Darling Basin Commission

Metadata — Information that describes the content, quality, condition, and other characteristics of data, maintained by the Federal Geographic Data Committee

Model — A conceptual or mathematical means of understanding elements of the real world that allows for predictions of outcomes given certain conditions. Examples include estimating storm run-off, assessing the impacts of dams or predicting ecological response to environmental change

Monitoring — (1) The repeated measurement of parameters to assess the current status and changes over time of the parameters measured (2) Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, animals and other living things

Native species — Any animal and plant species originally in Australia; see also 'indigenous species'

Natural recharge — The infiltration of water into an aquifer from the surface (rainfall, streamflow, irrigation etc). See also recharge area, artificial recharge

Natural resources — Soil, water resources, geological features and landscapes, native vegetation, native animals and other native organisms, ecosystems

NRM — Natural Resources Management; all activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively

Percentile — A way of describing sets of data by ranking the dataset and establishing the value for each percentage of the total number of data records. The 90th percentile of the distribution is the value such that 90% of the observations fall at or below it.

Perennial streams — Permanently inundated surface stream courses. Surface water flows throughout the year except in years of infrequent drought.

Permeability — A measure of the ease with which water flows through an aquifer or aquitard, measured in m^2/d

Phreatophytic vegetation — Vegetation that exists in a climate more arid than its normal range by virtue of its access to groundwater

Phytoplankton — The plant constituent of organisms inhabiting the surface layer of a lake; mainly single-cell algae

PIRSA — Primary Industries and Regions South Australia (Government of South Australia)

Population — (1) For the purposes of natural resources planning, the set of individuals of the same species that occurs within the natural resource of interest. (2) An aggregate of interbreeding individuals of a biological species within a specified location

PSU – Practical Salinity Units

Ramsar Convention — This is an international treaty on wetlands titled *The Convention on Wetlands of International Importance Especially as Waterfowl Habitat*. It is administered by the International Union for Conservation of Nature and Natural Resources. It was signed in the town of Ramsar, Iran in 1971, hence its common name. The convention includes a list of wetlands of international importance and protocols regarding the management of these wetlands. Australia became a signatory in 1974.

Recharge area — The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. See also artificial recharge, natural recharge

Rehabilitation (of water bodies) — Actions that improve the ecological health of a water body by reinstating important elements of the environment that existed prior to European settlement

Remediation (of water bodies) — Actions that improve the ecological condition of a water body without necessarily reinstating elements of the environment that existed prior to European settlement

Restoration (of water bodies) — Actions that reinstate the pre-European condition of a water body

Riparian — Of, pertaining to, or situated or dwelling on the bank of a river or other water body

Riparian areas — Geographically delineable areas with distinctive resource values and characteristics that comprise the aquatic and riparian ecosystems

Riparian-dependent resources — Resources that owe their existence to a riparian area

Riparian ecosystems — A transition between the aquatic ecosystem and the adjacent terrestrial ecosystem; these are identified by soil characteristics or distinctive vegetation communities that require free or unbound water

Riparian habitat — The transition zone between aquatic and upland habitat. These habitats are related to and influenced by surface or subsurface waters, especially the margins of streams, lakes, ponds, wetlands, seeps, and ditches

Riparian zone — That part of the landscape adjacent to a water body that influences and is influenced by watercourse processes. This can include landform, hydrological or vegetation definitions. It is commonly used to include the in-stream habitats, bed, banks and sometimes floodplains of watercourses

Riverine habitat — All wetlands and deep-water habitats within a channel, with two exceptions — wetlands dominated by trees, shrubs, persistent emergent mosses or lichens, and habitats with water that contains ocean-derived salt in excess of 0.5 parts per thousand

SAG - Scientific Advisory Group

SARDI — South Australian Research and Development Institute, a division within PIRSA

SA Water — South Australian Water Corporation (Government of South Australia)

Sensitive species — Those plant and animal species for which population viability is a concern

SBOP – Short-term Barrage Operating Plan

Sub-catchment — The area of land determined by topographical features within which rainfall will contribute to run-off at a particular point

Surface water — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir

SS —Suspended solids

Sustainability — The ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time

Taxa — General term for a group identified by taxonomy, which is the science of describing, naming and classifying organisms

TDS — Total dissolved solids, measured in milligrams per litre (mg/L); a measure of water salinity

Threatened species — Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range

Threatened waters — Waters that fully support their designated uses, but may not support uses in the future unless pollution control action is taken because of anticipated sources or adverse pollution trends

TL — Total length

TLM — The Living Murray

TN — Total nitrogen

TOC — Total organic carbon

To take water — From a water resource includes (a) to take water by pumping or siphoning the water; (b) to stop, impede or divert the flow of water over land (whether in a watercourse or not) for the purpose of collecting the water; (c) to divert the flow of water from the watercourse; (d) to release water from a lake; (e) to permit water to flow under natural pressure from a well; (f) to permit stock to drink from a watercourse, a natural or artificial lake, a dam or reservoir

Toxic — Relating to harmful effects to biota caused by a substance or contaminant

TP — Total phosphorus

Tributary — A river or creek that flows into a larger river

Turbidity — The cloudiness or haziness of water (or other fluid) caused by individual particles that are too small to be seen without magnification, thus being much like smoke in air; measured in Nephelometric Turbidity Units (NTU)

Underground water (groundwater) — Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground

Viable population — A population that has the estimated numbers and distribution of reproductive individuals to ensure the continued existence of the species throughout its existing range in the planning area

Water allocation — (1) In respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence. (2) In respect of water taken pursuant to an authorisation under s.11 means the maximum quantity of water that can be taken and used pursuant to the authorisation

WAP — Water Allocation Plan; a plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with the Act

Water body — Includes watercourses, riparian zones, floodplains, wetlands, estuaries, lakes and groundwater aquifers

Water column — a section of water extending from the surface of a body of water to its bottom. In the sea or ocean, it is referred to as 'pelagic zone'

Watercourse — A river, creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; a lake through which water flows; a channel (but not a channel declared by regulation to be excluded from the this definition) into which the water of a watercourse has been diverted; and part of a watercourse

Water dependent ecosystems — Those parts of the environment, the species composition and natural ecological processes, that are determined by the permanent or temporary presence of flowing or standing water, above or below ground; the in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems

Water licence — A licence granted under the Act entitling the holder to take water from a prescribed watercourse, lake or well or to take surface water from a surface water prescribed area; this grants the licensee a right to take an allocation of water specified on the licence, which may also include conditions on the taking and use of that water; a water licence confers a property right on the holder of the licence and this right is separate from land title

Water plans — The State Water Plan, catchment water management plans, water allocation plans and local water management plans prepared under Part 7 of the Act

Water quality criteria — comprised of both numerical criteria and narrative criteria. Numerical criteria are scientifically derived ambient concentrations developed by the EPA (Commonwealth Government of Australia) or the states for various pollutants of concern, so that human health and aquatic life can be protected. Narrative criteria are statements that describe the desired water quality goal.

Water quality data — Chemical, biological, and physical measurements or observations of the characteristics of surface and groundwater, atmospheric deposition, potable water, treated effluents, and wastewater, and of the immediate environment in which the water exists

Water quality information — Derived through analysis, interpretation, and presentation of water quality and ancillary data

Water quality monitoring — An integrated activity for evaluating the physical, chemical, and biological character of water in relation to human health, ecological conditions, and designated water uses

Water quality standard — A law or regulation that consists of the beneficial designated use or uses of a water body, the numerical and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement

Water resource monitoring — An integrated activity for evaluating the physical, chemical, and biological character of water resources, including (1) surface waters, groundwater, estuaries, and near-coastal waters; and (2) associated aquatic communities and physical habitats, which include wetlands

Water resource quality — (1) The condition of water or some water-related resource as measured by biological surveys, habitat-quality assessments, chemical-specific analyses of pollutants in water bodies, and toxicity tests. (2) The condition of water or some water-related resource as measured by habitat quality, energy dynamics, chemical quality, hydrological regime, and biotic factors

Water service provider — A person or corporate body that supplies water for domestic, industrial or irrigation purposes or manages wastewater

Water-use year — The period between 1 July in any given calendar year and 30 June the following calendar year; also called a licensing year

Wetlands — Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic to intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tides does not exceed six metres.

YoY — young of year.