Ramsar Management Plan: the Coorong and Lakes Alexandrina and Albert Wetland

2022

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Caveat: Note the document does not reflect the current (internationally accepted) boundary of the site. The boundary will be formally updated as part of the submission of the revised Ramsar Information Sheet.

Foreword

The Coorong is one of South Australia's most iconic natural assets. Recognised in 1985 as a 'Wetland of International Importance' under the *Convention on Wetlands (Ramsar 1971),* the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site provides significant environmental values which underpin the recreational benefits of the region, as well as economic values such as tourism and commercial fishing.

Culturally, the Coorong and Lakes Alexandrina and Albert Wetland is of great importance to the Ngarrindjeri and First Nations of the South East, who are the Traditional Owners of the Ramsar site's connected lands and waters. These Nations have cared for Country for thousands of years and their cultures are intrinsically linked to the region, whose health is integral to the health of their people.

The *Ramsar Management Plan: the Coorong and Lakes Alexandrina and Albert Wetland 2022* (RMP) outlines the actions required to manage and promote the site's ecological character and maintain the features that make the site internationally significant. The RMP sits within a suite of documents designed to provide essential information and guidance for the site and includes:

- Ramsar Management Plan
- Ramsar Information Sheet
- Ecological Character Description
- Boundary Description and map.

Since the first Ramsar Management Plan was developed in 2000, there has been significant progress in both environmental management practices and scientific investigations of the site. This progress has aided in identifying:

- priority values and threats to the ecological character of the wetland
- targets for managing different parts of the site
- triggers for taking action to protect the site.

To ensure a strategic approach to managing such a large and complex natural system, the RMP (2022) incorporates the experiences, knowledge and learnings from the Millennium Drought.

The RMP (2022) was developed over several years by the Department for Environment and Water and includes essential input from expert scientists, management authorities, government agencies, industry, First Nations and the community.

I would like to thank all who have been involved in the development of this plan, whose work supports the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site to be a healthy, productive and resilient wetland system that maintains its local and international significance.

Hon Susan Close MP
Minister for Climate, Environment and Water

Acknowledgement

First Nations of the South-East and Ngarrindjeri are the Traditional Owners of the waters of the seas, the waters of the Coorong, the waters of the rivers, the lakes, wetlands, underground waterways, and surrounding lands. These lands and waters have sustained unique First Nations cultures since the time of creation.

Ngarrindjeri and First Nations of the South East spiritual, social, cultural, and economic practices come from the lands and waters, and they continue to maintain their cultural heritage, economies, languages, and lores which are of ongoing importance.

The Ramsar Convention on Wetlands has a long-standing commitment to the full and effective participation of First Nations peoples and local communities in the management of wetlands.

Wetlands and water sources and bodies are precious areas for First Nations peoples. They are part of their traditional territories and resources and provide the basis for the livelihoods of their families and communities; they are also fundamental elements of their cultures since the lands and waters are a living body, and they are part of its existence. The waters of the Coorong include surrounding connected waters, many of these places are sacred and have high spiritual significance. The Traditional Owners of the Coorong have developed their cultures based on the interactions with wetlands and water – their ways of life, their cultural expressions and their value systems are deeply connected to those ecosystems.

The Department for Environment and Water acknowledges the range of First Nations' rights, interests and obligations for the Coorong and connected waterways and the cultural connections that exist between Ngarrindjeri Nations and First Nations of the South-East as distinct peoples across the region and seeks to support their equitable engagement.

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1.1 Introduction

The Coorong and Lakes Alexandrina and Albert Wetland Ramsar Management Plan (RMP) was released in 2000. Since then, there has been significant progress in both our understanding of the ecological character of the site and the strategic direction for management. As such, it is timely that the RMP is revised and community feedback sought to ensure it is reflective of today's climate, modern environmental management practices and emerging issues.

The RMP identifies priority values and threats to the ecological character of the wetland and includes targets for managing different parts of the site and triggers for taking action to protect the site. While similar ecological values, and threats exist in the adjacent and surrounding landscape, this RMP focuses only on those within the defined boundary of the Ramsar site. As required for a RMP, this plan describes the current condition, threats and management actions, while acknowledging that past conditions, and past actions (including regulation and extraction in the River Murray, and construction of the South East Drainage Network), have significantly influenced the current state.

1.2 Site description

The Coorong and Lakes Alexandrina and Albert Wetland (the Ramsar site) is located in South Australia at the mouth of the River Murray, approximately 75 kilometres south east of the city of Adelaide. The site encompasses Lake Alexandrina; a number of islands (e.g. Mundoo, Mud, Long, Hindmarsh, Tauwitchere and Salt Lagoon); the lower reaches of Currency and Tookayerta Creeks and the Finniss River; Lake Albert; Narrung Narrows; the Murray Mouth; the estuary; the Younghusband Peninsula and beach; and the Coorong lagoons and other ephemeral lakes (DEWNR, 2013). The Ngarrindjeri and First Nations of the South East are the Traditional Owners of the lands and waters of the Ramsar site.

The Ramsar site was nominated as a Wetland of International Importance under the Ramsar Convention in 1985. Site details for this Ramsar wetland are provided in Table 1.1 and a map of the site is provided in Figure 1.1.

Table 1.1 Site details for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar Site

Site name	The Coorong and Lakes Alexandrina and Albert Wetland
Location in coordinates	Latitude (GDA94): (approximately) 35° 18'S to 36°33'S. Longitude (GDA94): (approximately) 138° 44'E to 139° 51'E.
General location of the site	Located in South Australia at the mouth of the River Murray (Murrundi), approximately 75 kilometres south east of the city of Adelaide.
Area	144,986 hectares (based on the proposed updated Ramsar boundary)
Date of designation	1 November 1985
Ramsar Criteria	1,2,3,4,5,6,7,8
Management authority	South Australian Department for Environment and Water (DEW)
Ramsar Information Sheet (RIS)	RIS compiled by DEWNR (2013) RIS by DEW (2021) draft in preparation (undergoing approval)
Ecological Character Description(s) (ECD)	Phillips, W. and Muller, K.L. (2006), *Ecological Character of the Coorong, Lakes Alexandrina and Albert Wetland of International Importance.* South Australian Department for Environment and Heritage. Coorong ecological character description 2015 The Coorong and Lakes Alexandrina and Albert Wetland, DEW (2021a), draft in preparation.
Ramsar Management Plan(s)	DEH (2000) *Coorong and Lakes Alexandrina and Albert Ramsar Management Plan*. Department for Environment and Heritage. DEW (2025) Ramsar Management Plan: the Coorong and Lakes Alexandrina and Albert Wetland 2022.

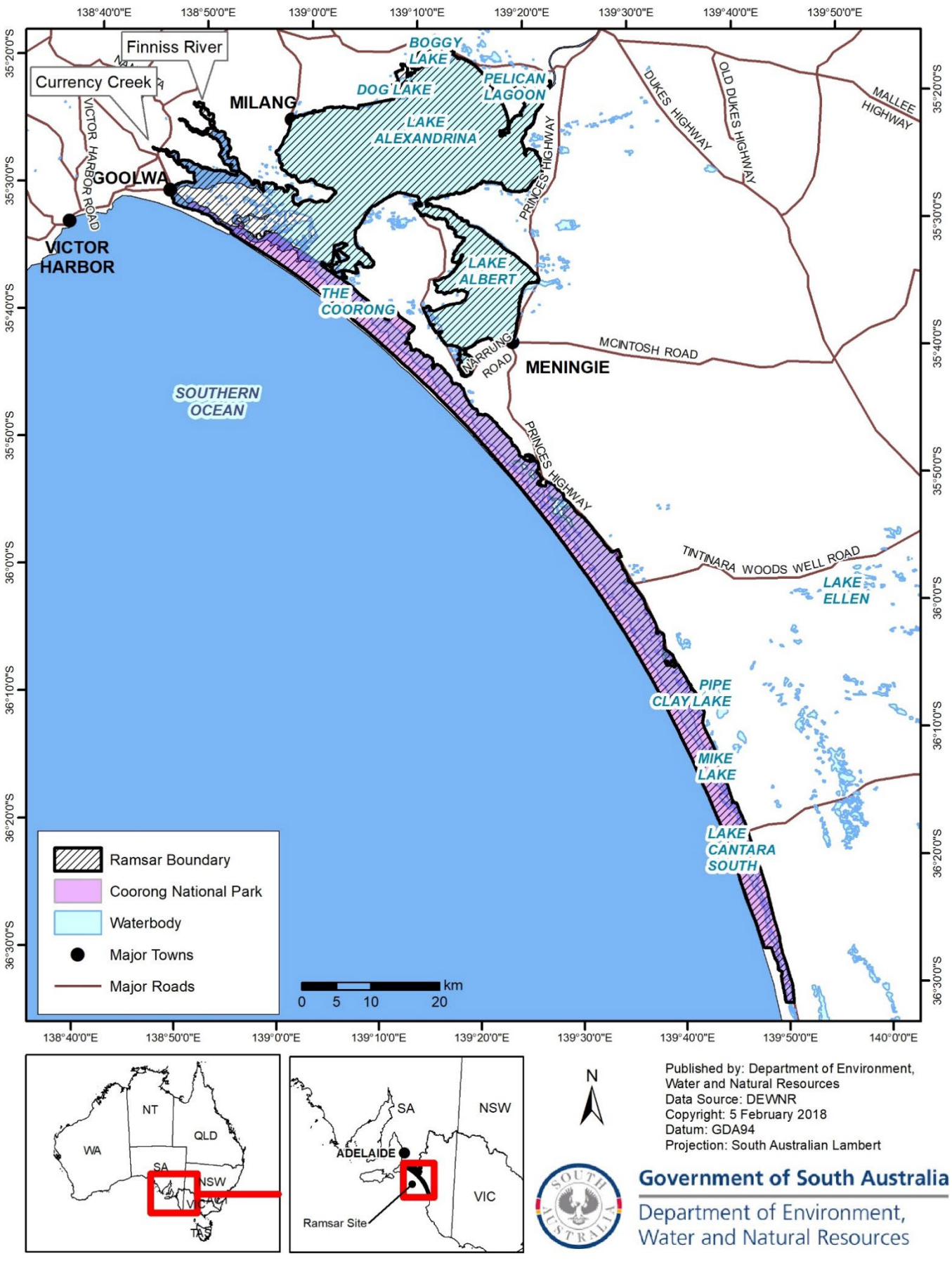

Figure 1.1 Coorong and Lakes Alexandrina and Albert Wetland Ramsar site area

1.3 Purpose of the Ramsar Management Plan

1.3.1 Obligations under the Ramsar Convention

The *Convention on Wetlands of International Importance Especially as Waterfowl Habitat* (United Nations, 1971) more commonly known as the Ramsar Convention, is an intergovernmental treaty. The Convention aims to halt and, where possible, reverse the worldwide loss of wetlands and to conserve those that remain through wise use and the implementation of management plans. Contracting parties to the convention designate sites containing representative, rare or unique wetlands, or wetlands that are important for conserving biological diversity, to the List of Wetlands of International Importance. These sites are commonly known as Ramsar sites.

Designating a Ramsar site carries with it certain obligations, including managing the site to maintain its 'ecological character' and having procedures in place to detect if any threatening processes are likely to, or have altered the 'ecological character'. Ecological character and 'change in ecological character' are defined as (Ramsar, 2005):

> *Ecological character is the combination of the ecosystem components, processes and benefits/services that characterise the wetlands at a given point of time; and*
>
> *Change in ecological character is the human induced adverse alteration of any ecosystem component, process and or ecosystem benefit/service.*

1.3.2 Ramsar site management

Management of Ramsar sites is guided by the following key documents developed using the *National framework and guidance for describing the ecological character of Australia's Ramsar wetlands* (DEWHA, 2008) and the *Australian Ramsar management principles* (EPBC, 2000).

Ramsar Information Sheet (RIS)

The RIS is a summary of the essential information relating to a site and its management. The RIS contains information on the location, boundary and tenure of the site; justification against the Ramsar criteria; physical, ecological and hydrological features of the site; wetland types, noteworthy flora and fauna, conservation measures and land use, recreation and tourism information about the site (DSEWPaC, 2012). The RIS is submitted to the Ramsar Convention Secretariat by the Australian Government and should be reviewed and updated (if required) every 6 years or on the occasion of any significant change in the sites ecological character.

Ecological Character Description (ECD)

The ECD provides a more detailed and technical description of the ecological character of the site at a given point of time (baseline). The ECD establishes a benchmark, which in the case of the Coorong and Lakes Alexandrina and Albert Wetland, is 2015. The ECD identifies the critical components, processes and services (critical CPS) of the site and can set Limits of Acceptable Change (LAC). The Australian Government has developed a standard method for describing ecological character (DEWHA, 2008). A revised ECD for the Coorong and Lakes Alexandrina and Albert Wetland has been written (DEW, 2021a).

Ramsar Management Plan (RMP)

The Ramsar Management Plan (RMP) documents the management strategies required to maintain and enhance the ecological character of a Ramsar site and build resilience to threats. The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) establishes the framework for the management of Australian Ramsar sites and Schedule 6 of *Environment Protection and Biodiversity Conservation Regulations 2000* (Commonwealth) outlines the principles relevant to the preparation of Ramsar site management plans. The RMP is informed and supported by the RIS, ECD and management plans for areas within the site and contains information on the roles and responsibilities for management, wetland water requirements and communication, education, participation and awareness activities (DSEWPaC, 2012).

1.3.3 Objective

The Coorong and Lakes Alexandrina and Albert Wetland Ramsar site supports a number of ecological, economic, social and cultural values. The economic (e.g. tourism, commercial fishing), social (e.g. recreation) and cultural values of the site result from maintaining the condition of the Ramsar site. This plan has been developed on the assumption that by maintaining (or improving) ecological character, the socio-economic and cultural values associated with the Ramsar site will also be conserved, within the concept of wise use.

The primary objective of the RMP is:

> *To support the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site to be a healthy, productive and resilient wetland system that maintains its local and international significance.*

1.3.4 Principles

The guiding principles for the development of the Ramsar Management Plan include:

- building on existing and previous activities rather than duplicating effort
- adopting an evidence-based approach using the best available knowledge
- adopting the precautionary principle – lack of full scientific certainty is not seen as a reason for postponing cost-effective measures to prevent environmental degradation
- recognising that First Nations have rights and interests in the lands and waters of the Ramsar site and have long-term valuable knowledge that supports present and future management of the site
- adaptive management including the principles of monitor, evaluate, report and improve
- developing the plan with input from a range of stakeholders (see section 12.1).

1.3.5 Relevant policy and legislation

The agreements, legislation and policies relevant to the site or to species or communities that use or are present at the site are set out in the section below.

International

- *Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention)* Provides the framework for local, regional and national actions, and international cooperation, for the conservation and wise use of wetlands.
- Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment (JAMBA)
- Convention on the Conservation of Migratory Species of Wild Animals (CMS)
- Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment (CAMBA)
- Agreement between the Government of Australia and the Government of the Republic of Korea on the Protection of Migratory Birds (ROKAMBA)
- East Asian-Australasian Flyway Partnership (EAAFP)
- United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP)

National

- *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Cth)

  This Act gives better protection and preservation of areas and objects that are of particular significance to Aboriginals and Torres Strait Islanders.

- *Intergovernmental Agreement on the Environment, 1992, between the Commonwealth of Australia and the States and Territories of Australia*

  This Agreement between the Commonwealth, the states, the Australian Capital Territory, the Northern Territory and the Australian Local Government Association is a statement of the relative roles and responsibilities of the 3 levels of government. It provides: (a) a cooperative national approach to the environment; (b) a better definition of the roles of the respective governments; (c) a reduction in the number of disputes between the Commonwealth and the states and territories on environment issues; (d) greater certainty of Government and business decision-making.

- *Native Title Act 1993* (Cth)

  This Act recognises the rights and interests of Aboriginal and Torres Strait Islander people in land and waters according to their traditional laws and customs.

- *Environment Protection and Biodiversity Conservation Act 1999* (Cth), *Environment Protection and Biodiversity Conservation Regulations 2000* (Cth), which include the Australian Ramsar Management Principles, set out in Schedule 6 of the Regulations.

  This Act regulates actions that will have or are likely to have a significant impact on any Matter of National Environmental Significance (MNES), which includes the Ecological Character of a Ramsar wetland (EPBC Act 1999 s16(1)). An action that will have or is likely to have a significant impact on a Ramsar wetland will require an environmental assessment and approval under the EPBC Act. An 'action' includes a project, a development, an undertaking or an activity or series of activities.

  The EPBC Act establishes a framework for managing Ramsar wetlands, through the Australian Ramsar Management Principles (EPBC Act 1999 s335), which are set out in Schedule 6 of the *Environment Protection and Biodiversity Conservation Regulations 2000*. These principles are intended to promote national standards of management, planning, environmental impact assessment, community involvement, and monitoring, for all of Australia's Ramsar wetlands in a way that is consistent with Australia's obligations under the Ramsar Convention.

  Some MNES protected under the EPBC Act are not protected under local or state/territory legislation; for example, many migratory birds are not specifically protected under state legislation. Species listed under international treaties JAMBA, CAMBA and CMS have been included in the List of Migratory species under the EPBC Act.

  Threatened species and communities listed under the EPBC Act may also occur, or have habitat in the Ramsar site; some species listed under state legislation as threatened are not listed under the EPBC Act as threatened, usually because they are not threatened at the national (often equivalent to whole-of-population) level.

  The Regulations also cover matters relevant to the preparation of management plans, environmental assessment of actions that may affect the site, and the community consultation process.

- *Water Act 2007* (Cth) including the Murray-Darling Basin Plan, 2012, prepared by the Murray-Darling Basin Authority for subparagraph 44(2)(c)(ii) of the *Water Act 2007* (Cth).

This Act provides the framework for ensuring that the Murray-Darling Basin is managed in the national interest. It required the Australian Government to prepare a strategic plan for the integrated and sustainable management of water resources to manage the Basin as a whole connected system.

The aim of the Murray-Darling Basin Plan is to bring the Basin back to a healthier and sustainable level, while continuing to support farming and other industries for the benefit of the Australian community.

- Intergovernmental Agreement on Implementing Water Reform in the Murray-Darling Basin, 2013

  The Murray-Darling Basin Agreement sets out the rules and plans for sharing water in the River Murray to support a reliable supply of water for communities and environments along the River Murray across New South Wales, South Australia and Victoria.

- Australia's Strategy for Nature, 2019–2030

  Australia's Strategy for Nature 2019-2030 is the overarching framework for all national, state and territory and local strategies, legislation, policies and actions that target nature. The strategy builds on previous and existing work, and is underpinned by science. However, it also takes an approach that is new and very different from that taken previously. It moves away from a purely protection-based approach and strives to incorporate adaptation, resilience and natural resource management in our cities, rural and natural environments, on land and at sea..

- Ngarrindjeri and Others Native Title Settlement Part A – Indigenous Land Use Agreement, 2017

  The Native Title Settlement Indigenous Land Use Agreement explains the terms under which the Ngarrindjeri can use the land in their native title and resolves compensation for past impairment of native title by the state for acts that have been done on the native title determination area.

South Australian

- *National Parks and Wildlife Act 1972* (SA)

  This Act allows for the establishment and management of reserves for public benefit and enjoyment and to provide for the conservation of wildlife in a natural environment.

- *Coast Protection Act 1972* (SA)

  This Act provides for the conservation and protection of the beaches and coast of this state.

- *Aboriginal Heritage Act 1988* (SA)

  This Act provides protection of Aboriginal sites, objects and remains through the Attorney Generals, Aboriginal Affairs and Reconciliation department. Any proposed works that have the potential to disturb Aboriginal heritage require approval under the Act.

- *Native Vegetation Act 1991* (SA)

  This Act protects native vegetation in South Australia and sets out processes for applying to clear vegetation and regulations for native vegetation management. The Act ensures that areas of high conservation value are protected, and that clearances are subject to a thorough assessment process.

- *South Eastern Water Conservation and Drainage Act 1992* (SA)

  This Act is responsible for the conservation and management of water and the prevention of flooding of rural land in the South East of the State and other related purposes.

- *Environment Protection Act 1993* (SA)

  This Act provides the regulatory framework to protect South Australia's (SA) environment, including land, air and water. It imposes an environmental duty on businesses to take all reasonable and practical measures to prevent or minimise any resulting environmental harm. It applies a precautionary approach to the assessment of environmental risk.

- *Harbors and Navigation Act 1993* (SA)

  This Act provides for the administration, development and management of harbours maximising their use and promoting trade to ensure efficient cargo transfer facilities, safe orderly movement within harbours and the safe navigation of vessels in South Australian waters.

- *Native Title Act 1994* (SA)

  The Native Title Act allows people to gain recognition of rights and interests they have in land and waters according to Aboriginal law and customs. It validates past acts and intermediate period acts on native title land.

- *Local Government Act 1999* (SA)

  This Act allows for a local Government in South Australia. Along with the *Constitution Act 1934* (SA) and the *Local Government (Elections) Act 1999* (SA) it creates the legal framework within which Local Government operates and the election processes.

- *River Murray Act 2003* (SA)

  The *River Murray Act* aims to protect, restore and enhance the River and its natural resources (including water, soil, ecosystems and heritage associated with the River).

- *Fisheries Management Act 2007* (SA)

  This Act provides the legislative framework, objectives and guiding principles for the management of fisheries in South Australia. The management rules for individual fisheries are provided in the fisheries regulations under the Act and practically implemented through fishery management plans.

- *Climate Change and Greenhouse Emissions Reduction Act 2007* (SA)

  The main target under this Act is to reduce greenhouse gas emissions within this state by at least 60% to an amount that is equal to or less than 40% of 1990 levels by 31 December 2050.

- *Marine Parks Act 2007* (SA)

  The Act provides certainty and security about the process for developing marine parks with multiple opportunities for stakeholder and community involvement.

- *Murray-Darling Basin Act 2008* (SA)

  This Act approves the Murray-Darling Basin Agreement 1992 and makes the necessary steps for its implementation in the territory of South Australia. It aims to facilitate the operation of the agreement to promote and coordinate effective planning and management for the equitable, efficient and sustainable use of water and natural resources of the Murray-Darling Basin. It can make any related amendments to any other South Australian Acts as required (for example the *Planning, Development and Infrastructure Act 2016, Landscape South Australia Act 2019, River Murray Act 2003, Water Industry Act 2012*).

- *Crown Land Management Act 2009* (SA)

  This Act provides for the disposal, management and conservation of Crown land. It ensures Crown land is managed and used for the benefit of all South Australians.

- Ngarrindjeri Regional Partnership Agreement, 2011

  This agreement is between the Ngarrindjeri people, the Australian Government and the South Australia Government. Its aim is to support the development of the Ngarrindjeri caring for country programs in combination with sustainable economic development. In signing the agreement the state and federal governments and the Ngarrindjeri have agreed to work together in partnership to share responsibility for building the environmental, social and economic assets in the Ngarrindjeri region.

- Ramsar ECD Statement of Commitment (SOC) 2013 (DEWNR and NRA)

  The Statement of Commitment establishes an agreed process to involve the Ngarrindjeri people in the review of the ECD and the development of the ECD Report. It intends to support the integration of the Ngarrindjeri values, perspectives and philosophies into the report.

- Ngarrindjeri Yannarumi - Speaking as Country Deed, 2014

  This agreement is between the South Australian Government and the Ngarrindjeri Nation to facilitate a program of intervention to keep the Murray Mouth open and support the health of the "the Meeting of the Waters". The deed further operationalises the Ngarrindjeri philosophy of being in local and national management plans 'governing' the Lower Murray region.

- *Planning, Development and Infrastructure Act 2016* (SA)

  This Act provides for matters that are relevant to the use, development and management of land and buildings, including by establishing a planning system to regulate development within the state, rules with respect to the design, construction and use of buildings, and other initiatives to facilitate the development of infrastructure, facilities and environments that will benefit the community.

- *Landscape South Australia Act 2019 (SA)*

  This Act is the key framework for the sustainable and integrated management of the state's land, water, pest plants and animals, and biodiversity across the state. It also provides for the protection of the state's natural resources.

1.4 Article 3.2 Notification

1.4.1 Change in ecological character

On 13 December 2006, the Australian Government wrote to the Ramsar Convention Secretariat to inform them of a change in the ecological character of the site in accordance with Article 3.2 of the Ramsar Convention. The notification was based on the findings of the 2006 ECD for the site, which reported that the site had been in decline for 20 to 30 years prior to listing and that further decline is likely or inevitable. At the time the report was written, 8 of the 9 Ramsar listing criteria continued to be met (Phillips & Muller, 2006).

In response to the Article 3.2 notification and with funding assistance from the Australian Government and the Murray-Darling Basin Ministerial Council, the Government of South Australia implemented a number of emergency measures during the peak of the Millennium Drought. Towards the end of the drought, the Coorong, Lower Lakes and Murray Mouth (CLLMM) Recovery Project was developed and implemented. The CLLMM Recovery Project consisted of a suite of management actions aimed to restore key ecological features of the Ramsar site, build resilience within the site and knowledge and understanding across communities, including collaboration with the community and the Ngarrindjeri.

Other initiatives including *The Living Murray* (TLM) Initiative and environmental water recovery and delivery under the Murray-Darling Basin Plan reforms, have improved water management and outcomes for the Coorong, increased environmental flows to the Coorong and addressed some critical knowledge gaps for the region. These initiatives, along with the return of regular flows of freshwater, have resulted in the region showing some signs of recovery;

however several characteristics of the Coorong South Lagoon in particular, have continued to experience substantial and sustained decline.

1.4.2 *Healthy Coorong, Healthy Basin*

Healthy Coorong, Healthy Basin (HCHB) is a commitment to work towards restoring a healthy Coorong, announced by the Australian and South Australian governments in December 2018. HCHB will support the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site to be a healthy, productive and resilient wetland of international significance in the long term.

Since 2020, HCHB has focused on addressing scientific knowledge gaps and working with First Nations and the community to investigate the feasibility of management options. The HCHB Action Plan presents working vision to restore the Coorong, so that it will once again be characterised by healthy vegetation with abundant and diverse populations of waterbirds, fish and plants.

This will be done by:

- Describing the Desired State for the site, especially the highly degraded Coorong South Lagoon.
- Undertaking short-term, no-regrets trials, investigations and on-ground works.
- Addressing critical scientific knowledge gaps.
- Identifying and investigating longer-term management options and preparing a business case for future investment in the option/s deemed feasible and most likely to provide the most benefit.
- Developing tools and systems to improve the transparency, efficiency and effectiveness of water delivery and management.
- Partnering with First Nations and local communities in on-ground action.

It should be noted that this RMP has been prepared based on what can be achieved using current management tools and infrastructure, which does not include any future work from HCHB. The RMP will be updated if management options change.

2 Ramsar site description

2.1 Location

The Coorong and Lakes Alexandrina and Albert Wetland Ramsar site is located in South Australia, approximately 75 km south east of Adelaide at the terminus of the Murray-Darling Basin (Figure 2.1). The site covers the proposed boundary of 144,986 ha, including 108,539 ha of permanent wetland and 7,067 ha of land subject to inundation.

The primary source of freshwater inflows into the Ramsar site is from the River Murray into the north of Lake Alexandrina, near Wellington. In addition to the River Murray, small seasonal inflows are provided by tributary streams draining the Eastern Mount Lofty Ranges (i.e. Currency Creek, Tookayerta Creek and Finniss, Angas and Bremer Rivers), which are typically less than 2% of the overall inflows into the Lakes, but are important hydrological inputs to local swamps. Freshwater flows from the South East also enter the Coorong South Lagoon via a regulator at Salt Creek (average 11.43 GL/year (1990-2020)). Rainfall and groundwater inputs at the site are minor when compared to River Murray inputs.

The Ramsar site is a complex system made up of 23 wetland types, including estuarine waters, coastal brackish/saline lagoons, permanent freshwater lakes and marshes, and seasonally flooded agricultural land. The wetland incorporates the freshwater bodies of Lake Alexandrina and Lake Albert (the Lakes), and estuarine to hypersaline waters of the Murray Mouth and Coorong (Figure 2.1). The Murray Mouth is the only connection to the sea in the Murray-Darling Basin. The site supports extensive and diverse waterbird, fish and plant assemblages as well as threatened ecological communities and species.

The freshwaters of Lake Alexandrina are separated from the more saline waters of the Murray Mouth and Coorong by a series of 5 barrages between Goolwa on the mainland, and Hindmarsh, Mundoo, Ewe and Tauwitchere Islands. The barrages were completed in 1940 to prevent seawater entering the lakes to maintain freshwater conditions during times of low flows (Blackmore, 2002), offsetting the impacts of basin-wide irrigated agriculture and ensuring water supplies for towns and agricultural productivity in the surrounding areas remained.

The Murray estuary and Coorong are the only estuarine areas within the Murray-Darling Basin. Salinity increases with distance from the mouth, but not in a uniform gradient. The Murray estuary and Coorong North Lagoon, which are directly influenced by freshwater flows through the barrages, are estuarine closer to the Murray Mouth becoming more saline at the southern end of North Lagoon. The Coorong South Lagoon is influenced indirectly by flows through the barrages (through the impact of these flows on Coorong North Lagoon salinity and water levels), and, to a lesser extent, flows from the Upper South East drainage scheme at Salt Creek. The Coorong South Lagoon has become predominately saline to hypersaline, although it was estuarine saline as recently as the 1970s (Geddes, 2005), (Mosley, et al., 2020).

The Murray Mouth is a tidal inlet restricted by the accumulation of dune material on the flanking spits of Sir Richard Peninsula and Younghusband Peninsula. It is located in a high energy environment and is extremely dynamic. The location, size and shape of the mouth and the adjacent estuary are dictated by a combination of river flows, tidal flows and ocean and coastal processes (Harvey, 2002). Dredging to maintain an open Murray Mouth began in 2002 and has operated continuously until 2022, even during periods of higher flows.

Much of the region has a Mediterranean-type climate, with cool, moist winters and warm, dry summers. Coastal areas can often be cooler with crisp sea breezes. Given the location of this site is at the downstream end of the basin, inflows are strongly influenced by rainfall across the whole basin, which includes sub catchments with winter and summer rainfall patterns, as well as local rainfall. The connection to the Southern Ocean and the geomorphology of the long coastal shoreline exposes the site to strong winds and tides. Wind, sea level and tide actions are important climatic drivers within the site and change across multiple temporal scales (i.e. daily, seasonally and annually), as well as being attenuated along the length of the lagoon system.

A detailed description of the Ramsar site can be found in the ECD (DEW, 2021a).

Figure 2.1 Map of the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site

2.2 Land tenure and land managers

The majority of the site is Crown land or reserves managed by the Government of South Australia (Table 2.1). Wetlands cover 115,940 ha, of which 96% is administered and/or managed by the Government of South Australia. Lakes Alexandrina and Albert are predominantly surrounded by private property, most of which has been cleared for agriculture adjacent the Ramsar site boundary, and the site contains the townships of Meningie, Goolwa, Milang and Wellington. There are a number of different agencies with responsibility associated with managing aspects of the site, which are summarised in Table 2.2.

The area is part of the traditional lands and waters of the Ngarrindjeri Nation as described in the Ngarrindjeri and Others Native Title Claim (SAD 6027/98) and includes registered Aboriginal sites such as the 'Meeting of the Waters'. In 2017 Ngarrindjeri Native Title Claim Part A was determined in the Federal Court of Australia (National Native Title Tribunal, 2017). The area covering the south of the Coorong is part of an overlapping claim with the First Nations of the South East (SAD 180/2017) (National Native Title Tribunal, 2017).

Table 2.1 Land tenure within the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site

Description	Proposed Area (ha)
Crown land - reserves under the *National Parks and Wildlife Act 1972* (Coorong National Park, Salt Lagoon Islands and Lawari Conservation Parks and Tolderol, Currency Creek and Mud Islands Game Reserves) managed by the Department for Environment and Water	54,006
Crown land – government agency land, land registered on council community land registers and crown land leased in accordance with terms and conditions administered under the *Crown Land Management Act 2009* by the Department for Environment and Water	80,384
Private land	10,596
TOTAL	**144,986**

Table 2.2 Lead management agencies and their key responsibilities

Agency	Overarching responsibility	Responsibility in the Ramsar site
Department for Environment and Water (DEW)	Strategic direction and management for the state's nature, parks, water, wildlife and cultural assets in South Australia. Whole of government action to address climate change risk and opportunity for South Australia.	Policy advice for the management of the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site, management of reserves under the *National Parks and Wildlife Act 1972*, management of waterbody lake beds, administration of land under the *Crown Land Management Act 2009* and ensuring River Murray water is managed sustainably to meet environmental objectives within the site.
SA Water	Provider of water and sewage services across South Australia. State constructing authority under the *Murray-Darling Basin Agreement 2008*.	Under the direction of the Murray-Darling Basin Authority (MDBA), SA Water operates and maintains the barrages and dredging of the Murray Mouth. Under the direction of DEW, SA Water operates the barrages for the delivery of environmental water to the Murray estuary and Coorong. Also supplies rural water to communities around the Ramsar site.

Agency	Overarching responsibility	Responsibility in the Ramsar site
Murray-Darling Basin Authority	Responsible for planning the Basin's water resources, with all planning decisions made in the interest of the Basin as a whole and operating the River Murray system to efficiently deliver water to users on behalf of partner governments.	Develops the Murray-Darling Basin Plan and annual environmental priorities and longer-term targets set within the Murray-Darling Basin Plan. Develops a work program to operate and maintain the barrages and maintain an open Murray Mouth following the documented objectives and outcomes for the operation of the River Murray system and the Murray-Darling Basin Plan.
Commonwealth Environmental Water Holder	Manages the Commonwealth environmental water holdings and administers the Environmental Water Holdings Special Account.	Contributes water for the environment to the site taking into account the *Water Act 2007*, the Murray-Darling Basin Plan and annual priorities and longer-term targets set within the Murray-Darling Basin Plan.
Alexandrina Council, Coorong District Council and The Rural City of Murray Bridge	Create and enforce local laws, manage services and activities which are adapted to the needs of the community they serve.	Manages foreshores adjoining urban areas on Lake Alexandrina and Lake Albert, operate and maintain council roads and administer the Planning and Design Code within the site.
Environment Protection Authority (EPA)	EPA is South Australia's independent environment protection regulator; protecting, restoring and enhancing the environment using risk-based regulation of pollution, waste, noise and radiation.	Licensing, inspecting and auditing activities under the *Environment Protection Act 1993* that have an impact on the site. Water quality and aquatic ecosystem monitoring of the Lakes and tributaries as required under the *Environment Protection Act 1993*.
Primary Industries and Regions	Strategic direction for the economic development and sustainability of the state's primary industries and to advance the liveability of regional communities.	Manage commercial and recreational fishing for the Ramsar site in accordance with the *Fisheries Management Act 2007*.
Department for Infrastructure and Transport	Strategic direction for planning policy, efficient transport, and valuable social and economic infrastructure. Manages the planning and land use system, state road network, building construction delivery and property related services to state government clients and licensing of vehicles and boats.	Administration of the *Harbors and Navigation Act 1993* within the Ramsar site. Maintenance and operation of the Hindmarsh Island bridge and navigation channels and beacons.

2.2.1 First Nations and Ramsar site management

The Ngarrindjeri and First Nations of the South East are the Traditional Owners of the lands and waters of the Ramsar site. Ngarrindjeri people have occupied, enjoyed, managed and used their inherited lands and waters within the area of the River Murray (Murrundi), Lakes Alexandrina and Albert, Coorong (Kurangk) and adjacent areas since the Kaldowinyeri (Ngarrindjeri Creation).

The health of the Coorong and its connected lands and waters are central to the culture and beliefs of the Traditional Owners – the Ngarrindjeri and First Nations of South East. Wetlands, water sources and bodies are precious areas for First Nations People. They are part of the traditional territories and resources and provide the basis for the livelihoods of their families and communities; they are also fundamental elements of their cultures since the lands and waters are a living body and they are part of its existence. The waters of the Coorong include surrounding connected waters, many of these places are sacred and have high spiritual significance.

The Traditional Owners of the Coorong have developed their cultures based on the interactions with wetlands and waters – their ways of life, their cultural expressions and their value systems are deeply connected to those ecosystems.

2.3 Ramsar criteria met

The Ramsar site has been assessed as meeting 8 of the 9 current Ramsar criteria and these are described below.

There has been no change in the ecological character and application of the criteria since 2013, however different species now meet criterion 2 and 6 than previously reported and are included in chapter 7 of this management plan (DEW 2023).

Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.

The hydrological patterns (freshwater and tidal) prevailing over the site's geomorphologic and topographic formations drive wetland extent and the diverse mosaic nature of the 23 Ramsar wetland types (See wetland types in Glossary). Wetland types include permanent (M) and seasonal (N) rivers, streams and creeks; permanent (O), (Tp) and seasonal (P) freshwater lakes and ponds; seasonal freshwater (Ts) and saline (R), (Ss) lakes and marshes; shrub dominated (W) and tree-dominated (Xf) wetlands; freshwater springs (Y); seasonally flooded land (4), drainage channels (9), permanent shallow marine waters (A), rocky marine shores (D), sand and dune systems (E), intertidal mud, sand and salt flats (G) and marshes (H), estuarine waters (F), intertidal wetlands (I), coastal brackish/saline lagoons (J), coastal freshwater lagoons (K), and water storage areas (6). The site is unique in its wide representation of wetland types within the bioregion and is the only estuarine system within the Murray-Darling Basin (Phillips & Muller, 2006).

Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

Eleven threatened species (3 flora and 9 fauna), which includes 2 migratory species (birds) and 2 ecological communities are regularly supported within the site. These are listed below, with their national threat status included in brackets after the species name (see Table 2.3 for description of threat status categories).

Table 2.3 IUCN Red List Categories

IUCN category	Definition
Vulnerable (VU)	Is considered to be facing a high risk of extinction in the wild.
Endangered (EN)	Is considered to be facing a very high risk of extinction in the wild.
Critically Endangered (CE)	Is considered to be facing an extremely high risk of extinction in the wild.

Threatened ecological communities:
- Swamps of the Fleurieu Peninsula community (CE) - found within the Eastern Mount Lofty Ranges tributaries (on the western margins of Lake Alexandrina) and is characterised by reeds and other heathy vegetation and organic (peat) or black clay soils (262 ha). It provides habitat for the Mount Lofty Ranges Southern Emu-wren (EN).
- Subtropical and temperate coastal saltmarsh community (VU) - found within the Murray estuary and Coorong (480 ha).

Threatened flora species:
- Metallic sun-orchid (EN).
- Sandhill greenhood orchid (VU) – a South Australian endemic wetland dependent species.
- Silver daisy bush (VU) – a South Australian endemic wetland dependent species.

Threatened fauna species
- Birds: Australasian bittern (EN); Australian fairy tern (VU); Curlew sandpiper (CE, Migratory); Eastern curlew (CE, Migratory); Hooded plover (VU); and Mount Lofty Ranges southern emu-wren (EN).
- Fish: Murray hardyhead (EN); Southern pygmy perch (Murray-Darling Basin lineage) (VU)
- Frog: Southern bell frog (VU).

Emergent vegetation on the margins and fringing wetlands of Lakes Alexandrina and Albert provide habitat for the Australasian bittern and the southern bell frog. Murray hardyhead and southern pygmy perch are distributed around Hindmarsh Island, Goolwa Channel, Clayton and Milang Bay. The Murray estuary and Coorong provide important foraging habitat for migratory shorebirds such as the curlew sandpiper and eastern curlew; and breeding habitat for the Australian fairy tern. The hooded plover forages and nests on shores of the Coorong and beaches of the Sir Richard and Younghusband Peninsulas.

Three threatened species (Yarra pygmy perch (VU), Australian painted snipe (EN) and orange bellied-parrot (CE)) only occur in very low numbers or are infrequent visitors.

Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

The Ramsar site supports more than 1,400 plant species, including 279 aquatic species ranging from obligate freshwater species to halophytic species and emergent riparian species.

A total of 104 fish species have been recorded in the Ramsar site, with 29 fish species regularly supported by the site (Bice, 2010). This includes species that are not found anywhere else within the Murray-Darling Basin, such as the small-mouthed hardyhead, lagoon goby and Tamar River goby. In addition to the conservation significant species listed under Criterion 2, fish species protected in South Australia have been recorded in the Ramsar site including freshwater catfish and southern purple-spotted gudgeon, dwarf flat-headed gudgeon, unspecked hardyhead, congolli, pouched lamprey, short-headed lamprey, mountain galaxias, estuary perch and short-finned eel (Bice, 2010). The site is the only connection between marine, estuarine and freshwaters in the Murray-Darling Basin for diadromous fish species such as congolli, common galaxias, pouched lamprey and short-headed lamprey.

The site supports high bird species richness, with 307 bird species recorded within one km of the site, 118 of which utilise wetland habitats (O'Connor, et al., 2012). The site supports the majority of waterbird species that occur within the Murray-Darling Basin and a number of species that are not recorded elsewhere within the basin (O'Connor, 2015). In addition to the 11 waterbirds listed as threatened under national or international conservation agreements (in Criterion 2), a number of waterbird species are of state or regional conservation significance. These include little tern, white-bellied sea eagle, banded stilt, freckled duck, Lewin's rail, Australasian shoveler, blue-billed duck and sooty oystercatcher (O'Connor, et al., 2015).

Eight frog species have been regularly recorded in the Ramsar site since 2009 (Mason & Durbridge, 2015), including the southern bell frog listed under Criterion 2, the common froglet, eastern banjo frog, long thumbed frog, spotted grass frog, brown tree frog, Peron's tree frog and painted frog. The eastern banjo frog and painted frog are true burrowing frogs with the others above-ground dwellers. Less commonly seen are the brown toadlet and the marbled toadlet, listed as rare and vulnerable respectively in South Australia. Other fauna of note include the common long-necked tortoise, the Macquarie short-necked tortoise, water rat and swamp rat.

Benthic invertebrates such as amphipods, polychates (*Capitella capitata, Simplisetia aequisetis*) and insect larvae form important components for the diet of shorebirds (Paton 2010) and many zoobenthivorous fishes (e.g. greenback flounder, small-mouthed hardyhead and Tamar River goby) (Hossain, et al., 2016; Earl, 2014).

The site supports several vegetation species and communities of significance, including diverse reed beds, river red gum, freshwater herbland, cutting grass sedgeland, swamp paperbark woodland and lignum shrubland.

Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.

The Ramsar site supports a number of migratory bird species, including 48 wetland-dependent species listed as migratory under the EPBC Act and international migratory species agreements.

The dominant submerged aquatic macrophyte community of the Coorong is a 'mixed' community often dominated by *Ruppia tuberosa* but also containing *Althenia cylindrocarpa* and other species where environmental conditions allow. This community is a major food source of the tens of thousands of waterbirds, including migratory shorebirds, that inhabit the Coorong (Asanopoulos & Waycott, 2020).

A total of 38 waterbird species are known to breed within the site (O'Connor, 2015). The Ramsar site is considered to support critical breeding habitat for the Australian pelican, Caspian tern, greater crested tern, Australian fairy tern, hooded plover, Australian pied oystercatcher and red-capped plover and important breeding habitat for black swan, Australian white ibis, straw-necked ibis, Australian pied cormorant and royal spoonbill. Other regularly breeding species include silver gulls (Paton, et al., 2015b), chestnut teal and pacific black duck (O'Connor, et al., 2012).

Bird species that rely on the site for adult survival when inland lakes are dry include the red-necked avocet, chestnut teal, Australian shelduck and banded stilt (O'Connor, et al., 2012).

At least 56 bird species regularly use the site as a critical refuge while moulting, including the Australian shelduck, chestnut teal, black swan, banded stilt, black-winged stilt, red-necked avocet and Australian pelican (O'Connor, 2015). All international migratory shorebirds gradually replace their flight feathers upon landing at the site in summer (O'Connor, et al., 2012).

The site supports a number of diadromous fish species, including congolli, common galaxias, pouched lamprey and short-headed lamprey, as well as estuarine, freshwater and marine fish species that use the site at critical stages of their life cycles or as a refuge from drought (Higham, et al., 2002; Phillips & Muller, 2006; Bice, 2010; Bice, et al., 2018).

Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.

The Coorong and Lakes Alexandrina and Albert Wetland has supported more than 20,000 waterbirds in every year that it has been surveyed (O'Connor, 2015). An average of 262,342 waterbirds are recorded in the January census each year, based on data from 2009 to 2020. The Coorong generally supports twice as many birds as the lakes in summer, with the average number of birds supported in the Coorong greater than 165,500 compared to an average of 82,500 birds in the lakes between 2009 and 2020. During the Millennium Drought (1996-2010) the Ramsar site was an important waterbird refuge and supported over 400,000 waterbirds in 2009.

Annual census data identified the following 17 species present in numbers of greater than 2,000 birds per year (in at least 6 out of 8 years during 2013-2020): Australian pelican (av. 11,844), Australian shelduck (av. 34,911), black swan (av. 6,043), chestnut teal (av. 5,743), Eurasian coot (av. 5,429), great cormorant (av. 19,222), greater crested tern (av. 4,418), grey teal (av. 58,861), hoary-headed grebe (av. 5984), little black cormorant (av. 3,227), Pacific black duck (av. 6,625), Australian pied cormorant (av. 9025), red-necked avocet (av. 4,485), red-necked stint (av. 25,171), sharp-tailed sandpiper (av. 14,865), silver gull (av. 10,573) and whiskered tern (av. 11,477).

Populations of banded stilts fluctuate greatly in response to off-site conditions. Moving to the coast from inland locations during periods of dry weather (Birdlife Australia, 2015), with peak abundances occurring in dry years. During 2013-2020 numbers peaked in 2016 during the drought at 13,301 (Paton, et al., 2016) before dropping to 136 in 2017, a wet year (Paton, et al., 2017).

The abundances of waterbirds that the Ramsar site supports greatly varies between geographic locations (Paton et al. 2009) and also varies substantially from year to year (Paton, et al., 2015b; Paton, et al., 2018).

Criterion 6: A wetland should be considered internationally important if it regularly supports one per cent of the individuals in a population of one species or subspecies of waterbird.

The Ramsar site is significant for the role it plays in supporting individual bird species. Regularly supporting 1% or more of the flyway population for the migratory curlew sandpiper (av. 1.6%, 2013-2020), red-necked stint (av. 5.2%, 2013-2020) and sharp-tailed sandpiper (av. 17.4%, 2013-2020).

Australian non-migratory species regularly supported include the Australian pied oystercatcher (av. 1.2%, 2013-2020), Australian fairy tern (av. 24.7%, 2013-2020), chestnut teal (av. 5.7%, 2013-2020) and red-capped plover (av. 1.3%, 2013-2020).

During 2013-2020, other waterbirds with more than 1% of their population at the site included the Australian pelican (av. 3.9%), Australian pied cormorant (av. 9%), Australian shelduck (av. 3.4%), Caspian tern (av. 1.6%), great cormorant (av. 19.0%), grey teal (av. 2.9%) and red-necked avocet (av. 4.1%).

The species that currently meet this criteria are different from those presented in the 2013 RIS, which used older population estimates (2006) (refer also Table 14.4). Whilst the species nominated to meet this criterion have varied over time, some species are always present that meet this criterion.

Criterion 7: A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.

A total of 104 species of fish have been recorded within the Ramsar site, with 45 species from the Lakes and 93 species from the Murray estuary and Coorong (Bice, et al., 2018). This represents over 50% of the number of fish species found within the Murray-Darling Basin. Species from all 17 Murray-Darling Basin fish families have been recorded at the site, making it the only site within the Basin to support representatives from all of the fish families known to occur in the Basin.

Around 29 species occur regularly within the site and represent an assemblage with a diverse range of morphologies, sizes and life histories (Bice, 2010; Watt, 2013). Of the freshwater straggler guild small-bodied species, include several species of conservation significance (southern pygmy perch and Murray hardyhead) and carp gudgeon and unspecked hardyhead common and widespread in the Lakes. The large bodied species golden perch supports the Lakes and Coorong commercial fishery (Ferguson, et al., 2018). Freshwater-estuarine opportunists include bony herring, Australian smelt and flat-headed gudgeon.

Solely estuarine species include black bream, small-mouthed hardyhead, Tamar River goby, lagoon goby and western blue-spot goby. Except for small-mouthed hardyhead, these species are typically most common in the Murray estuary and Coorong North Lagoon and only occasionally sampled in the Coorong South Lagoon and Lakes. Small-mouthed hardyhead is typically abundant in the Coorong South Lagoon, where it is often the only fish species present (Ye, et al., 2015). Marine estuarine opportunists are marine species that enter estuaries regularly in substantial numbers often as juveniles. Examples include mulloway, greenback flounder and yellow eye mullet (important commercial, cultural and recreational species), and sandy sprat (important in the Coorong food web) (Bice, et al., 2018).

The site is the only access point to the Murray-Darling Basin for diadromous fish species and supports a combination of life history strategies not found elsewhere in the Murray-Darling Basin. Patterns of fish assemblage structure (species composition and abundance) are highly variable (Zampatti et al. 2010 and Wedderburn et al. 2012 cited in (Watt, 2013)) and influenced by complex interactions between taxa and their physical environment (Watt, 2013).

Whilst the site supports high species richness, the fish community also exhibits high levels of biodisparity in regards to morphology and life history. Fishes range in size (adult length) from 40 mm to greater than 1 m, possess

contrasting morphologies, from benthic flatfishes (for example, Pleuronectidae) to fusiform pelagic species (for example, Arripidae) and represent a wide range of different life history strategies (Watt, 2013). It is the diversity of fish species and families, life history, morphologies and movement that contributes to the high biodisparity in the Ramsar site (Watt, 2013).

Criterion 8: A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

As the only connection to the sea for diadromous species in the Murray-Darling Basin, the site is a crucial as a migration pathway for 3 guilds of diadromous fish, including:

(1) Anadromous: pouched lamprey and short-headed lamprey, the only anadromous fish species in the Murray-Darling Basin (Bice, et al., 2018).

(2) Catadromous: congolli with the connectivity and habitats enabling winter spawning migrations of female congolli (from the lower River Murray, Eastern Mount Lofty Ranges tributaries) through the Murray estuary and into the ocean, but also larvae and juveniles to enter the Murray estuary (from the ocean) to migrate upstream into freshwater habitats (Bice, et al., 2012).

(3) Semi-catadromous: for example common galaxias undertake downstream migrations and spawning, where larvae are commonly washed out to the ocean, where they develop, before upstream migrations of juveniles (Bice, et al., 2018).

Fish which utilise the Murray estuary for their entire life cycle (spawning ground, nursery and as adult habitat) include the small-mouthed hardyhead, Tamar River goby and black bream. Mulloway use the Coorong as a nursery, typically entering the system from the ocean at ≤1 year of age and emigrating to the ocean at ~5 years of age (Ferguson, et al., 2014). Recruitment and strength of adult age classes are positively correlated with freshwater discharge to the Coorong and the Coorong nursery has a large influence on regional population dynamics for this species (Ferguson, et al., 2008).

Other marine estuarine opportunists that use the site include the sandy sprat who use it as a nursery (Watt 2013) and greenback flounder that enter estuaries, particularly as juveniles (Earl et al. 2014) .

3 Ecological character

A detailed description of the ecological character of the Coorong and Lakes Alexandrina and Albert Wetland is provided in the *Ecological character description Coorong and Lakes Alexandrina and Albert Wetland Ramsar site* (DEW, 2021a) draft in preparation, and a brief summary is provided here.

3.1 Critical components, processes and services

A brief summary of each critical components, processes and services (CPS) along with the important subcomponents is presented in Table 3.1. The descriptions include supplementary information since the ecological character description 2015 baseline that aligns with management targets and actions within this management plan.

Table 3.1 Summary of critical components, processes and services (CPS)

Critical CPS and subcomponents	Description	Type
Hydrology • Inflows • Rainfall and evaporation • Lake levels • Barrage flows • Tidal signal	• River Murray inflows into the north of Lake Alexandrina are the primary source of freshwater for the Ramsar site. • Lake Alexandrina is the source of freshwater for Lake Albert. • Barrage flow is the primary source of water for the Murray estuary and the Coorong. • Small seasonal inflows from the East Mount Lofty Ranges (EMLR) tributaries, flows from the USE and rainfall are minor freshwater inputs to the site. • Barrage flows are dependent on River Murray inflows, lake level management, losses and diversions. • Lakes and Coorong water levels fluctuate seasonally and are typically higher in winter than summer. • An open Murray Mouth allows tidal exchange and connectivity between the ocean and the estuary.	Component, process, supporting and cultural services
Salinity • Lake Alexandrina and Albert • EMLR tributaries • Murray estuary and Coorong	• Salinity is a major driver of the composition and distribution of species found within the site. • Salinity in the Lakes is closely linked to hydrology, particularly River Murray inflows and barrage outflows. • Lake Albert generally has a higher salinity than Lake Alexandrina. • The Murray estuary has a natural gradient from fresh to brackish during periods of high freshwater discharge to estuarine to marine during periods of lower freshwater discharge. • The Coorong is a reverse estuary with salinity increasing with distance from the Murray Mouth. The Coorong North Lagoon is estuarine to saline and the Coorong South Lagoon salinity is hypersaline, to predominantly hypersaline. • Salinity in the Coorong (North and South Lagoons) follows a seasonal cycle, which is magnified in the South Lagoon. Salinity in the South Lagoon is greatest in late summer/early autumn in response to high evaporative rates and reduced connectivity throughout summer.	Component
Vegetation	• Hydrology and salinity gradients, turbidity and wave action determine the composition and distribution of flora.	Component

Critical CPS and subcomponents	Description	Type
• Submergent freshwater vegetation • Emergent freshwater vegetation • Submergent halophytes • Emergent halophytes	• The diversity and abundance of submergent freshwater vegetation is greatest when the water regime is variable and turbidity is low. • Extensive stands of emergent vegetation (cumbungi and diverse reed beds) are present around the Lakes' shorelines. • Saline permanent waters are dominated by *Ruppia tuberosa* and occasionally algae. • Samphire and saltmarsh communities are fringed by lignum, native grasses and/or swamp paperbark.	
Fish • Diversity (species richness and biodisparity) • Movement and recruitment • Threatened fish species	• 104 species have been recorded at the site with 29 species using the site regularly. • The site contains a diverse assemblage of freshwater, diadromous and euryhaline estuarine species. • The site forms the only estuarine habitat in the Murray-Darling Basin and is therefore the only access point for diadromous fish species within the Basin. • The site supports important species for commercial and recreational fisheries. • 3 internationally and/or nationally listed threatened species occur within the site.	Component, process (recruitment) and cultural service
Waterbirds • Diversity • Abundance • Foraging, refuge and roosting habitat • Breeding • Threatened waterbird species	• 118 species of waterbirds use the wetland habitat. • The site supports 48 wetland-dependent species that are listed as migratory under the EPBC Act and international migratory agreements. • Regularly supports 1% or more of the flyway population of 7 species. • 38 waterbird species are known to breed at the site and 13 regularly breed within the site. • 8 internationally and/or nationally listed threatened species occur within the site.	Component, process (recruitment) and cultural service
Wetland habitat	• The site supports a unique mosaic of 23 wetland types. • The site is the only estuarine system within the Murray-Darling Basin.	Component
Threatened ecological communities and species • Swamps of the Fleurieu Peninsula • Subtropical and temperate coast marsh • Southern bell frog	• Part of the swamps of the Fleurieu Peninsula ecological community occurs within the Currency Creek and Finniss River areas. • The subtropical and temperate coastal saltmarsh ecological community is found in both the Murray estuary and Coorong North Lagoon. • The southern bell frog occurs around Lake Alexandrina, Lake Albert and Eastern Mount Lofty Ranges tributaries.	Component

Critical CPS and subcomponents	Description	Type
Coorong food web • *Ruppia tuberosa* • Macroinvertebrates • Small-mouthed hardyhead	• *R. tuberosa* is a keystone primary producer in the hypersaline food webs of the Coorong. • Macroinvertebrate diversity, abundance and biomass are highest in the Murray estuary and decrease southward into the Coorong South Lagoon. • Small-mouthed hardyhead with high salinity tolerance are the critical prey species for piscivorous fishes and birds.	Component and provisioning service

3.2 Site influences

At the broadest scale the Coorong and Lakes Alexandrina and Albert Wetland is influenced by natural factors beyond human control including:

- Rainfall and runoff in the Murray-Darling Basin which affects the amount of freshwater flowing into the system
- Local weather conditions, which influence:
  - The rate of evaporation from the surface of the water bodies
  - Water levels via seiching
  - The extent and timing of local direct rainfall
- Sea level, which changes:
  - Daily (tides)
  - Seasonally (sea level in Encounter Bay is higher in winter than in summer)
  - According to the weather (e.g. storm events can increase sea level)

A number of factors under human control, using current management levers, also influence the wetland, including:

- Flow regulation, consumptive water use (including groundwater extraction) and delivery of water for the environment in the Murray-Darling Basin, which influence:
  - Volume
  - Seasonality
  - Water quality of inflows into the site
  - Regulated inflows to the Coorong from the South-East Drainage Network
- Operation of the barrages and their associated fishways, which influence:
  - Water levels in the Lower Lakes
  - The openness of the Murray Mouth
  - The degree of connectivity between the estuarine-saline system units and the freshwater system units
- The openness of the Murray Mouth, maintained by continuous dredging from 2002 to 2022.

3.3 Management Units

The Ramsar site covers a diverse range of wetland systems, with the following sub-units are regularly referred to when describing critical CPS:

- **Lake Alexandrina and Lake Albert** which includes the freshwater environments of Lake Alexandrina, Lake Albert and the Goolwa Channel (to Goolwa barrage)
- **Eastern Mount Lofty Ranges tributaries** which includes the freshwater environments of the lower reaches of the Finniss River, Currency Creek and Tookayerta Creek
- **Murray estuary** which extends from the Goolwa barrage to Pelican Point, including the Goolwa, Coorong and Mundoo channels, the Murray Mouth and part of Younghusband Peninsula
- **Coorong North Lagoon** which extends from Pelican Point to Parnka Point and the coastal environments and beaches of Younghusband Peninsula from Pelican Point
- **Coorong South Lagoon** which extends from Parnka Point to the southern end of the Coorong National Park and includes the coastal environments and beaches of Younghusband Peninsula from Parnka Point

The sub-units are based on hydrological boundaries that are representative of the 5 broad habitat types of the site. The health of the Ramsar site relies on all units being interconnected and management of any one unit is undertaken in consideration of the entire Ramsar site. This management approach is reflective of the interconnectedness of the site which is described by Ngarrindjeri perspectives that the lands and waters of the Ramsar site are a living body - part of the Ngarrindjeri living body. Maintaining the health of Yarluwar-Ruwe (sea country) and the connectivity between all its aspects and elements is a key cultural responsibility, and fundamental to Ramsar site and Ngarrindjeri health and wellbeing (Ngarrindjeri Nation, 2019).

4 Threats

4.1 Threats to the ecological character

The major threats identified for the Ramsar site are:

- Water diversions upstream leading to reduced inflows and altered hydrological regimes (both River Murray and South East region).
- Climate change leading to changed rainfall, increased temperatures and evaporation, sea level rise and more frequent severe storms.
- Water quality changes through increased salinity, increased turbidity, high nutrient loads and exposure of acid sulfate soils.
- Invasive species and problematic natives.
- Recreational activities.

Table 4.1 summarises the potential and actual threats that may impact on the ecological character of the site that were identified in the updated *Ecological character description Coorong and Lakes Alexandrina and Albert Wetland Ramsar* (DEW, 2021a) as well as through research undertaken as part of the *Healthy Coorong, Healthy Basin* program (DEW, 2020a). These are the key threats that this management plan aims to mitigate through its management actions and proposed site governance arrangements.

For more detailed information about the threats to the ecological character of the site refer to the updated *Ecological character description Coorong and Lakes Alexandrina and Albert Wetland Ramsar* (DEW, 2021a).

Table 4.1. Summary of threats to The Coorong and Lakes Alexandrina and Albert Wetland Ramsar site.

Threat or threatening activity	Impact	Likelihood	Timing
Water diversions upstream that lead to: • **reduced inflows** • **altered hydrological regimes (timing, magnitude and frequency of flows)**	• Altered hydrological regimes (timing, magnitude and frequency of flows) • Decreases in water levels and increased salinity in the Lakes and Coorong • Changes to habitat availability from changes in wetland area, frequency of flooding and salinity distribution • Limited ecological and hydrological connectivity between fresh (Lakes), saline (Murray estuary) and Murray Mouth. • Decreased inflow/flushing to dilute and export salt and nutrients • High levels of plankton (chlorophyll-a), nitrogen, phosphorus and filamentous algae in the water and depositing into sediments • Decreased water quality from increasing turbidity due to increased erosion of Lake shorelines and pollutants and acidity from exposure of acid sulfate soils • Impacts on flora and fauna breeding events and vegetation distribution	Certain	Immediate

Threat or threatening activity	Impact	Likelihood	Timing
Climate change that results in: • **changed rainfall, increased temperatures and evaporation** • **sea level rise** • **more frequent and severe storms**	• Altered hydrological regimes (timing, magnitude and frequency of flows) • Reduced inflows (refer above) • Increased evaporation leading to reduced water levels and increased salinity in the Lakes and Coorong • Saltwater intrusions into the Lakes from sea level rise and storm surges • Increased probability of Murray Mouth closure caused by increased sedimentation from marine sources due to more frequent storms • Increased erosion and habitat destruction leading to reduced waterbird nesting	Certain	Immediate to long-term
Water quality changes through: • **increased salinity** • **increased turbidity** • **increased nutrients** • **exposure of acid sulfate soils**	• Sediment is degraded with high nutrient levels, algal mats making them anoxic, and sulfidic black oozes • Loss of key species, habitats and ecosystem processes • Food web changes • Loss of flora and fauna through the toxic effects of decreased pH and release of heavy metals • Reduced recruitment through sub-lethal impacts on survival of critical life history stages (i.e. fish eggs) • Behavioural changes, decreased growth and increased disease	Certain	Immediate
Invasive species and problematic natives	• Predation on native species • Displacement of native species • Increased vegetation grazing pressure • Reduced native vegetation cover and diversity due to spread of invasive weeds • Problematic abundant native species affecting resource use and impacting populations of other native species	Certain	Immediate to medium term
Recreational activities	• Disturbance of nesting sites by 4WD activity on beaches • Reduced abundance of fish species targeted by recreational fishing • Shoreline erosion from boating activity and wave wash	Certain	Immediate to medium term

4.1.1 The Millennium Drought

The Millennium Drought from late 1996 to 2010 had a profound impact on the Ramsar site. Between 2006 and 2010, River Murray flows were at historically low levels due to the combined impacts of extreme drought and over-allocation across the Murray-Darling Basin. As a result, inflows into the Lakes were not able to replenish evaporative losses and average lake levels dropped to unprecedented lows. In April 2009 average water levels were at their lowest in Lake Alexandrina, at just below -1. 0m AHD and the 2 lakes were disconnected (MDBA, 2014a).

Low water levels in the Lakes, disconnection of the wetlands, exposure of 20,000 ha of acid sulfate soils and increased salinity levels severely impacted the ecological character of the site. Wetlands dried out and they, along with exposed lakebed areas, were colonised by terrestrial plants, many of which were introduced species. Much of the region's submerged aquatic habitat, particularly in local channels, was significantly reduced or eliminated. Diadromous fish species, the life-cycles of which require movement between freshwater, estuarine and marine habitats, were unable to pass through the barrages to complete their life cycle due to the low water levels in Lake Alexandrina. Connectivity (both hydrological and ecological) was lost between Lake Alexandrina and the Goolwa Channel and Lake Albert due to the temporary construction of regulators and a bund (MDBA, 2016).

Evapoconcentration, the seepage of marine water through the barrages and low River Murray inflows led to salinity in the lakes increasing beyond values normally associated with freshwater environments. High salinity throughout the site impacted freshwater fish, vegetation, macroinvertebrates and turtles. Some parts of the Coorong South Lagoon were 7 times more saline than seawater. The Murray Mouth was kept open through the intervention of dredging (DEH, 2009), which continued until the River Murray 2022-23 flood, restarting after the flood receded.

Significant rainfall and flooding in the Murray-Darling Basin throughout winter and spring 2010 greatly increased inflows and the Lakes quickly refilled and caused re-wetting and mobilisation of acidity. The neutralising capacity of the lake water was sufficient to prevent widespread acidification, although 'hot spots' of low pH water were observed during refill. This flow event was considered to be a 1 in 8-year occurrence (Bloss, et al., 2015). Due to the volume of flows entering the region, habitats were hydrologically reconnected and in September 2010 water was released through the barrages for the first time since 2006. In total, over 19,000GL was estimated to have been released over the barrages in 2010–11 and 2011–12 reducing salinities significantly in Lake Alexandrina over a short period and Lake Albert over a longer period (in 2015 salinities in Lake Albert were greatly reduced but did not return to pre-drought levels until late 2017).

Years without significant flows over the barrages, supplemented only by the relatively minor flows from the Upper South East, resulted in extreme hypersaline conditions in the Coorong South Lagoon. Aquatic vegetation (particularly the key species *R. tuberosa*) was severely impacted and small-bodied fish species (such as the small-mouthed hardyhead, a key part of the Coorong South Lagoon food web) withdrew to the Coorong North Lagoon and Murray Mouth (Wilson, et al., 2016).

Since 2010, significant flows over the barrages, combined with increased flows from the South East, have reduced salinity in the Coorong South Lagoon and helped to maintain it generally below 100ppt (112,471 EC). However, the ecosystem has been slow to respond, demonstrating the long-term nature of impacts associated with periods of low inflows and extreme salinity.

Further information on flow events since the Millenium Drought can be found within the DEW Technical report 2020/18: *South Australian River Murray Basin Plan Environmental Outcome Evaluation: Coorong, Lower Lakes and Murray Mouth (CLLMM) Priority Environmental Asset* (DEW, 2020d).

5 Site management

5.1 Current management capability

Site managers can currently influence conditions at the Ramsar site using the following management levers:

1. Environmental water delivery – water for the environment that is recovered through the Murray-Darling Basin Plan can be delivered to the site through negotiations with the Commonwealth Environmental Water Holder (CEWH) or from other non-CEWH water.
2. Barrage operations – water can be released from Lake Alexandrina into the Murray estuary and the northern end of the North Lagoon of the Coorong through 593 independently operable gates placed in 5 barrages. Releases of water through these gates affects the water levels in Lakes Alexandrina and Albert as well as the volumes and patterns of water delivery to the Murray estuary and the Coorong. The relative proportions discharged through the different barrages and open gates enable managers to achieve different objectives, such as directing water into the North Lagoon or out the Murray Mouth.
3. Dredges – sand that accumulates in the Murray Mouth can be removed by dredges to maintain an open Murray Mouth and exchange between the Murray estuary and the Southern Ocean. This is particularly important for managing water levels and salinity in the Coorong lagoons as well as providing connectivity for organisms to move between the site and the ocean.
4. Upper South East drainage flows – water collected in the drain system of the Upper South East of South Australia that are connected to the Coorong can be delivered via Morella Basin and Salt Creek to provide localised freshening at the southern end of the South Lagoon of the Coorong.

These current management levers can be used to maintain the 2015 "baseline" ecological character, and improve a limited number of CPS.

HCHB is exploring opportunities for long-term large-scale solutions to manage salinity and nutrient loads in the Coorong South Lagoon, to improve ecological health. Feasibility investigations have identified that 3 variants of a connection between the Coorong South Lagoon and Southern Ocean (with or without targeted dredging as a complementary action) have the most potential for improving the health of the Coorong South Lagoon. All 3 infrastructure variants export salt and nutrients from the Coorong. This remains an investigations project and no decision has been made to proceed with any particular option.

This RMP will be considered for review at the end of the HCHB program and will be informed by all findings and outcomes from the program as required.

5.2 Management indicators

5.2.1 Resource condition targets

Resource condition targets (RCTs) were developed to guide the development of appropriate management strategies. Resource condition targets describe the contemporary state for the Ramsar site's critical CPS and take into account expected variation under current management.

RCTs are founded on the baselines identified in the *Ecological character description Coorong and Lakes Alexandrina and Albert Wetland Ramsar* (DEW, 2021a), and the targets or indices in the following established management programs within the Ramsar site:

- Murray-Darling Basin Plan (MDBA, 2012)

- The Basin-wide Environmental Watering Strategy (MDBA, 2014c)
- Long-term environmental watering plan for the River Murray South Australian water resource plan area (DEW, 2020b)
- The Living Murray – Lower Lakes, Coorong and Murray Mouth icon site condition monitoring plan (DEWNR, 2017)
- Lower Lakes, Coorong and Murray Mouth icon site environmental water management plan (MDBA, 2014b) and
- The barrage operating strategy (DEW, 2019).

Those RCTs that were not derived from existing documentation were developed using best available data and information, and/or expert opinion from scientists and site managers.

5.2.2 Management triggers

Management triggers (MTs) are pre-defined conditions or values used to raise an alert and act as decision points to initiate a management response. Thresholds for MTs are set at a value between the RCT and the Limit of Acceptable Change (LAC), as shown in Figure 5.1. They are typically set as thresholds for condition to indicate an undesired trend and highlight a potential need for management interventions designed to halt or reverse the undesirable trend. MTs are often on, or just beyond, the fringes of natural variation in condition of each critical CPS. MTs are set to allow sufficient time to investigate and implement management actions that aim to prevent further degradation (towards a LAC) that may potentially alter the ecological character of the site.

MT are set based on thresholds from existing programs, knowledge gained from the ECD, expert opinion and capability of current management.

5.2.3 Limits of acceptable change (LAC)

LAC are described in detail in the the *Ecological character description Coorong and Lakes Alexandrina and Albert Wetland Ramsar site* (DEW, 2021a) draft in preparation. LAC are set for each critical CPS and are undesirable condition thresholds set beyond natural variation that, if reached or breached, may indicate a change in ecological character has occurred. DEW is then required to investigate its cause and take steps to improve the condition of the site.

The relationship between the values set for RCTs, MTs and LAC is illustrated in Figure 5.1.

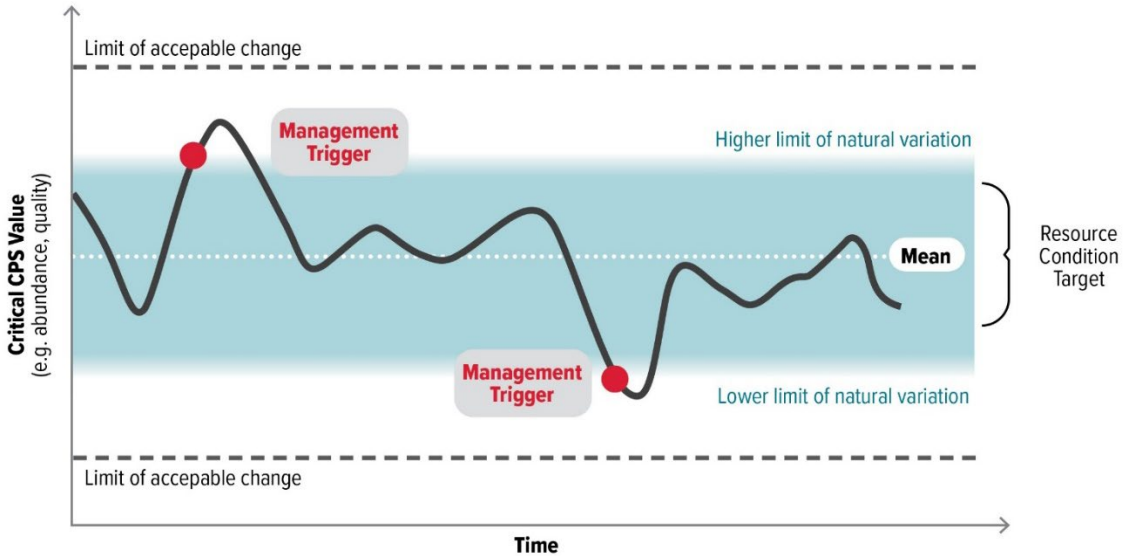

Figure 5.1 The relationship between resource condition target, management triggers and limits of acceptable change for a given component, process or service.

5.3 Management actions

Management actions are undertaken when the conditions of a MT are met. They are practical actions that aim to mitigate threats or risks to critical CPS.

A key aspect of this management plan is to collaborate with the existing programs that operate in the Ramsar site to:

- incorporate ongoing management and monitoring programs
- promote efficiency and longevity of management, monitoring and evaluation
- promote strategic planning within the site.

For many of the management actions identified to achieve RCTs and manage threats, an existing program is in place. Therefore, the management actions outlined within this plan often reflect those already undertaken by existing programs that contribute to maintaining ecological character (including positive effects on CPS where a potential change has occurred (DEW, 2021a)).

Management of high priority threats is an important part of achieving the RCT. Many federal, state and regional strategies and plans address priority threats to the Ramsar site, and where relevant the actions to address these threats are included in this management plan.

5.4 Structure of the management section

The management indicators and management actions that form part of this management plan, have been collated under the 8 critical CPS (see also Table 3.1):

1. Surface water regime
2. Salinity
3. Vegetation
4. Fish
5. Waterbirds
6. Wetland habitat
7. Threatened ecological communities and threatened species
8. Coorong food web

For each sub-component of each CPS, a management action table has been developed, which includes an objective, RCT, MT(s), management actions and LAC (see Chapter 6). These tables also provide a description of what data collection is required for assessment, the region (or sub-units) that the data collection takes place in, and justification for the required assessment. Table 5.1 provides an example to help navigate the management action tables in the next chapter.

Table 5.1. Example of the management action tables within each management theme

CRITICAL CPS – SUB-COMPONENT		
Objective The overarching desired state for the critical CPS in the Ramsar site		
Region The sub-units the data is collected in		
Data requirements The method of data collection, site locations and a reference to the methodology (if available)		
Resource condition target The desired set of conditions for the sub-component		
Management trigger	**Management action**	**Supporting information**
Set at a value between the Resource Condition Target and the LAC, reflective of the limit of natural variation under current management.	Action(s) required to shift condition from the point of the management trigger to within the range set for the resource condition target	Plans, reports or data that support the recommended management actions
Limits of acceptable change The point at which there has been a likely change in ecological character (as per the ECD (DEW, 2021a), draft in preparation)		
Justification Supporting evidence for how the targets, triggers, actions and LAC have been developed.		

5.5 Approach to describing management actions

Certain management actions (and knowledge gaps) apply to multiple critical CPS. This is especially true for management actions that address flow, water level and salinity, which act as key drivers and the primary levers for managing CPS within the site. A framework for describing management actions has been developed (Figure 5.2) to ensure that a coordinated and holistic approach is taken and that links between the CPS are clearly articulated.

CPS and related thresholds for nutrients and sediment quality, critical habitat requirements, the identification of food resources, and the influence of environmental factors on habitat quality and food resource availability for key biota, including fish and waterbirds, are identified knowledge gaps in the current ecological character description (DEW 2021a, draft in preparation). These knowledge gaps are being addressed through HCHB Trials and Investigations project and the results of this work will be available for future iterations of both the Ramsar Information Sheet and RMP. Using this framework, management actions are identified for each CPS using the following definitions:

- Primary management actions: the key drivers for managing the Ramsar site which strongly influence many of the CPS across the site. These are the primary levers for managing the condition of the site and its components.
- Secondary management actions: actions taken alongside the primary management actions which are specific to a CPS.

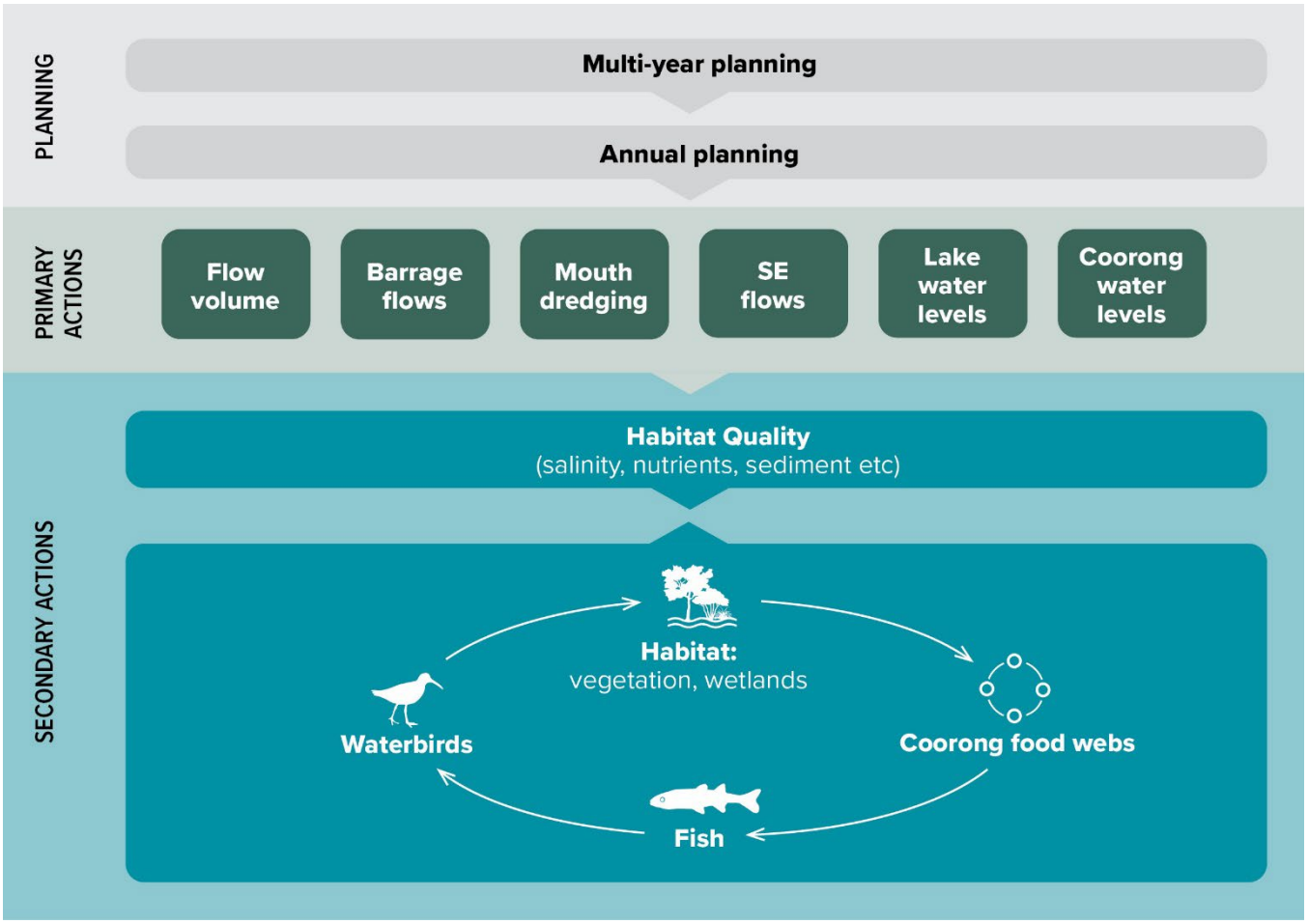

Figure 5.2 The framework for describing management actions in this document

Table 5.2 describes the alignment of primary management actions to relevant critical CPS subcomponents and identifies which drivers are relevant for each of the critical CPS subcomponents within the ecological character description and RMP.

It is expected that the management actions aligned to Lake Alexandrina water levels will address the needs of southern bell frog and thus they have not been identified as critical CPS in

Table 5.2 (see Sections 6.5 and 6.6 for details). RCTs are being developed for the swamps of the Fleurieu Peninsula and have been developed for subtropical and temperate coastal saltmarsh (Section 6.7.2) but these have not been included in Table 5.2 because they are included in the vegetation components. Complementary actions will also support these components (Table 14.6), and targeted monitoring will provide data on population status over time that can feed back into adaptive management planning (Section 10).

Table 5.2. Alignment of primary management actions to relevant critical CPS sub-components within the Ramsar Management Plan.

Critical CPS sub-components	Primary management Actions						
	Flow volume Murray (River flows)	Barrage flows	Open Murray Mouth (dredging)	Lake water levels*	Coorong water levels*	Lakes salinity*	Coorong salinity*
Submergent freshwater vegetation	X			X		X	
Emergent freshwater vegetation	X			X		X	
Submergent halophytes	X	X	X		X		X
Emergent halophytes	X	X	X	X	X		X
Fish diversity	X	X	X	X	X	X	X
Fish movement and recruitment	X	X	X				
Threatened fish species	X			X		X	X
Waterbird abundance**	X	X	X	X	X	X	X
Waterbird diversity – whole of Ramsar site	X	X	X	X	X	X	X
Waterbird diversity – Lakes Alexandrina and Albert	X			X		X	
Waterbird diversity – Murray estuary	X	X	X		X		X
Waterbird diversity – North Lagoon	X	X	X		X		X
Waterbird diversity – South Lagoon	X	X	X		X		X
Waterbird breeding	X	X	X	X	X		X
Threatened waterbirds	X	X	X	X	X	X	X
Wetland habitat	X	X	X	X	X	X	X
Coorong food web – R*uppia tuberosa*	X	X	X		X		X
Coorong food web – Macroinvertebrates	X	X	X		X		X
Coorong food web – small-mouthed hardyhead	X	X					X

*these drivers are influenced by flow volume, barrage flows and Murray Mouth openness.
** Ramsar site, presence/absence of migratory shorebird species, 1% EAAF population selected species and 1% Australian population selected species

5.6 Planning and prioritisation

Environmental water management along the River Murray in SA is coordinated by DEW, with significant involvement from First Nations, non-government organisations and other stakeholders. This portfolio of work includes:

- the development of a Long-Term Environmental Watering Plan, Annual Environmental Watering Priorities, the Annual Water for the Environment Plan and Annual Water for the Environment Report
- the development of the state's environmental watering policies and procedures
- the state's contribution to basin-wide environmental watering policy and planning reform
- management and operations of environmental water and works
- communication of planning, prioritisation and environmental outcomes to stakeholders and the broader public
- monitoring the impact of environmental water delivery and long-term ecological outcomes.

The development of the SA River Murray Annual Environmental Watering Plan is undertaken each year and reflects key planning and prioritisation requirements under the Murray-Darling Basin Plan. It identifies the water

requirements and ecological objectives for priority environmental watering sites and events under a range of climatic conditions for a particular year.

There is also a need for 'real time' water delivery planning and prioritisation within the water year to adapt to current conditions and balance the needs of the critical CPS at the site. There is a broad range of data and information that supports the planning process and real-time prioritisation of water delivery, including modelling, field observations and planning documentation (Figure 5.3).

Figure 5.3 Data and information supporting water planning, delivery and decision making

6 Management of critical components, processes and services

This chapter describes objectives, RCTs, MTs, and LAC for each subcomponent of the critical CPS of the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site. Management action tables provide the basis for monitoring, evaluation and reporting on Ecological Character.

6.1 Hydrology

Hydrology has been identified as a critical CPS in the *Ecological character description Coorong and Lakes Alexandrina and Albert Wetland Ramsar* (DEW, 2021a) draft in preparation. RCT, MT and LAC are described below for the following water regime subcomponents:

- Inflows; and
- Water levels – Lake Alexandrina.

6.1.1 Inflows

South Australia's Entitlement Flow provides critical base flows to the site but will need to be augmented by environmental water delivered in conjunction with unregulated flows. The delivery of flows is highly dependent on environmental water holders, antecedent climatic conditions and the conditions of different ecological assets in the Murray-Darling Basin, and it is not practical to identify a LAC. Lake Alexandrina water levels provide an indirect LAC.

6.1.2 Lake Alexandrina water level

SURFACE WATER REGIME-LAKE ALEXANDRINA WATER LEVELS		
Objective Variable lake levels are maintained to support the ecological character of the Ramsar site.		
Region Lake Alexandrina. Lake Albert water levels are indirectly managed through Lake Alexandrina water levels.		
Data requirements Lake Alexandrina monthly average water level is calculated from A4260574 (near Mulgundawa), A4260524 (Milang Jetty), A4260575 (Poltalloch Plains), A4260527 (Tauwitchere Barrage u/s), A4261133 (Beacon 90 – offshore Raukkan) at water.data.sa.gov.au.		
Resource Condition Target Water levels in Lake Alexandrina fluctuate seasonally between +0.4 m AHD in autumn and +0.85 m AHD in spring to early summer (Lester, et al., 2011).		
Management trigger	**Management actions**	**Supporting information**
Water levels have not risen to +0.85 m AHD in spring/early summer in the last 2 years.	Review past 2 years of water level data to identify volume of additional water needed and target lake levels. Operate in line with 3-month forward plans and based on modelling outputs.	Muller (2010) in Lester et al. (2011). Relevant 3-month forward plan: The use of Commonwealth Environmental Water Holder environmental water in the Coorong, Lower Lakes and Murray Mouth Region of South Australia. Water level data.

		Threatened fish monitoring data (The Living Murray Program). SA Source Murray Model (DEW, 2020c)
Water levels drop below +0.4 m AHD and there is a high likelihood that they cannot be maintained above +0.4 m AHD in the next 12 months.	The MDBA and South Australia initiate the planning phase of the Drought Emergency Framework for Lakes Alexandrina and Albert (DEFLAA).	Drought Emergency Framework for Lakes Alexandrina and Albert (MDBA, 2014a).

Limits of acceptable change

Direct LAC: Lake Alexandrina water levels fall below -0.25 m AHD for 8 consecutive months

Justification

RCT

Water levels in Lake Alexandrina have a direct impact on water levels in Lake Albert, during normal operations, hence a direct water level target has only been set for Lake Alexandrina. The target envelope for Lake levels varies between +0.4 m AHD and +0.85 m AHD (Lester, et al., 2011). It is critical that lake levels are maintained above +0.4 m AHD 95% of the time to maintain system connectivity through the discharge of water from the Lakes to the Coorong and Murray Mouth (MDBA, 2012). Lake levels above +0.4 m AHD avoid the exposure of fringing, submerged and emergent vegetation, which contributes to the maintenance of habitat for freshwater fish and waterbirds (MDBA, 2014b). The upper Lake level envelope was set at +0.85 m AHD as surcharges above this level are favourable to introduced invasive grasses; knotgrass (*Paspalum distichum*) and kikuyu (*Cenchrus clandestinus*) that outcompete native species in the littoral zone (Nicol, et al., 2019).

Operationally, lake levels should be maintained between +0.5 m AHD and +0.85 m AHD in line with the Barrage and Water Level Management Policy 2019 (DEW, 2019) and Drought Emergency Framework for Lakes Alexandrina and Albert (MDBA, 2014a) to achieve the following environmental outcomes associated with a more variable lake level management regime:

- Optimising periods of positive head loss (difference in upstream vs downstream water levels) at barrage fishways, particularly during winter and early spring when Coorong water levels are high to allow more effective operation of fishways that enable fish passage between the Lakes and Coorong at lake levels above +0.5 m AHD (Muller, et al., 2018).
- Maintenance of southern pygmy perch (*Nannoperca australis*) population abundance when lake levels are >+0.5 m AHD from January to March following Lake levels of +0.75 to +0.85 m AHD between September and December (see models of southern pygmy perch abundance in Wedderburn et al. (2019)). To enhance southern pygmy perch recruitment, lake levels should be maintained above +0.6 m AHD through January-March for ≥1 in 3 years (given the estimated species' generation time of 2.5 to 3 years). Lake levels above +0.6m AHD improves southern pygmy perch habitat by increasing food availability and decreasing competitor and predator-prey interactions with invasive fish (Wedderburn, et al., 2019).
- Seasonal fluctuation in lake levels between +0.5 m AHD and +0.85 m AHD to improve the condition of aquatic and littoral vegetation with recruitment of amphibious flora at +0.6 m AHD contributing to greater species richness (Nicol, et al., 2019).
- Surcharging the lakes to +0.85 m AHD in spring/early summer (at least every 3 years) to meet the environmental water requirements of the ecosystem (Lester, et al., 2011). High lake levels (+0.75 to 0.85 m AHD) inundate fringing wetlands that are critical to the spawning and recruitment of threatened small-bodied native fish (Wedderburn, et al., 2019) and frogs (e.g. southern bell frog *Litoria raniformis*) (Mason & Hillyard, 2011; Mason & Durbridge, 2015). Surcharging the Lakes to +0.85 m AHD in spring also stimulates primary production and hatching of zooplankton from the eggbank, which increases food resources for estuarine fish species (e.g. black bream *Acanthopagrus butcheri*) during barrage releases in early summer (Ye, et al., 2019c).

MT

Management actions are triggered if lake levels have not reached +0.85 m AHD in spring/early summer and/or not been maintained above +0.6 m AHD until at least the end of March in the last 2 years to allow for lead-in time to identify and implement management actions for the following year.

The Murray-Darling Basin Plan (MDBA, 2012) aims to keep the Lakes water levels above 0.0 m AHD 100% of the time and above +0.4 m AHD 95% of the time (Section 8.06 3e [i] [ii]) to ensure sufficient discharge to the Coorong and Murray Mouth and prevent river bank collapse and acidification of wetlands below Lock 1, and to avoid acidification and allow connection between

Lakes Alexandrina and Albert. These water levels are also triggers for planning and implementation of emergency mitigation actions and were incorporated into the Drought Emergency Framework for Lakes Alexandrina and Albert (MDBA, 2014a).

LAC

The LAC is set at a point where sustained low lake levels could be expected to trigger broad-scale lake acidification of Lake Albert and would be expected to have an impact on connectivity between Lakes. Water levels in Lake Alexandrina have a direct impact on water levels in Lake Albert hence, a water level LAC is only set for Lake Alexandrina.

6.2 Salinity

Salinity has been identified as a critical CPS (DEW, 2021a). RCTs, MTs and LAC are described below for the following salinity subcomponents:

- Salinity – Lake Alexandrina; and
- Salinity – Murray estuary, Coorong North and South Lagoons.

6.2.1 Salinity – Lake Alexandrina

SALINITY - LAKE ALEXANDRINA		
Objective Maintain salinities within a range suitable for freshwater flora and fauna communities that characterise Lakes Alexandrina and Albert.		
Region Lake Alexandrina		
Resource condition target Salinity in Lake Alexandrina at a long-term annual average of 700 EC, below 1,000 EC 95% of years, and below 1,500 EC all of the time.		
Data requirements Lake Alexandrina salinity is based on the average daily salinity at A4260574 (near Mulgundawa), A4260524 (Milang Jetty), A4260575 (Poltalloch Plains), A4261156 (3km west Point McLeay) and A4261133 (Beacon 90 – offshore Raukkan), available from water.data.sa.gov.au.		
Management trigger	**Management actions**	**Supporting information**
Lake Alexandrina daily salinity averaged over the previous 12 months exceeds 1,000 EC.	Close open barrage bays during reverse head events (i.e. when the water level in the Murray estuary is higher than in Lake Alexandrina). Review past 2 years of data to identify volume of additional water needed and target salinity levels. Operate in line with 3-month forward plans and modelling outputs. If possible, any unregulated flows within South Australia are to be prioritised for the Lower Lakes.	Development of flow regimes to manage water quality in the Lower Lake, South Australia (Heneker, 2010). Barrage Operating Strategy (DEW, 2019). River Murray long-term environmental watering plan for the South Australian River Murray water resource plan area (DEWNR, 2020). 3-month forward plans including environmental water delivery and related modelling.
Lake Alexandrina daily salinity averaged over the previous 2 years exceeds 1,000 EC.	Assess the need for engineering solutions (e.g., bunds) to assist in the maintenance of freshwater ecology by maintaining the connection between the water line and fringing vegetation.	
Limits of acceptable change **Direct LAC:** Lake Alexandrina average annual salinity levels greater than 1,500 EC for 2 consecutive years.		

Justification

The narrow connection between Lake Alexandrina and Lake Albert means that it is not practical to manage salinity levels within Lake Albert independently of Lake Alexandrina. Salinities above 2,000 EC in Lake Albert occur when salinities in Lake Alexandrina are greater than 1,000 EC (Heneker, 2010).

RCT

To meet the RCT, salinities in Lake Alexandrina need to be below 1,000 EC in 95% of years, and there cannot be sequential years where salinities in Lake Alexandrina exceed 1,000 EC. Salinities in Lake Alexandrina below 1,000 EC were associated with improvement in the condition of aquatic and littoral vegetation in the Lakes following the Millennium Drought (Nicol, 2016). Wetlands with low salinities (approx. <1,000 EC) and abundant submerged macrophytes (e.g. *Myriophyllum*, *Vallisneria*) are important habitat requirements for pygmy perches in the lakes (Wedderburn, 2014). Salinities must not exceed 1,500 EC in Lake Alexandrina to avoid adverse impacts on freshwater invertebrates and aquatic plants (Hart & Purser, 1995; Neilsen, et al., 2003).

MT

The MTs are based on the flow regimes identified in Heneker (2010) to manage salinity within Lake Alexandrina below 1,000 EC. There are 2 MTs for salinity levels exceeding 1,000 EC to allow for different management actions for short (one-year) and long-term (multi-year) salinity levels of 1,000 EC.

LAC

The LAC is set at 1,500 EC in Lake Alexandrina for 2 consecutive years. As mentioned above in the RCT justification, salinities above 1,500 EC are potentially detrimental to Australian freshwater aquatic biota. In addition, salinities >1,500 EC in Lake Alexandrina are expected to result in Lake Albert salinities that approach 3,000 EC (Lester, et al., 2011), which surpasses the desired upper threshold of 2,000 EC to maximise diversity of the submergent plant community (Nicol, 2016). The narrow connection between Lake Alexandrina and Lake Albert means that it is not practical to manage salinity levels within Lake Albert independently of Lake Alexandrina.

6.2.2 Salinity in the Murray Estuary, Coorong North and Coorong South lagoons

SALINITY- MURRAY ESTUARY, COORONG NORTH AND SOUTH LAGOONS		
Objective Maintain a seasonally fluctuating salinity gradient in the Murray estuary and Coorong North and South Lagoons.		
Region Murray estuary, Coorong North Lagoon, Coorong South Lagoon		
Data Requirements Murray estuary salinity is based on the average daily salinity at A4261036 (Beacon 12 Goolwa Channel), A4261039 (Barker Knoll), A4261128 (Mundoo Channel), A4261043 (Beacon 1, Ewe Island Shacks). North Lagoon salinity is based on the average daily salinity at A4261134 (Beacon 19 Pelican Point), A4261135 (Long Point), A4260572 (Robs Point). South Lagoon salinity is based on the average daily salinity at A4260633 (Parnka Point), A4261209 (near Cattle Island), A4261165 (NW Snipe Island). Data available from water.data.sa.gov.au.		
Resource Condition Target Salinity gradient in the Coorong is present, with Murray estuary average monthly salinities <35 ppt, North Lagoon average monthly salinities <45 ppt, South Lagoon average monthly salinities over winter <60 ppt and daily salinities year-round <100 ppt 95% of the time.		
Management trigger	**Management actions**	**Supporting information**
Murray estuary average monthly salinity level expected to exceed 36 ppt (using modelled values in the estuary).	Release flows from Goolwa and Mundoo barrages to freshen the Murray estuary and assist in maintaining an open Murray Mouth.	Barrage operating strategy (DEW, 2019). Relevant 3-month forward plan: The use of Commonwealth Environmental Water Holder environmental water in the Coorong, Lower Lakes and Murray Mouth Region of South Australia.
North Lagoon average monthly salinity level expected to exceed 45 ppt.	Release flows from Tauwitchere Barrage and Ewe Island to reduce North Lagoon salinity.	

	Opportunistic barrage releases to coincide with favourable wind and tide conditions from Pelican Point end of Tauwitchere barrage.	
South Lagoon average monthly salinity level in winter expected to exceed 60 ppt.	Seek environmental water to support water delivery to the Coorong in March or early April prior to/during reconnection of Coorong North and South Lagoons Release of flows from the South East, using modelling to determine most effective release to reduce salinity. Opportunistic barrage releases to coincide with favourable wind and tide conditions from Pelican Point end of Tauwitchere barrage. Source water from the South East or a River Murray environmental water holder for delivery to the site.	Barrage operating strategy (DEW, 2019). South East Flows restoration project operations manual (DEW, 2019).
South Lagoon average monthly salinity level expected to exceed 100 ppt.	Seek environmental water delivery to support water delivery to the Coorong. Release flows from the Pelican Point end of the Tauwitchere Barrage and Ewe Island to reduce South Lagoon salinity. Source water from the South East or River Murray Environmental Water Holder for delivery to the site.	
Limits of acceptable change **Direct LAC:** Murray estuary average monthly salinity greater than 40 ppt for more than any 18 consecutive months. **OR** North Lagoon average monthly salinity level greater than 70 ppt for more than any 18 consecutive months. **OR** South Lagoon average monthly salinity level greater than 100 ppt for more than 18 consecutive months		
Justification RCT Salinity is a major driver of the composition and distribution of species found within the site. The salinity of the Coorong fluctuates over an annual timescale, being lowest in late winter/early spring and highest in late summer/early autumn due to evapoconcentration. Targets for this critical component of the site aim to achieve a seasonally fluctuating longitudinal salinity gradient to maintain estuarine, marine, hypermarine and hypersaline habitats along the length of the Coorong. Target salinity ranges are based on salinity tolerances and seasonal life history requirements for key species in each of the 3 management units, including: **Murray estuary** Salinities in this management unit should be maintained below that of seawater 36 ppt. This can be achieved via the delivery of freshwater through the barrages, in conjunction with marine inputs via the Murray Mouth. Freshwater flows through the Murray estuary facilitate transport of phytoplankton and zooplankton (Bice, et al., 2016) and contribute to the maintenance of salinities that are within tolerable and/or favourable ranges for macroinvertebrates (Dittmann, 2015; Dittmann, et al., 2018), thereby increasing productivity in pelagic (water column) and benthic (sediment) zones (Bice, et al., 2016; Giatas & Ye, 2016).		

Salinities between freshwater and <36 ppt in the Murray estuary support:

- High abundances of macroinvertebrates and fishes in the Murray Mouth and upper North Lagoon (Dittmann, 2015; Giatas & Ye, 2016; Ye, et al., 2019a)
- Habitat for sandy sprat (Hossain, et al., 2016) and the crab *Paragrapsus gaimardii* (Ye, et al., 2019a), which are key prey species for fish and waterbirds (Giatas & Ye, 2016).
- Black bream, which are most abundant in areas where salinities range from 15–25 ppt, particularly during the spawning period (Hindall, et al., 2008). Studies in aquaria have determined the survival of black bream eggs to be optimal at salinities from 15–35 ppt and that physical abnormalities in larvae were lowest from eggs that were incubated at salinities from 15–35 ppt (Haddy & Pankhurst, 2000). Salt wedge habitats (salinity stratification at the freshwater and marine interface) are important for black bream recruitment, and favourable salinities (15–30 ppt) and haloclines (>10 ppt) were likely present during the successful recruitment event in the Murray estuary in 2017-18 (Ye, et al., 2019b).
- Conditions that are considered favourable to the recruitment of goby species (Ye, et al., 2015)
- Enhanced recruitment of estuarine fish species, including small-mouthed hardyhead, Tamar River goby, sandy sprat and yelloweye mullet as a result of freshwater flows (Ye, et al., 2015) that increase estuarine productivity (Bice, et al., 2016).

Coorong North Lagoon Salinities below <45 ppt in the Coorong North Lagoon support abundant and diverse macroinvertebrate, plant and fish communities.

Salinities <45 ppt in the Coorong North Lagoon support:

- Common macroinvertebrate species with hypermarine salinity tolerances (as shown in brackets) including: polychaete worms *Nephtys australiensis* (50 ppt), *Boccardiella limnicola* (40 ppt) and *Australonereis ehlersi* (50 ppt) and gastropod snails *Salinator fragilis* (45 ppt) and *Hydrobiidae* (45 ppt) (Dittmann, et al., 2018).
- Preferred habitats for adult greenback flounder: salinities <45 ppt were used by tracked greenback flounder over 91% of the time in the Murray estuary and Coorong (Earl, et al., 2017).
- Optimal conditions for fertilisation (35–45 ppt) and survival (15–45 ppt) of greenback flounder eggs (as shown in aquaria studies: (Hart & Purser, 1995)).
- Suitable conditions for juvenile black bream (0–48 ppt) to survive and grow (as shown in aquaria studies: (Partridge & Jenkins, 2002)
- Conditions that support *Ruppia* flowering and seed bank formation mainly in the southern section of the North Lagoon (optimal: 40–63 ppt, suboptimal: 17–102 ppt; (Collier, et al., 2017; Asanopoulos & Waycott, 2020).

Coorong South Lagoon The target salinity threshold for the South Lagoon is <100 ppt, 95% of the time* (assessed on an annual basis) and <60 ppt in winter (Lester, et al., 2011) based on the lowest salinities achievable with current management levers. It is expected that these salinities will continue to be tolerated by the biota that support the highly simplified foodweb within the Coorong South Lagoon, i.e. *Ruppia tuberosa*, small-mouthed hardyhead and chironomids. Abundance and diversity of macroinvertebrate, plant and fish communities will increase at salinity ranges lower than these thresholds are achieved (i.e. <60ppt).

Salinities <60 ppt in the Coorong South Lagoon in winter (June-August) support:

- At the higher end of the optimal conditions for *R. tuberosa* germination from seed (10–60 ppt), sprouting from turions (20–75 ppt) and vegetative growth (30–120 ppt; e.g. (Collier, et al., 2017; Asanopoulos & Waycott, 2020))
- Lowered potential for the South Lagoon to exceed upper salinity thresholds (100 ppt) in summer.

Salinities <100 ppt in the Coorong South Lagoon support:

- At the higher end of the suboptimal conditions for *R. tuberosa* flowering (leading to seed-set) between September and December (optimal: 40–63 ppt, suboptimal: 17–102 ppt; (Collier, et al., 2017; Asanopoulos & Waycott, 2020))
- At the higher end of the optimal salinity conditions (full range: 30–122 ppt) for *R. tuberosa* adult plant (vegetative) growth (Collier, et al., 2017; Asanopoulos & Waycott, 2020))
- Suboptimal conditions for small-mouthed hardyhead recruitment and distribution (Ye, et al., 2020), including avoiding lethal effects (i.e. the LC_{50} value is 108 ppt; (Lui, 1969)).
- Suboptimal conditions for larvae of salt-tolerant chironomids (*Tanytarsus barbitarsis*) (Dittmann 2015), including avoiding lethal effects (i.e. LC_{50} value is 96.9 ppt; (Kokkinn, 1986)).

*Salinities in the South Lagoon cannot exceed 100 ppt between 1 May and 31 December in any year to avoid negative impacts to *R. tuberosa* and small-mouthed hardyhead. For example:

- *R. tuberosa* require salinities <85 ppt (for up to 15 days) to germinate from seed (April to July) and <100 ppt to flower (August to December), but are tolerant of higher salinities (>100 ppt) when dormant (January to March) (Kim, et al., 2015; Collier, et al., 2017)
- Salinities <100 ppt may help to mitigate impacts to recruitment of small-mouthed hardyhead (Ye, et al., 2020), which spawn between September and December (Molsher, et al., 1994; Ye, et al., 2013)

MT

Management actions are triggered if average monthly salinities are expected to exceed the described thresholds. Annual hydrological modelling is used to identify the risk of exceeding salinity thresholds, and will allow for lead-time to identify and implement required management actions. Management actions will aim to avoid exceeding salinities which are suboptimal or at the tolerance level for *R. tuberosa* (e.g. (Collier, et al., 2017)), small-mouthed hardyhead (Lui, 1969; Ye, et al., 2020) and chironomids (Kokkinn, 1986).

Management of salinity in the Murray estuary and the Coorong may need to consider interactive effects of salinity on other ecological outcomes, such as excessive filamentous algal growth. For example, when water temperatures are above 22°C and inorganic nutrient or rapid turnover nutrient loads remain high, and salinities remain below 90 ppt, filamentous algal blooms will continue to occur (Waycott, et al., 2020). Refined MTs for salinity may need to consider the outcomes of current research regarding nutrient dynamics being explored in the HCHB program, as well as feasibility studies for large scale infrastructure that can remove salt and nutrients, thereby resetting the Coorong salinities to below these thresholds.

LAC

Murray estuary Salinity levels in the Murray estuary are primarily governed by the balance between inputs from Lake Alexandrina (barrage releases), seawater inflows through the Murray Mouth and evaporation. High salinity tends to be associated with periods of reduced barrage flows and/or closure of the Murray Mouth. The LAC is set at 40 ppt, 10% above the salinity level of sea water (36 ppt). Sustained salinity above the level of seawater will significantly affect the estuarine plankton and macroinvertebrate species in the Murray estuary, as there is no refuge for aquatic flora and fauna if salinities exceed the requirements of resident biota. The time period for the threshold level to be exceeded is 18 months which encompasses a second period of winter flows during periods of lower than average flows. The LAC was not exceeded during the Millennium Drought.

Coorong North Lagoon Salinity in the Coorong North Lagoon is controlled by freshwater inflows primarily from the Tauwitchere Barrage, tidal exchange through the Murray Mouth, rainfall, evaporation and inflows of hypersaline water from the Coorong South Lagoon (Lamontagne, et al., 2004). High salinity tends to be associated with periods of reduced barrage flows and/or closure of the Murray Mouth. Lethal salinities for target species in the Coorong North Lagoon begin to manifest at salinities greater than 45 ppt (61,200 EC) (Higham, 2012). The LAC is set at 70 ppt (86,342 EC), which exceeds the salinity tolerance of all polychaete species in the Coorong (with the exception of *Capitella capitata* that can occur in low densities in salinities up to 90 ppt). It represents a change in macroinvertebrate community from an estuarine and marine community to a hypersaline community (Dittmann, et al., 2018). Salinities of 70 ppt are just above or approaching the maximum observed field salinities for key estuarine fish, including black bream (*Acanthopagrus butcheri*) and Tamar River goby (*Afurcagobius tamarensis)* (60.1 ppt), greenback flounder (*Rhombosolea tapirina*) yelloweye mullet (*Aldrichetta forsteri*) (74.1 ppt) and mulloway (*Argyrosomus hololepidotus)* (62.4 ppt) (Ye, et al., 2013). The time period for the threshold level to be exceeded is 18 months which encompasses a second period of winter flows during periods of lower than average flows. The LAC was not exceeded during the Millennium Drought, but by then the site had already undergone a change in ecological character and thus more saline tolerant species had already been lost.

Coorong South Lagoon Salinity in the Coorong South Lagoon is not directly controlled by River Murray inflows but rather by water exchange with the Coorong North Lagoon, openness of the Murray Mouth, rainfall, evaporation, groundwater inputs and inflows from the South East of South Australia. Closure or restriction of the Murray Mouth increases salinity in the Coorong South Lagoon through evaporation from an essentially closed and already saline system. Lethal salinities for target species in the Coorong South Lagoon begin to manifest at salinities greater than 90 ppt (104,149 EC) (chironomids, small-mouthed hardyhead) (Higham, 2012). The LAC is set at 100 ppt (112,471 EC), the level that mobile species would have evacuated the habitat.

Although *R. tuberosa* will tolerate salinities above this level, growth, flowering, seed set and turion growth is severely curtailed at salinities above 120 ppt and those plants surviving will not provide adequate resources for the herbivorous shorebirds leading to a reduction or loss of migratory shorebirds, a critical component of the site's ecological character. The time period for the threshold level to be exceeded is 18 months which encompasses a second period of winter flows during periods of lower than average flows. The LAC was exceeded during the height of the Millennium Drought (2007-10) and was associated with the extirpation of key food resources (Paton & Bailey, 2012; Ye, et al., 2020). *R. tuberosa* populations have not recovered to pre-drought condition.

6.3 Vegetation

Aquatic vegetation has been identified as a critical CPS (DEW, 2021a). RCTs, MTs and LAC are described below for 4 critical aquatic vegetation subcomponents:

- submergent freshwater vegetation;
- emergent freshwater vegetation;
- submergent halophytes; and
- emergent halophytes.

The vegetation theme also includes RCTs, MTs and LAC for the 2 threatened ecological communities that are found within the Ramsar site, including:

- swamps of the Fleurieu Peninsula ecological community; and
- subtropical and temperate coastal saltmarsh.

6.3.1 Submergent freshwater vegetation

<table>
<tr><th colspan="3">SUBMERGENT FRESHWATER VEGETATION</th></tr>
<tr><td colspan="3">Objective
Maintain or improve diversity and extent of submergent freshwater vegetation in the Ramsar site</td></tr>
<tr><td colspan="3">Region
Lakes Alexandrina and Albert</td></tr>
<tr><td colspan="3">Data Requirements
Lake Alexandrina monthly average daily water level and monthly average salinity.

Surface water monitoring stations used for the assessment are A4260574 (near Mulgundawa), A4260524 (Milang Jetty), A4260575 (Poltalloch Plains), A4261156 (3km west Point McLeay), A4261133 (Beacon 90 – offshore Raukkan). Data available at water.data.gov.au.</td></tr>
<tr><td colspan="3">Resource Condition Targets
Water levels in Lake Alexandrina fluctuate seasonally between +0.4 m AHD in autumn and +0.85 m AHD in spring to summer.

Salinity in Lake Alexandrina at a long-term annual average of 700 EC.

Lake Albert salinity and water levels will depend on those of Lake Alexandrina.</td></tr>
<tr><th>Management triggers</th><th>Management actions</th><th>Supporting information</th></tr>
<tr><td>Water levels drop below +0.4 m AHD and there is a high likelihood that they cannot be maintained above +0.4 m AHD in the next 12 months.</td><td><u>Primary Actions</u>

Maintain water levels in the lakes (see Lake Alexandrina water levels, section 6.1.2)

Revegetation with Schoenoplectus tabernaemontani to stabilise lake shore and</td><td>CLLMM Environmental Water Requirements (DEW, 2020b).

Barrage operating strategy (DEW, 2019).

(Jellinek, et al., n.d.)</td></tr>
</table>

	enable reestablishment of submergent vegetation. Consider ceasing barrage releases before lake levels reach +0.3 m AHD based on flow projections. <u>Secondary Actions</u> Hydrologically manage fringing wetlands for submergent vegetation outcomes via inflow regulation (i.e. stop logs) and/or pumping. Consider reducing the cover of dominant native species, such as *Phragmites australis*, and exotic grasses such as *Paspalum distichum* and *Cenchrus clandestinus*, to maintain aquatic species diversity within fringing vegetation communities. Undertake seed bank studies to prioritise pumping to fringing wetlands (when small amounts of water are available).	Lower lakes vegetation monitoring (The Living Murray)
Annual average salinity levels exceed 1,500 EC for one year.	If not implemented, implement engineering solutions identified in Lake Alexandrina salinity section 6.2.1.	

Limits of acceptable change

Indirect LAC: Average daily Lake Alexandrina water levels less than +0.2 m AHD for greater than 2 consecutive years.

OR

Indirect LAC: Salinity in Lake Alexandrina >2,000 EC for greater than 2 consecutive years.

Justification

Water level and salinity are the primary drivers of submergent freshwater vegetation communities in the Lakes (Nicol, 2016), hence the RCTs, MTs and LAC for freshwater submergent vegetation are assessed and managed indirectly via water level and surface water salinity, rather than quantitative data on vegetation communities.

<u>RCT</u>

Seasonal water level management between +0.4 m AHD and +0.85 m AHD provides water level variability, a key requirement for submergent plant communities. Sufficient inundation during late winter, spring and early summer is needed for reproduction and growth, while a moderate drawdown facilitates light penetration in deeper water habitats, ensuring extent of the community is maximised. Lower salinity levels facilitate species diversity in the submergent plant community, therefore a resource condition target of a long-term annual average of 700 EC has been established.

<u>MT</u>

Submergent plants generally occupy sediments in Lake Alexandrina at elevations between +0.0 m AHD and +0.4 m AHD (and to -0.5 m AHD in the Goolwa Channel) (Nicol, 2016). If water levels are less than +0.4 m AHD then the majority of the habitable zone for submergent plants has insufficient inundation. This will limit reproduction and growth and reduce the extent of the community. Therefore, the management trigger was set to be breached when water levels fall below +0.4 m AHD to ensure that sub-optimal conditions for reproduction and growth will not occur for a prolonged duration.

Although submerged aquatic plants in the Goolwa channel have shown some resilience to higher salinities (Nicol, 2016), a management trigger of salinity in Lake Alexandrina >1,500 EC for one year takes into account salt-sensitive submergent species in the area of Lake Alexandrina outside the Goolwa Channel and seeks to avoid reductions in diversity.

LAC

The Lake Alexandrina water level LAC of less than +0.2 m AHD for greater than 2 consecutive years has been set as submergent plants generally do not grow in areas below sea level, with the exception of Goolwa channel (Nicol, 2016). Extended periods of low water levels, as observed during the Millennium Drought, lead to a loss of submergent vegetation from the lakes. Salinities above 2,000 EC are associated with reduced diversity and reduced condition of aquatic plants (Frahn, et al., 2014), hence salinities above 2,000 EC for greater than 2 consecutive years are considered detrimental to the submerged aquatic plant community. During the Millennium Drought, extended periods of high salinity were associated with either an absence of submergent species or monocultures of the one salt-tolerant species (i.e. *Potamogeton pectinatus* in the Goolwa Channel) (Nicol, 2016).

6.3.2 Emergent freshwater vegetation

EMERGENT FRESHWATER VEGETATION		
Objective Maintain or improve diversity and extent of emergent freshwater vegetation in the Ramsar site.		
Region Lakes Alexandrina and Albert		
Data requirements Lake Alexandrina monthly average daily water level. Surface water monitoring stations used for the assessment are A4260574 (near Mulgundawa), A4260524 (Milang Jetty), A4260575 (Poltalloch Plains), A4261156 (3km west Point McLeay), A4261133 (Beacon 90 – offshore Raukkan). Data available at water.data.gov.au.		
Resource condition targets Water levels in Lake Alexandrina fluctuate seasonally between +0.4 m AHD in autumn and +0.85 m AHD in spring to summer (Muller (2010) in (Lester, et al., 2011)). Lake Alexandrina water level raised to +0.9 m AHD at least once every 7 years		
Management trigger	**Management actions**	**Supporting information**
Water levels drop below +0.4 m AHD and there is a high likelihood that they cannot be maintained above +0.4 m AHD in the next 12 months	Primary Actions Maintain water levels in the Lakes (see Lake Alexandrina water levels, section 6.1.2) Secondary Actions Consider grazing to reduce the cover of dominant native species, such as *Phragmites australis*, and exotic grasses such as *Paspalum distichum* and *Cenchrus clandestinus*, to increase species diversity within fringing vegetation communities. Control of exotic weeds (e.g. controlled burns, crash grazing, cut and swab techniques) in fringing wetlands. Minimise the risk of lakeshore erosion in years where flow and water level are adequate by planting *Schoenoplectus tabernaemontani*is and fluctuating water levels. Maintain connection between vegetation and the waterline through pumping or dredging to provide habitat for fauna.	CLLMM Environmental Water Requirements (DEW, 2020b). Barrage operating strategy (DEW, 2019).

	If lake levels have been low for >1 year and vegetation has migrated downward, fluctuate water level at new waterline to maintain condition until water levels can be increased.	

Limits of acceptable change

Indirect LAC: Average daily Lake Alexandrina water levels less than +0.2 m AHD for greater than 2 consecutive years

Justification

Water level is a primary driver of emergent freshwater vegetation communities in the Lakes (Nicol, 2016), hence the RCTs, MTs and LAC for emergent freshwater vegetation are assessed indirectly via Lake Alexandrina water level rather than quantitative data on vegetation communities. Emergent species, particularly common reed *Phragmites australis*, bulrush *Typha domingensis* and lignum *Duma florulenta*, have a broader salinity tolerance than submergent species, therefore Lake Alexandrina salinity is not used as an indirect assessment for this vegetation sub-component.

RCT

Emergent vegetation requires high soil moisture in the root zone when growing out of water, so it is required that water levels be preferably maintained at +0.4 m AHD and above for hydrological connection (Nicol, 2016). Native amphibious and native emergent species, that typify diverse reed bed communities, are most prolific in the +0.6 m AHD to +0.8 m AHD zone on the elevation gradient (Nicol, 2016) and play a major contribution to the diversity of this vegetation sub-component. Larger emergent species such as common reed *Phragmites australis and* bulrush *Typha domingensis* have a wider extent on the elevation gradient (+0.0 m AHD to +0.8-0.9 m AHD (Nicol, 2016)). The RCT for emergent species; Lake Alexandrina water levels fluctuate seasonally between +0.4 m AHD and +0.85 m AHD, is set so that the majority of the extent of the vegetation community is inundated for at least part of the year.

In addition, Lake Alexandrina water levels should be raised to +0.9 m AHD at least once every 7 years to provide inundation for swamp paperbark *Melaleuca halmaturorum* and other high elevation species such as lignum *(Duma florulenta)* to encourage recruitment and improve condition. These species generally occur at >+0.8 m AHD on the elevation gradient (Nicol, 2016).

MT

Water levels above +0.4 m AHD should be maintained for emergent freshwater plants to ensure there is sufficient water for plants to grow at higher elevations (Nicol, 2016). When water levels are low, emergent freshwater plants can persist, however, other factors may limit recruitment further down the elevation gradient (Gehrig, et al., 2021). Furthermore, the value of emergent freshwater plant communities as aquatic habitat are compromised when they are not hydrologically connected (Nicol, 2016). Therefore, it is important that management is triggered prior to long-term impacts on emergent freshwater vegetation communities.

LAC

If average daily Lake Alexandrina water levels are less than +0.2 m AHD for greater than 2 consecutive years, the majority of the habitable zone for emergent species will have insufficient soil moisture and there will be a significant reduction in extent, a loss of amphibious species (and significant reduction in diversity) due to desiccation and an increase in terrestrial species (predominantly exotics). There will also be a possible disconnect between fringing lakeshore vegetation and the water's edge in many areas, limiting suitable habitat for cryptic waterbirds. The LAC has therefore been set at the point where sustained low water levels will result in significant changes to the emergent freshwater vegetation community, and where its function as habitat for key species will be compromised.

6.3.3 Submergent halophytes

<table>
<tr><th colspan="3">SUBMERGENT HALOPHYTE</th></tr>
<tr><td colspan="3">Objective
Maintain or improve cover and distribution of submergent halophytes in the Ramsar site.</td></tr>
<tr><td colspan="3">Region
Coorong North Lagoon and Coorong South Lagoon</td></tr>
<tr><td colspan="3">Data requirements
Annual winter and spring/summer Coorong Ruppia tuberosa monitoring and assessment, as per the methods described in (Paton, et al., 2017b).</td></tr>
<tr><td colspan="3">Resource condition targets
Ruppia tuberosa plants have an extent of occurrence of 43 km over the southern Coorong in winter and summer.

At least 30% cover of Ruppia tuberosa at 50% or more of all winter and summer monitored sites.</td></tr>
<tr><th>Management trigger</th><th>Management actions</th><th>Supporting information</th></tr>
<tr><td>Less than 10 per cent cover of Ruppia tuberosa recorded at greater than 50% of all winter monitored sites for 2 or more consecutive years.</td><td>Seek environmental flows for delivery to the Coorong in spring and summer (targeting August to December) to raise and maintain water levels in the South Lagoon (see also Section 7.1).

Prioritise barrage flows from the Pelican Point end of Tauwitchere barrage.</td><td>CLLMM Environmental Water Requirements (DEW, 2020b).

Barrage operating strategy (DEW, 2019).</td></tr>
<tr><td colspan="3">Limits of acceptable change
Direct LAC: Less than 5% cover of Ruppia tuberosa recorded at greater than 50% of all winter monitored sites for 2 or more consecutive years. See also LAC for Coorong food web (Section 6.8).</td></tr>
<tr><td colspan="3">Justification
R. tuberosa is the most important submergent halophyte in the Coorong, hence the RCT, MT and LAC for submergent halophytes are assessed directly via R. tuberosa cover and distribution in the Coorong. The term “cover” in the RCT, MT and LAC refers to the proportion of cores sampled that contain live R. tuberosa shoots rather than a density of live R. tuberosa shoots per core. In order to meet the RCT and not to exceed the MT or LAC, R. tuberosa must meet the conditions regarding cover for at least one water depth where the plant is sampled.

<u>RCT</u>
The RCTs for R. tuberosa were set based upon data collected in the late 1990s prior to the Millennium Drought. Prior to the Millennium Drought, R. tuberosa was distributed along at least 43 km of the southern Coorong and sites sampled had at least 30% of cores with R. tuberosa shoots in early July when monitoring commenced (Paton, et al., 2017b).

<u>MT</u>
The MT of less than 10% cover of R. tuberosa recorded at more than 50% of all winter monitored sites for a given year was set in consideration of the capacity for recovery (Paton, et al., 2015b). At 10% cover at more than 50% of all sites, there is still capacity for the system to recover to the required 30% cover described in the RCT within a reasonable amount of time if water level and salinity conditions improve in the Coorong South Lagoon (Paton, et al., 2015b).

<u>LAC</u>
The LAC of less than 5% cover of R. tuberosa recorded at greater than 50% of all winter monitored sites for 2 or more consecutive years reflects a risk that populations will disappear completely if conditions continue to be sub-optimal. To maintain some semblance of ecological character of the southern Coorong, absences of R. tuberosa must be avoided (Paton, et al., 2015b).</td></tr>
</table>

6.3.4 Emergent halophytes

<table>
<tr><th colspan="3">EMERGENT HALOPHYTES</th></tr>
<tr><td colspan="3">Objective
Maintain or improve diversity and extent of emergent halophyte vegetation in the Ramsar site.</td></tr>
<tr><td colspan="3">Region
Lakes Alexandrina and Albert, Murray estuary, Murray Mouth and Coorong North Lagoon</td></tr>
<tr><td colspan="3">Data requirements
Lake Alexandrina water level is based on monthly average water levels at A4260574 (near Mulgundawa), A4260524 (Milang Jetty), A4260575 (Poltalloch Plains), A4261156 (3km west Point McLeay), A4261133 (Beacon 90 – offshore Raukkan). Data available at water.data.sa.gov.au.</td></tr>
<tr><td colspan="3">Resource condition target
Lake Alexandrina water levels fluctuate seasonally between +0.4 and +0.85 m AHD.</td></tr>
<tr><th>Management trigger</th><th>Management action</th><th>Supporting information</th></tr>
<tr><td>Water levels drop below +0.4 m AHD and there is a high likelihood that they cannot be maintained above +0.4 m AHD in the next 12 months.</td><td><u>Primary actions</u>

Maintain water levels in the Lakes (see Lake Alexandrina water levels, section 6.1.2)

Maintain openness of the Murray Mouth (see barrage flows, 7.1)</td><td>CLLMM Environmental Water Requirements (DEW, 2020b).

Barrage Operating Strategy (DEW, 2019).</td></tr>
<tr><td colspan="3">Limits of acceptable change
Indirect LAC: Average daily water levels in Lake Alexandrina less than +0.2 m AHD for 2 or more consecutive years.</td></tr>
<tr><td colspan="3">Justification
Water level is the primary driver of emergent halophyte communities in the lakes (Nicol, 2016), hence the RCT, MT and LAC for emergent halophytes are assessed indirectly via Lake Alexandrina water level. If water levels fall below +0.4 m AHD in the Lakes or below +0.1 m AHD in the Coorong for an extended period then these communities become disconnected from the water's edge, leading to a decline in recruitment and poor condition in existing plants (Nicol, 2016). Seasonal water level variation in the Coorong means it is unlikely for water levels to remain below +0.1 m AHD for 2 or more consecutive years while the Murray Mouth remains open, therefore an indirect LAC has not been set for Coorong water levels.

<u>RCT</u>
Emergent halophytes (samphire and salt marsh vegetation) are intolerant of long-term flooding but grow well in water-logged soil. Emergent halophytes are typically situated at >+0.8 m AHD on the elevation gradient on the margins of Lakes Alexandrina and Albert (Nicol, 2016). The resource condition target specifies that Lake Alexandrina water levels should fluctuate seasonally between +0.4 m AHD and +0.85 m AHD, ensuring some inundation but limiting long-term flooding. Many emergent halophytes reproduce by releasing seeds that germinate on wet soil (Nicol, 2016). Therefore, the preferred water level regime aims to maximise optimal conditions for growth and reproduction.

<u>MT</u>
Samphire wetlands and channels occur in a number of areas surrounding Lakes Alexandrina and Albert. Water levels below +0.4 m AHD will result in saltmarsh and samphire vegetation becoming disconnected from open water habitats leading to a reduction in soil moisture and decline in recruitment and condition of emergent halophytes (Nicol, 2016).

<u>LAC</u>
The LAC of average daily Lake Alexandrina water levels less than +0.2 m AHD for greater than 2 consecutive years has been set at the point where complete and prolonged disconnection of samphire and salt marsh communities of Lakes Alexandrina and Albert would result in significant declines in condition and recruitment.</td></tr>
</table>

6.4 Fish

Native fish have been identified as a critical CPS (DEW, 2021a). RCTs, MTs and LAC are described below for the following fish critical subcomponents, which include:

- Fish diversity (species richness and biodisparity);
- Movement and recruitment; and
- Threatened species (Murray hardyhead *Craterocephalus fluviatilis* and southern pygmy perch *Nannoperca australis*).

6.4.1 Fish Diversity (species richness and biodisparity)

<table>
<tr><th colspan="3">FISH DIVERSITY (SPECIES RICHNESS AND BIODISPARITY)</th></tr>
<tr><td colspan="3">Objective
Maintain a spatio-temporally diverse fish community in the Ramsar site.</td></tr>
<tr><td colspan="3">Region
Freshwater sub-units defined as Lakes Alexandrina and Albert and Eastern Mount Lofty Ranges tributaries, Coorong sub-units defined as Murray estuary, Coorong North Lagoon and South Lagoon.</td></tr>
<tr><td colspan="3">Data requirements
Annual Coorong fish, diadromous fish and Lakes fish condition monitoring, as per the methods described in Ye et al. (2017a), Ye et al. (2017b). Bice and Zampatti (2017) and Wedderburn (2017). Commercial fishery data may also be used as a secondary data source to assess the presence of large-bodied fish in the Lakes (noting that gill nets are not expected to detect small-bodied fish).</td></tr>
<tr><td colspan="3">Resource Condition Targets

Species Richness: All common freshwater species recorded annually (lakes and tributaries), and all common estuarine and marine-estuarine opportunist species recorded annually (Murray estuary and Coorong)

Biodisparity: A spatio-temporally diverse fish community is present including all 17 fish families (in targeted surveys)</td></tr>
<tr><th>Management triggers</th><th>Management actions</th><th>Supporting information</th></tr>
<tr><td>Species Richness

Freshwater sub-units: Failure to record any one of the common freshwater species (Table 14.2) during any year with adequate sampling data, OR

Coorong sub-units: Failure to record any one of the common estuarine and marine-estuarine opportunist species (Appendix B) during 3 consecutive years of annual surveys or fishery catch.

Refer to Appendix B for the list of common freshwater, estuarine and estuarine-marine opportunist species to be assessed as part of the fish diversity (species richness) LAC for species list.

Biodisparity

Failure to record any one of the 17 fish families (Table 14.3) during any 2</td><td><u>Primary actions</u>

Ensure connectivity through continuous flows from Lake Alexandrina to the Murray estuary via fishway and/or barrage releases & connectivity to the ocean (see barrage flows, section 7.1)

Manage Lake Alexandrina water levels seasonally (see Lake Alexandrina water levels, section 6.1.2)

Maintain Lake Alexandrina salinity within target ranges (see Lake Alexandrina salinity, section 6.2.1)

Maintain salinity in the Coorong within target ranges (see Coorong salinity, section 6.2.2)

Maintain suitable habitat in Lake Alexandrina and Albert (see submergent and emergent vegetation, sections 6.3.1 and 6.3.2)

Maintain suitable habitat in the Coorong (see vegetation and Coorong food webs. Sections 0 and 6.8.1)</td><td>SA River Murray Long-Term Environmental Watering Plan (DEW, 2020b)

LLCMM Condition Monitoring Plan (DEWNR, 2017)

Barrage operating strategy (DEW, 2019)

Fisheries Management Act 2007 and Fisheries Management (General) Regulations 2017.</td></tr>
</table>

consecutive annual survey periods with adequate sampling data. Refer to Appendix B for the list of families to be assessed as part of the fish diversity (biodisparity) LAC for species list.	Secondary actions Consider seasonal fisheries closures in line with the Fisheries Management Act and Regulations.	

Limits of Acceptable Change

Direct LAC: Species Richness

Freshwater sub-units – Lakes Alexandrina and Albert and EMLR tributaries: Loss of any of the common freshwater species for 2 consecutive years which include targeted annual surveys **OR**
Coorong sub-units: Loss of any of the common estuarine and marine-estuarine opportunist species for 5 consecutive years which include targeted annual surveys

Direct LAC: Biodisparity
Less than 13 of the 17 fish families recorded in targeted surveys in any 3 consecutive years

Justification
Species richness and biodisparity have been selected to assess the RCTs, MTs and LAC for fish diversity within the Ramsar site. Species richness is assessed against the annual detection of common freshwater species and common estuarine and estuarine-marine opportunist species (Appendix B, Table 14.2). 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. The timeframes described within RCTs, MTs and LAC are based on the lifespan of key species; with longer allowable timeframes for MTs and LAC for Coorong species reflecting the dominance of longer-lived species over the often-annual species of the freshwater sub-units and the dynamic nature of estuaries.

6.4.2 Movement and recruitment

FISH MOVEMENT AND RECRUITMENT		
Objective Promote the successful migration and recruitment of diadromous fish species in the Ramsar site.		
Region Murray estuary (barrage fishways and adjacent barrage fishways)		
Data Requirements Annual spring/summer diadromous fish monitoring at barrage fishways, as per the methods described in Bice and Zampatti (2017).		
Resource Condition Targets The annual rate of upstream migrating young-of-the year (YOY) congolli is ≥44.46 YOY/hr. The annual rate of upstream migrating YOY common galaxias is ≥6.12 YOY/hr.		
Management Triggers	**Management Actions**	**Supporting Documents**
The annual abundance of upstream migrating YOY congolli is ≤22.67 YOY/hr. The annual abundance of upstream migrating YOY common galaxias is ≤3.12 YOY/hr.	Primary actions Continuous barrage fishway operation if possible. If year round barrage operation is not possible then operate all fishways from June to January to: 1. allow for upstream migrations of pouched lamprey and downstream spawning migrations of congolli and common galaxias from June to August; 2. allow for upstream migrations of short-headed lamprey from August to November; and	SA River Murray Long-Term Environmental Watering Plan (DEW, 2020b) LLCMM Condition Monitoring Plan (DEWNR, 2017) LLCMM Environmental Water Management Plan (MDBA, 2014b) Barrage operating strategy (DEW, 2019) (Zampatti, et al., 2011)

	3. allow for upstream migrations of the YOY congollis and common galaxias (and other species) from October to January. Where possible, in winter, direct attractant flow from open barrage bays adjacent to barrage fishways to guide fish to fishway entrances. Maintain an open Murray Mouth (see barrage flows, section 7.1) <u>Secondary actions</u> If water levels in Lake Alexandrina are insufficient to allow for fishway operation for 2 years use the Goolwa and Tauwitchere boat locks to facilitate downstream movement of adult congolli and common galaxias in winter.	

Limits of acceptable change

Direct LAC: YOY congolli not recorded in the site for more than 5 consecutive years (in targeted annual surveys at barrage fishways), **OR** YOY for common galaxias not recorded in the site for more than 3 consecutive years (in targeted annual surveys at barrage fishways).

Justification:

The annual abundance of migrating YOY congolli (*Pseudaphritis urvilli)* and common galaxias (*Galaxias maculatus)* have been identified as the most suitable indicators for fish movement and recruitment, given the importance of hydrological connection for their population condition. The RCT and MT for these species are based on annual recruitment indices (Bice & Zampatti, 2017). Data are available for other diadromous fish species that occur in the Ramsar site (e.g. lamprey, eel) and other migratory fish species (e.g. golden perch *Macquaria ambigua*, black bream *Acanthopagrus butcheri)*. However, congolli and common galaxias were selected to inform fish movement and recruitment success as the presence of their YOY provides and indicator for longitudinal connectivity between habitats (i.e. freshwater-estuarine-marine habitats). Estimates of the lifespan of these species have been used when setting the LAC, i.e. female congolli are assumed to take 4 to 6 years to mature (Hortle, 1978) and common galaxias generally live for 1-2 years (Lintermans, 2007).

6.4.3 Threatened species - Murray hardyhead

<table>
<tr><th colspan="3">THREATENED SPECIES - MURRAY HARDYHEAD</th></tr>
<tr><td colspan="3">Objective
Ensure recruitment success of threatened fishes in the Lower Lakes to maintain or establish self-sustaining populations.</td></tr>
<tr><td colspan="3">Region
Lakes Alexandrina and Albert</td></tr>
<tr><td colspan="3">Data requirements
Annual lakes small-bodied threatened fish condition monitoring, as per the methods described in (Wedderburn, 2017)</td></tr>
<tr><td colspan="3">Resource condition targets
Murray hardyhead occupation: Murray hardyhead are found in at least 70% of historical (2003 point of reference) capture sites within the icon site.
Murray hardyhead recruitment: Murray hardyhead have a level of recruitment within the icon site with young-of-the-year representing >50% of the fish captured in autumn.</td></tr>
<tr><th>Management triggers</th><th>Management actions</th><th>Supporting information</th></tr>
<tr><td>Murray hardyhead are found in < 70% of historical (2003 point of reference) capture sites within the icon site AND <50% of the fish captured in autumn within the icon site are young-of-the-year.</td><td><u>Primary actions</u>

Maintain Lake Alexandrina salinity within target ranges (see Lake Alexandrina salinity, section 6.2.1)

Maintain suitable habitat in Lakes Alexandrina and Albert (see freshwater submergent and emergent vegetation, section 6.3)

Use threatened fish data to determine if a strong recruitment event has occurred in the past 2 years to identify target lake levels for the coming year.

<u>Secondary actions</u>

Maintain connection to higher elevation wetlands and keep channels clear to maintain open water habitat.

Consider pumping water for the environment to wetland sites containing Murray hardyhead, maintaining where possible, salinity between 12 and 45 ppt, to keep remnant populations in-situ.

Captive breeding and reintroduction.</td><td>SA River Murray Long-Term Environmental Watering Plan (DEW, 2020b)

LLCMM Condition Monitoring Plan (DEWNR, 2017)

Barrage Operating Strategy (DEW, 2019)

LLCMM Environmental Water Management Plan (MDBA, 2014b)

Stoessel et al. (2019)</td></tr>
<tr><td>Water levels have not been maintained above +0.6 m AHD until the end of March in the last 2 years.</td><td>Seek environmental water to maintain Lake Alexandrina water levels above +0.6 m AHD until the end of March.</td><td>(Wedderburn, et al., 2019)</td></tr>
<tr><td colspan="3">Limits of Acceptable Change
Direct LAC: Absence of Murray hardyhead in any 3 out of 5 targeted surveys within a 3 year period</td></tr>
<tr><td colspan="3">Justification
Murray hardyhead Craterocephalus fluviatilis (Endangered – EPBC Act) are small-bodied threatened species that were common in the Ramsar site prior to the Millennium Drought. The RCT and MT for this species are based on a series of abundance, recruitment and extent indices (Wedderburn, 2017) and a water regime and salinity conditions that was modelled to be important to the recruitment of pygmy perches (Wedderburn, et al., 2019).
Management actions regarding lake levels are triggered if water levels have not been maintained above +0.6 m AHD from September/October until at least the end of March in the last 2 years. This would allow for lead-in time to identify and implement management actions for the following year.

The LAC for Murray hardyhead is based on their estimated lifespan, with Murray hardyhead generally an annual species that lives for one year (Hammer & Wedderburn, 2008).</td></tr>
</table>

6.5 Waterbirds

Waterbirds have been identified as a critical CPS (DEW, 2021a). RCTs, MTs and LAC are described below for the following waterbird critical subcomponents, which include:

- Waterbird diversity (species richness) by region within the Ramsar site;
- Waterbird abundance (whole of Ramsar site);
- One per cent species population East-Asian Australasian abundance;
- Presence of priority species – migratory shorebirds;
- Waterbird breeding; and
- Threatened species (including Australasian bittern *Botaurus poiciloptilus,* Australian fairy tern *Sternula neiris nereis,* Australian painted-snipe *Rostratula-australia,* curlew sandpiper *Calidris ferruginea,* eastern curlew *Numenius madagascariensis,* hooded plover *Thinornis rubicollis,* Mount Lofty Ranges southern emu-wren *Stipiturus malachurus intermedius* and the orange-bellied parrot *Neophema chrysogaster*.

6.5.1 Waterbird diversity (species richness)

<table>
<tr><th colspan="3">WATERBIRD DIVERSITY – LAKES ALEXANDRINA AND ALBERT</th></tr>
<tr><td colspan="3">Objective
Maintain or improve waterbird diversity in the Lakes Alexandrina and Albert.</td></tr>
<tr><td colspan="3">Region
Lakes Alexandrina and Albert</td></tr>
<tr><td colspan="3">Data requirements
Annual summer Coorong and lakes waterbird census as per methods described in Paton et al. (2017a).</td></tr>
<tr><td colspan="3">Resource condition target
At least ten selected waterbird species have counts above their median abundance during the annual census.</td></tr>
<tr><th>Management triggers</th><th>Management actions</th><th>Supporting information</th></tr>
<tr><td>Less than 17 of 20 selected waterbird species have counts above their 10th percentile abundance during the annual census.</td><td><u>Primary actions</u>
Maintain Lake Alexandrina salinity and water levels within target ranges (sections 6.1.2 and 6.2.1).

<u>Secondary actions</u>
Manage fringing wetlands of the Lower Lakes and wetlands in the South East to provide additional and/or complementary habitat.</td><td>LLCMM Condition Monitoring Plan (DEWNR, 2017)

Barrage operating strategy (DEW, 2019)

Waterbird metrics for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site (DEW, 2021b)</td></tr>
<tr><td colspan="3">Limits of acceptable change
Direct LAC: Less than 17 of 20 selected waterbird species have counts above their 10th percentile abundance during the annual census for 2 consecutive years.</td></tr>
<tr><td colspan="3">Justification
Guiding principles for the establishment of metrics for waterbird CPS subcomponents are detailed in DEW (2021b). All waterbird CPS subcomponents; RCTs had a 0.5 probability of being met (positive outcome). The probability of MTs and LAC thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively.

The RCT was set on the expectation that at least half (n=10) of the 20 selected waterbirds species (Appendix C) should be at or above their median abundance in a given annual census.

The MT was set at the lower 80% confidence limit for the number of selected waterbird species (with 10th percentile abundances ≥1) (Appendix C) that are expected to be at or above their 10th percentile abundance in a given year. If the MT were to be breached, then a process to determine whether factors internal or external to the system led to the breach will be conducted. Management actions are to be initiated where internal factors contributed significantly to the MT breach.

If the MT was breached in 2 consecutive years, then the LAC threshold is exceeded. An investigation is then initiated to determine the relative influence of local, national and international factors to the event.</td></tr>
</table>

WATERBIRD DIVERSITY – MURRAY ESTUARY/GOOLWA CHANNEL		
Objective Maintain or improve waterbird diversity in the Murray estuary.		
Region Murray estuary		
Data requirements Annual summer Coorong waterbird census as per methods described in Paton et al. (2017a). The Murray estuary was delineated to range between Goolwa Barrage and Pelican Point.		
Resource condition target At least 12 selected waterbird species have counts above their median abundance during the annual census.		
Management triggers	**Management actions**	**Supporting information**
Less than 18 of 21 selected waterbird species have counts above their 10th percentile abundance during the annual census	<u>Primary actions</u> Maintain salinity in the Murray estuary within target ranges (section 6.2.2) Maintain desired Coorong water levels (section 7.2) Provide continuous barrage flows from Lake Alexandrina to the Murray estuary (section 7.1). Maintain an open Murray Mouth (section 7.1) <u>Secondary actions</u> Manage fringing wetlands of the lakes and wetlands in the South East to provide additional and/or complementary habitat.	LLCMM Condition Monitoring Plan (DEWNR, 2017) Waterbird metrics for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site (DEW, 2021b)
Limits of acceptable change **Direct LAC:** Less than 18 of 21 selected waterbird species have counts above their 10th percentile abundance during the annual census for 2 consecutive years.		
Justification Guiding principles for the establishment of metrics for waterbird CPS subcomponents are detailed in DEW (2021b). All waterbird RCTs had a 0.5 probability of being met (positive outcome). The probability of MTs and LAC thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively. The RCT was set on the expectation that at least half (n=12) of the 24 selected waterbirds species (Appendix C) should be at or above their median abundance in a given annual census. The MT was set at the lower 80% confidence limit for the number of selected waterbird species (with 10th percentile abundances ≥1) (Appendix C) that are expected to be at or above their 10th percentile abundance in a given year. If the MT were to be breached, then a process to determine whether factors internal or external to the system led to the breach will be conducted. Management actions are to be initiated where internal factors contributed significantly to the MT breach. If the MT was breached in 2 consecutive years, then the LAC threshold is exceeded. An investigation is then initiated to determine the relative influence of local, national and international factors to the event.		

WATERBIRD DIVERSITY – COORONG NORTH LAGOON		
Objective Maintain or improve waterbird diversity in the Coorong North Lagoon.		
Region Coorong North Lagoon		
Data Requirements Annual summer Coorong waterbird census as per methods described in Paton et al. (2017a). The Coorong North Lagoon was delineated to range from Pelican Point to near Parnka Point.		
Resource Condition Target At least 12 selected waterbird species have counts above their medina abundance during the annual census.		
Management Trigger	**Management Actions**	**Supporting Documents**
Less than 19 of 24 selected waterbird species have counts below their 10th percentile abundance during the annual census.	<u>Primary actions</u> Maintain salinity in the Murray estuary within target ranges (section 6.2.2) Maintain desired Coorong water levels (section 7.2) Provide continuous barrage flows from Lake Alexandrina to the Murray estuary (section 7.1). Maintain an open Murray Mouth (section 7.1) <u>Secondary actions</u> Manage fringing wetlands of the lakes and wetlands in the South East to provide additional and/or complementary habitat.	LLCMM Condition Monitoring Plan (DEWNR, 2017) Waterbird metrics for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site (DEW, 2021b)
Limits of Acceptable Change **Direct LAC:** Less than 19 of 23 selected waterbird species counts below their 10th percentile abundance during the annual census for 2 consecutive years.		
Justification Guiding principles for the establishment of metrics for waterbird CPS subcomponents are detailed in DEW (2021b). All waterbird RCTs had a 0.5 probability of being met (positive outcome). The probability of MTs and LAC thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively. The RCT was set on the expectation that at least half (n=12) of the 23 selected waterbirds species (Appendix C) should be at or above their median abundance in a given annual census. The MT was set at the lower 80% confidence limit for the number of selected waterbird species (with 10th percentile abundances ≥1) (Appendix C) that are expected to be at or above their 10th percentile abundance in a given year. If the MT were to be breached, then a process to determine whether factors internal or external to the system led to the breach will be conducted. Management actions are to be initiated where internal factors contributed significantly to the MT breach. If the MT was breached in 2 consecutive years, then the LAC threshold is exceeded. An investigation is then initiated to determine the relative influence of local, national and international factors to the event.		

WATERBIRD DIVERSITY – COORONG SOUTH LAGOON		
Objective Maintain or improve waterbird diversity in the Coorong South Lagoon.		
Region Coorong South Lagoon		
Data requirements Annual summer Coorong waterbird census as per methods described in Paton et al. (2017a). The South Lagoon was delineated to range between near Parnka Point and 42 Mile Crossing.		
Resource condition target At least 12 selected waterbird species have counts above their median abundance during the annual census.		
Management triggers	**Management actions**	**Supporting information**
Less than 18 of 23 selected waterbird species have counts below their 10th percentile abundance during the annual census.	Primary actions Maintain salinity in the Murray estuary within target ranges (section 6.2.2) Provide continuous barrage flows from Lake Alexandrina to the Murray estuary (section 7.1). Maintain an open Murray Mouth (section 7.1)	LLCMM Condition Monitoring Plan (DEWNR, 2017) Waterbird metrics for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site (DEW, 2021b)
Limits of acceptable change **Direct LAC:** Less than 18 of 21 selected waterbird species have counts below their 10th percentile abundance during the annual census for 2 consecutive years.		
Justification Guiding principles for the establishment of metrics for waterbird CPS subcomponents are detailed in DEW (2021b). All waterbird CPS RCTs had a 0.5 probability of being met (positive outcome). The probability of MTs and LAC thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively. The RCT was set on the expectation that at least half (n=12) of the 23 selected waterbirds species (Appendix C) should be at or above their median abundance in a given annual census. The MT was set at the lower 80% confidence limit for the number of selected waterbird species (with 10th percentile abundances ≥1) (Appendix C) that are expected to be at or above their 10th percentile abundance in a given year. If the MT were to be breached, then a process to determine whether internal or external factors to the system led to the breach will be conducted. Management actions are to be initiated where internal factors contributed significantly to the MT breach. If the MT was breached in 2 consecutive years, then the LAC threshold is exceeded. An investigation is then initiated to determine the relative influence of local, national and international factors to the event.		

6.5.2 Waterbird abundance

<table>
<tr><th colspan="3">WATERBIRD ABUNDANCE – RAMSAR SITE</th></tr>
<tr><td colspan="3">Objective
Maintain or improve waterbird abundance in the Ramsar site.</td></tr>
<tr><td colspan="3">Region
Lakes Alexandrina and Albert, Murray estuary, Coorong North Lagoon and South Lagoon.</td></tr>
<tr><td colspan="3">Data Requirements
Annual summer Coorong and lakes waterbird census as per methods described in Paton et al. (2017a)</td></tr>
<tr><td colspan="3">Resource Condition Targets
282,212 or more waterbirds are counted over the Ramsar site in the annual waterbird census.</td></tr>
<tr><th>Management Triggers</th><th>Management Actions</th><th>Supporting Information</th></tr>
<tr><td>Less than 190,122 waterbirds are counted over the Ramsar site in the annual waterbird census for the Lakes and Coorong.</td><td><u>Primary actions</u>
Management of hydrological drivers:
Barrage flows (section 7.1)
Lake levels (section 6.1.2)
Lakes salinity (section 6.2.1)
Coorong water levels (section 7.2)
Coorong salinity (section 6.2.2)
<u>Secondary actions</u>
Undertake actions that support and provide habitat and food (see sections 6.3, 6.4 and 6.7.3).
Manage other regional wetlands (the lakes, South East and lower River Murray) to provide additional and/or complementary habitat and potentially offset adverse impacts in Coorong.</td><td>Waterbird metrics for the Coorong, and Lakes Albert and Alexandrina Wetland Ramsar site (DEW, 2021b)</td></tr>
<tr><td colspan="3">Limits of Acceptable Change
Direct LAC: Fewer than 190,122 waterbirds are counted over the Ramsar site in the annual census over 2 consecutive years.</td></tr>
<tr><td colspan="3">Justification:
Guiding principles for the establishment of metrics for waterbird CPS are detailed in (DEW, 2021b). All waterbird CPS RCTs had a 0.5 probability of being met (positive outcome). The probability of MTs and LAC thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively.

The median abundance of all waterbirds counted over the Ramsar site during waterbird censuses from 2000–15 were used to set the RCT.

The 10th percentile abundance of all waterbirds counted over the Ramsar site during waterbird censuses from 2000–15 were used to set the MT. If the MT were to be breached, then a process to determine whether internal or external factors to the system led to the breach will be conducted. Management actions are to be initiated where internal factors contributed significantly to the MT breach.

The 10th percentile abundance of all waterbirds counted over the Ramsar site during censuses from 2000–15 for 2 consecutive years were used to set the LAC threshold. If the LAC threshold were to be exceeded, then an investigation will be initiated to determine the relative influence of local, national and international factors to the event.</td></tr>
</table>

6.5.3 Presence of priority species – migratory shorebirds

PRIORITY (MIGRATORY SHOREBIRDS) SPECIES ABUNDANCE

Objective

Maintain or improve the abundance of priority migratory shorebirds in the Ramsar site

Region

Murray estuary and Coorong

Data requirements

Annual summer Coorong waterbird census as per methods described in Paton et al. (2017a)

Resource condition target

Counts of each priority species in the Coorong during an annual census are at or above their median abundance from 2000–15.

Priority Species	**Median (2000–15)**
Black-tailed godwit *Limosa limosa*	38
Common greenshank *Tringa nebularia*	430
Curlew sandpiper *Calidris ferruginea*	2,252
Pacific golden plover *Pluvialis fulva*	36
Red-necked stint *Calidris ruficollis*	26,286
Sanderling *Calidris alba*	6
Sharp-tailed sandpiper *Calidris acuminata*	13,179

Management trigger	**Management actions**	**Supporting information**
Counts or detection for any of the 7 priority species are at the following levels. **Common greenshank, curlew sandpiper, Pacific golden plover, red-necked stint and sharp-tailed sandpiper**: Counts of each priority species in the Coorong during an annual census are below their 10th percentile abundance from 2000–15. **Black-tailed godwit**: Black-tailed godwit are not detected over 2 consecutive years of census in the Coorong. **Priority Species** — **10th percentile (2000–15)** Common greenshank *Tringa nebularia* — 225 Curlew sandpiper *Calidris ferruginea* — 508 Pacific golden plover *Pluvialis fulva* — 3 Red-necked stint *Calidris ruficollis* — 15,703 Sharp-tailed sandpiper *Calidris acuminata* — 4,823 **Priority Species** — **Proportion of years present (2000–15)** Black-tailed godwit *Limosa limosa* — 0.69 Sanderling *Calidris alba* — 0.56	<u>Primary actions</u> Maintain salinity in the Murray estuary within target ranges (section 6.2.2) Maintain desired Coorong water levels (section 7.2) targeting 0 to +0.2 m AHD in the South Lagoon. Provide continuous barrage flows from Lake Alexandrina to the Murray estuary (section 7.1). Maintain an open Murray Mouth (section 7.1)	Barrage operating strategy (DEW, 2019) Waterbird metrics for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site (DEW, 2021b)

Limits of Acceptable Change

Direct LAC: Counts for any 3 of the 7 priority species during an annual census (University of Adelaide, D Paton) are at the following levels.

Common greenshank, curlew sandpiper, Pacific golden plover, red-necked stint and sharp-tailed sandpiper: Counts of these priority species in the Coorong during an annual census are below their 10th percentile abundance (2000–15) for 2 consecutive years.

Black-tailed godwit: black-tailed godwit are not detected for 4 consecutive years of census in the Coorong.

Sanderling: sanderling are not detected for 6 consecutive years of census in the Coorong.

Justification

Guiding principles for the establishment of metrics for waterbird CPS subcomponents are detailed in DEW (DEW, 2021b). All waterbird CPS subcomponents; RCTs had a probability of being met (positive outcome) of 0.5 and the probability of MTs and LAC thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively.

The median abundances of priority species in the Coorong during annual censuses from 2000–15 were used to set the RCT.

Common greenshank, curlew sandpiper, Pacific golden plover, red-necked stint and sharp-tailed sandpiper MTs were set at the 10th percentile abundances of priority species in the Coorong during annual censuses from 2000–15. LAC thresholds were set to be exceeded if the MTs were breached for 2 consecutive years.

Black-tailed godwit and sanderling MTs and LAC thresholds were set based upon the number of consecutive years of absence during annual censuses that that equated to a probability of 0.1 and 0.01, respectively, based upon the proportion of years that the species was present from 2000–15.

6.5.4 Selected East-Asian Australasian flyway species

PERCENT OF 1% EAST-ASIAN AUSTRALASIAN FLYWAY POPULATION FOR SELECTED SPECIES

Objective

Maintain or improve abundance of East-Asian Australasian (EAA) Flyway species in the Ramsar site.

Region

Murray estuary and Coorong

Data Requirements

Annual summer Coorong waterbird census as per methods described in Paton et al. (2017a).

Resource Condition Targets

The median percentages of the total flyway populations of curlew sandpipers, red-necked stints and sharp-tailed sandpipers present in the Coorong during annual censuses from 2000–15 are met or exceeded.

1% EAA Flyway Species	Median (2000–15)	EAA Flyway population
Curlew sandpiper *Calidris ferruginea*	2.50%	90,000
Red-necked stint *Calidris ruficollis*	5.53%	475,000
Sharp-tailed sandpiper *Calidris acuminata*	15.50%	85,000

Management trigger

The 10th percentile values of the total flyway populations of any 2 of curlew sandpipers, red-necked stints and sharp-tailed sandpipers present in the Coorong during annual censuses from 2000–2015 are not met in any one year.

1% EAA Flyway Species	10th percentile (2000–15)	EAA Flyway population
Curlew sandpiper	0.56%	90,000
Red-necked stint	3.30%	475,000
Sharp-tailed sandpiper	5.67%	85,000

Management Actions

Primary actions

Reinstate salinity in the Murray estuary within target ranges (section 6.2.2)

Provide continuous barrage flows from Lake Alexandrina to the Murray estuary (section 7.1.

Maintain an open Murray Mouth (section 7.1)

Secondary Actions

Manage fringing wetlands of the lakes and wetlands in the South East and lower River Murray to provide additional and/or complementary habitat.

Supporting Documents

LLCMM Condition Monitoring Plan (DEWNR, 2017)

Waterbird metrics for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site (DEW, 2021b)

Limits of Acceptable Change

Direct LAC: The 10th percentile values of the total flyway populations of any 2 of curlew sandpiper, red-necked stint or sharp-tailed sandpiper present in the Coorong during annual censuses from 2000–15 are not met for 2 consecutive years.

Justification

Guiding principles for the establishment of metrics for waterbird CPS subcomponents are detailed in DEW (2021b). All waterbird RCTs had a 0.5 probability of being met (positive outcome). The probability of MTs and LAC thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively.

The median percentages of the total flyway populations of curlew sandpipers, red-necked stints and sharp-tailed sandpipers counted over the Coorong during waterbird censuses from 2000–2015 were used to set the RCT. The East-Asian Australasian flyway population of each migratory shorebird species were estimated by Hansen et al. (2016)

The MT were set using 10th percentiles of the total flyway populations of curlew sandpipers, red-necked stints and sharp-tailed sandpipers counted over the Coorong during waterbird censuses from 2000–2015, and is breached if values for any one species falls below that value in any one year. If the MT were to be breached, then a process to determine whether factors internal or external to the system led to the breach will be conducted. Site-level management actions are to be initiated where internal factors contributed significantly to the MT breach.

If the MT is breached for 2 consecutive years, then the LAC threshold is exceeded. An investigation is then initiated to determine the relative influence of local, national and international factors to the event.

6.5.5 Selected Australian non-migratory waterbird species

PERCENT OF 1% AUSTRALIAN POPULATION FOR SELECTED SPECIES

Objective
Maintain or improve abundance of Australian species in the Ramsar site.

Region
Murray estuary and Coorong

Data Requirements
Annual summer Coorong waterbird census as per methods described in Paton et al. (2017a).

Resource Condition Targets
The median percentages of the total populations of Australian pied oystercatcher, chestnut teal, Australian fairy tern and red-capped plover present in the Coorong during annual censuses from 2000–15 are met or exceeded.

1% Australian Species	Median (2000–15)	Australian population
Australian pied oystercatcher *Haematopus longirostris*	1.44%	11,000
Chestnut teal *Anas castanea*	7.22%	100,000
Australian fairy tern *Sternula nereis*	22.4%	1,500
Red-capped plover *Charadrius ruficapillus*	1.3%	95,000

Management trigger

The 10th percentile values of the total Australian populations of any 2 of Australian pied oystercatchers, Chestnut teal, fairy tern and red-capped plover present in the Coorong during annual censuses from 2000–2015 are not met in any one year.

1% Australian Species	10th percentile (2000–15)	Australian population
Australian pied oystercatcher	1.04%	11,000
Chestnut teal	4.33%	100,000
Australian fairy tern	15.1%	1,500
Red-capped plover	0.48%	95,000

Management Actions

Primary actions

Reinstate salinity in the Murray estuary within target ranges (section 6.2.2)

Provide continuous barrage flows from Lake Alexandrina to the Murray estuary (section 7.1).

Maintain an open Murray Mouth (section 7.1)

Secondary Actions

Manage fringing wetlands of the lakes and wetlands in the South East and lower River Murray to provide additional and/or complementary habitat.

Supporting Documents

LLCMM Condition Monitoring Plan (DEWNR, 2017)

Waterbird metrics for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site (DEW, 2021b)

Limits of Acceptable Change
Direct LAC: The 10th percentile values of the total populations of any 2 of Australian pied oystercatcher, chestnut teal, Australian fairy tern and red-capped plover present in the Coorong during annual censuses from 2000–15 are not met for 2 consecutive years.

Justification
The median percentages of the total populations of Australian pied oystercatcher, chestnut teal, Australian fairy tern and red-capped plover counted over the Coorong during waterbird censuses from 2000–2015 were used to set the RCT.

The MT were set using 10th percentiles of the total populations of Australian pied oystercatcher, chestnut teal, Australian fairy tern and red-capped plover counted over the Coorong during waterbird censuses from 2000–2015, and is breached if values for any one species falls below that value in any one year. If the MT were to be breached, then a process to determine whether factors internal or external to the system led to the breach will be conducted. Site-level management actions are to be initiated where internal factors contributed significantly to the MT breach.

6.5.6 Waterbird breeding

<table>
<tr><th colspan="3">WATERBIRD BREEDING</th></tr>
<tr><td colspan="3">Objective
Improve waterbird breeding success in the Ramsar site.</td></tr>
<tr><td colspan="3">Region
Lakes Alexandrina and Albert, Murray estuary, Coorong North Lagoon and Coorong South Lagoon.</td></tr>
<tr><td colspan="3">Data requirements
Annual summer Coorong and lakes waterbird census as per the methods described in Paton et al. (2017a), annual aerial waterbird survey as per the methods described in Kingsford et al. (2009) and biennial hooded plover counts as per methods described in Adams et al. (2018). Opportune records and records from targeted investigations regarding waterbird breeding (O'Connor, et al., 2013) would also be used for evaluation.</td></tr>
<tr><td colspan="3">Resource Condition Targets

Detection of annual breeding success (juveniles and/or dependent fledglings) for all 13 target species:
• Australian pelican (Pelecanus conspicillatus)
• Black swan (Cygnus atratus)
• Caspian tern (Hydropogne (Sterna) caspia)
• Greater crested tern (Thalasseus bergii)
• Australian fairy tern (Sternula nereis nereis)
• Hooded plover (Thinornis rubricollis)*
• Australian white ibis (Threskiornis molucca)
• Australian pied oystercatcher (Haematopus longirostris)*
• Red-capped plover (Charadrius ruficapillus)*
• Straw-necked ibis (Threskiornis spinicollis)
• Pied cormorant (Phalacrocorax varius)
• Royal spoonbill (Platalea regia)
• Silver gull (Chroicephalus novaehollandiae)
*Denotes waterbird species that primarily nest on beaches in the Ramsar site.</td></tr>
<tr><th>Management triggers</th><th>Management actions</th><th>Supporting information</th></tr>
<tr><td>Lack of successful breeding for Australian pelican, Caspian tern, greater crested tern, Australian fairy tern, hooded plover, Australian pied oystercatcher and red-capped plover in any one year (and that breeding outcomes are attributable to local site conditions).

Lack of successful breeding for black swan, Australian white ibis, straw-necked ibis, pied cormorant, royal spoonbill and silver gull for 2 consecutive years (and that breeding outcomes are attributable to local conditions).</td><td><u>Primary actions</u>
Maintain Lake Alexandrina water levels within target ranges (section 6.1.2).

Maintain salinity in the Murray estuary within target ranges (section 6.2.2)

Provide continuous barrage flows from Lake Alexandrina to the Murray estuary (section 7.1).

Maintain an open Murray Mouth (section 7.1)

Manage water level regimes in the Coorong to support protection of breeding sites (including islands).</td><td>LLCMM Condition Monitoring Plan (DEWNR, 2017)

CLLMM Environmental Water Requirements (DEW, 2020b)

Barrage operating strategy (DEW, 2019)</td></tr>
<tr><td colspan="3">Limits of acceptable change

<u>Annual breeding species</u>

Direct LAC: Annual breeding species: No successful breeding events (juveniles and/or dependent fledged young) in any 3 consecutive years for the following species and attributable to on-site changes, assessed for each species. Shorebird species</td></tr>
</table>

are underlined: Australia pelican, black swan, Caspian tern, crested tern, Australian fairy tern, hooded plover, Australian white ibis, Australian pied oystercatcher, red-capped plover and straw-necked ibis. Regular breeding species **Direct LAC:** Regular breeding species: No successful breeding events in any 4 consecutive years for the following species and attributable to on-site changes:, pied cormorant, royal spoonbill and silver gull.
Justification The 13 target waterbird species identified are considered to regularly breed (typically each year) within the Ramsar site (Paton, et al., 2015a; Paton, et al., 2018). As current monitoring does not aim to measure recruitment success for all 13 target waterbird species, the RCT for each target species was set at the detection of breeding success via the presence of juveniles and/or fledglings. It must be recognised that breeding success of beach nesting birds, such as hooded plovers, may remain undetected, as only nestlings that hatch early in the breeding season (i.e. early September) would be fledged by the time of the biennial count in November (Adams, et al., 2018). Moreover, counts of beach nest species are conducted biennially, and therefore, evaluation of metrics for beach nesting species must occur on a biennial rather than annual basis unless additional censuses are conducted. MTs were set differently between species dependent on whether they have critical or important breeding habitat in the Ramsar site. Critical breeding habitat was defined as sites that support annual breeding opportunities for species with spatially restricted breeding habitat, such as islands and beaches. Important breeding habitat was defined as sites that support regular breeding opportunities, however, under certain conditions could be relatively widely spread, i.e. inundated floodplains during flood. Based upon the aforementioned definitions, the Ramsar site is considered to support critical breeding habitat for Australian pelican, Caspian tern, greater crested tern, Australian fairy tern, hooded plover, Australian pied oystercatcher and red-capped plover and important breeding habitat for black swan, Australian white ibis, straw-necked ibis, pied cormorant and royal spoonbill. MTs were set to be breached if a target species with critical breeding habitat in the Ramsar site was not detected to have successfully bred in any one year, and breached if a target species with important breeding habitat in the Ramsar site was not detected to have successfully bred for 2 consecutive years. Similarly, LAC were set to be exceeded if a target species with critical breeding habitat in the Ramsar site was not detected to have successfully bred for 3 consecutive years, and exceeded if a target species with important breeding habitat in the Ramsar site was not detected to have successfully bred for 4 consecutive years. A successful breeding event should be defined by a measure of fledgling success, however this measure is currently a knowledge gap.

6.5.7 Threatened species - Waterbirds

THREATENED WATERBIRDS – Australasian bittern *Botaurus poiciloptilus*		
Objective Maintain or improve threatened waterbird populations in the Ramsar site.		
Region Lakes Alexandrina and Albert, eastern Mount Lofty Ranges tributaries		
Data requirements Targeted surveys as per the methods described in (O'Connor, 2015) and community wetland monitoring programs in the Ramsar site.		
Resource condition target Australasian bittern is detected at greater than 50 per cent of sites that contain suitable habitat in all targeted surveys.		
Management triggers	**Management actions**	**Supporting information**
Australasian bittern detected at less than 20% of sites that contain suitable habitat in any targeted surveys (in any one year)	Primary actions Management of hydrological drivers: • Lake levels (section 6.1.2) • Lake salinity (section 6.2.1) Secondary actions Maintain reed beds and connectivity between the water line and fringing vegetation (section 6.3) at known sites.	Conservation advice (TSSC, 2019) Draft National Recovery Plan for the Australasian Bittern (2019)

	Undertake lakeshore fencing and grazing control at known sites. Manage fringing wetlands of the lakes and wetlands in the south east region to provide additional and/or complementary habitat.	
Limits of acceptable change **Direct LAC:** Absence of Australasian bittern at greater than 20% of sites that contain suitable habitat in 3 out of any 5 targeted surveys.		
Justification Data on the Australasian bittern is limited to relatively recent surveys of cryptic species (O'Connor, 2015). The species has been recorded at several sites around the Lakes and the RCT, MT and LAC have been set using the recent survey data. It is likely that the LAC would be met in future.		

THREATENED WATERBIRDS – Australian fairy tern *Sternula nereis*		
Objective Maintain or improve threatened waterbird populations in the Ramsar site		
Region Murray estuary, Coorong North Lagoon and Coorong South Lagoon		
Data requirements Annual summer Coorong waterbird census as per methods described in Paton et al. (2017a).		
Resource condition target Australian fairy terns are recorded at or above their long-term median abundance of 337 individuals during the annual waterbird census in the Coorong.		
Management Triggers	**Management Actions**	**Supporting Documents**
Direct MT: Australian fairy terns are recorded below their 10th percentile abundance of 226 individuals during the annual waterbird census in the Coorong **OR** **Indirect MT**: Breeding islands are expected to become accessible by land due to low Coorong water levels.	<u>Primary actions</u> Management of hydrological drivers: • Barrage flows (section 7.1) with delivery of flows to the Coorong during spring and summer. • Coorong water levels (section 7.2) • Coorong salinity (section 6.2.2) Undertake actions that support and provide habitat and food (see sections 6.3, 6.4 and 6.7.3). <u>Secondary actions:</u> Reduction of disturbance at key roosting and breeding sites (e.g. via targeted fox baiting and fencing of breeding colonies to protect from terrestrial predators).	Waterbird metrics for the Coorong, and Lakes Albert and Alexandrina Ramsar site (DEW, 2021b) Conservation advice (TSSC, 2011) *Our Coorong Our Coast* Project (2019-2023) Draft National Recovery Plan for the Australian Fairy Tern (DEE, 2019)
Limits of acceptable change **Direct LAC:** Abundance of Australian fairy tern less than 226 in the January census for 2 consecutive years.		

Justification

Guiding principles for the establishment of metrics for waterbird CPS subcomponents are detailed in DEW (2021b). All waterbird RCTs had a 0.5 probability of being met (positive outcome). The probability of MTs and LAC thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively.

The median abundance of Australian fairy tern counted over the Coorong during annual waterbird censuses from 2000–15 was used to set the RCT.

The 10th percentile abundance of Australian fairy tern counted over the Coorong during annual waterbird censuses from 2000–15 was used to set the direct MT. If the direct MT were to be breached, then a process to determine whether factors internal or external to the system led to the breach will be conducted. Management actions are to be initiated where internal factors contributed significantly to the direct MT breach. If the direct MT was breached in 2 consecutive years, then the LAC threshold is exceeded. An investigation is then initiated to determine the relative influence of local, national and international factors to the event.

The nest success of Australian fairy terns on islands surrounded by water is significantly higher than sites that are accessible via land. The protection offered by water around breeding islands is critical to preventing the destruction of nests by fox predation (Paton & Rogers, 2009; Baker-Gabb & Manning, 2011). Therefore, the indirect MT is to be breached if water levels are expected to decline and result in breeding islands becoming accessible by land.

THREATENED WATERBIRDS – Curlew sandpiper *Calidris ferruginea*		
Objective Maintain or improve threatened waterbird populations in the Ramsar site		
Region Murray estuary and Coorong		
Data Requirements Annual summer Coorong waterbird census as per methods described in Paton et al. (2017a).		
Resource Condition Target Curlew sandpipers are recorded at or above their long-term median abundance of 2,252 individuals during the annual waterbird census in the Coorong.		
Management Triggers	**Management Actions**	**Supporting Documents**
Curlew sandpipers are recorded below their 10th percentile abundance of 508 individuals during the annual waterbird census in the Coorong.	<u>Primary actions</u> Management of hydrological drivers: • Barrage flows (section 7.1) • Coorong salinity (section 6.2.2) <u>Secondary actions</u> Undertake actions that support and provide habitat and food (see sections 6.3, 6.4 and 6.7.3). Reduction of disturbance at key roosting and feeding sites by protecting key areas and controlling predators Manage fringing wetlands of the lakes and wetlands in the South East region to provide additional and/or complementary habitat.	Waterbird metrics for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site (DEW, 2021b) LLCMM Condition Monitoring Plan (DEWNR, 2017) Conservation advice (TSSC, 2015)
Limits of acceptable change **Direct LAC:** Abundance of curlew sandpiper less than 508 in the January census for 2 consecutive years.		

Justification

Guiding principles for the establishment of metrics for waterbird CPS subcomponents are detailed in DEW (2021b). All waterbird RCTs had a 0.5 probability of being met (positive outcome). The probability of MTs and LAC thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively.

The median abundance of curlew sandpiper counted over the Coorong during annual waterbird censuses from 2000–15 was used to set the RCT.

The 10th percentile abundance of Curlew sandpiper counted over the Coorong during annual waterbird censuses from 2000–15 was used to set the MT. If the MT were to be breached, then a process to determine whether factors internal or external to the system led to the breach will be conducted. Management actions are to be initiated where internal factors contributed significantly to the MT breach. If the MT was breached in 2 consecutive years, then the LAC threshold is exceeded. An investigation is then initiated to determine the relative influence of local, national and international factors to the event.

THREATENED WATERBIRDS –Eastern curlew *Numenius madagascariensis*		
Objective Maintain or improve threatened waterbird populations in the Ramsar site		
Region Murray estuary and Coorong North Lagoon		
Data requirements Annual summer Coorong waterbird census as per methods described in Paton et al. (2017a).		
Resource Condition Target Eastern curlews are recorded at or above their long-term median abundance of 13 individuals during the annual waterbird census in the Coorong.		
Management Triggers	**Management Actions**	**Supporting Documents**
Eastern curlews are recorded below their 10th percentile abundance of 2 individuals during the annual waterbird census in the Coorong.	<u>Primary actions</u> Management of hydrological drivers: • Barrage flows (section 7.1) • Coorong salinity (section 6.2.2) <u>Secondary actions</u> Undertake actions that support and provide habitat and food (see sections 6.3, 6.4 and 6.7.3). Reduction of disturbance at key roosting and feeding sites by protecting key areas and controlling predators	Waterbird metrics for the Coorong, Lake Alexandrina and Albert Ramsar site (DEW, 2021b) Conservation advice TSSC 2015b LLCMM Condition Monitoring Plan (DEWNR, 2017)
Limit of Acceptable Change **Direct LAC:** Abundance of eastern curlew less than 2 in the January census for 2 consecutive years.		

Justification

Guiding principles for the establishment of metrics for waterbird CPS subcomponents are detailed in DEW (2021b). All waterbird RCTs had a 0.5 probability of being met (positive outcome). The probability of MTs and LAC thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively.

The median abundance of eastern curlew counted over the Coorong during annual waterbird censuses from 2000–15 was used to set the RCT.

The 10th percentile abundance of eastern curlew counted over the Coorong during annual waterbird censuses from 2000–15 was used to set the MT. If the MT were to be breached, then a process to determine whether factors internal or external to the system led to the breach will be conducted. Management actions are to be initiated where internal factors contributed significantly to the MT breach. If the MT was breached in 2 consecutive years, then the LAC threshold is exceeded. An investigation is then initiated to determine the relative influence of local, national and international factors to the event.

THREATENED WATERBIRDS – Hooded plover *Thinornis rubricollis*		
Objective Maintain or improve hooded plover populations in the Ramsar site		
Region Coastline of the Ramsar site.		
Data requirements Biennial hooded plover counts by Birdlife Australia.		
Resource condition target Densities of adult Hooded Plovers are ≥0.13 birds per kilometre over the Coorong ocean beaches.		
Management triggers	**Management action**	**Supporting Information**
Densities of adult hooded plovers are <0.10 birds per kilometre.	Secondary actions Review the effectiveness of current policies in regards to protection of beach nesting birds from vehicles on beaches, and adapt as required. Maintain beach closures in peak summer.	
Limit of Acceptable Change **Direct LAC:** Absence of hooded plover in any 3 out of 5 targeted surveys assessed over a rolling 10-year period.		
Justification Hooded plovers use the beaches of the Younghusband Peninsula and the Coorong lagoons as habitat, however, will only breed along the Coorong ocean beaches. Therefore, the status of hooded plovers across the Ramsar site is best informed through monitoring of its population at the Coorong ocean beaches. The RCT for adult Hooded Plovers was set at the median density (0.13 birds per kilometre) of individuals observed from 2010 to 2014 during biennial counts by Birdlife Australia along the Coorong ocean beaches from the Murray Mouth to Rosetown (Adams, et al., 2018). As adult hooded plovers exhibit high fidelity to breeding territories (TSSC, 2014), any reduction in the densities of adult hooded plovers below those recorded in baseline years is of concern. As the densities of adult hooded plovers over the Coorong ocean beaches ranged from 0.12 to 0.17 birds per kilometre between 2010 and 2014 (Adams, et al., 2018), densities below 0.10 birds per kilometre are expected to signal the need for management action. If densities below 0.10 birds per kilometre were to occur for 3 consecutive biennial counts, it would likely signify a significant long-term reduction in the population of hooded plovers using the Coorong ocean beaches for breeding.		

THREATENED WATERBIRDS – Mount Lofty Ranges southern emu-wren *Stipiturus malachurus intermedius*		
Objective Maintain or improve threatened waterbird populations in the Ramsar site		
Region Lake Alexandrina and eastern Mount Lofty Ranges tributaries		
Data requirements Targeted surveys of Mount Lofty Ranges southern emu-wren at swamps of the Fleurieu Peninsula that are within the Ramsar site. Methods to follow those undertaken by the Conservation Council SA, in partnership with DEW.		
Resource condition target Mount Lofty Ranges southern emu-wren detected in all known core population locations in any year of targeted surveys.		
Management triggers	**Management actions**	**Supporting information**
Mount Lofty Ranges southern emu-wren not detected in at least one known core population location in any year of targeted surveys.	Secondary actions Develop and implement site management plans for the swamps of the Fleurieu Peninsula within the lakes and tributaries.	Conservation advice TSSC (2016) National Recovery Plan (1998)

Limits of Acceptable Change **Direct LAC:** Absence of Mount Lofty Ranges southern emu-wren from all known core population locations in any one out of 5 targeted surveys assessed over a rolling 10-year period.
Justification There is insufficient data to determine an abundance LAC for the Mount Lofty Ranges southern emu-wren. As of 2012, there were 3 core populations in the lower Finniss River and lower Tookayerta Creek (Conservation Council SA). The RCT, MT and LAC are based on expert opinion.

6.6 Habitat

Wetland habitat has been identified as a critical CPS of the Coorong and Lakes Alexandrina and Albert Wetland (DEW, 2021a). RCT(s), MT(s) and LAC(s) are described below for wetland habitat.

<table>
<tr><th colspan="3">WETLAND HABITAT</th></tr>
<tr><td colspan="3">Objective
Improvement in habitat condition within the Ramsar site.</td></tr>
<tr><td colspan="3">Data requirements
Habitat condition assessed according to the methodology outlined in Seaman (2003) and used at the sites identified in Thiessen (2010), Billows, et. al (2014), Dickson, et. al (2015) at 5 yearly intervals commencing in 2023.</td></tr>
<tr><td colspan="3">Resource condition target
Habitat condition is assessed as being equal to or greater than ‘good’ in ≥80% of the sites assessed every 5 years.</td></tr>
<tr><th>Management triggers</th><th>Management actions</th><th>Supporting documents</th></tr>
<tr><td>Percentage of degraded sites increases to ≥30% in a 5-yearly assessment.</td><td rowspan="2">Manage the disturbances that are causing the degraded conditions.

Identify the cause/s of the decline in condition and undertake actions to remedy, if possible.</td><td rowspan="2">Habitat management plan for the CLLMM region. Volume 2: Detailed action plans and guidelines for On-Ground Works (DENR, 2011).</td></tr>
<tr><td>Decline in condition at ≥40% of the sites assessed over any ten-year period.</td></tr>
<tr><td colspan="3">Limits of acceptable change
Direct LAC: Decline in condition at ≥60% of the sites assessed over any ten-year period.</td></tr>
<tr><td colspan="3">Justification
Habitat condition considers ecological values such as hydraulic and habitat connectivity, pest plants, human impacts, integrity of vegetation associations and condition of core habitat areas. Habitat condition descriptions are based on previous landscape and ecosystem scale assessments made within South Australia, as described in Seaman (2003). The LAC applies to the whole Ramsar site and at a point above the number of sites assessed as having declined in habitat condition in Lakes Alexandrina and Albert than during the assessment undertaken in 2010 during the Millennium Drought.</td></tr>
</table>

6.7 Threatened ecological communities and species

6.7.1 Swamps of the Fleurieu Peninsula

SWAMPS OF THE FLEURIEU PENINSULA ECOLOGICAL COMMUNITY
Objective Maintain or improve the extent and condition of swamps of the Fleurieu Peninsula ecological community.
Region Eastern Mount Lofty Ranges tributaries and Lake Alexandrina
Data requirements Assessment of extent and condition of threatened ecological community in the Ramsar site using aerial imagery and ground-truthing.
Resource condition target Extent and condition RCT to be developed

Management trigger	Management actions	Supporting information
Extent and condition MT still to be developed	Develop methodologies to assess swamp extent and condition within the Ramsar site Implement priority actions as described in the Conservation Advice for the Swamps of the Fleurieu Peninsula ecological community Implement Recovery Plan for the Mount Lofty Ranges Southern Emu-Wren	Approved Conservation Advice for the Swamps of the Fleurieu Peninsula ecological community (DCCEEW, 2013). Swamps of the Fleurieu Peninsula Information Sheet Recovery Plan for the Mount Lofty Ranges Southern Emu-Wren
Limits of Acceptable Change Insufficient data available to develop a baseline and a LAC. To be defined in future.		
Justification Phillips & Muller (2006) estimated that there were approximately 262 ha of this community within the Currency Creek, Tookayerta Creek and Finniss River catchments (within the Eastern Mount Lofty Ranges tributaries sub-unit) however, there is no recent estimation for the area within the Ramsar site post considerable restoration efforts over the last ten years. More than 75% of the remaining swamps are less than 5 hectares in size and are isolated (TSSC, 2003).		

6.7.2 Subtropical and temperate coastal saltmarsh

SUBTROPICAL AND TEMPERATE COASTAL SALTMARSH ECOLOGICAL COMMUNITY		
Objective Maintain or improve the extent of the subtropical and temperate saltmarsh ecological community.		
Region Murray estuary and Coorong North Lagoon		
Data requirements Refer to DEW (2018) *Technical information supporting the 2018 coastal saltmarsh (percentage cover) trend and condition report card*, DEW Technical Report 2018/32.		
Resource condition target Extent of the subtropical and temperate coastal saltmarsh ecological community remains at 480 ha or greater.		
Management trigger	**Management action**	**Supporting information**
Reduction of 5% in percentage cover over any 10-year period.	Management of hydrological drivers: • Barrage flows (section 7.1) • Coorong water levels (section 7.2) Implement relevant priority conservation actions to support the maintenance or improvement of the temperate coastal saltmarsh ecological community in the Ramsar site.	Approved Conservation Advice for the subtropical and coastal saltmarsh ecological community (DCCEEW, 2013)
Limits of acceptable change **Direct LAC:** Murray Estuary and Coorong**:** Reduction of greater than 10% in percentage cover over any 10 year period		
Justification Saltmarsh communities are influenced by the tide and require some form of ongoing connection to the tidal regime and are generally restricted to areas above +0.2 m AHD in the Coorong (Nicol, 2016). Detailed mapping of the saltmarsh communities in the Murray estuary and Coorong was completed in 2006. The mapping provides the type and habitats present and can be accessed through DEW Nature Maps. The percentage cover of the temperate coastal saltmarsh ecological community on the lagoon edges of the Murray estuary and the Coorong is stable at 480 ha (DEW, 2018), with the majority found within the Coorong National Park.		

6.7.3 Southern bell frog *Litoria raniformis*

Southern bell frog *Litoria raniformis* is listed as Vulnerable under the *EPBC Act 1999* and the IUCN Red List and is considered Vulnerable in South Australia. Threatened species, including the southern bell frog, have been identified as a critical CPS of the Coorong and Lakes Alexandrina and Albert Wetland (DEW, 2021a). See LAC for freshwater submergent and emergent vegetation and Lake Alexandrina salinity LAC.

6.8 Coorong food web

The Coorong food web has been identified as a critical CPS (DEW, 2021a). In its current state, the Coorong can only support a very simple foodweb, comprising those species that can tolerate the hypersaline conditions. RCTs, MTs, LAC are described below for 3 key elements of this highly simplified Coorong food web:

- The submergent halophyte *Ruppia tuberosa*
- The Coorong benthic macroinvertebrate community; and
- The small-bodied fish small-mouthed hardyhead (*Atherinosoma microstoma*).

6.8.1 *Ruppia tuberosa*

<table>
<tr><th colspan="3">COORONG FOOD WEB – RUPPIA TUBEROSA</th></tr>
<tr><td colspan="3">Objective
Maintain or improve Ruppia tuberosa colonisation and reproduction.</td></tr>
<tr><td colspan="3">Region
Coorong North Lagoon and Coorong South Lagoon.</td></tr>
<tr><td colspan="3">Data requirements
Annual winter and spring/summer Coorong Ruppia tuberosa condition monitoring and data assessment, as per the methods described in Paton, et al. (2017b).</td></tr>
<tr><td colspan="3">Resource condition targets
At least 50% of cores should have seeds present in winter and an accumulated (i.e. across winter and summer sampling) seed density >2,000 seeds/m^2 at ≥50% of sites.

At least half of all sites monitored at the end of summer should have 50% or more of all cores containing turions (at least type I turions).

At least half of all winter and summer monitored sites should have at least 30% of cores with R. tuberosa present (submergent halophyte RCT).</td></tr>
<tr><th>Management triggers</th><th>Management actions</th><th>Supporting information</th></tr>
<tr><td>There is a high likelihood that water levels in the Coorong South Lagoon could drop below +0.15 m AHD between June and December.</td><td><u>Primary actions:</u>
Maintain Coorong water levels (see Coorong water levels, section 7.2).

Seek environmental flows for delivery to the Coorong in spring and summer (targeting August to December), to raise and maintain water levels in the South Lagoon.

Prioritise barrage flows from the Pelican Point end of Tauwitchere barrage.

<u>Secondary actions:</u>
Investigate and implement on-ground works to mitigate threats to R. tuberosa.</td><td rowspan="2">LLCMM Condition Monitoring Plan (DEWNR, 2017)

Barrage operating strategy (DEW, 2019)

Healthy Coorong, Healthy Basin Action Plan

(Collier, et al., 2017)</td></tr>
<tr><td>South Lagoon average monthly salinity expected to exceed 110,879 EC (85 ppt) between April</td><td><u>Primary actions:</u>
Maintain South Lagoon salinity (see Coorong salinity, section 6.2.2).</td></tr>
</table>

and July and 126,145 EC (100 ppt) between August and December.		

Limits of Acceptable Change

Direct LAC: Viable seeds of *R. tuberosa* in less than 20% of sediment cores at 2 thirds of sampling locations across the Coorong South Lagoon for 4 consecutive seasons.

Cascade LAC: Less than 5% cover of *Ruppia tuberosa* recorded at greater than 50% of all winter monitored sites for 2 or more consecutive years (submergent halophyte LAC).

Justification

Ruppia tuberosa is an important submergent halophyte in the Coorong, being a key element of the Coorong food web and the most salt tolerant of the Coorong halophytes.

RCT

The RCT for the *R. tuberosa* seedbank was based upon the densities of seeds (~2,000 seeds/m^2) present at sites in winter in the 1990s and is considered to be adequate to provide an initial level of resilience for the plant (Paton, et al., 2017b).

The RCT for *R. tuberosa* turions were set by Paton et al. (2017b) based upon values that would provide a chance of establishing a similar percent cover (% of cores with shoots) of *R. tuberosa* in the following winter.

The RCT for *R. tuberosa* cover were set based upon data collected in the late 1990s prior to the Millennium Drought. Prior to the Millennium Drought, *R. tuberosa* was distributed along at least 43 km of the southern Coorong and sites sampled had at least 30% of cores with *R. tuberosa* shoots in early July when monitoring commenced (Paton, et al., 2017b).

MT

The water level management trigger for *R. tuberosa* was set at +0.15 m AHD as very few (1%) of *R. tuberosa* and *A. cyclindrocarpa* plants were found to occur at higher elevations in spring 2020 (Oerman, 2021). Water levels below +0.15 m AHD from June to December would subject plants within the core elevation range (-0.15 to+0.15 m AHD, (Oerman, 2021)) to desiccation during periods critical for vegetative growth (June-September) and seed bank and turion production (August – December) (Collier, et al., 2017; Asanopoulos & Waycott, 2020). The water level (m AHD) MT for *R. tuberosa* needs to be confirmed by field data and new digital elevation model information collected for shallow water environments.

The salinity management trigger for *R. tuberosa* was set at South Lagoon monthly averages that were expected to exceed 85 ppt between April and July and 100 ppt between August and December. These thresholds were set as *R. tuberosa* require salinities:

- <85 ppt (for up to 15 days) to germinate from seed (April to July) (Kim, et al., 2013)
- <102 ppt to provide conditions for flowering (leading to seed-set) between September and December (optimal: 40–63 ppt, suboptimal: 17–102 ppt; (Collier, et al., 2017; Asanopoulos & Waycott, 2020))
- 30–122 ppt for optimal adult (vegetative) growth (Collier, et al., 2017; Asanopoulos & Waycott, 2020).

Management of salinity in the Coorong may need to consider interactive effects of salinity on other ecological outcomes, such as excessive filamentous algal growth. For example, when water temperatures are above 22°C and inorganic nutrient or rapid turnover nutrient loads remain high, and salinities remain below 90 ppt, filamentous algal blooms will continue to occur (Waycott, et al., 2020). Refined MTs for salinity may need to consider the outcomes of current research regarding nutrient dynamics being explored in the HCHB program.

LAC

The LAC of less than 5% cover of *R. tuberosa* recorded at greater than 50% of all winter monitored sites for 2 or more consecutive years reflects a risk that populations will disappear completely if conditions continue to be sub-optimal. The LAC for seed density was set at less than 20% of sediment cores at two thirds of sampling locations have viable seeds, for 4 consecutive seasons. To maintain some semblance of ecological character of the southern Coorong, absences of *R. tuberosa* must be avoided (Paton, et al., 2015b).

6.8.2 Macroinvertebrates

<table>
<tr><th colspan="3">COORONG FOOD WEB – MACROINVERTEBRATES</th></tr>
<tr><td colspan="3">Objective
Maintain or improve Coorong macroinvertebrate communities</td></tr>
<tr><td colspan="3">Region
Murray estuary, Coorong North Lagoon and Coorong South Lagoon</td></tr>
<tr><td colspan="3">Data requirements
Annual summer Coorong benthic invertebrate condition monitoring and assessment, as per the methods described in (Dittmann, 2017).

Murray estuary salinity is based on the average daily salinity at A4261036 (Beacon 12 Goolwa Channel), A4261039 (Barker Knoll), A4261128 (Mundoo Channel), A4261043 (Beacon 1, Ewe Island Shacks). North Lagoon salinity is based on the average daily salinity at A4261134 (Beacon 19 Pelican Point), A4261135 (Long Point), A4260572 (Robs Point). South Lagoon salinity is based on the average daily salinity at A4260633 (Parnka Point), A4261209 (near Cattle Island) and A4261165 (NW Snipe Island). Data available from water.data.sa.gov.au/.</td></tr>
<tr><td colspan="3">Resource condition targets
Macroinvertebrate species richness increases throughout the Murray Mouth and Coorong.

Macroinvertebrate occurrence extends along the Coorong into the South Lagoon.

Macroinvertebrate abundance is maintained, or increases above, reference levels.

Salinity gradient in the Coorong is present, with Murray estuary average monthly salinities <35 ppt, North Lagoon average monthly salinities <45 ppt, South Lagoon average monthly salinities over winter <60 ppt and daily salinities year-round <100 ppt 95% of the time.</td></tr>
<tr><th>Management triggers</th><th>Management actions</th><th>Supporting information</th></tr>
<tr><td>Murray estuary average monthly salinity level expected to exceed 35 ppt.

Coorong North Lagoon average monthly salinity level expected to exceed 45 ppt.

Coorong South Lagoon average monthly salinity level expected to exceed 100 ppt.</td><td><u>Primary actions</u>

Maintain Coorong salinity levels within LAC (section 6.2.2)</td><td>LLCMM Condition Monitoring Plan (DEWNR, 2017)

CLLMM Environmental Water Requirements (DEW, 2020b)

Barrage operating strategy (DEW, 2019)

Healthy Coorong, Healthy Basin Action Plan</td></tr>
<tr><td colspan="3">Limits of acceptable change
Indirect LAC: Murray estuary average monthly salinity greater than 40 ppt for more than any 18 consecutive months
OR
North Lagoon average monthly salinity level greater than 70 ppt for more than any 18 consecutive months
OR
South Lagoon average monthly salinity level greater 100 ppt for more than 18 consecutive months.</td></tr>
<tr><td colspan="3">Justification
Benthic macroinvertebrates (or mudflat invertebrates) are the primary consumers of the Coorong food web and are a food source for fish, birds and other invertebrates, hence their inclusion as a key element of the Coorong food web.

<u>RCT</u>
The RCT for species richness (i.e. species number is the count of taxa per site), extent of occurrence (i.e. the number of sites a species is found) and abundance (i.e. number of taxa counted) are based on data collected between 2004 and 2013 (Dittmann, 2017).</td></tr>
</table>

Target salinity ranges are based on salinity tolerances and seasonal life history requirements for key species in each of the 3 management units, including:

Murray estuary: Salinities between freshwater and <35 ppt support:

- High abundances of macroinvertebrates in the Murray Mouth and upper North Lagoon (Dittmann, 2015; Dittmann, et al., 2016; Ye, et al., 2019a)

Coorong North Lagoon: Salinities <45 ppt support:

- Common macroinvertebrate species with hypermarine salinity tolerances (as shown in brackets) including: polychaete worms *Nephtys australiensis* (50 ppt), *Boccardiella limnicola* (40 ppt) and *Australonereis ehlersi* (50 ppt) and gastropod snails *Salinator fragilis* (45 ppt) and *Hydrobiidae* (45 ppt) (Dittmann, et al., 2018)

Coorong South Lagoon: Salinities <100 ppt support:

- Suitable conditions for larvae of salt-tolerant chironomids (*Tanytarsus barbitarsis*) (Dittmann, 2015), including avoiding lethal effects (i.e. LC_{50} value is 96.9 ppt; (Kokkinn, 1986)).

MT

Management is triggered if average monthly salinities are expected to exceed the described thresholds. Annual hydrological modelling is used to identify the risk of exceeding salinity thresholds, and will allow for lead-time to identify and implement required management actions. Management actions will aim to avoid exceeding salinities that are required for high macroinvertebrate abundance in the Murray estuary (35 ppt), above the salinity tolerance of common macroinvertebrate species in the North Lagoon (45 ppt) and above the salinity tolerance of salt-tolerant chironomids (*Tanytarsus barbitarsis*) in the South Lagoon (100 ppt).

LAC

As salinity is the primary driver of benthic macroinvertebrate communities in the Coorong, the LAC for benthic macroinvertebrates are assessed indirectly via the Murray estuary and Coorong North and South Lagoon salinity LAC. The LAC for the Murray estuary was set at >40 ppt for ≥18 consecutive months. Salinities above that of seawater (35 ppt will significantly affect the distribution, abundance and diversity of estuarine macroinvertebrates (Dittmann, 2015; Dittmann, et al., 2018)

The LAC for the North Lagoon was set at >70 ppt for ≥18 consecutive months, which exceeds the salinity tolerance of all polychaete species in the Coorong (with the exception of *Capitella capitata* that can occur in low densities in salinities up to 90 ppt). It represents a change in macroinvertebrate community from an estuarine and marine community to a hypersaline community (Dittmann, et al., 2018).

The LAC for the South Lagoon is set at >100 ppt for ≥18 consecutive months, which was recorded at the height of the Millennium Drought (height of drought being 2007–10) and was associated with the extirpation of salt-tolerant chironomids (*Tanytarsus barbitarsis*) (Paton & Bailey, 2012).

6.8.3 Small-mouthed hardyhead

COORONG FOOD WEB – SMALL-MOUTHED HARDYHEAD
Objective Maintain abundant self-sustaining populations of small-mouthed hardyhead in the Coorong
Region Coorong South Lagoon
Data requirements Annual Coorong fish condition monitoring and assessment, as per the methods described in Ye et al. (2017b). South Lagoon salinity is based on the average daily salinity at A4260633 (Parnka Point), A4261209 (near Cattle Island) and A4261165 (NW Snipe Island). Data available from waterdata.sa.gov.au.
Resource condition targets Maintain an average Catch-Per-Unit-Effort (CPUE) of small-mouthed hardyhead of >120 for adults sampled in spring/early summer and >800 for juveniles sampled in summer/early autumn.

Maintain the proportional abundance of small-mouthed hardyhead juveniles at 60% in >75% monitoring sites in the Coorong.

Salinity gradient in the Coorong is present, with South Lagoon average monthly salinities over winter <60 ppt and daily salinities year-round <100 ppt 95% of the time.

<table>
<tr><th>Management triggers</th><th>Management actions</th><th>Supporting information</th></tr>
<tr><td>Average CPUE of adult small-mouthed hardyhead is ≤120 in spring/early summer and ≤800 juvenile small-mouthed hardyhead sampled in summer/early autumn.

<70% of defined sites (i.e. 5 or less out of 8 sites) has the proportional abundance of juvenile small-mouthed hardyhead is >60%.</td><td><u>Primary actions</u>

Seek environmental flows for delivery via the barrages to the Coorong in spring and summer to promote productivity inputs.

Provide freshwater releases from Salt Creek to meet target salinities for smallmouth hardyhead distribution and recruitment.

<u>Secondary actions</u>

Undertake actions to restore Ruppia tuberosa in the Coorong South Lagoon (see section 0)</td><td rowspan="2">LLCMM Condition Monitoring Plan (DEWNR, 2017)

Barrage operating strategy (DEW, 2019)

Healthy Coorong, Healthy Basin Action Plan</td></tr>
<tr><td>South Lagoon average monthly salinity level expected to exceed 100 ppt.</td><td><u>Primary action</u>
Maintain salinity levels in the South Lagoon below the LAC (section 6.2.2).

Maintain Coorong water levels (see section 7.2).

Maintain functional fish passage by opening Salt Creek and Morella fishways to provide refugia.</td></tr>
</table>

Limits of acceptable change

Indirect LAC: South Lagoon average monthly salinity level greater than 100 ppt for more than 18 consecutive months.

Justification

Small-mouthed hardyhead are a key element of the Coorong food web, as the most abundant fish in the southern Coorong (Ye, et al., 2017b). They are highly responsive to freshwater flow and changes in salinity (Ye, et al., 2017b; Wedderburn, et al., 2016)). RCTs and MTs are assessed via annual small-mouthed hardyhead population assessments and Coorong South Lagoon salinities.

<u>RCT</u>

The direct RCT for adult and juvenile CPUE uses the average CPUE (±25% fish-per-unit-effort) during 2011-12, 2012-13 and 2013-14, where adults are defined by fish ≥40 mm Total Length sampled in spring/early summer and juveniles (early) defined by fish <40 mm Total Length sampled in summer/early autumn (Ye, et al., 2017b).

The indirect RCT is a salinity gradient, where North Lagoon average monthly salinities are <45 ppt, South Lagoon average monthly salinities over winter are <60 ppt and daily salinities year-round are <100 ppt 95% of the time. Providing these salinity conditions would support:

- Suitable conditions for the widespread distribution of small-mouthed hardyhead (Ye et al. 2020). They have a wide range of salinity tolerance in aquaria (i.e. ~3-108 psu; (Lui, 1969)), and an even greater tolerance observed under natural conditions where they have been observed at ~130 psu in the Coorong (Noell, et al., 2009).
- Salinities <100 ppt may help to mitigate impacts to recruitment of small-mouthed hardyhead (Ye, et al., 2020), which spawn between September and December (Molsher, et al., 1994; Ye, et al., 2013)

The winter salinity target has been set to lower the potential for the South Lagoon to exceed the upper salinity threshold of small-mouthed hardyhead presence and recruitment ~100 ppt in summer. Furthermore, seasonal reduction of salinity by freshwater influence has been suggested as a partial cue to spawning in small-mouthed hardyhead (Molsher, et al., 1994).

MT

The direct MTs for small-mouthed hardyhead are set based upon the failure of meeting the RCTs. If either of the 2 direct RCTs are not met, then the population condition of small-mouthed hardyhead has been impacted by low recruitment and/or recruitment over a limited distribution. Management is therefore to be initiated to improve the distribution and abundance of small-mouthed hardyhead in order to support greater food resource availability for piscivorous fish and waterbirds.

The indirect salinity MT is triggered if average monthly salinities are expected to exceed the described thresholds for small-mouthed hardyhead. Annual hydrological modelling is used to identify the risk of exceeding salinity thresholds, and will allow for lead-time to identify and implement required management actions.

LAC

The indirect LAC for small-mouthed hardyhead is based on Coorong South Lagoon salinity, with the assumption that if the LAC for the Coorong South Lagoon average monthly salinity is exceeded, it would result in reduced abundances and a contraction of distribution in the Coorong (DEW, 2021a). Such salinities were recorded in the South Lagoon during the Millennium Drought (height of drought during 2007–10) and were associated with the extirpation of small-mouthed hardyhead (Paton & Bailey, 2012).

7 Additional management priorities and targets

7.1 Barrage flows

This section outlines management priorities and indicators that were not outlined as critical components in the Ecological Character description as at 2015, but require consideration in future management of the site.

<table>
<tr><th colspan="3">SURFACE WATER REGIME – BARRAGE FLOWS</th></tr>
<tr><td colspan="3">Objective
Freshwater flows, primarily River Murray flows, are delivered to and through the site to support the ecological character of the Ramsar site.</td></tr>
<tr><td colspan="3">Region
Lake Alexandrina, Murray estuary and northern part of Coorong North Lagoon</td></tr>
<tr><td colspan="3">Data requirements
Barrage flows are calculated by DEW and available at site A4261002 on water.data.sa.gov.au. Diurnal Tide Ratio (DTR) data is maintained by SA Water.</td></tr>
<tr><td colspan="3">Environmental indicators
Barrage flows greater than 650 GL on an annual basis and ≥2,000 GL/yr on a rolling 3-year average are required to maintain salinities below 1,000 EC in Lake Alexandrina (Heneker 2010; Lester al. 2011). High flows of ≥6,000 GL/yr are required one in every 3 years and flows ≥10 000 GL/yr are required one in every 7 years (Lester, et al., 2011).</td></tr>
<tr><td>Management priority</td><td>Management action</td><td>Supporting information</td></tr>
<tr><td>Annual barrage flows are <650 GL in any one year.</td><td>Model different barrage release profiles for barrage flows <650 GL in a second year to determine the impact in the salinity in both the Coorong and the Lower Lakes and assess tradeoffs. Results to be addressed through the 3-month forward plan.

Undertake prioritisation of watering actions within South Australia in alignment with annual priorities.</td><td rowspan="2">River Murray long-term environmental watering plan for the South Australian River Murray water resource plan area (DEW, 2020b).

Barrage Operating Strategy (DEW, 2019)

Lester et al. (2011)

Development of flow regimes to manage water quality in the Lower Lakes, South Australia (Heneker, 2010).

SA Source Murray Model (DEW, 2020c)

DEW Annual Environmental Watering Plan and priorities.</td></tr>
<tr><td>Cumulative barrage flows <6,000 GL in any 3 year period.</td><td>Model different barrage release profiles for barrage flows <6,000 GL in a second year to determine the impact in the salinity in both the Coorong and the Lower Lakes and assess tradeoffs. Results to be addressed through South Australia's annual priorities.</td></tr>
<tr><td>No dredging is occurring and the DTR is <0.20 at Goolwa and 0.05 at Tauwitchere.</td><td>Dredging of the Murray Mouth to maintain an open Murray Mouth.</td><td>The Murray Mouth Sand Pumping Progress Report 2002-2009 (BMT WBM, 2009).</td></tr>
<tr><td colspan="3">Extreme Environmental Indicator
Barrage flows<600 GL for over any 2-year period</td></tr>
<tr><td colspan="3">Justification
<u>Environmental Indicator</u>
South Australia's entitlement flow provides critical base flows into the Lakes but only minimal flow across the Barrages; so needs to be augmented by environmental water delivered in conjunction with unregulated flows. The delivery of flows is highly dependent on environmental water holders, antecedent climatic conditions and the conditions of different</td></tr>
</table>

ecological assets in the Murray-Darling Basin. Ideally, barrage flows should peak over late winter and spring and decline over mid-summer and autumn to mimic natural patterns and accommodate ecological lifecycle processes.

Inter-annual variation in barrage flows is needed to support the environmental water requirements of the Lakes and Coorong, with flows >650 GL/yr required annually and >2,000 GL/yr on a rolling 3-year average, while higher barrage flows of 6,000 GL/yr and 10,000 GL/yr are required at a frequency of every 3 and 7 years, respectively (Heneker, 2010; Lester, et al., 2011; O'Connor, 2015)

Management Priority

The management priority of annual barrage flow 650 GL is the minimum barrage outflow required in a given year to maintain Lake Alexandrina salinities below 1,000 EC. Cumulative barrage flows of 6,000 GL in any 3-year period is the minimum barrage outflow required over a 3-year period to maintain Lake Alexandrina salinities below 1,000 EC (Heneker, 2010). Investigation of the low-flow requirements for the Coorong demonstrated that the volumes sufficient to meet the target of 1,000 EC in Lake Alexandrina were sufficient to limit ecological degradation in the Coorong (Lester, et al., 2011) and a minimum daily barrage flow of 2,000 ML/day (730 GL/yr) was the minimum volume likely to minimise sand ingress and potentially maintain an open mouth (BMT WBM, 2009). The DTR is a measure of the reduction in the 24 hour tide amplitude between that measured at Victor Harbor and that recorded at the barrages, Tauwitchere and Goolwa (MDBA, 2014b). The Murray Mouth is considered to be constricted when DTR falls below 0.05 at Tauwitchere and 0.2 at Goolwa, signaling the need for dredging of the Murray Mouth to maintain system connectivity (MDBA, 2014b; DEW, 2019). The MTs based on DTR thresholds do not apply under high flow conditions or during dredging as tidal fluctuations become masked.

Barrage flows and DTR should be monitored throughout the year to assess MPs.

EEI

The EEI is set at a point where sustained low barrage flows will not maintain salinities in Lake Alexandrina below 1,500 EC or support healthy states in the Coorong.

7.2 Coorong water levels

SURFACE WATER REGIME-COORONG WATER LEVELS		
Objective Variable Coorong water levels are maintained to support the ecological character of the Ramsar site.		
Region Coorong		
Data requirements North Lagoon water level is based on the average daily water level at A4261134 (Beacon 19 Pelican Point), A4261135 (Long Point) and A4260572 (Robs Point). South Lagoon water level is based on the average daily water level at A4260633 (Parnka Point), A4261209 (near Cattle Island), A4261165 (NW Snipe Island). Data available from water.data.sa.gov.au.		
Environmental indicators Water levels in Coorong North Lagoon fluctuate seasonally between 0.0 m AHD in autumn to +0.8 m AHD in winter. Water levels in the Coorong South Lagoon to be maintained >+0.3 m AHD from June to August, between +0.4 m AHD and +0.2 m AHD from September to December.		
Management priority	**Management action**	**Supporting information**
There is a high likelihood that water levels could drop below +0.2 m AHD in the Coorong South Lagoon between June and August (through forecasting using modelling).	Release water through barrages, actual volume required to be based on current mouth openness and modelling. Dredging of the Murray Mouth commences/increases to maintain an open Murray Mouth No further action can be taken if additional water is not available.	Long-term environmental watering plan for the South Australian River Murray water resource plan area (DEW, 2020b). SA Source Murray Model (DEW, 2020c) and Coorong Hydrodynamic Model (Webster, 2007).

There is a high likelihood that water levels in the Coorong South Lagoon could drop below +0.15 m AHD between September and December.	Release water through barrages, actual volume required to be based on current mouth openness and modelling. Improved water levels following the breach of the management trigger will be reliant upon unregulated flows.	

Extreme environmental indicator: Coorong South Lagoon water levels fall below 0.0 m AHD for 8 consecutive months.

Justification

Environmental indicator

Water levels in the Coorong vary over timescales of seasons down to hours. A combination of wind, sea level, evaporation and barrage releases all influence water levels in the Coorong, which undergo a seasonal cycle of up to approximately +0.7 m AHD in range, with higher water levels in late winter-early spring and with lower water levels in late summer-early autumn (Webster, 2010).

North Lagoon

Target water levels in the North Lagoon are set to fluctuate seasonally between 0.0 m AHD in autumn and +0.8 m AHD in winter. This water regime is expected to provide:

- Conditions for *Ruppia tuberosa* and *Althenia cylindrocarpa* growth in the central North Lagoon and for growth and reproduction in the southern sections of the North Lagoon.
- Connectivity with the South Lagoon (i.e. water levels above +0.2 m AHD, M Gibbs Pers. Comm. 2021) to support the passage of fish between the Coorong lagoons and *R. tuberosa* and *A. cylindrocarpa* growth and reproduction in the South Lagoon.
- Protection of mudflat habitats from long-term exposure that otherwise makes them uninhabitable for certain benthic macroinvertebrates (i.e. (Dittmann, et al., 2018)
- Extensive mudflat availability at low (~+0.1 m AHD) water levels (Hobbs, et al., 2019) from mid-summer to autumn that provides foraging habitat for shorebirds.

South Lagoon

Target water levels in the South Lagoon from June to August were set at >0.30 m AHD. Most (88%) *R. tuberosa* and *A. cylindrocarpa* plants in spring 2020 occurred at elevations between -0.15 and +0.15 m AHD in the South Lagoon (Oerman, 2021). As *R. tuberosa* (and presumably *A. cylindrocarpa*) had greatest shoot densities in water depths of +0.2 to +0.6 m (Kim, et al., 2015) water levels in the South Lagoon of +0.35 m AHD over June and July should provide optimal growth conditions. Water levels above +0.3 m AHD would help facilitate connectivity and exchange of water between the North and South Lagoon, which could benefit ecosystem function through improved water and sediment quality (Mosley, et al., 2020).

Target water levels in the South Lagoon from September to December are set between +0.4 m AHD and +0.2 m AHD, with the anticipation that water levels will recede from ≥+0.4 m AHD in September and be maintained above +0.2 m AHD until the end of the December. This water regime should:

- Maintain water levels from September to December that are critical to successful *R. tuberosa* (and presumably *A. cylindrocarpa*) sexual (seed) and asexual (turions) reproduction (Collier, et al., 2017). Optimal water levels for *R. tuberosa* (and presumably *A. cylindrocarpa*) reproductive output are approximately +0.25 m AHD as the vast majority (88%) of *R. tuberosa* and *A. cylindrocarpa* plants were distributed between -0.15 to +0.15 m AHD in spring 2020 and densities of *R. tuberosa* flowers, seeds and turions are greatest in +0.1–0.4 m of water (Kim, et al., 2015). This optimal water level of +0.25 m AHD for *R. tuberosa* and *A. cylindrocarpa* needs to be confirmed by field data and new digital elevation model information collected for shallow water environments.
- Provide shallow water habitats for waterbirds that congregate from late spring (Delroy, 1974) and occur in their highest numbers over summer and autumn (Paton, 2010). Waterbird activity is concentrated in shallow water habitats (Paton, et al., 2018), which become greatly reduced as water levels exceed +0.4 m AHD (Hobbs, et al., 2019).

Management priority

The management point between June and August was set at +0.2 m AHD and between September and December was set at +0.15 m AHD. In winter, water levels above +0.2 m AHD enable connectivity between the North and South Lagoons (Gibbs, 2021), which would have water quality benefits (i.e. lower salinities) and enable the passage of fish between the lagoons.

Moreover, as very few (1%) *R. tuberosa* and *A. cyclindrocarpa* plants were found to occur elevations above +0.15 m AHD in spring 2020 (Oerman, 2021) water levels below +0.15 m AHD from June to December would subject plants within the core elevation range (-0.15 to +0.15 m AHD, (Oerman, 2021)) to desiccation during periods critical for vegetative growth (June–September) and seed bank and turion production (August–December) (Collier, et al., 2017; Asanopoulos & Waycott, 2020). The water level of +0.15 m AHD MT for *R. tuberosa* and *A. cylindrocarpa* needs to be confirmed by field data and new digital elevation model information collected for shallow water environments.

Extreme Environmental Indicator

The EEI is set at a point where water levels would be expected to result in the failed completion of multiple life stages of *R. tuberosa*, loss of annual plants and dependence upon a seed bank for future recolonisation. Such impacts to *R. tuberosa*, would be expected to have detrimental flow on effects on the Coorong food web.

7.3 Threatened fish species – southern pygmy perch

There is a critical CPS for fish - threatened species and southern pygmy perch *Nannoperca australis Murray-Darling Basin lineage* was listed as vulnerable under the EPBC Act from 13 April 2021, after the 2015 ECD baseline was set.

THREATENED SPECIES (SOUTHERN PYGMY PERCH)		
Objective Ensure recruitment success of threatened fishes in the Lower Lakes to maintain or establish self-sustaining populations.		
Region Lakes Alexandrina and Albert		
Data requirements Annual lakes small-bodied threatened fish condition monitoring, as per the methods described in (Wedderburn, 2017)		
Resource condition targets **Southern pygmy perch occupation:** Southern pygmy perch are found in at least 50% of historical (2003 point of reference) capture sites within the icon site. **Southern pygmy perch recruitment:** Southern pygmy perch have a level of recruitment within the icon site with young-of-the-year representing >30% of the fish captured in autumn.		
Management priority	**Management actions**	**Supporting information**
Southern pygmy perch are found in <50% of historical (2003 point of reference) capture sites within the icon site **AND** <30% of the fish captured in autumn within the icon site are young-of-the-year.	Primary actions Maintain Lake Alexandrina water levels above +0.75 m AHD in the early part of the southern pygmy perch recruitment period (spring) and maintain water levels above +0.6 m AHD in the later part of their recruitment period to February. Maintain water levels above +0.5 m AHD in March to protect southern pygmy perch habitat and maintain southern pygmy perch populations. Secondary actions Maintain connectivity and quality southern pygmy perch habitats by opening flow constrictions (dredging or slashing) where considered to be beneficial. Consider pumping to areas of southern pygmy perch refugia (starting at lake levels of +0.3 m AHD) with consideration of salinity and timing.	(Wedderburn, et al., 2019) (Wedderburn, 2017) Conservation advice (TSSC, 2021)

	Use pumping techniques (e.g. screens on pump offtakes) to stop predatory fish such as red fin and carp entering wetlands. Consider removal of predatory fish at disconnected wetlands. Captive breeding and reintroduction.	
Water levels have not been maintained above +0.6 m AHD until the end of March in the last 2 years.	Seek environmental water to maintain Lake Alexandrina water levels above +0.6 m AHD until the end of March.	(Wedderburn, et al., 2019)
Extreme Environmental Indicator Absence of southern pygmy perch in any 3 out of 5 targeted surveys within a 3 year period		
Justification Southern pygmy perch (*Nannoperca australis*) (Vulnerable – *EPBC Act*) are small-bodied threatened species that were common in the Ramsar site prior to the Millennium Drought. The EI and MP for this species is based on a series of abundance, recruitment and extent indices (Wedderburn, 2017) and a water regime and salinity conditions that was modelled to be important to the recruitment of pygmy perches (Wedderburn, et al., 2019). Management actions regarding lake levels are triggered if water levels have not been maintained above +0.6 m AHD from September/October until at least the end of March in the last 2 years. This would allow for lead-in time to identify and implement management actions for the following year. Lake levels maintained above +0.6 m AHD from September/October until at least the end of March for ≥1 in 3 years would enhance southern pygmy perch recruitment through greater habitat and food availability and fewer interactions (competition and predator-prey) with alien fish. As pygmy perch are estimated to have a generation time of 2.5 to 3 years, conditions conducive to recruitment are required at least once every 3 years to support a sustainable population (Wedderburn, et al., 2019). The EEI for southern pygmy perch are based on their estimated lifespan, of up to 5 years, however, most individuals in a population are less than 3 years old (Lintermans, 2007).		

7.4 Threatened waterbird species – bar-tailed godwit

There is a critical CPS for waterbirds - threatened species and Bar-tailed godwit *Limosa lapponica baueri* was listed as vulnerable under the EPBC Act from 5 May 2016, after the 2015 ECD baseline was set.

THREATENED WATERBIRDS – Bar-tailed godwit *Limosa lapponica baueri*		
Objective Maintain or improve bar-tailed godwit populations in the Ramsar site.		
Region Murray estuary and Coorong		
Data requirements Annual summer Coorong waterbird census as per methods described in Paton et al. (2017a).		
Environmental indicator Bar-tailed godwits are recorded at or above their long-term median abundance of 27 individuals during the annual waterbird census in the Coorong.		
Management priority	**Management actions**	**Supporting information**
Bar-tailed godwits are not detected during the annual waterbird census in the Coorong.	Primary actions Management of hydrological drivers: • Barrage flows (section 7.1) • Coorong water levels (section 7.2) • Coorong salinity (section 6.2.2)	Waterbird metrics for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site (DEW, 2021b) Conservation advice (TTSC, 2016)

Extreme environmental indicator
Bar-tailed godwits are not detected during the annual waterbird census in the Coorong for 3 consecutive years.

Justification
Guiding principles for the establishment of metrics for waterbird CPS subcomponents are detailed in DEW (2021b). All waterbird EIs had a 0.5 probability of being met (positive outcome). The probability of MPs and EEI thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively.

The median abundance of bar-tailed godwit counted over the Coorong during annual waterbird censuses from 2000–15 was used to set the EI.

The 10th percentile abundance of bar-tailed godwit counted over the Coorong during annual waterbird censuses from 2000–15 was used to set the MP. If the MP were to be breached, then a process to determine whether factors internal or external to the system led to the breach will be conducted. Management actions are to be initiated where internal factors contributed significantly to the MP breach. If the MP was breached in 2 consecutive years, then the EEI threshold is exceeded. An investigation is then initiated to determine the relative influence of local, national and international factors to the event.

7.5 Threatened waterbird species – great knot

There is a critical CPS for waterbirds - threatened species and great knot *Calidris tenuirostris* was listed as critically endangered under the EPBC Act from 5 May 2016, after the 2015 ECD baseline was set.

THREATENED WATERBIRDS – Great Knot *Calidris tenuirostris*		
Objective Maintain or improve the abundance of great knot in the Ramsar site.		
Region Murray estuary and Coorong		
Data Requirements Annual summer Coorong waterbird census as per methods described in Paton et al. (2017a).		
Environmental indicator Great knot are detected during the annual waterbird census in the Coorong.		
Management priority	**Management action**	**Supporting information**
Great knot are not detected during the annual waterbird census in the Coorong for 5 consecutive years.	Primary actions Management of hydrological drivers: • Barrage flows (section 7.1) • Coorong salinity (section 6.2.2)	Waterbird metrics for the Coorong, and Lakes Albert and Alexandrina Ramsar site (DEW, 2021b) Conservation advice (TSSC, 2016)
Extreme Environmental Indicator Great Knot are not detected during the annual waterbird census in the Coorong for 10 consecutive years.		
Justification Guiding principles for the establishment of metrics for waterbird CPS subcomponents are detailed in DEW (2021b). All waterbird EIs had a 0.5 probability of being met (positive outcome). The probability of MPs and EEI thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively. The EI for great knot was based upon the number of consecutive years of failed detection during annual censuses that equated to a probability of 0.5 based upon the proportion of years that the species was detected from 2000–15 (DEW, 2021b). The MP and EEI threshold for great knot were based upon the number of consecutive years of failed detection during annual censuses that equated to a probability of 0.1 and 0.01, respectively, based upon the proportion of years that the species was present from 2000–15 (DEW, 2021b).		

7.6 Threatened waterbird species – red knot

There is a critical CPS for waterbirds - threatened species and Red knot *Calidris canutus rogersi* was listed as endangered under the EPBC Act from 5 May 2016, after the 2015 ECD baseline was set.

<table>
<tr><th colspan="3">THREATENED WATERBIRDS – Red knot Calidris canutus rogersi</th></tr>
<tr><td colspan="3">Objective
Maintain or improve the abundance of red knot in the Ramsar site.</td></tr>
<tr><td colspan="3">Region
Murray estuary and Coorong</td></tr>
<tr><td colspan="3">Data requirements
Annual summer Coorong waterbird census as per methods described in Paton et al. (2017a).</td></tr>
<tr><td colspan="3">Environmental indicator
Red knot are detected at least once in every 2 annual censuses.</td></tr>
<tr><th>Management priority</th><th>Management actions</th><th>Supporting information</th></tr>
<tr><td>Red knot are not detected in the Coorong for 8 consecutive years of census.</td><td><u>Primary actions</u>
Management of hydrological drivers:
• Barrage flows (section 7.1)
• Coorong salinity (section 6.2.2)</td><td>Waterbird metrics for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site (DEW, 2021b)

Conservation advice (TSSC, 2016)</td></tr>
<tr><td colspan="3">Extreme Environmental indicator
Red knot are not detected in the Coorong for 16 consecutive years of census.</td></tr>
<tr><td colspan="3">Justification
Guiding principles for the establishment of metrics for waterbird CPS subcomponents are detailed in DEW (2021b). All waterbird EIs had a 0.5 probability of being met (positive outcome). The probability of MPs and EEI thresholds being breached (negative outcomes) was 0.1 and 0.01, respectively.

The EI for red knot were set based upon the number of consecutive years of failed detection during annual censuses that equated to a probability of 0.5 based upon the proportion of years that the species was detected from 2000–15 (DEW, 2021b).

The MP and EEI threshold for red knot were based upon the number of consecutive years of failed detection during annual censuses that equated to a probability of 0.1 and 0.01, respectively, based upon the proportion of years that the species was present from 2000–15 (DEW, 2021b).</td></tr>
</table>

8 First Nations and Ramsar site management

8.1 Introduction

The Government of South Australia, as site managers, recognise that the lands and waters of the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site are a part of a highly significant cultural landscape. Ngarrindjeri and First Nations of the South East peoples have been and will continue to be part of the site management of the Coorong, Lower Lakes and Murray Mouth. Cultural knowledge has been incorporated into this plan which acknowledges the rights and interests of the Traditional Owners of the region.

The Ngarrindjeri Aboriginal Corporation (NAC) is the prescribed body corporate of the Ngarrindjeri Nation and represents the common law holders under the *Native Title Act 1993*. The Ngarrindjeri and other Native Title was determined in 2017 and covers an area that encapsulates, the Coorong North Lagoon, portions of the Coorong South Lagoon, Lower Lakes and Murray Mouth. The vast majority of the Coorong and Lakes Alexandrina and Albert Wetland site is located within the current Ngarrindjeri native title determination.

The First Nations of the South East (represented by the South East Aboriginal Focus Group) has a membership of First Nations Peoples including Meintangk, Potaruwutj, Bunganditj, Tatiara/Ngarkat and Tanganekald who advise and partner with the Limestone Coast Landscape Board and DEW. The Focus Group represents the interests of Aboriginal persons with sovereign, spiritual connections to the area.

The South East Aboriginal Focus Group takes a leading role in Aboriginal natural resources management matters in the South East; coordinate Aboriginal input for its First Nations members into regional planning and prioritisation of natural resources matters and activities; and provide oversight, reference, opinion and advice for its First Nations members for all Aboriginal natural resources matters in the South East. Aboriginal members of the South East Aboriginal Focus Group have traditional connection to the South East region. An ongoing native title claim is currently being processed and was initiated in October 2017 under the name First Nations of the South East #1 and #2 There is an overlapping native title claim within the southern portions of the Coorong with Ngarrindjeri and First Nations of the South East.

The separation of components and processes within the Ramsar Management Plan does not align easily with First Nations concepts of Country. The reason for this being First Nations of the South-East and Ngarrindjeri concept of Country cannot separate the lands, waters and living things. All these elements are seen as part of a whole, where one cannot be healthy without the other. The people, too, form part of this whole and are a critical service to the Ramsar site. This interconnectedness of water, land, living things, First Nations and their ancestors all having responsibility to each other. Exercising this responsibility ensures that they benefit from all aspects of a healthy Country.

8.2 Ngarrindjeri

8.2.1 Background

Ngarrindjeri Yarluwar- Ruwe

The Ngarrindjeri Nation in southern South Australia use the term Yarluwar-Ruwe to encapsulate the interconnection between Country, body, and spirit. This interconnection is fundamental to wellbeing, and it is for this reason that healthy lands and waters are critical to healthy Ngarrindjeri people and culture.

Ngarrindjeri Philosophies

Yarluwar-Ruwe Plan

The *Ngarrindjeri Nation Yarluwar-Ruwe Plan* (2006) outlines Ngarrindjeri plans for Ngarrindjeri Ruwe/Ruwar and highlights opportunities for the development of educational, research and tourism initiatives. This plan is officially recognised by the state and Australian governments, and underpins a formal Regional Partnership Agreement focusing on Caring for Country and Economic Development.

The culture and economy of the Ngarrindjeri have always depended on a healthy Yarluwar-Ruwe and its resources. The land and waters are a living body, and the Ngarrindjeri are part of its existence.

Yarluwar-Ruwe is vital to Ngarrindjeri culture and spiritual beliefs. This association is expressed through creation stories (cultural and spiritual histories) about Yarluwar-Ruwe which reveals the significance of the relationship between the country and the people, both practically and spiritually.

The Yarluwar-Ruwe Plan refers to Ngarrindjeri creation stories which record dramatic changes in coastal sea levels. These creation stories explain the richness of natural resources, especially a wealth of fresh and salt water marine life, Ngartjis and water plants. Ngarrindjeri Creation Ancestor, Ngurunderi travelled throughout Ruwe creating landforms, waterways, and life. Creation stories such as this provide Ngarrindjeri with the laws and lessons for sustainable use, care, and management of these species. In fact, Ngarrindjeri Yarluwar-Ruwe supported amongst the highest density of Aboriginal People anywhere in Australia prior to European invasion of their lands and waters.

Ngurunderi the Creator

The following Ngarrindjeri Creation narrative is reproduced from the Yarluwar-Ruwe Plan (2006). It provides an account of the cultural connections (Ruwe/Ruwar) between Ngarrindjeri and Yarluwar-Ruwe (all Ngarrindjeri lands, waters, and sky).

> *A long, long time ago Ngurunderi our Spiritual Ancestor chased Pondi, the giant Murray Cod, from the junction where the Darling and Murrundi (River Murray) meet. Back then, the River Murray was just a small stream and Pondi had nowhere to go. As Ngurunderi chased him in his bark canoe he went ploughing and crashing through the land and his huge body and tail created the mighty River Murray. When Ngurunderi and his brother-in-law Nepele caught Pondi at the place where the fresh and saltwater meet, they cut him up into many pieces, which became the fresh and saltwater fish for the Ngarrindjeri people. To the last piece Ngurunderi said, "you keep being a Pondi (Murray Cod)". As Ngurunderi travelled throughout our Country, he created landforms, waterways, and life. He gave to his people the stories, meanings and laws associated with our lands and waters of his creation. He gave each Lakalinyeri (clan) our identity to our Ruwe (country) and our Ngartjis (animals, birds, fish, and plants) - who are our friends. Ngurunderi taught us how to hunt and gather our foods from the lands and waters. He taught us, don't be greedy, don't take any more than what you need, and share with one another. Ngurunderi also warned us that if we don't share, we will be punished.*
>
> *Ngarrindjeri respect the gifts of Creation that Ngurunderi passed down to our Spiritual Ancestors, our Elders and to us. Ngarrindjeri must follow the Traditional Laws; we must respect and honour the lands, waters, and all living things. Ngurunderi taught us our Miwi, which is our inner spiritual connection to our lands, waters, each other, and all living things, and which is passed down through our mothers since*

Creation. Our great grandmothers, grandmothers and mothers fought to protect our Spiritual waters from desecration when a bridge to Kumarangk (Hindmarsh Island) was to be built (Hemming, et al., 1989)

Ngarrindjeri state that Ngurunderi taught us how to sustain our lives and our culture from what were our healthy lands and waters. Our lands and waters must be managed according to our laws to make them healthy once again. As the Ngarrindjeri Nation we must maintain our inherent sovereign rights to our Yarluwar-Ruwe. Ngarrindjeri people have a sovereign right to make our living from the lands and waters in a respectful and sustainable way. We are asking non-Indigenous people to respect our traditions, our rights, and our responsibilities according to Ngarrindjeri laws.

8.2.2 Current Management

Ngarrindjeri have a cultural responsibility to speak for their Yarluwar-Ruwe in accordance with their laws and traditions, this right has never been ceded and was formally acknowledged by the Australian Government with the Ngarrindjeri and Other Native Title Determination in 2017 and prior to this in 2009 with the Kungun Ngarrindjeri Yunnan Agreement - listening to Ngarrindjeri People speaking. For Ngarrindjeri people to be healthy their Yarluwar-Ruwe must be healthy and spiritually alive. Ngarrindjeri understand that the Ramsar model of assessing the health of the Coorong is not perfect but is a helpful start in the process of creating greater understanding in Western Science for Ngarrindjeri Knowledge and its importance in the management of the Kurrangk (Coorong).

Ngarrindjeri require connectivity, flow and mixing to occur between all living things and the lands the waters and the spirit world. For Ngarrindjeri, flow and interconnectivity are crucial components and processes that determine Ngarrindjeri responsibility. Ruwe/Ruwar requires connectivity and flow to occur between all living things and the lands, waters and the spirit world. Flows come together and produce life as fish breed in the Lakes and Kurrangk (Coorong) where the freshwater and saltwater mix; birds breed in the places where life is produced; and the complexity and interrelatedness of the processes concerned are recognised in Ngarrindjeri philosophy. Ruwe/Ruwar therefore can be understood as a system of interconnected benefit through flow, connectedness, responsibility, and reciprocity (Ngarrindjeri Nation, 2006; Bell, 1998; Bell, 2008; Hemming, et al., 2016; Ngarrindjeri Nation, 2019).

The last 2 centuries has seen drastic change in the management of the Coorong and Lakes Alexandrina and Albert Wetland site which has seen declines in Ngarrindjeri indicators of a healthy Yarluwar-Ruwe. As part of the HCHB Program, Ngarrindjeri Aboriginal Corporation (the registered Native Title Body Corporate) has developed an assessment tool to help guide future management of Yarluwar-Ruwe.

The Ngarrindjeri Yarluwar-Ruwe Assessment is a tool used by Ngarrindjeri which takes a holistic approach to Caring for Ruwe. The assessment tool incorporates Ngarrindjeri cultural values and knowledge, which will inform the design and implementation of key activities, and effective management of associated risks and leveraging of opportunities within the landscape. The Yarluwar-Ruwe assessment process will ensure Ngarrindjeri values, traditions and heritage are protected, enhanced, and managed during on-ground activities. Ultimately this will ensure that Ngarrindjeri knowledge is considered and cultural values are protected, contributing to the wellbeing of the Ngarrindjeri people.

The assessment is designed to be approachable to all Ngarrindjeri People and aid in broad community input to Country management. Categories for assessing health include, but are not limited to, Ngarrindjeri name of place, cultural transmission, stories, Ngartjis health and abundance, water quality, land quality and presence of tangible cultural heritage. This on-ground component of the assessment process will feed into a Yannarumi conversation.

Yannarumi is speaking lawfully as Ngarrindjeri and encompasses information like that of the Yarluwar-Ruwe assessment to guide the direction of management of the Coorong. This process currently sits with the Ngarrindjeri Aboriginal Corporation board of Directors who are the representative prescribed body corporate of the Ngarrindjeri common law holders (Ngarrindjeri Aboriginal Corporation, 2022).

Further to the Yarluwar-Ruwe assessment process there are a number of management actions that have been highlighted by Ngarrindjeri to contribute to their goals to manage Country. These actions are highlighted in table 8.1 below.

Table 8.1 Ngarrindjeri management actions

Management Action	Relevant Management Strategy/initiative	Responsibility
Maintain existing commitments and utilise and improve existing tools and mechanisms to respectfully apply and integrate Ngarrindjeri knowledge and values in research, planning, implementation and long-term management of Ramsar site management.	Ngarrindjeri and Others Native Title Settlement Part A – Indigenous Land Use Agreement, 2017 Ngarrindjeri Yannarumi - Speaking as Country Deed 2014 Ngarrindjeri Working Group Ramsar ECD SOC The Water Resource Planning Statement of Commitment The Living Murray Indigenous Partnerships Program funded Yarluwar-Ruwe Coordinator First Nations Partnerships Project under HCHB Strong People Strong Country – Co-managing parks in South Australia. Coorong National Park Management Plan	DEW NAC
Implement cooperative Ramsar site governance arrangements that supports Ngarrindjeri to respectfully apply and integrate their knowledge and values into Ramsar site management.		DEW NAC
Support the development and incorporation of the Ngarrindjeri Yarluwar-Ruwe assessment process into Ramsar site management.	First Nations Partnership Project under HCHB Ngarrindjeri Working Group	DEW NAC
Support the Ngarrindjeri to engage in, and better represent, their water interests in Ramsar site and state water policy and planning, over time.	Water Resource Plans Cultural Flows Research Project	DEW NAC
Support the development of Coorong National Park Co-management arrangements in accordance with DEW's co-management framework – *Strong People, Strong Country* and their Native Title recognition.	Strong People Strong Country – Co-managing parks in South Australia.	DEW NAC
Support the Ngarrindjeri to exercise their rights under the *Ngarrindjeri and Others Native Title Determination (Part A) and Indigenous land Use Agreement* on DEW managed lands.	Ngarrindjeri and Others Native Title Settlement (Part A). NAC	DEW NAC

Management Action	Relevant Management Strategy/initiative	Responsibility
Support the economic development of the Ngarrindjeri Nation by supporting the Ngarrindjeri to develop and implement business plans for existing and emerging economic ventures based on looking after country.	First Nations Partnership Project under HCHB	DEW NAC
Support the economic development of the Ngarrindjeri Nation by contracting Ngarrindjeri business in the implementation of natural resource management projects within the Ramsar site.	First Nations Partnership Project under HCHB	DEW NAC
Continue to protect Ngarrindjeri cultural sites in the Ramsar site by ensuring cultural assessment and protective measures are undertaken for all soil affecting activities.	All soil affecting activities Ngarrindjeri and Others Indigenous Land Use Agreements (ILUA)	DEW NAC Aboriginal Affairs and Reconciliation (DPC)
Support Ngarrindjeri to work on and care for country through the employment and support of Ngarrindjeri Cultural Rangers in the Coorong National Park and Ngarrindjeri owned and managed lands around the Ramsar site.	Coorong National Park Management Australian Government Working on Country – Ngarrindjeri working on Ruwe (Country) and Raukkan Natural Resource Management Project	DEW NAC

8.2.3 Vision and Goals

The Ngarrindjeri Nation in Southern South Australia use the term Ngarrindjeri Ruwe (Land) or Yarluwar-Ruwe (Sea Country) to encapsulate the interconnection between country, body, spirit, and all living things. This interconnection is fundamental to wellbeing, and it is for this reason that healthy lands and waters are critical to healthy Ngarrindjeri people and culture. Ngarrindjeri have the cultural responsibility to manage the health of Ngarrindjeri lands and waters. Exercising this responsibility ensures that Ngarrindjeri people benefit from all aspects of a healthy Ruwe.

Ngarrindjeri people have an ongoing connection to Ruwe, although disruption due to colonisation occurred Ngarrindjeri people continue to utilise Ruwe for cultural practice, such as camping, hunting and ceremonial practises. The extraction and diversion of waters has contributed to an environmental decline and Ngarrindjeri people have had to adapt their management practices.

The lands and waters must be able to provide life for Ngarrindjeri. There is fishing, hunting, gathering, drinking, swimming, walking, feeling, tasting, and smelling implications as well as the fundamental role of the lands and waters forming the stage for a healthy Ngarrindjeri life.

Ngarrindjeri see ecological and cultural values as fundamentally interconnected; they also consider activities such as recreation, tourism, and research a significant aspect of producing wellbeing for Ngarrindjeri Yarluwar-Ruwe.

> *Our Lands, Our Waters, Our People, All Living Things are connected. We implore people to respect our Ruwe (Country) as it was created in the Kaldowinyeri (the Creation). We long for sparkling, clean waters, healthy land and people and all living things. We long for the Yarluwar-Ruwe (Sea Country) of our ancestors. Our vision is all people Caring, Sharing, Knowing and Respecting the lands, the waters, and all living things* (Ngarrindjeri Nation, 2006).

The values and principles articulated in the narratives of Ngarrindjeri Creation Ancestors, Ngarrindjeri gives Ngarrindjeri the expertise to appropriately care for and manage Yarluwar-Ruwe.

Our Goals are:

- For our people, children, and descendants to be healthy and to enjoy our healthy lands and waters
- To see our lands and waters healthy and spiritually alive
- For all our people to benefit from our equity in our lands and waters
- To see our closest friends, our Ngartjis (special friends) healthy and spiritually alive
- For our people to continue to occupy and benefit from our lands and waters
- To see all people respecting our laws and living in harmony with our lands and waters (Ngarrindjeri Nation, 2006).

8.3 First Nations of the South East

8.3.1 Background

The First Nations of the South East (FNSE) include the Meintangk, Potaruwutj, Bunganditj, Tatiara/Ngarkat and Tanganekald peoples who have traditional ties to the South East region including the Coorong South Lagoon and the associated Ephemeral Lakes and wetlands in the Ramsar site.

FNSE have managed the lands from time immemorial and maintain strong laws which have ensured the sustainability of all things in their natural worlds. The strength of laws maintained their country in the beautiful condition which ensured their health and that of their children for hundreds of generations. The diversity of Aboriginal Australia is evidence of the strong connections they have to their lands, and the laws keep to care for Country and maintain diversity. Since the coming of the British in 1788 and the advent of colonisation First Nations have struggled to maintain their obligations to care for Country; nevertheless, they continue to uphold those obligations, even as they have become '*two-world peoples',* living in the world of their ancestors with ancient obligations to their land and the contemporary world of the colonial settler society which would restrict their access to it. In comparison with the Aboriginal laws which are connected and integral to their obligations as carers for Country, the Australian legal system provides weak laws which do not offer it the same protections.

For more than 60,000 years the FNSE region managed their Country in an ecologically sustainable way. At the time of colonisation, the region had up to 50% more wetlands than that which it has today. Drainage of land began in the 1870s and has continued into present times. The drains have resulted in the changed landscape we now experience, a drier South Eastern landscape.

First Nations have a spiritual connection to the land and waterways and it is important that those values be understood by non-Indigenous people. There is a need to stimulate greater cultural awareness and understanding of Aboriginal knowledge and culture.

Historically, quantities of freshwater flowed into the wetlands of the South-East and eventually into the Coorong South Lagoon. This source of freshwater has been reduced by drainage works in the South-East over the past 150 years. Salinity levels of the Coorong South Lagoon are determined by flows from the River Murray through the barrages, the ocean through the river mouth, water from the southeast, mainly via Tilley Swamp, and groundwater flows, generally from the east (Watson, 2017).

In 1988 Kungari Aboriginal Heritage Association was established to participate in representing the cultural heritage concerns of the south east and with the responsibility to Care for country. Kungari was inclusive of Meintangk, Potaruwutj, Bunganditj, Tatiara/Ngarkat and Tanganekald peoples. In 2004 the South East Aboriginal Focus Group (SEAFG), was established with the involvement of members of Kungari, including Leonie Casey and Des Hartman.

Since then, the SEAFG and the South East Natural Resources Management Board (now Limestone Coast Landscape Board) (LCLB) have had a meaningful working relationship. This 15 year relationship has supported FNSE to come together to be involved in environmental planning, school education activities, on ground works projects and engaging/promoting Aboriginal culture to the broader South East Community. In acknowledging the consistency of the group, the Attorney-General's Department's Aboriginal Heritage Branch use them as the default Aboriginal heritage group in the South East region.

In 2011 the SEAFG developed their Lartara-Wirkeri Cultural Governance framework to guide their inclusion with environmental planning and on ground actions. In 2015 this framework progressed to become their Lartara-Wirkeri Cultural Governance Agreement with Burrandies Aboriginal Corporation. This Agreement formalises the Aboriginal community business structure and autonomy to competitively deliver fee for service outcomes, including: environmental consultation, on ground labour hire, and Aboriginal heritage services.

8.3.2 Current Management

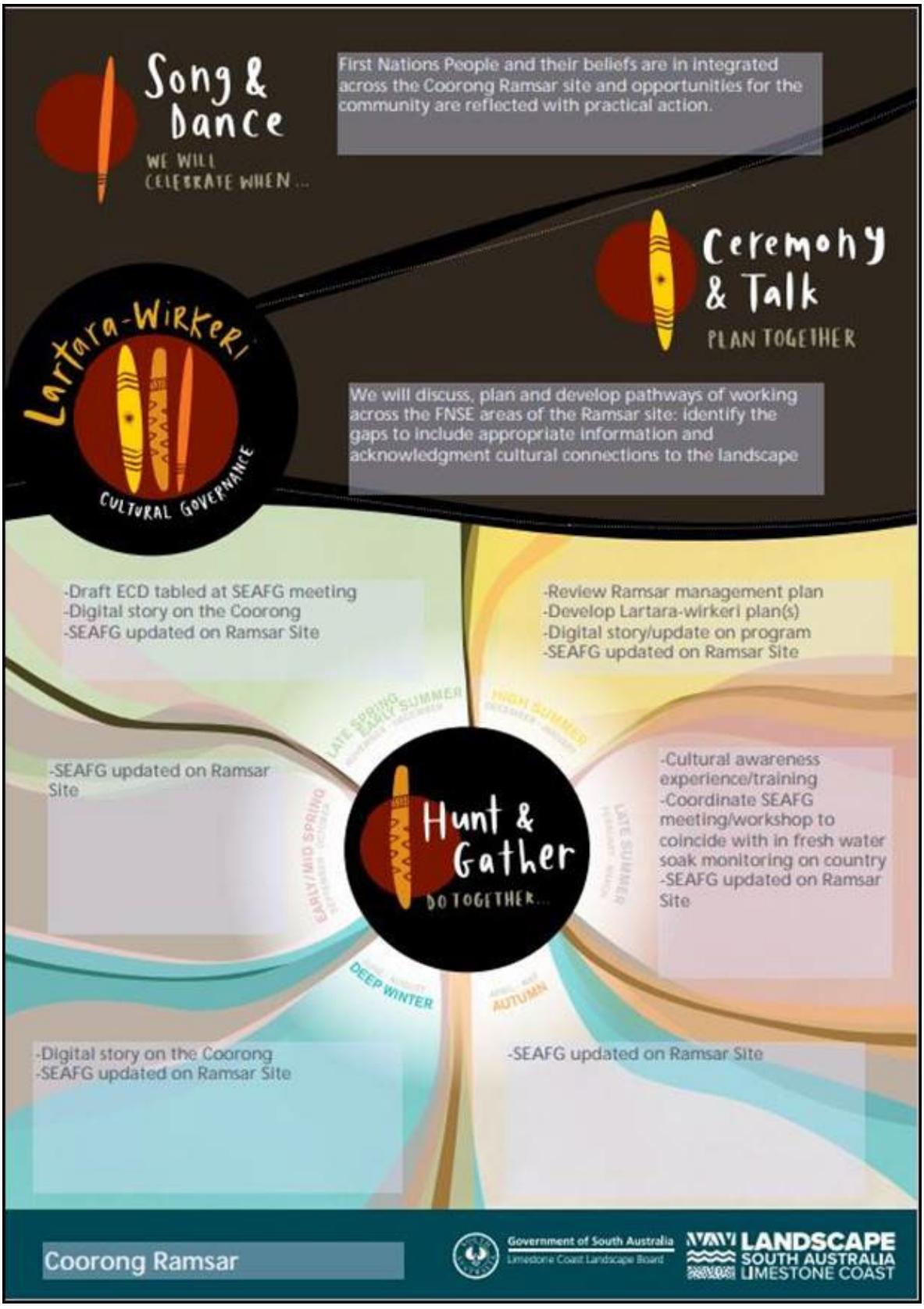

Figure 8.1: Example of the First Nations of the South East cultural governance structure used to manage Country

Table 8.2 FNSE management actions

Management Action	Relevant Management Strategy/initiative	Responsibility
Build on existing engagement arrangements with the Limestone Coast Landscapes Board (LCLB) and DEW to respectfully apply and integrate FNSE knowledge and values in research, planning, implementation and long-term management of the Coorong in accordance to their Native Title recognition.	South East Aboriginal Focus Group cultural agreements with the LCLB. Our Coorong Our Coast Project (2019-2023) First Nations Partnerships Project under HCHB	DEW LCLB FNSE
Implement cooperative Ramsar site governance arrangements that supports FNSE to respectfully apply and integrate their knowledge and values into Ramsar site management in accordance to their Native Title recognition.		DEW FNSE LCLB
Support the economic development of the FNSE by supporting the SEAFG and Burrandies Aboriginal Corporation to develop and implement business plans for existing and emerging economic ventures based on looking after country.	First Nations Partnerships Project under HCHB	DEW FNSE
Support the economic development of the FNSE by contracting the Burrandies Aboriginal Corporation in the implementation of natural resource management projects within the Ramsar site.	Our Coorong Our Coast Project (2019-2023) First Nations Partnerships Project under HCHB	DEW FNSE LCLB
Support the FNSE through the SEAFG and Burrandies to develop and implement a cultural risk assessment tool for assessing impacts of on-ground works.	Our Coorong Our Coast Project (2019-2023) First Nations Partnerships Project under HCHB	DEW FNSE LCLB
Continue to protect cultural sites in the Ramsar site by undertaking cultural risk assessments on all on-ground works and implementing protective measures where required	Our Coorong Our Coast Project (2019-2023) First Nations Partnerships Project under HCHB	DEW FNSE LCLB Aboriginal Affairs and Reconciliation (DPC)
Improve opportunities for employment of FNSE Cultural Rangers in the Coorong National Park and Ramsar management area.	Coorong National Park Management. Australian Government Working on Country Program. Our Coorong Our Coast Project (2019-2023)	DEW FNSE LCLB

8.3.3 Vision and Strategic Goals

The FNSE are the Traditional Owners of the South East of South Australia. DEW formally recognises the SEAFG and acknowledge that the Lartara-Wirkeri cultural governance framework will guide how the Department undertakes its business with the SEAFG and on behalf of the FNSE. The overarching vision established by the Focus Group in 2011 is *'The South East Aboriginal people will maintain and respect the natural resources of the Mother Earth and surrounding waters to establish sustainable resources for everyone.'*

First Nations of the South East have highlighted a number of key goals for their community which are:

- Provide a cultural connection for First Nations people to improve knowledge and cultural identity.
- Provide culturally safe and appropriate programs to First Nations people to nurture and support their families and community to improve educational outcomes.
- Demonstrate effective leadership in the community and to foster unity and empowerment within the community.
- Positively impact First Nations people's participation in Ramsar site planning
- Maintain culture and language; support healing and protect heritage.
- Provide ongoing support to connect First Nations people with training, employment and self-employment opportunities.

9 Communication and engagement

During the development of the ECD (DEW, 2021a), draft in preparation, a number of priority messages have been identified for communication, education and public awareness activities. These include the following:

- The Coorong and Lakes Alexandrina and Albert Wetland is a site of enormous environmental, cultural, social and economic value and is of local, regional, national and international significance.
- The health of the site is central to the culture and beliefs of the First Nations – the Ngarrindjeri and the First Nations of the South East.
- The Coorong and Lakes Alexandrina and Albert Wetland has shown positive signs of recovery following the devastating impacts of the Millennium Drought and still maintains its international significance.
- Many of the ecological features that make the Coorong and Lakes Alexandrina and Albert Wetland unique and valuable are still in place, but more work is needed to restore the site (and in particular, the Coorong South Lagoon) back to health.
- The purpose of the ECD is to document conditions for the Ramsar site as at 2015 (i.e. 2015 baseline). These are the conditions that the site will be managed for through the implementation of the Ramsar Management Plan based the management levers currently available.
- The ECD incorporates the extensive knowledge gathered through the Coorong, Lower Lakes and Murray Mouth (CLLMM) Recovery Project since 2009 and monitoring associated with the delivery of water for the environment since 2007.
- Only the most salt-tolerant species remain in the Coorong South Lagoon, despite the high salinity not because of it.
- With current management levers the Coorong South Lagoon will likely continue to decline. We therefore need investment in new management options to reduce salinity and nutrient loads that have accumulated over the long-term.

Ramsar site communications and engagement will be coordinated through the implementation of this Ramsar Management Plan and community reference groups, science panels and networks associated with existing government programs and initiatives.

10 Monitoring, evaluation, reporting and improvement

10.1 MERI framework

A monitoring, evaluation, reporting and improvement (MERI) framework (Figure 10.1) has been adopted to guide Ramsar site management and continuous improvement. In line with the MERI framework, the effectiveness and appropriateness of the Ramsar site's management will be assessed regularly through monitoring which assesses the condition of the Ramsar site and allows for adaptive management. Ramsar site monitoring will be achieved primarily through existing monitoring programs operating in the Ramsar site (refer to the next section for more details).

In line with the Australian Ramsar Management Principles, this Ramsar site management plan is scheduled to be reviewed in 7 years. This review will be informed by monitoring (see next section); lessons learnt; the outcomes from the HCHB Program; the outcomes of the adaptive management approach; and by community and scientific experts through a consultative approach to the review. It is expected that a revision of this Ramsar Management Plan will be required if HCHB feasibility studies show that large-scale infrastructure can reverse the impacts in the Coorong South Lagoon.

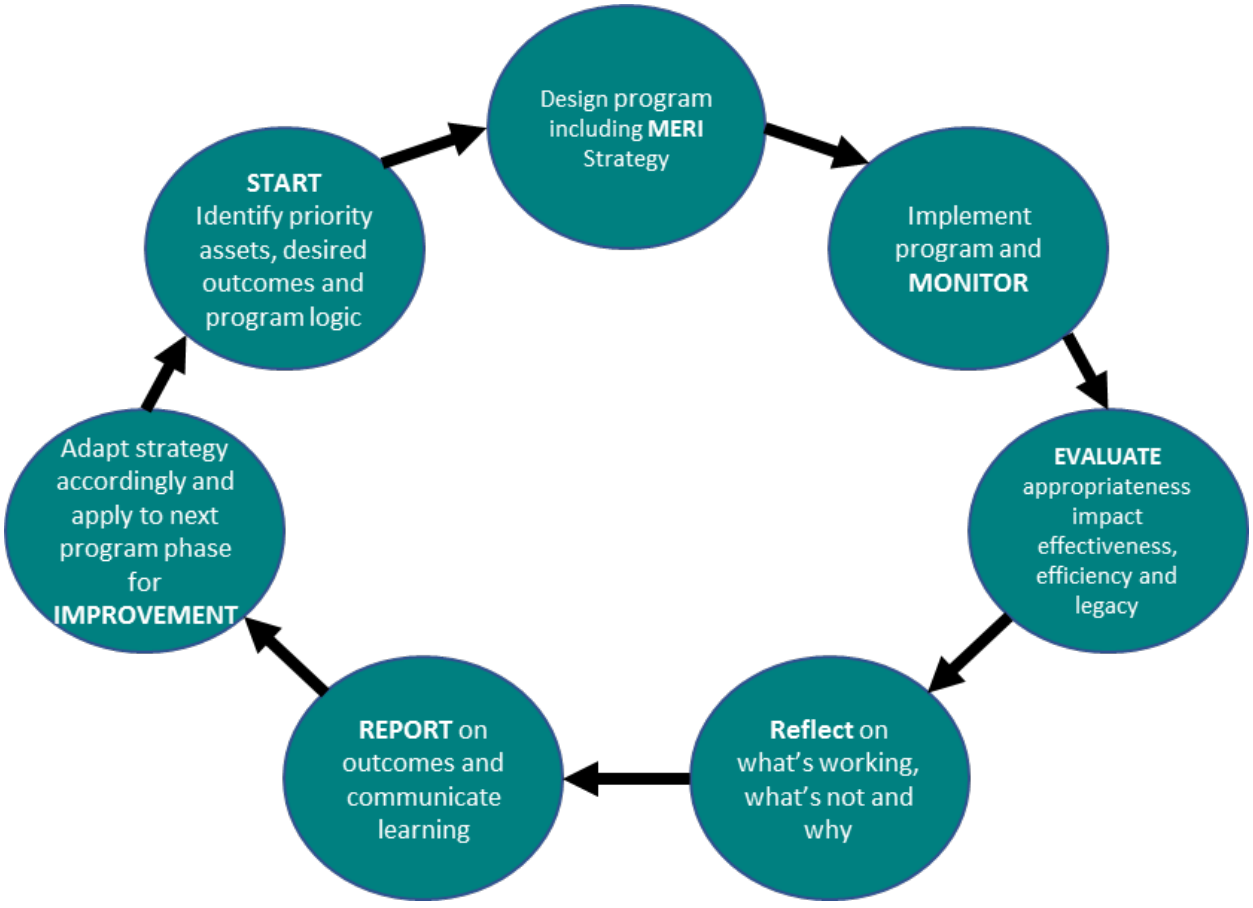

Figure 10.1 MERI framework proposed by the Australian Government (adapted from CEWO 2013, Commonwealth of Australia, 2009)

10.2 Ramsar monitoring and evaluation obligations

The Australian Government, as a Contracting Party to the Ramsar Convention, is expected to report any change in the ecological character of Australian Ramsar sites to the Ramsar Convention Secretariat. DEW, as the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site manager, holds the responsibility for ensuring that monitoring and evaluation activities can be used to determine whether the ecological character is being maintained. The monitoring program will be used to inform management actions aimed at maintaining or improving the ecological character of the site and to determine the effectiveness of the management plan.

The key steps for monitoring and evaluation activities for the Ramsar site include:

- Identify objectives for monitoring key components, processes, services and/or threats
- Identify indicators or measures to be used and the frequency of monitoring
- Identify priorities for monitoring
- Identify relevant existing monitoring programs
- Identify key knowledge gaps identified for the site.

Monitoring and evaluation contributes to Australia's reporting obligations for the Ramsar site under the Ramsar Convention. This process will also contribute towards DEW's reporting obligations for other key state and national legislation, such as the Murray-Darling Basin Plan, and commitments under the *Native Title Act 1993*.

10.3 Ramsar site monitoring and evaluation needs

Ramsar site monitoring is largely achieved through existing monitoring programs operating in the site. While these various existing monitoring programs are targeted for their assigned purposes and objectives, they are often also used for multiple needs. For the Ramsar site's monitoring needs, the existing programs fulfil most of the requirements however there are monitoring gaps that vary within and across years, pending resourcing and information priorities.

The Ramsar site's monitoring requirements (Table 10.1) have been identified to fulfil the objectives of:

- Assessing whether the ecological character of the site is being maintained or improved;
- Informing management actions directed at maintaining or improving ecological character; and
- Fulfilling Ramsar reporting requirements.

Information about the existing monitoring programs is provided in Section 10.4 and within Table 10.1. It should be noted that a full assessment of current monitoring against the Ramsar site's monitoring needs will be required as part of the implementation of this management plan.

A description of the monitoring and data assessment requirements to inform RCT(s), MT(s) and LAC(s) for critical CPS is summarised below in Table 10.1. The monitoring program outlined below excludes the likely intervention monitoring requirements and frequencies adopted to determine the effectiveness of specific management actions.

10.3.1 Monitoring indicators and frequencies

The RCT(s) and MT(s) specified in Chapter 6 guide management, while the LAC(s) exist to indicate a potential change in ecological character. The monitoring data requirements/assessments and frequencies (Table 10.1) are, therefore, set to track the achievement of the RCT(s), detect when MT(s) have been breached and track proximity to the LAC(s).

RCT(s) provide a desirable state for the site (achievable within current management levers) and MT(s) serve as an early warning signal to managers that one or more CPS has reached its limit of natural variation. If a MT has been

detected an investigation is required to determine the need for a management response to prevent potential further degradation towards the LAC (refer to section 5.1 for background on RCT(s), MT(s) and LAC(s).

10.3.2 Monitoring priorities

Ramsar site monitoring priorities (Table 10.1) have been identified for all critical CPS. More 'at risk' aspects of the site (for example the Coorong food web) are identified as a higher priority over the more resilient aspects, while data that is used for multiple critical CPS (for example water level, salinity) is also identified as a high priority. It should be noted that these priorities are a guide only for Ramsar monitoring purposes and may not reflect broader (beyond Ramsar) monitoring priorities for the site.

The priorities of any monitoring program, including the Ramsar site monitoring program described below, should be adaptive, where priorities are identified annually and are based on current conditions and trends in condition. To achieve the objectives of the monitoring program, monitoring should occur on at least the high priority data requirements. Medium priority data requirements will be undertaken pending annual conditions and priorities. This adaptive approach will ensure Ramsar site monitoring and reporting can be undertaken in consideration with the other data and information requirements.

10.4 Existing monitoring programs

Ramsar site monitoring is largely achieved through existing monitoring programs operating in the site and in collaboration with a number of partners including the South Australian Research and Development Institute (SARDI), The University of Adelaide, Flinders University, the Murraylands and Riverland Landscape Board, the Limestone Coast Landscape Board, the Murray-Darling Basin Authority and the Commonwealth Environmental Water Holder (CEWH).

10.4.1 The Living Murray

The majority of the available and relevant ecological data is collected through The Living Murray (TLM) condition monitoring program, for which the Lower Lakes, Coorong and Murray Mouth is considered one of 6 designated icon sites. TLM is a joint initiative funded by the New South Wales, Victorian, South Australian and Australian Governments, coordinated by the Murray-Darling Basin Authority. Many of the indices within the RCTs and MTs have also been developed by the TLM program to determine change in condition over time, and are described in the Lower Lakes, Coorong and Murray Mouth condition monitoring plan (DEWNR, 2017).

Through TLM, data is collected for the following parameters:

- Birds
- Fish
    - diadromous fish
    - lakes threatened fish
    - small-mouthed hardyhead
    - black bream and greenback flounder
- Invertebrates
- Vegetation
    - *Ruppia tuberosa*
    - lakes vegetation
    - mudflats (sediment size and organic content)
    - water (salinity)

10.4.2 *Healthy Coorong Healthy Basin* (HCHB)

Data has been collected through HCHB to fill critical knowledge gaps, develop modelling tools and provide the scientific evidence base to inform management actions at the site. Data collected (2019-2022) includes:

- Sediment and water quality data, with a focus on nutrient cycling in the Coorong
- Aquatic plant and algal distribution and condition, including new techniques to map floating algae in the Coorong
- Availability and quality of food sources for key fish and waterbird species, which include macroinvertebrates, plankton and fish
- Waterbird field data, habitat quality data and modelling to forecast how waterbirds will respond to changes in habitat conditions and management interventions
- Water quality, flow rates, water depth and temperature
- Meteorological conditions

10.4.3 Flow-MER

The Commonwealth Environmental Water Holder Monitoring, Evaluation and Research (MER) Program (Flow-MER) replaces monitoring and research activities that were previously undertaken through the Long-Term Intervention Monitoring (LTIM) and Environmental Water Knowledge and Research (EWKR) projects. The Flow-MER Program consists of evaluation, research and engagement at in the laboratory and on ground monitoring, evaluation, research and engagement across 7 selected areas, including the lower River Murray. SARDI are the lead agency in South Australia for this program.

Monitoring focuses on the main channel of the lower River Murray between the South Australian border and Wellington, however the modelling components of the flow-MER Program extend to Lakes Alexandrina and Albert and the Coorong. This includes:

- Daily discharge from the barrages and water level data
- The estimation of hydraulic characteristics (depth, velocity) through the use of hydrodynamic models
- Using salinity data and modelled water level data to estimate the extent of fish and *Ruppia tuberosa* habitats in the Coorong.

10.4.4 Regional Wetland Monitoring

Wetland monitoring is carried out by Landscape Boards (Murraylands and Riverland, and Limestone Coast) in partnership with local action planning associations, landcare associations and community groups at a number of managed wetlands within the region.

Parameters monitored at wetlands include:

- surface water quality
- groundwater level and salinity (electrical conductivity)
- photo points
- tree condition
- vegetation
- birds, frogs and fish.

Table 10.1 Ramsar site monitoring requirements to assess RCTs, MTs and LAC relevant to critical CPS

Critical CPS	Sub-component	Data Requirements/ Assessment	Locations	Frequency	Existing program
Surface water regime	Flows (indirect via Lake Alexandrina water levels)	Monthly average daily water level at telemetered surface water monitoring stations - Lake Alexandrina water level (m AHD)	See Lake Alexandrina monitoring stations (below)	Continuous	Telemetered data
		Total annual barrage discharge (GL) – calculated using upstream and downstream water levels and barrage opening dimensions	All barrages and fishways (including Hunters Creek)	Annual	Telemetered data
	Lake Alexandrina water levels	Monthly average daily water level at telemetered surface water monitoring stations – Lake Alexandrina water level (m AHD)	A4260574 (near Mulgundawa), A4260524 (Milang Jetty), A4260575 (Poltalloch Plains), A4260527 (Tauwitchere Barrage u/s), A4261133 (Beacon 90 – offshore Raukkan). In the event of extremely low water levels below sensors (e.g. below 0 m AHD), substitute stations may be established to ensure water level in a nearby location is recorded.	Continuous	Telemetered data
Salinity	Lake Alexandrina salinity	Annual average daily salinity at telemetered surface water monitoring stations – Lake Alexandrina salinity (EC)	Lake salinity is based on the average daily salinity at A4260574 (near Mulgundawa), A4260524 (Milang Jetty), A4260575 (Poltalloch Plains), A4261156 (3km west Point McLeay), A4261133 (Beacon 90 – offshore Raukkan). In the event of extremely low water levels below sensors (e.g. below 0 m AHD), substitute stations may be established to ensure water level in a nearby location is recorded.	Continuous	Telemetered data
	Coorong salinity	Average monthly salinity at telemetered surface water monitoring stations – Coorong salinity (EC converted to ppt)	Murray estuary: A4261036 (Beacon 12 Goolwa Channel), A4261039 (Barker Knoll), A4261128 (Mundoo Channel), A4261043 (Beacon 1, Ewe Island Shacks). North Lagoon: A4261134 (Beacon 19 Pelican Point), A4261135 (Long Point), A4260572 (Robs Point). South Lagoon: A4260633 (Parnka Point), A4261209 (near Cattle Island), A4261165 (NW Snipe Island).	Continuous	Telemetered data
		Total annual barrage discharge (GL)	All barrages and fishways (including Hunters Creek)	Annual	Telemetered data

Critical CPS	Sub-component	Data Requirements/ Assessment	Locations	Frequency	Existing program
		Diurnal Tide Ratio (DTR)	Tauwitchere and Goolwa barrages	Monthly	Calculated by SA Water
Vegetation	Submergent freshwater (indirect via Lake Alexandrina water levels and salinity)	Telemetered surface water monitoring stations - Lake Alexandrina water level (m AHD) and salinity (EC)	See Lake Alexandrina surface water level monitoring stations (above)	Continuous	Telemetered data
	Emergent freshwater (indirect via Lake Alexandrina water levels)	Telemetered surface water monitoring stations - Lake Alexandrina water level (m AHD)	See Lake Alexandrina surface water level monitoring stations (above)	Continuous	Telemetered data
	Submergent halophytes	Annual Coorong *Ruppia tuberosa* monitoring (using % cover data), as per (Paton, et al., 2017b)	Sediment cores sampled at 13 sites; including 4 sites in the North Lagoon, 8 sites in the South Lagoon (including 3 on the western side) and 1 site at Lake Cantara	July each year	TLM
	Emergent halophytes (indirect via Lake Alexandrina water level)	Telemetered surface water monitoring stations - Lake Alexandrina water level (m AHD)	See Lake Alexandrina surface water level monitoring stations (above)	Continuous	Telemetered data
	Threatened ecological communities	Extent of threatened ecological community – number of hectares of threatened ecological community confirmed via aerial photography and ground-truthing. Condition assessment methodology required.	*Swamps of the Fleurieu Peninsula* and *Subtropical and Temperate Coastal Saltmarsh* threatened ecological communities within the eastern Mount Lofty Ranges tributaries, Lake Alexandrina, Lake Albert and Murray estuary	At least once every 10 years	
Fish	Fish diversity (species richness and biodisparity)	Fish species and families present, using data from the Lakes (Wedderburn, 2017), Coorong (Ye, et al., 2017a; Ye, et al., 2017b), barrage fishways (Bice & Zampatti, 2017) and Lakes and Coorong Fishery data	Entire Ramsar site	Annual	TLM

Critical CPS	Sub-component	Data Requirements/ Assessment	Locations	Frequency	Existing program
	Fish movement and recruitment	Presence of upstream migrating YOY congolli and common galaxias, as per methods described in (Bice & Zampatti, 2017)	Vertical slot fishways at Tauwitchere and Goolwa barrages and Hunters Creek, fyke netting adjacent to Tauwitchere rock ramp and Goolwa barrage.	Annual (October – January)	TLM
	Threatened species (Murray hardyhead and Yarra pygmy perch)	Presence of Murray hardyhead and Yarra pygmy perch, as per (Wedderburn, 2017)	Fyke net surveys at 17 sites in Lake Alexandrina and 3 sites in Lake Albert. Majority of sites on the western side of Lake Alexandrina.	Annual (March) Bi-annual (November)	TLM
Waterbirds	Waterbird diversity	Annual waterbird abundance assessed against abundance thresholds, per target species, per region. Waterbird census methods as per (Paton, et al., 2017a)	Abundance of target waterbird species assessed in Lake Alexandrina and Albert, Murray estuary, Coorong North Lagoon and Coorong South Lagoon	Annual (January)	TLM
	Waterbird abundance	Total annual waterbird abundance, as per (Paton, et al., 2017a)	Entire Ramsar site	Annual (January)	TLM
	1% East-Asian Flyway species abundance	Annual abundances assessed against abundance thresholds for curlew sandpiper, red-necked stint and sharp-tailed sandpiper with data from the waterbird census (Paton, et al., 2017a)	Murray estuary and Coorong	Annual (January)	TLM
	Priority (migratory shorebirds) abundance	Presence of 7 target migratory species in the Ramsar site during the waterbird census (Paton, et al., 2017a)	Murray estuary and Coorong	Annual (January)	TLM
	Waterbird breeding	Assessment of breeding success for 10 annual breeding species and 3 regular breeding species. Breeding occurrence assessed via waterbird census (Paton, et al., 2017a) and annual aerial survey (Kingsford and Porter 2009)	Entire Ramsar site	Annual (January census and November aerial survey)	TLM
	Threatened species – Australasian bittern	Detection in sites that contain suitable habitat, as per targeted surveys described in (O'Connor, 2015)	Lakes Alexandrina and Albert and Eastern Mount Lofty Ranges Tributaries	At least once every 3 years	
	Threatened species –	Adult population abundance in annual census, as per methods described in (Paton, et al.,		Annual (January)	TLM

Critical CPS	Sub-component	Data Requirements/ Assessment	Locations	Frequency	Existing program
	Australian fairy tern	2017a) and fledging success as a measure of juveniles within the population, as per methods described in (Paton & Paton, 2016)	Murray estuary, Coorong North Lagoon and Coorong South Lagoon		
		Habitat condition; including whether breeding islands are accessible by land and the distance from nesting sites to adequate prey (fish) densities			
		Coorong South Lagoon salinity during breeding season	Coorong South Lagoon – refer to Coorong salinity above for surface water monitoring stations	Continuous	Telemetered data
	Threatened species - Australian painted snipe	Confirm presence/absence of species within the Ramsar site (noting a baseline for LAC development is lacking and the species was last recorded in the site in 2002).	Lake Alexandrina	To be determined	
	Threatened species – curlew sandpiper	Presence or absence in annual census, as per methods described in (Paton, et al., 2017a)	Murray estuary, Coorong North Lagoon and Coorong South Lagoon	Annual (January)	TLM
	Threatened species – eastern curlew	Presence or absence in annual census, as per methods described in (Paton, et al., 2017a)	Murray estuary and Coorong North Lagoon	Annual (January)	TLM
	Threatened species – hooded plover	Presence or absence in targeted bi-annual surveys by Birdlife Australia	Coorong ocean beach	Bi-annual	BirdLife
	Threatened species – Mount Lofty Ranges southern emu-wren	Presence or absence at known population locations in targeted surveys	Swamps of the Fleurieu Peninsula within the Ramsar site	Bi-annual	
	Threatened species – orange-bellied parrot	Indirect assessment via wetland habitat condition (below) and emergent halophytes (above)	Habitat adjacent to the Murray estuary, Coorong North Lagoon and Coorong South Lagoon	Every 10 years (habitat)	
		Targeted surveys in preferred habitat	Fringing habitat adjacent to the Murray estuary, Coorong North and Coorong South Lagoons	Annual (August)	

Critical CPS	Sub-component	Data Requirements/ Assessment	Locations	Frequency	Existing program
Habitat	Wetland habitat condition	Habitat condition assessed at sites as per methods described in (Seaman, 2003)	Entire Ramsar site	Once every 10 years	
Threatened species	Southern bell frog	Telemetered surface water monitoring stations - Lake Alexandrina water level (m AHD) and salinity (EC)	See Lake Alexandrina surface water level monitoring stations (above)	Continuous	Telemetered data
		Targeted southern bell frog monitoring (call recording and response to call playback)	Various sites at western side of Lake Alexandrina and the lower reaches of the Eastern Mount Lofty Ranges tributaries	Annual (Nov-Dec)	
Coorong food web	*Ruppia tuberosa* (includes cascade submergent halophyte LAC)	The presence of viable *Ruppia tuberosa* seeds in Coorong South Lagoon sites, as per methods described in (Paton, et al., 2017b) Refer to submergent halophyte (above) for % cover assessment	9 Coorong South Lagoon sites in January survey and 8 Coorong South Lagoon sites in July survey	Annual – winter (July) and summer (January)	TLM
	Macroinvertebrates	Telemetered surface water monitoring stations – Coorong salinity (measured in EC then converted to ppt)	See Coorong monitoring stations (above) for Murray estuary, North Lagoon and South Lagoon sites	Continuous	Telemetered data
		Coorong macroinvertebrate species richness, occurrence and abundance, as per methods described in (Dittmann, 2017)	7 Coorong North Lagoon sites and 4 Coorong South Lagoon sites	Annual (December)	TLM
	Small-mouthed hardyhead	Telemetered surface water monitoring stations – Coorong salinity (measured in EC then converted to ppt)	See Coorong monitoring stations (above) for North Lagoon and South Lagoon sites	Continuous	Telemetered data
		Small-mouthed hardyhead adult and juvenile CPUE, and proportional abundance of juveniles across sites, as per methods described in (Ye, et al., 2017b)	4 Coorong North Lagoon sites and 4 Coorong South Lagoon sites	Spring / summer and early autumn	TLM

11 Knowledge gaps

A number of knowledge gaps were identified when compiling the ECD and when developing the thresholds and management actions in this document. These are listed in Table 11.1.

Table 11.1. Knowledge gaps in Ramsar site monitoring requirements to assess RCTs, MTs and LACs relevant to critical CPS

Component/ process	Gap	Recommended action	Program that may address gap (if relevant)
General	Updated scientific understanding of the site and interactions between components	Update the RIS and RMP, as required, with relevant HCHB information to incorporate updated scientific results	HCHB
Targets and thresholds	Targets and thresholds for Lake Albert	Identify the need for separate targets for Lake Albert and develop if necessary	
Climate change	Thresholds and management actions do not adequately address the impact of climate change on the site	Update the RIS and RMP, as required, with relevant HCHB information to incorporate outputs from the Climate Adaptation project	HCHB
	Lack of information about the impact of climate change on the site and effectiveness of management actions under future climate change scenarios	Update the RIS and RMP, as required, with relevant HCHB information to incorporate outputs from the Climate Adaptation project	HCHB
CPS for nutrients and sediment quality	No CPS or thresholds have been identified for nutrients (in the water column and sediment) and sediment quality	Update the RIS and RMP, as required, with relevant HCHB information to incorporate outputs from the Nutrients project	HCHB
Vegetation	Limited understanding of the impact of salinity on the growth and survival of many species of vegetation	Undertake germination studies for some species to better understand the impact of salinity, and the appropriateness of salinity thresholds	
Fish	Better documentation required to guide management of fishways	Undertake prioritisation process for the shutdown of fishways to guide management response, incorporating the needs of functional groups	
		Functional assessments of Salt Creek and Morella fishways to better understand effectiveness	
	Require updated information on drivers of the small-mouthed hardyhead population	Understand broader drivers of small-mouthed hardyhead population (e.g. nutrients and algae)	HCHB and TLM

Component/ process	Gap	Recommended action	Program that may address gap (if relevant)
Waterbirds	Lack of understanding around which species contribute most to management thresholds being exceeded	Sensitivity analysis for thresholds that are not species-specific to better understand which species contribute to the management trigger being exceeded	
	Lack of understanding around link between water levels and available habitat in the Lakes	Undertake analysis to understand how mudflat extent changes with water level in the Lakes (habitat starts to present itself at +0.4 m AHD)	
	Lack of data for hooded plover population	Improved assessment of hooded plover population and breeding success	
	Lack of data for waterbirds on Sir Richard Peninsula	Investigate the monitoring of waterbirds (and hooded plovers specifically) on Sir Richard Peninsula	

12 Climate change

The purpose of this chapter is to outline the likely impact of future climate on the Coorong and Lakes Alexandrina and Albert Wetland. The information is drawn from the results of the NSW Australian Regional Climate Modelling Project stage 1.5 (NARCLiM 1.5), which is based on the Coupled Model Intercomparison Project Phase 5 (CMIP5) (DEW, 2022). The CMIP5 ensemble of climate models run under different possible paths of future greenhouse gas concentrations to the year 2100, known as Representative Concentration Pathway (RCP) scenarios.

The RCP8.5 scenario represents a future with little curbing of emissions and atmospheric carbon dioxide continuing to rapidly rise to 940 parts per million (ppm) by 2100. Under the RCP4.5 scenario emissions peak around 2040 and the carbon dioxide concentration is 540 ppm by 2100. Carbon dioxide levels were 410 ppm in 2019 and global emissions are currently tracking at or above the RCP8.5 scenario (CSIRO, 2021).

12.1 Current local climate and sea level

Annual rainfall variability is high, ranging from 241 mm in 1944 to 696 mm in 2010. Between 1991 and 2020 the average was 463 mm. Most of the rain falls from April to October each year. In the last 30 years seasonal rainfall has been relatively stable with winter rainfall reliable; autumn and spring less reliable and summer rainfall unreliable (Charles & Fu, 2015).

The highest monthly average maximum temperature for Meningie is 26.3°C in January and February (range 15.5°C to 46.1°C). Instances of days above 40°C are becoming more frequent. In 2009 and 2014, Meningie experienced periods of 4 days in a row above 40°C. This had not happened since 1966 when temperature records began (Bureau of Meteorology, 2021).

Current high tide peaks around 0.6 m in winter and the barrage structures are a further 0.55 m above that water level (DEW, 2021c) to protect the lakes from saltwater intrusion.

12.2 Future local climate and sea level

Annual rainfall will decline in both the Murraylands and Riverlands and Limestone Coast landscape regions (DEW, 2022). By 2050 rainfall could decrease by 10.2% (RCP4.5) and 15.0% (RCP8.5) in the Murraylands and Riverland, and 9.4% (RCP4.5) and 4.7% (RCP8.5) in the Limestone Coast. By 2090, rainfall declines are almost twice as much (30.6% and 23% for Murraylands and Riverland and Limestone coast respectively) under the high emissions (RCP8.5) scenario compared to the RCP4.5 scenario (13.7% and 7.3% for Murraylands and Riverland and Limestone coast respectively). Rainfall in the eastern Mount Lofty Ranges catchments will also decline (DEW, 2022). The decrease in rainfall across these landscape regions will decrease the runoff entering the lakes and Coorong.

Both maximum and minimum temperatures will increase in both the Murraylands and Riverlands and Limestone Coast landscape regions (DEW, 2022). Under the stabilised emissions (RCP4.5) daily maximum temperatures could increase by 1.7°C by 2050 and 2.2°C by 2090 in the Murraylands and Riverland, and by 1.5°C by 2050 and 1.9°C by 2090 in the Limestone Coast. Changes are even greater under high emissions (RCP8.5), with an increase in maximum temperatures of 1.9°C by 2050 and 4.1°C by 2090 in the Murraylands and Riverland, and by 1.6°C by 2050 and 3.6°C by 2090 in the Limestone Coast.. Daily minimum temperatures are consistently higher under the high emissions scenario. By 2090, the projected change in minimum temperatures under the high emissions scenario RCP8.5 (3.0 % and 2.6% for Murraylands and Riverland and Limestone coast respectively) are more than double those under the RCP4.5 scenario (1.6% and 1.5% for Murraylands and Riverland and Limestone coast respectively).

Sea levels at Victor Harbor are expected to increase up to 0.12 m (+0.08 m to+0.16 m) by 2030 (RCP4.5) and +0.60 m (+0.39 m to +0.83 m) under (RCP8.5) in 2090 (DEW, 2022). Modelling undertaken using a +1.5 m sea level rise to 2109 indicates that the dune barrier on Sir Richard and Younghusband Peninsulas will not be breached (Coastal

Studies, 2009). Sea level rise would alter the hydrodynamics of the Coorong and Murray Mouth, as well as increase seawater ingression into the lakes. based on projected sea level rises, the earliest that sea levels would reach the top of the barrages is around 2070.

12.3 Future Murray-Darling Basin climate

The vast majority of the freshwater entering the Coorong and Lakes Alexandrina and Albert Wetland comes from the River Murray. Changes in the climate of the Murray-Darling Basin may have significant implications for water entering the wetland. Climate science predicts that the southern Murray-Darling Basin is likely to become drier and hotter in the future. The predictions for the northern Murray-Darling Basin are not so clear at this point in time (Whetton & Chiew, 2021).

In the near future, natural rainfall variability in the Murray-Darling Basin will dominate over trends due to greenhouse gas emissions. By the end of the century, the change in rainfall is around -5% in the south (Timbal, et al., 2015) and around -6% in the north for RCP8.5 (Ekström, et al., 2015). The effect of emissions on temperature is more noticeable with an increase of 2 and 4.1°C in maximum temperatures and 1.7 and 3.5°C in minimum temperatures for RCP4.5 and RCP8.5 respectively (Timbal, et al., 2015; Ekström, et al., 2015).

Decreased rainfall and higher temperatures are expected to lead to decreased catchment run-off across the Basin. Increased potential evapotranspiration is simulated to occur with increased temperature across the Basin, which will enhance the reduction in runoff where rainfall declines. Recent hydrological modelling studies show a decrease in annual runoff of 14% in the southern Murray-Darling Basin by 2070 under the RCP4.5 scenario. In the northern Murray-Darling Basin the projected decline in annual runoff is 10%. The decline in runoff is similar to the volume of water returned to the environment under the Murray-Darling Basin Plan (Whetton & Chiew, 2021).

12.4 Future management for climate change

There is no doubt that climate change will present challenges to the management of the Coorong and Lakes Alexandrina and Albert Wetland in future. In the meantime, the additional inflow to the lakes secured under the Murray-Darling Basin Plan will significantly enhance the ecological outcomes of the wetland, by building resilience in the system and providing inflow during dry years.

Future management of the Coorong and Lakes Alexandrina and Albert Wetland must be considered as part of whole-of-basin planning and adaptation in response to climate change risk. Exploring adaptation of the ecosystems and the services they provide under future climate scenarios with the local community would assist future management.

13 Governance and implementation

13.1 Governance

Coordination of Ramsar site management in South Australia and management of the Coorong and Lakes Alexandrina and Albert Wetland is the responsibility of the Government of South Australia through the Department for Environment and Water.

It is common practice to have stakeholder involvement in guiding the management of Ramsar sites.

DEW has long-standing partnerships with Traditional Owner groups, as well as community and scientific reference groups who act as a conduit between community and key land managers, including:

- The Coorong, Lower Lakes and Murray Mouth Community Advisory Panel;
- Coorong Partnership; and
- The Coorong, Lower Lakes and Murray Mouth Scientific Advisory Group

The membership of these groups includes:

- Community with knowledge, skills, leadership and experience in conservation, tourism and recreation, science, commercial fishing, agriculture, economic development, and/or heritage
- Ngarrindjeri through the Ngarrindjeri Aboriginal Corporation
- First Nations of the South East through the Burrandies Aboriginal Corporation
- Local government representatives
- Landscape Board representatives

These groups are consulted in relation to:

- Ramsar, management and operational priorities and plans;
- Monitoring and evaluation of activities; and
- Targeted investment proposals.

Executive support is provided by DEW.

13.2 Resourcing Implementation

Implementation of this plan will be influenced by available funding and resources. The implementation approach will ensure coordination and prioritisation of management actions so that maximum benefit is achieved with the resources that are available. The best available information tools will be used to support the establishment of annual priorities. Annual priorities and programs will be developed to best match the funding cycles of investors. Investment proposals to support specific management actions of the RMP will be developed as investment opportunities arise.

14 Appendices

A. Values and threats prioritisation methods and results

Risk assessment

A risk assessment was used as a key input into prioritising ecosystem values and threats (and associated stressors) for management purposes undertaken via a multi criteria analysis.

The risk assessment process adopted was consistent with the Australian/New Zealand Standard: Risk Management (AS/NZS 4360:2004; Standards Australia and Standards New Zealand 2004) and the Standards Australia Handbook: Environmental risk management - principles and process (HB 203-2000; Standards Australia and Standards New Zealand 2006). The risk assessment approach follows a structured and iterative process which involves the following steps:

1. Establish the context – identify and collate existing values and threats for each management unit (lakes and tributaries, Murray estuary and Coorong)
2. Identify risks – threats and associated potential impacts;
    a. An impact pathway approach was used to identify and analyse risks. Using the following hierarchical process to identify potential risks:
        i. Threats (threatening activities) – actions in the Ramsar site or catchment that could affect ecological character;
        ii. Stressors – the physical or chemical changes that could arise because of a threat or threatening activity;
        iii. Effects – the potential responses caused by the stressors.
3. Analyse risks – assign likelihoods and consequences to determine level of risk for single impact pathways
    a. The following guiding principles were adopted in undertaking the risk assessment:
        i. The risk assessment was focussed on assessing risks to ecological character over the next 15 years.
        ii. In assessing each impact pathway all likely future changes (population, land use, climate change) were considered.
        iii. Where possible all decisions were based on multiple lines of evidence and relied on sound knowledge of the ecological character of the Ramsar site.
4. Identify possible cumulative risks – review the single pathways to calculate the additive cumulative impacts for threats, stressors and values.

Multiple threats acting together (i.e. cumulative risks) can have greater effects on values such as species abundance (e.g. via reduced habitat availability and increased predation) than threats acting in isolation. An additional risk assessment was undertaken to identify cumulative risks.

The threat-stressor combinations that were assessed as high risks are shown in Table 14.1.

Table 14.1. High risk threats identified by a risk assessment

High-risk Threats	Management Unit		
	Lakes and tributaries	Murray estuary	Coorong
Residential and commercial development: housing and urban areas	X		
Natural systems modifications: fire & fire suppression	X		X
Natural system modifications: dams and water management	X	X	X
Invasive species: non-native and problematical native species	X	X	X
Human intrusion and disturbance: recreational activities - off road vehicles;	X	X	
Agriculture and aquaculture: livestock grazing.	X		
Climate change: change in precipitation and hydrological regimes	X	X	X
Climate change: change in temperature regimes		X	X
Pollution: agricultural effluents - increased suspended sediments	X		

B. Fish – species and family lists for RCT, MT and LAC assessment

Table 14.2. List of common freshwater, estuarine and estuarine-marine opportunist species to be assessed as part of the fish diversity (species richness) RCT, MT and LAC.

Common name (Ngarrindjeri name)	Scientific name
Common freshwater species	
Australian smelt	*Retropinna semoni*
Bony herring (Thukeri)	*Nematalosa erebi*
Carp gudgeon complex	*Hypseleotris* spp.
Common galaxias (Pulangi)	*Galaxias maculatus*
Congolli (Kungguldhi)	*Psedaphritis urvillii*
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*
Flat-headed gudgeon	*Philypnodon grandiceps*
Golden perch (Pilalki)	*Macquaria ambigua*
Murray hardyhead (Terukurar)	*Craterocephalus fluviatilis*
Unspecked hardyhead	*Craterocephalus fulvus*
Common estuarine and marine migrant species	
Australian herring	*Arripis georgianus*
Black bream (Tjeri, Tulari)	*Acanthopagrus butcheri*
Western bluespot goby	*Pseudogobius olorum*
Greenback flounder (Minmekutji)	*Rhombosolea tapirina*
Bridled goby	*Arenigobius bifrenatus*
Goldspot mullet	*Liza argentea*
Lagoon goby	*Tasmanobius lasti*
Longsnout flounder	*Ammotretis rostratus*
Mulloway (Mandi-watjeri, Naraingki)	*Argyrosomus japonicus*
Western river garfish	*Hyporhamphus regularis regularis*
Sandy sprat	*Hyperlophus vittatus*
Small-mouth hardyhead	*Atherinosoma microstoma*
Smooth toadfish	*Tetractenos glaber*
Soldierfish	*Gymnapistes marmoratus*
Tamar River goby	*Afurcagobius tamarensis*
Western Australian salmon	*Arripis truttaceus*
Yelloweye mullet (Kunmari)	*Aldrichetta forsteri*

Table 14.3. List of families to be assessed as part of the fish diversity (biodisparity) RCT, MT and LAC.

Fish Families
Arripidae
Atherinidae
Bovichtidae
Clupeidae
Eleotridae
Galaxiidae
Geotriidae
Gobiidae
Hemiramphidae
Mugilidae
Percichthyidae
Pleuronectidae
Retropinnidae
Sciaenidae
Sparidae
Tetraodontidae
Tetrarogidae

C. Waterbirds – median abundance and abundance thresholds for target waterbird species by region

Table 14.4. From: (Robinson, 2017) Summary of statistics (median abundance and 10th percentile threshold) for listed species of importance (target species) in the Ramsar site

Refer to the Ecological Character Description (DEW, 2021a) and Robinson 2017 for more detail about how the abundance medians and thresholds were derived.

*=omitted from calculations as they are expected to be absent naturally.

*Species with 10th percentiles of 0 were omitted from compliance calculations to set a Management Trigger.

Lake Alexandrina and Albert Waterbirds					
Target Species	**Median abundance 2009-2015**	**10th percentile abundance threshold**	**Target Species**	**Median abundance 2009-2015**	**10th percentile abundance threshold**
Australasian shoveler	17	7	Grey teal	5,780	932
Australian pelican	4,460	2,877	Hardhead	44	2
Australian shelduck	14,296	11,952	Little black cormorant	907	290
Australian white ibis	611	349	Little pied cormorant	96	67
Black swan	1,799	1,159	Masked lapwing	553	394
Cape barren goose	1,303	939	Pacific black duck	4,408	1,485
Eurasian coot	3,165	167	Pied cormorant	3,955	1,198
Great cormorant	9,375	3,831	Silver gull	2,819	1,558
Great crested grebe	108	19	Straw necked ibis	532	206
Greater crested tern	335	311	Whiskered tern	3,744	2,154

Estuary and Goolwa Channel					
Target Species	**Median abundance 2000-2015**	**10th percentile abundance threshold**	**Target Species**	**Median abundance 2000-2015**	**10th percentile abundance threshold**
Australian pelican	577	236	Little pied cormorant	138	19
Black swan	820	215	Masked lapwing	97	53
Black tailed godwit*	21	0	Pacific black duck	173	34
Black winged stilt	157	52	Pacific golden plover	18	3
Caspian tern	209	48	Pied oystercatcher	52	34
Common greenshank	194	113	Red capped plover	94	12
Curlew sandpiper	877	24	Red necked avocet*	206	0
Eastern curlew	12	2	Red necked stint	4,234	719
Greater crested tern	330	183	Sanderling*	1	0
Grey teal	1,682	528	Sharp tailed sandpiper	4,289	740
Hoary headed grebe	30	1	Silver gull	1,612	985
Little black cormorant	116	19	Whiskered tern	865	338

Coorong North Lagoon					
Target Species	**Median abundance 2000-2015**	**10th percentile abundance threshold**	**Target Species**	**Median abundance 2000-2015**	**10th percentile abundance threshold**
Australian pelican	1,413	916	Little black cormorant	861	169
Australian shelduck	4,342	905	Little pied cormorant	116	21
Black swan	483	171	Masked lapwing	213	141
Black-winged stilt	122	37	Pacific golden plover*	7	0
Cape Barren goose	26	3	Pied cormorant	211	84
Caspian tern	295	109	Pied oystercatcher	53	23
Common greenshank	186	83	Red capped Plover	458	185
Curlew sandpiper	752	178	Red necked Avocet	646	77
Great cormorant	544	92	Red necked Stint	12,448	7,009
Greater crested tern	303	139	Sharp tailed sandpiper	5,622	2,806
Grey teal	6,499	1,448	Silver gull	3,179	2,204
Hoary headed grebe	1,410	266	Whiskered tern	3,439	1,236

Coorong South Lagoon					
Target Species	**Median abundance 2000-2015**	**10th percentile abundance threshold**	**Target Species**	**Median abundance 2000-2015**	**10th percentile abundance threshold**
Australian pelican	1,600	354	Hoary headed grebe	2,263	63
Australian shelduck	3,205	1,473	Little black cormorant*	26	0
Banded stilt	8,179	848	Masked lapwing	177	115
Black swan	148	7	Pied oystercatcher	48	17
Caspian tern	62	7	Red capped plover	529	198
Chestnut teal	2,757	334	Red necked avocet	945	69
Common greenshank	39	13	Red necked stint	6,781	2,089
Curlew sandpiper	44	7	Sharp tailed sandpiper	2,304	301
Fairy tern	128	6	Silver gull	1,960	1,193
Great crested grebe*	13	0	Whiskered tern	1,058	118
Greater crested tern	2,989	1,409	White faced heron	23	10
Grey teal	4,267	941			

Table 14.5.Regularly supports one percent populations

Target Flyway Species * shows the East Asian Australasian flyway species	**1 percent of global population**	**2000-2015 mean for the Ramsar site (based on Coorong and Estuary Census data)**	**10th Percentile threshold (based on Coorong and Estuary Census data)**
Australian fairy tern	15	362	175
Australian pied oystercatcher	110	155	113
Banded stilt	3,700	30,611	1,311
Chestnut teal	1,000	8,477	3,037
Curlew sandpiper*	9,000	2,371	208
Red capped plover	950	1,207	153
Red necked stint*	4,750	26,388	6,505
Sharp tailed sandpiper*	850	13,318	146

D. Complementary management actions

Table 14.6. Complementary management actions to support critical CPS in the Ramsar site

Critical CPS	Sub-component	Description of Action	Responsible
Surface Water	Water level – Lake Alexandrina	Utilise forecasted River Murray flow data to undertake surface water modelling, to help plan and manage barrage releases to ensure water levels in the lakes do not fall below critical levels.	DEW, MDBA
		Follow barrage release guidelines described in the Barrage Operating Strategy on when to reduce barrage flow volumes to fishways only and when to cease flows.	DEW
	Salinity – Lake Alexandrina	Maximise use of automated barrage bays to implement short response times for required barrage bay closures.	SA Water, DEW
	Salinity – Lake Alexandrina / Murray estuary, Coorong North Lagoon and Coorong South Lagoon	Deliver barrage flows as per the required volumes, timing, seasonality and duration described in the CLLMM Environmental Water Requirements within the Long-Term Environmental Watering Plan for the SA River Murray Water Resource Area, to maintain required salinity and water levels in Lake Alexandrina and the Coorong.	DEW, SA Water
	Salinity – Murray estuary, Coorong North Lagoon and Coorong South Lagoon	Investigate long-term management options to manage Coorong water quality, as described in the *Healthy Coorong, Healthy Basin* Action Plan, such as pumping to/from the Coorong South Lagoon, options to improve the openness of the Murray Mouth and improving connectivity through Parnka Point and the Needles.	DEW
Fish	Fish diversity	Manage sustainable recreational and commercial fisheries within the Ramsar site in accordance with the South Australian *Fisheries Management Act 2007*.	PIRSA
		Protect the Marine Park Sanctuary Zones (Coorong Beach North and Encounter Bay) within and adjacent to the Ramsar site in accordance with the South Australian *Marine Parks Act 2007*.	DEW
	Threatened fish species	Maintain and improve threatened fish habitat at key lakes wetlands (e.g. Hindmarsh Island and Mundoo Island) by improving hydrological connectivity via sediment removal, dredging, reed control, upgrading culverts and removing sand drift.	Landscapes SA, DEW
		Maintain and utilise surrogate/captive-bred populations of threatened fish to increase numbers and genetic diversity of wild populations, with targeted releases to suitable Lakes wetlands during spring/summer.	Big Little 4 Working Group, Landscapes SA, DEW
		Implement actions outlined in the National Recovery Plans for Murray hardyhead and Yarra pygmy perch (Backhouse et al. 2008; Saddlier and Hammer 2010).	DEW, DEWA, Landscape Boards

Critical CPS	Sub-component	Description of Action	Responsible
Waterbirds	Waterbird abundance	Improve waterbird habitat and food resources (vegetation, invertebrates, fish) in the Lakes by implementing actions described in wetland management plans, such as: • Operating managed wetlands (those with a flow control structure (i.e. Narrung, Jennies Lagoon, Waltowa) to wet and dry seasonally, • Pumping water for the environment to above pool level wetlands (i.e. Tolderol, Milang Snipe Sanctuary, Teringie South Basin) in spring/summer, and • Improving through-flow in key permanent wetlands (i.e. Hindmarsh and Mundoo Island freshwater channels) to maintain open water habitats.	Landscapes SA, Nature Foundation SA
		Improve waterbird habitat in the Coorong, under the Our Coorong, Our Coast project: • Action plans for migratory shorebird sites and the Murray Mouth seabird site, • A fire program for controlling invasive shrubs in sedgelands in the southern Coorong, • Revegetation plans to provide threatened species habitat, and • A cat control program.	Landscapes SA, DEW, Birdlife Australia
	Waterbird breeding	Minimise the impacts of feral and domestic animals on waterbird breeding by undertaking fox baiting, improving cat control methods (through investment and training in *Felixer* cat control units) and promoting responsible cat and dog ownership.	DEW, Friends of Groups, local government
Threatened species	Southern bell frog	Undertake in-situ habitat management at known Lakes southern bell frog wetlands, including: • Spring/summer water level surcharge using wetland regulating structures or pumping, • Drying of habitat in autumn to remove fish, and • Protecting adjacent permanent water habitat	Landscapes SA
		Investigate and implement a captive breeding program and reintroduce southern bell frog to suitable habitat in the Lakes and Eastern Mount Lofty Ranges tributaries	Landscapes SA
		Implement actions outlined in the National Recovery Plan for the southern bell frog (Clemann and Gillespie 2012).	DEW, Landscapes SA
Vegetation	Emergent freshwater, emergent halophytes, threatened ecological communities	Manage the impact of priority pest plants on vegetation and habitats in the Ramsar site through continued implementation of management initiatives including: • Strategic weed control programs that target priority weeds, protect remnant vegetation and revegetation sites (e.g. African boxthorn and spiny rush control in the Coorong National Park), • Pest plant management advice and support to landowners including coordination of strategic control programs and access to funding opportunities.	DEW, Landscapes SA, landholders, local government

Critical CPS	Sub-component	Description of Action	Responsible
		Manage the impact of pest animals on native vegetation and habitats in the Ramsar site through continued implementation of management initiatives including: • Annual aerial deer cull programs in the Coorong National Park and adjoining areas, • Development and implementation of strategic rabbit control programs in the Coorong National Park in coordination with adjoining landowners, • Pest animal management advice and support to landowners including coordination of baiting programs, advice on best practice control methods and access to funding opportunities.	DEW, Landscapes SA, landholders
		Protect remnant emergent vegetation by: • Minimising impact (grazing and trampling) of livestock by continued maintenance of stock exclusion fences that protect remnant vegetation and wetlands, • Minimising the impact of tourism, camping and 4-wheel driving in the Coorong National Park and other protected areas, • Undertaking revegetation to enhance and buffer remnant vegetation, • Developing and implementing a burn program to maintain and improve the condition of *Gahnia filum* sedgelands in the Coorong National Park.	DEW, National Parks and Wildlife Service, Landscapes SA, landholders
	Submergent freshwater, emergent freshwater	Maintain aquatic vegetation in key fringing lakes wetlands by**:** • Using in-situ flow management structures where available (i.e. culverts with stop logs) to manage water levels and promote aquatic plant growth, • Pumping to discrete basins to manage water levels and promote aquatic plant growth, • Removing impediments to flow (i.e. dredging, reed control, removal of barriers, upgrade of culverts).	DEW, Landscapes SA, Nature Foundation SA
Vegetation / Coorong food web	Submergent halophytes / *Ruppia tuberosa*	Investigate actions (and implement feasible actions) to restore *Ruppia tuberosa* in the Coorong in the *Healthy Coorong, Healthy Basin* Action Plan, such as physical removal of filamentous green algae and improvements to Coorong surface water quality.	DEW
Coorong food web	Coorong benthic invertebrates	Implement actions to manage filamentous green algae in the Coorong, as described in the *Healthy Coorong, Healthy Basin* Action Plan, and maintain continuous barrage flows to the Coorong estuary.	DEW
Climate change	Whole system	Investigate the likely impacts of climate change and develop a detailed adaptation plan, including a timeline for responding to sea level rise and barrage operability.	DEW

15 Units of measurement

15.1 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	1,000 kg	mass
year	Y	365 or 366 days	time interval

16 Glossary

Definitions of words associated with ecological character descriptions (DEWHA 2008 and references sited within unless otherwise indicated.)

Anticyclone	A weather system with high barometric pressure at its centre, around which air slowly circulates in an anticlockwise (Southern Hemisphere) direction. Anticyclones are associated with calm, fine weather.
Adaptive Management	A management approach often used in natural resource management where there is little information and/or a lot of complexity, and there is a need to implement some management changes sooner rather than later. The approach is to use the best available information for the first actions, implement the changes, monitor the outcomes, investigate the assumptions, and regularly evaluate and review the actions required. Consideration must be given to the temporal and spatial scale of monitoring and the evaluation processes appropriate to the ecosystem being managed.
Benefits	Benefits/ services are defined in accordance with the Millennium Ecosystem Assessment definition of ecosystem services as 'the benefits that people receive from ecosystems' (Ramsar Convention 2005a, Resolution IX.1 Annex A). See also 'Ecosystem services'.
BP	Before Present (BP) years is a time scale to specify when events occurred in the past.
Biodisparity	The range of morphologies and reproductive styles in a community. The bio disparity of a wetland community is determined by the diversity and predictability of its habitats in time and space.
Biogeographic region	A scientifically rigorous determination of regions as established using biological and physical parameters such as climate, soil type, vegetation cover, etc (Ramsar Convention 2005a).
Biological diversity	The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species (genetic diversity), between species (species diversity), of ecosystems (ecosystem diversity) and of ecological processes. This definition is largely based on the one contained in Article 2 of the Convention on Biological Diversity (Ramsar Convention 2005a).
CAMBA, JAMBA and ROKAMBA or CMS	Bilateral agreements with China (CAMBA), Japan (JAMBA) and the Republic of Korea (ROKAMBA) or the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) to foster international cooperation on the conservation of migratory birds.
Change in ecological character	Defined as the human-induced adverse alteration of any ecosystem component, process and/ or ecosystem benefit/ service (Ramsar Convention 2005a, Resolution IX.1 Annex A).
Community	An assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another (ANZECC and ARMCANZ 2000).
Community Composition	All the types of taxa present in a community (ANZECC and ARMCANZ 2000).
Conceptual model	Wetland conceptual models express ideas about components and processes deemed important for wetland ecosystems (Gross 2003).
Contracting Parties	Countries that are Member States to the Ramsar Convention on Wetlands; 171 as at October 2019. Membership in the Convention is open to all states that are members of

	the United Nations (UN), one of the UN specialised agencies, or the International Atomic Energy Agency, or is a Party to the Statute of the International Court of Justice.
Critical stage	Critical stages are those activities (breeding, migration stopovers, moulting etc.) in the life of a wetland-dependent species which if interrupted or prevented from occurring may threaten long-term conservation of the species.
Declining populations	Populations that have lost abundance and extent of their range over time.
Ecological character	The combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time. [Within this context, ecosystem benefits are defined in accordance with the definition of ecosystem services as 'the benefits that people receive from ecosystems'.] (Ramsar 2012, Resolution IX.1 Annex A).
Ecosystems	The complex of living communities (including human communities) and non-living environment (ecosystem components) interacting (through ecological processes) as a functional unit which provides inter alia a variety of benefits to people (ecosystem services) (Millennium Ecosystem Assessment 2005).
Ecosystem components	The physical, chemical and biological parts of a wetland (from large scale to very small scale, for example habitat, species and genes) (Millennium Ecosystem Assessment 2005).
Ecosystem processes	The changes or reactions which occur naturally within wetland systems. They may be physical, chemical or biological. (Ramsar Convention 1996, Resolution VI.1 Annex A). They include all those processes that occur between organisms and within and between populations and communities, including interactions with the non-living environment that result in existing ecosystems and bring about changes in ecosystems over time (Australian Heritage Commission 2002).
Ecosystem services	The benefits that people receive or obtain from an ecosystem. The components of ecosystem services are provisioning (for example, food and water), regulating (for example, flood control), cultural (for example, spiritual, recreational) and supporting (for example, nutrient cycling, ecological value) (Millennium Ecosystem Assessment 2005). See also Benefits.
Endemic	Endemic species (Guidelines for Criterion 7) – a species that is unique to one biogeographical region, i.e. it is found nowhere else in the world. A group of fishes may be indigenous to a subcontinent with some species endemic to a part of that subcontinent (Ramsar Convention 2009).
Endemism	The ecological state of being unique to a geographic location – see endemic.
Fish	Fish orders that typically inhabit wetlands (as defined by the Ramsar Convention) and which are indicative of wetland benefits, values, productivity or biological diversity, include (from Ramsar 2012): i) Jawless fishes – Agnatha • hagfishes (Myxiniformes) • lampreys (Petromyzontiformes) ii) Cartilaginous fishes – Chondrichthyes • dogfishes, sharks and allies (Squaliformes) • skates (Rajiformes) • stingrays and allies (Myliobatiformes) iii) Bony fishes – Osteichthyes • Australian lungfish (Ceratodontiformes) • South American and African lungfishes (Lepidosireniformes) • bichirs (Polypteriformes) • sturgeons and allies (Acipenseriformes) • gars (Lepisosteiformes)

	• bowfins (Amiiformes) • bonytongues, elephant fishes and allies (Osteoglossiformes) • tarpons, bonefishes and allies (Elopiformes) • eels (Anguilliformes) • pilchards, sardines and herrings (Clupeiformes) • milkfishes (Gonorhynchiformes) • carps, minnows and allies (Cypriniformes) • characins and allies (Characiformes) • catfishes and knifefishes (Siluriformes) • pikes, smelts, salmons and allies (Salmoniformes) • mullets (Mugiliformes) • silversides (Atheriniformes) • halfbeaks (Beloniformes) • killifishes and allies (Cyprinodontiformes) • sticklebacks and allies (Gasterosteiformes) • pipefishes and allies (Syngnathiformes) • cichlids, perches and allies (Perciformes) • flatfishes (Pleuronectiformes) iv) Several groups of shellfishes • shrimps, lobsters, freshwater crayfishes, prawns and crabs (Crustacea) • mussels, oysters, pencil baits, razor shells, limpets, winkles, whelks, scallops, cockles, clams, abalone, octopus, squid and cuttlefish (Mollusca) v) Certain other aquatic invertebrates • sponges (Porifera) • hard corals (Cnidaria) • lugworms and ragworms (Annelida) • sea urchins and sea cucumbers (Echinodermata) • sea squirts (Ascidiacea)
Fledging rate	The number of young that survive to leave nesting grounds and successfully enter the breeding population. A measure of the reproductive success of breeding events.
Geomorphology	The study of the evolution and configuration of landforms.
Habitable area	The area a species or community is expected to occur.
Hypersaline	Saltier than typical seawater.
Hypersulfidic	Soil material that had a field pH of 4 or more and the pH dropped by at least 0.5 units to less than 4 when incubated at field capacity for at least 8 weeks.
Hyposulfidic	Soil material that had a field pH of 4 or more and the pH dropped by at least 0.5 units to not less than 4 when incubated at field capacity for at least 8 weeks.
Indigenous species	A species that originates and occurs naturally in a particular country (Ramsar Convention 2005a).
Isolated populations	Populations that are genetically isolated from other members of the same species.
Limits of Acceptable Change	The variation that is considered acceptable in a particular component or process of the ecological character of the wetland without indicating change in ecological character that may lead to a reduction or loss of the criteria for which the site was Ramsar listed (modified from definition adopted by Phillips 2006).
List of Wetlands of International Importance ('the Ramsar List')	The list of wetlands which have been designated by the Ramsar Contracting Party in which they reside as internationally important, according to one or more of the criteria that have been adopted by the Conference of the Parties.

Millennium Drought	From late 1996 to mid 2010, much of southern Australia (except parts of central Western Australia) experienced a prolonged period of dry conditions, known as the Millennium Drought. The drought conditions were particularly severe in the more densely populated southeast and southwest and severely affected the Murray-Darling Basin and virtually all of the southern cropping zones.
Monosulfidic	Soil material containing ≥0.01% acid volatile sulfide.
Ramsar	City in Iran, on the shores of the Caspian Sea, where the Convention on Wetlands of International Importance especially as Waterfowl Habitat was signed on 2 February 1971; the Convention's short title, 'Ramsar Convention on Wetlands'.
Ramsar Criteria	Criteria for Identifying Wetlands of International Importance, used by Contracting Parties and advisory bodies to identify wetlands as qualifying for the Ramsar List on the basis of representativeness or uniqueness or of biodiversity values.
Ramsar Convention	Convention on Wetlands of International Importance especially as Waterfowl Habitat. Ramsar (Iran), 2 February 1971. UN Treaty Series No. 14583. As amended by the Paris Protocol, 3 December 1982 and Regina Amendments, 28 May 1987. The abbreviated names 'Convention on Wetlands (Ramsar, Iran, 1971)' or 'Ramsar Convention' are more commonly used.
Ramsar Information Sheet (RIS)	The form upon which Contracting Parties record relevant data on Wetlands of International Importance for inclusion in the Ramsar Database; covers identifying details like geographical coordinates and surface area, criteria for inclusion in the Ramsar List and wetland types present, hydrological, ecological and socioeconomic issues among others, ownership and jurisdictions and conservation measures taken and needed.
Ramsar List	The List of Wetlands of International Importance.
Ramsar Sites	Wetlands designated by the Contracting Parties for inclusion in the List of Wetlands of International Importance because they meet one or more of the Ramsar Criteria.
Salinity and units of measurement	Salinity is the measure of the concentration of dissolved (soluble) salts in water. Salinity in the Lakes is described using electrical conductivity (EC) which is often the adopted unit for freshwater systems. EC is a measure of how well a solution can carry an electrical charge and is described in microsiemens per centimetre (µS/cm) or EC. Typically the higher the salinity the better it will carry a charge. Absolute pure water has a low EC value of around 0.055 µS/cm, tap water typically has a value of around 50-100 µS/cm and sea water has a value of around 50,000 µS/cm. Salinity in the Estuary and Coorong is described using parts per thousand (ppt) which is generally the adopted measure for saltwater environments. Ocean salinity is 35 ppt (49,900 EC) which means that there is 35 grams of salt in every kilogram (1,000 grams) of seawater.
Step change	A sudden or major change in the way that something happens or behaves. In this report step change is used to describe a major, sudden change in rainfall and water quality measures.
Stressor	Defined in Barrett et al. (1976) as 'physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level'.
Sulfuric material	Soil material that has a pH <4 (1:1 by weight in water, or in a minimum of water to permit measure) when measured as a result of oxidation of sulfidic materials and evidence of sulfidic material, such as underlying sulfidic material and/or the presence of yellow masses of jarosite along old root channels and faces of peds (aggregates of soil particles).

The Ramsar Site	Refers to the Coorong and Lakes Alexandrina and Albert Wetland .
Waterbirds	Defined as 'birds ecologically dependent on wetlands' (Ramsar Convention 1996, Article 1.2) and includes any wetland bird species. At the broad level of taxonomic order, it includes: • penguins: Sphenisciformes • divers: Gaviiformes • grebes: Podicipediformes • wetland related pelicans, cormorants, darters and allies: Pelecaniformes • herons, bitterns, storks, ibises and spoonbills: Ciconiiformes • flamingos: Phoenicopteriformes • screamers, swans, geese and ducks (wildfowl): Anseriformes • wetland related raptors: Accipitriformes and Falconiformes • wetland related cranes, rails and allies: Gruiformes • wetland related jacanas, shorebirds, gulls, skimmers and terns: Charadriiformes • coucals: Cuculiformes • wetland related owls: Strigiformes.
Wetlands	Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 metres (Ramsar Convention 1987).
Wetland types	As defined by the Ramsar Convention's wetland classification system https://www.dcceew.gov.au/water/wetlands/ramsar/wetland-type-classification

17 List of abbreviations

ADAM	Australian Data Archive for Meteorology
CAMBA	China Australia Migratory Bird Agreement
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office now CEWH
CLLMM	Coorong, Lower Lakes and Murray Mouth
CPS	Components, Processes and Services
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEW	Department for Environment and Water (South Australia)
DCCEEW	Department of Climate Chance, Energy, the Environment and Water (Australian Government)
DEWHA	former Department of the Environment, Water, Heritage and the Arts (Australian Government) now DCCEEW
DEWNR	former Department of Environment, Water and Natural Resources (South Australia) now DEW
DTR	Diurnal Tidal Ratio
ECD	Ecological Character Description
EMLR	Eastern Mount Lofty Ranges
EPA	Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
FNSE	First Nations of the South East
HCHB	*Healthy Coorong, Healthy Basin*
IUCN	International Union for Conservation of Nature
JAMBA	Japan Australia Migratory Bird Agreement
KNYA	Kungun Ngarrindjeri Yunnan Agreement 2009
LAC	Limits of Acceptable Change
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
MNES	Matter of National Environmental Significance
MT	Management Triggers
NAC	Ngarrindjeri Aboriginal Corporation
NRA	Ngarrindjeri Regional Authority
RCT	Resource Condition Targets
RIS	Ramsar Information Sheet
RMP	Ramsar Management Plan
ROKAMBA	Republic of Korea Australia Migratory Bird Agreement
SOC	Statement of Commitment
YOY	Young-of-the year+

18 References

Adams, A., Maguire, G. & Driessen, J., 2018. *Report on the 2018 Biennial Hooded Plover Count,* Adelaide: Birdlife Australia.

Asanopoulos, C. & Waycott, M., 2020. *The growth of quatic macrophytes (Ruppia tuberosa spp. and Althenia cylindrocarpa) and the filamentous algal community in the Southern Coorong,* Adelaide: Goyder Institute for Water Research.

Baker-Gabb, D. & Manning, C., 2011. *Local Action Plan the Coorong fairy tern Sternula nereis South Australia,* Adelaide: Department of Environment and Natural Resources.

Bell, D., 1998. *Ngarrindjeri Wurruwarrin: A World that is, was and will be.* Geelong: Spinifex.

Bell, D., 2008. *Kungan Ngarrindjeri Miminar Yunnan: Listen to Ngarrindjeri women speak.* Geelong: Spinifex.

Bice, C., 2010. *Literature Review of the ecology of fishes of the Lower Murray, Lower Lakes and Coorong,* Adelaide: Australian Department of Environment and Heritage.

Bice, C. et al., 2016. *The influence of freshwater discharge on productivity, microbiota community structure and trophic dynamics of the Murray estuary: evidence of freshwater derived trophic subsidy in the sandy sprat,* Adelaide: Goyder Institute for Water Research Technical Report Series No. 15/40.

Bice, C. M., Zampatti, B. P., Jennings, P. R. & Wilson, P., 2012. *Fish assemblage structure, movement and recruitment in the Coorong and Lower Lakes in 2011/12,* Adelaide: SARDI.

Bice, C. et al., 2018. Fishes of the Lower Lakes and Coorong: A Summary of life history, population dynamics and management. In: *Natural History of Coorong, Lower Lakes and Murray Mouth Region.* Adelaide: Royal Society of South Australia, pp. 371-399.

Bice, C. & Zampatti, B., 2017. *Diadromous fish, in Condition Monitoring Plan (Revised) 2017. The Living Murray – Lower Lakes, Coorong and Murray Mouth Icon Site,* Adelaide: Department of Environment, Water and Natural Resources Technical report 2016–17.

Billows, C., Bachmann, M., Whiterod, N. & Ascah, L., 2014. *Coorong, Lower Lakes and Murray Mouth (CLLMM) Wetland Condition Assessments, 2014,* Adelaide: Department of Environment, Water and Natural Resources.

Birdlife Australia, 2015. *The State of Australia's Birds 2015. Headline Trends for Terrestrial Birds,* Carlton: Birdlife Australia.

Blackmore, D., 2002. *Foreward: The Murray Mouth: Exploring the implications of closure or restricted flow,* Adelaide: Department of Water, Land and Biodiversity.

Bloss, C. M., Eckert, G. & Cetin, L., 2015. *River Murray flood mitigation planning: Assessment of flood consequences,* Adelaide: Department of Environment, Water and Natural Resources Technical Report 2015/56.

BMT WBM, 2009. *Review of schemes for maintaining an open Murray Mouth ,* Brisbane: BMT WBM.

Bureau of Meteorology, 2021. *Climate Data Online.* [Online]
Available at: www.bom.gov.au/climate/data

Charles, S. P. & Fu, G., 2015. *Statistically Downscaled Projections for South Australia,* Adelaide: Goyder Institute for Water Research Technical Report Series No. 15/1.

Coastal Studies, 2009. *Coorong sea level rise vulnerability study,* Adelaide: Department for Environment and Heritage.

Collier, K. et al., 2017. *Optimising Coorong ruppia habitat - Strategies to improve habitat conditions for Ruppia tuberosa in the Coorong (South Australia) based on literature review, manipulative experiments and predictive modelling,* South Australia: Department of Environment, Water and Natural Resources.

CSIRO, 2021. *Greenhouse Gases.* [Online]
Available at: https://www.csiro.au/en/research/environmental-impacts/climate-change/State-of-the-

Climate/Previous/State-of-the-Climate-2018/Greenhouse-gases
[Accessed 14 10 21].
DCCEEW, 2013. *Approved Conservation Advice for the Swamps of the Fleurieu Peninsula ecological community.* [Online]
Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/http://www.environment.gov.au/biodiversity/threatened/communities/pubs/031-conservation-advice.pdf
DCCEEW, 2013. *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (s266B).* [Online]
Available at: http://www.environment.gov.au/biodiversity/threatened/communities/pubs/118-conservation-advice.pdf
DEE, 2019. *Draft National Recovery Plan for the Australian Fairy Tern,* Adelaide: Department of the Environment and Energy.
DEH, 2000. *Coorong, and Lakes Aleandrina and Albert Ramsar Management Plan,* Adelaide: Department for Environment and Heritage.
DEH, 2009. *The Coorong, Lower Lakes and Murray Mouth: Directions for a Healthy Future,* Adelaide: Department for Environment and Heritage.
Delroy, L. B., 1974. The food of waterfowl (Anatidae) in the southern Coorong saltwater habitat of South Australia. *South Australian Ornithologist*, Volume 26.
DENR, 2011. *Habitat Managment Plan for the CLLMM region. Volume 2: Detailed Action Plans and Guidelines for On-Ground Works,* Mount Gambier: Department of Environment and Natural Resources.
DEW, 2018. *Coastal Saltmarsh: environmental trend and condition report card 2018.* [Online]
Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://data.environment.sa.gov.au/Content/Publications/Booklet_32_RC502_Saltmarsh.pdf
DEW, 2019. *Barrage Operating Strategy,* Adelaide: Department for Environment and Water.
DEW, 2020a. *The Desired State of the Southern Coorong - discussion paper,* Adelaide: Department for Environment and Water.
DEW, 2020b. *Long term environmental watering plan for the South Australian River Murray Water resource plan area,* Adelaide: Department for Environment and Water.
DEW, 2020c. *Refinements to the River Murray source model in South Australia,* Adelaide: Department for Environment and Water Technical report 2020/06, .
DEW, 2020d. *South Australian River Murray Basin Plan Environmental Outcome Evaluation: Coorong, Lower Lakes and Murray Mouth (CLLMM) Priority Environmental Asset, DEW Technical report 2020/18,* Adelaide: Government of South Australia.
DEW, 2021a. *Ecological Character Description 2015 The Coorong and Lakes Alexandrina and Albert Wetland Ramsar site,* Adelaide, South Australia: Department for Environment and Water.
DEW, 2021b. *Waterbird metrics for the Coorong, and Lakes Albert and Alexandrina Ramsar site, DEW Technical Report 2021/07,* Adelaide: Department for Environment and Water Technical Report 2021/07.
DEW, 2021c. *Methodology for calculating flow through the River Murray barrages, DEW Technical Report 2021/07,* Adelaide: Department for Environment and Water Technical report 2021/04.
DEW, 2022. *Guide to Climate Projections for Risk Assessment and Planning in South Australia,* Adelaide: Department for Environment and Water.
DEW, 2025. *Ramsar Management Plan: the Coorong and Lakes Alexandrina and Albert Wetland 2022,* Adelaide: Department for Environment and Water.

DEWHA, 2008. *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands. Module 2 of the national Guidelines for Ramsar Wetlands - Implementing the Ramsar Convention in Australia,* Canberra: Australian Government Department of the Environment, Water, Heritage and the Arts.
DEWNR, 2013. *The Coorong and Lakes Alexandrina and Albert Wetland Ramsar Information Sheet.* [Online] Available at: https://www.environment.gov.au/water/topics/wetlands/database/pubs/25-ris.pdf
DEWNR, 2017. *Condition Monitoring Plan (Revised) 2017. The Living Murray - Lower Lakes, Coorong and Murray Mouth Icon Site,* Adelaide: Department of Environment, Water and Natural Resources.
DEWNR, 2020. *Long-term environmental watering plan for the South Australian River Murray water resource plan area,* Adelaide: Department for Environment, Water and Natural Resources.
Dickson , C., Billows, C., Whiterod, N. & Bachmann, M., 2015. *Coorong, Lower Lakes and Murray Mouth (CLLMM) Wetland Condition Assessments: Coorong sites, 2015,* Adelaide: Department of Environment, Water and Natural Resources.
Dittmann, S., 2015. *Macroinvertebrate monitoring, analysis and synthesis for Coorong and Murray Mouth locations. Progress Report and preliminary response to "Condition of the RAMSAR site since listing" July 2015,* Adelaide: Department of Environment, Water and Natural Resources.
Dittmann, S., 2017. *Invertebrates in Condition Monitoring Plan (Revised) 2017. The Living Murray – Lower Lakes, Coorong and Murray Mouth Icon Site,* Adelaide: Department of Environment, Water and Natural Resources Technical report 2016–17.
Dittmann, S., Baring, R. & Ramsdale, T., 2016. *Macroinvertebrate monitoring, analysis and synthesis for Coorong and Murray Mouth locations. Final report and response on key monitoring questions,* Adelaide: Department of Environment, Water and Natural Resources.
Dittmann, S., Rolston, A. & Baring , R., 2018. Estuarine and lagoon macro-invertebrates - patterns and processes. In: *Natural History of the Coorong, Lower Lakes, and Murray Mouth Region.* Adelaide: Royal Society of South Australia, pp. 332-348.
DSEWPaC, 2012. *Australian Ramsar Site Nomination Guidelines. Module 4 of the National Guidelines for Ramsar Wetlands - Implementing the Ramsar Convention in Australia.,* Canberra: Australian Government Department of Sustainability, Environment, Water Population and Communities.
Earl, J., 2014. *Population biology and ecology of the greenback floudner (Rhombosolea tapirina) in the Coorong estuary,* Adelaide: Flinders University.
Earl, J., Fowler, A., Ye, Q. & Dittmann, S., 2017. Complex movement patterns of greenback flounder (Rhombosolea tapirina) in the Murray River estuary and Coorong, Australia. *Journal of Sea Research*, Volume 122, pp. 1-10.
Ekström, M. et al., 2015. *Central Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. et al,* Adelaide: CSIRO and Bureau of Meterology.
EPBC, 2000. *Environment Protection and Biodiversity Conservation Regulations 2000,* Canberra: Australian Government.
Ferguson, G. J., Earl, J. & Ye, Q., 2018. The histories of fisheries in the Lower Lakes and Coorong. In: *Natural History of the The Coorong, Lower Lakes and Murray Mouth Region (Yerluwar-Ruwe).* Adelaide: University of Adelaide Press, pp. 452-476.
Ferguson, G. J., Ward, T. M. & Geddes, C., 2008. Do recent age structures and historical catches of mulloway, Argyrosomus japonicus, reflect freshwater infows in the remnant estuary of the Murray River, South Australia. *Aquatic Living Resources*, Volume 21, pp. 145-152.
Ferguson, G. J., Ward, T. M., Ivey, A. & Barnes, T., 2014. Life history of Argyrosomus japonicus, a large sciaenid at the southern part of its global distribution: Implications for fisheries management.. *Fisheries Research*, Volume 151, pp. 148-157.

Frahn, K., Gehrig, S., Nicol, J. & Marsland, K., 2014. *Lower Lakes Vegetation Condition Monitoring - 2013/2014,* Adelaide: SARDI Publication No. F2009-000370-6. SARDI Research Report Series No. 798.
Geddes, M. C., 2005. *Ecological outcomes for the Murray Mouth and Coorong from the managed barrage release Sept-Oct 2003,* Adelaide: SARDI Aquatic Sciences for the Department of Water, Land and Biodiversity Conservation.
Gehrig, S., Nicol, J., Frahn, K. & Marsland, K., 2021. *Lower Lakes vegetation condition – 2011/12,* Adelaide: SARDI Publication No. F2010/000370-4.
Giatas, G. & Ye, Q., 2016. *Conceptual food-web models for the Coorong: A focus on fishes and the influence of freshwater inflows,* Adelaide: SARDI Publication No. F2016/000124-1, Research Report Series No. 892.
Gibbs, M., 2021. *Ecological Investigations Findings Report - Phase 1, September 2021. Coorong Infrastructure Investigations Project,* Adelaide: Department for Environment and Water.
Haddy, J. & Pankhurst, N., 2000. The effect of salinity on reproductive development, plasma steroid levels, fertilisation and egg survival in black bream, Acanthopagrus butcheri. *Aquaculture*, Volume 118, pp. 115-131.
Hammer, M. P. & Wedderburn, S., 2008. The threatened Murray hardyhead: natural history and captive rearing. *Fishes of Sahul*, 22(1).
Hansen, B. D. et al., 2016. *Revision of the East Asian-Australasian Flyway Population Estimates for 37 Migratory Shorebird Species,* Melbourne: Unplished rerport for the Department of Environment and Water.
Hart, P. & Purser, G., 1995. Effects of salinity on reproductive development, plasma steroid levels, fertilisation and egg survival in black bream. *Aquaculture*, Volume 136, pp. 221-230.
Harvey, P., 2002. *Introduction: The Murray Mouth: Exploring the implications of closure or restricted flow, a report prepared for the Murray-Darling Basin Commission,* Adelaide: Department of Water, Land and Biodiversity Conservation.
Hemming, S., Jones, P. & Clarke , P., 1989. *Ngurunderi: An Aboriginal Dreaming.* s.l.:South Australian Museum.
Hemming, S. et al., 2016. Speaking as Country: A Mgarrindjeri Methodology of Transformative Engagment. *Ngiya: Talk the Law*, Volume 5, pp. 22-46.
Heneker, T., 2010. *Development of flow regimes to manage water quality in the Lower Lakes, South Australia,* Adelaide: Department for Water.
Higham, J., 2012. *An analysis of MDBA modelling outputs for the draft Basin Plan: Hydrodynamic modelling of the Coorong and Murray Mouth,* Adelaide: Department of Environment, Water and Natural Resources.
Higham, J., Hammer, M. & Geddes, M., 2002. Fish and Invertebrates. In: *The Murray Mouth: Exploring the implications of closure or restricted flow. Prepared for theMurray-Darling Basin Commission.* Adelaide: Deaprtment of Water, Land and Biodiversity, pp. 53-64.
Hindall, J., Jenkins, G. & Womersley, B., 2008. Habitat utilisation and movement of black bream Acanthopagrus butcheri (Sparidae) in an Australian estuary. *Marine Ecology Progress*, Volume 366, pp. 219-229.
Hobbs, T., O'Connor, J. & Gibbs, M., 2019. *Improved elevation and bathmetry models for the Coorong,* Adelaide: Department for Environment and Water Technical report 2019/23.
Hortle, M. E., 1978. *The ecology of the sandy sprat Pseudaphritis urvilii, in south-east Tasmania. Honours thesis..* Hobart: University of Tasmania.
Hossain, A., Ye, Q. & Qin, J. G., 2016. Spatial and temporal changes of three prey-fish assemblage structure in a hypersaline lagoon: The Coorong, South Australia. *Australian Journal of Marine and Freshwater Research* , 68(2).
Jellinek, s. et al., n.d. Facilitating the restoration of aquatic plant communities in a Ramsar wetland. *Restoration Ecology*, 24(4), pp. 528-537.
Kim, D., Aldridge, K., Ganf, G. & Brookes, J., 2015. Physiochemical influences on Ruppia tuberosa abundance and distribution mediated through life cycle stages. *Inland Waters*, 5(4), pp. 451-460.

Kim, D. H., Aldridge, K. T., Brookes, J. D. & Ganf, G. G., 2013. The effect of salinity on the germindation of Ruppia tuberosa and Ruppia megacarpa and implications for the Coorong: A coastal lagoon of southern Australia. *Aquatic Botany*, Volume 111, pp. 81-88.
Kingsford, R. & Porter, J., 2009. Monitoring waterbird populations with aerial surveys – what have we learnt?. *Wildlife Research*, 36(1), pp. 29-40.
Kokkinn, M., 1986. *A control strategy for 'Tanytarsus barbitarsis' Freemann (Diptera, Chironomidae), a small-scale pest organism / PhD thesis,* Adelaide: Department of Zoology, University of Adelaide.
Lamontagne, S. et al., 2004. *Coorong, Lower Lakes and Murray Mouth. Knowledge gaps and knowledge needs for delivering better ecological outcomes,* Adelaide: CSIRO.
Lester, R. et al., 2011. *Specifying an environmental water requirement for the Coorong and Lakes Alexandrina and Albert. A first iteration.,* Adelaide: Government of South Australia.
Lintermans, M., 2007. *Fishes of the Murray-Darling Basin: An introductory guide*. Adelaide: MDBC Publication No. 10/07.
Lui, L., 1969. Salinity tolerance and osmoregulation in Taenomembrus microstomus (Gunther, 1861) (Pisces: Mugiliformes: Atherinidae) from Australian salt lakes. *Australian Journal of Marine and Freshwater Research*, Volume 20, pp. 157-162.
Mason, K. & Durbridge, R., 2015. *Frog Monitoring in the Coorong, Lower Lakes and Murray Mouth Region 2014/15, Final Report,* Murray Bridge, South Australia: Department of Environment, Water and Natural Resources.
Mason, K. & Hillyard, K., 2011. *Southern Bell Frog (Litoria raniformis) monitoring in the Lower Lakes, Goolwa River, Murray Channel, tributaries of the Currency Creek and Finiss River and Lakes Alexandrina and Albert,* Adelaide: Department for Environment, Water and Natural Resources.
MDBA, 2012. *Murray-Darling Basin Plan,* Canberra: Murray-Darling Basin Authority.
MDBA, 2014a. *Drought Emergency Framework for Lakes Alexandrina and Albert,* Canberra: Murray-Darling Basin Authority.
MDBA, 2014b. *Lower Lakes, Coorong and Murray Mouth Environmental Water Management Plan,* Canberra: Murray-Darling Basin Authority Publication No 10/14.
MDBA, 2014c. *Basin-wide environmental water strategy,* Canberra: Murray-Darling Basin Authrority.
MDBA, 2016. *Since the Millenium Drought - the River Murray System lessons learnt and changes made,* Adelaide: Murray-Darling Basin Authority.
Molsher, R., Geddes, M. & Paton, D., 1994. Population and reproductive ecology of the small-mouthed hardyhead, Atherinosoma microstoma (Gunther) (Pisces: Atherinidae) along a salinity gradient in the Coorong, South Australia. *Transactions of the Royal Society of South Australia*, Volume 118, pp. 207-216.
Mosley, L. M. et al., 2020. *Coorong water quality synthesis with a focus on drivers of eutrophication,* Adelaide: Goyder Institute for Water Research Technical Report Series No. 20/10.
Mosley, L. et al., 2023. Extreme eutrophication and salinisation in the Coorong estuarine-lagoon ecosystem of Australia's largest river basin (Murray-Darling). *Marine pollution bulletin*.
Mt Lofty Ranges Southern Emu-wren Recovery Team, 1998. *Recovery Plan for the Mt Lofty Ranges Southern Emu-wren Stipiturus malachurus intermedius 1999-2003,* Adelaide: Wildlife Australia.
Muller, K., Seaman, R., Eaton , J. & Mosley, M., 2018. Management in a crisis: responses to the Millenium Drought. In: *Natural History of the Coorong, Lower Lakes and Murray Mouth Region*. Adelaide: Royal Society of South Australia.
National Native Title Tribunal, 2017. *SCD2017/002 - Ngarrindjeri and Others Native Title Claim,* Canberra: National Native Title Tribunal.
Neilsen, D. L., Brock, M. A., Rees, G. N. & Baldwin, D. S., 2003. Effects of increasing salinity on freshwater ecosystems in Australia. *Australian Journal of Botany*, Volume 51, pp. 655-665.

Ngarrindjeri Aboriginal Corporation, 2022. *Ngarrindjeri research project: final report,* Adelaide: Department for Environment and Water.
Ngarrindjeri Nation, 2006. *Ngarrindjeri Nations Yarluwar-Ruwe Plan: Caring for Ngarrindjeri sea country and culture,* Adelaide: Prepared by Ngarrindjeri Tendi, Ngarrindjeri Heritage Committee, Nagrrindjeri Native Title Management Committee, Camp Coorong: Nagrrindjeri Land and Progress Association.
Ngarrindjeri Nation, 2019. *Information provided by the Ngarrindjeri Nation during the development of this document subject of a formal request and /or consultation with the Ngarrindjeri Nation.* s.l.:s.n.
Nicol, J., 2016. *An assessment of Ramsar criteria and limits of acceptable change for aquatic and littoral vegetation in the Coorong, and Lakes Alexandrina and Albert wetland,* Adelaide: SARDI Publication No. F2016/000262-1. SARDI Research Report Series No. 910. 63pp..
Nicol, J., Frahn, K., Gehrig, S. & Marsland, K., 2019. *Lower Lakes vegetation conditioning monitoring,* Adelaide: SARDI Publication No. F2009/000370-10, Research Report Series No. 1030. .
Noell, C. J. et al., 2009. *Fish assemblages of the Murray Mouth and Coorong region, South Australia, during an extended drought period,* Adelaide: CSIRO: Water for a Healthy Country National Research Flagship and South Australian Research and Development Institute.
O'Connor, J., 2015. *An assessment of Ramsar criteria and limits of acceptable change for waterbirds in the Coorong, and Lakes Alexandrina and Albert Wetland, DEWNR Technical report,* Adelaide: Department of Environment, Water and Natural Resources Technical report 2015/58.
O'Connor, J., Rogers, D. & Pisanu, P., 2012. *Monitoring the Ramsar status of the Coorong, Lakes and Murray Mouth: a case study using birds,* Adelaide: South Australian Department for Environment and Natural Resources.
O'Connor, J., Rogers, D. & Pisanu, P., 2013. *Cryptic and colonial nesting waterbirds in the Coorong, Lower Lakes and Murray Mouth.,* Adelaide: Department of Environment and Natural Resources.
O'Connor, J., Steggles, T., Higham, J. & Rumbelow, A., 2015. *Ecological objectives, targets and environmental water requirements for the Coorong, Lower Lakes and Murray Mouth. DEWNR Technical Report 015/45,* Adelaide: Government of South Australia, through the Department of Environment, Water and Natural Resources.
Oerman, G., 2021. *Elevation distribution of Ruppia tuberosa and Althenia cylindrocarpa in the Southern Coorong,* Adelaide: Department for Environment and Water.
Partridge , G. & Jenkins, G., 2002. The effect of salinity on growth and survival of juvenile black bream (Acanthopagrus butcheri). *Aquaculture*, 210(1), pp. 219-230.
Paton, D., 2010. *At the end of the river: the Coorong and Lower Lakes.* Hindmarsh, South Australia: ATF Press.
Paton, D. & Bailey, C., 2012. *Annual monitoring of Ruppia tuberosa in the Coorong region of South Australia, July 2011,* Adelaide: Department of Environment, Water and Natural Resources.
Paton, D. C., Bailey, C. P. & Paton, F., 2016. *Condition monitoring of The Lower Lakes, Murray Mouth and Coorong Icon Site: Waterbirds in the Coorong 2016. Source:.* s.l.:The University of Adelaide under a Creative Commons Attribution 3.0 Australia Licence..
Paton, D. C., Bailey, C. P. & Paton, F. L., 2015a. *Condition monitoring of the Coorong, Lower Lakes and Murray Mouth Icon Site: Waterbirds in the Coroong 2015,* Adelaide: University of Adelaide.
Paton, D. C., Paton, F. & Bailey, C., 2017a. Waterbirds. In: *Condition Monitoring Plan (Revised) 2017. The Living Murray - Lower Lakes, Coorong and Murray Mouth Icon Site..* Adelaide: Department of Environment, Water and Natural Resources.
Paton, D. C., Paton, F. & Bailey, C., 2017b. *Ruppia tuberosa,* Adelaide: Department of Environment, Water and Natural Resources Technical report 2016–17.
Paton, D. C., Paton, F. & Bailey, C. P., 2017. *Condition monitoring of the Coorong, Lower Lakes and Murray Mouth Icon Sites: waterbirds in the Coorng and Lower Lakes 2017.* s.l.:Adelaide School of Biological Sciences, The University of Adelaide.

Paton, D. C., Paton, F. L. & Bailey, C. P., 2015b. *A broad synthesis of waterbird knowledge for the Coorong, Lower Lakes and Murray Mouth region, including comment on future management and monitoring options,* Adelaide: The University of Adelaide.
Paton, D. C., Paton, F. L. & Bailey, C. P., 2018. Waterbirds of the Coorong, Lower Lakes and Murray Mouth. In: *Natural History of The Coorong, Lower Lakes, and Murray Mouth Region (Yarluwar-Ruwe).* Adelaide, South Australia: University of Adelaide, pp. 400-418.
Paton, D. C. & Rogers, D. J., 2009. *Ecology of Bredding Fairy Terns Sternula nereis in the Coorong,* Adelaide: Unviersity of Adelaide.
Paton, D., Paton, F. & Bailey, C., 2015b. *Ecological Character Description for Ruppia tuberosa in the Coorong.,* Adelaide: School of Biological Sciences, The University of Adelaide.
Paton, F. L. & Paton, D. C., 2016. *Colonial breeding birds in the Coorong during summer 2015-16, Report for the Department of Environment, Water and Natural Resources,* Adelaide: The University of Adelaide.
Phillips, B. & Muller, K., 2006. *Ecological Character of the Coorong, Lakes Alexandrina and Albert Wetland of International Importance,* Adelaide: Department of Environment and Heritage.
Ramsar, 2005. *Resolution IX.1 Annex A: A Conceptual Framework for the Wise Use of Wetlands and the Maintenance of their Ecological Character,* Ramsar: Ramsar.
Robinson, W. A., 2017. *Setting refined waterbird LAC for the CLLMM Ramsar site,* s.l.: Department of Environment, Water and Natural Resources..
Seaman, R. L., 2003. *Coorong and Lower Lakes habitat-mapping program,* Adelaide: Deaprtment for Environment and Heritage.
Stoessel, D. J. et al., 2019. Salinity tolerance during early development of threated Murray hardyhead (Craterocephalus fluviatilis) to guide environmental watering. *Aquatic Conservation: Marine and Freshwater Ecosystems*, Volume 30, pp. 173-182.
Thiessen, J., 2010. *Habitat Condition of Ramsar Wetland Types in Lake Alexandrina, Lake Albert, Goolwa Channel and Associated Tributaries,* Adelaide: Department of Environment and Natural Resources.
Timbal, B. et al., 2015. *Murray Basin Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds Ekström, M. et al,* Adelaide: CSIRO and Bureau of Meterology.
TSSC, 2003. *Swamps of the Fleurieu Peninsula, South Australia. Listing advice.* [Online]
Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicshowcommunity.pl?id=31
TSSC, 2011. *Approved Conservation Advice for Sternula nereis nereis (Fairy Tern),* s.l.: Threatened Species Scientific Committee.
TSSC, 2014. *Conservation Advice, Thinornis rubricollis rubricollis, Hooded Plover (eastern),* s.l.: Threatened Species Scientific Committee.
TSSC, 2015. *Conservation Advice, Calidris ferrguginea, Curlew Sandpiper,* s.l.: Threatened Species Scientific Committee.
TSSC, 2016. *Conservation advice Stipiturus malachurus intermedius,* s.l.: Threated Species Scientific Committee.
TSSC, 2016. *Conservation Advice Calidris canutus Red knot,* Canberra: Threatened Species Scientific Committee.
TSSC, 2016. *Conservation Advice Calidris tenuirostriss Great knot,* Canberra: Threatened Species Scientific Committee.
TSSC, 2019. *Conservation Advice, Botaurus poiciloptilus, Australasian Bittern,* s.l.: Threated Species Scientific Committee.
TSSC, 2021. *Conservation Advice Nannoperca australis Murray-Darling Basin lineage Southern Pygmy Perch-MDB,* Canberra: Department of Agriculture, Water and the Environment.
TTSC, 2016. *Conservation Advice Limosa lapponica baueri Bar-tailed godwit (western Alaskan),* Canberra: Department of the Environment..

United Nations, 1971. *Convention on wetlands of international importance especially as waterfowl habitat,* Ramsar: United Nations Educational, Scientific and Cultural Organization.
Watson, M., 2017. *South-East Aboriginal Focus Group Position Paper: South-East Flows Restoration Project Augmentation,* Adelaide: South East Aboriginal Focus Group Meeting.
Watt, A., 2013. *Biodisparity in fish communites in the Coorong, and Lakes Alexandrina and Albert Ramsar site.,* Adelaide: Department of Environment, Water and Natural Resources.
Waycott, M., McDougall, A. & O'Loughlin, E., 2020. *Experimental testing of Coorong filamentous algal growth with increasing temperature and salinity,* Adelaide: Goyder Institute for Water Technical Report Series No. 19/36.
Webster, I. T., 2007. *Hydrodynamic modelling of the Coorong,* Adelaide: CSIRO.
Webster, I. T., 2010. The hydrodynamics and salinity regime of a coastal lagoon - The Coorong, Australia - Seasonal to multidecadal timescales. *Estuarine, Coastal and Shelf Science*, pp. 264-274.
Wedderburn, D., Bailey, C. P., Delean, S. & Paton, D. C., 2016. Population and osmoregulatory responses of a euryhaline fish to extreme salinity fluctuations in coastal lagoons of the Coorong, Australia. *Estuarine, Coastal and Shelf Science*, Volume 168, pp. 50-57.
Wedderburn, S., 2014. *An assessment of threatened fish populations in Lake Alexandrina and Lake Albert, South Australia,* Adelaide: The University of Adelaide .
Wedderburn, S., 2017. *Lower Lakes threatened fish,* Adelaide: Department of Environment, Water and Natural Resources Technical report 2016-17.
Wedderburn, S., Furst, D. & Barnes, T., 2019. *Responses of threatened fish populations to environmental management scenarios for Lake Alexandrina determined with Generalized Additive Models. Report for the Department for Environment and Water,* Adelaide: The University of Adelaide.
Whetton, P. & Chiew, F., 2021. Chapter 12 - Climate change in the Murray-Darling Basin. *Ecohydrology from Catchment to Coast*, Volume 1, pp. 253-274.
Wilson, H., Maxwell, S., Kilsby, N. & Taylor, B., 2016. *South East Flows Restoration Project: Water quality risk assessment for the Coorong.* Adelaide: Department of Environment, Water and Natural Resources Technical Report 2016/01.
Ye, Q. et al., 2019c. *Monitoring salt wedge dynamics, food availability and black bream (Acanthopagrus butcheri) recruitment in the Coorong during 2018-19,* Adelaide: SARDI Publication No. F2018/000425-2, Research Report Series No. 1045.
Ye, Q., Bucater, L., Giatis, G. & Short, D., 2017a. Black bream and greenback flounder. In: *Condition Monitoring Plan (Revised) 2017. The Living Murray - Lower Lakes, Coorong and Murray Mouth.*. Adelaide: Department of Environment, Water and Natural Resources, pp. 44-51.
Ye, Q., Bucater, L., Giatis, G. & Short, D., 2017b. *Small-mouthed hardyhead,* Adelaide: Department of Environment, Water and Natural Resources Technical report 2016–17.
Ye, Q. et al., 2019b. *Monitoring salt wedge conditions and black bream (Acanthopagurs butcheri) recruitment in the Coorong during 2017-18,* Adelaide: SARDI Publication No. F2018/000425-1, Research Report Series No. 1012.
Ye, Q., Bucater, L. & Short, D., 2015. *Fish response to flows in the Murray estuary and Coorong during 2013/14,* Adelaide: SARDI Publication No. F2014/000786-1, SARDI Research Report Series No. 884. 91pp.
Ye, Q., Bucater, L., Short, D. & Giatas, G., 2020. *Coorong fish condition monitoring 2008-2019: Black bream (Acanthopagrus butcheri), greenback flounder (Rhombosolea tapirina) and smallmouth hardyhead (Atherinosoma microstoma) populations,* Adelaide: SARDI Publication No. F2011/000471-6, Research Report Series No. 979. .
Ye, Q. et al., 2019a. *The current state of food resources supporting waterbird and fish populations in the Coorong,* Adelaide: Goyder Institute for Water Research Technical Report Series No. 19/33.
Ye, Q. et al., 2013. *Flow related fish and fisheries ecology i the Coorong, South Australia,* Adelaide: SARDI Publication No. F2009/000014-2. SARDI Research Report Series No. 698. 84pp.

Zampatti, B., Bice, C. & Jennings, P., 2011. *Movements of female congolli (Pseudaphritis urvilli) in the Coorong and Lower Lakes of the River Murray,* Adelaide: South Australian Research and Development Institute (Aquatic Sciences).

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