Review and update of the ecological objectives and targets for the Coorong, Lower Lakes and Murray Mouth priority environmental asset

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Acknowledgement of Country

We acknowledge and respect the Traditional Custodians whose ancestral lands we live and work upon and we pay our respects to their Elders past and present.

We acknowledge and respect their deep spiritual connection and the relationship that Aboriginal and Torres Strait Islanders people have to Country.

We also pay our respects to the cultural authority of Aboriginal and Torres Strait Islander people and their nations in South Australia, as well as those across Australia.

In particular, we pay respect to the Ngarrindjeri and the First Nations of the South-East people as Traditional Custodians of the Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset. We also acknowledge their continuous and on-going connection to Country and that the health and functionality of this ecosystem are central to their health, well-being, culture and beliefs. Parallel processes are underway to engage First Nations representatives in this review of the South Australian River Murray Long-Term Environmental Watering Plan.

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Subject matter experts involved in the facilitated discussions were:

- Chris Bice (South Australian Research and Development Institute, SARDI)
- Sabine Dittmann (Flinders University)
- Sam Hardy (Murraylands and Riverland Landscape Board)
- Ryan Lewis (DEW)
- Luke Mosley (The University of Adelaide)
- Jason Nicol (SARDI)
- David Paton (Bio-R Oz)
- Adrienne Rumbelow (DEW)
- Claire Sims (DEW)
- Michelle Waycott (DEW)
- Scotte Wedderburn (The University of Adelaide)
- Qifeng Ye (SARDI)

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Summary

As part of the overall Murray-Darling Basin planning framework, the Long-term Environmental Watering Plan for the South Australian River Murray (SA River Murray LTWP) sets out the ecological objectives and targets for managing environmental water to achieve healthy and functional ecosystems across 3 Priority Environmental Assets (PEAs), including the Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset (CLLMM PEA), which is the subject of this review.

The existing SA River Murray LTWP (2020) has 8 ecological objectives and 29 ecological targets for the CLLMM PEA (Appendix A). The purpose of this report is to document the review process and provide recommended updates for these objectives and targets, as part of a broader suite of work being undertaken by Department for Environment and Water (DEW) to review the plan. A group of 16 subject matter experts and DEW staff undertook this review using a collaborative workshop approach, relevant literature, extensive and long-term data sets and their regional expertise and capacity to describe in detail what a healthy and functional CLLMM PEA would be in terms of the recommended updated objectives and targets. In some cases, knowledge gaps or further refinements of objectives and targets that can be undertaken using available or novel data have been identified.

This 2024 technical review and update of the ecological objectives and targets for the CLLMM PEA is part of the overarching SA River Murray LTWP review process, which includes reviews of objectives and targets for the other PEAs (i.e. the SA River Murray Channel PEA and the SA River Murray Floodplain PEA). It builds on the extensive knowledge and expertise of many people and other regional plans and will be a key input to the SA River Murray LTWP review. The recommendations presented here, include:

- Updating the descriptions of the four subregions to better reflect the eco-hydrological subunits and connections across the site.
- New management terms for healthy and functional habitats, e.g. mudflats with harvestable resources, submerged macrophyte (aquatic plant) communities.
- Fifteen objectives across 9 revised ecological themes – Waterbirds, Fish, Macroinvertebrates, Sediments, Turtles, Frogs, Vegetation, Water Quality and Ecosystem processes.
- Sixty targets nested under the 15 objectives and 9 Themes that provide the species or community level detail for what constitutes a healthy and functional CLLMM PEA.
- Updated assessment of the Environmental Water Requirement contributions to achievement of these 60 targets linked to the magnitude and seasonality of barrage outflows and water levels in Coorong South Lagoon and Lakes Alexandrina and Albert.

It is acknowledged that not all of these objectives and targets will be achievable with current environmental water provisions, and some are not measurable in the short-term. They are, however, indicative of a healthy and functional CLLMM PEA, which is the aim of the SA River Murray LTWP. The EWR evaluation undertaken here shows that lower flows are unlikely to support waterbird, fish or frog targets or support the re-establishment of vigorous submerged macrophyte communities in the Coorong that are the foundation of restoration. Higher flows will be needed to achieve critical ecosystem processes and habitat quality targets, especially those relating to soil health. Other targets will be achieved at any flows that sustain water levels in Lakes Alexandrina and Albert.

This report is a collation of technical advice that will feed into the SA River Murray LTWP review. DEW is working with each of the First Nation groups to collaboratively develop content for the whole SA River Murray LTWP region that reflects their cultural values and environmental watering objectives, as well as their on-going involvement in the management of water for the environment.

1 Introduction

The Long-term Environmental Watering Plan for the South Australian River Murray (hereafter, SA River Murray LTWP) is a critical instrument for managing environmental water across the three Priority Environmental Assets (PEA) in its area; the SA River Murray Floodplain PEA, the SA River Murray Channel PEA and the Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset (CLLMM PEA), the last of which is the subject of this review.

The SA River Murray LTWP was first submitted to the Murray-Darling Basin Authority (MDBA) in 2015. Under Chapter 8 of the Basin Plan, DEW is required to periodically review this plan. The first review and submission of an updated version occurred in 2020. There was a commitment made to review again in 2024 in a more comprehensive manner, including considerations of the ecological objectives and targets as well as the assessment of each of the Environmental Water Requirements (EWR) contributions to achieving these targets.

This report documents the process and recommended updates to the ecological objectives and ecological targets for the CLLMM PEA in the SA River Murray LTWP. It only relates to the review of the CLLMM PEA objectives and targets. A separate project is underway to review the objectives and targets for the other two PEAs covered by the SA River Murray LTWP, that is the SA River Murray Channel PEA and the SA River Murray Floodplain PEA. DEW is also working with each of the First Nation groups within the region to collaboratively develop content for the SA River Murray LTWP that reflects their cultural values and environmental watering objectives, as well as their on-going involvement in the management of water for the environment across the Basin.

The SA River Murray LTWP CLLMM PEA is equivalent to two other management zones, namely:

- The *Living Murray* Lower Lakes, Coorong and Murray Mouth Icon Site (LLCMM Icon site), and
- The Coorong, Lakes Alexandrina and Albert Wetland of International Importance site listed under the Ramsar Convention in 1985.

The following definitions were used to guide this 2024 SA River Murray LTWP review:

- Each ecological objective provides a clear statement of what delivery of a hydrological regime (as defined by the environmental water requirements) are intended to achieve and reflect a healthy and functional CLLMM PEA. There are multiple objectives for each PEA, with each objective focussed on a key biotic group or ecological process (theme); however, the inter-dependencies between the objectives should not be overlooked.
- Ecological targets specify a condition state (often described by a numerical value) that allows for assessment against a benchmark over time. The targets are nested within an ecological objective and there may be more than one target per objective. As much as possible, the targets are 'SMART' i.e. Specific, Measurable, Achievable, Relevant and Time-bound. This format informs monitoring and provides a means of assessing the change in condition and progress towards achieving the objectives, as well as determining the EWR contributions associated with that target. It is recognised, however, that monitoring is continuously improved and that it is important that the objectives and targets included in the updated SA River Murray LTWP are flexible and have longevity. For these reasons, some targets that are not SMART have been recommended because, even though they are not currently being monitored and/or able to be monitored, they are important descriptors of a healthy and functional CLLMM PEA.

The EWRs and the ecological objectives and targets:

- Are applicable at the whole of CLLMM PEA or sub-regional scale,
- Represent the ecological condition of a healthy, functioning ecosystem,
- Are not constrained by what can be delivered under the Basin Plan (based on water recovery modelling) or other existing policies or plans, but have a degree of pragmatism applied, and
- Are not limited to those metrics that are or will be monitored through known funding sources.

This framing has not changed from when the original SA River Murray LTWP was developed and was provided to the subject matter experts (SMEs) at the initial context-setting workshop.

Geomorphologically and hydrologically, the CLLMM PEA is complex and highly modified (Phillips and Muller 2006; Murray Darling Basin Authority, 2013; O'Connor et al, 2015; Mosley et al. 2018), requiring environmental water holders and managers to make multiple decisions regarding water allocations to the site and delivery to different components within the site. River Murray flows enter the CLLMM PEA near Wellington (the confluence of the River Murray and Lake Alexandrina) and flow through the site before being retained in the 142,530 ha wetland system that comprises the CLLMM PEA or discharged to the Southern Ocean through the Murray Mouth. The freshwater lakes, Lakes Alexandrina and Albert, and the Eastern Mount Lofty Ranges tributaries are separated from the more saline parts of the system, the Murray Mouth estuary, Coorong Lagoons and Southern Ocean, by a series of five barrages constructed in 1939–40 (Walker 2006).

The existing SA River Murray LTWP (2020) has 8 ecological objectives and 29 ecological targets for the CLLMM PEA (Appendix A). They were developed for the first version of the plan (prior to 2015) by collating and consolidating planning material from *The Living Murray* and *Coorong, Lower Lakes and Murray Mouth* programmes (O'Connor *et al.* 2015). At that time, the CLLMM PEA was just emerging from the Millennium Drought and was still responding to the adversity of prolonged barrage closures and very low lake levels, followed by a relatively rapid refill and recommencement of barrage flows in 2010/11 when high flows returned to South Australia (Department for Water 2011; Wedderburn et al. 2014). Since then, climate conditions have varied across the years from relatively dry years to another high flow event in 2016/17 and a significant flood in 2022/23. Water levels in the Lower Lakes have remained above the critical minimum levels and have been managed for variability within the variable water envelope. In addition, there has been over a decade of continuous flows from the River Murray to the Coorong and out the Murray Mouth. In the last decade there has also been significant work done to better understand the ecology of the system (e.g. DEW projects such as Healthy Coorong Healthy Basin (HCHB) Trials and Investigations, Ramsar Management planning process, *The Living Murray* condition monitoring program, River Murray Flood Response monitoring project). It is time, therefore, from ecological and legislative perspectives to draw on recent data and expertise to review the SA River Murray LTWP (2020).

This 2024 review of the CLLMM PEA ecological objectives and targets was conducted using a subject matter expert (SME) collaboration approach involving sixteen SMEs and site managers with expertise across different ecological themes, who work for a variety of organisations, and each have decades of experience researching and/or managing the CLLMM region. New objectives and targets have been added through this review. Some existing objectives and targets were amended to better reflect current knowledge, and others were removed if they were considered no longer relevant as descriptors of a healthy, functional CLLMM ecosystem or were encapsulated in other new or amended targets. It is important to recognise that the SA River Murray LTWP is not constrained by what can be achieved through current environmental water policies and plans, but rather it is focused on representing a healthy and functional ecosystem. That said, this review has been undertaken in a manner that is consistent with the requirements of Chapter 8 of the Basin Plan and is primarily a document to inform the review and update of the SA River Murray LTWP in 2025.

As well as reviewing the objectives and targets, the capacity for each of the 4 CLLMM EWRs to contribute towards achieving the targets was also reviewed. This was based on updating the tables that assess the contribution of Environmental Water Requirements (EWR) to each of the recommended targets as developed by Wallace et al (2014) and Gehrig et al. (2020). They can be used to inform environmental water planning by indicating the likely outcomes of delivering certain flow conditions to the CLLMM PEA.

This 2024 review builds on the extensive work undertaken to date by many scientists and managers over decades and has been presented in a manner that seeks to be transparent, collaborative and technically sound, as well as providing a base for continual improvement. This report will be a key input to the SA River Murray LTWP review for the CLLMM PEA component and has been informed by other work undertaken for the draft Ramsar Management Plan for the Coorong, Lower Lakes and Murray Mouth Wetland of International Importance (RMP, DEW 2024) and The Living Murray – Lower Lakes, Coorong and Murray Mouth Icon Site Condition Monitoring Plan (CMP, DEWNR 2017).

2 Methodology

2.1 Subject matter expert (SME) collaboration process

This 2025 SA River Murray LTWP review has been undertaken by DEW in a comprehensive manner consistent with Chapter 8 of the Basin Plan. It was based on the existing SA River Murray LTWP, the ecological objectives and targets within which were developed prior to 2015 and the EWRs which were reviewed in 2020 (Gehrig et al. 2020).

The 8 ecological objectives and 29 ecological targets for the CLLMM PEA in the existing SA River Murray LTWP (2020; Appendix A) were organised into the following 6 themes, which align with other Basin Plan instruments, around which the 2024 review methodology was designed:

- Waterbirds
- Fish
- Macroinvertebrates
- Vegetation
- Water quality
- Ecosystem processes

Dr. Kerri Muller (AU2100) was engaged by DEW in March 2024 to facilitate and document a subject matter expert (SME) collaboration process for this review. This was a formal process by which statements describing a healthy functional ecosystem (e.g. objectives and targets) were developed from discussions with a panel of experts for inclusion into decision-making processes, in this case environmental water planning. It is a sound approach for this purpose because existing data and models alone cannot provide all the information required and subject matter expert opinions are needed to bridge the gap between current knowledge and planning requirements.

A total of 16 SMEs were involved in the 2024 SA River Murray LTWP review (Table 2.1), including environmental water managers from DEW with technical expertise in site management or modelling plus external scientific experts with experience in field research, management and/or modelling from The University of Adelaide, Flinders University, SARDI and private consulting organisations. See Acknowledgements for further details.

Each expert was selected by DEW as someone with local, mostly multi-decadal, experience in researching or managing the site as well as for their specific expertise. This ensured that as a group, there was expertise and experience that covered the different biotic groups and ecological processes (themes) relevant to the CLLMM PEA (with multiple experts per theme, where possible). This effectively weighted the inputs of the selected experts based on their known 'performance' as relevant experts for the CLLMM PEA review, as opposed to selection of freshwater scientists not intimately familiar with the site, and is likely to have increased the validity of the collective experts' judgements compared to eliciting statements from experts without known, high-level 'performance' in the CLLMM region (Colson and Cooke, 2018).

At the beginning of the process, DEW provided a spreadsheet with the relevant ecological objectives and targets from the existing SA River Murray LTWP (2020), the draft Ramsar Management Plan (RMP, DEW 2024) and *The Living Murray* Condition Monitoring Plan (CMP, DEWNR 2017). Each expert was provided with the spreadsheet/s that related to their theme (e.g. Waterbirds, Vegetation) prior to the workshop. In some cases, revised 2024 SA River Murray LTWP objectives or targets were proposed in the spreadsheet by DEW as suggestions for discussion.

The first workshop was held on-line (9 May 2024). All participants were invited and 13 out of 16 attended (**Table 2.1**). The purpose of this first workshop was to explain the background and context of the project, the use of the objectives and targets and the SME collaboration process. A similar workshop was held for the Channel and Floodplain PEA project to ensure a consistent approach was taken for all 3 PEAs.

Then a series of themed workshops were held during May and June 2024, mostly on-line, with smaller groups of experts to discuss the details of the objectives and targets for that theme. Participants were able to choose which workshops to attend and the agendas for each were tailored to the theme and the expertise of the attendees. For some workshops, themes were combined for spatial management units (e.g. Lower Lakes) to increase efficiencies in structured discussions with the resultant suite of workshops, themes and participants shown in Table 2.1. The core DEW project team (Adrienne Rumbelow, Tracey Steggles and Sarah Ryan) and the facilitator (Kerri Muller) attended all workshops to guide the discussions, maintain consistency in approach (across themes and other plans, where appropriate) and look for any knowledge gaps or trade-offs between objectives and targets across the six themes.

Table 2.1. SA River Murray long-term watering plan 2024 review workshops and attendees

Theme	Date	Attendees
Context setting	09-05-2024	Claire Sims, Jason Nicol, David Paton, Sam Hardy, Qifeng Ye, Scotte Wedderburn, Ryan Lewis, Adrienne Rumbelow, Tracey Steggles, Sarah Ryan, Kerri Muller, Sabine Dittmann Attended previous: Chris Bice, Luke Mosley.
Ecosystem Processes	20-05-2024	Claire Sims, Adrienne Rumbelow, Tracey Steggles, Sarah Ryan, Kerri Muller.
Waterbirds	27-05-2024	David Paton, Sam Hardy, Adrienne Rumbelow, Tracey Steggles, Sarah Ryan, Kerri Muller.
Lamprey & Estuary/Coorong Fish	28-05-2024	Chris Bice, Qifeng Ye, Adrienne Rumbelow, Tracey Steggles, Sarah Ryan, Kerri Muller.
Lower Lakes (Fish, Vegetation, Turtles, Mussels, Yabbies)	31-05-2024	Jason Nicol, Scotte Wedderburn, Sam Hardy, Adrienne Rumbelow, Tracey Steggles, Sarah Ryan, Kerri Muller (apology: Qifeng Ye)
Submerged macrophyte/Ruppia communities	11-06-2024	Luke Mosley, Jason Nicol, David Paton, Michelle Waycott, Adrienne Rumbelow, Tracey Steggles, Sarah Ryan, Kerri Muller
Macroinvertebrates & Sediments	13-06-2024	Ryan Lewis, Sabine Dittmann, Luke Mosley, Adrienne Rumbelow, Tracey Steggles, Sarah Ryan, Kerri Muller
Draft target review & EWR Contributions	17-07-2024	Sabine Dittmann, Jason Nicol, , Sam Hardy, Michelle Waycott, Scotte Wedderburn, Ryan Lewis, Adrienne Rumbelow, Tracey Steggles, Sarah Ryan, Kerri Muller

The workshops each followed a similar format of reviewing the existing objectives and targets from the SA River Murray LTWP (2020), RMP (DEW 2024) and CMP (2017) for that theme. Each expert group developed recommendations to keep, amend or remove each objective or target. In some cases, new objectives and targets were developed based on updated knowledge or the wording of the objectives and targets in the RMP or CMP were adjusted for use in the SA River Murray LTWP. All inputs from participants were recorded in meeting minutes or recordings of MS Teams workshops and the notes were circulated back to the group for verification within 2 business days of the workshop. These minutes and notes have been used to generate the recommendations for

SA River Murray LTWP updates in Section 3. Where there were a variety of opinions regarding a given objective or target, the different views are outlined in the rationale sections of **Table 3.1** to 3.6.

An initial draft of this report was prepared by Dr. Muller in June 2024 and distributed for comments before a final workshop for all participants was held in late July 2024. During and after the final workshop, the wording of the recommended ecological objectives, targets and the rationale behind their selection was finalised (Section 3) and the EWR contributions towards the targets (Section 4) were discussed based on the suite of recommended ecological objectives and targets and the CLLMM EWRs as defined in Appendix D. The final draft was distributed to the experts and the peer reviewer in mid-August 2024 prior to finalisation.

2.2 Alignment with other site plans

The original ecological objectives and targets provided to the experts were based on those in the following key references include:

- Long-Term Environmental Watering Plan for the South Australian River Murray Water Resource Plan Area (updated November 2020) ('Existing SA River Murray LTWP')
- Condition Monitoring Plan (Revised) 2017 The Living Murray – Lower Lakes, Coorong and Murray Mouth Icon Site August 2017 (TLM CMP; DEWNR 2017)
- Ecological objectives, targets and environmental water requirements for the Coorong, Lower Lakes and Murray Mouth (O'Connor et al., 2015)
- Ramsar Management Plan: The Coorong and Lakes Alexandrina and Albert Wetland– draft for public consultation 2022 (DEW, 2024). (RMP). Note: only an excerpt from the draft RMP document was provided to the experts as a spreadsheet containing the Resource Condition Targets (RCTs).

The objectives and targets within each of these documents are broadly consistent, although there are differences in phrasing, timelines or foci due to the different purposes of the different plans. For example, the CMP describes TLM monitoring indices, the RMP describes the target resource condition for Ramsar planning, and the SA River Murray LTWP describes a healthy, functional ecosystem. It is recommended that this review is read in conjunction with the CMP (DEWR 2017) and latest version of the RMP, noting that the RMP is in draft form at the time of this review. Where appropriate, the whole of icon site (WOISS) scores used for the TLM CMP have been used for consistency across parameters and different plans for the site. The Objectives and RCTs for the RMP were largely developed in 2018-2021 and, where possible, adopted the TLM CMP objectives and targets, with some minor amendments to wording based on consultation with relevant scientific experts. The RMP includes objectives and RCTs in addition to those within the TLM CMP (e.g. various waterbird targets) as they were relevant to Ramsar listing criteria but less relevant to hydrological management.

Since the time that the content of the RMP was developed, the *Healthy Coorong, Healthy Basin* (HCHB) Trials and Investigations and Coorong Flood Response Project have been completed, with a particular focus on the ecology of the Coorong. This research addressed critical knowledge gaps and testing assumptions to determine how to transform the Coorong from its current vulnerable state to a healthier and more resilient ecosystem.

Collectively the HCHB project has provided the scientific evidence-base to inform management actions to improve the long-term health of the Coorong. These investigations have improved the understanding of the Coorong's processes, drivers and responses to increased freshwater flows. In addition, monitoring, evaluation and reporting against the CMP targets as part of *The Living Murray* Initiative has continued and been used to inform environmental water management. New information from this research and monitoring has been incorporated into this review of the CLLMM PEA through the involvement of subject matter experts, allowing the 2025 update of the SA River Murray LTWP to be based on the most up-to-date science.

3 Recommended updates

3.1 CLLMM PEA subregions

The existing SA River Murray LTWP identifies 4 sub-regions of the CLLMM PEA, as originally identified in the Lower Lakes, Coorong and Murray Mouth Environmental Water Management Plan (MDBA 2013). In reviewing and updating the ecological objectives and targets as part of this project, some amendments to the sub-regions are recommended.

Existing SA River Murray LTWP 2020 Subregions

1. The Lower Lakes - comprise Lake Alexandrina (c. 65,000 hectares) and Lake Albert (c. 23,000 hectares); both are large, shallow, permanent freshwater lakes fringed by various pool-connected (i.e. with sill levels lower than typical lake levels) and ephemeral wetlands (i.e. with sill levels above typical lake level). Lake Albert, however, is a terminal lake with no flow through to the estuary.
2. The lower reaches of the Eastern Mount Lofty Ranges (EMLR) tributaries - the lower reaches of the tributaries lie within the boundaries of the CLLMM PEA and their flows can influence ecological aspects of some areas associated with Lake Alexandrina but the tributaries themselves are part of the EMLR Water Resource Plan Area, which requires a separate LTWP.
3. The Murray Mouth estuary - the area typically extending from the Goolwa Barrage to Pelican Point that is highly dynamic being influenced strongly by barrage outflows, wind, tides and sand ingress.
4. The Coorong - a long (c. 140 km), narrow (c. 2 - 3 km), shallow lagoon, which is separated into the North Lagoon and South Lagoon by a narrow constriction at Parnka Point.

Recommended updates:

Adopt the following definitions and boundaries of the subregions and the additional definitions of terms developed to simplify the wording, better articulate the meaning, and define the scope of the objectives and targets. The EMLR tributaries were brought into the Lower Lakes because most of the targets apply to all suitable freshwater wetland habitats, which are interconnected around the fringes of the lakes.

Amend to the following 4 CLLMM PEA subregions:

1. **Lower Lakes and wetlands** (Wellington to the Barrages) **–** comprises Lake Alexandrina (c. 65,000 hectares) and Lake Albert (c. 23,000 hectares), the wetlands downstream of the confluence of the River Murray and Lake Alexandrina (near Wellington) that fringe the lakes and those located in the lower reaches of the Eastern Mount Lofty Ranges tributaries, noting that there is a separate long-term watering plan for the Eastern Mount Lofty Ranges PEA (DEW 2020).
2. **Murray Mouth and Barrages** (Goolwa Barrage, the most northerly barrage, to Pelican Point) – represents high energy areas with direct impacts of River Murray flows through the five barrages mixing with sea water coming in through an open Murray Mouth (five barrages from north to south: Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere Barrages).
3. **Coorong North Lagoon** (south of Pelican Point to north of Parnka Point) – refers to the hydrological North Lagoon of the Coorong, the flow through which constricts at Parnka Point before entering the South Lagoon, noting that the ecological processes and habitats do not entirely align with this hydrological unit spatially.
4. **Coorong South Lagoon** (Parnka Point to southern most extremity of South Lagoon) – refers to the hydrological South Lagoon of the Coorong, including the connected water bodies south of Parnka Point to the southern extent of the Coorong lagoon water body and the confluence with Salt Creek.

Rationale - These 4 subregions are more closely aligned to the gross geomorphological features and hydrology used for management purposes than the existing subregions. From an ecological perspective, however, there are different habitat or population boundaries and different dispersal attributes of different taxa that provide eco-hydrological connections within and between these subregions. Some of the updated objectives and targets refer specifically to one or more of the four subregions and others operate across the whole of the CLLMM PEA.

Note: **if an objective does not specify** an area, then it applies to the whole CLLMM PEA. For example, "Maintain or improve waterbird populations" refers to all areas of the CLLMM PEA, but not to areas outside of the SA River Murray LTWP CLLMM PEA area.

Recommended new management terms to simplify the wording of the objectives and targets, articulate their meaning and further describe ecologically functional units the following management terms have been used:

- **The Coorong** – refers to the two, connected lagoons, North Lagoon and South Lagoon. That is the area from Pelican Point to the southernmost extremity of the South Lagoon.
- **Functional mudflats** – are habitats with diverse and abundant macroinvertebrate communities and healthy sediments. A variety of macroinvertebrates bioturbate or bioirrigate the sediments, creating well-oxygenated sediments with high surface areas for efficient biogeochemical cycling by a range of microbes that cycle and remove nutrients (e.g. nitrification-denitrification). Healthy, well-oxygenated sediments with strong macroinvertebrate populations are less likely to form Acid Sulfate Soils (ASS), including the most hazardous Monosulfidic Black Oozes (MBOs) that are unhealthy and hostile habitats for macroinvertebrates. Functional mudflats also need to provide harvestable prey resources for predators such as birds and fish. To be functional foraging habitat, therefore, mudflats are not dominated by Acid Sulfate Soils (ASS), carry diverse and abundant macroinvertebrate communities (i.e. food resources for predators) and have water levels that, although fluctuating due to tidal influence and wind seiching, are periodically less than 5 cm deep to enable depth-limited foragers to access food (e.g. short-beaked waders). It is acknowledged that the spatial areas that will satisfy this definition will occur at the water's edge in many parts of the whole CLLMM PEA, and that these may alter over time at a range of scales from hours to months, depending on river flows, barrage outflows, lake levels, tides, winds and seasonal water level changes.
- **Submerged macrophyte communities –** are communities of aquatic plants that have most of their plant tissue growing in the water column (as opposed to emergent plants that have leaves or stems above the water surface). These plants require suitable substrates that they can grow in (i.e. not rocky), appropriate water depths to remain within the euphotic zone and shear forces weak enough to allow strong growth without damage or being scoured out of the substrate. The target submerged macrophyte community for the Coorong includes salinity tolerant species as described by Lewis et al. (2022) and Waycott et al. (2022) (i.e. *Ruppia tuberosa* ± *Althenia cylindrocarpa* vegetation associations) and the *Ruppia tuberosa* communities described in Paton et al. (2017). In addition, where salinities are on average lower than 60 ppt during the growing season (winter and spring), the target submerged macrophyte community would be expected to include additional species such as *Ruppia megacarpa* and other species tolerant of wide ranges of salinities (e.g. *Lamprothamnium papulosum*). A healthy, functional Coorong is, therefore, expected to have a diversity of submerged macrophyte species in a dynamic mosaic that shifts in species composition in response to physico-chemical conditions (e.g. salinity and water levels). The exceptions are areas in the high energy zones of the Murray Mouth and Barrages subregion where shear forces and sediment instability are too high to support colonisation of dense or permanent submerged macrophyte beds and therefore the Coorong vegetation targets do not include this subregion but only the North and South Coorong lagoons. It is also important to acknowledge that stipulation of targets to the plant species level is complicated by their co-occurrence, highly responsive life history strategies and morphological similarities, which require DNA sequencing to confirm plant tissue to species level, unless gross morphological features (e.g. flowering or fruiting structures and/or turions) are present and destructively harvested for identification purposes. It is acknowledged that the Coorong South Lagoon has been dominated by the highly salt tolerant *Ruppia tuberosa*, a favoured and valuable waterbird fodder plant, for the last 50 years (Paton pers. comm. August 2024). It is expected that the salinity and water level targets presented here for a healthy and functional CLLMM PEA will favour a diverse range of macrophyte species with

lower salinity preferences, however, conditions suitable for *R. tuberosa* will also occur in more saline areas of the South Lagoon at different times due to evapo-concentration, especially during dry conditions, ensuring that this valuable plant remains part of the submerged macrophyte assemblage.

3.2 Waterbirds objectives and targets

The existing SA River Murray LTWP (2020) had one objective and four targets for waterbirds that are reviewed in **Table 3.1**. The experts involved in this review (**Table 2.1**) recommended that:

- The objective be amended and simplified to include all sub-regions of the CLLMM PEA
- Two targets – those relating to abundance, occupation and occurrence, and breeding – be replaced with nine updated targets (note: six of these are taken from TLM CMP)
- The recommended functional mudflat definition is used as described above; and
- The flyway target is removed and not replaced.

The recommended wording and the rationale for these recommendations are presented in **Table 3.1**, along with potential complementary actions to enhance the health and function of the CLLMM PEA for waterbirds. Reference data for the targets is provided in Appendix B. It is important to recognise that waterbirds are mobile and opportunistic users of wetland habitats that can be difficult to monitor. Their use of the CLLMM PEA may be affected by international factors (i.e. habitat loss and degradation of key staging sites in the Yellow Sea; Clemens et al. 2016; Studds et al. 2017; Lisovski et al. 2021) or continental factors outside of the Murray-Darling Basin (e.g. wet and dry climate phases, rainfall patterns in south-east SA, filling of outback lakes; Wen et al. 2016; Prowse et al. 2022; Jackson et al. 2022; Porter et al. 2022) or outside of management influence (e.g. large floods in the River Murray filling floodplain lakes; see also complementary DEW project for Basin Plan Matter 8 reporting in progress). Species that rarely or do not breed in the Coorong or Murray Mouth and Barrages (e.g. Banded Stilt, Red-necked Avocet, Hoary-headed Grebes, Whiskered Terns, Black-winged Stilts, and Eurasian Coots) can show dramatic reductions in abundance when the availability of inland wetlands increases (Paton et al. 2018). Complementary actions such as fox control to increase waterbird breeding and survival, and wetland management to ensure that abundant food and habitat resources are always available were also considered important to enhance waterbirds in the CLLMM PEA.

Table 3.1. Recommended updates to waterbird objectives and targets

Waterbird Objectives and Targets – Recommended Updates
Waterbird Objective – Whole of site
Existing SA River Murray LTWP 2020 Objective Maintain or improve waterbird populations in the Coorong and Lower Lakes.
Recommended update **Amend to –** Maintain or improve waterbird populations.
Rationale The objective has been simplified to include all parts of the CLLMM PEA by not specifying any. This ensures no areas were excluded such as the Murray Mouth and Barrages subregion, which was not included in the 2020 objective, and are known to be important areas for waterbirds, especially when macroinvertebrates (an important

Waterbird Objectives and Targets – Recommended Updates
waterbirds food source) are restricted to, or concentrated in these northern areas downstream of the barrages. This recommended update also includes the wetlands fringing the lakes and those in the lower reaches of the EMLR tributaries (part of the recommended "Lower Lakes and wetlands" subregion).
Waterbird Targets
Existing SA River Murray LTWP 2020 Target Abundances, area of occupation and extent of occurrence of TLM target waterbird species (Table 18 in Appendix 4) to be above defined median reference values (median of data from the 15 years between 2000 and 2014) (Paton 2014a).
Recommended update **Replace** the one existing target with the following targets which were based on the CMP Waterbird abundance, occupation and occurrence targets, noting that the species lists are documented in the TLM CMP and provided in Appendix B: • Exceed the long-term (2000–2015) median value for abundance of each of 40 selected waterbird species in the Coorong in two of the last three years. • Exceed the 75% threshold for the long-term (2000–2015) area of occupation (AOO) for each of 40 selected waterbird species in the Coorong. • Exceed the 75% threshold for the long-term (2000–2015) extent of occurrence (EOO) for each of 40 selected waterbird species in the Coorong. • Exceed the recent (2013–2015) median value for abundance of each of 25 selected waterbird species in the Lower Lakes in two of the last three years. • Exceed the lower 75% threshold for the recent (2013–2015) AOO for each of 25 selected waterbird species in the Lower Lakes and fringing wetlands. • Exceed the lower 75% threshold for the recent (2013–2015) EOO for each of 25 selected waterbird species in the Lower Lakes and fringing wetlands.
Rationale Significant data analysis was undertaken to develop the CMP targets for abundance and area of occupancy that can be adopted by the LWTP for consistency. All these targets are being monitored and reported on so all six CMP targets have been included. The 2000-2015 period is important for the Coorong because it reflects the drought and the post-drought period when the system was getting 'back into phase' after the perturbations of the Millennium Drought. Waterbird abundances may have diminished during the drought although there were areas where some species could congregate. The 2013-2015 period is important for the Lower Lakes because although the census data was collected from 2009, it took until 2013 for the waterbird populations to recover after the very low lake levels experienced during the Millennium Drought. Peak abundances were observed around the Lower Lakes in 2015, but they have declined since, which may be due to changes in competition and/or food resource disruptions (e.g. lower carp numbers after drought that have now returned to pre-drought levels). Neither of these periods are ideal baselines for targets and it needs to be acknowledged that waterbird abundances had already been significantly diminished by 2000 and thus these baselines may underestimate waterbird abundances that would represent a healthy and functional ecosystem.

Waterbird Objectives and Targets – Recommended Updates
Modern management of Lower Lakes levels may be consistently too high to optimise foraging opportunities, which is why complementary management of wetlands fringing the Lower Lakes is also recommended (e.g. Tolderol Game Reserve and Teringie wetlands).
Existing SA River Murray LTWP 2020 Target Detect annual breeding activity in waterbird species that are expected to breed annually at the site (Table 19 in Appendix 4) and at least two breeding events in any four consecutive years in species that breed regularly at the site (Table 20 in Appendix 4) (DEWNR in prep(a)).
Recommended update **Replace** with two new targets as follows, noting that the list of waterbird species known to breed annually in the CLLMM PEA is provided in Appendix B: • Maintain annual breeding of waterbird species that are known to breed at the site annually. • Increase the number of threatened waterbirds of breeding age compared to 2000– 2015.
Rationale Breeding success is difficult to detect. Ibis and Swan nests are relatively obvious and easy to see, but others not so. The CLLMM PEA is not like other icon sites that support large colonial breeding events. It is also difficult to know how waterbird breeding relates to water delivery at a site scale – for example, it would be appropriate to increase environmental water volumes to prevent the decline in water levels in the Coorong to support breeding for some species, but not others. Maintaining annual breeding for the species listed in Appendix B is appropriate for the CLLMM PEA, but the aim should be to enhance breeding for some threatened species (e.g. Fairy tern and Hooded plover) and thus there is a need for two targets. It should be noted that the list of species that categorised as threatened is increasing over time due to global declines in populations.
Existing SA River Murray LTWP 2020 Target Provide functional mudflat habitat to sustain active shorebird foraging behaviour during November- March with a foraging effort of 50% (Murray-Daring Basin Authority 2014e).
Recommended update **Amend to** - Provide functional mudflat habitats to sustain shorebirds, especially during September to April.
Rationale The main foraging areas in the Lower Lakes (and EMLR) sub-regions are fringing wetlands, irrigated pasture and recently inundated wetlands. Foraging occurs in these habitats when areas are inundated leading to the terrestrial bugs departing and emergence of new populations from sediment egg banks (e.g. ostracods, rotifers). In the Coorong, the foraging areas are functional mudflats (see definition above) from the Murray Mouth and Barrages south to the southern extremity of the South Lagoon. Extensive areas of functional mudflats are foundational to a healthy and functional CLLMM PEA, however, their presence may not necessarily lead to them being utilised by waterbirds for various reasons. It is also difficult to define, and measure, functional mudflats given that the water levels could be right, but the mudflats may not be functional as foraging areas due to other factors (e.g. dense filamentous algae smothering the mud surface, utilisation of alternative feeding areas; also see other targets below that further address this risk). It is also important to recognise that water birds are feeding on mudflats that are covered by shallow water (optimal <5cm) rather than exposed mudflats, which means that the functionality of mudflats is also highly dynamic at a patch and a whole of site scale, and depends on a range of factors, including rising or falling water levels, tidal

Waterbird Objectives and Targets – Recommended Updates
range, the types of macroinvertebrates present and at what depth, etc. It is important that waterbirds have the right food in the right place. It is difficult to define how much functional mudflat is needed to support a healthy and functional ecosystem at a whole of site scale, and it is also important to acknowledge that freshwater wetlands and Coorong lagoon mudflats provide very different habitats and resources.
Existing SA River Murray LTWP 2020 Target Maintain abundances of 12 waterbird species (Table 21 in Appendix 4) at or above 1% of the total flyway population size (DEWNR in prep (a)).
Recommended update **Remove** target and do not replace.
Rationale This is not needed in the SA River Murray LTWP because abundance of the 12 identified flyway species is already assessed above by the proposed abundance target, as the 12 waterbird species are included in the 40 Coorong species.
Waterbird – Complementary actions
• Environmental watering and barrage operations – seasonal water level manipulation in Lakes Alexandrina and Albert using water for the environment and variable bulk water delivery to the Coorong in spring and summer to promote food resources. • Wetland management – wetting and drying of managed wetlands (e.g. Tolderol Game Reserve, Teringie) around the Lower Lakes increases the habitat and food resources for a range of waterbirds; relatively small areas but they can provide significant resources and at critical times in the migratory bird season (November to April). • Fox control – south-east SA had many more waterbird nests before the introduction of foxes; particularly important to control foxes on Younghusband Peninsula for Fairy terns, Hooded plovers and Pied oyster catchers. • 4WD management – hooded plovers breed on ocean beaches in summer and are vulnerable to 4WDs and other recreational activities. • Disease management – it is likely that the risk of disease is always present, however, it can be affected by water regime and provision of food resources (e.g. areas where birds congregate will be likely to have higher transmission rates). Risk can be reduced by providing a mosaic of wetland habitats across the site with healthy and functional food webs and variable water levels. • Hunting controls – Tolderol Game Reserve includes the adjacent shores of Lake Alexandrina. DEW administers hunting permits and has provided a guide for responsible and sustainable hunting. Members of the hunting community are strong advocates for wetland conservation and are among the volunteers that manage Tolderol Game Reserve wetlands.

3.3 Fish objectives and targets

The existing SA River Murray LTWP (2020) had 1 objective and 10 targets for Fish that are reviewed in **Table 3.2**. The experts involved in this review (**Table 2.1**) recommended that:

- The existing objective be amended into a more general Fish Diversity objective that includes the whole CLLMM PEA.
- New objectives are included for the different functional groups of fish: Diadromous fish, Estuarine fish, Small-bodied Coorong fish and Threatened fish.
- The ten targets are amended and collated with new targets, such that there are 16 targets nested under the 4 fish functional groups as described in Table 3.2.

The recommended wording and the rationale for these recommendations are presented in **Table 3.2**, along with potential complementary actions to enhance the health and function of the CLLMM PEA for fish. It is important to recognise that the CLLMM PEA fish community is highly dynamic and will respond on a range of spatial and temporal scales to a range of environmental drivers (e.g. connectivity, water levels, water quality see Bice et al. (2018); Wedderburn et al. (2019); Ye et al. (2016)). Some species range into marine and/or freshwater environments outside of the CLLMM PEA and the conditions in those habitats may affect the CLLMM population dynamics. Complementary actions such as fishway, barrage and dredge operations are also important factors in determining the diversity, abundance and distribution of fish across the CLLMM PEA. See also fish passage targets in Ecosystem Processes (Section 3.9).

Table 3.2. Recommended updates to Fish objectives and targets

Fish Objectives and Targets – Recommended Updates
Fish Diversity Objective
Existing SA River Murray LTWP 2020 Objective Maintain a spatio-temporally diverse fish community and resilient populations of key native fish species in the Lower Lakes and Coorong.
Recommended update **Amend to -** Maintain a spatio-temporally diverse and resilient fish community.
Rationale The fish diversity objective may not be considered essential because the different fish groups are covered in other objectives and targets below. It is a community-level and whole of site objective, however, which is a useful indicator even though it may be difficult to quantify. A general objective like this also acknowledges that the CLLMM PEA is a dynamic system that would have highly dynamic, diverse and resilient fish communities when it is healthy and functional.
Fish Diversity Targets
Existing SA River Murray LTWP 2020 Target A spatio-temporally diverse fish community is present including all 23 fish families stated in the Ramsar site draft Ecological Character Description (Table 22 in Appendix 4) (Department of Environment Water and Natural Resources, in prep (a)).

Fish Objectives and Targets – Recommended Updates

Recommended update

Amend to the following wording, noting that the list of fish families is shown in Appendix C:

A spatio-temporally diverse native fish community present across the whole site, including all 17 fish families, with annual observations of both common and threatened species.

Rationale

As for the overarching fish diversity objective, this fish diversity target is not essential, but it does provide an indicator of what is happening at the community level not just the functional group level. The data to evaluate this target are available and it is a good measure of a healthy and functional CLLMM PEA due to the need for a diversity of fish to move around the site and have adequate habitat and food resources available to support a resilient community. Also, the annual observations of threatened species (e.g. Murray hardyhead) would provide a specific, quantifiable measure of success in meeting this target as a robust indicator of healthy freshwater fish communities resulting from successful water management). The number of fish families was amended from 23 to 17 to be consistent with the review and update of the RMP (DEW 2024; Appendix C).

Diadromous Fish Objective

Existing SA River Murray LTWP 2020 Objective

No existing objective for diadromous fish.

Recommended updates

New Objective- Successful migration and recruitment of diadromous fish.

Rationale

Diadromous fish are an important functional group within the CLLMM PEA fish community because they rely on successful migration between the ocean, the freshwater parts of the site and the River Murray to complete their life cycles. This is a specific ecological process that occurs at the CLLMM PEA and not at any other MDB PEA because the CLLMM PEA is the only marine connection in the MDB, and therefore the only site at which diadromous fish can access the ocean. The existing SA River Murray LTWP had just one fish objective and it is recommended that a specific objective is added for this functional group.

Diadromous Fish Targets

Existing SA River Murray LTWP 2020 Targets

- Annual detection of juvenile Catadromous fish at abundances ≥ that of defined 'Recruitment Index' values (44.5 for Congolli, and 6.1 for Common galaxias) (Bice et al., 2014).
- Annual detection of migration for Anadromous species (short-headed and pouched lamprey) at index values of >0.6 (Bice et al., 2014).

Recommended updates

Amend into four new/revised diadromous fish targets as follows:

- The annual abundance of upstream migrating YOY congolli (*Pseudaphritis urvillii*) is ≥ the mean recruitment reference value (i.e. 44.5 YOY/hr).

Fish Objectives and Targets – Recommended Updates

- The annual abundance of upstream migrating YOY common galaxias (*Galaxias maculatus*) is ≥ the mean recruitment reference value (i.e. 6.1 YOY/hr).
- Pouched lamprey (*Geotria australis*) are sampled from ≥60% of large vertical-slot fishway sites* when barrage discharge is <30,000 ML/d across the winter sampling season and present when discharge is ≥ 30,000 ML/d and all years.
- Short-headed lamprey (*Mordacia mordax*) present in all years^.

Footnotes: *Large fish ways include Mundoo, Goolwa, Ewe Island, trap and large Vertical slot fishway at Tauwitchere and exclude Boundary Creek and the small fishways at Tauwitchere, Goolwa and Hunters Creek. ^presence in a year includes detection in any fishway, at Lock 1 or any other part of the River Murray system.

Rationale

These recruitment conditions are likely to be met in years with "good flows" and are less likely to be met in "poor flow" years and thus they are considered to be reasonable estimates. The target recruitment reference values could be updated because they were based on the 2006-2012 period and therefore include data from immediately prior to the Millennium Drought, during the drought and the first few years after the Lower Lakes refilled and the barrages reopened. It is difficult to know if this is the most appropriate reference level given that it was a period of sequential disturbances and does not necessarily reflect a healthy and functional ecosystem. It is important that the fish targets consider trajectories and not just reference points. The SA River Murray LTWP objectives and targets refer to a healthy and functional ecosystem and therefore should be more ambitious than TLM CMP targets to reflect higher abundances expected in a healthier and more functional system. The TLM CMP target values are annual means based on seasonal sampling of several fishways. Lampreys are difficult to catch, are often caught in low numbers and have hard to define spatial boundaries. Catch numbers may not be a true indication of abundance, therefore, which may indicate that a frequency detection method may be more appropriate than a firm reference value i.e. data could be analysed to look at the proportion of fishways at which they were detected in "good" and "poor" and develop a range from that. This may also elucidate threshold values/preferred fishway movements to describe a reference for a healthy, functional ecosystem. The target is focussed on the primary fishways and includes detection at Lock 1 or other sites outside of the CLLMM PEA as a measure of successful connectivity between marine and freshwater habitats.

Estuarine Fish Objective

Existing SA River Murray LTWP 2020 Objective

No existing objective for estuarine fish.

Recommended updates

New Objective- Restore resilient populations of estuarine fish.

Rationale

Estuarine fish had targets in the existing SA River Murray LTWP, but not a specific objective. They are an important indicator of a healthy, functional ecosystem and should have their own objective to reinforce their importance, be consistent with other fish functional groups and ensure that all the components of the diverse fish community are accounted for. Estuarine fish may occasionally use the Lower Lakes, but the Murray Mouth and Barrages subregion is vital habitat for this group and contains the most productive habitats in the CLLMM PEA for estuarine fish. Three species are the focus of monitoring and reporting for this group: Black bream, Greenback flounder and Mulloway.

Fish Objectives and Targets – Recommended Updates

Estuarine Fish Targets

Existing SA River Murray LTWP 2020 Targets

- Maintain or improve abundances, distribution and recruitment of Black bream and Greenback flounder with population condition score ≥3 (Ye et al. 2014a).
- Facilitate regular recruitment and a broader distribution of juvenile Mulloway (Ye et al. 2014a).

Recommended updates

Amend into three new/revised estuarine fish targets as follows, where WOISS refers to Whole of Icon Site Target:

- Revised Target - WOISS equal to 4 (maximum value) for Black bream (*Acanthopagrus butcheri*) on an annual basis.
- Revised Target - WOISS equal to 4 (maximum value) for Greenback flounder (*Rhombosolea tapirina*) on an annual basis.
- New Target - Detect juvenile Mulloway in at least 50% of the Coorong and Murray Mouth and Barrages subregions.

Rationale

The targets for Black bream and Greenback flounder are based on WOISS which include distribution, abundance, demographics and YOY recruitment factors. The WOISS of '4' is the best that can be expected and is therefore considered an appropriate fish population condition for the SA River Murray LTWP that aims for healthy functioning ecosystem (Ye et al. 2023). Updated targets will not contain references to the tables but rather will reference the CMP.

Knowledge gap - for the Mulloway target, the recruitment component generally aligns with the BEWS QEEO, and the distribution target largely aligns with the BEWS QEEO for other estuarine fish distribution (Black bream and Greenback flounder). The Coorong and Murray Mouth and Barrages subregions provide an important nursery ground for Mulloway, noting all Mulloway caught by commercial fishers inside the Murray Mouth (within the Coorong) are juveniles – even legal ones (minimum legal length within the Coorong: 46 cm total length), noting this species use estuaries as nursery ground and they are not mature till approximately 5-6 years of age (>80 cm total length). The extent of suitable estuarine habitat for Mulloway is strongly driven by freshwater inflows from the River Murray and salinity gradient from the Murray Mouth along the full length of the Coorong. The distribution target for Mulloway could be examined using fishery catch data reported by fishing block to indicate Mulloway distribution across the Coorong and Murray Mouth and Barrages areas. In addition, assessing Mulloway recruitment could be done by examining population age structure via collecting otoliths from recreational/commercial fishers for age determination. It would also improve consistency across targets if a WOISS index for Mulloway was developed.

Small-bodied Coorong Fish Objective

Existing SA River Murray LTWP 2020 Objective

No existing objective for estuarine fish.

Fish Objectives and Targets – Recommended Updates

Recommended updates

New Objective- Maintain abundant, resilient populations of small-bodied fish in the Coorong and Murray Mouth and Barrages, including Small-mouthed hardyhead and Sandy sprat.

Rationale

Different flow requirements, life histories and distribution of small-bodied Coorong fish compared to large-bodied fish justifies a specific objective for these fish as part of a healthy, functioning ecosystem. Small-bodied Coorong fish are also key prey species in the Coorong and Murray Mouth and Barrages subregions. Sandy sprat are a marine-estuarine opportunistic species, not a solely estuarine species like Small-mouthed hardyhead, which can reproduce in the estuary. If this objective was just for Small-mouthed hardyhead it could use the term "self-sustaining" rather than "resilient" to reflect this difference between the species and their use of the Murray Mouth estuary. The existing objective in the TLM CMP was 'to maintain abundant self-sustaining populations of Small-mouthed hardyhead in the North Lagoon and South Lagoon of the Coorong'. The term "self-sustaining" is considered less appropriate to cover both fish species than the term "resilient" because Sandy sprat do not complete their life-history cycle within the Coorong.

Small-bodied Coorong Fish Targets

Existing SA River Murray LTWP 2020 Targets

- Maintain an average Catch-Per-Unit-Effort (CPUE) of Small-mouthed hardyhead sampled in spring/early summer of >120 for adults, and in autumn >790 for juveniles (Ye et al. 2014b)
- Maintain the proportional abundance of Small-mouthed hardyhead juveniles at >60% in 75% of defined monitoring sites within the CLLMM (Ye et al. 2014b).

Recommended updates

Amend into two new small-bodied Coorong fish targets as follows:

- Small-mouthed hardyhead (*Atherinosoma microstoma*) populations achieve a WOISS of ≥4 on an annual basis.
- Maintain annual population abundance (Catch Per Unit Effort – CPUE) of Sandy sprat (*Hyperlophus vittatus*) throughout the Coorong and Murray Mouth and Barrages subregions.

Rationale

Including both species is consistent with BEWS QEEO. Small-mouthed hardyhead and Sandy sprat are the most abundant prey species in the Coorong. They are sensitive to freshwater inflows. Small-mouthed hardyhead generally dominate the Coorong North and South Lagoons while Sandy sprat are most abundant in the Murray Mouth and Barrages subregion. Under typical conditions, Sandy sprat are highly abundant in the Murray Mouth estuary and northern Coorong, whereas Small-mouthed hardyhead dominate the southern parts of the Coorong. With higher inflows and consequent reduced salinities in the Coorong, Sandy sprat can increase in distribution to occupy habitats at the southern end of the North Lagoon and sometimes the South Lagoon, making them good indicators of a healthy, functional ecosystem. The WOISS value of 4 indicated here for Small-mouthed hardyhead represents a healthy population, and therefore it is an appropriate target for the SA River Murray LTWP. The best score '5' indicates extremely good condition for this species.

Knowledge gap – do not have a WOISS index for Sandy Sprat yet, although the data is available to be analysed.

Fish Objectives and Targets – Recommended Updates

Threatened Fish Objectives

Existing SA River Murray LTWP 2020 Objective

No existing objective for threatened fish.

Recommended update

New Objective - Increase distribution and recruitment success of threatened fishes in the Lower Lakes and wetlands to enhance resilience of existing, and establish new, self-sustaining populations.

Rationale

Threatened native fishes in the Lower Lakes are key indicator species (ecological specialists) that are sensitive to changes in physical habitat, water quality and water levels. The recommended objective refers to existing and new populations because the three threatened species were lost from the Lower Lakes during the Millennium Drought. Reintroductions have been successful for southern pygmy perch (Marshal et al. 2022), and the species continues to meet the WOISS target for the Lower Lakes (Wedderburn and Bailey 2024). Initial reintroductions were unsuccessful for Yarra pygmy perch (Wedderburn et al. 2020; Wedderburn et al. 2022) but further re-stocking commenced over 2023–24 (Zukowski 2024). The dynamic nature of Murray hardyhead means the objective is difficult to define for the species.

Threatened Fish Targets

Existing SA River Murray LTWP 2020 Target

- Maintain or improve abundances of Murray hardyhead and Pygmy perch so that 'Relative Abundance Index' values of ≥1 are achieved on an annual basis (Wedderburn 2014)
- Detect recruitment success of Murray hardyhead and Pygmy perch at least every second year (Wedderburn 2014)

Recommended update

Amend into five new/revised threatened fish targets as follows:

- Murray hardyhead (*Craterocephalus fluviatilis*) WOISS >0.5 in autumn of low to moderate flow years and detected in years of moderate to high river flows*.
- Yarra pygmy perch (*Nannoperca obscura*) WOISS >0.5 on an annual basis with wild recruits detected in autumn sampling and maintenance of populations at release sites.
- Southern pygmy perch (*Nannoperca australis*) WOISS >0.5 on an annual basis with wild recruits detected in autumn sampling and maintenance of populations at release sites.

*If Murray hardyhead are detected in March then likely to be YOY because adults will have been lost from the populations after breeding in spring.

Rationale

It is recommended that Murray hardyhead and the two pygmy perches have different targets to better reflect their ecological differences and recovery following reintroductions after the Millennium Drought. Murray hardyhead are rarely detected during higher flows because they disperse readily (Hammer and Wedderburn 2008), and the species' abundance and distribution is closely linked to changing salinities (Wedderburn et al.

Fish Objectives and Targets – Recommended Updates
2007). Conversely, Southern pygmy perch numbers are greater during and following moderate to high river flows and high lake water levels (>0.6 m AHD: Wedderburn et al. 2019). The CMP contains more details about Murray hardyhead dynamics and the way the targets are outlined. The CMP targets are working well for Southern pygmy perch. Yarra pygmy perch remains extinct in the Lower Lakes. It is the first freshwater fish to have been extirpated in the Murray Darling Basin. The WOISS target will not be met until the population establishes following stocking (Zukowski 2024). The renewed and dedicated efforts to reintroduce Yarra pygmy perch to the habitats associated with Lake Alexandrina from 2023 to 2026 aim to see a positive trajectory in Yarra pygmy perch populations towards a WOISS of 0.5 by March 2027. It is expected that future release sites for both Yarra pygmy perch and Southern pygmy perch will be in low-risk salinity sites, that is sites that are far enough upstream from the barrages to be protected from salinity increases due to future seawater ingress. It is expected that the targets for Yarra pygmy perch will fail until 2027. The success of Yarra pygmy perch releases and maintenance of Southern pygmy perch populations depends on suitable river flows and lake water levels with spring flow pulses to >0.8 m AHD and maintenance of autumn levels >0.6 m AHD, where the species should be detected at condition monitoring sites in future years (see Section 4). It should also be noted that under EPBC Act guidelines, new translocated stocks/subpopulations were not considered for protection until the introduced subpopulation has produced viable offspring (i.e. offspring that have reached maturity or are likely to do so) and at least five years have passed since the introduction. **Knowledge gap –** it is not known if the WOISS for Murray hardyhead will be sensitive enough to periods of changing flows. It should work well when the fish are present in low to medium flow years but if they are in low numbers, it may not be as meaningful. At minimum, Murray hardyhead should be detected during monitoring to confirm its presence in the Lower Lakes, which would indicate the species is ready to increase in abundance and distribution when its most favoured conditions occur (i.e. low lake levels and associated increases in salinities). It should be noted that TLM condition monitoring occurs at 24 sites and Murray hardyhead may shift to different sites during times of moderate to high flows, but this requires investigation.
Large -bodied Freshwater Fish Objective
Existing SA River Murray LTWP 2020 Objective No existing objective for large-bodied freshwater fish.
Recommended updates **New Objective**- Restore resilient populations of Golden perch (*Macquaria ambigua*).
Rationale The large-bodied freshwater fish objective is centred on Golden perch because there are very little data on Silver perch or Murray cod for downstream of Wellington. They are both in low abundance in the CLLMM PEA and are protected species, therefore, there are no commercial fishery data. Developing objectives for restoration of Silver perch and Murray cod would be consistent with the SA River Murray LTWP describing a healthy and functional ecosystem given that all three of these large-bodied freshwater fish would be abundant in that ecosystem state.
Existing SA River Murray LTWP 2020 Target No existing targets for large-bodied freshwater fish.
Recommended updates **Amend into three new large-bodied freshwater fish targets** as follows:

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- Population age structure[a] of Golden perch has at least one strong (>20%) cohort in the first 5 years, two or more moderate (>15%) cohorts and >10% fish >10 years of age.
  [a] Based on commercial fishery catch by large mesh gill net in the Lower Lakes.
- Biomass of Golden perch (measured as targeted CPUE[a]) >1.04 kg.net-day^{-1}.
  [a] Based on commercial fishery catch by large mesh gill net in the Lower Lakes.
- Cohorts of Golden perch originate from multiple spatial recruitment sources including the lower Murray and Lower Lakes.

Rationale

For developing the first Golden perch target for the Lower Lakes, the age structure target for Golden perch in the River Murray Channel was considered, however unlike the Channel and Floodplain PEA target, which was based on fishery-independent data, the Lower Lakes target was developed based on the age structure of commercial fishery catch (legal sized fish, similar to Black bream). Currently there is no long-term fishery-independent sampling program for large-bodied freshwater fish in the Lower Lakes. Note that Golden perch will take ~3-5 years to grow to legal size and enter the fishery, therefore, the proposed target of age structure largely reflects the demographics of adult population with regular large recruitment events at expected frequency under favourable flow conditions. The target for >10% fish >10 years of age is based on the age structures of Golden perch in the South Australian lower River Murray from 2015 to 2023, which was not impacted by commercial fishery. Similarly, due to lack of fishery-independent monitoring, the second Golden perch target was developed based on commercial fishery catch data using *annual targeted catch per unit effort* (CPUE) as an indicator of biomass/abundance of this species in the Lower Lakes. The reference point aligns with that in the Lakes and Coorong Fishery Management Plan (PIRSA 2022), which was determined based upon historical CPUE data from the reference period of 1985–2017. Catch rates during this period effectively maintained golden perch stock at, or above sustainable levels in the Lower Lakes. The target reference point represents the 10th highest annual catch rate during the reference time period, suggesting population abundance was among the 10th highest level over a period of 33 years with variable hydrology including years with favourable high flows. The third Golden perch target is adapted from the proposed target for the Channel regarding recruitment sources, considering population connectivity (movement) between the River Murray Channel and the Lower Lakes and a level of local spawning at times (Bice et al. 2023).

Fish – Complementary actions

- Operation of the fishways and barrages to optimise connectivity and fish movement at different lake levels and barrage outflows (see Section 3.6).
- Operation of a dredge to keep the Murray Mouth open, if freshwater discharges are inadequate (see Section 3.6).
- Further stocking of SPP and YPP into new locations, targeting sites with *Ceratophyllum demersum* and *Typha sp.* to provide shady, complex habitats with healthy invertebrate communities.
- Hydrological manipulation of the Lower Lakes to ensure that Hindmarsh Island sites containing SPP and YPP experience variable water levels including spring flow pulses and lake water levels >0.6 mAHD in summer–autumn.
- Commercial fishing management – i.e. Black bream no take periods during spawning season

Fish Objectives and Targets – Recommended Updates
• Salt Creek management – provides connectivity and refuge habitat when environmental condition deteriorates in the South Lagoon (e.g. salinity increases to unfavourable levels).

3.4 Microinvertebrate and sediment objectives and targets

The existing SA River Murray LTWP (2020) has 1 objective and 4 targets for macroinvertebrates, as well as 1 objective and 2 targets for habitable sediment conditions that are reviewed in **Table 3.3**. The experts involved in this review (**Table 2.1**) recommended that:

- The objective be amended to include all sub-regions of the CLLMM PEA;
- The 4 macroinvertebrate targets are amended, which will require updating of the reference ranges;
- The sediment objective is revised to include macrophytes as well as macroinvertebrates;
- The sediment targets are reviewed and new targets included; and
- Three new targets relating to Yabbies and Floodplain mussels are included.

The recommended wording and the rationale for these recommendations are presented in **Table 3.3** along with potential complementary actions to enhance the health and function of the CLLMM PEA for macroinvertebrates. It is important to recognize that macroinvertebrate communities are highly dynamic and respond quickly to environmental changes, which has led to their use as indicators for estuarine environmental health globally (Wildsmith et al. 2011; Tweedley et al. 2012; Vinagre et al. 2015; Ndhlovu et al. 2024). Their occurrence in estuaries aligns with environmental drivers, most notably salinity, as most macroinvertebrate species are not tolerant to hypersaline conditions (Kangas and Geddes 1984; Whitfield et al. 2012; Dittmann et al. 2015; Little et al. 2017). Sediment characteristics (e.g. grain size, thickness of oxic layers) also effect macroinvertebrate occurrence, but macroinvertebrates are also able to improve biogeochemical processes through bioturbation and bioirrigation of sediments (Lam-Gordillo et al. 2022 a,b). Macroinvertebrates are important prey items for shorebirds and benthivorous fish in the Coorong and Murray Mouth and Barrages subregions (Ye et al. 2020; Giatas et al. 2022). Complementary actions such as enhanced connectivity and reduced eutrophication and filamentous algal mats are important for their diversity, abundance and distribution in the Coorong lagoons.

Table 3.3. Recommended updates to Macroinvertebrate objectives and targets

Macroinvertebrate Objectives and Targets – Recommended Updates
Macroinvertebrate Diversity Objective
Existing SA River Murray LTWP 2020 Objective Maintain or improve invertebrate communities in estuarine and lagoon sediment.
Recommended update **Amend to –** Improve and maintain diverse macroinvertebrate communities.
Rationale The whole of the CLLMM PEA has been included in this revised objective to reflect the importance of having healthy and functional macroinvertebrate communities in all the sub-regions, not just the seaward side of the barrages (which is the focus of TLM monitoring). It is also important not to constrain the objective to just

Macroinvertebrate Objectives and Targets – Recommended Updates

benthic macroinvertebrates. It needs to be broad enough to include aquatic macroinvertebrates as well. These recommended changes also allow for the inclusion of freshwater macroinvertebrates that are culturally important traditional foods, e.g. Floodplain mussels (*lokeri*) and Yabbies (*kultawari*), that the Ngarrindjeri want to see increase in abundance and distribution.

Macroinvertebrate Targets – Coorong and Murray Mouth and Barrages.

Existing SA River Murray LTWP 2020 Targets

- Macroinvertebrate taxonomic distinctness falls within the expected ranges of a regional reference (Dittmann 2014)
- The distribution of macroinvertebrate species remains within or above the species-specific reference level for their index of occurrence (Dittmann 2014)
- The area of occupancy where abundance and biomass are at or above the reference level should be >20% of the monitoring sites (Dittmann 2014)
- The macroinvertebrate community has a higher multivariate similarity to the community present in years with flow than without flow (Dittmann 2014)

Recommended update

Amend to

- Macroinvertebrate species richness and community composition remains within or exceeds the long-term (2004-2023) reference for the Coorong and Murray Mouth and Barrages subregions.
- The index of occurrence of macroinvertebrate species remains within or exceeds their long-term (2004-2023) species-specific reference level.
- Abundance of macroinvertebrate species are at or above reference levels for the Coorong and Murray Mouth and Barrages subregions.
- The proportional distribution and abundance of bioturbating Nereididae (*Simplisetia aequisetis*, *Australonereis ehlersi*) for the Coorong and Murray Mouth and Barrages subregions is ≥50%.
- Macroinvertebrate biomass is at or above reference levels for the Coorong and Murray Mouth and Barrages subregions.
- Macroinvertebrate communities are similar to those occurring under intermediate continuous flows.
- Populations of larger-bodied bivalves (*Spisula trigonella*, *Hiatula alba*) are maintained in the Coorong and/or Murray Mouth and Barrages subregions.

Rationale

The long-term data set (2004-2023) includes periods of high and low flows and thus provides a robust reference that is specific to species in the Coorong and Murray Mouth and Barrages subregions. Recent floods have shown what the macroinvertebrate communities could look like in a healthy, functional ecosystem, and are being used to inform development of specific Coorong reference conditions that align well with TLM CMP.

The macroinvertebrate species richness has increased since the end of the Millennium Drought and exceeded reference levels in recent years, reflecting the recovery and recolonisation after high flow periods. This increase

was delayed by several years, especially in the Murray Mouth and North Lagoon. In the South Lagoon, increases flows occur mostly within the high flow year. Species richness can also be at or above the reference in years with lower flows that follow higher flow years.

The index of occurrence reflects that under higher flows, which lead to lower salinities in the Coorong, the macroinvertebrates which cannot tolerate hypersaline conditions can extend their distribution further south into the lagoons. There are additional drivers for distribution changes (e.g. including sediment conditions, biotic interactions), and some species have a more restricted distribution after high flows, if salinities become too fresh for them, but generally, it is expected that abundances will increase with higher flows, especially in the Coorong South Lagoon. While flood events can cause a temporary decrease in abundance in the Murray Mouth and Barrages subregion, macroinvertebrates will increase in years following floods, and have remained above reference levels since the 2022/23 flood (S. Dittmann, pers. comm, August 2024).

Bioturbating macroinvertebrates (e.g. nereid polychaetes) provide important ecosystem functions which can also support remediation of sediments (Lam-Gordillo et al 2022), which is captured by evaluating relative distribution and abundances throughout the Coorong. There was loss of bioturbation function during the Millennium Drought, followed by several years of recovery after the flows returned in 2010/11, and that condition was sustained in the following years. Nereid polychaetes are also important prey items.

Shell remains throughout the Coorong indicate that large-bodied bivalves have been historically abundant in the lagoons, however, they were rarely found after the drought. The 2022/23 flood came after several years with higher flow, and this enabled recruitment events and populations to establish in the North and South Lagoons. These species are also important prey items. The biomass index will detect recovery in macroinvertebrate communities after higher flows when more large-bodied macroinvertebrates are expected to occur than small-bodied, opportunistic species. Combined with the higher abundance targets this leads to an increase in biomass, which again has remained above reference for the North Coorong since the 2022/23 flood and increases above reference in the South Coorong have been noted in high flow years (S. Dittmann, pers. comm, August 2024). Communities under continuous intermediate flows are abundant and species rich. In the North Coorong, a shift occurred separating the communities before and after the Millennium Drought, which is the rationale for including this target.

It is important to recognise the differences in communities between the North and South Lagoons and the ecological transition points around Parnka Point and have targets that aim for on-going colonisation of the South Lagoon by macroinvertebrates from the north. It was decided to not have separate targets for the two lagoons, but rather aim for reference conditions across all areas downstream of the barrages.

The target relating to the community being similar to those under intermediate continuous flows is important for the CLLMM PEA because it refers to whether the flow regime over periods of a year or more are sufficient to support healthy and functional macroinvertebrate communities, rather than just focussing on flow volumes or flow peaks in single flow years. The new score index for bioturbating Nereididae was derived by calculating the (% sites present/sites sampled) + (% sites with >1600 individuals/sites sampled)/2. The 1600 individuals represent the 25% quartile from the entire long-term monitoring data set. The score, therefore, reflects how widespread and abundant these bioturbating worms are. Biomass has been included as a separate target to abundance because it is an important metric for food-provisioning services and species-specific biomass data is available and coefficients have been generated that can be used to calculate biomass from wet or dry mass to AFDM for several species (Nitschke et al. 2024).

Further development - Significant data have been collected through *The Living Murray* programme that are yet to be published (includes 11 sites from Goolwa barrages to Salt Creek). These data will be analysed to establish a new regional reference through the complementary TLM CMP process. The expected range of regional reference levels can be benchmarked with those from WA to Victoria building on a new large database of macroinvertebrates from around the southern coast of Australia (Lam-Gordillo et al. 2020). Salinity ranges

Macroinvertebrate Objectives and Targets – Recommended Updates

can be captured in the regional references too. Inclusion of all TLM monitoring data, HCHB T&I and the flood response projects will be important. Most of the data are from the mudflats on the landward shore of the Coorong and Murray Mouth and Barrages. Expansion of the monitoring would be needed to collect data for the whole CLLMM PEA.

Complementary Actions

- Barrage operations and other actions to enhance connectivity across the site, but especially around the Murray Mouth and Hells Gate.
- Filamentous algae mat removal or reduction through on-ground works.

Macroinvertebrate Targets – Lower Lakes

Existing SA River Murray LTWP 2020 Targets

No existing targets for Lower Lakes macroinvertebrates.

Recommended update

New Targets

- *Lokeri* (Floodplain mussel, *Velesunio ambiguus*) population comprises all size classes, including small individuals (<4 years old), in both Lakes Alexandrina and Albert.
- *Kaltuwari* (yabby, *Cherax destructor*) populations have at least 50% of individuals with <15 mm occipital carapace length (OCL) in November and at least 70% of individuals with >30 mm OCL in March with increasing total abundance and distribution.

Rationale

Floodplain mussels and Yabbies, along with Turtles (Section 3.3) and Black swans (see Waterbirds) have been identified as fauna of special interest to the Ngarrindjeri community and are now being actively monitored. These species are of cultural significance including their use as traditional foods but are not currently in sufficient numbers to be harvested. A healthy and functional CLLMM PEA would support large populations of these species with regular recruitment, therefore the recommended targets are focussed on evidence for increased abundances, and enhanced demographics (range of age classes) or adults that are of harvestable size. There is not yet data for Floodplain mussels to use for reference levels, but data will be collected over 2024–25 through a research project funded by the Goyder Institute CLLMM Research Centre in Goolwa. Sparse historic data and anecdotal evidence strongly suggests Freshwater mussels were extirpated from the Lower Lakes during the Millennium Drought, probably due to a relatively low salinity tolerance (Walker 1981). There is no evidence of Floodplain mussel recovery following the drought, although it is expected the population will reproduce and recruit under most flow conditions except extreme low lake levels and salinities >3 g/L.

Yabby abundances have been recorded during TLM condition monitoring since 2008, and modelling reveals spring flow pulses lead to higher numbers recorded in March (S. Wedderburn, unpublished data). Ngarrindjeri community members are monitoring Yabbies (3 years of data to date) and this includes measuring sizes to examine links between recruitment and water levels and other environmental factors (e.g. annual variations in spring water temperatures). Sampling of Yabbies can be biased away from capturing egg laying females, which are less likely to be caught in nets. It can be assumed, however, that larger Yabbies in March (i.e. end of the breeding and growth season) are indicative of a healthier and more functional ecosystem. Adequate river flows and lake levels are likely to be required to support good breeding and recruitment by the start of summer and

Macroinvertebrate Objectives and Targets – Recommended Updates
for high survivorship of young-of-the-year over summer, which will lead to higher abundances of adults by the following autumn.
Macroinvertebrate– Lower Lakes – Complementary actions
• Monitoring - Conduct first ever survey of *Lokeri* (Floodplain mussels) in the Lower Lakes through a research project funded by the CLLMM Research Centre in Goolwa to determine 2024–25 population status (distribution, abundance and size structure). • Monitoring - Continue to work with the Ngarrindjeri community to record abundances and measure occipital carapace length of *Kaltuwari* (Yabby) captured in November and March TLM condition monitoring of small-bodied threatened fishes and model the first 5–10 years of data to determine environmental relationships with *Kaltuwari* abundance and recruitment. • Fisheries management – PIRSA manage the take of yabbies. There is no size limit, but there are personal bag limits of 200 Yabbies and daily boat limit of 600 yabbies when 3 or more people are fishing on board.
Sediment Objectives– Coorong and Murray Mouth and Barrages
Existing SA River Murray LTWP 2020 Target Maintain habitable sediment conditions in mudflats.
Recommended update **Amend to -** Improve sediment conditions in the Coorong and Murray Mouth and Barrages subregions to support diverse and abundant macroinvertebrate and macrophyte communities.
Rationale Sediment health is at the foundation of wetland ecosystem health. Healthy and functioning ecosystems have nutrient cycling and other biogeochemical cycling happening at a rate and through microbial pathways that provide sediment conditions in which diverse macroinvertebrate and macrophyte communities can thrive. Sediments are very complex environments, and their biogeochemistry is driven by bacteria, fungi and algae that are assumed to be ubiquitous and not requiring specific management. That said, eutrophic and low oxygen sediments may occur where nutrient and sediment loads are greater than the decomposition capacity of the receiving ecosystem. In the case of the Coorong lagoons, the sediments have become hostile over time in terms of being highly saline and highly nutrient-rich (hypersaline and hypereutrophic; Mosely et al. 2023). Monosulfidic black oozes (MBOs), a type of Acid Sulfate Soils, have formed in some areas of these subregions and, although there is not a lot of evidence of direct toxicity from these sediments, they are not considered habitable for many macroinvertebrates or macrophytes based on field observations, except for those that can tolerate high sulfide concentrations (e.g. Capitella). There are also complex interactions between sediment biogeochemical processes and the presence of different types of macroinvertebrates and macrophytes. For example, burrowing macroinvertebrates and productive macrophytes oxygenate sediment and stimulate the breakdown of nutrients and organic matter, which in turn can remediate sediments in poor health or prevent the formation of Acid Sulfate Soils (see HCHB Conceptual models, Lam-Gordillo et al 2022 a,b). For these targets, filamentous algae are not considered a 'beneficial' macrophyte given that filamentous algal mats can be problematic and may limit colonisation of the sediments by macroinvertebrates and macrophytes and/or

Macroinvertebrate Objectives and Targets – Recommended Updates
enhance ASS development and/or low dissolved oxygen levels by providing large quantities of readily degradable organic matter.
Sediment Targets – Coorong and Murray Mouth and Barrages
Existing SA River Murray LTWP 2020 Targets: • Median grain size of sediments in the Coorong and Murray Mouth will remain between 125 – 500 µm (Dittmann 2014) • Sediment organic matter content between 1 and 3.5 % dry weight in the Coorong and Murray Mouth (Dittmann 2014)
Recommended updates: **Keep existing targets –** • Median grain size of sediments in the Coorong and Murray Mouth and Barrages will remain between 125 – 500 µm. • Sediment organic matter content between 1 and 3.5 % dry weight in the Coorong and Murray Mouth and Barrages. **Add new target** - No further expansion of mono-sulfidic black oozes (MBOs).
Rationale: Sediment grain size is affected by river flows, seawater inputs, the rates of deposition of different particle size sediments and the resuspension of sediments within the water body. Sedimentation is a natural part of a healthy and functional ecosystems, but if the sediments are too fine, then they can become anoxic. Having a target for median grain size will detect if there is a shift towards mud accumulation or deposition of coarser grains. The River Murray and Darling Rivers both deliver natural clayey colloids and sediments <2 µm that need to be considered as part of a healthy and functional sediment for the Murray Mouth and Barrages, however, these very fine sediments are more likely to become anoxic, if deposited in large quantities, and would contain less macroinvertebrates than would be considered healthy and functional. The rates of sedimentation have increased markedly since European colonisation and catchment development (Phillips and Muller 2006), and now represent a risk to the health of the CLLMM PEA. During the Millennium Drought, a shift towards coarser median grain size in the Coorong from aeolian deposition of sand from the sand dunes on the mudflats (that were widely exposed with the low water levels) was detected (Dittmann pers. comm. August 2024), indicating that grain size is an important variable. This target can be refined by undertaking a few years of Rapid Assessment Methods and grazing size composition assessments side-by-side to determine the best metric and any nuances regarding target particle sizes. It is included here to ensure that this important habitat consideration is not overlooked. The biogeochemical processes that affect sediment habitability are very complex and it is difficult to set meaningful thresholds for the microbial processes themselves. The macroinvertebrate targets are, however, effective surrogates for sediment habitability. Healthy and functional ecosystems do not have extensive MBOs and should have acid volatile sulfide concentrations >0.01% (Mosley et al. 2022; Sullivan et al 2018).

Macroinvertebrate Objectives and Targets – Recommended Updates
Further development: • Undertake a few years of Rapid Assessment Methods and grain size composition assessments side-by-side to determine the best metric and target reference values; • Consider whether specific targets for eutrophication measures and/or reducing or avoiding filamentous algae should be developed. • Compare Total Organic Carbon (TOC) data with sediment organic matter data from Loss on Ignition (LOI) from TLM monitoring. Note – a number of graphs and figures were provided by experts to support these discussions and the identification of actions during the discussions that have not been included here. These will be used to inform parallel processes for further developing reference levels, indices and scoring systems.
Sediment - Coorong and Murray Mouth and Barrages – Complementary actions
• HCHB program assessed a range of on-ground works and other strategies for re-establishing ecosystems in the Coorong. These include site scale habitat modifications, dredging to improve connectivity between the Coorong lagoons and large-scale Coorong Infrastructure Improvement Program (CIIP). These investigations and investment strategies are on-going. • Catchment management – sediment health in the CLLMM PEA is also a function of total catchment management of nutrient and sediment loads entering the CLLMM PEA. • Dredging – may influence grain sizes in the Murray Mouth region.

3.5 Turtles (Thukabi) objectives and targets

The existing SA River Murray LTWP (2020) does not have ecological objectives or targets for fauna in the Lower Lakes other than fish and waterbirds. This is a new theme for Freshwater turtles - *Thukabi*, which are culturally important for Ngarrindjeri people (along with Yabbies - *Kultawari* and Floodplain mussels – *Lokeri*, see Section 3.3) and are important parts of a healthy, functional ecosystem. Two species of turtle inhabit the Lower Lakes – Eastern long-neck turtles (*Chelodina longicollis*) and Murray short-neck turtles (*Emydura macquarii*). The experts involved in the Lower Lakes workshop (**Table 2.1**) recommended that:

- One new objective and one new target be included relating to freshwater turtles.

The recommended wording and the rationale for these recommendations are presented in **Table 3.4** along with potential complementary actions to enhance these species.

Table 3.4. Recommended inclusion of Turtle (Thukabi) objectives and targets

Turtle (*Thukabi*) Objectives and Targets – Recommended Updates
Turtle (*Thukabi*) Processes – Objectives & targets
Existing SA River Murray LTWP 2020 Objective & targets

Turtle (*Thukabi*) Objectives and Targets – Recommended Updates
No existing objective for turtles.
Recommended updates: **New Objective-** Improve recruitment of Thukabi (Eastern long-necked turtle, *Chelodina longicollis* and Murray short-necked turtle, *Emydura macquarii*) in Lakes Alexandrina and Albert.
New Target - Carapace length frequency distribution demonstrates presence of juvenile *Thukabi* by 2030, and regular, successful recruitment detected at three or more Ngarrindjeri *Thukabi* monitoring sites.
Rationale During a series of yarning circles in 2021 (Hartman 2021), turtles, Floodplain mussels and Yabbies (Section 3.3), were identified as fauna of special interest to the Ngarrindjeri community. This led to the Ngarrindjeri *Thukabi* (turtle) monitoring and the Ngarrindjeri *Kaltuwari* (yabby) monitoring projects. Apart from other cultural values, all three species are traditional foods (or eggs of turtles) that are not currently in sufficient numbers to be harvested. The Ngarrindjeri *Thukabi* monitoring program since February 2023 shows the turtle populations are heavily skewed towards larger, older individuals which will change over coming years as management actions are instigated. A healthy and functional CLLMM PEA would support large populations of these species with regular recruitment, therefore, the recommended targets are focussed on evidence for increasing proportions of juvenile turtles and increase abundances and sizes of yabbies. Ngarrindjeri have begun monitoring *Thukabi* and have February 2023 and 2024 data that could be used as an interim reference while more information is gathered about the populations. In short, the early data shows *Thukab*i populations currently in the Lower Lakes are skewed towards larger (older) individuals with no evidence of successful recruitment at most sites, and very limited recruitment evident for eastern long-necked turtle only at two sites (Wedderburn unpublished paper).
Turtles (*Thukabi*) – Complementary actions
Predator control – turtles and their eggs are highly vulnerable to predation by foxes and cats. Pest animal control is an important action, particularly around known nesting areas. Research is needed to determine whether Redfin perch predate on juvenile turtles before their shells harden and what mitigation actions could be taken. There may be wetland sites with lower Redfin perch abundances that could be targeted for turtle breeding. Nest protection and turtle fencing – fencing materials can be used in various ways to support turtles, including the installation of wire or plastic mesh over nests to protect eggs from being dug up by foxes and turtle fences around the cleared lake edges to create areas where they can penetrate the dense reeds around the lakes and find suitable nesting sites. Water level management – it is not clear how lake water levels affect turtles, but there are likely to be direct (e.g. food availability) and indirect effects (e.g. consequences of blue-green algal blooms) on turtle populations. Re-establish vast beds of littoral vegetation (see Vegetation targets) – beds of *Vallisneria* sp. (ribbon weed) are an important habitat for Murray short-necked turtles. Key areas are the littoral zones of the Lower Lakes and fringing wetlands, particularly near known nesting sites of Murray short-necked turtle. Young-of-the year and Juvenile Murray short-necked turtles use the ribbon weed beds as cover from predators and they eat the plant material and associated invertebrates (Pers. Comm. Mike Thompson).

3.6 Frog objectives and targets

The existing SA River Murray LTWP (2020) does not have ecological objectives or targets for fauna in the Lower Lakes other than fish and waterbirds. This is a new theme for Frogs of which there are six species known to occur in Lakes Alexandrina and Albert. Frogs are important parts of a healthy, functional ecosystem.

The experts involved in the Lower Lakes workshop (**Table 2.1**) recommended that:

- One new objective and 2 new targets be included relating to frogs in the Lower Lakes and wetlands.

The recommended wording and the rationale for these recommendations are presented in **Table 3.5** along with potential complementary actions to enhance these species.

Table 3.5. Recommended inclusion of Frog objectives and targets

Frog Objectives and Targets – Recommended Updates
Frog Processes – Objectives & targets
Existing SA River Murray LTWP 2020 Objective & targets No existing objective for frogs.
Recommended update **New Objective-** Restore resilient populations of frogs in Lower Lakes, especially in the fringing wetlands.
New Targets • Each of the six frog species known to occur in Lower Lakes and wetlands will be detected at least once every two years at 75% of surveyed sites. • Maintain and/or improve habitat suitable for the nationally listed Southern bell frog (*Litoria raniformis*) at wetlands where they are known to have previously occurred.
Rationale Frogs are important indicators of a healthy and functional Lower Lakes and fringing wetlands subregion due to their dependence on wetland and littoral habitats. The prolonged dry conditions during the Millennium Drought led to marked declines in the CLLMM PEA, and loss of species from former CLLMM PEA habitats or a retraction to refuge areas (Mason 2014). Once common species, such as Southern bell frog, have not recovered from the drought and were last recorded in the Lower Lakes in 2018 (S/ Hardy, pers. comm., August 2024). The target reflects the need to provide suitable habitats for Southern bell frog to naturally disperse into, if conditions are favourable, or to act as release sites for tadpoles and frogs bred in captivity. The six frog species known to occur in the Lower Lakes and wetlands subregion are: 1. Common froglet (*Crinia signifera)* 2. Southern brown tree frog *(Litoria ewingii)* 3. Peron's tree frog (*Litoria peronii)* 4. Long-thumbed frog *(Limnodynastes fletcheri)* 5. Spotted grass frog (*Limnodynastes tasmaniensis)* 6. Eastern banjo frog (*Limnodynastes dumerili)*

Frog Objectives and Targets – Recommended Updates
Neobatrachus spp. may also occasionally be recorded in these habitats, but these are not considered strong indicator species for the target.
Frogs – Complementary actions
• Water level management – operation of the barrage and wetland infrastructure to achieve seasonally and interannually variable lake levels (0.5 to 0.9 mAHD) and wetting and drying sequences in managed wetlands will promote diverse and abundant vegetated habitats for frogs.

3.7 Vegetation objectives and Targets

The existing SA River Murray LTWP (2020) has 2 objectives and 5 targets for Vegetation that are reviewed in **Table 3.6**. The experts involved in this review (Table 2.1) had a range of views on what should be the targets for vegetation downstream of the barrages and the following recommendations are reflective of the discussions and different points of view and state that:

- The Lower Lakes objective be amended to include extent and diversity of vegetation.
- The Lower Lakes target by updated to 2 new targets that include a WOISS.
- The Coorong vegetation objective and targets be revised to refer to "submerged macrophyte communities", where applicable, rather than just *Ruppia tuberosa*, noting that some subject matter experts would prefer the wording to be "*Ruppia tuberosa* community" to highlight the importance of this specific macrophyte, others wanted a broader definition. This wording is considered to be the most appropriate to encapsulate as many expert onions as possible and has ecological relevance for all suitable habitats downstream of the barrages.
- CMP targets be adopted for the South Lagoon (but with wording change as above) and new targets be included for the North Lagoon and the seedbank.

The recommended wording and the rationale for these recommendations are presented in **Table 3.6**. See also the rationale for defining "submerged macrophyte communities" in Section 3.1.

Table 3.6. Recommended updates to Vegetation objectives and targets

Vegetation Objectives and Targets – Recommended Updates
Vegetation Objectives - Lower Lakes
Existing SA River Murray LTWP 2020 Objective Maintain or improve aquatic and littoral vegetation in the Lower Lakes.
Recommended update **Amend to** - Maintain or improve the extent and diversity of aquatic and littoral vegetation in the Lower Lakes and wetlands.
Rationale Diverse and wide bands of aquatic and littoral vegetation in the Lower Lakes are a key component of a healthy, functional ecosystem and prime habitat for a range of fauna, including threatened fish. Low lake levels during the

Vegetation Objectives and Targets – Recommended Updates

Millennium Drought led to the drying and desiccation of aquatic and littoral Lakes vegetation and the influx of terrestrial weed species. The seasonally variable lake level envelope is designed to promote the dispersal, recruitment and growth of native aquatic vegetation, especially in the elevation band between 0.4 and 0.9 mAHD around both lakes. Lake water level variations also affect connected wetland water levels and others (e.g. Tolderol Game Reserve Wetlands, Teringie Wetlands) are managed using infrastructure or pumps for aquatic vegetation targets.

Aquatic and littoral vegetation are defined in the CMP (Nicol et al. 2014b) as follows:

- Littoral vegetation - the plant community that occupies the fringes of waterbodies
- Aquatic vegetation - the plant community that requires the presence of surface water at some point in their life history

Vegetation Targets - Lower Lakes

Existing SA River Murray LTWP 2020 Target

Maintain or improve diversity of aquatic and littoral vegetation in the Lower Lakes as quantified using the CLLMM vegetation indices (Nicol et al. 2014b).

Recommended update

Replace the one existing target with the following two targets:

- Lower Lakes aquatic and littoral vegetation achieves a WOISS >=0.6 on an annual basis (both autumn and spring) as quantified using the LLCMM TLM vegetation indices.
- Expand the distribution of littoral vegetation at 0 mAHD across the site compared to 2012 baseline.

Rationale

There are close to 50 TLM aquatic and littoral vegetation targets that are related to the data collected within five habitats and at different elevations around the Lakes. This means that the WOISS is underpinned by numerous measures of vegetation condition. A WOISS of 0.6 represents a healthy condition. The Lakes vegetation WOISS has been trending upwards in the last few years due to some targets being hit or being close to the threshold. These targets should also be achieved in the Lakes and wetlands if the CLLMM PEA was a healthy, functional ecosystem.

Vegetation – Lower Lakes - Complementary actions

- Barrage operations – Seasonally and interannually variable lake levels (0.5 to 0.9 mAHD) promote diverse and abundant aquatic and littoral vegetation in the Lakes and the connected wetlands.
- Wetland management – wetting and drying of managed wetlands (e.g. Tolderol, Teringie) around the Lower Lakes helps to maintain aquatic and littoral diversity at a whole site scale.
- Revegetation - Wave action is main factor limiting establishment of vegetation around the lakes. Planting *Schoenoplectus tabernaemontani* can reduce wave action and facilitate other plants to establish.

Vegetation Objectives and Targets – Recommended Updates

- Fencing and grazing management – lakeshore graziers work with local NGOs to fence off the lakeshore and protect the littoral vegetation from grazing, trampling, pugging and eutrophication associated with cattle grazing.

Vegetation Objectives - Coorong

Existing SA River Murray LTWP 2020 Objective

Restore *Ruppia tuberosa* colonisation and reproduction in the Coorong at a regional and local scale.

Recommended update

Amend to - Restore and maintain submerged macrophyte communities in the Coorong.

Rationale

The submerged macrophyte (aquatic plant) communities in the Coorong lagoons contain multiple species of the Genus *Ruppia* as well as macrophytes from other Genera. *Ruppia megacarpa*, for example, was prevalent before the Millennium Drought but has been recorded at less sites since. The composition of the macrophyte communities will change over space and time with changing water levels and salinity. It is, therefore, more accurate to refer to submerged macrophyte communities in the objective rather specifying *Ruppia tuberosa*, although it is acknowledged that *R. tuberosa* is a preferred and important food source for some target waterbirds and it has been dominant in the South Lagoon for the last 50 years (Section 3.1; D. Paton pers. comm. August 2024). It is also appropriate to refer to communities in the plural rather than a single *Ruppia* community because the macrophyte composition can vary in time and space, which is a characteristic of healthy and functional ecosystems like the CLLMM PEA. A healthy, functional CLLMM PEA should have submerged macrophytes along the length of the North and South Lagoons, however, *Ruppia* communities in the central and southern Coorong (Needles to south of Parnka Point) provide the most important waterbird habitats.

The Murray Mouth is not included in the objectives and targets because it is a physically dynamic environment, and it is not realistic to have targets for permanent, shallow macrophyte beds given that the water movements and scour would remove plants regularly. The plants are also living in deeper water near the Murray Mouth than in the Coorong lagoons making it more difficult for them to grow and to be sampled, although a few sites around the Murray Mouth have been surveyed previously.

Vegetation Targets – Coorong

Existing SA River Murray LTWP 2020 Target

- A continuous distribution of *Ruppia tuberosa* beds along a 50 km section of the southern Coorong (excluding outliers) (Paton 2014b)
- Within the abovementioned distribution, 80% of the monitored sites should have *Ruppia tuberosa* plants present in winter and summer (Paton 2014b)
- 50% of sites with *Ruppia tuberosa* to exceed the local site indicators for a healthy *Ruppia tuberosa* population (Paton 2014b)
- Support a resilient *Ruppia tuberosa* population with seed densities of 2000 seeds/m^2 by 2019 and 50% of sites having 60% cover in winter and a seed bank of 10,000 seeds/m^2 by 2029 in the Coorong South Lagoon (Paton 2014b)

Vegetation Objectives and Targets – Recommended Updates

Recommended update

Amend to – include TLM CMP Ruppia targets but with alterations to wording to reflect recommended definition of "submerged macrophyte communities" (see Section 3.1) and to differentiate between local and regional population vigour indices**:**

- Vigorous submerged macrophyte populations at the regional scale have:
    - Extent of occurrence (EOO) - macrophyte beds containing *Ruppia tuberosa* occur for at least 43 km along the Coorong.
    - Area of occupation (AOO) – 80% of sites within the sampled distribution have a submerged macrophyte community containing *Ruppia tuberosa* present in winter.
    - Vigour - 50% of sites exceed the local (site) vigour levels.
    - Resilience (RES) – 50% of sites should exceed 2,000 seeds/m^2.
- Vigorous submerged macrophyte populations at the local scale have:
    - At least 30% of cores (75 mm diam.) contain aquatic plants in winter and in summer.
    - At least 10 shoots per core (75 mm diam.) in winter.
    - At least 50 flower-heads/m^2 for 50% of the area sampled at a site during spring/early summer flowering.
    - At least 50% of surface sediment cores (75 mm diam. x 40 mm deep) with seeds in summer.
    - At least 50% of cores (75 mm diam) taken across area sampled at a site in late summer contain turions.

New North Lagoon Target - Submerged macrophyte communities detected at >50% of sites with suitable habitats between Pelican Point and The Needles (North Lagoon).

New seedbank target - By 2029: 10,000 seeds/m^2 at one or more sampling zones at 50% of sites (≥40 seeds per 75 mm diam. × 40 mm deep core).

Rationale

The submerged macrophyte communities in the Southern Coorong have been relatively well-studied and SMART targets have been developed for them based on long-term data sets. The focus has been on the 43 km between the Needles and Tea Tree Crossing because this area has been the prime waterbird habitat historically. The plant communities of the North Lagoon are less well-studied, although it is known that they were dominated by *Ruppia megacarpa* prior to the Millennium Drought and this plant has declined since. Different salinity and water levels will support different macrophyte community assemblages. The North Lagoon target refers to suitable habitats, which excludes those habitats at which macrophytes are note expected to grow (e.g. rocky habitats, deep sites, see Section 3.1). The seedbank target is based on densities observed in healthy regional lakes (e.g. Lake Cantara). The full suite of TLM CMP targets have been adopted here because they are all monitored and reported on, but the wording has been simplified and updated to reflect the recommended change to the term "submerged macrophyte communities" (see Section 3.1) and to distinguish between local and regional measures of population vigour.

Coorong Vegetation – Complementary actions

Vegetation Objectives and Targets – Recommended Updates
Complementary Actions: the HCHB program assessed a range of on-ground works and other strategies for re-establishing healthy ecosystems in the Coorong. These include sites scale seed dispersal or habitat modifications, dredging to improve connectivity between the Coorong lagoons and large-scale Coorong Infrastructure Improvement Program (CIIP). These investigations and investment strategies are on-going.

3.8 Water quality objectives and targets

The existing SA River Murray LTWP (2020) had one objective and two targets for water quality that related only to salinity. These are reviewed in **Table 3.7**. Water quality for the CLLMM PEA is covered to some extent by Basin Plan Matter 12 reporting and is linked to the Basin Plan targets and Priority Ecosystem Processes described in the SA River Murray LTWP to export salt at a rate of 2 million tonnes per year (as a long-term average, Schedule 5, MDBA 2012).

For a range of reasons, Water quality was not workshopped in the same way as the other Themes. It is acknowledged that several experts expressed their concerns that salinity targets were not being addressed in this review, particularly those for the Coorong South Lagoon. Significant work is still underway with DEWs complementary HCHB projects, RMP development and engagement with the CLLMM Scientific Advisory Group and the Community Advisory Panel, especially with regard to salinity, nutrients and algae (chlorophyll a) targets. The recommended wording and the rationale for these recommendations presented in Table 3.7 reflect the discussions relating to these targets held during this review. They may not represent the opinions of all the participants and are likely to be amended and added to in the latter half of 2024, which is beyond the temporal scope of this review.

Table 3.7. Recommended updates to Water Quality objectives and targets

Water Quality Objectives and Targets – Recommended Updates
Water quality Objective
Existing SA River Murray LTWP 2020 Objective Establish and maintain stable salinities in the Lower Lakes and a variable salinity regime in the Murray Mouth estuary and Coorong lagoons.
Proposed update **Amend to –** Maintain salinities within a range suitable for freshwater flora and fauna communities that characterise the Lower Lakes and suitable dissolved oxygen levels across a seasonally fluctuating salinity gradient in the Coorong and Murray Mouth and Barrages subregions.
Rationale To be discussed in detail through complementary DEW projects (e.g. HCHB, RMP, Flood response monitoring) and with the CLLMM Scientific Advisory Group and the Community Advisory Panel. Salinity targets are fundamental to the description of a healthy and functional CLLMM PEA. There are large amounts of data that can demonstrate preferred salinity ranges and habitats for different target taxa that are specific to the CLLMM PEA. It is acknowledged that the salinity regime of the CLLMM PEA is strongly linked to River Murray inflows, which have been fundamentally altered by catchment development. Whilst there was consensus around the proposed salinity target for Lake Alexandrina from those SMEs that provided comment, the SMEs had differing views on what the salinity targets for the Coorong should be and how they should be described. The underlying consideration is whether the targets should reflect the more saline conditions over the last 50 years or whether

Water Quality Objectives and Targets – Recommended Updates
a healthy and functional Coorong has lower salinities than that and therefore the targets should be closer to estuarine conditions.
Water quality Targets
Existing SA River Murray LTWP 2020 Target • Barrage outflows sufficient to maintain electrical conductivity in Lake Alexandrina at a long-term average of 700 µS/cm, below 1,000 µS/cm 95% of years and below 1,500 µS/cm 100% of the time (Heneker 2010) • To support aquatic habitat: maintain a salinity gradient from 0.5 ppt to 35ppt between the Barrages and Murray Estuary area, <45ppt in the North lagoon, and from 60ppt to 100 ppt in the South lagoon (Lester et al. 2011)
Proposed update **Amend to –** • Salinity in Lake Alexandrina is maintained at the long-term (1975-2000) annual average of 700 EC, below 1000 EC 95 % of years and below 1500 EC all of the time and salinity in Lake Albert at a long-term annual average of 1,000 EC, below 1400 EC 95 % of years and below 1800 EC all of the time. • Maintain daytime and night-time dissolved oxygen levels within the Australian Water Quality guidelines.
Rationale The Lower Lakes and fringing wetlands subregion is a significant refuge and provides a wide range of freshwater habitats. The long-term average for Lake Alexandrina was defined as the period from 1975 to 2000 to cover the pre-Millennium Drought long-term average, which was calculated at an average of 660 EC for the pre-drought data series ((approximately 25 years), with graphed data back to 1975 in Oliver et al. (2015). The Lake Alexandrina target is also based on that in the RMP, which does not contain a salinity target for Lake Albert. The recommended Lake Albert targets presented here were based on the original ecological character description for the Ramsar site (Phillips and Muller 2006). It was considered important by those SMEs that provided comment to have a target for Lake Albert so that it is not overlooked (given that it is a large freshwater wetland of conservation significance in its own right regardless of its connection to the CLLMM PEA), to provide rationale for routine lake level cycling to flush salt out of Lake Albert and to ensure that salt exported from the MDB does get exported out to sea and does not concentrate in the terminal Lake Albert basin. The dissolved oxygen target has been included in the recommendations because it is expected that dissolved oxygen improvements will be a long-term challenge to achieving a healthy and functional ecosystem, especially in the South Lagoon, given the high organic load in the sediments, high primary productivity levels and dominance by algae. Australian guidelines (ANZECC 2000) for South Central Australia (including SA) state surface waters should have no less than 90% dissolved oxygen saturation levels (without stipulating daytime only), therefore, this recommended target aims to prevent dissolved oxygen levels dropping overnight when photosynthesis ceases. This is consistent with a healthy and functional Coorong ecosystem dominated by submerged macrophyte, macroinvertebrate and fish communities.
Water quality – Complementary actions

Water Quality Objectives and Targets – Recommended Updates
• HCHB program assessed a range of on-ground works and other strategies for re-establishing healthy and functional ecosystems in the Coorong. These include site scale habitat modifications, dredging to improve connectivity between the Coorong lagoons and large-scale Coorong Infrastructure Improvement Program (CIIP). These investigations and investment strategies are on-going.

3.9 Ecosystem process objectives and targets

The existing SA River Murray LTWP (2020) has 2 objectives and 2 targets for ecosystem processes that are reviewed in **Table 3.8**. The first objective and target relate to Murray Mouth openness, whereas the second relates to fish passage and connectivity (see also Section 3.3). The experts involved in the Ecosystem processes and Fish workshops (**Table 2.1**) recommended that:

- The Murray Mouth objective be amended to remove references to tidal variations and incorporate the fish passage objective with amendment to focus on connectivity; and
- The wording of the targets be simplified for clarity and to focus on freshwater releases and fish passage.

The recommended wording and the rationale for these recommendations are presented in **Table 3.8**, along with potential complementary actions to enhance Murray Mouth openness. It is important to recognise that a healthy, functional CLLMM PEA would have the Murray Mouth open at all times due to freshwater discharge and would have connectivity across the whole site at all times. Complementary actions such as dredging to keep the Murray Mouth open are considered necessary when freshwater flows are insufficient to perform this ecological process. Likewise, barrage and fishway operations are essential for meeting these objectives and targets under most lake levels and flow conditions. Lake water levels are generally limited to maximum of $^{+}$0.9 mAHD, however, full supply level is considered to be $^{+}$1.2 mAHD, which was the peak lake water levels during the 2022/23 flood when the barrages were still operational, albeit at absolute maximum capacity with all gates open (C. Sims pers. comm, August 2024).

Table 3.8. Recommended updates to Ecosystem Processes objectives and targets

Ecosystem Processes Objectives and Targets – Recommended Updates
Ecosystem Processes – Objective
Existing SA River Murray LTWP 2020 Objective Maintain a permanent Murray Mouth opening through freshwater outflows with adequate tidal variations to improve water quality and maximise connectivity between the Coorong and the sea.
Recommended update **Amend -** Maintain a permanently open Murray Mouth through freshwater outflows to maximise fish passage and connectivity between the Murray Mouth and Barrages, the Coorong and the sea and improve water quality across the whole site.
Rationale It is important that the Murray Mouth is open 365 days a year, preferably being kept open by freshwater releases through the barrages, but if not, then by the complementary action of dredging. This target is more aspirational than Schedule 5 (2)(c) of the Basin Plan, which ensures that the mouth of the River Murray is open without the need for dredging in at least 95% of years with flows every year through the barrages. It is, however, recommended that the mouth is kept open with freshwater flows every day to achieve a healthy and functional ecosystem. It is also essential that the mouth is well flushed with river water to achieve the Basin Plan target of

Ecosystem Processes Objectives and Targets – Recommended Updates

exporting 2 million tonnes of salt per year as a long-term average and to sustain a range of vital ecosystem processes (e.g. connectivity, reductions in nutrient levels to support macrophytes and macroinvertebrates). Early investigations by Walker and Jessup (1992) and later Walker (2001) used analytical methods to predict Murray Mouth behaviour and the degree of constriction based on a relationship between tidal energy inside and outside the mouth, flow over the barrages and time. A modified version of this relationship, reflecting the diurnal tidal energy components, the Diurnal Tide Ratio (DTR) was adopted as a Key Performance Indicator to monitor the effectiveness of dredging operations. Analysis demonstrated the effect of increased barrage flows on a reduction in sand congestion in the mouth and an increase in the DTR following such flow events (DWLBC 2008).

Although an important indicator of Murray Mouth constriction, it is recommended that references to tidal variations be removed from the objective because it is not utilised as a measure in managing barrage releases in support of maintaining an open Murray Mouth (see Ecosystem process target review below). Subsequent investigations, including those with detailed hydrodynamic models, have instead highlighted the critical role of barrage releases in minimising sand ingress and deposition inside the Murray Mouth, as well as the critical ecosystem processes of providing connectivity for fauna and dispersal of propagules.

Barrage releases via the opening of fishways and/or barrage gates are essential to achieving connectivity between the freshwater Lower Lakes and the Murray Mouth estuary, Coorong lagoons and the Southern Ocean at all lake levels when the barrages are operable. Barrage operations seek to balance achievement of variable lake levels, maintenance of lake levels above the lower management threshold of $^{+}$0.4 mAHD and freshwater discharges through the fishways and barrages. This objective for maximising fish passage connectivity was taken from the CMP, although it is recommended that the word "and" be inserted to read "fish passage and connectivity" to acknowledge that connectivity is an important ecological process in itself that provides a variety of ecosystem services (e.g. dispersal of propagules and eggs, transport of organic matter, biotic movement). In terms of fish passage, connectivity is critical for some species (e.g. diadromous fish, Section 3.3) and beneficial for others (e.g. estuarine fish, Section 3.3).

Ecosystem Processes –Targets

Existing SA River Murray LTWP 2020 Target

Maintain an open Murray Mouth, as indicated when the Diurnal Tidal Ratio (DTR) at Goolwa exceeds 0.3, with minimum DTR values of 0.05 and 0.2 at Tauwitchere and Goolwa respectively (Murray-Darling Basin Authority 2013b; DWLBC 2008)

Recommended update

Amend - Murray Mouth is open at all times maintained by freshwater releases from the barrages.

Rationale

It is difficult to directly measure Murray Mouth openness and thus proxy data sets are used e.g. periodic bathymetric surveys, satellite imagery and barrage releases. Ideally, a target minimum Murray Mouth depth could be set (e.g. days more than 1 m deep and/or a depth permitting navigable boat passage), however, this would require bathymetry to be measured daily, which has significant OHS risks and is not feasible. For this reason, barrage releases are considered the most appropriate proxy data set to use in the context of management to support a healthy and functional ecosystem, and it is recommended that reference to DTR values is removed from the target. As discussed above, the DTR has continued to be used as a trigger for the initiation of Murray Mouth dredging, and as a measure of effectiveness of dredging to be achieved by dredging contractors. Therefore, the DTR is not appropriate to use as a measure of Murray Mouth openness with respect to a healthy and functional ecosystem.

Ecosystem Processes Objectives and Targets – Recommended Updates

As noted above, barrage flows are a key factor in both periodically improving (under very high flows) and maintaining (under lower flows) Murray Mouth openness. Walker (2001) suggested that a sustained threshold barrage release flow of around 200 GL/m was needed during times of prolonged low flows to maintain Murray Mouth openness. However, subsequent analysis of barrage operations in tandem with dredging between 2002 and 2007 indicated that flows as low as 2,000 ML/d (60 GL/m) may be sufficient to maintain an open Murray Mouth (DWLBC 2008). Further work is required to investigate the response of the Murray Mouth to barrage releases (total volumes, release rates and splits, timing) and their interaction with environmental conditions including dredging, tide, wind, and releases from the Upper South East drainage system using sophisticated models capable of representing sediment transport and a dynamic Murray Mouth,

Knowledge gaps:

- How open does the Murray Mouth need to be to facilitate connectivity that supports a healthy and functional ecosystem?
- What surrogate indicators are most useful e.g. barrage releases, fish movements?
- Given the critical role that barrage releases play in maintaining an open Murray Mouth, what are the minimum thresholds for barrage releases, both annual and daily, that achieve this under a range of conditions?

Ecosystem Processes - Fish passage and Connectivity Targets

Existing SA River Murray LTWP 2020 Target

Maximise fish passage connectivity between the Lower Lakes and Coorong and the sea by allowing fishways to operate year-round (Murray-Darling Basin Authority 2013b).

Recommended update

Amend to three targets –

- All barrage fishways are open every day.
- Attractant flows, via the operation of barrage bays adjacent to fishways, are provided every day.
- Maximise number of barrage gates open at all times of year and especially between June to September to facilitate greater fish movement and connectivity (based on water availability and lake level management).

Rationale

Diadromous fish have different needs at different stages of their life cycles and at different times of year. The period from June to September covers most of seasonal migration needs, however, monitoring data show that low numbers of diadromous fish are the fish passages in other months (e.g. October to February is also important for upstream passage vis fishways for YOY Congolli and Common galaxias). Having a target for open fish passages and attractant flows every day, therefore, supports migration at any time of year, but it also facilitates passage of other fish at any time. Operation of the fishways and attractant flow gates in the barrages every day will also provide a base level of connectivity for other biota and ecological processes (e.g. dispersal, matter transport). These targets also link to the TLM CMP indices and EWRs are relatively well-defined (e.g. 11 fishways use ~240 ML/d).

See also Fish Objectives and Targets (Table 3.2).

Ecosystem Processes Objectives and Targets – Recommended Updates
Ecosystem Processes – Complementary actions
• Barrage operations – flows through the fishways, attractant gates and all 572 barrage gates need to be managed on a daily basis to achieve the objectives and targets for Murray Mouth openness, fish passage and connectivity. • Dredging - where freshwater releases are inadequate to maintain an open Murray Mouth, as determined by evaluating bathymetry data, dredges will be used to maintain Diurnal Tidal Ratio (DTR) that exceed 0.3 at Goolwa, with minimum DTR values of 0.05 and 0.2 at Tauwitchere and Goolwa respectively).

4 EWR contribution review

Environmental Water Requirements (EWRs) are descriptions of the hydrological regime required to sustain an aquatic ecosystem at a low level of risk (DEWNR 2014), and in the context of the SA River Murray LTWP, to achieve the ecological objectives and targets of the PEAs. They are used by environmental water managers for annual planning and as part of the rationale for watering proposals to the Commonwealth Environmental Water Holder (CEWH) as well as for tracking environmental water delivery and achievement of ecological objectives and targets at the CLLMM PEA.

In the SA River Murray LTWP, EWRs are described for the three PEAs individually with 4 out of 13 EWRs relating to the CLLMM PEA. The EWR metrics for all three PEAs were updated by Gehrig et al. (2020) based on consideration of how the EWRs were applied, and new knowledge of modelled natural hydrology and eco-hydrological relationships for key biota and ecosystem processes in the SA River Murray LTWP. Metrics for each of the four CLLMM PEA EWRs (Appendix D) include volume, average and maximum return intervals for annual barrage flows, timing of barrage flows and water levels for the Lower Lakes and the South Lagoon (Appendix D; Gehrig et al. 2020). It is important to note that the timing, duration, frequency and water levels are essential components of the EWRs, and that they are not simply total water volumes over a given time period.

The approach used to establish EWRs for the SA River Murray LTWP means that it does not provide a single EWR per objective or target. Rather, the set of EWRs for each PEA describes a variable flow regime which is required to achieve the ecological targets for a range of biota and ecological processes over the long-term. To assist with the application of EWRs during annual planning and real-time decision-making under different flow conditions, a matrix was developed that assessed the likely contribution of each EWR in isolation towards achieving each of the ecological targets within a single year or season (Wallace, et al., 2014a). The matrix was first populated for the CLLMM PEA by O'Connor *et al* (2015) and updated by Gehrig *et al* (2020) and the same methodology, which used expert opinion and knowledge of hydro-ecological relationships, was employed for this update.

Each of the four EWRs for the CLLMM PEA have different likelihoods of achieving each of the targets. This is described as contributions of the 4 CLLMM EWRs towards the recommended ecological objectives and targets, shown in Table 4.1. This 2024 review of the CLLMM PEA components of the SA River Murray LTWP has recommended 15 objectives and 59 targets for the site (that have been kept, amended or developed as new targets through the subject matter expert (SME) collaboration process) and it is these recommended targets that are used in Table 4.1. Numbers have been assigned to the recommended targets to assist clarity in discussions at workshops and when evaluating actual environmental water delivery. The likely contribution of an EWR towards the ecological targets used a 5-point scale (Gehrig et al 2020) as follows:

1. unlikely to contribute (U)
2. difficult to detect (D)
3. low contribution (L)
4. moderate contribution (M)
5. high contribution (H)

This analysis shows that not all the targets will be met with the same EWRs, and that for many targets their expected responses do not progress in a linear fashion from EWR CLLMM1 to EWR CLLMM4, noting that due to the use of a relatively coarse ranking system, it does not necessarily mean there is no improvement in contribution. There is low likelihood of achieving waterbird, fish or frog targets or supporting the re-establishment of vigorous submerged macrophyte communities in the Coorong at EWR CLLMM1. Critical ecosystem processes and habitat quality targets (e.g. preventing further expansion of MBOs, achieving dissolved oxygen levels) are unlikely to be met until flows approach EWR CLLMM4. Other targets, such as those related to Lower Lakes

vegetation and turtles, are highly likely to be achieved at any EWR because they are linked to lake water levels, which will be achieved under EWR CLLMM1 to EWR CLLMM4 conditions.

Table 4.1. Contributions of the Coorong, Lower Lakes and Murray Mouth (CLLMM) EWRs towards the ecological targets outlined for the channel in the SA River Murray LTWP

Red cells = Unlikely to contribute (U); Orange Cells = Difficult to detect contribution (D); Yellow cells = Low contribution (L); Light Green cells = Moderate contribution (M) and Dark Green cells = High contribution (H). CLLMM EWR#s and metrics are detailed in Appendix **D**.

CLLMM PEA - Recommended Targets	**CLLMM EWR# Contribution**			
	1	**2**	**3**	**4**
1. Exceed the long-term (2000–2015) median value for abundance of each of 40 selected waterbird species in the Coorong in two of the last three years.	L	H	H	M
2. Exceed the 75% threshold for the long-term (2000–2015) area of occupation (AOO) for each of 40 selected waterbird species in the Coorong.	L	H	H	M
3. Exceed the 75% threshold for the long-term (2000–2015) extent of occurrence (EOO) for each of 40 selected waterbird species in the Coorong.	L	H	H	M
4. Exceed the recent (2013–2015) median value for abundance of each of 25 selected waterbird species in the Lower Lakes in two of the last three years.	L	H	H	M
5. Exceed the 75% threshold for the recent (2013–2015) AOO for each of 25 selected waterbird species in the Lower Lakes and fringing wetlands.	L	H	H	M
6. Exceed the 75% threshold for the recent (2013–2015) EOO for each of 25 selected waterbird species in the Lower Lakes and fringing wetlands.	L	H	H	M
7. Maintain annual breeding of waterbird species that are known to breed at the site annually.	L	H	H	M
8. Increase the number of threatened waterbirds of breeding age compared to 2000 – 2015.	L	H	H	M
9. Provide functional mudflat habitats to sustain shorebirds, especially during September to April.	M	H	H	M
10. A spatio-temporally diverse native fish community present across the whole site, including all 17 fish families, with annual observations of both common and threatened species.	M	H	H	H
11. The annual abundance of upstream migrating YOY congolli (*Pseudaphritis urvillii*) is ≥ the mean recruitment reference value (i.e. 44.5 YOY/hr).	M	H	H	H

CLLMM PEA - Recommended Targets	CLLMM EWR# Contribution			
	1	2	3	4
12. The annual abundance of upstream migrating YOY common galaxias (*Galaxias maculatus*) is ≥ the mean recruitment reference value (i.e. 6.1 YOY/hr).	M	H	H	H
13. Pouched lamprey (*Geotria australis*) are sampled from ≥60% of large vertical-slot fishway sites* when barrage discharge is <30,000 ML/d across the winter sampling season and present when discharge is ≥ 30,000 ML/d and all years. * Large fish ways include Mundoo, Goolwa, Ewe Island, trap and the large Vertical slot fishway at Tauwitchere and exclude Boundary Creek and the small fishways at Tauwitchere, Goolwa and Hunters Creek.	L	H	H	H
14. Short-headed lamprey (*Mordacia mordax*) present in all years^. ^ presence in a year includes detection in any fishway, at Lock 1 or any other part of the River Murray system.	L	H	H	H
15. WOISS equal to 4 (maximum value) for Black Bream (*Acanthopagrus butcheri*) on an annual basis.	M	H	H	L
16. WOISS equal to 4 (maximum value) for Greenback Flounder (*Rhombosolea tapirina*) on an annual basis.	M	H	H	H
17. Detect juvenile Mulloway (*Argyrosomus japonicus*) in at least 50% of the Coorong and Murray Mouth and Barrages subregions.	D	L	M	H
18. Small-mouthed hardyhead (*Atherinosoma microstoma*) populations achieve a WOISS of ≥4 on an annual basis.	M	H	H	H
19. Maintain annual population abundance (Catch Per Unit Effort – CPUE) of Sandy sprat (*Hyperlophus vittatus*) throughout the Coorong and Murray Mouth and Barrages subregions.	M	H	H	H
20. Murray hardyhead (*Craterocephalus fluviatilis*) WOISS >0.5 in autumn of low to moderate flow years and detected in years of moderate to high river flows.	M	L	D	D
21. Yarra pygmy perch (*Nannoperca obscura*) WOISS >0.5 on an annual basis with wild recruits detected in autumn sampling and maintenance of populations at release sites.	L	M	H	H
22. Southern pygmy perch (*Nannoperca australis*) WOISS >0.5 on an annual basis with wild recruits detected in autumn sampling and maintenance of populations at release sites.	L	M	H	H
23. Population age structure[a] of golden perch has at least one strong (>20%) cohort in the first 5 years, two or more moderate (>15%) cohorts and >10% fish >10 years of age. [a] Based on commercial fishery catch by large mesh gill net in the Lower Lakes.	L	M	H	H
24. Biomass of golden perch (measured as targeted CPUE[a]) >1.04 kg.net-day-1.	L	M	H	H

CLLMM PEA - Recommended Targets	CLLMM EWR# Contribution			
	1	2	3	4
[a] Based on commercial fishery catch by large mesh gill net in the Lower Lakes.				
25. Cohorts of golden perch originate from multiple spatial recruitment sources including the lower Murray and Lower Lakes.	L	M	H	H
26. Macroinvertebrate species richness and community composition remains within or exceeds the long-term (2004-2023) reference for the Coorong and Murray Mouth and Barrages subregions.	M	M	H	H
27. The index of occurrence of macroinvertebrate species remains within or exceeds the long-term (2004-2023) species-specific reference level.	M	M	H	M
28. Abundance of macroinvertebrate species are at or above reference levels for the Coorong and Murray Mouth and Barrages subregions.	M	H	H	M
29. The proportional distribution and abundance of bioturbating Nereididae (*Simplisetia aequisetis*, *Australonereis ehlersi*) for the Coorong and Murray Mouth and Barrages subregions is ≥50%.	M	M	H	M
30. Macroinvertebrate biomass is at or above reference levels for the Coorong and Murray Mouth and Barrages subregions.	M	H	H	H
31. Macroinvertebrate communities are similar to those occurring under intermediate continuous flows.	M	H	H	H
32. Populations of larger-bodied bivalves (*Spisula trigonella*, *Hiatula alba*) are maintained in the Coorong and/or Murray Mouth and Barrages subregions.	L	L	M	H
33. *Lokeri* (Floodplain mussel, *Velesunio ambiguus*) population comprises all size classes, including small individuals (<4 years old), in both Lakes Alexandrina and Albert.	M	H	H	M
34. *Kaltuwari* (yabby, *Cherax destructor*) populations have at least 50% of individuals with <15 mm occipital carapace length (OCL) in November and at least 70% of individuals with >30 mm OCL in March with increasing total abundance and distribution.	L	M	M	H
35. Median grain size of sediments in the Coorong and Murray Mouth and Barrages will remain between 125 – 500 µm.	M	H	H	M
36. Sediment organic matter content between 1 and 3.5 % dry weight in the Coorong and Murray Mouth and Barrages.	M	H	H	M
37. No further expansion of mono-sulfidic black oozes (MBOs).	U	L	M	H
38. Carapace length frequency distribution demonstrates presence of juvenile *Thukabi* by 2030, and regular, successful recruitment at three or more Ngarrindjeri *Thukabi* monitoring sites.	H	H	H	H

CLLMM PEA - Recommended Targets	CLLMM EWR# Contribution			
	1	2	3	4
39. Each of the six frog species known to occur in the Lower Lakes and wetlands will be detected at least once every two years at 75% of surveyed sites.	L	M	H	H
40. Maintain and/or improve habitat suitable for the nationally listed Southern bell frog (*Litoria raniformis*) at wetlands where they are known to have previously occurred.	L	M	H	H
41. Lower Lakes aquatic and littoral vegetation achieves a WOISS ≥ 0.6 on an annual basis as quantified using the LLCMM TLM vegetation indices.	H	H	H	H
42. Expand the distribution of littoral vegetation at 0 mAHD across the site compared to the 2024 baseline.	H	H	H	H
43. Extent of occurrence (EOO) - macrophyte beds containing *Ruppia tuberosa* occur for at least 43 km along the Coorong.	L	M	H	H
44. Area of occupation (AOO) – 80% of sites within the sampled distribution have a submerged macrophyte community containing *Ruppia tuberosa* present in winter.	L	M	M	H
45. Regional Vigour - 50% of sites exceed the local (site) vigour levels.	D	L	M	H
46. Local Vigour - At least 30% of cores (75 mm diam.) contain aquatic plants in winter and in summer.	L	M	M	H
47. Local Vigour - At least 10 shoots per core (75 mm diam.) in winter.	L	M	M	H
48. Local Vigour - At least 50 flower-heads/m^2 for 50% of the area sampled at a site during spring/early summer flowering.	L	M	M	H
49. Local Vigour - At least 50% of surface sediment cores (75 mm diam. x 40 mm deep) with seeds in summer.	L	M	M	H
50. Local Vigour - At least 50% of cores (75 mm diam) taken across area sampled at a site in late summer contain turions.	L	M	M	H
51. Resilience – 50% of sites should exceed 2,000 seeds/m^2.	L	M	M	H
52. Colonisation - Submerged macrophyte communities detected at >50% of sites with suitable habitats between Pelican Point and The Needles (North Lagoon).	L	M	M	H
53. Recruitment - By 2029: 10,000 *Ruppia* sp. seeds/m^2 in multiple samples from >50% of sites (e.g. ≥40 seeds per 75 mm diam. × 40 mm deep core).	L	M	M	H
54. Salinity in Lake Alexandrina maintained at a long-term annual (1975-2000) average of 700 EC, below 1000 EC 95 per cent of years and below 1500 EC all of the time and salinity in Lake Albert at a long-term annual average of 1,000 EC, below 1400 EC 95 per cent of years and below 1800 EC all of the time.	M	H	H	H

CLLMM PEA - Recommended Targets	CLLMM EWR# Contribution			
	1	2	3	4
55. *Coorong target(s) TBD through complementary DEW projects*				
56. Maintain daytime and night-time dissolved oxygen levels within the Australian guidelines.	U	U	L	M
57. Murray Mouth is open at all times maintained by freshwater releases from the barrages.	M	M	H	H
58. All barrage fishways are open every day.	H	H	H	H
59. Attractant flows, via the operation of barrage bays adjacent to fishways, are provided every day.	H	H	H	H
60. Maximise number of barrage gates open at all times of year and especially between June and September to facilitate greater fish movement and connectivity.	M	H	H	H

5 Appendices

A. Ecological objectives and targets identified in the 2020 SA River Murray LTWP for the CLLMM Priority Environmental Asset title.

Table taken from O'Connor, et al. (2015). Note, additional target detail and supplementary information, and the source reference for the target information have not been transferred into this long-term plan and should be sourced from Table 1 in O'Connor, et al. (2015).

Type	Ecological objective	Ecological targets
Waterbirds	Maintain or improve waterbird populations in the Coorong and Lower Lakes	Abundances, area of occupation and extent of occurrence of TLM target waterbird species to be above defined median reference values (median of data from the 15 years between 2000 and 2014) (Paton, 2014a)
		Detect annual breeding activity in waterbird species that are expected to breed annually at the site and at least two breeding events in any four consecutive years in species that breed regularly at the site (Department of Environment Water and Natural Resources, in prep (a))
		Provide functional mudflat habitat to sustain active shorebird foraging behaviour during November-March with a foraging effort of <50%. (Murray-Darling Basin Authority, 2014e)
		Maintain abundances of 12 waterbird species (Table 22 in Appendix 4) at or above 1% of the total flyway population size (Department of Environment Water and Natural Resources, in prep (a))
Fish	Maintain a spatio-temporally diverse fish community and resilient populations of key native fish species in the lower lakes and Coorong	A spatio-temporally diverse fish community is present including all 23 fish families stated in the Ramsar site draft Ecological Character Description (Department of Environment Water and Natural Resources, in prep (a))
		Annual detection of juvenile Catadromous fish at abundances ≥ that of defined 'Recruitment Index' values (44.5 for *Congolli*, and 6.1 for *Common galaxias*) (Bice, et al., 2014)
		Annual detection of migration for Anadromous species (short-headed and pouched lamprey) at index values of >0.6 (Bice, et al., 2014)
		Maximise fish passage connectivity between the Lower Lakes and Coorong, and between the Coorong and the sea by allowing fishways to operate year-round (Murray-Darling Basin Authority, 2013b)
		Maintain or improve abundances of Murray hardyheads and pygmy perch so that 'Relative Abundance Index' values of ≥1 are achieved on an annual basis (Wedderburn, 2014)

Type	Ecological objective	Ecological targets
		Detect recruitment success of Murray hardyheads and pygmy perch at least every second year (Wedderburn, 2014)
		Maintain or improve abundances, distribution and recruitment of black bream and greenback flounder with population condition score ≥3 (Ye, et al., 2014a)
		Facilitate regular recruitment and a broader distribution of juvenile mulloway (Ye, et al., 2014a)
		Maintain an average Catch-Per-Unit-Effort (CPUE) of small-mouthed hardyhead sampled in spring/early summer of > 120 for adults, and >790 for juveniles (Ye, et al., 2014b)
		Maintain the proportional abundance of small-mouthed hardyhead juveniles at >60% in 75% of defined monitoring sites within the CLLMM (Ye, et al., 2014b)
Macroinvertebrates	Maintain or improve invertebrate communities in estuarine and lagoon sediments	Macroinvertebrate taxonomic distinctness falls within the expected ranges of a regional reference (Dittmann, 2014)
		The distribution of macroinvertebrate species remains within or above the species-specific reference level for their index of occurrence (Dittmann, 2014)
		The area of occupancy where abundance and biomass are at or above the reference level should be >20% of the monitoring sites (Dittmann, 2014)
		The macroinvertebrate community has a higher multivariate similarity to the community present in years with flow than without flow (Dittmann, 2014)
	Maintain habitable sediment conditions in mudflats	Median grain size of sediments in the Coorong and Murray Mouth will remain between 125 – 500 µm (Dittmann, 2014)
		Sediment organic matter content between 1 and 3.5 % dry weight in the Coorong and Murray Mouth (Dittmann, 2014)
Vegetation	Restore *Ruppia tuberosa* colonisation and reproduction in the Coorong at a regional and local scale	A continuous distribution of *Ruppia tuberosa* beds along a 50 km section of the southern Coorong (excluding outliers) (Paton, 2014b)
		Within the abovementioned distribution, 80% of the monitored sites should have *Ruppia tuberosa* plants present in winter and summer (Paton, 2014b)
		50% of sites with *Ruppia tuberosa* to exceed the local site indicators for a healthy *Ruppia tuberosa* population (Paton, 2014b)
		Support a resilient *Ruppia tuberosa* population with seed densities of 2000 seeds/m^2 by 2019 and 50% of sites having 60% cover in winter and a seed bank of 10,000 seeds/m^2 by 2029 in the Coorong South Lagoon (Paton, 2014b)

Type	Ecological objective	Ecological targets
	Maintain or improve aquatic and littoral vegetation in the Lower Lakes	Maintain or improve diversity of aquatic and littoral vegetation in the Lower Lakes as quantified using the LLCMM vegetation indices (Nicol, et al., 2014b)
Water quality	Establish and maintain stable salinities in the lakes and a variable salinity regime in the Murray estuary and Coorong.	Barrage outflows sufficient to maintain electrical conductivity in Lake Alexandrina at a long-term average of 700 µS/cm, below 1,000 µS/cm 95% of years and below 1,500 µS/cm 100% of the time (Heneker, 2010)
		To support aquatic habitat: maintain a salinity gradient from 0.5 ppt to 35ppt between the Barrages and Murray Estuary area, <45ppt in the North lagoon, and from 60ppt to 100 ppt in the South lagoon (Lester, et al., 2011)
Ecosystem processes	Maintain a permanent Murray Mouth opening through freshwater outflows with adequate tidal variations to improve water quality and maximise connectivity between the Coorong and the sea	Maintain an open Murray Mouth, as indicated when the Diurnal Tidal Ratio (DTR) at Goolwa exceeds 0.3, with minimum DTR values of 0.05 and 0.2 at Tauwitchere and Goolwa respectively (Murray-Darling Basin Authority, 2013b; DWLBC, 2008)
		Maintain a minimum annual flow required to keep the Murray Mouth open (730—1,090 GL/year) (Murray-Darling Basin Authority, 2013b)

B. Waterbird lists relating to objectives and targets,

Table B1: Median abundances, area of occupation (AOO) and extent of occurrence (EOO) for 40 waterbird species in the Coorong. Medians were calculated for 16 years of data (2000–2015) collected in January and excluding birds counted in the creek at Salt Creek. The abundance data include birds scored as flying. Data for AOO and EOO do not include birds that were flying over when counted, as these may not have been using the actual area in which they were seen. The AOO was based on dividing the 1-km strips that were used for the bird census into three parts (eastern, centre, western) for 110 km of the Coorong. Data for EOO is expressed as the length (km) of the Coorong between the most northerly and most southerly records in each year. The lower value of the 95% confidence interval (CI) and the 75% value for AOO and EOO are given. The target median abundance, AOO and EOO are shaded.

Waterbird species	Median abundance	Area of Occupation (km^2)			Extent of Occurrence (km^2)		
		Mean ±s.e.	Lower 95% CI	75% AOO	Mean ±s.e.	Lower 95% CI	75% EOO
Australian Pelican	3410	134 ±10	113	101	100 ±1.0	98	75
Australian Shelduck	8426	128 ±4	120	96	98 ±1.6	95	74
Australian White Ibis	300	29 ±3	23	22	36 ±3.6	29	27
Black-faced Cormorant	130	6 ±1	4	5	56 ±9.4	38	42
Banded Stilt	15092	61 ±11	40	46	86 ±4.8	76	65
Black Swan	1633	61 ±5	51	46	96 ±4.2	87	72
Black-winged Stilt	417	41 ±4	33	31	82 ±3.1	76	62
Caspian Tern	598	69 ±7	55	52	84 ±4.3	75	63
Cape Barren Goose	97	7 ±1	6	5	22 ±4.7	13	17
Chestnut Teal	7216	109 ±6	96	82	97 ±1.0	95	73
Eurasian Coot	62	7 ±3	2	5	19 ±7.2	5	14
Crested Tern	3897	66 ±8	50	50	93 ±1.6	90	70
Curlew Sandpiper	2252	35 ±5	26	26	82 ±5.3	72	62
Eastern Curlew	13	4 ±1	3	3	8 ±2.2	3	6
Fairy Tern	337	35 ±5	25	26	76 ±5.5	66	57
Common Greenshank	430	88 ±4	80	66	100 ±0.6	99	75
Great Crested Grebe	199	35 ±5	25	34	71 ±8.4	54	53
Great Cormorant	1287	41 ±3	34	31	62 ±6.3	50	47
Great Egret	36	26 ±7	12	20	53 ±8.6	36	40
Grey Teal	11846	124 ±13	99	93	101 ±1.2	98	76
Hoary-headed Grebe	4218	67 ±10	48	50	94 ±6.3	82	71
Hooded Plover	8	6 ±1	4	5	51 ±8.1	35	38
Little Black Cormorant	1253	34 ±6	22	26	66 ±7.5	51	50
Little Egret	8	6 ±1	4	5	52 ±7.2	38	39
Little Pied Cormorant	258	35 ±4	27	26	52 ±5.7	41	39
Musk Duck	171	18 ±2	14	14	82 ±4.7	73	62
Masked Lapwing	466	97 ±3	91	73	103 ±0.5	102	77
Pacific Black Duck	223	19 ±2	14	14	63 ±7.2	49	47
Pied Cormorant	271	45 ±5	35	34	66 ±6.1	54	50
Pacific Golden Plover	36	4 ±1	3	3	24 ±4.4	15	18
Pied Oystercatcher	158	41 ±3	35	31	92 ±1.4	89	69
Red-capped Plover	1234	77 ±5	68	58	99 ±2.4	94	74
Red-necked Avocet	3007	66 ±10	46	50	85 ±6.5	72	64
Red-necked Stint	26285	118 ±11	97	89	103 ±0.7	101	77

Waterbird species	Median abundance	Area of Occupation (km^2)			Extent of Occurrence (km^2)		
		Mean ±s.e.	Lower 95% CI	75% AOO	Mean ±s.e.	Lower 95% CI	75% EOO
Royal Spoonbill	22	7 ±1	4	5	33 ±5.3	22	25
Silver Gull	8274	201 ±6	189	151	104 ±0.5	103	78
Straw-necked Ibis	25	3 ±1	2	2	21 ±3.9	13	16
Sharp-tailed Sandpiper	13179	121 ±11	99	91	95 ±2.8	89	71
White-faced Heron	156	61 ±5	50	46	100 ±1.1	98	75
Whiskered Tern	5360	160 ±14	133	120	97 ±4.3	89	73

Table B2: Median abundance, area of occupation (AOO) and extent of occurrence (EOO) are given for 25 species of waterbirds using the Lower Lakes in January over the three years from 2013–2015. Area of occupation is given as an actual area (# 1 km2 cells in which the bird was counted). Extent of occurrence is calculated as the area that contains the minimum convex polygon that includes all locations (cells) where the species was seen. Note that birds that were flying when encountered in a cell were excluded from calculations of AOO and EOO as these birds may not have been using that particular cell. The lower value of the 95% confidence interval (CI) and the 75% value for AOO and EOO are given. The target median abundance, AOO and EOO are shaded.

Waterbird species	Median abundance	Area of Occupation ($km^{2)}$			Extent of Occurrence (km^2)		
		Mean ±s.e.	Lower 95% CI	75% AOO	Mean ±s.e.	Lower 95% CI	75% EOO
Australian Pelican	5901	305 ±8	290	229	1729 ±8	1714	1297
Australian Shelduck	12704	183 ±4	175	137	1582 ±50	1484	1187
Australian White Ibis	568	107 ±6	95	80	1660 ±10	1640	1245
Black Swan	1786	200 ±7	186	150	1652 ±39	1575	1239
Caspian Tern	535	110 ±8	95	83	1508 ±18	1472	1131
Cape Barren Goose	974	36 ±5	27	27	1041 ±11	1019	781
Eurasian Coot	3339	152 ±41	72	114	1644 ±39	1569	1233
Crested Tern	418	92 ±17	59	69	1428 ±77	1277	1071
Darter	67	29 ±9	12	22	857 ±267	334	643
Great Crested Grebe	128	39 ±18	3	29	978 ±227	533	734
Great Cormorant	12509	304 ±18	270	228	1714 ±13	1688	1286
Great Egret	110	98 ±46	8	74	1281 ±339	616	961
Grey Teal	3782	89 ±30	29	67	1577 ±92	1396	1183
Hoary-headed Grebe	801	30 ±12	6	23	987 ±22	159	740
Little Black Cormorant	784	83 ±34	17	62	1456 ±140	1181	1092
Little Pied Cormorant	74	42 ±12	19	32	1384 ±116	1157	1038
Masked Lapwing	555	74 ±4	67	56	1560 ±42	1478	1170
Pacific Black Duck	4892	216 ±12	193	162	1700 ±16	1669	1275
Pied Cormorant	8390	228 ±17	194	171	1538 ±75	1390	1154
Purple Swamphen	461	111 ±8	95	83	1555 ±62	1434	1166
Royal Spoonbill	200	29 ±5	19	22	1338 ±35	1270	1004
Silver Gull	1650	99 ±15	69	74	1511 ±15	1481	1133
Straw-necked Ibis	1214	36 ±9	19	27	1322 ±154	1021	992
White-faced Heron	108	64 ±3	58	48	1595 ±8	1579	1196
Whiskered Tern	4086	357 ±27	303	268	1722 ±15	1693	1292

Table B3: Waterbirds known to breed in the Coorong.

Provided by David Paton (2024) based on a collation of long-term data and observations.

Species	Breeding frequency	Comment
1. Australian Pelican (*Pelecanus conspicillatus*)	Annual	Breeds annually on selected islands in the South Lagoon.
2. Australian Darter (*Anhinga novaehollandiae)*	Frequent	Small numbers may breed around the lower lakes in flooded willows around the margins of the lakes, and/or less frequently redgums as well as willows that line the Murray River south of Wellington. Up to 50 pairs in some years (e.g. January-February 2023) but usually a few nests most years.
3. Little Pied Cormorant (*Microcarbo melanoleucos)*	Frequent	Small numbers breed in some years in flooded willows in northern areas of lakes, and on the islands within Salt Lagoon on the southern margin of Lakes Alexandrina.
4. Great Cormorant (*Phalacrocorax carbo)*	Frequent	Substantial numbers (several thousand pairs) breed regularly on islands in Salt Lagoon but not necessarily every year.
5. Little Black Cormorant (*Phalacrocorax sulcirostris)*	Frequent	Modest numbers (probably <1000 birds) breed in islands in Salt Lagoon but not necessarily every year.
6. Australian Pied Cormorant (*Phalacrocorax varius)*	frequent	Substantial numbers breed in most years on islands in Salt Lagoon, with others nesting in some years off Tolderol.
7. Black Swan (*Cygnus atratus*)	Annual	Cygnets unable to fly in the accompaniment of adult birds seen in the Lower Lakes most years, and in the Coorong in some years (the latter may have been hatched from nests in the nearby Lower Lakes and moved to the Coorong).
8. Caspian Tern (*Hydropogne* (*Sterna*) *caspia*)	Annual	Breed on islands in the southern Coorong, Small numbers in most years (<20 pairs) but in some years lager numbers breed (>50 pairs)
9. Greater Crested Tern (*Thalasseus bergii*)	Annual	Several colonies establish on islands in the southern Coorong each year (breeding anywhere south of Goat Island (near the Needles) southwards. Colonies can consist of several 1000 pairs, and breeding often shifts from one island to another between years.
10. Fairy Tern (*Sterna nereis nereis*)	Annual	Approximately 150-200 pairs breed either at the Murray Mouth or on islets in the southern Coorong from Goat Island (near the Needles) southwards.
11. Little Tern (*Sternula albifrons)*	Annual	Up to 5 pairs breeding in association with Fairy Terns, some evidence of interbreeding.
12. Australian Gull-billed Tern (*Gelochelidon macrotarsa)*	Rare	One pair bred successfully on an island in South Lagoon in one year.
13. Hooded Plover (*Thinornis rubricollis*)	Annual/ Infrequent	Breeds annually along the ocean beach of Younghusband Peninsula, infrequently breeds around southern Coorong shoreline.
14. Red-capped Plover (*Charadrius ruficapillus*)	Infrequent	A few pairs (probably <5) may breed along the shorelines of the southern Coorong and on islands in the southern Coorong in some years.

Species	Breeding frequency	Comment
15. Silver Gull (*Chroicocephalus novaehollandiae*)	Annual	Likely to breed mainly in spring on islands in the South Lagoon, but often see young birds (unable to fly) with parents in association with other colonial nesting species (e.g. pelican, crested tern) in Dec/Jan.
16. Banded Stilt (*Cladorhynchus leucocephalus)*	Rare	During the summer of 2005-06 during Millennium drought a moderate number bred (producing about 1000 chicks).
17. Red-necked Avocet (*Recurvirostra novaehollandiae)*	Rare	During the summer of 2005-06, small numbers of avocet bred on multiple islands in the southern Coorong.
18. Australian Pied Oystercatcher (*Haematopus longirostris*)	Annual	Small numbers breed on islands in the southern Coorong in most years including Goat Island, Stonywell Island.
19. Australian White Ibis (*Threskiornis molucca*)	Frequent	Small numbers (10-50 pairs, possibly more breed around the margins of the Lower lakes (including islands in Salt Lagoon and in association with Straw-necked Ibis near Tolderol and on the western side of Lake Albert.
20. Straw necked Ibis (*Threskiornis spinicollis*)	Annual	Substantial numbers breed in most years around the margins of the Lower Lakes, including the western side of Lake Albert, on islands in Salt Lagoon, near Tolderol, and occasionally at other locations (e.g., wetlands off Eckert Rd on eastern side of Lake Alexandrina).
21. Yellow-billed Spoonbills (*Platalea flavipes)*	Frequent	A few pairs nest in flood willows or flooded redgums around the northern fringes of Lake Alexandrina (e.g. near Brinkley homestead) and in the upper reaches of the Finniss River (EMLR tributaries).
22. Royal Spoonbill (*Platalea regia*)	Annual	Breeding detected in areas of reeds around the margins of both lakes. Colonies are usually modest ca 10-20 pairs, and sometimes less.
23. Pacific Black Duck (*Anas superciliosa)*	Frequent	Small numbers of adults detected with ducklings in multiple years around lakes in Jan-Feb. Breeding may be more widespread in spring.
24. Grey teal (*Anas gracilis)*	Frequent	A few ducklings detected in some years during annual waterbird census of Lower Lakes in January- February.
25. Chestnut Teal (*Anas castanea)*	Frequent	Occasional pair with a flotilla of ducklings seen during the Coorong January census, likely breeds earlier in the flooded ephemeral *Melaleuca halmatorurum* wetlands associated with the Coorong.
26. Purple Swamphen (*Porphyrio porphyrio)*	Frequent	Juvenile birds unable to fly detected around margins of lower lakes, especially where there is access to manicured lawns etc
27. Dusky Moorhen (*Gallinula tenebrosa)*	Frequent	Juvenile birds unable to fly detected around margins of the Goolwa Channel where there were fringing lawns.

C. Fish families used in targets.

Proposed updated LTWP target is based on the 17 fish families identified in RMP (DEW 2024)– refer Table 14.3 in Appendix B (p110).

See RMP p49 where it states: 'Biodisparity considers the different life histories, morphologies and movement strategies of different species and families (Watt, 2013) and is assessed against the annual detection of a range of fish families (Appendix B, Table 14.3). Alien species and marine stragglers are excluded from the assessments.'

Seventeen fish families

1. Arripidae
2. Atherinidae
3. Bovichtidae
4. Clupeidae
5. Eleotridae
6. Galaxiidae
7. Geotriidae
8. Gobiidae
9. Hemiramphidae
10. Mugilidae
11. Percichthyidae
12. Pleuronectidae
13. Retropinnidae
14. Sciaenidae
15. Sparidae
16. Tetraodontidae
17. Tetrarogidae

D. SA River Murray LTWP Environmental Water Requirements (EWRs) for the CLLMM PEA showing the specified target values for individual metrics, taken from Gehrig et al. (2020).

EWR #	EWR metrics									
	Average Annual Barrage flow (GL/yr)	Total barrage flow over rolling 3-yr period (GL)	Barrage outflow annual pattern^	Frequency[#] (# flows-per-ARI; [% of years]; {#yr in 10-yr})	Critical Max Interval[&] (years)	Lakes water level (m AHD)	Lakes water level peak and/or minimum timing (months)	Coorong South Lagoon peak water level (m AHD)	Coorong South Lagoon peak water level timing (months)	Coorong South Lagoon peak water level duration (days)
CLLMM1	≥2,000	≥6,000*	Total volume released in Sep–Dec > Total volume released in Jan–Aug	1-in-1 [100%] {10 yr in 10}	0	0.5 to ≥0.75		0.0 to 0.1	Sep–Dec	≥90
CLLMM2	≥4,000	≥12,000**	Total volume released in Sep–Dec > Total volume released in Jan–Aug	1-in-2 [50%] {5 yr in 10}	3	0.5 to ≥0.83	Peak: Sep–Dec	0.2 to 0.45	Sep–Jan	≥150
CLLMM3	≥6,000	N/A	Total volume released in Sep–Jan >Total volume released in Feb–Aug	1-in-3 [33.3%] {3–4 yr in 10}	5	0.6 to ≥0.83	Min: Mar–May	0.2 to 0.45	Sep–Feb	≥180
CLLLMM 4	≥10,000	N/A	Total volume released in Sep–Jan >Total volume released in Feb–Aug	1-in-7 [14%] {1–2 yr in 10}	17	0.6 to ≥0.9		N/A	N/A	N/A

* CLLMM1 = no less than 650 GL in a single year, and no less than 6,000 GL over 3 years

** CLLMM2 = no less than 3150 GL in a single year, and no less than 12,000 over 3 years

^ see Figure A1_8 for hypothetical representation of annual barrage release pattern

[#]Frequency is expressed as: 1) number of flows per Average Return Interval (ARI), 2) percentage of years and 3) the number of years that the EWR should occur within a 10-yr period.

[&]represents the critical maximum interval (years) between EWRs before a significant decline in CLLMM condition is likely to occur. This period should not be exceeded wherever possible.

6 Units of measurement

6.1 Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	μg	10^{-6} g	mass
microlitre	μL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	365 or 366 days	time interval

7 Glossary

ANZECC — Australia New Zealand Environmental Consultative Council.

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.

Basin Plan — Murray–Darling Basin Plan (MDBA 2012).

BWS — Basin-Wide Environmental Watering Strategy – published by the Murray-Darling Basin Authority, a legislative requirement under Chapter 8 of the Basin Plan

CLLMM — Coorong, Lower Lakes and Murray Mouth.

DEW — Department for Environment and Water.

Discharge — The volumetric flow rate of water i.e. volume of streamflow over a given time. In South Australia, this is often represented as ML/day.

DTR — Diurnal tide ratio — a measure of the openness of the Murray mouth, as the ratio of the amplitude of the tidal signal recorded at Victor Harbor compared to downstream of Goolwa and Tauwitchere barrage.

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

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 Total Dissolved Solids (TDS).

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

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

Ecosystem services — All biological, physical or chemical processes that maintain ecosystems and biodiversity and provide inputs and waste treatment services that support human activities.

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.

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 runoff from the land.

Fishways — structures that allow fish to navigate through obstacles in rivers and creeks.

Lower Lakes — Lakes Alexandrina and Albert.

LTWP — Long-Term Environmental Watering Plan – a legislative requirement under Chapter 8 of the Basin Plan.

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

MDBA — Murray-Darling Basin Authority.

ML/day — Megalitres per day – a measure of flow or discharge, where a megalitre equals 1,000,000 litres.

PEA — Priority Environmental Asset – defined in section 8.49 of the Basin Plan as an environmental asset that can be managed with environmental water.

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.

Salinity — The concentration of dissolved salts in water or soil, expressed in terms of concentration (mg/L) or electrical conductivity (EC).

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

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.

TLM — The Living Murray Program – a long-running collaborative programme between the Murray-Darling Basin Authority and partner governments aimed at restoring the health of the River Murray system by recovering 500 gigalitres of water and constructing major water management structures at six environmental icon sites.

WOISS — Whole of Icon Site Score - calculated using a range of indices and references specific to each site and species as part of The Living Murray Icon Site Condition Monitoring Plan.

WRP area — Water resource plan area – identified for the purpose of implementing the Basin Plan, the water resource plan areas are listed in Chapter 3 of the Basin Plan.

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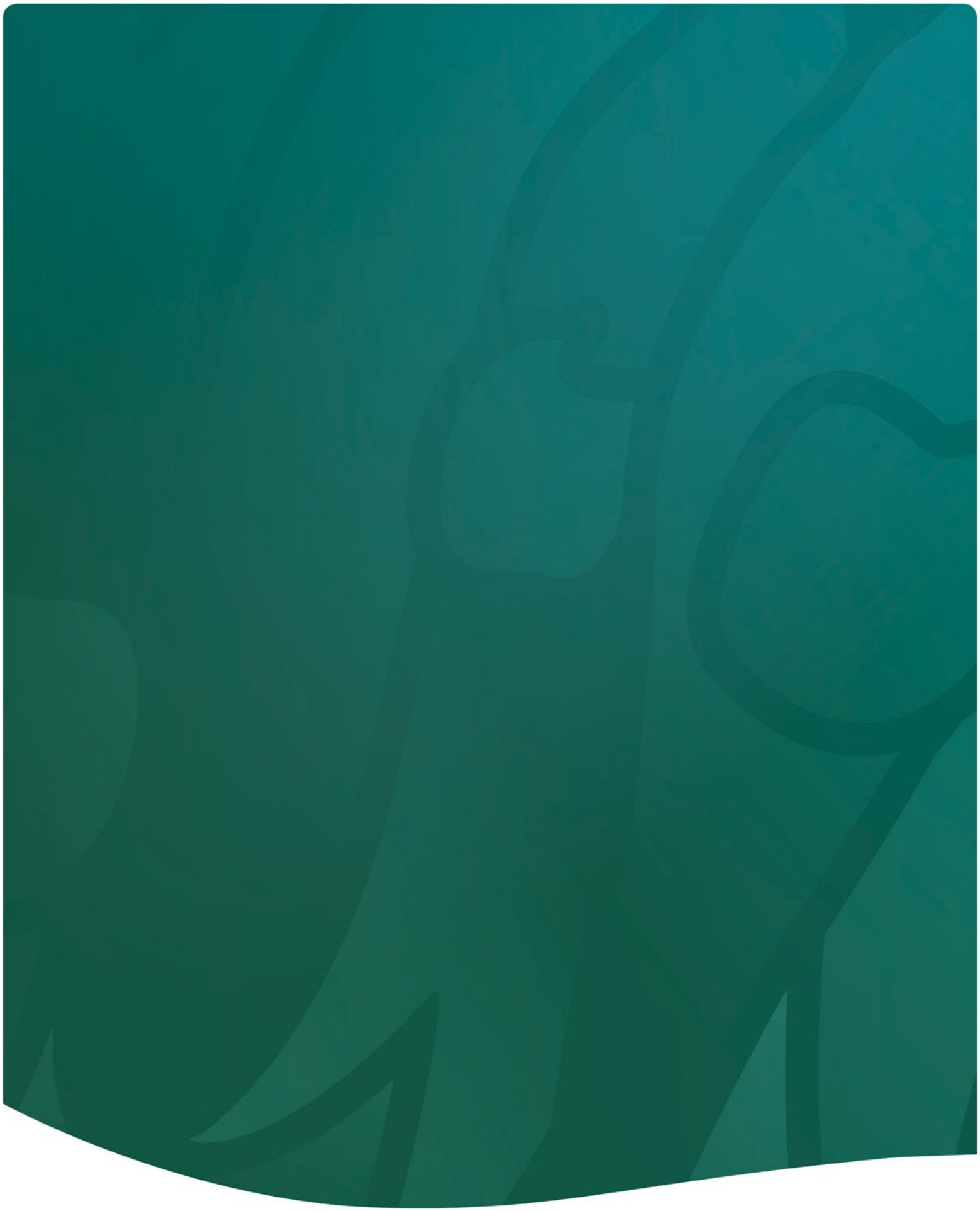

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