# **Ecological character description 2015**The Coorong and Lakes Alexandrina and Albert Wetland

Department for Environment and Water 2023



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.

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The Department for Environment and Water acknowledges the Australian Aboriginal and Torres Strait Islander peoples of this nation. We acknowledge the traditional custodians of the lands on which the Department is located and where we conduct our business. We pay our respects to ancestors and Elders, past and present.

The Department for Environment and Water acknowledges and thanks the Ngarrindjeri for contributing their traditional knowledge, cultural expressions and intellectual property to this project and document and acknowledges their continuing ownership of such.

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#### Caution when reading this report

Aboriginal people are warned that this publication may contain images of deceased persons or culturally sensitive material.

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# **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.		
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'.		
ВР	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 biodisparity 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)		
	<ul><li>skates (Rajiformes)</li><li>stingrays and allies (Myliobatiformes)</li></ul>		
	<ul><li>iii) Bony fishes – Osteichthyes</li><li>Australian lungfish (Ceratodontiformes)</li></ul>		
	South American and African lungfishes (Lepidosireniformes)		
	bichirs (Polypteriformes)		
	sturgeons and allies (Acipenseriformes)     agra (Lenicostaiformes)		
	<ul><li>gars (Lepisosteiformes)</li><li>bowfins (Amiiformes)</li></ul>		
	<ul> <li>bonytongues, elephant fishes and allies (Osteoglossiformes)</li> </ul>		
	tarpons, bonefishes and allies (Elopiformes)		
	t in the state of		
	eels (Anguilliformes)     pilcharde cardings and harrings (Cluppiformes)		
	pilchards, sardines and herrings (Clupeiformes)		

	a satisface and legistiches (Cilevisormes)		
	<ul> <li>catfishes and knifefishes (Siluriformes)</li> <li>pikes, smelts, salmons and allies (Salmoniformes)</li> <li>mullets (Mugiliformes)</li> <li>silversides (Atheriniformes)</li> <li>halfbeaks (Beloniformes)</li> <li>killifishes and allies (Cyprinodontiformes)</li> <li>sticklebacks and allies (Gasterosteiformes)</li> <li>pipefishes and allies (Syngnathiformes)</li> <li>cichlids, perches and allies (Perciformes)</li> <li>flatfishes (Pleuronectiformes)</li> <li>iv) Several groups of shellfishes</li> <li>shrimps, lobsters, freshwater crayfishes, prawns and crabs (Crustacea)</li> <li>mussels, oysters, pencil baits, razor shells, limpets, winkles, whelks, scallops, cockles, clams, abalone, octopus, squid and cuttlefish (Mollusca)</li> <li>v) Certain other aquatic invertebrates</li> <li>sponges (Porifera)</li> <li>hard corals (Cnidaria)</li> <li>lugworms and ragworms (Annelida)</li> </ul>		
	<ul> <li>sea urchins and sea cucumbers (Echinodermata)</li> <li>sea squirts (Ascidiacea)</li> </ul>		
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. For more information see:  http://www.bom.gov.au/climate/updates/articles/a010-southern-rainfall-decline.shtml		

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 perturbati system that are either (a) foreign to that system or (b) natural to the system 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 permit measure) when measured as a result of oxidation of sulfidic material evidence of sulfidic material, such as underlying sulfidic material and/or the yellow masses of jarosite along old root channels and faces of peds (agging 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 <a href="https://www.ramsar.org/sites/default/files/documents/library/key_rec_4.07e.pdf">https://www.ramsar.org/sites/default/files/documents/library/key_rec_4.07e.pdf</a>

# **Units of measurement**

With the exception of the shortened forms of measurement below, units of measurement within the text are written in full and abbreviated in the tables.

#### **Shortened forms**

% percentage

AHD Australian Height Datum EC electrical conductivity

pH acidity

ppt parts per thousand

		Definition in terms of	
Name of unit	Symbol	other metric units	Quantity
day	D	24 h	time interval
gigalitre	GL	$10^6  \text{m}^3$	volume
gram	G	10 <sup>-3</sup> kg	mass
hectare	На	$10^4  \text{m}^2$	area
kilogram	Kg	base unit	mass
kilolitre	kL	1 m <sup>3</sup>	volume
kilometre	Km	10 <sup>3</sup> m	length
litre	L	10 <sup>-3</sup> m <sup>3</sup>	volume
megalitre	ML	$10^3 \text{ m}^3$	volume
metre	М	base unit	length
microgram	μд	10 <sup>-6</sup> g	mass
microlitre	μL	$10^{-9} \text{ m}^3$	volume
milligram	mg	10 <sup>-3</sup> g	mass
millilitre	mL	$10^{-6} \text{ m}^3$	volume
millimetre	mm	10 <sup>-3</sup> m	length
tonne	T	1000 kg	mass
year	Υ	365 or 366 days	time interval

# List of abbreviations

BDBSA Biological Databases of South Australia

BOM Bureau of Meteorology

CAMBA China Australia Migratory Bird Agreement

CEPA Communication, Education, Participation and Awareness
CLLMM Coorong, Lower Lakes and Murray Mouth (Recovery Project)

CMS Convention on the Conservation of Migratory Species of Wild Animals, Bonn 1979

CPS Components, processes and services

CSIRO Commonwealth Scientific and Industrial Research Organisation

DAWE Department of Agriculture, Water and the Environment (Commonwealth)

DAWR former Department of Agriculture and Water Resources (Commonwealth) now

DAWE

DEW Department for Environment and Water (South Australia)

DEWHA former Department of the Environment, Water, Heritage and the Arts

(Commonwealth) now DAWE

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

now DEW

DoEE former Department of the Environment and Energy (Commonwealth) now DAWE

EC Electrical conductivity (unit of salinity measurement)

ECD Ecological Character Description
EMLR Eastern Mount Lofty Ranges

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

ESLT Environmentally Sustainable Level of Take as outlined in the Water Act 2007 (Cth)

FU Flinders University

GDE Groundwater dependent ecosystem

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
NRA Ngarrindjeri Regional Authority
NRM Natural Resource Management
RIS Ramsar Information Sheet

ROKAMBA Republic of Korea Australia Migratory Bird Agreement

RMP Ramsar Management Plan

SDL Sustainable Diversion Limits as outlined in the Water Act 2007 (Cth)

SOC Statement of Commitment

USE Upper South-East

USED Upper South-East Drainage (scheme)

# Ngarrindjeri words and concepts

#### Ngarrindjeri Culture

Lakalinyeri Clan

Kaldowinyeri The Creation
Kaldowinyeri stories Creation stories

Krowi Thukabi Giant Turtle Creation ancestor

Miminar Ngarrindjeri women

Miwi Personal connection to the lands, waters, each other and all living things and which

is passed down through mothers since Creation

Muntjingga Seven Sisters Creation ancestor

Ngarrindjeri Rupelli Traditional leader

Ngarrindjeri Ruwe Country

Ngurunderi Creation ancestor

Ngartji Best friend, closest relative (animals, birds, fish, plants).

'Ngartji to non-Aboriginal people is like a totem which each one of us has and each group belongs to. It could be the pelican. It could be the swan. It could be the mullet. There are different species of... animal, fish, plant, but each group belongs to that Ngartji. A Ngartji is something that is more than a close friend. It's more your best

friend.' (George Trevorrow in Bell 2014).

Pondi (Ngarrindjeri

Creation ancestor)

Murray cod

Ruwe/Ruwar Interconnectivity between land, waters, spirit and all living things

Yannarumi Speaking lawfully as Ngarrindjeri Ruwe/Ruwar

Yarluwar-Ruwe Sea Country (includes all of Ruwe)

#### Place names and waterways

Kaike Granite Island Kangaroo Island Karta Kurangk Coorong Lentelin Long Island the Bluff Longkuwar Murrundi River Murray Tagalung Tailem Bend Warriewar the Milky Way

#### **Species names**

Kalpari Australasian shoveler
Kraurarli Royal spoonbill
Kungari Black swan
Kunmari Yelloweye mullet

Kuti Pipi

Lawari Cape Barren goose
Leiwulgi, Keili Dusky moorhen
Minmekutji Greenback flounder

Mullowi Mulloway
M:nanawuli, F:rtilmeri, Musk duck

Peldi

xvi

Na:ri

Australian wood duck

#### **Species names**

Nakari, Pebulaipuri,

Pacific black duck

Teintar

Ngalgurindi Pied cormorant Ngamat Hooded plover Ngarraki Chestnut teal

Ngarthari Eggs

Ngori Australian pelican Nitinyi Red-necked avocet Nyilkanyi Black-winged stilt

Parowani Samphire

Pitjangoli, Purnar,

Australian shelduck

Tarankinyi

Pilalki Golden perch

Pinyali Emu
Pomeri Catfish
Pondi (Ngarrindjeri Murray cod

Creation ancestor)

Prukal Australian pied oystercatcher

Pulangi Common galaxias
Pulki-nyeri Blue-billed duck
Pungkari, Waranggaiperi Hardhead

Talamarari Australian fairy tern
Talkuri Australasian bittern
Teilakawari, Tereiwari Little pied cormorant

Tenatjeri Caspian tern

Terilteril Common greenshank
Terukurar Murray hardyhead
Tjiri Black bream
Tloperi Straw-necked ibis

Throkarri Silver gull
Thukabi Turtle
Thukabi ngather Turtle eggs
Thukeri Bony bream
Thukeri mami Bream fish
Waatji Lignum
Wanggami Kangaroos

Wirili Pulyeri Mount Lofty Ranges southern emu-wren

Witjuwandi, Wiwuldi Pink-eared duck Wuri River red gum

# **Executive summary**

The Coorong and Lakes Alexandrina and Albert Wetland (the Ramsar site) is located in South Australia at the mouth of the River Murray (Murrundi), 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 Creek 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. Ngarrindjeri have occupied, enjoyed, managed and used their inherited lands and waters within the area of the River Murray (Murrundi), Lower Lakes, Coorong (Kurangk) and adjacent areas since the Kaldowinyeri (Ngarrindjeri Creation). The First Nations of the South East have traditional ties to the South East region and in particular, to the Coorong South Lagoon and the associated ephemeral lakes and wetlands.

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).

The First Nations of the South East Claim occurred in November 2017 after the development of this document with the Ngarrindjeri. It is recognised that as Native Title Claimants, the health and revitalisation of these places is of cultural, spiritual, social and economic significance to the First Nations of the South East people.

The Ramsar site was designated as a Wetland of International Importance under the Ramsar Convention in 1985. 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 Ecological Character Description (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 (Department of the Environment and Heritage 2006).

After the notification in 2006, flows down the River Murray into the Ramsar site were significantly less than extraction and losses from evaporation and seepage. The water levels of Lake Alexandrina and Lake Albert fell to unprecedented lows leading to increased salinity and extensive drying of the Lakes exposing thousands of hectares of actual and potential acid sulfate soils and the disconnection of core refuge areas in the southern section of Lake Alexandrina. Falling lake levels and lack of flow over the barrages into the Murray Estuary and the Coorong continued to exacerbate environmental issues in the Coorong such as increasing hypersalinity, loss of submergent vegetation and subsequent changes in bird populations. The challenges facing the site were numerous but were principally driven by the altered hydrological regimes which were exacerbated by the Millennium Drought (Department of the Environment, Water, Heritage and the Arts 2008).

In response to the Article 3.2 notification and with funding assistance from the Australian Government and the Murray–Darling Basin Ministerial Council, the South Australian Government 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.

Through these actions, the Coorong and Lakes Alexandrina and Albert Wetland has shown positive signs of recovery and 8 of the 9 Ramsar listing criteria continue to be met.

<u>Criterion 1</u>: 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.

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

<u>Criterion 3</u>: 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.

<u>Criterion 4</u>: 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.

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

<u>Criterion 6</u>: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

<u>Criterion 7</u>: 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.

<u>Criterion 8</u>: 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.

The ecological character of the Ramsar site has improved. This ECD describes the ecological characteristics of the Ramsar site in 2015. The ECD incorporates the extensive knowledge gathered through monitoring associated with the delivery of water for the environment since 2007, the CLLMM Recovery Project since 2009 and the development of the Basin Plan in 2012.

The Coorong and Lakes Alexandrina and Albert Wetland is large and complex and the following sub-units are regularly referred to in this document:

- 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 (EMLR) 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 and includes the Murray Mouth
- **Coorong North and Coorong South lagoons** which extend from Pelican Point to the southern end of the Coorong National Park and include the coastal environments and beaches of Younghusband Peninsula.

The driver of the site's ecology is the surface water regime (the volume, timing and quality of water that reaches and moves through the site). The interaction of this water with the landforms and the barrages produces the high diversity of habitats (23 Ramsar wetland types) which support a high diversity of species. Fish, waterbirds and plants are notable in terms of species richness, diversity and abundance at the bioregional scale. The site contains the Murray Mouth, the only connection to the Southern Ocean for the Murray–Darling Basin, supporting diadromous fish migrations and connection of the estuarine nursery habitat with the ocean. The majority of the site, more than 96% of the wetlands, are managed by the Government of South Australia.

The Ramsar site is central to Ngarrindjeri culture and spiritual beliefs and from a Ngarrindjeri perspective 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 Ngarrindjeri health and wellbeing. Ngarrindjeri knowledge of Yarluwar-Ruwe is incorporated into this ECD and demonstrates how Indigenous knowledge can inform the process of describing the

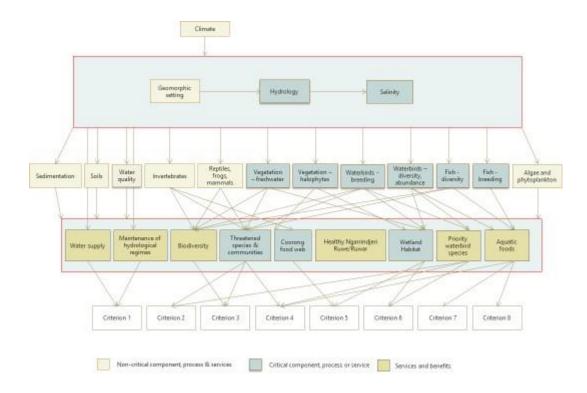
ecological character of a Ramsar site. This document incorporates Ngarrindjeri understandings of the relationship between culture and environment into the ECD.

ECDs identify, describe and, where possible, quantify the critical components, processes and services (CPS) of the site which determine its character and ultimately allow detection and monitoring of change in that character. These are the aspects of the wetland, which, if they were to be significantly altered, could result in a significant change in the system. The critical CPS along with the important subcomponents for this Ramsar site are presented below.

Critical CPS and subcomponents	Description Type			
Hydrology  Inflows Rainfall and evaporation Lake levels Barrage flows Tidal signal	<ul> <li>River Murray inflows into the north of Lake Alexandrina are the primary source of freshwater for the Ramsar site.</li> <li>Lake Alexandrina is the source of freshwater for Lake Albert.</li> <li>Barrage flows are the primary source of water for the Murray Estuary and the Coorong.</li> <li>Seasonal inflows from the EMLR tributaries, flows from the Upper South East and rainfall are minor freshwater inputs to the site.</li> <li>Barrage flows are dependent on River Murray inflows, lake level management, losses and diversions.</li> <li>Lakes and Coorong water levels fluctuate seasonally and are typically higher in winter than summer.</li> <li>An open Murray Mouth allows tidal exchange and connectivity between the ocean and the Estuary.</li> </ul>	Component, process, supporting and cultural services		
<ul> <li>Lakes Alexandrina and Albert</li> <li>EMLR tributaries</li> <li>Murray Estuary and Coorong</li> </ul>	<ul> <li>Salinity is a major driver of the composition and distribution of species found within the site.</li> <li>Salinity in the Lakes is closely linked to hydrology, particularly River Murray inflows and barrage outflows.</li> <li>Lake Albert generally has a higher salinity than Lake Alexandrina.</li> <li>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.</li> <li>The Coorong North Lagoon is estuarine to saline with lower salinity in the north-west and higher salinity towards the south-east at the connection with the Coorong South Lagoon.</li> <li>The Coorong South Lagoon is saline to hypersaline with lower salinity in the north-west and south-east of the Lagoon.</li> <li>The salinity of the Coorong fluctuates naturally over an annual timescale, being lowest in late winter/early spring and highest in late summer/early autumn.</li> </ul>	Component		
Vegetation     Submergent freshwater vegetation     Emergent freshwater vegetation     Submergent halophytes     Emergent halophytes	<ul> <li>The diversity and abundance of submergent freshwater vegetation is greatest when the water regime is variable and turbidity is low.</li> <li>Extensive stands of emergent vegetation (monospecific cumbungi and diverse reed beds) are present around the</li> </ul>			

Critical CPS and subcomponents	Description	Туре
<ul> <li>Fish</li> <li>Diversity (species richness and biodisparity)</li> <li>Movement and recruitment</li> <li>Threatened species</li> </ul>	<ul> <li>104 species have been recorded at the site with 29 species using the site regularly.</li> <li>The site contains a diverse assemblage of freshwater, diadromous and euryhaline estuarine species.</li> <li>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.</li> <li>The site supports important species for commercial and recreational fisheries.</li> <li>3 internationally and/or nationally listed threatened species occur within the site.</li> </ul>	Component, process (recruitment) and cultural service
<ul> <li>Waterbirds</li> <li>Diversity</li> <li>Abundance</li> <li>Foraging, refuge and roosting habitat</li> <li>Breeding</li> <li>Threatened species</li> </ul>	<ul> <li>118 species of waterbirds use the wetland habitat.</li> <li>The site supports 48 wetland-dependent species that are listed as migratory under the EPBC Act and international migratory agreements.</li> <li>The site regularly supports 1% or more of the flyway population of 7 species.</li> <li>38 waterbird species are known to breed at the site and 13 regularly breed within the site.</li> <li>6 internationally and/or nationally listed threatened species occur within the site.</li> </ul>	Component, process (recruitment) and cultural service
Wetland habitat	<ul> <li>The site supports a unique mosaic of 23 wetland types.</li> <li>The site is the only estuarine system within the Murray–Darling Basin.</li> </ul>	Component
Threatened ecological communities and species  • Swamps of the Fleurieu Peninsula  • Subtropical and temperate coast saltmarsh  • Southern bell frog	<ul> <li>Part of the Swamps of the Fleurieu Peninsula ecological community occurs within the Currency Creek and Finniss River areas.</li> <li>The subtropical and temperate coastal saltmarsh ecological community is found in the Murray Estuary and Coorong North Lagoon.</li> <li>The southern bell frog occurs around Lake Alexandrina, Lake Albert and EMLR tributaries.</li> </ul>	Component
Coorong food web  • Ruppia tuberosa – primary producer  • Benthic macroinvertebrates – primary consumers  • Small-mouthed hardyhead – secondary consumer	<ul> <li>R. tuberosa is a keystone primary producer in the hypersaline food webs of the Coorong.</li> <li>Macroinvertebrate diversity, abundance and biomass are highest in the Murray Estuary and decrease southward into the Coorong South Lagoon.</li> <li>Small-mouthed hardyhead are the critical prey species for piscivorous fishes and birds.</li> </ul>	Component and provisioning service

A simple conceptual model showing key relationships between selected components, processes, services and benefits and the criteria the site was nominated for as a Wetland of International Importance is shown below.



The major threats identified for the Ramsar site are as follows:

- Water diversions upstream leading to reduced inflows and altered hydrological regimes
- 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, nutrients and exposure of acid sulfate soils
- Invasive species and problematic natives
- Recreational activities.

Limits of Acceptable Change (LAC) are the variation that is considered acceptable for a measure or parameter of a particular component or process of the ecological character of the wetland. The inference is that if the particular measure or parameter moves outside the LAC this may indicate a change in ecological character that could lead to a reduction or loss of the values (criteria) for which the site was listed.

In reality, however, patterns of natural variability are rarely fully understood, and even with long-time series data, it can be difficult to resolve whether shifts in patterns of variability are natural cycles occurring over longer time scales than the data available, natural shifts between different stable states, or change in response to some external pressure.

The LAC described in this ECD and summarised in the table below are thresholds, set at the point at which a *potential* change in a critical CPS has occurred, which *may* represent a change in ecological character. If a LAC is exceeded, this *may* require an investigation to determine whether there has been a change in ecological character within the meaning of the Ramsar Convention. Several LAC will need to be updated with new baselines once adequate data is collected.

# Summary of critical CPS, subcomponents, attributes measured and LAC.

Critical CPS and subcomponent	Attribute measured	LAC
Hydrology		
Inflows	Lake Alexandrina water level	Lake Alexandrina water levels fall below – 0.25m AHD for 8 consecutive months.
Lake Alexandrina water level	Lake Alexandrina water level	Lake Alexandrina water levels fall below – 0.25m AHD for 8 consecutive months.
Salinity		
Lake Alexandrina salinity	Electrical conductivity in Lake Alexandrina	Lake Alexandrina average annual salinity levels greater than 1,500 EC for 2 consecutive years.
Murray Estuary and Coorong salinity	Salinity as ppt in the Murray Estuary, Coorong North and Coorong South lagoons	Murray Estuary (Goolwa Channel, Murray Mouth to Pelican Point) average monthly salinity greater than 40 ppt (55,658 EC) for more than 18 consecutive months.  OR  Coorong North Lagoon average monthly salinity level greater than 70 ppt (86,342 EC) for more than 18 consecutive months.  OR
		Coorong South Lagoon average monthly salinity level greater than 100 ppt (112,471 EC) for more than 18 consecutive months.
Vegetation		
Submergent freshwater vegetation	Lake Alexandrina water level and salinity	Average daily Lake Alexandrina water levels less than +0.2 m AHD or salinity greater than 2,000 EC for 2 consecutive years.
Emergent freshwater vegetation	Lake Alexandrina water level	Average daily Lake Alexandrina water levels less than +0.2 m AHD for greater than 2 consecutive years.
Submergent halophytes	Cover of Ruppia tuberosa	Less than 5% cover of <i>R. tuberosa</i> recorded at greater than 50% of all winter monitored sites for 2 or more consecutive years. See also Coorong food web LAC.
Emergent halophytes	Lake Alexandrina water level	Average daily water levels in Lake Alexandrina less than +0.2 m AHD for 2 or more consecutive years.
Fish		
Diversity (species richness and biodisparity)	Species richness	<u>Lake Alexandrina and Albert and EMLR tributaries</u> : Loss of any of the common freshwater species for 2 consecutive years which include targeted surveys.  OR
		<u>Coorong</u> : Loss of any of the common estuarine and marine-estuarine opportunist species for 5 consecutive years which include targeted surveys. Refer to Table 6-2 for the species list.

<b>Critical CPS and subcomponent</b>	Attribute measured	LAC
	Number of fish families (biodisparity)	Less than 13 of the 17 fish families (in targeted surveys) recorded in any 3 consecutive years. Refer to Table 6-3 for the families list.
Movement and recruitment	Young of year for congolli ( <i>Pseudaphritis</i> urvillii) and common galaxias ( <i>Galaxias</i> maculatus)	Young of year for congolli not recorded in the site for more than 5 consecutive years (in targeted surveys).  OR  Young of year for common galaxias not recorded in the site for more than 3 consecutive years (in targeted surveys).
Threatened species  Murray hardyhead	Presence/absence of Murray hardyhead (Craterocephalus fluviatilis)	Absence of Murray hardyhead in any 3 out of 5 targeted surveys within a 3-year period.
Waterbirds		
Diversity (species richness)	Abundances of selected waterbird species	<u>Lakes Alexandrina and Albert</u> : Less than 17 of 20 selected waterbird species have counts above their 10th percentile abundance for 2 consecutive years. Refer to Table 6-4 for the target species.
		<u>Murray Estuary/Goolwa Channel</u> : Less than 18 of 21 selected waterbird species have counts above their 10th percentile abundance for 2 consecutive years. Refer to Table 6-5 for the target species.
		<u>Coorong North Lagoon</u> : Less than 19 of 23 selected waterbird species have counts below their 10th percentile abundance for 2 consecutive years. Refer to Table 6-6 for the target species.
		Coorong South Lagoon: Less than 18 of 21 selected waterbird species have counts above their 10th percentile abundance for 2 consecutive years. Refer to Table 6-7 for the target species.
Abundance	Abundance across Ramsar site	Fewer than 190,122 waterbirds counted over the Ramsar site in the annual census over 2 consecutive years.
	Presence/absence of priority migratory shorebird species	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 10 <sup>th</sup> percentile abundance (2000–2015) for 2 consecutive years.
		<u>Black-tailed godwit</u> : Black-tailed Godwit are not detected for 4 consecutive years of census in the Coorong.
		<u>Sanderling</u> : Sanderling are not detected for 6 consecutive years of census in the <u>Coorong</u> .

Critical CPS and subcomponent	Attribute measured	LAC					
	Percent of 1% East Asian Australasian	The 10 <sup>th</sup> percentile percenta	The 10 <sup>th</sup> percentile percentages of the total flyway populations of any 2 of curled				
	Flyway population for selected species		•		_		
		during annual censuses from 2000–2015 are not met for 2 consecutive years.					
		Species	10th percentile (2000–2015)	Median			
		Curlew sandpiper	,	, ,	_		
		Red-necked stint					
		Sharp-tailed sandpiper	4,819	13,175			
	Percent of 1% Australian population for	The 10th percentile percent	ages of the total po	pulations of any 2 o	f Australian		
	selected species	·		•			
		present in the Coorong dur	ing annual censuses	from 2000-15 are i	not met for		
		2 consecutive years.			_		
			10th percent				
		Species	(2000–2015)	` `			
		Australian pied oystercatch					
		Chestnut teal		*			
		Fairy tern					
		Red-capped plover					
Breeding	Number of breeding events of annual and						
	regular breeding species			_			
		•	•	•			
			•		ne list below:		
		·	sustralian pelican ( <i>Pelecanus conspicillatus</i> )				
		Black swan ( <i>Cygnus a</i>		4330 7,220 226 336 456 1,235  ccessful breeding events in any 3 consecutive and attributable to on-site changes, assessed for ing event occurs when greater than 5% of prebird species are underlined in the list below: our conspicillatus) (s) (e) caspia) (e) caspia) (e) cula nereis nereis)			
		• Caspian tern ( <i>Hydrop</i>	,	ed sandpiper present in the Coorong are not met for 2 consecutive years.    Median   (2000–2015)			
		·	n (Thalasseus bergii)				
		Australian fairy tern ()		s)			
		<ul> <li><u>Hooded plover (Thing</u>)</li> </ul>	-				
		Australian white ibis (	(Threskiornis molucco	a)			
		<ul> <li>Australian pied oyste</li> </ul>	<u>r</u> catcher ( <i>Haematop</i> o	us longirostris)			
		<ul> <li>Red-capped plover (7)</li> </ul>	Thinornis rubricollis)				
		<ul> <li>Straw-necked ibis (Th</li> </ul>	reskiornis spinicollis)				

Critical CPS and subcomponent	Attribute measured	LAC
		Regular breeding species: No successful breeding events in any 4 consecutive years for the following species and attributable to on-site changes. A successful breeding event occurs when greater than 5% of recorded nests fledge young.
		Pied cormorant ( <i>Phalacrocorax varius</i> )
		<ul><li>Royal spoonbill (<i>Platalea regia</i>)</li><li>Silver gull (<i>Chroicocephalus novaehollandiae</i>)</li></ul>
Threatened species		
<ul> <li>Australasian bittern (Botaurus poicilopilus)</li> </ul>	Absence in targeted surveys	Absence of Australasian bittern at greater than 20% of sites that contain suitable habitat in 3 out of any 5 targeted surveys.
Australian fairy tern     (Sternula nereis nereis)	Abundance	Abundance of Australian fairy tern less than 226 in the January census for 2 consecutive years.
Curlew sandpiper     (Calidris ferruginea)	Abundance	Abundance of curlew sandpiper less than 508 in the January census for 2 consecutive years.
<ul> <li>Eastern curlew         (Numenius         madagascariensis)</li> </ul>	Abundance	Abundance of eastern curlew less than 2 in the January census for 2 consecutive years.
Hooded plover     (Thinornis rubricollis)	Absence in targeted surveys	Absence of hooded plover in any 3 out of 5 targeted surveys assessed over a rolling 10-year period.
<ul> <li>Mount Lofty Ranges southern emu-wren (Stipiturus malachurus intermedius)</li> </ul>	Absence in targeted surveys	Absence of Mount Lofty Ranges southern emu-wren from all known core population locations in any 1 out of 5 targeted surveys assessed over a rolling 10-year period.
Habitat		
Wetland habitat	Condition	Decline in condition at greater than 60% of the sites assessed over any 10-year period.
Threatened ecological communities and species		
Swamps of the Fleurieu Peninsula	Extent or condition of threatened community	Insufficient data to develop a baseline. To be defined in future.
Subtropical and temperate coastal saltmarsh	Extent of threatened community	Murray Estuary and Coorong: Reduction of greater than 10% in percentage cover over any 10-year period.

Critical CPS and subcomponent	Attribute measured	LAC
Southern bell frog	Lake Alexandrina water level and salinity	See LAC for freshwater submergent and emergent vegetation and the Lake Alexandrina salinity LAC.
Coorong food web		
Ruppia tuberosa – primary producer	Cover of <i>R. tuberosa</i> and percent viable seeds in sediment cores	Less than 5% cover of <i>R. tuberosa</i> recorded at greater than 50% of all winter monitored sites.  AND  Viable seeds of <i>R. tuberosa</i> in less than 20% of sediment cores at two-thirds of sampling locations across the Coorong South Lagoon for 4 consecutive seasons.
Benthic macroinvertebrates – primary consumers	Salinity as ppt in the Murray Estuary, Coorong North and Coorong South lagoons	See LAC for salinity for the Murray Estuary and the Coorong North and Coorong South lagoons.
Small-mouthed hardyhead – secondary consumer	Salinity in the Coorong South Lagoon	See LAC for salinity in the Coorong South Lagoon.

Long-term monitoring data has been integral to developing LAC for critical CPS and assessing change in condition over time. Research and monitoring efforts as part of the former The Living Murray Program (TLM), the CSIRO CLLAMMecology, the CLLMM Recovery Project and the Basin Plan in association with management interventions during and post Millennium Drought have greatly improved the ecological character of the site. However, there remain key knowledge gaps and monitoring requirements to inform the assessment of current LAC, future development of LAC, to address knowledge gaps and assess the impact of any change that has been identified.

These are the key messages on the ecological character for the site:

- 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 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.
- 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 Coorong South Lagoon back to health.
- The purpose of this ECD is to document baseline conditions for the Ramsar site as at 2015. These are the conditions that the site will be managed for in the future through the implementation of the Ramsar Management Plan currently under development.
- The ECD incorporates the extensive knowledge gathered through the CLLMM Recovery Project since 2009 and monitoring associated with the delivery of water for the environment since 2007.
- 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.

# 1 Introduction

#### 1.1 Brief site details

The Coorong and Lakes Alexandrina and Albert Wetland (the Ramsar site) is located in South Australia at the mouth of the River Murray (Murrundi), 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 Creek 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. Ngarrindjeri have occupied, enjoyed, managed and used their inherited lands and waters within the area of the River Murray (Murrundi), Lower Lakes, Coorong (Kurangk) and adjacent areas since the Kaldowinyeri (Ngarrindjeri Creation). The First Nations of the South East have traditional ties to the South East region and in particular, to the Coorong South Lagoon and the associated ephemeral lakes and wetlands.

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.

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 km south east of the city of Adelaide.		
Area	144,986 ha (based on the updated Ramsar boundary)		
Date of designation	1 November 1985		
Ramsar Criteria	1, 2, 3, 4, 5, 6, 7, and 8		
Management authority	South Australian Department for Environment and Water (DEW)		
Date the ECD applies	2015		
Status of description	This represents the second ECD for the site, reflecting the ecological character in 2015. This ECD is the first to be completed in South Australia in partnership with the Ngarrindjeri nation through the Kungun Ngarrindjeri Yunnan Agreement (KNYA) 2009 and the Ramsar ECD Statement of Commitment (SOC) (2014).		
Date of compilation	February 2021		
Name(s) of compiler(s)	Rhonda Butcher, Shane Brooks, Peter Cottingham, Rebecca Quin (DEW), Adrienne Rumbelow, Jason Higham (DEW), Adam Watt (DEW) and Ben Shepherd (DEW) on behalf of the DEW and Steve Hemming (FU), Amy-Della Sale (FU) and Daryle Rigner (FU) and the Ngarrindjeri Regional Authority.		
Ramsar Information Sheet (RIS)	RIS compiled by the DEW (in preparation).		
References to Management Plan(s)	DEW (2023), The Coorong and Lakes Alexandrina and Albert Wetland Ramsar Site Management Plan (in preparation).		

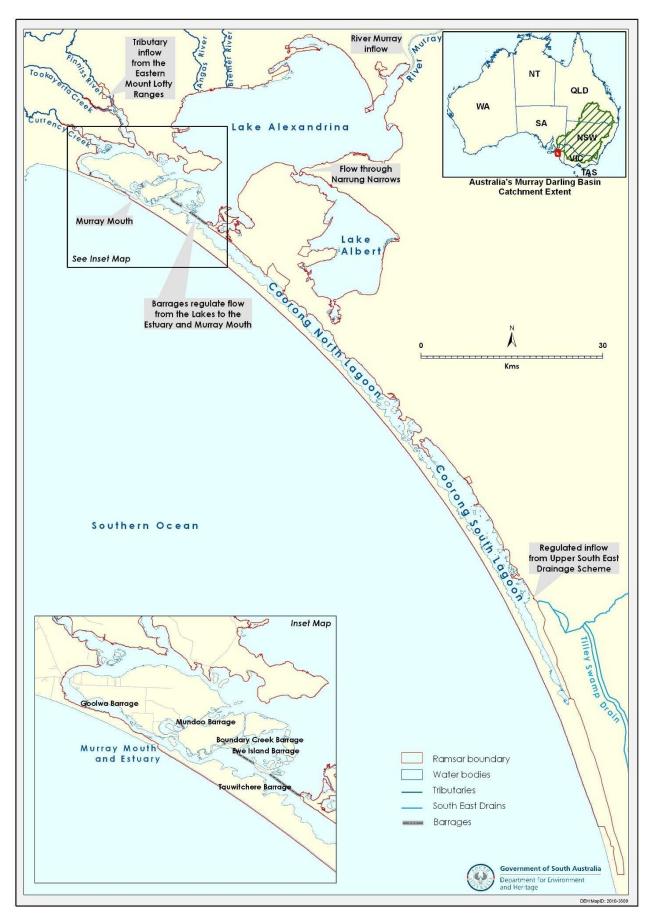


Figure 1.1 Extent of the Ramsar Site.

#### 1.2 Statement of purpose

The purpose of this ECD is to document the ecological character of the Ramsar site at 2015 following the change in ecological character reported under Article 3.2 of the Ramsar Convention in 2006 and subsequent recovery actions undertaken at the site. This document has been prepared in accordance with the National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands (DEWHA 2008). Note that the 2008 Guidance for Describing the Ecological Character is no longer consistent with guidance provided by the Ramsar Convention and is being revised. For further information about the revised guidance, contact the Australian Ramsar Administrative Authority, Wetlands Section, Department of Agriculture, Water and the Environment (email: wetlandsmail@environment.gov.au).

The Ramsar Convention has defined 'ecological character' and 'change in ecological character' as:

Ecological character is the combination of the ecosystem components, processes and benefits/services that characterise the wetlands at a given point in time... and

... change in ecological character is the human induced adverse alteration of any ecosystem component, process and or ecosystem benefit/service. (Ramsar Convention 2005)

In order to detect change in ecological character, it is necessary to establish a baseline description for management and planning purposes. An ECD forms the foundation on which the Ramsar aspects of the site are managed and monitoring and evaluation activities are based. The ecological character of Australian Ramsar sites are protected as a Matter of National Environmental Significance under the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act). This legislation is the primary tool for the protection and management of Australian Ramsar sites. However, other legislation, such as the *Water Act 2007*, includes provisions relating to Ramsar sites.

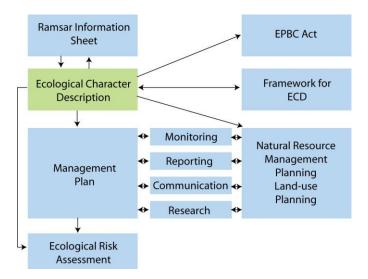


Figure 1.2 The ECD in the context of other requirements for the management of Ramsar sites (adapted from DEWHA 2008). Note Ngarrindjeri and First Nations of the South East caring for land and waters and natural resource management (NRM) is included under the NRM Planning and Land-use Planning box.

In 1985, the Coorong and Lakes Alexandrina and Albert Wetland was listed as a Wetland of International Importance under the Ramsar Convention on Wetlands. At the time of listing in 1985, the site was in a state of decline from the impacts of water extraction from the Murray–Darling Basin since the late 1800s. Extraction of high volumes of water for human consumption reduced the availability of water for the environment.

From late 1996 to mid-2010 (known as the Millennium Drought, BOM 2018), much of southern Australia, including the Coorong region, experienced a prolonged period of dry conditions.

In December 2006, in accordance with Article 3.2 of the Ramsar Convention and following advice from the South Australian Government, the Australian Government notified the Ramsar Convention Secretariat of a change in the ecological character of the Ramsar site. This notification was made in response to information presented in the draft 2006 ECD, which concluded that the site had been declining for at least 20 to 30 years prior to Ramsar listing, with the decline exacerbated by the Millennium Drought.

In response to the Article 3.2 notification and with funding assistance from the Australian Government and the Murray–Darling Basin Ministerial Council, the South Australian Government implemented emergency measures during the peak of the Millennium Drought. Towards the end of the drought, the CLLMM Recovery Project was developed and implemented. The project consisted of a suite of management actions aimed at restoring key ecological features of the Ramsar site, building resilience within the site, and building knowledge and understanding across communities, including collaboration with the community and the Ngarrindjeri.

Through these actions, the return of flows after the Millennium Drought and with the delivery of environmental water, the ecological character of the Ramsar site has improved since 2006. Aspects of the ecological character that were described in the 2006 ECD are not expected to return to the same condition as at the time of Ramsar listing without further intervention. To reflect that the site is moving towards a new equilibrium and guide future management, the South Australian Government has documented the ecological character of the Ramsar site as of 2015:

- (1) To assist in implementing Australia's obligations under the Ramsar Convention, as stated in Schedule 6 (Managing wetlands of international importance) of the *Environment Protection and Biodiversity Conservation Regulations 2000* (Cth):
  - a. to describe and maintain the ecological character of declared Ramsar wetlands in Australia; and
  - b. to formulate and implement planning that promotes:
    - i. conservation of the wetland; and
    - ii. wise and sustainable use of the wetland for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem.
- (2) To assist in fulfilling Australia's obligation under the Ramsar Convention to arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the Ramsar List has changed, is changing or is likely to change as the result of technological developments, pollution or other human interference.
- (3) To supplement the description of the ecological character contained in the RIS submitted under the Ramsar Convention for each listed wetland and, collectively, form an official record of the ecological character of the site.
- (4) To assist the administration of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act), particularly:
  - a. to determine whether an action has, will have or is likely to have a significant impact on a declared Ramsar wetland in contravention of sections 16 and 17B of the EPBC Act; or
  - b. to assess the impacts that actions referred to the Minister under Part 7 of the EPBC Act have had, will have or are likely to have on a declared Ramsar wetland.
- (5) To assist any person considering taking an action that may impact on a declared Ramsar wetland whether to refer the action to the Minister under Part 7 of the EPBC Act for assessment and approval.
- (6) To inform members of the public who are interested generally in declared Ramsar wetlands to understand and value the wetlands (McGrath 2006).

The act of designating a wetland as a Ramsar site carries with it certain obligations, including managing the site to retain its 'ecological character' and to have procedures in place to detect if any threatening processes are likely to, or have altered, the site's 'ecological character'.

The South Australian Government, as site manager, recognises that the lands and waters of the Ramsar site are a part of the living body of the Ngarrindjeri nation and that the Ngarrindjeri are involved in site management. Ngarrindjeri cultural character/values have been incorporated into the ECD and the South Australian Government acknowledges the deep Ngarrindjeri knowledge of the site and that Ngarrindjeri have the right and responsibility to speak as country.

Inclusion of Ngarrindjeri values in this ECD addresses commitments to maintaining the character of the Meeting of the Waters (a registered Aboriginal heritage 'site') and broader requirements to take into account Ngarrindjeri native title rights and interests. It also supports the South Australian Government as site manager to fulfil obligations under the Kungun Ngarrindjeri Yunnan Agreement 2009 (KNYA) and international obligations under the United Nations Declaration on the Rights of Indigenous Peoples relating to the rights of indigenous peoples.

# 1.3 Relevant agreements, legislation and policies

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 below.

#### 1.3.1 International Conventions, Agreements and Partnerships

Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention)

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)

#### 1.3.2 National Legislation, Intergovernmental Agreements, Initiatives and Strategies

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

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

Native Title Act 1993 (Cth)

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

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).

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

Australia's Biodiversity Conservation Strategy, 2010–2030

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

#### 1.3.3 State Acts, Agreements and Commitments:

National Parks and Wildlife Act 1972 (SA)

Coast Protection Act 1972 (SA)

Aboriginal Heritage Act 1988 (SA)

Native Vegetation Act 1991 (SA)

South Eastern Water Conservation and Drainage Act 1992 (SA)

Development Act 1993 (SA)

Environment Protection Act 1993 (SA)

Harbors and Navigation Act 1993 (SA)

Native Title Act 1994 (SA)

Local Government Act 1999 (SA)

River Murray Act 2003 (SA)

Fisheries Management Act 2007 (SA)

Climate Change and Greenhouse Emissions Reduction Act 2007 (SA)

Marine Parks Act 2007 (SA)

Murray-Darling Basin Act 2008 (SA)

Kungun Ngarrindjeri Yunnan Agreement, 2009 (KNYA) (Ngarrindjeri/South Australian Government)

Crown Land Management Act 2009 (SA)

Ngarrindjeri Regional Partnership Agreement, 2011

Ramsar Ecological Character Description Statement of Commitment (SOC) 2013 (DEWNR and NRA)

Ngarrindjeri Yannarumi - Speaking as Country Deed, 2014

Planning, Development and Infrastructure Act 2016 (SA)

Landscape South Australia Act 2019 (SA)

Healthy Coorong, Healthy Basin Partnerships

- Ngarrindjeri Partnership-through Ngarrindjeri Aboriginal Corporation
- First Nations of the South East Partnership-through the Burrandies Aboriginal Corporation

#### 1.3.4 Arrangements between the Ngarrindjeri and the South Australian Government

#### Kungun Ngarrindjeri Yunnan Agreement 2009 (KNYA) (Ngarrindjeri/ South Australian Government)

This is a legally binding agreement entered into between Ngarrindjeri and various Ministers of the Crown in South Australia. This agreement creates a formal context for the Ngarrindjeri Regional Authority (NRA) to negotiate regarding South Australian Government programs on Ngarrindjeri Ruwe/Ruwar.

#### Ramsar Ecological Character Description Statement of Commitment (SOC) 2013 (NRA and DEWNR)

The Ramsar SOC provides a set of jointly developed guidelines, principles, outcomes and actions that provide the framework for Ngarrindjeri engagement in the ECD review. This includes protection of Ngarrindjeri cultural knowledge.

#### Ngarrindjeri Yannarumi - Speaking as Country Deed 2014 (NRA and DEWNR)

This is a formal agreement, which acknowledges that the Ngarrindjeri speak as country, as they have always done. The deed seeks to promote the importance of an open Murray Mouth and for the parties to work together to align end of system flow objectives with the maintenance of the cultural health of the registered Meeting of the Waters heritage site, an area encompassing the waters and the bed of the Lakes, river and Estuary.

#### 1.4 Ngarrindjeri Yarluwar-Ruwe (Sea Country – all Ngarrindjeri lands and waters)

The Ramsar site and surrounding areas are the central homelands of the Traditional Owners, the Ngarrindjeri. The Ngarrindjeri people have occupied, enjoyed, managed and used their land and waters within the area of the River Murray, Lower Lakes, Coorong, Murray Mouth and adjacent areas since Creation. The Lower Lakes, Kurangk (Coorong), Murrundi (River Murray) and Murray Mouth of the Ramsar site are central to Ngarrindjeri culture and spiritual beliefs. From a Ngarrindjeri perspective the lands and waters are a living body – the Coorong and Lakes Alexandrina and Albert Wetland are part of the Ngarrindjeri living body. Kaldowinyeri stories (creation stories) about Yarluwar-Ruwe (Sea Country) reveal the significance of the relationship between the country and the people in a practical and spiritual sense. Maintaining the health of Yarluwar-Ruwe and the connectivity between all aspects and all elements of the region is a key cultural responsibility and fundamental to Ngarrindjeri health and wellbeing. Ngarrindjeri leaders and Elders developed the following vision statement to communicate this philosophy:

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).

Ngarrindjeri knowledge, perspectives and stories are further outlined in Chapter 3 and throughout the ECD.

#### 1.5 Preparing the ECD

This ECD was developed in accordance with the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEWHA 2008) and the *National Guidance on Notifying Change in Ecological Character (Article 3.2)* (DEWHA 2009). Note that the 2008 Guidance for Describing the Ecological Character is no longer consistent with guidance provided by the Ramsar Convention and is being revised by the Australian Government.

This ECD was developed primarily through a desktop assessment and review of material presented in Phillips and Muller (2006) and data and information collected between 2006 and January 2015. Key technical experts were formally engaged to provide input and comment on the ECD.

In 2013, the NRA and DEWNR established a new partnership to investigate how best to include Ngarrindjeri interests and philosophies in this ECD. Underpinned by the engagement processes established by the KNYA in 2009 and the Ngarrindjeri partnerships project, the parties established a joint working group and developed a Ramsar Ecological Character Statement of Commitment (SOC) to develop and agree upon processes to support the integration of Ngarrindjeri values, perspectives and philosophies into the review process (DEWNR and NRA 2014a; DEWNR and NRA 2014b). Joint initiatives were created to examine the application of the National Framework and negotiate the appropriate use of Ngarrindjeri cultural knowledge. This approach sought to merge the National Framework with the Ramsar Convention resolutions pertaining to culture, wetlands and indigenous peoples through understanding the relationship between Ngarrindjeri cultural values and wetland conservation and wise use (refer to Chapter 3).

This engagement framework has been crucial for Ngarrindjeri knowledge of Yarluwar-Ruwe to be part of the ecological description of the Ramsar site and demonstrates how Indigenous knowledge can inform the process of describing the ecological character of a Ramsar site. This ECD brings Ngarrindjeri understandings of the relationship between culture and environment into describing ecological character. It has provided new opportunities for supporting the overall health of the Ramsar site through acknowledging Ngarrindjeri cultural rights and responsibilities to speak as country (Hemming and Rigney 2008; Hemming and Rigney 2014; Hemming and Rigney 2016; Hemming et al. 2016).

The First Nations of the South East Claim occurred in November 2017 after the development of this document with the Ngarrindjeri.

### 2 General description

#### 2.1 Overview of the site

The Ramsar site is a series of freshwater, estuarine and hypersaline sub-units with the freshwater units of Lakes Alexandrina and Albert upstream of the barrages and the estuarine to hypersaline units of the Murray Estuary and Coorong lagoons downstream of the barrages. The wetland is surrounded by flat to undulating agricultural land and has 3 rural waters-edge townships. The lagoons of the Murray Estuary and Coorong are connected to the sea via the Murray Mouth. Included within the Ramsar boundary is the Younghusband Peninsula, a peninsula of dunes and beachfront that protects the Coorong from the Southern Ocean. The site incorporates the entire Coorong National Park which, in addition to the Coorong lagoons, includes woodlands, shrublands and swamps. Refer to Figure 2.1 for site photos.

Looking south over Currency Creek with the Goolwa Channel and Goolwa township in the background



Looking east over the wetlands on the northern fringes of Lake Alexandrina

Looking north over the Narrung Narrows with Lake Alexandrina in the background Looking south across Lake Albert with the Coorong in the background

Looking southeast over Tauwitchere Barrage and the Coorong Looking east over the Goolwa Barrage and Coorong Estuary

Looking southeast over the southern Coorong North Lagoon with the Southern Ocean in the background



Looking south over Parnka Point and adjacent islands between the Coorong North and Coorong South lagoons, with the Younghusband Peninsula and the Southern Ocean in the background

Figure 2.1 Ramsar site photos.

The Ramsar site lies approximately 75 kilometres south-east of Adelaide at the end of the River Murray (Murrundi) and is the terminus of the Murray–Darling Basin which extends across Queensland, New South Wales, the Australian Capital Territory, Victoria and South Australia (Figure 1.1).

The primary source of freshwater inflows into the Ramsar site is from the River Murray (Murrundi) 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 and Finniss, Angus and Bremer Rivers) which are typically less than 2% of the overall inflows into the Lakes; and from the Upper South East which drains into the Coorong South Lagoon at Salt Creek. Rainfall and groundwater inputs at the site are also 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 the estuarine waters of the Coorong and the Murray Mouth (Figure 1.1) which 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 by a series of 5 barrages between Goolwa on the mainland and Hindmarsh, Mundoo, Ewe and Tauwitchere islands. The barrages were completed in the 1940s to offset the impact of irrigated agriculture. They prevent seawater entering the Lakes to maintain freshwater conditions during times of low flows (Blackmore 2002).

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 over the barrages, are estuarine. The Coorong South Lagoon is influenced by flows over the barrages through the impact of these flows on Coorong North Lagoon salinity and water levels as wells as flows from the Upper South East. The Coorong South Lagoon is predominately saline to hypersaline.

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).

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 bottom of the Basin, it is strongly influenced by rainfall across the whole Basin as well as local rainfall. The connection to the Southern Ocean exposes the site to strong winds and tides. Wind, sea level and tide actions are important climatic drivers within the site and change seasonally and annually.

The Coorong, Lower Lakes and Murray Mouth region has a mix of predominantly irrigated and dryland agriculture; manufacturing industries centred on wine, machinery and equipment; boat building and maintenance; and recreation and tourism activities (DEH 2010). In terms of production and employment value, irrigated agriculture is the most important industry with viticultural production (38,921 tonnes with an estimated value of \$30 million in the Langhorne Creek Geographical Indication region (*Wine Australia* 2015) and milk production (estimated value of \$25 million) being major contributors. The towns associated with the Ramsar site include Goolwa, Clayton Bay, Milang, Langhorne Creek, Wellington, Meningie, Narrung, Raukkan and Salt Creek.

The Lakes and Coorong Fishery is a small-scale, multi-species fishery largely driven by 4 species; pipi (Goolwa cockle) (*Donax deltoides*), golden perch (*Macquaria ambigua*), mulloway (*Argyrosomus japonicas*) and yelloweye mullet (*Aldrichetta forsteri*). Other species that make a significant contribution include bony bream (*Nematalosa erebi*) and carp (*Cyprinus carpio*). In 2014–15 there were 36 licence holders with a catch of 1,598 tonnes and a catch value of \$7.7 million (EconSearch 2017).

Recreational fishing accounts for a significant proportion of the total catch of a number of Lakes and Coorong Fishery species and includes high value species such as mulloway, yelloweye mullet, golden perch and pipi (PIRSA 2017).

In 2014–15, the tourism industry contributed an estimated \$167 million to the Murraylands regional economy, or 12.8% of the gross regional product and directly employed approximately 700 people (Strathearn 2017).

The Ngarrindjeri are the Traditional Owners of this region and the area is within the Ngarrindjeri Native Title area. The site (particularly the Coorong National Park) is acknowledged as culturally vital to the Ngarrindjeri nation. Ngarrindjeri carry out their responsibilities to care for the country and tell the creation stories that guide sustainable use. For many thousands of years, the lower River Murray (Murrundi), including the Lakes and Coorong (Kurangk) was one of the most densely populated areas of Australia. The Ramsar site contains an archaeological record spanning over 5,000 years of continuous Ngarrindjeri occupation. These Old People's living places (e.g. middens, burial grounds and other sacred places) provide evidence of Ngarrindjeri customs, knowledge and traditions over many thousands of years (Ngarrindjeri Nation 2006; Ngarrindjeri 2019).

#### 2.2 Murray-Darling Basin Agreement

There is no specific water allocation for this site. The volume and pattern of River Murray flows to the site are determined by the water sharing arrangements in the *Murray–Darling Basin Agreement 2008* (the Agreement) and the delivery of environmental water. River Murray water sharing arrangements have been in place since 1914 and have fundamentally remained the same over time. Each year South Australia receives a River Murray water entitlement of up to 1,850 gigalitres and must use that entitlement according to the rules in the Agreement. South Australia's Entitlement flow of 1,850 gigalitres is delivered at the South Australian border at rates ranging from 3 gigalitres per day (June) to 7 gigalitres per day (December and January). The components of the entitlement are as follows:

- Consumptive Entitlement up to 1,154 gigalitres per year
- Dilution and Loss Entitlement of 696 gigalitres per year (58 gigalitres per month)
- additional quantities for dilution as determined by the Ministerial Council.

A Consumptive Entitlement of 1,154 gigalitres is the maximum volume of entitlement for non-dilution and loss purposes provided to South Australia in any year and is distributed under the provisions of the *Water Allocation Plan for the River Murray Prescribed Watercourse* (SA MDB NRM Board 2019) and varies each year depending on the available water in the River Murray system. The Consumptive Entitlement is divided into water to be taken for consumptive purposes, water specifically for allocation to the environment, and water that remains unallocated (SA MDB NRM Board 2019). The unallocated water will either be deferred and stored to meet South Australia's future Critical Human Water Needs or remain in the river to support dilution and loss and for environmental purposes, in particular for management of water levels in the Lakes.

The Dilution and Loss Entitlement of 696 gigalitres per year (58 gigalitres per month) is provided to meet conveyance losses and salinity dilution to Wellington and provides a small inflow into the Lakes. While the Lakes receive some benefit from this entitlement, there is no specific provision for dilution and losses to maintain the condition of Lakes Alexandrina and Albert and the Coorong.

South Australia's Entitlement of up to 1,850 gigalitres, by itself, does not provide sufficient water to maintain the ecological character of the Ramsar site, which is highly dependent on the delivery of environmental water and unregulated flows.

#### 2.3 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 -1.0 metres AHD and the 2 lakes were disconnected (MDBA 2014a).

Low water levels in the Lakes, disconnection of the wetlands, exposure of 20,000 hectares 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).



Figure 2.2 Images of the Lakes during the Millennium Drought. Clockwise from top left: cracking clays of exposed lake beds; dry lake beds adjacent to the Coorong and barrages; jetty on dry lake bed.

Evapoconcentration, the seepage of marine water through the barrages and low Murray inflows led to salinity in the Lakes increasing beyond values normally associated with freshwater environments. High salinity 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).

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. 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 19,000 gigalitres 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 (as at 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, *Atherinosoma microstoma*, 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 100 ppt (112,471 EC). However, the ecosystem has been slow to respond, demonstrating the long-term nature of impacts associated with periods of low River Murray flows and extreme salinity.

Several characteristics of the Coorong have undergone a substantial and sustained change. Most notably this included large reductions in the abundance of some waterbirds, particularly fairy tern and migratory shorebirds. The decline in abundance of migratory shorebirds is due to habitat loss in the East Asian-Australasian Flyway, but may also be associated with the prevalence of filamentous algae. This algae prevents aquatic plants from completing their life-cycle and interferes with the ability of waterbirds to feed on both plants and invertebrates in mudflats (Brookes et al. 2018).

#### 2.4 The Basin Plan

The Millennium Drought exposed the limits and weaknesses of how water in the Murray–Darling Basin was managed and highlighted the need for continuing reform. In response, the Australian Government passed the *Water Act 2007* (Cth). As a requirement of the Act, the MDBA developed the Basin Plan which was adopted in 2012. The Basin Plan provides a coordinated approach to water management across the Murray-Darling Basin's 4 states (New South Wales, Queensland, South Australia and Victoria) and the Australian Capital Territory. It represents a significant step in the ongoing process of managing the Basin's water for the benefit of all its users and the environment.

The Basin Plan is designed to:

- ensure a more consistent, Basin-wide approach to water planning under accredited State Water Resource Plans
- provide an environmental watering plan to optimise the environmental outcomes for the Basin, including
  - o promoting the conservation of declared Ramsar wetlands in the Murray–Darling Basin
  - o taking into account the ECDs of all declared Ramsar wetlands within the Murray-Darling Basin.
- incorporate the water quality and salinity management framework into the Basin Plan
- include a mechanism to manage critical human water needs during drought
- include rules for water trading
- include an approach to monitoring and evaluating the effectiveness of the Basin Plan in meeting its objectives.

The Basin Plan required Basin state governments to involve Traditional Owners in identifying Aboriginal objectives and outcomes based on Aboriginal values and uses (MDBA 2020).

The Basin Plan also required the development of a Basin-wide environmental watering strategy, which identifies quantified environmental outcomes specific to the Ramsar site (Table 2-1). While environmental water is available to help manage the ecological character of the Ramsar site, it is important to recognise that the available volumes are managed to achieve outcomes across the entire Murray–Darling Basin.

#### Table 2-1 Basin Plan environmental outcomes expected to occur beyond 2019 (MDBA 2014c)

#### **Expected outcomes for river flows and connectivity**

Longitudinal connectivity

• a 30 to 40% increase in flows to the Murray Mouth

#### End-of-basin flows

- barrage flows are greater than 2,000 GL/year on a 3-year rolling average basis for 95% of the time, with a 2-year minimum of 600 GL at any time
- water levels in the Lower Lakes are maintained above:
  - o sea level (0m AHD) and
  - +0.4m AHD, for 95% of the time, as far as practicable, to allow for barrage releases
- salinity in the Coorong and Lower Lakes remains below critical thresholds for key flora and fauna including:
  - salinity in Lake Alexandrina is lower than 1,000 EC 95% of the time and less than 1,500 EC all the time
  - o salinity in the Coorong's south lagoon is less than 100 g/L 95% of the time
- the Murray Mouth is open 90% of the time to an average annual depth of one metre.

#### **Expected outcomes for water-dependent vegetation**

- to maintain the extent of non-woody vegetation
- a sustained and adequate population of R. tuberosa in the Coorong South Lagoon, including:
  - o by 2019, R. tuberosa to occur in at least 80% of sites across at least a 50 km extent
  - o by 2029, the seed bank to be sufficient for the population to be resilient to major disturbances.

#### **Expected outcomes for waterbirds**

- that the number and type of waterbird species present in the Basin will not fall below current observations
- a significant improvement in waterbird populations in the order of 20 to 25% over the baseline scenario, with increases in all waterbird functional groups
- breeding events (the opportunities to breed rather than the magnitude of breeding per se) of colonial nesting waterbirds to increase by up to 50% compared to the baseline scenario
- breeding abundance (nests and broods) for all of the other functional groups to increase by 30–40% compared to the baseline scenario, especially in locations where the Basin Plan improves over-bank flows.

#### **Expected outcomes for native fish**

#### Broad outcomes:

- no loss of native species currently present within the Basin
- improved population structure of key species through regular recruitment
- increased movement of key species
- expanded distribution of key species and populations in the northern and southern Basin.

#### For short-lived species:

• restored distribution and abundance to levels recorded pre 2007 (prior to major losses caused by extreme drought). This will require annual or biennial recruitment events depending on the species.

#### For moderate to long-lived species:

- improved population structure (i.e. a range of size/age classes for all species and stable sex ratios where relevant) in key sites. This will require annual recruitment events in at least 8 out of 10 years at 80% of key sites, with at least 4 of these being 'strong' recruitment events
- a 10–15% increase of mature fish (of legal take size) for recreational target species (Murray cod and golden perch) in key populations
- annual detection of species and life stages representative of the whole fish community through key fish passages; with an increase in passage of Murray cod, trout cod, golden perch, silver perch, Hyrtl's tandan, congolli, shortheaded lamprey and pouched lamprey through key fish passages to be detected in 2019–2024, compared to passage rates detected in 2014–2019.

#### For estuarine species:

- detection of all estuarine-dependent fish families throughout 2014–2024
- maintenance of annual population abundance (Catch Per Unit Effort) of key estuarine prey species (sandy sprat and small-mouthed hardyhead) throughout the Coorong
- detection of a broad spatial distribution of black bream and greenback flounder; with adult black bream and all life stages of greenback flounder present across >50% of the Coorong in 8 out of 10 years
- detection in 9 out of 10 years of bi-directional seasonal movements of diadromous species through the barrages and fishways between the Lower Lakes and Coorong
- increased rates of native fish passage in 2019–2024 compared to 2014–2019
- improved population structure of mulloway, including spawning aggregations at the Murray Mouth in 6 out of 10 years and recruitment in at least 5 out of 10 years.

The Basin Plan aims to keep the Lakes' water levels above 0.0 metres AHD 100% of the time and above+0.4 metres AHD 95% of the time. These levels are not related to the requirements for a variable flow regime but a strategy to avoid broad-scale acidification of the Lakes should water levels fall below 0.0 metres AHD¹. The flora and fauna of the Lakes require a variable flow regime in addition to the flow-related indicators.

#### 2.5 Land tenure

More than 96% of the site is Crown Land, including the Coorong National Park, Salt Lagoon Islands and Lawari Conservation Parks and Tolderol, Currency Creek and Mud Islands Game Reserves which are 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. A summary of the land tenure is provided 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).

<sup>&</sup>lt;sup>1</sup> Drought Emergency Framework for Lakes Alexandrina and Albert

Table 2-2 Land tenure (hectares) within the Ramsar site (DEW 2023). Note the categories do not equal the total area of the site due to overlaps.

Statistics	Area (hectares)
Total area	144,986
Government land (total including Crown land inclusive of Conservation Reserves)	54,006
Private land	10,596
Water – Permanent (may include government and private land)	108,539
Water – Land subject to inundation (may include government and private land)	7,067
Water – Intermittent (may include government and private land)	334

#### 2.6 Wetland types

The 23 different wetland types (Table 2-3) found in the Ramsar site can be broadly assigned as freshwater or saline systems. To assist this description of these wetland types, the Ramsar site has been sub-divided into the following 6 sub-units:

#### **Freshwater components**

- Lake Alexandrina
- Lake Albert
- EMLR tributaries (lower reaches of the Finniss River, Currency Creek and Tookayerta Creek)

#### **Estuarine-saline components**

- Murray Estuary
- Coorong North Lagoon
- Coorong South Lagoon

Each of these 6 units are described in detail below with maps showing the distribution of wetlands types within each unit. For detailed descriptions of each of the 23 wetland types refer to Phillips and Muller (2006).

Ngarrindjeri refer to freshwater wetlands as 'nurseries' in recognition of the important role these areas play in providing food and shelter for many types of animals, birds and fish (ngartjis) and in particular safe shelter for the young. Submerged plants in these nursery areas are critical for food and shelter for animals and their young. The wetlands are the parts of the system that cleanse the Ruwe/Ruwar – the land/body and are understood to be like the lungs of the system. Ngarrindjeri consider all the Ramsar site wetlands to be crucial and created by Ngarrindjeri Creation ancestors such as Ngurunderi, Pondi and Thukabi (Ngarrindjeri 2019).

Table 2-3 Ramsar wetland types within the Ramsar site and extent as at 2005 from Phillips and Muller (2006) based on Seaman (2003). Wetland extent in 2015 is the same as it was in 2005.

Ramsar wetland type	Description	Ramsar site component (freshwater/saline)	Area (hectares)
М	Permanent rivers, streams and creeks	Freshwater and saline	221
N	Seasonal/intermittent rivers, streams and creeks	Freshwater	200
0	Permanent freshwater lakes (over 8 ha), including large oxbow lakes	Freshwater	79,480
Р	Seasonal/intermittent freshwater lakes (over 8 ha), including floodplain lakes	Freshwater	120
R	Seasonal/intermittent saline/brackish/alkaline lakes and flats	Saline	1,729
Ss	Seasonal/intermittent saline/brackish/alkaline marshes/pools	Freshwater and saline	1,289
Тр	Permanent freshwater marshes/pools: ponds (below 8 ha), marshes and swamps on inorganic soils with emergent vegetation water-logged for at least most of the growing season	Freshwater	4,474
Ts	Seasonal/intermittent freshwater marshes/pools on inorganic soils, including sloughs, potholes, seasonally flooded meadows, sedge marshes	Freshwater	1,037
W	Shrub-dominated wetlands: shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils	Freshwater and saline	4,875
Xf	Freshwater, tree-dominated wetlands, including freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils	Freshwater and saline	1,470
Υ	Freshwater springs, oases	Saline	less than 10
4	Seasonally flooded agricultural land, including intensively managed or grazed wet meadow or pasture	Freshwater	1,235
6	Water storage areas: reservoirs/barrages/dams/impoundments (generally over 8 ha)	Freshwater	1
9	Canals and drainage channels, ditches	Freshwater	44
Α	Permanent shallow marine waters	Saline	50
D	Rocky marine shores, including rocky offshore islands, sea cliffs	Saline	788*
E	Sand, shingle or pebble shores, including sand bars, spits and sandy islets, dune systems and humid dune slacks	Saline	1,020#
F	Estuarine waters: permanent water of estuaries and estuarine systems of deltas	Saline	2,200
G	Intertidal mud, sand or salt flats	Saline	3,142
Н	Intertidal marshes, including salt marshes, salt meadows, saltings, raised salt marshes, and tidal brackish and freshwater marshes	Saline	536
I	Intertidal forested wetlands, including mangrove swamps, nipah swamps and tidal freshwater swamp forests	Saline	4
J	Coastal brackish/saline lagoons: brackish to saline lagoons with at least one relatively narrow connection to the sea	Saline	10,128
K	Coastal freshwater lagoons, including freshwater delta lagoons	Saline	41

<sup>\*</sup> includes 165 hectares from Lake Alexandrina, (a freshwater part of the system)

<sup>#</sup> includes 6 hectares from Lake Alexandrina and 1 hectare from Lake Albert (freshwater parts of the system)

#### 2.6.1 Freshwater units

Lakes Alexandrina and Albert cover approximately 650 square kilometres, which makes them one of the largest freshwater bodies in South Australia (DEH 2000). There are different opinions on whether Lakes Alexandrina and Albert were predominately freshwater, estuarine or saline before European settlement; however the weight of evidence shows that the Lakes were predominately fresh. This is because most of the time, flows of freshwater down the River Murray would have been sufficient to fill the Lakes and keep seawater from creeping in (MDBA 2011a). Salinity and water level are the key determinants of the ecology of Lakes Alexandrina and Albert (MDBA 2012a).

#### Lake Alexandrina

Lake Alexandrina is shallow and covers approximately 64,900 hectares (Figure 2.3). The deepest areas are 4.75 metres with an average lake depth of approximately 2.9 metres. It supports complex, extensive fringing vegetation and an array of sand and mud islands. In addition to inflows from the River Murray, Lake Alexandrina also receives surface water from the tributaries of the Eastern Mount Lofty Ranges and local rainfall directly onto the surface of the lake. River Murray water enters Lake Alexandrina immediately downstream of Wellington. Water leaves Lake Alexandrina through 5 barrages (Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere) connecting the islands (Hindmarsh, Mundoo, Ewe and Tauwitchere) in the southern section of the lake. The barrages separate the estuarine habitat (and the Coorong) from Lake Alexandrina and artificially hold the Lakes at about 0.75 metres above sea level. They are designed and operated to ensure that Lake Alexandrina remains fresh for environmental reasons and as a water supply.

Water and salinity levels in Lake Alexandrina are determined by inflows into the lake and releases through the barrages. Lake levels vary across years and seasons but are generally operated between +0.5 metres AHD and +0.85 metres AHD annually, to permit barrage releases (DEW 2019). During the latter part of the drought in 2007–10, Lake Alexandrina water levels dropped to almost -1.0 metres AHD. During times of high inflows minor flooding occurs at water levels between +1.3 to +1.6 metres AHD. The operating water level range and variability is dependent on the flow available in the River Murray system. Under a variable water-level regime, fringing aquatic vegetation and soils experience wetting and drying cycles which are critical for the maintenance of healthy lake fringe habitats that support water birds, small-bodied fish including threatened fish, frogs and invertebrates. Barrage releases provide ecological (freshwater) cues for fish migration and recruitment.

Lake salinity is generally below 1,500 EC<sup>2</sup> although it increased to between 3,000–6,000 EC during the latter part of the Millennium Drought from December 2007 until 2010 (Heneker 2010). When River Murray flows are limited to entitlement flows, evaporation from the Lakes exceeds inflow and lake levels drop.

Reserves around Lake Alexandrina include Tolderol, Mud Islands and Currency Creek Game Reserves. The rest of the Lake Alexandrina component of the Ramsar site is mainly open water and Crown Lands.

Freshwater submerged aquatic vegetation communities are restricted to near-shore habitats with good light penetration and low turbidity, including the natural confluence of the River Murray and Lake Alexandrina, other tributary or wetland confluences, and some irrigation channels and drains that mimic natural conditions.

The fringing emergent vegetation around the lake has been simplified. In 2015, plants such as *Phragmites australis* and the *Typha* species are dominant, whilst species dependent on variable water regimes (e.g. *Eleocharis* spp. and *Baumea* spp.) are restricted to fringing wetlands and tributaries (Nicol J 2016). Many fringing wetlands also support lignum (*Duma florulenta*) and samphire at the high-water mark (behind the reeds) where the evaporation, watering and salinity levels provide suitable conditions for their growth. The hypersaline samphire communities occur at higher elevations, away from the zone inundated by seasonal lake level maximums. The samphire areas receive run-off from their own local catchments and from saline groundwater discharge.

<sup>&</sup>lt;sup>2</sup> Electrical conductivity (EC) as defined in Heneker (2010) as 1 EC = 1 microsiemen per centimetre at 25° Celsius

The islands within the Lakes, including Hindmarsh Island have historically provided flows between Lake Alexandrina and the Estuary with densely vegetated channels, acting as critical aquatic habitat connections. These freshwater habitats are critical for small-bodied freshwater fish such as the Murray hardyhead (*C. fluviatilis*).

The waters of the sea, the Kurangk (Coorong), the river and Lakes, all have powerful spiritual significance. Freshwater flows down the Murray–Darling system bring life to the waters of the Ramsar site and therefore bring life to the Ngarrindjeri. The importance of the Lakes is both literal and symbolic. It is rich in physical resources and spiritual symbolism, with the themes of flow and cycles echoed in the flows of freshwater and saltwater, the changing of the seasons and the reproductive cycles of Ngartjis and other plant and animal species (Ngarrindjeri 2019).

Creation ancestors such as Ngurunderi and Pondi, Jekejeri, Thukabi and the Yartuka created the Lakes and consequently the Ngarrindjeri consider that these ancestors continue to be part of these lands and waters (Bell 1998; Hemming et al. 2002; Bell 2008). The Creation Story of the Muntjinggar (Seven Sisters) explains the connection between the lives of these ancestral women, the Lower Lakes and Murray Mouth, the Meeting of the Waters, the spirit world and all Ngarrindjeri women. The following account of the Creation Story was passed on by Ngarrindjeri Elder Veronica Brodie and published in *Kungun Ngarrindjeri Miminar Yunnan: Listen to Ngarrindjeri women speaking* (Bell 2008):

It begins with Ngurunderi's cave that is situated under signal point [at Goolwa]. From the cave he looked across to the island. Ngurunderi felt it was his responsibility to look after the sky, the bird life, the waters, because he made the environment and the island. He was the god of Ngarrindjeri. His connection with the Seven Sisters was that he sent a young man, Orion, after the Seven Sisters to chase them and bring them back. They didn't want to be caught so they headed up to the sky, up and up and over the Milky Way and hid there and became the Seven Sisters. When they want to come back and see their Mum, who is still in the waters – near where the ferry crosses, just a little over towards the mouth, to the south – there has to be a clear way, so they can return and they'll be returning shortly, when it gets cold, that's when they disappear from the sky. Then they come back down and go under the water to be with their mother. (Veronica Brodie, in Bell 2008:29; Ngarrindjeri 2019)

The islands are extremely important nurseries particularly because of their location at the junction of the freshwater of the Lakes and the saltier water of the Murray Mouth and Estuary. These nesting islands have critical importance to Ngarrindjeri as Ngartji breeding places. The Ngarrindjeri have very strong spiritual connection to the islands which feature heavily in their creation and teaching stories. Islands such as Mundoo and Kumarangk (Hindmarsh Island) and the associated channels and streams in the area are part of the Creation stories associated with the Meeting of the Waters (Ngarrindjeri 2019).

George Trevorrow (deceased), a Ngarrindjeri leader (Rupelli), highlights the central significance of the Meeting of the Waters area and the islands in Lake Alexandrina (Bell 2014; Ngarrindjeri 2019):

Kumarangk [Hindmarsh Island], that area, is the central point for the Ngarrindjeri people... that's why our Ngartjis are there. That's the homeland. That's their area... That area is to us, that's our creation area and that's why so many of our stories, of our beliefs and our culture and heritage all revolves from that area outward upon the land of the Ngarrindjeri. It's a rich environment. It supports all the birdlife. You know, you could see that for yourself when you go there but to us Ngarrindjeri people it's a spiritual environment (Trevorrow, in Bell 2014:205).

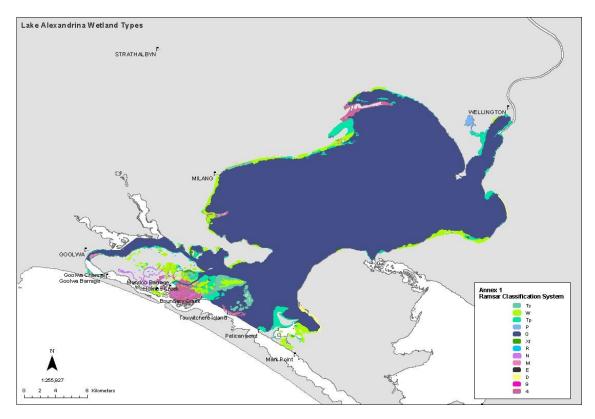


Figure 2.3 Lake Alexandrina and associated Ramsar wetland types (Seaman 2003) from (Phillips and Muller 2006).

#### **Key for Ramsar wetland types**

- Ts Seasonal/intermittent freshwater marshes/pools on inorganic soils, including sloughs, potholes, seasonally flooded meadows, sedge marshes.
- W Shrub-dominated wetlands: shrub swamps, shrub-dominated freshwater marshes, shrub-carr and alder thicket on inorganic soils.
- Tp Permanent freshwater marshes/pools: ponds (below 8 ha), marshes and swamps on inorganic soils, with emergent vegetation water-logged for at least most of the growing season.
- P Seasonal/intermittent freshwater lakes (over 8 ha), including floodplain lakes.
- O Permanent freshwater lakes (over 8 ha), including large oxbow lakes.
- Xf Freshwater, tree-dominated wetlands, including freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.
- R Seasonal/intermittent saline/brackish/alkaline lakes and flats.
- N Seasonal/intermittent/irregular rivers/streams/creeks.
- M Permanent rivers/streams/creeks, including waterfalls.
- E Sand, shingle or pebble shores, including sand bars, spits and sandy islets, dune systems and humid dune slacks.
- D Rocky marine shores, including rocky offshore islands and sea cliffs.
- 9 Canals and drainage channels, ditches.
- 4 Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture).

#### Lake Albert

Lake Albert is shallow and covers approximately 17, 710 hectares with an average depth of approximately 1.7 metres (Figure 2.4). It lies to the south-east of Lake Alexandrina connected via a narrow channel (Narrung Narrows) near Point Malcolm. The channel at Narrung Narrows is 230 metres wide with an average depth of approximately 2.0 metres. As Lake Albert has no through-flow connection to the Coorong, it represents a local, inland terminus of the River Murray system. As a terminal wetland with a narrow connection to Lake Alexandrina, flow into and out of Lake Albert is controlled by the water level in Lake Alexandrina. Wind patterns greatly influence flow patterns and water levels by tilting the lake surface, or creating waves that generate head differences within and between the Lakes (Phillips and Muller 2006). In addition to inflows from Lake Alexandrina, Lake Albert is supplemented by inputs from rainfall, local runoff and groundwater (DEWNR 2014b). Water levels and water quality, specifically salinity levels, in Lake Albert cannot be managed independently of those in Lake Alexandrina (Heneker 2010).

Lake Albert is smaller than Lake Alexandrina and typically more saline – between 1,000 and 3,000 EC (Heneker 2010) although salinity increased to above 20,000 EC during the Millennium Drought (Figure 4.6). Lake Alexandrina is the primary source of inflows to Lake Albert, with supplementation from local rainfall directly onto the surface of the lake and groundwater discharge. The groundwater table is shallow and saline under much of Lake Albert's floodplain and groundwater discharge creates seasonal and permanent salt-water marshes in depressions or swales around the lake edge.

Both Lake Albert and Lake Alexandrina have a long fetch (distance of lake surface in-line with prevailing winds) and water can wash backwards and forwards between the 2 lakes depending on wind direction and speed and the resultant wave action (Bourman and Barnett 1995).

Prior to European settlement, Lake Albert was significantly fresher than today and supported extensive beds of submerged aquatic plants and diverse emergent macrophyte communities that fringed the lake shore (Sim and Muller 2004). Submerged aquatic plants are now restricted in range to sheltered, littoral habitats.

The slow-moving water allows for deposition of silts and sediments, particularly at the southern end of the lake, where extensive siltation has resulted in reduced water depth and topographical diversity. This will promote the growth of reeds and riparian species and decrease the submerged wetland habitat. However, in so doing this, sedimentation could result in more high-quality island habitat and provide opportunities for *Ruppia* species growth, replacing beds from the Coorong and increasing habitat availability for nesting swans and ducks (Phillips and Muller 2006).

Lake Albert supports remnant patches of the sedge *Gahnia filum* and extensive, highly significant *Phragmites australis* and *Typha domingensis* reed beds. These provide excellent sheltered habitat for a range of fish and other vertebrate species, as well as long-term rookery sites for ibis, spoonbill and cormorants. Waltowa Swamp is a significant wetland complex connected to Lake Albert at high water levels that supports a range of flora, including significant orchids, reeds, lignum, samphire and freshwater marshes (Phillips and Muller 2006).

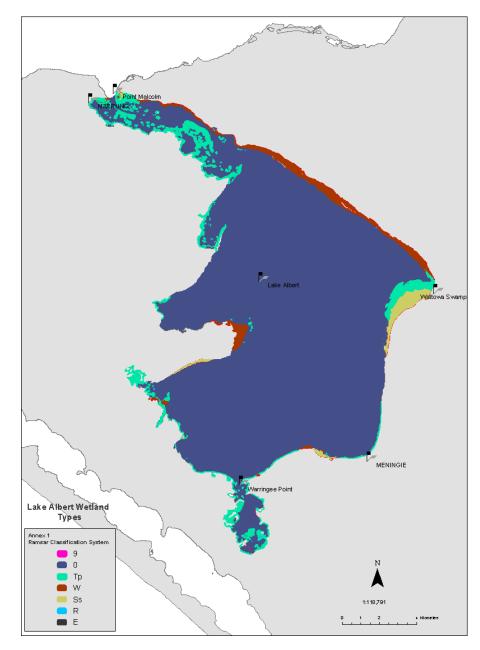


Figure 2.4 Lake Albert and associated Ramsar wetland types (Seaman 2003) from (Phillips and Muller 2006).

#### **Key for Ramsar wetland types**

- 9 Canals and drainage channels, ditches.
- O Permanent freshwater lakes (over 8 ha), including large oxbow lakes.
- Tp Permanent freshwater marshes/pools: ponds (below 8 ha), marshes and swamps on inorganic soils, with emergent vegetation water-logged for at least most of the growing season.
- 4 Seasonally flooded agricultural land, including intensively managed or grazed wet meadow or pasture.
- W Shrub-dominated wetlands: shrub swamps, shrub-dominated freshwater marshes, shrub-carr and alder thicket on inorganic soils.
- Ss Seasonal/intermittent saline/brackish/alkaline marshes/pools.
- R Seasonal/intermittent saline/brackish/alkaline lakes and flats.
- E Sand, shingle or pebble shores, including sand bars, spits and sandy islets, dune systems and humid dune slacks.

#### **Eastern Mount Lofty Ranges tributaries**

Five streams from the Eastern Mount Lofty Ranges (EMLR) discharge into Lake Alexandrina: Currency Creek, Tookayerta Creek, Finniss River, Angas River and the Bremer River (Figure 2.5). These streams gain water from catchment runoff largely in the hills and from discharge of underground water into the watercourses. Streams also lose water to underground water resources. Flow in these streams is seasonal or ephemeral, with the exception of Tookayerta Creek where underground water contribution to streamflow is sufficient to maintain permanent flow in most years (SA MDB NRM Board 2013). Streamflow modelling (1971–2006) for the *Eastern Mount Lofty Ranges Water Allocation Plan* estimated that mean annual end-of-system flows to the Lower Murray River and Lakes is 85 gigalitres (Alcorn 2011). The lower reaches of the Finniss River, Tookayerta Creek and Currency Creek lie within the Ramsar site boundary.

The Finniss River, Currency Creek and Tookayerta Creek and the freshwater wetlands these permanent streams support are important fishing, gathering and hunting places for Ngarrindjeri. Kaldowinyeri stories linked to these waterways include Ngurunderi, Neilung (netting for fish), the ancestral birds fishing around the Lakes and in the fringing wetlands, the Kaldowinyeri stories associated with the Meeting of the Waters such as Muntjingga and Kondoli, the Ancestral Whale (Bell 1998; Hemming at al. 1989; Ngarrindjeri Nation 2006; Bell 2008; Kaempf and Bell 2014; Ngarrindjeri 2019).

In this region, Ngarrindjeri belief is that Ngurunderi created the characteristic local freshwater springs and giant river red gums. For Ngarrindjeri, tributaries supporting red gums (wuri) have particular characteristics and these trees are connected with Ngurunderi. The wuri (river red gums) are considered to be Ngurunderi's trees and wuri and pondi (Murray cod) are closely connected through Ngarrindjeri Kaldowinyeri stories (Ngarrindjeri Nation 2006; Ngarrindjeri 2019).

The terminal reaches of the Finniss River and Tookayerta Creek, below Tuckers Ford on the Finniss River arm, are structurally diverse and support a dense and diverse wetland flora, ranging from river red gum (*Eucalyptus camaldulensis*) and reed-lined channels to swamps and freshwater marsh areas (Seaman 2003). This wetland system supports endangered fauna, such as Mount Lofty Ranges southern emu-wren (MLR Southern Emu-wren Recovery Team, 1998) and pygmy perch *spp*. (Wedderburn and Hammer 2003) and receives a relatively large but variable discharge from the Finniss River and Tookayerta Creek (via Black Swamp) catchments (Savadamuthu 2003). The patterns of release are relatively natural in terms of timing, frequency and duration of flows (although flow rates and extent of inundation have been reduced). Capture of flows in the headwaters may delay the onset of flows in dry years when dams take several weeks or months to fill before upper reaches provide flow (Savadamuthu 2003). Water quality is generally fresh with a tannic stain and high transparency, particularly in areas directly receiving stream flow.

Based on current extraction rates (2015), groundwater inflows across the plains counteract the reduced flows off the hills to a certain extent by sustaining flows over summer or initiating early autumn flows in dry years or in more intensely developed sub-catchments. The Finniss and Angas catchments are underlain by 2 aquifers, a local shallow system to about 25 metres, separated from an underlying deeper fractured rock aquifer by a 15 metre thick confining layer (Banks et al. 2007). Recharge rates in these catchments have been estimated to be relatively slow, in the order of 18 and 22 millimetres per year for the Angas and Finniss River catchments, respectively (Banks et al. 2007).

Currency Creek begins as a narrow, river red gum lined, rocky channel broadening to a wetland habitat and finally open water as part of Lake Alexandrina. It is characterised by permanently inundated channels and wetlands and the lower reaches of the creek are influenced by lake levels and wind seiching (wind tides), which can raise and lower water levels depending on wind direction.

#### Groundwater dependent freshwater soaks

There are a number of groundwater fed freshwater soaks that line the shores of the Coorong and these are discussed in the section on the Coorong South Lagoon.

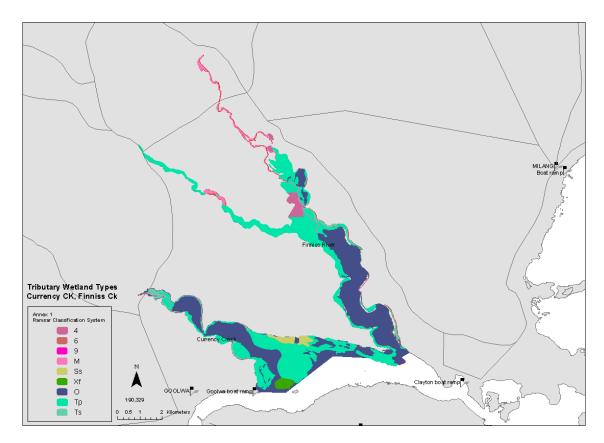


Figure 2.5 EMLR tributaries and associated Ramsar wetland types (Seaman 2003) from (Phillips and Muller 2006).

#### **Key for Ramsar wetland types**

- 4 Seasonally flooded agricultural land, including intensively managed or grazed wet meadow or pasture.
- 6 Water storage areas: reservoirs/barrages/dams/impoundments (generally over 8 ha).
- 9 Canals and drainage channels, ditches.
- M Permanent rivers/streams/creeks, including waterfalls.
- Ss Seasonal/intermittent saline/brackish/alkaline marshes/pools.
- Xf Freshwater, tree-dominated wetlands, including freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.
- O Permanent freshwater lakes (over 8 ha), including large oxbow lakes.
- Tp Permanent freshwater marshes/pools: ponds (below 8 ha), marshes and swamps on inorganic soils, with emergent vegetation water-logged for at least most of the growing season.
- Ts Seasonal/intermittent freshwater marshes/pools on inorganic soils, including sloughs, potholes, seasonally flooded meadows, sedge marshes.



Ramsar type D is the most applicable wetland type for the shorelines of Lake Alexandrina, which support inland remnants of ancient shorelines. These rocky shorelines contain more than 50% cover of strew (stones) on the beaches and have cliff areas comprising exposed calcrete outcrops. The vegetation is dominated by exotic grasses that are degraded by cattle grazing and trampling.

These areas are located along the eastern shore of Lake Alexandrina below Wellington (Poltalloch Plains); the southern edge of Point Sturt; and in patches along lake shore between Clayton and Point Sturt.

Ramsar type D Clayton Bay, Lake Alexandrina (Kerri Muller)



Samphire channels, with open areas of mudflat that receive flow during winter and dry off over the summer months, occur in brackish to saline conditions across the Hindmarsh Island flats. *Melaleuca halmaturorum* trees are sparse and are being planted around some of these samphire areas to increase habitat value by maintaining habitat connectivity and diversity on the islands.

Ramsar type N channel on Hindmarsh Island (Russell Seaman)



Ramsar type M at Currency Creek (Russell Seaman)

The most diverse plant assemblages associated with this habitat type are usually in sites found behind the main lake shores ranging from shallow depressions to large freshwater swamps, and areas in the Finniss River, Tookayerta Creek and Currency Creek tributaries where wave action was limited.

Figure 2.6 Examples of wetlands in the freshwater components of the site.

#### 2.6.2 Saline components

The Coorong is about 140 kilometres long, separated from the Southern Ocean by a narrow coastal dune system. River Murray flows enter the Coorong over the barrages and are a key driver of salinity in the Coorong (Phillips and Muller 2006). The other source of freshwater (apart from local rainfall) is from the South East, which drains north into the Coorong South Lagoon and is regulated by the Upper South East Drainage Network. This is a relatively small volume when compared to River Murray flows but does influence salinity in the Coorong South Lagoon.

Salinity and water levels fluctuate with flows over the barrages and the openness of the Murray Mouth. Seawater enters the Coorong North Lagoon from the Southern Ocean when river inflows to the Murray Mouth are absent. The Coorong is a reverse estuary (i.e. salinity increases with distance from the Mouth), with salinities ranging from fresh to brackish in parts of the Murray Estuary and saline to hypersaline in the areas of the Coorong South Lagoon (DEWNR 2015).

#### **Murray Estuary**

The Murray Estuary extends from the Goolwa Barrage to Pelican Point, including the Goolwa, Coorong and Mundoo channels, covering an area of approximately 3,400 hectares (Phillips and Muller 2006) (Figure 2.7). A large variety of habitats are present in the Murray Estuary, ranging from freshwater marshes to intertidal forested wetlands. The area provides important foraging grounds for many wader species. The Estuary is an important transitional area for many species of fish that rely on estuarine conditions to complete their lifecycles (MDBA 2014b).

The Murray Mouth has always been relatively narrow, but it has been and continues to be extremely dynamic, influenced by the flow of River Murray water from Lake Alexandrina via barrage releases and tidal movement from the Southern Ocean. When the flow to South Australia is low, barrage releases are low and sand deposits occur inside the mouth causing restrictions and increasing the risk of closure.

An open Murray Mouth is important to maintain connectivity between the river, the Coorong and the Southern Ocean, to discharge salt and other nutrients out to sea and to maintain healthy ecosystems in the Coorong. The location of the Murray Mouth has varied over a range of approximately 6 kilometres during the last 3,000 years and over 1.4 kilometres in the last 160 years (Bourman and Murray-Wallace 1991).

Prior to European settlement, flows of River Murray water out of the Murray Mouth exceeded 2 gigalitres per day more than 95% of the time (Sim and Muller 2004) and were adequate to maintain an open Murray Mouth. Under natural conditions, the median flow to the sea at the Murray Mouth was 11,880 gigalitres per annum (MDBA 2011a).

Continuous barrage releases of about 2 gigalitres (2,000 megalitres) per day are desired to assist in maintaining an open mouth. Much larger volumes are required to provide a scouring effect, removing sand from the mouth.

The Murray Mouth closed for the first time in 1981. In 2002, during Millennium Drought conditions, the mouth almost closed and dredging was required for 8 years to keep it open. Dredging recommenced on 9 January 2015 and is yet to cease. Dredging is considered the most effective method of keeping the mouth open in terms of cost and environmental outcomes, when compared with other intervention methods.

Maintaining an open mouth is a key objective under the Murray–Darling Basin Plan, which was adopted in 2012. The Basin Plan seeks to ensure that the Murray Mouth remains open without the need for dredging 95% of the time.

Recreation in the form of boating, fishing, swimming and camping is concentrated in this part of the Ramsar site because of relatively easy access and close proximity to Adelaide.

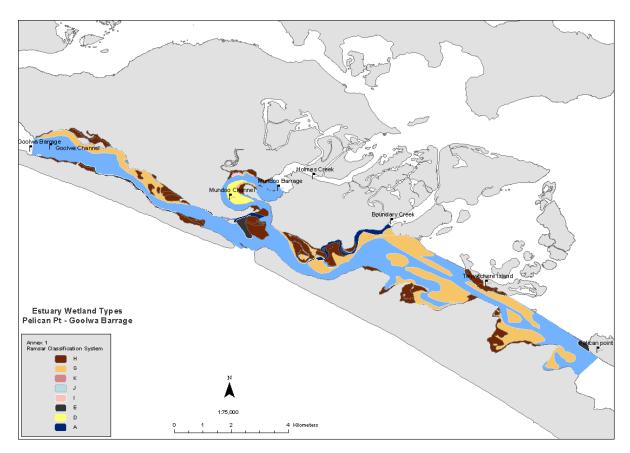


Figure 2.7 Murray Estuary and associated Ramsar wetland types (Seaman 2003) from (Phillips and Muller 2006).

#### **Key for Ramsar wetland types**

- H Intertidal marshes, including salt marshes, salt meadows, saltings, raised salt marshes, and tidal brackish and freshwater marshes.
- G Intertidal mud, sand or salt flats.
- K Coastal freshwater lagoons, including freshwater delta lagoons.
- J Coastal brackish/saline lagoons: brackish to saline lagoons with at least one relatively narrow connection to the sea.
- I Intertidal forested wetlands, including mangrove swamps, nipah swamps and tidal freshwater swamp forests.
- E Sand, shingle or pebble shores, including sand bars, spits and sandy islets, dune systems and humid dune slacks.
- D Rocky marine shores, including rocky offshore islands, sea cliffs.
- A Permanent shallow marine waters in most cases less than 6 m deep at low tide, including sea bays and straits.

The Murray Mouth is a part of the Meeting of the Waters, a highly significant cultural and spiritual place for Ngarrindjeri people. It is fundamental to their wellbeing. The Murray Mouth area, a place where the freshwater and saltwater mix, is the Ngarrindjeri place of creation – a place of birthing for Ngarrindjeri Ngartjis. This site is particularly important as it dramatically illustrates the key principles of flow, reproduction and interconnected benefit that underpin much of Ngarrindjeri philosophy. Kaldowinyeri stories such as Thukabi, Ngurunderi, the Muntijinggar and the Mulyewongk are associated with the Murray Mouth connecting Ngarrindjeri spiritually and culturally to this part of Yarluwar-Ruwe (Ngarrindjeri 2019).

Ngarrindjeri families continue this 'mixing of the waters' through marriages that connect the saltwater and freshwater parts of Ngarrindjeri Ruwe. This follows the traditions established in the Kaldowinyeri story of the Mulyewongk connecting the River Murray, lakes and the Murray Mouth. The following Kaldowinyeri stories (Creation stories) are different accounts linked to the connection of the river, lakes and Murray Mouth and mixing of the waters in this area:

#### Mulyewongk

The woman Mulyewongk drew from her mouth the water from the sea, she sucked the sea in and over the land, she opened the Murray to the sea and it mixed with fresh water so the salt water can preserve the sedges and can hold the land. This story is about before Ngurunderi came down the Murray and carved out the River channel to the sea making it the river it is today (Daisy Rankine in Bell 2014; Ngarrindjeri 2019).

#### Krowi thukabi (giant short-necked turtle)

The Kaldowinyeri story of Krowi Thukabi (the giant short-necked turtle) explains the creation of the Murray Mouth and connects Ngarrindjeri culturally and spiritually to this part of Yarluwar-Ruwe. Krowi Thukabi the giant turtle travelled across the country from the Darling before Ngurunderi's travels. As Thukabi travelled looking for a place to lay her eggs she made many wetlands and backwaters. When she got to the sea she made the mouth of the river by pushing herself into the sea (see Hemming et al. 2002; Bell 1998; Kaempf and Bell 2014; Ngarrindjeri 2019).

#### 2.6.2.1 Coorong North Lagoon

A long coastal lagoon stretching from Pelican Point to Parnka Point, the Coorong North Lagoon is approximately 50 kilometres long with an average width of less than 3 kilometres and covers an area of approximately 11,069 hectares (Figure 2.8). The Coorong North Lagoon may be classified as estuarine-saline with salinity controlled by freshwater inflows (primarily from Tauwitchere Barrage), tidal exchange through the Murray Mouth, evaporation and inflows of hypersaline water from the Coorong South Lagoon (Lamontagne et al. 2004). Although the Coorong North Lagoon is a permanent waterbody, the area of inundation varies diurnally and seasonally with the tide and inflows, resulting in the exposure of mudflats and intertidal marshes along the shoreline (Boon 2000). This area provides important habitat for a large number of waterbirds, including migratory shorebirds, which are recorded in high numbers during spring and summer (Oborne 2003 cited in Phillips and Muller 2006).

A salinity gradient generally exists in the North Lagoon, with lower salinity in the northwest (as low as 5 ppt during times of freshwater inflow) and higher salinity towards the Needles and the connection to the Coorong South Lagoon (up to 90 ppt during low flow periods) (Phillips and Muller 2006). Horizontal salinity gradients can form in the water column suggesting stratification under certain conditions (Geddes 2003 cited in Phillips and Muller 2006).

The completion of the barrages in the 1940s created a sharp disjunct between estuarine and freshwater systems resulting in a change to the salinity gradient of the Coorong North Lagoon. Saline to hypersaline conditions (equal or greater than seawater) now dominate the Coorong North Lagoon and much of the flora and fauna that are adapted to fresher conditions are no longer present.

The distribution of seagrasses in the Coorong predominately reflects the hyper-salinity tolerance of the seagrass and changes to the saline gradient in the Coorong. *R. tuberosa* is the most salt tolerant, followed by *Ruppia megacarpa* and other primarily estuarine seagrass species. Submerged vegetation, including *Ruppia*, provides much of the detritus in the Coorong North Lagoon and, as such, is the food source for detritivores such as fish and macroinvertebrates. *Ruppia* also provides an important habitat for fish and aquatic invertebrates and its leaves, seeds and turions are a source of food for a large number of waterfowl, (including the black swan, Australian shelduck, grey teal and chestnut teal) and migratory shorebirds (Ecological Associates 2010).

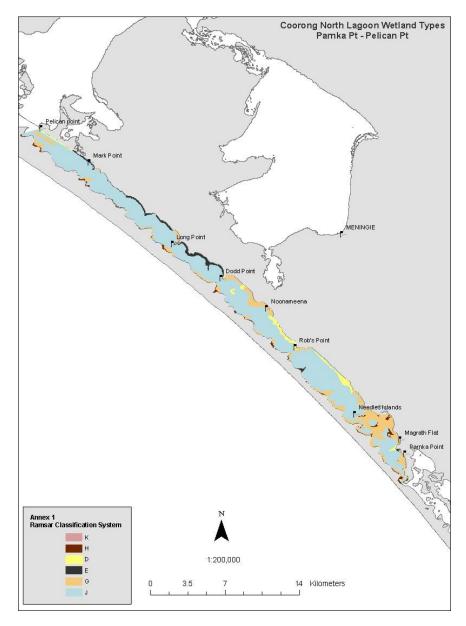


Figure 2.8 Coorong North Lagoon and associated Ramsar wetland types (Seaman 2003) from (Phillips and Muller 2006).

#### **Key for Ramsar wetland types**

- K Coastal freshwater lagoons, including freshwater delta lagoons.
- H Intertidal marshes, including salt marshes, salt meadows, saltings, raised salt marshes, and tidal brackish and freshwater marshes.
- D Rocky marine shores, including rocky offshore islands, sea cliffs.
- E Sand, shingle or pebble shores, including sand bars, spits and sandy islets, dune systems and humid dune slacks.
- G Intertidal mud, sand or salt flats.
- J Coastal brackish/saline lagoons: brackish to saline lagoons with at least one relatively narrow connection to the sea.

#### **Coorong South Lagoon**

The Coorong South Lagoon is a long, narrow coastal saline to hypersaline lagoon extending from Parnka Point to 42 Mile Crossing, covering an area of approximately 9,440 hectares (Figure 2.11). The Coorong South Lagoon is connected to the Coorong North Lagoon by a narrow channel at its northwest end. Evidence suggests that the Coorong South Lagoon was fresher prior to the mid 1950s (Krull et al. 2009). Increased salinity and unfavourable water levels in the Coorong South Lagoon over recent years, brought about by low freshwater inflows, have led to a severe decline of keystone species such as *R. tuberosa*, chironomids and small-mouthed hardyheads (*A. microstoma*) (MDBA 2014b).

Water levels vary seasonally by approximately 0.9 metres (Lamontagne et al. 2004 cited in Phillips and Muller 2006) with predominantly higher levels in winter and lower in summer. This results in the seasonal exposure of extensive areas of mudflats, which provides foraging and nesting habitat for large numbers of waterbirds. At its southern end, the Coorong South Lagoon contracts through an annual drying cycle into a series of shallow and ephemeral salt lakes (Boon 2000 cited in Phillips and Muller 2006).

Salinity is considerably higher in the Coorong South Lagoon than in the Coorong North Lagoon. From 2012 to 2016 salinity was 71 ppt in the Coorong South Lagoon with the 95<sup>th</sup> percentile 120 ppt. Salinity in the Coorong South Lagoon is influenced by salinity and water levels in the Coorong North Lagoon, which are determined by flows over the barrages. Coorong South Lagoon salinity is also influenced by flows from the Upper South East. The groundwater fed freshwater soaks found along the Coorong Lagoon shoreline of the Younghusband Peninsula are the only freshwater bodies on the Peninsula. They support a range of aquatic plants and waterfowl (Paton 2010).

During the Millennium Drought, salinity, total nitrogen and total phosphorus increased significantly between 2004 and 2010. Chlorophyll *a* and turbidity were lower from 2007 to 2010, probably due to lack of nutrient supply for algal production and high salinities promoting particle aggregation. The return of higher River Murray flows and water releases through the barrages in late 2010, as a result of extensive flooding, resulted in decreasing salinity, total nitrogen and total phosphorus, while chlorophyll *a* and turbidity increased in the recovery period from 2011 to 2016 (Stone et al. 2016).

Construction of the South East Flows Restoration Program (SEFRP) was completed in April 2019. The SEFRP was constructed primarily for the purpose of preventing salinity in the Coorong South Lagoon reaching ecologically damaging high levels during periods of low barrage flows, such as that which occurred during the Millennium Drought. Prior to the SEFRP, there have been South East flow events that have arguably over-freshened the Coorong South Lagoon. For example, in 2013 total inflows at Salt Creek were 46,760 megalitres (DEW 2018) and Coorong South Lagoon salinity dropped to approximately 53 g/L at Snipe Island (DEW 2018). By increasing the capacity of terminal storage in the South East drainage network from approximately 8 gigalitres to 42 gigalitres and retaining the ability to divert Blackford Drain flows to sea, the SEFRP will greatly improve the ability to control releases to the Coorong, as they are required.

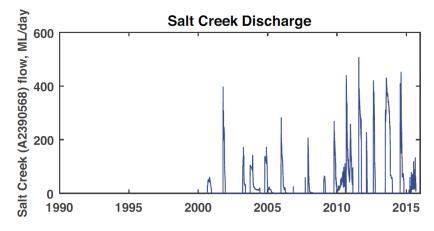


Figure 2.9 Salt Creek/Morella basin outflows from 1996 to 2016 (no previous data available).

Prior to the Millennium Drought, the submerged annual plant *R. tuberosa* dominated the Coorong South Lagoon. *R. tuberosa* is a key aquatic plant for the Coorong, as it is a food source for waterbirds (black swan, Australian shelduck, grey teal, chestnut teal and migratory shorebirds) and provides habitat and food for fish and other species (Government of South Australia 2014). Changes to the hydrology of the Coorong and the Millennium Drought led to hyper-salinity (of up to 200 ppt) and low water levels that exceeded the tolerance of *R. tuberosa*. Its distribution contracted out of the Coorong South Lagoon, leaving small, isolated patches only in the Coorong North Lagoon in 2010. Seedbanks became depleted and when water returned to the Coorong in 2010, *R. tuberosa* populations did not recover to pre-drought densities. Given the importance of *R. tuberosa* for the Coorong ecosystem, a translocation program was established to facilitate its recovery. Translocation from a seedbank from Lake Cantara to Policeman Point and Woods Well in 2013 and to Fat Cattle Point, Jacks Point and Seagull Island in 2014 facilitated recovery at these sites. Since 2012–13, there has been an increase in the occurrence of filamentous green algae blooms in the Coorong that has interfered with the recovery of *R. tuberosa* (Paton and Bailey 2014).



Figure 2.10 R. tuberosa with filamentous algae (Photograph: Jason Nicol).

Significant alterations to the drainage processes of the South East, which once naturally flowed slowly north-west through wetlands and into the Coorong South Lagoon, had a negative effect on the Ngarrindjeri. Freshwater has been redirected from the traditional flow paths that fed the Kurangk, the associated ephemeral lakes, wetlands and important freshwater wells and soaks. Locally useful soaks dried up and other changes occurred such as alterations to the feeding habits of swans and the patterns of fish behaviour associated with the use of fish traps.

The following statement by George Trevorrow (deceased) highlights the importance of maintaining connectivity (Ngarrindjeri 2019):

Years and years ago, they started draining the southeast and they've turned it into farm country. Because of what we've been told from our Old People, the country is on an angle, coming from the southeast. We've got underground waterways that run right through here where the water comes through. And we have the surface water that used to come through every year. We're not saying this was full, absolutely full of this precious water every year, all year round. But it certainly was for the better part of the year. It held good quality water and that water gave life. It gave life to what we describe as our Ngartjis, that's like a spiritual connection between us and the animals and the fish and the plants. We're linked to one thing. Our Ngartjis live off those things. There's things that we don't see any more growing here, because the mixtures of the waters aren't here anymore. And that makes us sad. (Trevorrow in Bell, 2014:653)

#### **PUBLIC**

Historically, water flowed through and freshened the Coorong, making it a combination of fresh and salty water which would bring life to fish and birds. The Coorong South Lagoon was a major breeding ground for Ngarrindjeri Ngartjis such as wankeri (jumping mullet) and birds such as ngori (Australian pelican). This flow of freshwater brought life to Ngarrindjeri Yarluwar-Ruwe and therefore ensured the wellbeing of Ngarrindjeri people. It is important to the health of Yarluwar-Ruwe that flows are restored. Freshwater soaks along the Coorong continue to be crucial for Ngarrindjeri and they are connected with Ngurunderi's Kaldowinyeri story (Ngarrindjeri 2019).

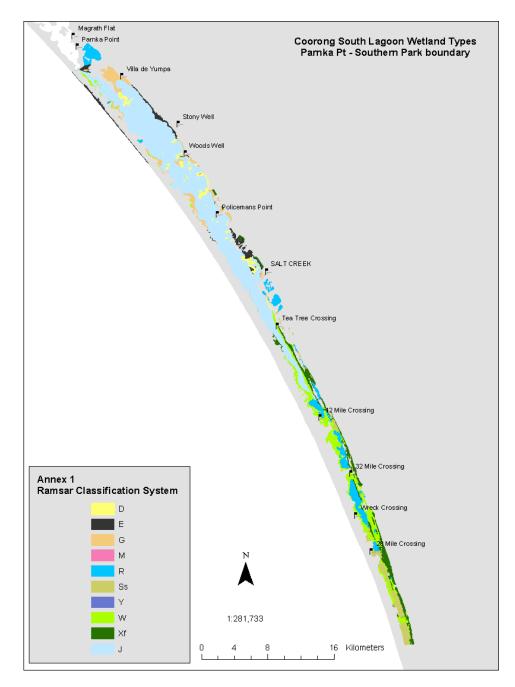


Figure 2.11 Coorong South Lagoon and associated Ramsar wetland types (Seaman 2003) from (Phillips and Muller 2006).

#### **Key for Ramsar wetland types**

- D Rocky marine shores, including rocky offshore islands, sea cliffs.
- E Sand, shingle or pebble shores, including sand bars, spits and sandy islets, dune systems and humid dune slacks.
- G Intertidal mud, sand or salt flats.
- M Permanent rivers/streams/creeks, including waterfalls.
- R Seasonal/intermittent saline/brackish/alkaline lakes and flats.
- Ss Seasonal/intermittent saline/brackish/alkaline marshes/pools.
- Y Freshwater springs, oases.
- W Shrub-dominated wetlands: shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.
- Xf Freshwater, tree-dominated wetlands, including freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.
- J Coastal brackish/saline lagoons: brackish to saline lagoons with at least one relatively narrow connection to the sea.



Ramsar types E, G & H Murray Mouth and Murray Estuary (Shane Reid)

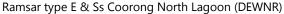
The Murray Mouth is the only break in the oceanic sand dunes along the 2 peninsulas. Sandy shores and bays occur between Goolwa Channel, Sir Richard Peninsula and Bird Island, with spits and sand bars near the Murray Mouth.

Intertidal mud, sand or salt flats and intertidal marshes are the dominant wetland types in the Murray Estuary.



Sections of narrow sandy shorelines occur in patches along the Coorong.

Small saline marshes support complex samphire communities (e.g. Salicorna blackiana) and exist in a mosaic of habitats with wetland types R, Xf and W to form a complex of wetland floral assemblages





The type W samphire communities are supported by a fresher water regime than the SS communities and are not dominated by evaporating salinas. They are connected to Type Ss, XF and R wetlands and form part of a mosaic to fresh to hypersaline habitats.

Ramsar type J & W, Coorong (Alysha Menzel)

Figure 2.12 Examples of wetlands in the saline components of the site.

#### 2.7 Ramsar Criteria

#### 2.7.1 Current Ramsar criteria met

In 2015 the Ramsar site has been assessed as meeting 8 of the 9 of the current Ramsar criteria as described below.

For Ngarrindjeri each of the criteria below are culturally recognised aspects of Ngarrindjeri Ruwe/Ruwar. Various species are key Ngartjis and have powerful, cultural significance. The Creation stories reinforce the value of the Ramsar site as fundamental to the reproduction of all living things within Yarluwar-Ruwe. As such, the following criteria also embody Ngarrindjeri Ruwe/Ruwar and cannot solely be perceived as 'ecological' in this context (Ngarrindjeri 2019).

## 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 Coorong and Lakes Alexandrina and Albert Wetland consists of a mosaic of 23 Ramsar wetland types, including intertidal mud, sand or salt flats, coastal brackish/saline lagoons, permanent freshwater lakes, permanent freshwater marshes/pools, shrub-dominated wetlands and water storage areas. 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 and Muller 2006). Refer to section 2.6 for more information on the extent of wetland types in the Ramsar site.

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

This criterion applies to nationally threatened wetland dependent species/communities, listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or internationally listed under the International Union for Conservation of Nature (IUCN) Red List (IUCN 2012). The Ramsar site regularly supports 8 threatened species and 2 ecological communities:

- Swamps of the Fleurieu Peninsula (EPBC: critically endangered)
- Subtropical and temperate coastal saltmarsh (EPBC: vulnerable)
- Murray hardyhead (EPBC: endangered)
- Australasian bittern (EPBC, IUCN: endangered)
- Australian fairy tern (EPBC, IUCN: vulnerable)
- Curlew sandpiper (EPBC: critically endangered)
- Eastern curlew (EPBC: critically endangered, IUCN: endangered)
- Hooded plover (IUCN: vulnerable)
- Mount Lofty Ranges southern emu-wren (EPBC, IUCN: endangered)
- Southern bell frog (EPBC: vulnerable, IUCN: endangered).

The Swamps of the Fleurieu Peninsula ecological community occur sparsely throughout the Fleurieu Peninsula, with only a component of the community (estimated at approximately 262.5 hectares in the Ramsar site in 2005; a significant proportion of the Swamps remaining at that time) found within the Currency Creek and Finniss River areas located in the Ramsar site. This community is dependent on surface water runoff and groundwater, is associated with the freshwater submergent and emergent vegetation communities, and supports the Mount Lofty Ranges southern emu-wren (*Stipiturus malachurus intermedius*).

The subtropical and temperate coastal saltmarsh found within the Murray Estuary and Coorong North Lagoon was listed in 2013. The extent and condition of this community within the Ramsar site has not formally been established but is estimated to be more than 1,000 hectares.

Emergent vegetation of the margins and fringing wetlands of Lakes Alexandrina and Albert provide habitat for the endangered Australasian bittern (*Botaurus poiciloptilus*). The Coorong provides important foraging habitat for migratory shorebirds such as the critically endangered curlew sandpiper (*C. ferruginea*) and eastern curlew (*Numenius madagascariensis*) and breeding habitat for the vulnerable Australian fairy tern (*S. nereis nereis*). The vulnerable hooded plover (*T. rubricollis*) forages and nests on shores of the Coorong and beaches of the Sir Richard and Younghusband Peninsulas.

The nationally listed southern bell frog (*Litoria raniformis*) is 1 of 8 frog species that have been regularly recorded in the Ramsar site since 2009 (Mason and Turner 2018).

Three threatened species, the Yarra pygmy perch (*Nannoperca obscura*), Australian painted snipe (*Rostratula australis benghalensis*) and orange-bellied parrot (*Neophema chrysogaster*) currently only occur in very low numbers or are infrequent visitors to the site and are not regularly supported at the site.

## 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 a vast array of species not encountered together elsewhere in the Murray–Darling Basin bioregion, due to the diverse range of aquatic ecosystem types present, ranging from inland freshwater and saline lacustrine and palustrine systems to estuarine and near-shore marine habitats.

The site supports over 1400 species of flora which includes 279 aquatic plant species ranging from obligate freshwater species to halophytic species and emergent riparian species (DEW 2013). There are 23 wetland types within the Ramsar site, which provides a diversity of habitats for many species, notably waterbirds and fish, as well as contributing to regional aquatic biodiversity values.

A total of 104 fish species have been recorded in the Ramsar site, with approximately 30 fish species that are regularly supported by the site (Bice 2010; Watt 2013; Bice at al. 2018) (refer to Appendix A for species lists). This includes species that are not found anywhere else within the Murray–Darling Basin, such as the small-mouthed hardyhead (A. microstoma), lagoon goby (Tasmanogobius lasti) and Tamar River goby (Afurcagobius tamarensis). In addition to the conservation significant species listed under Criterion 2, 3 fish species protected under the South Australian Fisheries Management Act 2007 have been recorded in the Ramsar site, including freshwater catfish (Tandanus tandanus), southern purple-spotted gudgeon (Mogurnda adspersa) and southern pygmy perch (Nannoperca australis) (Bice 2010; Bice et al. 2018). Other species of conservation significance in South Australia include: dwarf flat-headed gudgeon (Philypnodon macrostomus), unspecked hardyhead (Craterocephalus stercusmuscarum fulvus), congolli (Pseudaphritis urvillii), pouched lamprey (Geotria australis), short-headed lamprey (Mordacia mordax), mountain galaxias (Galaxias olidus), estuary perch (Macquaria colonorum) and short-finned eel (Anguilla australis) (Bice 2010; Lintermans 2007). The Ramsar site forms the only estuarine habitat in the Murray–Darling Basin and is therefore the only access point for diadromous fish species within the Murray–Darling Basin.

The site supports high bird species richness, with 307 bird species recorded within one kilometre of the site, 118 of which utilise wetland habitats (O'Conner 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 2015a). The site supports the highest waterbird species richness and abundance of any of the Ramsar sites in the southern connected Murray-Darling Basin, with 92% of the approximately 250,000 waterbirds counted across all 6 sites and 44 of the 46 waterbird species surveyed (O'Conner et al. 2012).

In addition to the 8 waterbirds listed as threatened under national or international conservation agreements (under Criterion 2), a number of waterbird species are of state or regional conservation significance. These include little tern (*Sternula albifrons*), white-bellied sea eagle (*Haliaeetus leucogaster*), banded stilt (*Cladorhynchus leucocephalus*), freckled duck (*Stictonetta naevosa*), Lewin's rail (*Lewinia pectoralis*), Australasian shoveler (*Anas rhynchotis*), blue-billed duck (*Oxyura australis*) and sooty oystercatcher (*Haematopus fuliginosus*) (O'Connor et al. 2015).

Eight frog species have been recorded in the Ramsar site since 2009 (Mason and Durbridge 2015), including brown toadlet (*Pseudophryne bibronii*), which is rare in South Australia, and the marbled toadlet (*Pseudophryne semimarmorata*), which is listed as vulnerable in South Australia. The nationally listed southern bell frog (*L. raniformis*) is one of the 8 species that have been regularly recorded in the Ramsar site since 2009 (Mason and Turner 2018). Other fauna of note include the common long-necked tortoise (*Chelodina longicollis*), the Macquarie tortoise (*Emydura macquarii*), water rat (*Hydromys chrysogaster*) and swamp rat (*Rattus lutreolus*). The latter 2 are considered rare in South Australia (based on data from BDBSA extracted November 2013).

## 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 that are listed as migratory under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and international migratory species agreements (i.e. CAMBA, JAMBA, ROKAMBA or CMS) (Table 13-5 in Appendix B).

A total of 38 waterbird species are known to breed within the site, of which 15 bird species are known to regularly breed at the site (O'Connor 2015a). This includes annual breeding species such as the Australian pelican (*Pelecanus conspicillatus*), silver gull (*Chroicocephalus novaehollandiae*) and straw-necked ibis (*Threskiomis spinicollis*) (O'Connor et al. 2012). See Appendix B for a summary of the breeding records of the site. Other bird species that rely on the site for adult survival when inland lakes are dry include the red-necked avocet (*Recurvirostra novaehollandiae*), chestnut teal (*Anas castanea*), Australian shelduck (*Tadorna tadornoides*) and banded stilt (*Cladorhynchus leucocephalus*) (O'Connor et al. 2012).

At least 56 bird species regularly use the site as a critical refuge while moulting, including the Australian shelduck (*T. tadornoides*), chestnut teal (*A. castanea*), black swan (*C. atratus*), banded stilt (*C. leucocephalus*), black-winged stilt (*Himantopus himantopus*), red-necked avocet (*R. novaehollandiae*) and Australian pelican (*P. conspicillatus*) (O'Connor et al. 2015). All internationally migratory shorebirds gradually replace their flight feathers upon landing at the site in summer (Paton 2010) (O'Connor et al. 2012).

The site supports a number of diadromous fish species, including congolli (*P. urvillii*), common galaxias (*G. maculatus*) and pouched lamprey (*G. australis*) (with records also of short-headed lamprey (*M. mordax*)), 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 and 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 2015a). An average of 256,602 waterbirds are recorded in the January census each year, based on data from 2000 to 2015. The Coorong generally supports twice as many birds as the Lakes in summer, with the average number of birds supported in the Coorong (in January) greater than 167,000 between 2000 and 2015 compared to an average of 79,000 birds in the Lakes between 2009 and 2015 (Paton et al. 2015d). During the Millennium Drought (2000–10) the Ramsar site was an important waterbird refuge and supported over 400,000 waterbirds at times (Figure 8.15) (Paton et al. 2015d).

Annual census data identified 17 species present in numbers of greater than 1000 birds per year (in at least 3 out of 5 years). Species that contribute substantially to this abundance include Australian pelican (*P. conspicillatus*), Australian shelduck (*T. tadornoides*), banded stilt (*C. leucocephalus*), grey teal (*Anas gracilis*) and red-necked stint (*C. ruficollis*).

The abundances of waterbirds that the Ramsar site supports greatly varies between geographic locations (Paton et al. 2009a) and also varies substantially from year to year, reflecting the nature of the bird's use of the site (Paton et al 2015; Paton et al. 2018).

## Criterion 6: A wetland should be considered internationally important if it regularly supports 1% 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 7 species. These species include Australian pied oystercatcher (*H. longirostris*), Australian fairy tern (*S. nereis nereis*), chestnut teal (*A. castanea*), curlew sandpiper (*C. ferruginea*), red-capped plover (*Charadrius ruficapillus*), red-necked stint (*C. ruficollis*) and sharp-tailed sandpiper (*Calidris acuminata*). The estimated total population size for these species is from the Wetlands International estimates published in 2013 and as described in (O'Connor 2015a).

The species that currently meet this criteria are different from those presented in O'Connor et al. (2012) and the 2013 RIS, which used older population estimates (2006).

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.

One hundred and four 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. Of the 104 species, around 30 species occur regularly within the site and represents an assemblage with a diverse range of morphologies, sizes and life histories (Phillips and Muller 2006; Bice 2010; Watt 2013; Bice et al. 2018).

The site is the only access point to the Murray–Darling Basin for diadromous fish species (DEWNR 2013) 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 regard to morphology and life history. Fishes range in size (adult length) from 40 millimetres to greater than one metre, 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). The site is home to a number of genetically distinct fish populations in the context of both South Australia and the Murray–Darling Basin (Hammer et al. 2009). However, as these populations represent species that are found in other areas of Australia, it is thought that this site does not meet this aspect of the criterion (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 (Table 13-1) (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 crucial as a migration pathway for a number of fish species, including common galaxias (*G. maculatus*), congolli (*P. urvillii*), pouched lamprey (*G. australis*) and short-headed lamprey (*M. mordax*) (Bice 2010; Watt 2013). Within the Ramsar site, 3 guilds of diadromous fish are found, including:

- (1) Anadromous migration from adult marine habitats to freshwater spawning and nursery habitats (Potter et al. 2015). The Ramsar site supports pouched lamprey and short-headed lamprey, which are the only anadromous fish species in the Murray–Darling Basin (Bice et al. 2018).
- (2) Catadromous migration from adult freshwater habitats to marine habitats for spawning (Potter et al. 2015). Congolli is a catadromous fish species supported by the Ramsar site, with the connectivity and habitats enabling winter spawning migrations of female congolli (from the lower River Murray, EMLR 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— generally catadromous life-history but migration from freshwater habitats ceases in estuarine environments (Potter et al. 2015). The connectivity and habitats supported in the Ramsar site enable species, such as common galaxias, to 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).

Resident Murray Estuary fish which utilise estuaries for their entire life cycle (Elliott et al. 2007) are commonly encountered within the Murray Estuary and Coorong North Lagoon (Ye et al. 2012). These include the small-mouthed hardyhead (A. microstoma), Tamar River goby (A. tamarensis), greenback flounder (Rhombosolea tapirina) and black bream (Acanthopagrus butcheri). These species utilise the site as a spawning ground, nursery and as adult habitat. The Ramsar site is important for marine estuarine opportunist species, such as mulloway (Argyrosomus japonicus) which tend to utilise the Murray Estuary during their juvenile life stage. The population of mulloway located in the River Murray system are estuarine-dependent, as the Estuary provides important refuge for juveniles (Ferguson et al. 2008). Other marine estuarine opportunists to use the site as a nursery include the sandy sprat (Hyperlophus vittatus) (Watt 2013). These marine estuarine opportunist species (also including yelloweye mullet and greenback flounder) are important in commercial and recreational fisheries (Ferguson et al. 2018).

The Ramsar site provides a range of fish species with sources of food, spawning grounds and nurseries and acts as a migration path on which diadromous fishes of the region depend.

# 3 Ngarrindjeri perspective of the Ramsar site and its health

The text contained within this chapter has been provided by the Ngarrindjeri. In recognition of the Ngarrindjeri's continuing ownership of their traditional knowledge, cultural expressions and intellectual property, any proposed use of Ngarrindjeri text or cultural knowledge contained herein should be the subject of a formal request and/or consultation with the Ngarrindjeri nation.

For Ngarrindjeri, the freshwater flows travelling down the Murray–Darling system and into their lands and waters are seen as the life blood of the living body of Yarluwar-Ruwe (Sea Country), the Murrundi (River Murray), Lower Lakes and the Kurangk (Coorong). These waters bring life to the Ramsar site's waters and therefore they bring life to the Ngarrindjeri. The waters of the seas, the waters of the Kurangk, the waters of the rivers and the Lakes are all spiritual waters (Bell 1989, 2008 and 2014; Hemming et al. 2002; Ngarrindjeri 2006; Birckhead 2011).

Kaldowinyeri stories (Creation stories) are passed down from generation to generation to explain how the land and water, animals and people came to be what and who they are. Creation ancestors such Ngurunderi, Pondi, the Muntjinggar, Thukabi and Wururi teach Ngarrindjeri how to respect and understand the connection between the lands, the waters and the sky. These stories also document changes in the ecological character of the region over millennia and carry deep Ngarrindjeri ecological knowledge of the Ramsar site, including connectivity with the surrounding lands. They explain the richness of the available natural resources, including freshwater and saltwater aquatic life such as fish, shellfish, eels, waterbirds and water plants. Fundamentally they provide Ngarrindjeri with the laws and lessons for sustainable use, care and management of these species, lands and waters and are Ngarrindjeri descriptions of the Ramsar site. Tom Trevorrow (deceased) explains:

...everything is connected: the lands, the water, the plants, the animals, our relationship with our country, our responsibilities for caring for our Ngartjis, all of these things have been managed collectively. If our Ngartjis die and our land and waters die in our stories we die and that's where our stories were created to tell us how to manage country and care for country. It was a completely balanced system and we have obligations to our Ngartjis that look after country and it's our essential wellbeing of who we are as Ngarrindjeri. We have cared for this country for thousands of years and it has sustained us. (Tom Trevorrow, Change Media and NRA 2013)

Ngarrindjeri men and women hold specific cultural and environmental knowledge and both genders continue to be involved in passing down Ngarrindjeri knowledge between generations and in the decision-making about Ngarrindjeri affairs, land, waters and resources. This is illustrated by Ngarrindjeri kinship systems and the strong cultural and spiritual connections Ngarrindjeri have to particular places, to particular species of animals and plants and to various elements of the environment. Particular animal and plant species are the Ngartjis (totems or special friends) of Ngarrindjeri people, who in turn have special responsibility to care for their Ngartji. This relationship is described in the following statement made by Ngarrindjeri Rupelli (traditional leader), George Trevorrow (deceased):

Ngartji to non-Aboriginal people is like a totem which each one of us has and each group belongs to. It could be the pelican. It could be the swan. It could be the mullet. There are different species of... animal, fish, plant, but each group belongs to that Ngartji. A Ngartji is something that is more than a close friend. It's more your best friend. It is something that is more closely to you. (George Trevorrow in Bell 2014)

Ngartjis are of great importance and to care for Ngartji is to care for country. Without their Ngartjis, Ngarrindjeri believe they cannot survive. Ngartjis are indicators of the health of the lands and waters, a function they can also perform from the western scientific perspective. If Ngartjis are numerous, in good health and breeding readily, it is an indication that the whole of Yarluwar-Ruwe is functioning well.

The Ramsar site contains an archaeological record spanning over 5,000 years of continuous Ngarrindjeri occupation. These Old People's living places (e.g. middens, burial grounds and other sacred places) are very important to the Ngarrindjeri and provide evidence of Ngarrindjeri customs, knowledge and traditions over many thousands of years.

To explain this interconnectivity between land, waters, spirit and all living things Ngarrindjeri use the term Ruwe/Ruwar. This fundamental spiritual connection (Ruwe/Ruwar) is reliant on healthy lands and waters and the maintenance of connectivity between the Kurangk, Lower Lakes and Murray Mouth as created by Ngurunderi and other Creation ancestors. It is the responsibility of present Ngarrindjeri to care for and speak for Ngarrindjeri Ruwe/Ruwar (Yannarumi). For Ngarrindjeri the Ramsar site is a part of Yarluwar-Ruwe and a cultural landscape, shaped during the Creation by ancestor beings and by the management of Ngarrindjeri as custodians of the land over thousands of years.

From this perspective and using the language of the ECD, Ngarrindjeri and their responsibilities for Yarluwar-Ruwe can be understood as embodying all components, process and services of the Ramsar site (see Hemming and Rigney 2016; Hemming et al. 2016). Kaldowinyeri stories explain the cultural connections between Ngarrindjeri and Yarluwar-Ruwe and provide Ngarrindjeri descriptions of the Ramsar site. While not all of these stories are appropriate for public knowledge, others have been made public for educational purposes and are included throughout the ECD, as they provide insight into Ngarrindjeri philosophy that does not divide between Ngarrindjeri and what western science define as the physical landscape. The following provides an overview of key parts of the Ngurunderi Kaldowinyeri story:

#### **Ngurunderi the Creator**

A long time ago Ngurunderi, our Spiritual Ancestor, travelled down the River Murray in a bark canoe in search of his 2 wives who had run away from him. At that time the River was only a small stream below the junction with the Darling River. A giant Murray Cod, Pondi, swam ahead of Ngurunderi. Pondi had nowhere to go, so he went ploughing and crashing through the land. His huge body and tail created the mighty River Murray. Near Murray Bridge, Ngurunderi threw a spear, but it missed and was changed into Lentelin (Long Island). At Tagalung (Tailem Bend) he threw another spear. The giant fish surged ahead and created a long straight stretch in the River. When Ngurunderi and his brother-in-law Nepele caught Pondi, at the place where the fresh and salt water meet they cut him up into many pieces and made the fresh and salt water fish for the Ngarrindjeri people. To the last piece Ngurunderi said, "You keep being a Pondi".

Meanwhile, Ngurunderi's 2 wives, the sisters of Nepele, had made camp. They were cooking thukeri (bony bream), a fish forbidden to Ngarrindjeri miminar (women). Ngurunderi smelt the fish cooking and knew his wives were close. He abandoned his camp and came after them. His huts became 2 hills and his bark canoe became the Warriewar (the Milky Way). Hearing Ngurunderi coming, his 2 wives built a raft of reeds and grass trees to escape across Lake Albert. On the other side, their raft turned back into reeds and grass trees. The women hurried south.

Ngurunderi followed his wives as far south as Kingston. Here he met a powerful man, Purumpari. The 2 men fought, using weapons and special powers, until Ngurunderi won. He burned Purumpari's body in a huge fire. It became granite boulders on the beach. Ngurunderi turned north along the Coorong Beach. Here he camped several times, digging soaks in the sand for fresh water and fishing in the Coorong Lagoon. Ngurunderi made his way across the Murray Mouth and along Encounter Bay towards Victor Harbour. He made a fishing ground near Middleton by throwing a huge tree into the sea to make a seaweed bed. Here he hunted a seal and its dying gasps can still be heard among the rocks. At Port Elliot he camped and fished again, without seeing a sign of his wives. He became angry and threw his spears into the sea at Victor Harbor, creating the islands there. Finally, after resting under a giant granite shade-shelter on Kaike (Granite Island), Ngurunderi heard his wives laughing and playing in the water near King's Beach. He hurled his club to the ground, creating Longkuwar, (the Bluff) and strode after them.

His wives fled along the beach in terror until they reached Cape Jervis. At this time Karta (Kangaroo Island) was still connected to the mainland and the 2 wives began to hurry across it. Ngurunderi had arrived at Cape Jervis and seeing his wives still fleeing from him, he called out in the voice of thunder for the waters to rise. The women were swept from their path by huge waters and soon drowned. They became the Pages islands.

Like other creation stories, Ngurunderi's journey ended at Karta from where he dived into the sea to cleanse his spirit and then ascended into the sky and became the bright star in Warriewar. Ngurunderi's story also refers to the role of ancestral women (in this case Ngurunderi's 2 wives) in creating the Country we know today.

As Ngurunderi the Creation ancestor travelled throughout Ngarrindjeri Country, he created landforms, waterways and life. He gave to his people the stories, meanings and laws associated with the lands and waters of his creation. He gave each Lakalinyeri (clan) its identity to Ngarrindjeri Ruwe (country) and Ngarjitis (animals, birds, fish and plants) - who are Ngarrindjeri peoples friends. Ngurunderi taught Ngarrindjeri how to hunt and gather foods from the lands and waters. He taught people don't be greedy, don't take any more than what you need and share with one another. Ngurunderi also warned Ngarrindjeri that if they don't share they will be punished. (Ngarrindjeri Nation 2006)

Ngarrindjeri respect the gifts of Creation that Ngurunderi passed down to their spiritual ancestors, to their Elders and to the present generations. Ngarrindjeri must follow the Traditional Laws; they must respect and honour the lands, waters and all living things. Ngurunderi taught Ngarrindjeri about their Miwi, which is their inner spiritual connection to the lands, waters, each other and all living things and which is passed down through their mothers since Creation. Thukeri (bony bream) are important in Ngarrindjeri law and the creation story associated with how the bony bream was created tells of the need to not be greedy, to always share and not to take too much – this is a story of reciprocity and responsibility. The Ngurunderi and Thukeri encapsulates the example of wise use.

#### **Thukeri Creation Story**

A long time ago 2 Ngarrindjeri men went fishing in a bay near Lake Alexandrina to catch the thukeri mami (bream fish). They set off in their bark canoe to catch the big fat thukeri. They fished and fished until their canoe was over full and they said we have plenty of thukeri we will paddle to shore before we sink. As they paddled to shore they saw a stranger coming towards them so they covered up the thukeri with their woven mats they said this man might want some of our thukeri, when they approached the shore the stranger said to them hey brothers I'm hungry have you got any fish to share, but the 2 Ngarrindjeri men said no we haven't got many fish we only have enough to feed our families. So the stranger began to walk away then he turned and said you have plenty of fish and because you are greedy and don't want to share you will not enjoy the thukeri fish ever again. As the stranger walked away the 2 Ngarrindjeri men laughed at him. When the 2 Ngarrindjeri men unloaded the thukeri on to the banks to scale and clean them, they saw that their nice big fat thukeri were bony and they didn't know what had happened. The 2 Ngarrindjeri men went home to the campsite in shame and told the Elders what had happened. The Elders were angry and said the stranger was Ngurunderi our Spirit Ancestor and because you 2 were greedy and would not share with him he has put a curse on our thukeri mami. Now all the Ngarrindjeri people will be punished. (Ngarrindjeri Nation 2006)

#### Wururi - the Huntsman Spider

The story of Wururi, the huntsman spider ngatji, tells how this bad tempered old woman living near Goolwa would roam about at night and scatter fires with her digging stick while people slept. When she died there was much happiness and messengers went forth, here and there, with the news. The people – women, men and children- gathered to feast and celebrate. As each group arrived and ate a different part of her body, they began to speak a distinct dialect. In the Wuruwi story, different dialects go to different parts of Ngarrindjeri Ruwe from the body of a female spider ngatji, just as food goes into the mouths of everyday huntsmen spiderlings who then scatter far and wide across Ngarrindjeri Ruwe (based on account in Kungun Ngarrindjeri Miminar Yunnan, Bell 2008).

For Ngarrindjeri the concept of Ruwe/ Ruwar provides a clear understanding of the requirements for a healthy relationship between Ngarrindjeri and Yarluwar-Ruwe. Incorporating a Ngarrindjeri Yannarumi assessment of the health, resilience and productivity of the region adds another dimension to understanding the markers of change that result in changes to ecological character.

# 3.1 Ngarrindjeri Yannarumi

Ngarrindjeri have a cultural responsibility to Speak as Yarluwar-Ruwe in accordance to Ngarrindjeri tradition/law to maintain the health of their lands and waters as a part of their own living body. When Ngarrindjeri exercise their right to speak and care for Yarluwar-Ruwe this is Yannarumi – Ngarrindjeri speaking lawfully as Country. To speak as Country highlights the centrality of Ngarrindjeri as an embodiment of Country and when this responsibility is not exercised, Ngarrindjeri wellbeing is compromised (see Hemming and Rigney 2016; Hemming et al. 2016).

Ngarrindjeri Yannarumi has a historical meaning and is being reconceptualised by Ngarrindjeri leaders in a contemporary form to take into account the impacts and changes that have occurred to Ngarrindjeri Yarluwar-Ruwe as a result of colonisation. When Ngarrindjeri meet to Speak as Country about things that impact on the wellbeing of Ngarrindjeri people and Ngarrindjeri Country (Ngarrindjeri Ruwe/Ruwar – Country, Body, Spirit and all living things) they make judgements based on the cultural principles passed down by the ancestors. This group of leaders and Elders is traditionally called the Tendi and when it meets, speaks and makes decisions this is known as a Yannarumi. This continuity of values and traditions is expressed as follows:

Our knowledge of Sea County will continue to underpin our survival and our economy. Tendi, our formal governing council, ensured and will continue to ensure our stable and sustainable society, which maintains our obligations to Sea Country (Ngarrindjeri Nation 2006).

# 3.2 A Ngarrindjeri Yannarumi assessment process

Ngarrindjeri speaking lawfully as country or Yannarumi has a historical meaning based on cultural principles that follow the laws of the Kaldowinyeri Ancestors and are guided by Elders and Ngarrindjeri leaders. A Yannarumi assessment is an assessment that takes into account Ngarrindjeri 'ecological' values/ knowledge based on interconnectedness of people and Country (Ruwe/ Ruwar). A Yannarumi assessment allows Ngarrindjeri to identify where the problems are within the system (environmental, political, education, health, economy) and why it is not reproducing Ngarrindjeri health and wellbeing. For example from a Ngarrindjeri perspective Ruwe/Ruwar is unhealthy if partnerships and relationships are not healthy and culturally appropriate; if people can't speak as country and that's not being recognised; if there are things that are affecting spiritual connection between people and Country; if what's going on disconnects lands and waters, people, plants and animals, rivers and lakes from the Coorong and sea and if the laws that were laid down in the Kaldowinyeri are not being respected. A Yannarumi assessment can be applied to a particular period of time to reach an overall assessment of the health and wellbeing of Ruwe/Ruwar at that point in time (Ngarrindjeri Nation 2006).

The Yannarumi assessment process applies Ngarrindjeri terms to communicate a 'measure' of the health of something that is being assessed. For example, connectivity is a critical principle in the health of Yarluwar-Ruwe so when things become disconnected or sick the words Wiran, Wurangi, Pukli, and Blewilin are used. Likewise, terms such as Katjeri or Nragi are applied when something is assessed as healthy (Table 3-1 and Table 3-2).

Table 3-1 Ngarrindjeri Yannarumi assessment – Ramsar site (Yarluwar-Ruwe) – summary.

	Kaldowinyeri	Ruwe/Ruwar	Miwi	Yannarumi	Ngiangiampe	Ngarrindjeri Yarluwar –
	Creation, Change	Country, body, spirit,	Spirit, connection	Speaking as Country,	Relationships, partnerships	Ruwe
	-	all living things	resilience	responsibility, management		Health assessment
Kaldowinyeri	Ruwe/Ruwar	Katjeri	Pritji	Rupelli	Tendi, Nguldun	Katjeri, Nraqi
Ngurunderi	All things connected	Beautiful, healthy	Strong	Elders Speaking as	Governance, agreements,	Beautiful
Creation	connected	ricultify		country	Being healthy	healthy
Parpun miwi	locks, barrages,	Wirun,	Pritji,	Blewilin	Wurangi	Blewilin,
Colonisation, Ramsar listing,	land cleared	Wurangi,	Wurreng- wulun	Unhealthy	Bad, disrespectful	<b>Pukli</b> Unhealthy,
Longing for wellbeing		Sick, Bad	Strong, Sorrowful			indicators of sickness

Table 3-2 Ngarrindjeri Yannarumi assessment definitions.

Ngarrindjeri Yannarumi assessment	Definition
Katjeri	Beautiful, healthy
Pritji	Strong
Nragi	Very healthy
Katjeri Nragi	Beautiful, very healthy
Wurangi	Bad, damaging, disrespectful,
Wirun	Very unhealthy, very sick
Wirun wurangi	Very sick, damaging
Wurreng-wulun	Sorrowful
Blewilin	Unhealthy, getting sick
Pulki	Strong markers of sickness

#### 3.2.1 A Yannarumi assessment of the Coorong and Lakes Alexandrina and Albert Wetland

Ngarrindjeri recognise that the Ramsar site was unhealthy at the time of listing as a result of human (non-Ngarrindjeri) impact and historical processes that have impacted on the reproductive capacity of Yarluwar-Ruwe. Past exclusion of Ngarrindjeri from exercising their cultural responsibility for Yarluwar-Ruwe has also contributed to the poor health of the Ramsar site and has impacted Ngarrindjeri wellbeing. Further losses of species, water quality, flows, breeding events etc. will have an increased detrimental effect on Ngarrindjeri wellbeing (Hemming and Rigney 2016).

From the mid-1980s Ngarrindjeri began to build new institutions such as Camp Coorong Race Relations and Cultural Education Centre (which closed in 2018) to begin educating the broader Australian society about their culture, identity and traditions. At the heart of this education was an attempt to provide the Ngarrindjeri perspective on the impacts of colonisation to their lives and their lands/waters and to explain the unique relationship that Ngarrindjeri have with their Country. Ngarrindjeri worked with the South Australian Education Department and the South Australian Museum to educate the non-Indigenous community about Ngarrindjeri history and understanding of the interconnectedness of the lands and waters, the people and all living things (Hemming et al. 2007; Hemming et al. 2016).

In the early 2000s Ngarrindjeri leaders made the following statement based on a Yannarumi assessment of the health of the Ramsar site and in particular the closure of the Murray Mouth:

The land and waters is a living body.

We the Ngarrindjeri people are a part of its existence.

The land and waters must be healthy for the Ngarrindjeri people to be healthy.

We are hurting for our country.

The Land is dying, the River is dying, the Kurangk (Coorong) is dying and the Murray Mouth is closing.

What does the future hold for us? (Trevorrow in Hemming et al. 2002)

By the mid to late 2000s the new Ngarrindjeri nations peak body, the Ngarrindjeri Regional Authority negotiated agreements with the South Australian Government that recognise Ngarrindjeri responsibilities to Care as Country such as the 2009 Whole of Government Kungun Ngarrindjeri Yunnan Agreement (KNYA) Listen to Ngarrindjeri speaking (Hemming et al. 2011).

#### The Meeting of the Waters - a registered Aboriginal heritage site

Through the KNYA process the Meeting of the Waters was registered as an Aboriginal heritage site under the *Aboriginal Heritage Act 1988* (SA). This 'site' includes the waters and the bed of the River Murray, lakes, Murray Mouth and Murray Estuary and also includes the Currency Creek and Finniss River wetlands. Its spiritual and cultural significance is essential to the wellbeing of the Ngarrindjeri Nation, Ngarrindjeri lands and waters and all living things (Bell 1998, 2008; Ngarrindjeri Nation 2006).

The South Australian Government and the Ngarrindjeri Regional Authority entered into a Ngarrindjeri Speaking as Country Deed (Yannarumi) 2014 that commits both parties to work together to develop broader understanding of the Meeting of the Waters cultural site/concept and what is meant by Speaking as Country (Yannarumi – Ngarrindjeri Ruwe/Ruwar). The deed affirms the importance of freshwater flows down the River Murray and an open Murray Mouth and commits parties to work together to ensure end-of-system flow objectives supporting the maintenance of the cultural health of the registered Meeting of the Waters heritage site.

Aligning Yannarumi assessment processes to the ECD and Ramsar management planning presents challenges for the Ngarrindjeri Nation. However, it is clear that traditional Yannarumi processes can be translated into a series of steps and decision points, enabling a consistent, replicable, decision-making process resulting in an assessment of the health of the Yarluwar-Ruwe (Hemming and Rigney 2016; Hemming et al. 2016). An assessment of health or wellbeing of Yarluwar-Ruwe is more consistent with Ngarrindjeri understandings of interconnected benefit and responsibility than the development of a static Ngarrindjeri character description (Bignall et al. 2016; Hemming and Rigney 2016).

# 4 Components, processes and services

# 4.1 Definitions

In this ECD the following definitions are adopted to describe ecological character.

**Ecosystem components** include the physical, chemical and biological parts of a wetland (from large scale to very small scale, e.g. habitat, species and genes) (Ramsar Convention 2005).

**Ecosystem processes** are changes or reactions which occur naturally within wetland ecosystems. They may be physical, chemical or biological. In laymen's terms, this equates to processes such as carbon cycling, denitrification, acidification, sedimentation, migration, breeding, reproduction, etc. (Ramsar Convention 1996).

**Ecosystem services** are 'the benefits that people receive from ecosystems' (Ramsar Convention 2005). This includes benefits that directly affect people such as the provision of food or water resources as well as indirect ecological benefits. The *Millennium Ecosystem Assessment* (Millennium Ecosystem Assessment 2005) defines 4 main categories of ecosystem services:

- **Provisioning services** the products obtained from the ecosystem such as food, fuel and freshwater
- **Regulating services** the benefits obtained from the regulation of ecosystem processes such as climate regulation, water regulation and natural hazard regulation
- **Supporting services** the services necessary for the production of all other ecosystem services such as water cycling, nutrient cycling and habitat for biota. These services will generally have an indirect benefit to humans or a direct benefit over a long period of time
- **Cultural services** the benefits people obtain through spiritual enrichment, recreation, education and aesthetics.

Whilst cultural services and benefits are included as a class of ecosystem services (above), cultural values are currently addressed through other international treaties (such as the World Heritage Convention and the United Nations Declaration on the Rights of Indigenous Peoples) and legislation (such as World Heritage and National Heritage provisions of the EPBC Act). The ecosystems services classification used in this ECD follows the terminology of the National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands (DEWHA 2008).

# 4.2 Ngarrindjeri Ruwe/Ruwar and Ngarrindjeri wellbeing: perspectives on components, processes, services and benefits

Ecological based descriptions of components and processes, services and benefits in this ECD are based on understandings of the relationship between humans and non–humans – conceived in Western terms as the divide between 'nature' and 'culture'. Ngarrindjeri philosophies of being, as applied within this ECD, attempt to redefine relationships by emphasising the interconnectivity of all things (Ngarrindjeri Nation 2006; Bignall et al 2016; Hemming and Rigney 2016; Ngarrindjeri 2019).

The concepts of components, processes, services and benefits do not easily relate to the Ngarrindjeri concept of being (Ruwe/Ruwar). This is because the Ngarrindjeri concept of being (Ruwe/Ruwar) does not separate the lands and waters and all living things into components, processes, benefits and services. Ngarrindjeri see these elements as an embodiment of Ruwe/Ruwar and as a consequence of Creation ancestors, intricately linked through this spiritual connection and crucial to the character of Ngarrindjeri Yarluwar-Ruwe. Ngarrindjeri see themselves as a component, process and critical service of the Ramsar site. For Ngarrindjeri, the concept of *interconnected benefit* helps to explain the fundamental interdependence and cyclical relationship that Ngarrindjeri have with their Yarluwar-Ruwe or Sea Country. The lands, the waters, all living things, the ancestors and Ngarrindjeri are all part of the living body – all have responsibility to each other. This is a reciprocal relationship that reproduces wellbeing for the 'body'. Ngarrindjeri have a cultural responsibility to maintain the health of their lands and waters as a part of their own living body. Exercising this responsibility ensures that they benefit from all aspects of a healthy 'Country' (Ngarrindjeri Nation 2006; Bell 2008; Hemming and Rigney 2016; Ngarrindjeri 2019).

Ngarrindjeri Ruwe/Ruwar requires connectivity, flow and mixing to occur between all living things and the lands and 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 and waters and the spirit world. Flows come together and produce life as fish breed in the Lakes and 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 2019).

It should be noted that from the Ngarrindjeri perspective, the simple conceptual model illustrating key relationships within the Ramsar site in Figure 4.2 is incomplete without full recognition being given to the unique interactions Ngarrindjeri experience with Yarluwar-Ruwe. This understanding of Ruwe/Ruwar also makes the distinction between critical and non-critical components and services an artificial and potentially misleading one. Another significant concern for Ngarrindjeri is that cultural values and indeed any human influence is marginalised rather than being given its proper place within the system (Ngarrindjeri 2019).

Ngarrindjeri Ruwe/Ruwar frames the rights and responsibilities of Ngarrindjeri as Traditional Owners. Recognising Ngarrindjeri philosophies of Ruwe/Ruwar supports an interconnected interpretation of ecosystem services. It shows that the Ramsar site has distinctive Ngarrindjeri 'cultural values linked to the ecological functioning of these wetlands' (Pritchard 2013; Ngarrindjeri 2019).

This relationship defines the critical service of ecological connectivity to its widest scope and places the relationship emphasis equally on all aspects of Yarluwar-Ruwe – the lands, the waters, all living things found there and the spiritual connectivity between all of these elements. Every aspect of the Yarluwar-Ruwe is connected to every other aspect and to change one element is to effect change on every other element of the Ngarrindjeri lands and nation (Ngarrindjeri 2019).

Ngarrindjeri have a cultural responsibility to maintain the health of their lands and waters. Exercising this responsibility ensures that they benefit from all aspects of a healthy 'Country'. In this sense, Western models of intermediate services, final service and benefits fail to include Ngarrindjeri understandings of interconnected benefit. It is evident that the benefits identified in this model leave out Ngarrindjeri benefits and exclude Ngarrindjeri 'human capital'. Furthermore, they further exclude human influence through intermediate and final services. Fundamentally for Ngarrindjeri, Ruwe/Ruwar is not about service delivery (Ngarrindjeri 2019).

To Ngarrindjeri, critical services are intertwined – the lands and waters must be able to provide life for Ngarrindjeri. There are 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 also perceive many 'supporting' services as significant, because they are intrinsic characteristics of Yarluwar-Ruwe. For example, because Ngarrindjeri see ecological and cultural services as fundamentally interconnected, they also consider services such as recreation, tourism and scientific research a significant aspect of producing wellbeing for Ngarrindjeri Yarluwar-Ruwe. These services will generally have an indirect benefit to humans or a direct benefit over a long period of time. For Ngarrindjeri, however, these benefits are viewed differently; they are seen as an interconnected system of services providing direct benefits to the health of Ngarrindjeri Yarluwar-Ruwe (Hemming and Rigney 2016; Ngarrindjeri 2019).

The Ngarrindjeri accept that, while this Western model is imperfect, it is a useful tool for beginning the complex task of describing Yarluwar-Ruwe (Ngarrindjeri Sea Country) in a manner Western science can readily approach. The diagram presented in Figure 4.1 is an attempt to illustrate the interwoven complexity of Ngarrindjeri wellbeing. This diagram is based on a similar diagram developed in 2007 by Ngarrindjeri leaders and Elders in workshops during discussions about the importance of water and water related resources for Ngarrindjeri people (Birckhead 2011). At its centre lies Ruwe/Ruwar, the Creation ancestor Ngurunderi and the overarching Ngarrindjeri concept of spirit and wellbeing known as Miwi. The lines extending out from the centre of the diagram refer to the symbolism contained in Ngarrindjeri weaving. Ngarrindjeri weaving symbolises and enacts Ngarrindjeri creative and spiritual connections to Country. Emerging in these discussions was the Ngarrindjeri Ruwe/Ruwar concept and the importance of Ngurunderi as the Creator and Law Giver. Additionally, Ngarrindjeri emphasised the strong connection between decline in both Ngarrindjeri wellbeing and the health of Ruwe and the loss of control, power and decision-making resulting from the non-Indigenous invasion of Ngarrindjeri Yarluwar-Ruwe (Ngarrindjeri 2019).

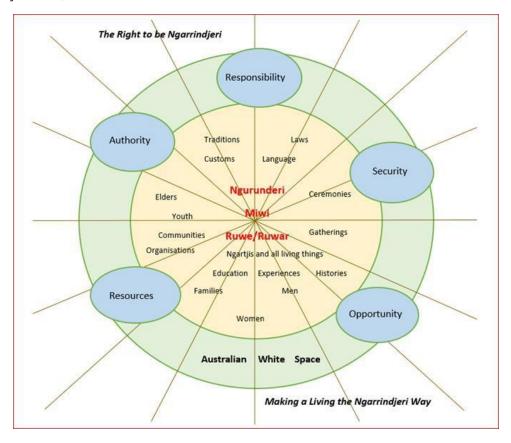


Figure 4.1 Diagrammatic representation of Ngarrindjeri wellbeing linked to Ruwe/Ruwar showing the interwoven associated threads of authority, security, opportunity, resources and responsibility that encompass Ngarrindjeri connections to Country. Note that the connections on this diagram move well beyond the usual boundaries associated with ecological systems as Western science describes it (Birckhead 2011).

Ngarrindjeri provided input into the description of the components, processes and services (CPS) of the Ramsar site in an attempt to meaningfully interact with a Western method of describing Ngarrindjeri Ruwe/Ruwar. The Ngarrindjeri note however, that the identification of CPS disconnects people from the Indigenous concept of Country and is therefore fundamentally at variance with Ngarrindjeri perceptions of Ruwe/Ruwar. It should be noted that for Ngarrindjeri, the non-critical CPS are characteristics of Ruwe/Ruwar and therefore inseparable from critical CPS (Ngarrindjeri 2019).

#### 4.3 Ramsar site sub-units

The following sub-units are regularly referred to when describing CPS:

- Lake Alexandrina and Lake Albert which includes the freshwater environments of Lake Alexandrina, Lake Albert and the Goolwa Channel (to Goolwa Barrage)
- **EMLR 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 and includes the Murray Mouth
- **Coorong North and Coorong South lagoons** which extends from Pelican Point to the southern end of the Coorong National Park and includes the coastal environments and beaches of Younghusband Peninsula.

# 4.4 Identifying components, processes and services

ECDs identify, describe and where possible, quantify the critical components, processes and services (CPS) of the site which determines its character and ultimately allow detection and monitoring of change in that character. These are the aspects of the wetland, which, if they were to be significantly altered, would result in a significant change in the system.

The process for identifying the CPS for the Coorong and Lakes Alexandrina and Albert is detailed in Butcher and Cottingham (2016). Under the National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands DEWHA (2008), critical CPS:

- are important determinants of the site's unique character
- are important for supporting the Ramsar criteria under which the site was listed
- are those for which change is reasonably likely to occur over short to medium time scales (<100 years);</li>
   and
- will cause significant negative consequences if change occurs.

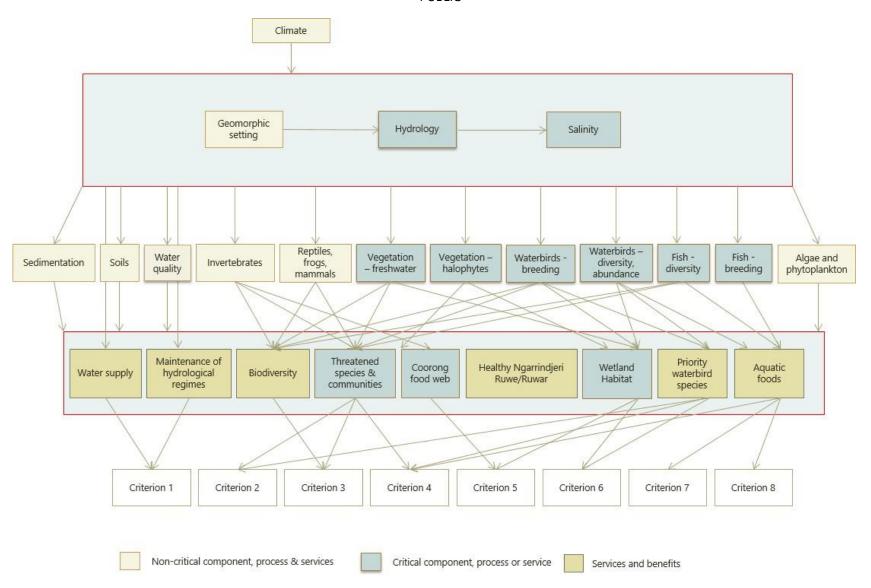


Figure 4.2 Simple conceptual model showing key relationships between selected components, processes, services and benefits and the criteria under which the site was nominated as a Wetland of International Importance.

# 4.5 Critical components, processes and services

A brief summary of each critical CPS along with the important subcomponents is presented in Table 4-1 and further detail regarding each critical CPS is presented after the summary table.

Table 4-1 Summary of critical components, processes and services (CPS).

Critical CPS and subcomponents	Description	Туре
Hydrology Inflows Rainfall and evaporation Lake levels Barrage flows Tidal signal	<ul> <li>River Murray inflows into the north of Lake Alexandrina are the primary source of freshwater for the Ramsar site.</li> <li>Lake Alexandrina is the source of freshwater for Lake Albert.</li> <li>Barrage flows are the primary source of water for the Murray Estuary and the Coorong.</li> <li>Seasonal inflows from the EMLR tributaries, flows from the Upper South East and rainfall are minor freshwater inputs to the site.</li> <li>Barrage flows are dependent on River Murray inflows, lake level management, losses and diversions.</li> <li>Lakes and Coorong water levels fluctuate seasonally and are typically higher in winter than summer.</li> <li>An open Murray Mouth allows tidal exchange and connectivity between the ocean and the Estuary.</li> </ul>	Component, process, supporting and cultural services
<ul> <li>Salinity</li> <li>Lakes Alexandrina and Albert</li> <li>EMLR tributaries</li> <li>Murray Estuary and Coorong</li> </ul>	<ul> <li>Salinity is a major driver of the composition and distribution of species found within the site.</li> <li>Salinity in the Lakes is closely linked to hydrology, particularly River Murray inflows and barrage outflows.</li> <li>Lake Albert generally has a higher salinity than Lake Alexandrina.</li> <li>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.</li> <li>The Coorong North Lagoon is estuarine to saline with lower salinity in the north-west and higher salinity towards the south-east at the connection with the Coorong South Lagoon.</li> <li>The Coorong South Lagoon is saline to hypersaline with lower salinity in the north-west and south-east.</li> <li>The salinity of the Coorong fluctuates naturally over an annual timescale, being lowest in late winter/early spring and highest in late summer/early autumn.</li> </ul>	Component
<ul> <li>Submergent         freshwater vegetation</li> <li>Emergent freshwater         vegetation</li> <li>Submergent         halophytes</li> <li>Emergent halophytes</li> </ul>	<ul> <li>Hydrology and salinity gradients, turbidity and wave action determine the composition and distribution of flora.</li> <li>The diversity and abundance of submergent freshwater vegetation is greatest when the water regime is variable and turbidity is low.</li> <li>Extensive stands of emergent vegetation (monospecific cumbungi and diverse reed beds) are present around the Lakes' shorelines.</li> <li>Saline permanent waters are dominated by <i>Ruppia tuberosa</i> and occasionally water-mat and charophytes.</li> <li>Samphire and saltmarsh communities are fringed by lignum, native grasses and/or swamp paperbark.</li> </ul>	Component

Critical CPS and subcomponents	Description	Туре	
<ul> <li>Diversity (species richness and biodisparity)</li> <li>Movement and recruitment</li> <li>Threatened species</li> </ul>	<ul> <li>104 species have been recorded at the site with 29 species using the site regularly.</li> <li>The site contains a diverse assemblage of freshwater, diadromous and euryhaline estuarine species.</li> <li>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.</li> <li>The site supports important species for commercial and recreational fisheries.</li> <li>3 internationally and/or nationally listed threatened species occur within the site.</li> </ul>	Component, process (recruitment) and cultural service	
Waterbirds	<ul> <li>118 species of waterbirds use the wetland habitat.</li> <li>The site supports 48 wetland-dependent species that are listed as migratory under the EPBC Act and international migratory agreements.</li> <li>The site regularly supports 1% or more of the flyway population of 7 species.</li> <li>38 waterbird species are known to breed at the site and 13 regularly breed within the site.</li> <li>6 internationally and/or nationally listed threatened species occur within the site.</li> </ul>	Component, process (recruitment) and cultural service	
Wetland habitat	<ul> <li>The site supports a unique mosaic of 23 wetland types.</li> <li>The site is the only estuarine system within the Murray–Darling Basin.</li> </ul>	Component	
Threatened ecological communities and species	<ul> <li>Part of the Swamps of the Fleurieu Peninsula ecological community occurs within the Currency Creek and Finniss River areas.</li> <li>The subtropical and temperate coastal saltmarsh ecological community is found in both the Murray Estuary and Coorong North Lagoon.</li> <li>The southern bell frog occurs around Lake Alexandrina, Lake Albert and EMLR tributaries.</li> </ul>	Component	
Ruppia tuberosa –     primary producer     Benthic     macroinvertebrates –     primary consumers     Small-mouthed     hardyhead –     secondary consumer	<ul> <li>R. tuberosa is a keystone primary producer in the hypersaline food webs of the Coorong.</li> <li>Macroinvertebrate diversity, abundance and biomass are highest in the Murray Estuary and decrease southward into the Coorong South Lagoon.</li> <li>Small-mouthed hardyhead, with high salinity tolerance, are the critical prey species for piscivorous fishes and birds.</li> </ul>	Component and provisioning service	

# 4.5.1 Hydrology

Hydrology, in particular inflows and outflows, is a key driver of the ecological character of the site and vary within and between years. Inputs of water include inflows from the River Murray, surface water from tributaries of the Eastern Mount Lofty Ranges, groundwater sources, the Southern Ocean and the Upper South East Drainage Scheme which drains into the Coorong South Lagoon at Salt Creek. Lake levels and barrage flows are the 2 main means by which the hydrological regime of the site is managed.

The waters of the seas, the waters of the Kurangk (Coorong), the waters of the rivers and the lakes are all spiritual waters. As people with strong ties to both freshwater and saltwater, Ngarrindjeri view the freshwater flows of the River Murray as the life blood of the river, Lower Lakes and Coorong. In bringing life to the Ramsar site, these

flows also bring life to Ngarrindjeri. Ngarrindjeri Ruwe/Ruwar requires flow and connectivity to occur between all living things, the lands and waters and the spirit world. Flows come together and produce life in the lakes and Coorong where the freshwater and saltwater mix and the complexity and interrelatedness of processes (i.e. flow, connectivity, fish and bird breeding) are recognised within Ngarrindjeri philosophy (Ngarrindjeri 2019).

The change in surface water regime and the increasing degree of external control or management exerted over these, has been observed by Ngarrindjeri. The 5 barrages at the southern end of Lake Alexandrina were constructed for the purpose of preventing the flow of saltwater into Lake Alexandrina and the River Murray. The barrages were built at the request of European landowners and without the consent of Ngarrindjeri people. Until that time, saltwater mixed with freshwater and, according to Ngarrindjeri traditional knowledge, this sometimes moved great distances up the river. The ecosystems of the Lakes and the river depended on the mixing of saltwater and freshwater. This mixing process is of considerable cultural importance to the Ngarrindjeri, as the Meeting of the Waters is a place of spiritual and biological creation where Ngarrindjeri Ngartjis breed (Ngarrindjeri 2019).

# Inflows

The primary source of freshwater inflows is from the River Murray. Flows are required to maintain stable salinities in the Lakes and a variable salinity regime in the Murray Estuary and Coorong. River Murray flows also maintain connectivity between the River Murray, the Coorong and the Southern Ocean, to discharge salt and other nutrients out to sea and contribute to the maintenance of waterbird populations, fish communities and aquatic and littoral vegetation.

River Murray flows (average annual volume of 5,908 gigalitres per year entering Lake Alexandrina) enter the Ramsar site at the northern end of Lake Alexandrina immediately downstream from Wellington. Flows move southward through Lake Alexandrina with a portion funnelled through the narrows and into the terminal wetland of Lake Albert. The remainder of the water moves further southward and leaves Lake Alexandrina through 5 barrages (Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere) connecting the islands (Hindmarsh, Mundoo, Ewe and Tauwitchere) in the southern section of the lake. Water regulated through the barrages then enters the Murray Estuary and moves into the Coorong or out the Murray Mouth to the Southern Ocean.

Inflows to Lake Alexandrina from the EMLR tributaries are relatively small (modelled average annual volume of 85 gigalitres per year (Alcorn 2011) but are important to the ecological character because of the biodiversity, habitat and ecological connectivity the tributaries support.

Small inflows also enter the Coorong South Lagoon at Salt Creek. A number of drainage networks have been constructed in the upper south-east of South Australia to restore some of the natural flow paths toward the Coorong. As a result, limited inflows (modelled average annual volume of 56.2 gigalitres per year) from the south-east of South Australia into the Coorong South Lagoon can occur under regulated conditions to periodically freshen the hypersaline waters (Natural Resources South East 2014).

#### Rainfall and evaporation

The site gains freshwater from rainfall on the surfaces. Average annual rainfall is 468 millimetres and is winter-dominated with the majority of the rain falling from April to October. Similar to other coastal areas of South Australia variability is high with the lowest annual rainfall being 241 millimetres and the highest annual rainfall being 696 millimetres (BOM, 2020).

Typically rainfall is more than evaporation in June and July and for around half the time in the adjacent months of May and August. For the remainder of the year (September to April), evaporation is typically more than rainfall. Annual net evaporation ranges between approximately 600 and 1,000 millimetres with a median value of 807 millimetres. Evaporation is typically fairly consistent each month with the variability in rainfall causing the variation in net evaporation and the volume ultimately lost from the Lakes and Coorong each year (Figure 4.3) (Gibbs et al. 2018).

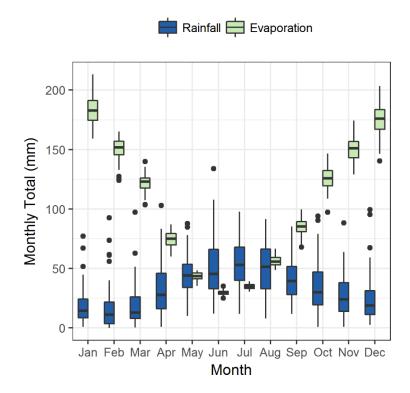


Figure 4.3 Monthly rainfall and evaporation (July 1960 to June 2016). Evaporation can be seen to exceed rainfall from September to April most years. (Data derived from Scientific Information for Land Owners (SILO) database (Jeffrey et al. 2001), representing a weighted average of 6 stations around the Lakes (Gibbs et al. 2018).

#### Lake levels

Variable lake levels are required to maintain or improve the diversity of aquatic and lakeshore vegetation and provide available habitat (e.g. for feeding, refuge, or breeding) for key biota including waterbirds and fish.

The pattern of gradually raising and lowering water levels is driven by the seasonal requirements of the ecology in and around the Lakes. Winter-spring filling of the Lakes supports the growth of new vegetation while ensuring that fauna have access to vegetation for food, shelter and recruitment. Water levels are kept high in spring to ensure fauna access to habitat (Lester et al. 2011). A gradual drawdown over the summer and autumn aims to expose mudflats and support diverse vegetation while allowing fishways and some gates at each barrage to remain open over summer during the low flow period.

Lake levels are determined by inflows into Lake Alexandrina and releases through the barrages. Lake Alexandrina levels vary across years and seasons but generally rise in winter and fall in summer between +0.85 metres AHD and +0.5 metres AHD annually (Figure 4.4) (DEW 2019). The nature of Lake Albert as a terminal wetland, with its narrow connection with Lake Alexandrina, means levels in Lake Albert rise in winter and fall in summer in accord with the levels in Lake Alexandrina (Heneker 2010). Factors such as wind direction and speed, water extraction rates and local rainfall to evaporation rates affect water levels in and transfer between both lakes.

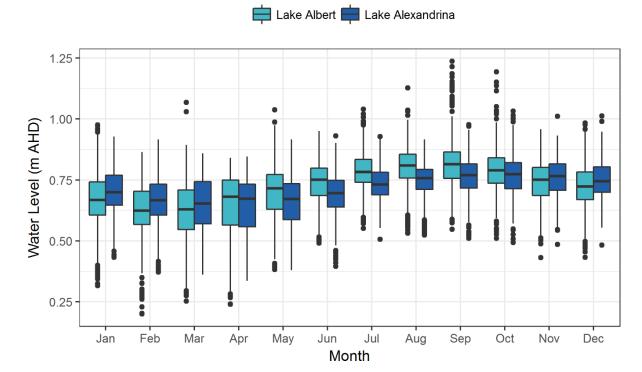


Figure 4.4 Variation in daily water levels for Lake Alexandrina and Albert (period of extremely low water levels from July 2006 to September 2010 excluded). The impact of wind on the difference between the lakes can be seen, with southerly winds resulting in Lake Albert water levels typically lower than Lake Alexandrina from November to March and higher in July and August with typically northerly winds (Gibbs at al. 2018).

Should Lake Alexandrina water levels drop below +0.4 metres AHD and there is a high likelihood that they cannot be maintained above +0.4 metres over the next water year, then the barrages flows are reduced (MDBA 2014a). Below +0.3 metres AHD, freshwater wetland habitats surrounding Lakes Alexandrina and Albert, Finniss River and Currency Creek start to become disconnected from Lake Alexandrina. As lake levels reduce, fish communities in certain areas become isolated and high value wetlands on Hindmarsh Island start to dry. This results in the desiccation of aquatic plants and aquatic fauna. As lake beds are exposed, the acidity expressed in wetlands starts to have an ecological impact (MDBA 2014a). Further information on the ecological impacts of lake levels can be found in the Drought Emergency Framework for Lakes Alexandrina and Albert (MDBA 2014a).

As with the Lakes, water levels and salinity in the Coorong have a strong influence on ecosystem variability and the habitat conditions for aquatic plants, fish and birds (Paton et al. 2009a; Ye et al. 2015a). Water levels also influence particle resuspension and turbidity generated by wind and wave action in the shallow lagoons and thereby reducing the light conditions necessary for plankton and aquatic plants. Variation in water levels in the Murray Estuary and Coorong exposes and inundates extensive areas of mudflats for invertebrates. 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 metres AHD in range; higher water levels tend to occur in late winter-early spring, with lower water levels in late summer-early autumn (Webster 2010).

#### **Barrage flows**

Barrage flows are required to maintain hydrological and ecological connectivity between the River Murray, the Coorong and the Southern Ocean to discharge salt and other nutrients out to sea and to maintain healthy ecosystems in the Coorong. Flow through the barrages is the result of lake inflows and losses and diversions across the Lakes and is affected by lake level, tide and wind conditions.

Mean annual discharge from the barrages is 4,733 gigalitres per year (Figure 4.5) and is dependent on the magnitude of inflows into Lake Alexandrina and net evaporative losses. During times of high inflows from the River Murray significant volumes of freshwater can pass through the barrages (e.g. 1988 to 1993 in Figure 4.5). Between 2001 and 2010, in the period now known as the Millennium Drought, flows across the barrages were extremely low. From 2007 to 2010, flows were so low that the river ceased to discharge to the ocean (Mosley et al. 2012). The drought broke in 2010–11 resulting in a large flooding event across the southern Murray–Darling Basin and high flows through the barrages until 2012. This was followed by moderate flows from 2013 to 2015.

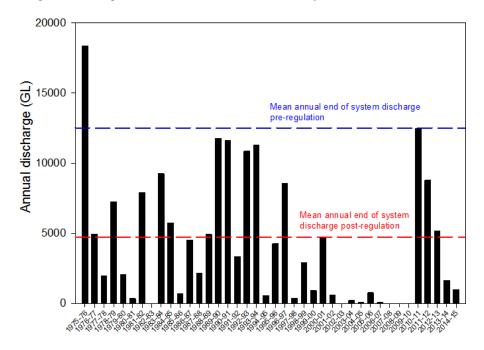


Figure 4.5 Annual freshwater discharge (gigalitres) through the barrages into the Coorong from 1975 to May 2015 from (Bice and Zampatti 2012).

As far as practicable, barrage outflows have been managed to provide an annual cycle in lake levels ranging from +0.5 to +0.85 metres AHD (DEW 2019). Minimum barrage flows of approximately 52 gigalitres per year are required to operate the 11 fishways on the barrages. Fishway operation is dependent on sufficient downstream flow and lake levels to provide connectivity. Vertical slot fishways on the Goolwa Barrage have the largest operating range and can pass flows to 0.0m AHD. The rock ramp and trapezoidal fishways at Tauwitchere Barrage have the smallest operating range and become ineffective at lake levels around +0.5 to +0.6 metres AHD.

Modelling of Coorong hydrodynamics and ecosystem states has determined a series of flow targets for the Coorong. Lester et al. (2011) describe flows of at least 2,500 gigalitres over 2 years as a minimum target (95% of the time) to prevent the Coorong from existing in degraded states and flows of at least 6,000 gigalitres per year and 10,000 gigalitres per year maintained every 3 and 7 years respectively to ensure healthy ecosystem states. High River Murray inflows provide targeted opportunities to scour the Murray Mouth and the opportunity to maintain and/or improve estuarine salinity conditions to support the provision of habitat, available food resources and recruitment of estuarine fish populations.

The pattern of flow discharge through the Estuary channels has been altered by the reduction in total flow through the Murray system and the Millennium Drought. Since the end of the Millennium Drought around 60% of the annual flow across the barrages goes through Tauwitchere Barrage to freshen the Coorong. Flows through Goolwa Barrage and Mundoo Barrage are approximately 27% and 9% respectively. Less than 5% of flows leave Lake Alexandrina through the Ewe Island and Boundary Creek Barrages.

# Tidal signal

The coast at the Murray Mouth has a high off-shore gradient that results in only a 20% loss of wave power, resulting in a high energy system capable of influencing the influx of marine sediment into the Murray Mouth. Sea water enters the system via the Murray Mouth under tidal influence and wave dynamics, mixing with the freshwater from Lake Alexandrina, groundwater and rainfall to create the estuarine environment. The degree of Murray Mouth openness is influenced by barrage flows and in the other direction by flow driven by tides and waves. An open Murray Mouth allows tidal exchange and connectivity between the ocean and Estuary. The tidal signal in water level is mainly visible in the Coorong North Lagoon closer to the Murray Mouth where it can reach up to 0.2 metres. Most of the time the tidal signal does not persist more than 30 kilometres from the Murray Mouth.

# Ngarrindjeri significance

The Ngarrindjeri have strong traditional ties to the Coorong South Lagoon and the associated ephemeral lakes and wetlands. These areas have cultural, spiritual, social and economic significance. The existing drains in the south-east have redirected freshwater from the traditional flow paths that fed the Kurangk (Coorong), the associated ephemeral lakes, wetlands and important freshwater wells and soaks. This freshwater brought life to Ngarrindjeri Yarluwar-Ruwe and therefore ensured the wellbeing of Ngarrindjeri people (Ngarrindjeri Nation 2006; Ngarrindjeri Ramsar Working Group 1998; Ngarrindjeri 2019).

The freshwater soaks on the Coorong and on the Younghusband Peninsula were used to support all the freshwater needs of both the aquatic and terrestrial animals of the Coorong, as well as providing the Ngarrindjeri people themselves with drinking water and water for a range of cultural purposes. Ngarrindjeri monitored and maintained soaks and wells for their own use and for the use of the animals, birds and other living things they relied on. The Coorong South Lagoon was a major breeding ground for Ngarrindjeri Ngartjis such as wankeri (jumping mullet) and birds such as ngori (pelicans). Elders remember times when flows were abundant:

...what we've been told from our Old People the country is on an angle, coming from the southeast. We've got underground waterways that run right through here where the water comes through. And we have the surface water that used to come through every year. We're not saying this was full, absolutely full of this precious water every year, all year round. But it certainly was for the better part of the year. It held good quality water and that water gave life. It gave life to what we describe as our Ngartjis, that's like a spiritual connection between us and the animals and the fish and the plants. We're linked into one thing. Our Ngartjis live off those things. There's things that we don't see any more growing here, because the mixtures of the waters aren't here anymore. (George Trevorrow in Bell 2014; Ngarrindjeri 2019)

#### 4.5.2 Salinity

The Coorong and Lakes Alexandrina and Albert Wetland supports more than 1000 species from plankton to vertebrates (Phillips and Muller 2006). One of the main reasons for the diversity of biota supported by the wetland is the historical salinity gradient that has existed across the site, from freshwater lakes to an estuarine, marine and hypersaline Coorong. Maintaining a persistent gradient within the salinity tolerance limits of wetland species will help ensure that this diversity is maintained (Lester et al. 2011). Within each sub-unit salinity also needs to vary, within maximum levels of salinity tolerances over time to support those species and communities that have evolved to depend and thrive on this variability as cues to spawning and recruitment. For example, sprouting from *R. tuberosa* turions requires a lower salinity than the requirements needed for their formation (Collier et al. 2017). Salinity is considered to be of great importance by Ngarrindjeri, as it has been the direct or indirect cause of significant unwelcome environmental change across the site (Ngarrindjeri 2019).

#### Lakes Alexandrina and Albert

The water levels and salinities experienced within the Lakes are a function of the inflows, barrage outflows and climatic factors. Lake Alexandrina has a median salinity of 742 EC and an interquartile range (occurring 50% of the time) of 558 EC to 1,154 EC. Reduced River Murray inflows during the Millennium Drought led to a peak salinity in Lake Alexandrina of over 6,000 EC in 2010. Lake Albert, as a terminal wetland with a narrow connection to Lake Alexandrina, acts as a sink for salt and salinity in Lake Albert is consistently higher than in Lake Alexandrina, with a median salinity of 1,734 EC and interquartile range of 1,385 to 2507 EC. Peak salinities in the Millennium Drought in Lake Albert were over 20,000 EC, before inflows returned in 2010 (Figure 4.6).

Analysis of historical barrage outflows and the salinity regime in Lake Alexandrina showed that there is a marked increase in salinity as annual barrage outflows fall below 2,000 gigalitres per year and 3-year cumulative outflows fall below 4,000 gigalitres (Heneker 2010). Heneker (2010) showed that 2-year cumulative barrage outflow above 4,000 gigalitres generally kept Lake Alexandrina salinity at between 500–800 EC. For 3-year cumulative barrage outflow, 6,000 gigalitres are required to keep salinity between 500–800 EC, suggesting that the inter-annual distribution of outflows is important in maintaining salinity levels in the Lakes (Heneker 2010). The sequence of outflows is also important in determining salinity levels in the Lakes, showing that once cumulative totals drop, salinity rises quickly. The same pattern occurs in both lakes (Figure 4.6) (Heneker 2010; Oliver et al. 2015).

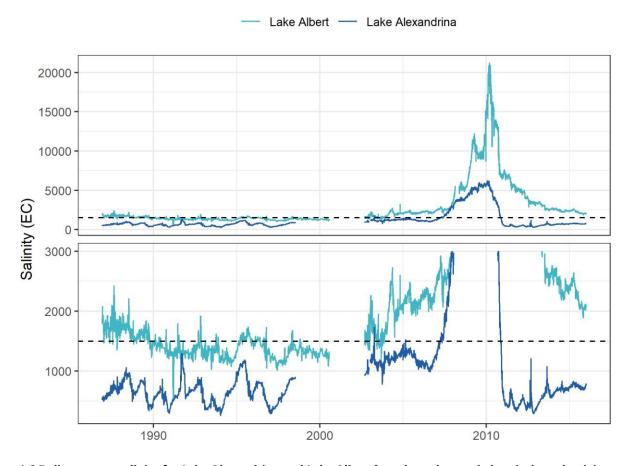


Figure 4.6 Daily average salinity for Lake Alexandrina and Lake Albert based on observed electrical conductivity at telemetry stations between 1985 and 2015 (6 sites in Lake Alexandrina, 3 sites in Lake Albert), showing all observed values (top) and salinity below 3,000 EC (bottom), with the LAC of 1,500 EC shown as the dashed horizontal line (Department for Environment and Water SA).

#### Eastern Mount Lofty Ranges tributaries

The EMLR tributaries are highly dependent on rainfall, with trends in streamflow and salinity primarily climate driven. There is a clear pattern of increasing salinity in the spring and summer months and decreasing salinity in the autumn and winter months, highlighting the climatic influence. In general, salinity levels in Currency Creek are greater than those in the Finniss River. Salinity ranges from less than 100 mg/L to greater than 4,500 mg/L for the Finniss River and from 100 mg/L to greater than, 5000 mg/L in Currency Creek (Figure 4.7) (DEWNR 2014a).

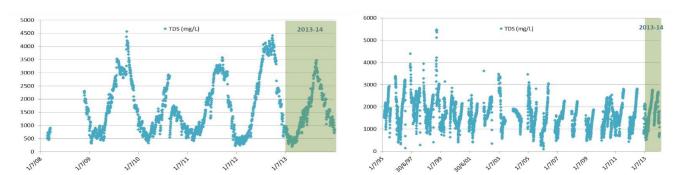


Figure 4.7 Salinity at Currency Creek (A4260530) from 2008–14 and Finniss River (A4261075) from 2004–14 (DEWNR 2014a).

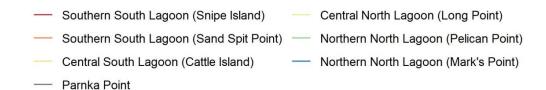
#### Murray Estuary and Coorong

The connected Murray Estuary and Coorong sub-units of the Ramsar site have a natural gradient from estuarine to marine conditions (up to 36 ppt/ 51,070 EC) in the Murray Estuary to hypersaline conditions in the Coorong South Lagoon at the terminal end of the system (Geddes and Butler 1984; Brookes et al. 2009b; Fairweather and Lester 2010; Webster 2010). This salinity gradient characterises the diversity of habitats and biota across the system (Paton et al. 2009a).

Salinity levels in the Murray Estuary are governed by the balance between freshwater flows through barrage releases, seawater inflows through the Murray Mouth and evaporation. High salinity tends to be associated with periods of reduced barrage flows and closure of the Murray Mouth. During periods of high freshwater discharge from the barrages, salinity in the Murray Estuary and Coorong North Lagoon can range from fresh to brackish(5-30 ppt/ 8,656-43,898 EC) (Geddes 1987; Bice C et al. 2012).

The Coorong North Lagoon is estuarine to saline with lower salinity in the north-west and higher salinity towards the south-east at the connection with the Coorong South Lagoon. Salinity in the Coorong North Lagoon is controlled by freshwater inflows from primarily the Tauwitchere Barrage, tidal exchange through the Murray Mouth, rainfall, evaporation and flows of hypersaline water from the Coorong South Lagoon. Salinity in the Coorong North Lagoon undergoes a seasonal cycle with maximum salinity occurring in mid-summer. Barrage flows in the Millennium Drought were small and salinities in the Coorong North Lagoon exceeded 100 ppt (112,471 EC).

The Coorong South Lagoon is saline to hypersaline. Similar to the Coorong North Lagoon it has a salinity gradient with lower salinity in the north-west and higher salinity towards the south-eastern end. 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. The Coorong South Lagoon also undergoes a seasonal cycle with peak salinity occurring after the Coorong North Lagoon near the end of March.



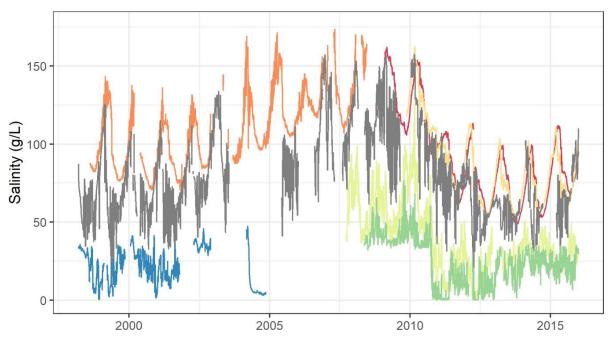


Figure 4.8 Average salinity in the Coorong from 1998 to 2015 (Gibbs at al. 2018).

# 4.5.3 Vegetation

The Ramsar site is characterised by 4 major wetland vegetation communities that provide habitat, food resources and contribute to the biodiversity of the site. The critical vegetation communities and their water level and salinity preferences are described below in Table 4-2.

Table 4-2 List of critical vegetation communities with a summary of their key water level and salinity preferences.

Vegetation Community	Water level preferences	Salinity preferences	Reference
Submergent freshwater	+0.4 m AHD to +0.8 m AHD (Lakes)	<2,000 EC (Lakes)	Nicol (2016)
Emergent freshwater	+0.4 m AHD to +0.8 m AHD (Lakes)	<5,000 EC (Lakes) (<2,000 EC for diverse reed	Nicol (2016)
		beds in Lakes)	Nicol et al. (2018)
Submergent halophytes*	>+0.2 m AHD (Coorong)	>30-123 g/L(Coorong) >43,898-130,434 EC	Collier et al. (2017)
Emergent halophytes	+0.4 m AHD to +0.8 m AHD (Lakes)	>5,000 EC (Lakes)	Nicol (2016)
			Nicol et al. (2018)

<sup>\*</sup>optimal water level and salinity for adult plant growth of *R. tuberosa* as the dominant submergent halophyte within the Ramsar site.

# Submergent freshwater vegetation

Submergent vegetation species represent the 'true' aquatic plants that require the presence of water to complete their lifecycle (Casanova 2011). Submergent freshwater vegetation provides food for herbivorous waterbirds; provides habitat for invertebrates, frogs and fish; oxygenates the water column and improves water quality (Nicol 2016). Submergent vegetation generally do not colonise areas below sea level, except in the Goolwa Channel where plants often grow in areas as low as -0.5 to -1 metres AHD (Gehrig et al. 2012). The open water areas of the Lakes have generally been devoid of plants, with submergent and amphibious vegetation species generally restricted to fringing wetlands, sheltered bays, Goolwa Channel and the lower reaches of Currency Creek and the Finniss River (Nicol et al. 2018). Species within this vegetation grouping include water milfoil (*Myriophyllum salsugineum*), coarse water milfoil (*Myriophyllum caput-medusae*), curly pondweed (*Potamogeton crispus*), sago pondweed (*Potamogeton pectinatus*), widgeon grass (*Ruppia polycarpa*), large fruit tassel (*R. megacarpa*), hornwort (*Ceratophyllum demersum*), ribbonweed (*Vallisneria australis*), stoneworts (*Chara* spp.) and thread-leaf crowfoot (*Ranunculus trichophyllus*) (Nicol et al. 2018).

The main factors that influence the composition of submerged vegetation within the Ramsar site are water regime, salinity, turbidity and wave action (Ganf 2000; Nicol et al. 2018). The interaction of these factors and their timing differentially influences the various life stages of plants and other biota and in turn the species present (Nicol et al. 2018). The diversity and abundance is greatest in areas where the water regime is variable and turbidity is low. While data on the extent of this vegetation community is limited, submergent vegetation is an important food resource, supports high productivity, is thought to be key habitat to several listed fish species (Wedderburn and Hammer 2003) and provides nesting material for waterbirds.

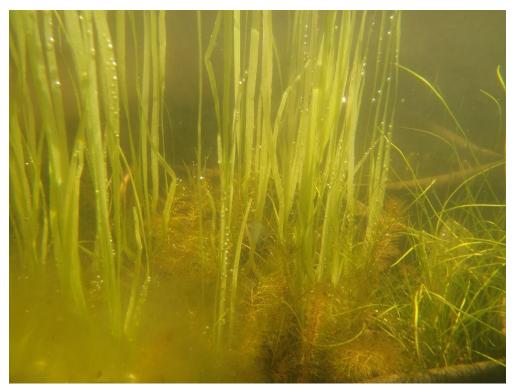


Figure 4.9 Submergent freshwater vegetation – *T. domingensis, Myriophyllum sp.* and *Ruppia sp.* (Photograph: A. Rumbelow).

# **Emergent freshwater vegetation**

Emergent freshwater vegetation provides habitat for cryptic waterbirds, frogs and invertebrates, provides oxygen to the water column and is important in controlling lakeshore erosion (Nicol 2016). In the Lakes, extensive stands of emergent vegetation are present around the shorelines (Nicol et al. 2018). Stands are often monospecific common reed (Phragmites australis) or cumbungi (Typha domingensis) (Nicol et al. 2018). Cumbungi can form extensive monospecific stands around the shorelines of the Lakes and generally colonises areas between +0.8 metres AHD and 0 metres AHD, but will grow in deeper water (around -0.2 metres AHD) in areas that are protected from wave action (e.g. the lower Finniss River) (Nicol et al. 2018). It also occurs in the Coorong along the western shoreline of the Sir Richard and Younghusband peninsulas alongside freshwater soaks (Lester et al. 2013). Similar to cumbungi, common reed often forms monospecific stands around the edges of the Lakes and tends to occupy higher elevations (+0.9 metres AHD to +0.4 metres AHD), but will colonise deeper water (0.0 metres AHD), especially in areas with steep banks that are protected from wave action (e.g. the lower Finniss River) (Nicol et al. 2018). Although common reed can be important for controlling erosion of exposed shorelines, it can also be invasive and can both prevent other vegetation species from establishing and restrict water flow in drains and channel (Nicol et al. 2018). There are however some areas of the Lakes where there is distinctive zonation of tangled lignum (D. florulenta) and common reed (at the top of the elevation gradient, greater than +1 metres AHD to +0.8 metres AHD), cumbungi (middle elevations) and river clubrush (Schoenoplectus tabernaemontani) (low elevation), or there is a diverse assemblage of submergent-emergent species (Nicol et al. 2018).

Diverse reed beds found around the Lakes are characterised by a mixed assemblage of emergent, floating and submergent species (Gehrig et al. 2012), (Lester et al. 2013). Typically, these reed beds have greater than 5% cover of native amphibious and emergent species (other than cumbungi and common reed) between +0.8 metres AHD and +0.6 metres AHD and greater than 5% cover of native submergent and emergent species (other than cumbungi and common reed) between 0 and +0.6 metres AHD (Nicol et al. 2018). They are found at similar elevations to cumbungi and common reed stands, but generally in areas protected from wave action with gentle sloping shorelines (Nicol et al. 2018). Taxa present in these diverse reed beds include common reed, cumbungi, river clubrush, tangled lignum, sharp clubrush (*Schoenoplectus pungens*), common rush (*Juncus usitatus*), common spike rush (*Eleocharis acuta*), water ribbons (*Triglochin procera*) and spiny flat sedge (*Cyperus gymnocaulos*) (Nicol et al. 2018). The diverse reed beds provides important nursery habitat (i.e. concealed substrate) and foraging habitat that supports diverse prey types for waterbirds in the Ramsar site, including cryptic waterbird species (O'Connor et al. 2013).



Figure 4.10 River clubrush (S. tabernaemontani) in Lake Albert (Photograph: S Blight).

Reeds are very important to Ngarrindjeri people, because they provide nursery habitats for many fish, birds and other animals and also because they are used as a fibre for basket weaving and other traditional craft. The main species of reed used for basket weaving is the spiny flat sedge. This sedge is preferred over other species as it has strong fibres and the longer stem length (1.0–1.5 metres) required for weaving. As the reeds are harvested, Ngarrindjeri are careful to leave behind the growing shoots to ensure the stand of sedges continues to survive (Ngarrindjeri 2019).

Ellen Trevorrow explains the significance of reeds and the impact of changing water regimes on their growth:

The rushes like freshwater and a lot of considerate farmers leave them so we have supplies. I move around and just thin out the good places. I'm finding it very hard down our end close to the Coorong because there was a lot there, but the salt water table is taking over. We need freshwater. Sometimes along the roadside, because it's not on the farmer's property, but just where the water runs off the road, the rushes are growing very nice and you'll see someone picking them. But I move around in a cycle. I pick and move and let the other lot grow. They grow very quick. Later I can return when the young ones have come up again. You can see where I've been...Its cultural weaving because I use the same rushes that my Old People used – it's the 3-pronged type of freshwater rushes – there's a lot of different types of rushes, but this is one that was used because its lasts a long time" (Ellen Trevorrow in Bell 2008; Ngarrindjeri 2019).

Other freshwater emergent species include sharp-leaved rush (*S. pungens*), lesser water parsnip (*Berula erecta*), bindweed (*Calystegia sepium*), common spike rush (*E. acuta*), Australian gypsywort (*L australis*), pennyworts *Hydrocotyle verticillata* and *Centella asiatica*, spiny flat sedge (*C. gymnocaulos*) and pale knotweed (*Persicaria lapathifolia*) (Gehrig et al. 2012). They occur in sheltered areas at similar elevations to other emergent reed and grasslands (+0.9 to 0 metres AHD, with a preference greater than +0.2 metres AHD), (Nicol 2016) and typically along gentle sloping shorelines (Gehrig et al. 2012). These amphibious species are vulnerable to long periods (greater than 2 years) without access to surface water.

The distribution of swamp paperbark (*Melaleuca halmaturorm*) is restricted to several areas around Lakes Alexandrina and Albert. These areas include an isolated patch along the northern edge of Goolwa Channel and near the mouth of Currency Creek. Goose Island, opposite the township of Clayton, has significance stands and the Salt Lagoon Island Complex in Loveday Bay also has dense paperbark woodlands. Several areas on Hindmarsh Island contain paperbark woodlands, including a patch on the northern shoreline and dense areas along Eastick Creek and Hunters Creek mouth leading into Mundoo Channel. Two islands in Mundoo Channel also contain individual trees (Seaman 2003).

The river red gum (wuri) is considered to be Ngurunderi's tree and it is closely associated with Murray Cod (pondi) in Ngarrindjeri culture. The following excerpt from a 1999 public speech by Ngarrindjeri Elder, Tom Trevorrow (deceased), explains the significance of the wuri (Ngarrindjeri 2019):

This old Wuri was born upon this ground and has stood here for many, many years, tall and proud. If it could speak it would have so many stories to tell us, stories like: My roots grow deep in the earth. My heritage goes back a long, long time. Over the years I have provided shelter for mother earth. Over the years I have provided food and shelter for all creatures who wish to live under me or upon me. I have provided shelter and my branches for fire, for the people who camped alongside of me. I have provided my skin for the people to make their canoe. I have shared myself with all living things. Maybe through what has happened and what is happening today this old Wuri is speaking to us. Maybe it's telling us to come together and respect each other and respect and acknowledge each other's cultural and spiritual beliefs. Maybe we could also call this old Wuri a reconciliation tree.

The main factors that determine the distribution and abundance of emergent freshwater vegetation communities (similar to freshwater submergent vegetation) are water level and salinity (Nicol 2016). Most emergent species require high soil moisture in the root zone when growing out of the water (Sainty and Jacobs 1981; Sainty and Jacobs 2003; Roberts and Marston 2011) and most emergent species but will not recruit further down the elevation gradient and can then become hydrologically disconnected from the water (Gehrig et al. 2012).

## Submergent halophytes

Submergent halophytes are critical to the Ramsar site as they provide habitat, foraging substrates and food for fish, invertebrates and herbivorous waterbirds (Paton et al. 2015b). Saline permanent waters are dominated by species such as *R. tuberosa* and occasionally water-mat *Lepilaena* species and charophytes including *Lamprothamnium* species. In the subtidal zones of the Estuary and Coorong there are a number of opportunistic green filamentous alga genera including *Ulva* species, *Cladophora* species and *Rhizoclonium* species (Ganf 2000; Collier et al. 2017).

*R. tuberosa* is the dominant submergent halophyte in the Coorong and provides a key food source (e.g. for waterbirds that feed on the seeds and turions) and habitat for invertebrates and fish communities (Paton 2010). Section 4.5.7 provides further information about the ecology of *R. tuberosa* as a part of the Coorong food web. It is one of the most salt-tolerant plants with a recorded maximum for adult plants of 230 g/L (199,806 EC) (Brock 1982) and once exploited ephemeral mudflats in water depths ranging from +0.3 to +0.9 metres AHD (Womersley 1975), (Paton 1982), (Paton, 1996), (Triest and Sierens 2013), (Paton and Bailey 2012a). It requires salinity lower than 85 g/L (99,852 EC) for germination from seed and less than 125 g/L (131,928 EC) to sprout from turions (Kim at al. 2013). It requires water levels to be maintained above +0.2 metres AHD until plants are able to produce seed and replenish the seed bank (Paton et al. 2015). *R. tuberosa* abundance and distribution in the Coorong has been affected over time by water level changes and increased salinity (including the lack of freshwater pulses at key times) resulting in the loss of propagules and seed banks (Whipp 2010). See section 4.5.7 for more detail on changes in *R. tuberosa*.

#### **Emergent halophytes**

Samphire and saltmarsh are important ecosystems in coastal areas, forming wherever sediment accumulation exceeds the rate of land subsidence and where there is adequate protection from destructive waves and storms. These communities are often closely associated with other vegetation communities (e.g. fringed by lignum, native grasses and/or swamp paperbark) and this is an important feature of their habitat value. They are highly productive ecosystems that export energy into adjacent waters and are significant contributors to detrital food webs and to a lesser extent grazing food webs (Nicol 2007b). This vegetation association is widespread throughout the Ramsar site, particularly in areas where there is moderate to high salinity (Seaman 2003; Nicol et al. 2018). Common taxa found include samphire (Sarcocornia spp., Tecticornia spp.), seablite (Suaeda australis), streaked arrow-grass (Triglochin striatum), sea rush (Juncus kraussii), sharp clubrush (Schoenoplectus pungens), round-leaf wilsonia (Wilsonia rotundifolia) and creeping bookweed (Samolus repens) (Frahn et al. 2014). These species are generally intolerant of long-term inundation but grow well in waterlogged soil; hence they are restricted to areas above +0.7 metres AHD in the Lakes and above +0.2 metres AHD in the Coorong and Murray Estuary (Nicol et al. 2018).

#### 4.5.4 Fish

Fish are a critical component of the site, providing a number of services and benefits. They are key elements in food webs, important for local recreational and commercial fisheries and contribute greatly to the biodiversity, ecosystem function and the economic, social and cultural values of the site (Phillips and Muller 2006; Bice et al. 2018; Ferguson et al. 2018).

All fish are of important cultural value to Ngarrindjeri, who hold them in high esteem as a part of their living culture, both as a food source and also as a connection with their spiritual beliefs. Pondi (Murray cod) is an exceptionally important freshwater fish to the Ngarrindjeri, as this was the first fish created in the Kaldowinyeri and all the other fish found in these waters were later cut from his body as part of the Ngurunderi Creation story (refer to Chapter 3). The actions of Ngurunderi and his brother Nepele describe the creation of fish species in the Ramsar site: after Pondi was chased down the River Murray by Ngurunderi he was eventually caught and speared at the place where the freshwater and saltwater meet and cut into many pieces to make the freshwater and saltwater fish for the Ngarrindjeri people. Ngurunderi threw each piece into the waters and told it to become a new fish – 'pilarki, thukari, kunmuri, mulawi' with the last piece being kept as pondi (Ngarrindjeri Nation 2006; Bell 2008; Ngarrindjeri 2019).

Pondi was also pivotal in the formation of the River Murray – as Ngurunderi chased Pondi, Pondi created bends and wetlands along the River Murray. In practical terms, pondi also formed an important part of the Ngarrindjeri diet. As pondi is a large fish, one typical fish would 'feed an entire family for a week'. It was mostly men who caught pondi because of their size. The preferred method of catching was with cord lines. While knowledge and experiences relating to pondi are not always disclosed publically, some Elders who had lived in the Ramsar site region for much of their lives have caught pondi and pondi were abundant until the 1960s (Birckhead 2011; Ngarrindjeri 2019).

Mulloway (mullawi) continues to be an important food source for Ngarrindjeri people. Elders prize the liver. Mullawi used to be plentiful in the Coorong but today most are caught from the Southern Ocean beach. Before the barrages were installed mullawi were speared from sandbars in Lake Albert near Meningie. Ngarrindjeri people continue to dry and smoke fish and trade it among other traditional owner groups in exchange for other goods. The former abundance of Mullawi in the Coorong is recalled in a contemporary story that, around 1980, a boat was sunk following a single cast with a net and a catch that overfilled the boat to the extent that it sank. For generations Ngarrindjeri used spears and nets to catch Mullawi for personal consumption and sale. In earlier years, Ngarrindjeri held fishing licences and participated in the commercial fishing industry. They also earned money by repairing nets for other fishermen (Birckhead 2011; Ngarrindjeri 2019).

The meeting of the waters is an important place for the breeding of fish. The following quote illustrates the importance of the mixing of freshwater and saltwater in this area in supporting diverse fish species:

Well that's the place there, where I know of the meeting of the waters. That's where you can fish, one side for fresh water and the other side for salt water fish... You could sit in a dinghy and could throw one line over here for fresh water for pilkari [callop] and throw one line over here for salt water and catch both in one dinghy. That's what I learnt about the meeting of the waters and I've been there, seen the place. (Maggie Jacobs in Bell 2014)

The need to manage fishing wisely is emphasised in the Thukeri (bony bream) Creation story (refer to Chapter 3), which explains how Thukeri was created. It shows not only how it came into being but provides important teachings in the importance of not taking more than one needs and the importance of sharing. It is a Ngarrindjeri law story of wise-use (Ngarrindjeri 2019).

Data at the time of the site's listing were limited, other than for incomplete species lists and as such information on the fish community composition, abundances and population dynamics are mainly based on anecdotal evidence and expert opinion. Nonetheless, substantial data on the fish of the site have been collected in recent years from numerous monitoring programs and are described below for the critical subcomponents, including fish diversity, movement and recruitment.

# Diversity (species richness and biodisparity)

As the dynamic interface between the lower River Murray and the Southern Ocean, the Ramsar site supports a diverse assemblage of fishes which is unique within the Murray-Darling Basin (Bice et al. 2018). Presence and abundance of fish species in the Ramsar site is spatially and temporally variable. Within the Lakes, the variability of

River Murray inflow has a large influence on freshwater fish populations (Bice et al. 2018). Flow variability influences critical life history processes such as spawning, larval drift and migration. It also influences water level and salinity in the Lakes which affects fish habitat and resource availability (Wedderburn et al. 2012; Bice et al. 2018).

In the Murray Estuary and Coorong, River Murray inflows, barrage outflows, the connection between freshwater, Estuary and sea, and salinity influence the fish populations (Bice 2010; Zampatti et al. 2011; Ye et al. 2015b; Bice et al. 2018). This occurs directly by influencing life history processes and physiological preference/tolerances and indirectly by determining the availability of structural habitat (e.g. aquatic plants) and the distribution and abundance of food resources (e.g. invertebrates) (Bice et al. 2018; Ye et al. 2019a).

One hundred and four species of fish have been recorded within the Ramsar site. Forty-five species have been recorded from the Lakes and 93 species from the Murray Estuary and Coorong (Appendix A, Bice et al. 2018). Of the 104 species, 29 species occur regularly within the site (Table 4-3). This represents a diverse range of morphologies, sizes, life histories and commercial, recreational and conservation significance (Phillips and Muller 2006; Bice 2010; Watt 2013; Bice et al. 2018). The diversity of fish species and families, life history, morphologies and movement contributes to the high biodisparity in the Ramsar site (Table 13-4) (Watt 2013). Further information for key species in relation to their functional guild is summarised below (Table 4-3).

Table 4-3 Fish species and distribution that are regularly supported in the Coorong and Lakes Alexandrina and Albert Wetland (modified from Bice 2010 and Bice et al. 2018). Spatial units include: LAx = Lake Alexandrina, LAb = Lake Albert, ME = Murray Estuary, NL = Coorong North Lagoon, SL = Coorong South Lagoon and bold spatial units represent where the species is typically common. @ denotes alien species.

Common name (Ngarrindjeri name)	Scientific name	Family	Guild	Spatial units where recorded
Freshwater				
Murray hardyhead (Terukurar)	Craterocephalus fluviatilis	Atherinidae	Freshwater straggler	LAx, LAb, ME
Unspecked hardyhead	Craterocephalus fulvus	Atherinidae	Freshwater straggler	LAx, LAb, ME
Goldfish <sup>@</sup>	Carassius auratus	Cyprinidae	Freshwater straggler	<b>LAx</b> , LAb, MErat
Common carp <sup>®</sup>	Cyprinnus carpio	Cyprinidae	Freshwater straggler	<b>LAx</b> , LAb, ME, NL
Carp gudgeon complex	Hypseleotris spp.	Eleotridae	Freshwater straggler	LAx, LAb, ME
Dwarf flat-headed gudgeon	Philypnodon macrostomus	Eleotridae	Freshwater straggler	LAx, LAb, ME
Golden perch (Pilarki)	Macquaria ambigua	Percichthyidae	Freshwater straggler	LAx, LAb, ME
Southern pygmy perch	Nannoperca australis	Percichthyidae	Freshwater straggler	LAx
Redfin perch@	Perca fluviatilis	Percidae	Freshwater straggler	LAx, LAb, ME
Eastern gambusia@	Gambusia holbrooki	Poecilidae	Freshwater straggler	LAx, LAb, ME
Bony herring (Thukeri)	Nematalosa erebi	Clupeidae	Freshwater estuarine opportunist	<b>LAx, LAb, ME</b> , NL, SL
Flat-headed gudgeon	Philypnodon grandiceps	Eleotridae	Freshwater estuarine opportunist	LAx, LAb, ME, NL
Australian smelt	Retropinna semoni	Retropinnidae	Freshwater estuarine opportunist	LAx, LAb, ME, NL

Common name (Ngarrindjeri name)	Scientific name	Family	Guild	Spatial units where recorded
Diadromous				
Pouched lamprey	Geotria australis	Geotriidae	Anadromous	LAx, ME
Congolli (Kungguldhi)	Pseudaphritis urvillii	Bovichtidae	Catadromous	LAx, LAb, ME, NL, SL
Common galaxias (Pulangi)	Galaxias maculatus	Galaxiidae	Semi-catadromous	LAx, LAb, ME, NL
Estuarine				
Small-mouthed	Atherinosoma	Atherinidae	Solely estuarine	LAx, LAb, ME,
hardyhead	microstoma			NL, SL
Tamar River goby	Afurcagobius tamarensis	Gobiidae	Solely estuarine	LAx, LAb, <b>ME</b> , <b>NL</b>
Western bluespot goby	Pseudogobius olorum	Gobiidae	Solely estuarine	LAx, LAb, <b>ME</b> , NL
Lagoon goby	Tasmanobius lasti	Gobiidae	Solely estuarine	LAx, LAb, <b>ME</b> ,
Black bream (Tjeri, Tulari)	Acanthopagrus butcheri	Sparidae	Solely estuarine	LAx, LAb, <b>ME</b> , <b>NL</b> , SL
Western river garfish	Hyporhamphus regularis	Hemiramphidae	Solely estuarine	LAx, <b>ME</b> , NL
Bridled goby	Arenigobius bifrenatus	Gobiidae	Estuarine and marine	LAx, LAb, <b>ME</b> , NL
Soldierfish	Gymnapistes marmoratus	Tetrarogidae	Estuarine and marine	ME, NL
Marine				
Australian herring	Arripis georgianus	Arripidae	Marine estuarine opportunist	ME, NL
Western Australian salmon	Arripis truttaceus	Arripidae	Marine estuarine opportunist	ME, NL
Sandy sprat	Hyperlophus vittatus	Clupeidae	Marine estuarine opportunist	LAx, <b>ME</b> , NL
Yelloweye mullet (Kunmari)	Aldrichetta forsteri	Mugilidae	Marine estuarine opportunist	LAx, <b>ME</b> , <b>NL</b> ,
Goldspot mullet	Liza argentea	Mugilidae	Marine estuarine opportunist	LAx, <b>ME</b> , NL,
Longsnout flounder	Ammotretis rostratus	Pleuronectidae	Marine estuarine opportunist	ME, <b>NL</b>
Greenback flounder (Minmekutji)	Rhombosolea tapirina	Pleuronectidae	Marine estuarine opportunist	ME, <b>NL</b> , SL
Mulloway (Mullawi)	Argyrosomus japonicus	Sciaenidae	Marine estuarine opportunist	LAx, <b>ME</b> , NL
Smooth toadfish	Tetractenos glaber	Tetraodontidae	Marine estuarine opportunist	ME, NL

#### Freshwater species – freshwater straggler and freshwater-estuarine opportunist

Lakes Alexandrina and Albert support a distinct assemblage of fishes dominated by freshwater species (Table 4-3) (Wedderburn and Hammer 2003). This includes native and non-native species representative of a broad range of sizes (e.g. small-bodied and large-bodied) and habitats (e.g. pelagic and benthic). The freshwater straggler guild comprises species of conservation significance, including the small-bodied southern pygmy perch and Murray hardyhead (Bice et al. 2018). The population of Murray hardyhead comprises a distinct genetic management unit within the Murray–Darling Basin (Adams et al. 2011). Several other small-bodied species, including carp gudgeon and unspecked hardyhead, are common and widespread in the Lakes (Bice et al. 2018). The large-bodied species, golden perch, are also common and widespread in the Lakes, (Ferguson et al. 2013; Earl 2015) supporting Lakes and Coorong commercial fishery in this region (Ferguson et al. 2018).

Freshwater-estuarine opportunist species are those freshwater species that commonly use estuarine habitats in substantial numbers, including bony herring, Australian smelt and flat-headed gudgeon (Table 13-1) (Bice et al. 2018). These species are ecological generalists, exhibit flexible reproductive characteristics (e.g. protracted spawning seasons), broad physico-chemical tolerances (e.g. salinity) and flexible habitat requirements (Bice et al. 2018). Bony herring are also supporting commercial fishery in this site (Ferguson et al. 2018).

#### **Diadromous species**

Diadromous fish are those species that must migrate between freshwater and marine environments to complete their life cycles. Within the Ramsar site this includes 3 guilds defined by the environment in which reproduction occurs and where the majority of the adult life is spent: 1) anadromous, 2) catadromous and 3) semi-catadromous (Bice et al. 2018).

Anadromous species are those whose adult life is spent primarily in the marine environment, prior to upstream migration into freshwater environments for spawning (Potter et al. 2015). The Ramsar site supports the pouched lamprey and short-headed lamprey, which are the only anadromous fish species in the Murray-Darling Basin (Bice et al. 2018). The Ramsar site represents a migration pathway from adult marine habitats to freshwater spawning and nursery habitats (Bice et al. 2018).

Catadromous species are those whose adult life is spent in freshwater, prior to downstream migration into the marine environment for spawning (Potter et al. 2015). Larvae and juveniles develop in the ocean before migrating upstream into freshwater habitats (Bice et al. 2018). For example, congolli is a catadromous species that occurs in the Ramsar site, with smaller males favouring estuarine habitats and larger females most abundant in freshwater habitats (Bice et al. 2018). The connectivity and habitats that the Ramsar site provides enables winter spawning migrations of female congolli (from the lower River Murray and EMLR tributaries) through the Murray Estuary and into the ocean. It also allows larvae and juveniles to enter the Murray Estuary (from the ocean) to migrate upstream into freshwater habitats (Bice and Zampatti 2012). Congolli is highly valued as a Ngarrindjeri Ngartji and knowledge of its reliance on interconnected fresh, marine and estuarine environments is deeply embedded in Ngarrindjeri tradition. Ngarrindjeri have been sharing their knowledge of Ngartjis such as congolli to non-Indigenous Australians, in order to teach them about the ecology of Ngarrindjeri Yarluwar-Ruwe (DEH 2010).

Semi-catadromous species are those with a generally catadromous life-history, but whose downstream migrations cease in estuarine environments (Potter et al. 2015). The site regularly supports common galaxias, a semi-catadromous species that is common in the Lakes and the tributaries (Wedderburn et al. 2014). Common galaxias undertake downstream migrations and spawning. Larvae are commonly washed out to the ocean, where they develop, before migrating upstream as juveniles (Bice et al. 2018).

# Estuarine species – solely estuarine and estuarine and marine

Solely estuarine species are those whose reproduction is confined to estuarine habitats, including black bream, an important species for commercial and recreational fisheries in this site. Other species include small-mouthed hardyhead, Tamar River goby, lagoon goby and western blue-spot goby (Table 13-1) (Bice et al. 2018). These species, except small-mouthed hardyhead, are typically most common in the Murray Estuary and Coorong North Lagoon and are occasionally sampled in the Coorong South Lagoon and Lakes. Small-mouthed hardyhead is typically abundant in the Coorong South Lagoon, where it is dominant and often the only fish species present (Ye

et al. 2015a). For the estuarine fish species, suitable flow, salinity regimes including a salinity gradient from freshwater to hypermarine is paramount (Ye et al. 2016). The connectivity and productivity that is provided by River Murray inflows and barrage outflows is also required.

Estuarine and marine species may form discrete self-sustaining populations in both estuarine and marine environments (Potter et al. 2015). This includes bridled goby which are abundant and broadly distributed in the Ramsar site (Bice et al. 2018).

# Marine species – marine-estuarine opportunist

Marine-estuarine opportunists are marine species that enter estuaries regularly, in substantial numbers, often as juveniles, but use marine environments to varying degrees as alternative nurseries (Potter et al. 2015). The Ramsar site supports mulloway, greenback flounder and yelloweye mullet which are important for commercial, cultural and recreational fisheries (Ferguson et al. 2018) and species that are important in the trophic dynamics of the Coorong, such as the sandy sprat (Bice et al. 2016).

Marine straggler species have not been identified as regularly supported by the Ramsar site though they represent approximately 5% of fish species recorded in the site (Appendix A). These species enter estuaries sporadically, typically in low numbers (Potter et al. 2015) and are found occasionally in areas of the Murray Estuary and Coorong where salinities are similar to sea water (Bice et al. 2018).

#### Movement and recruitment

Long term Ngarrindjeri knowledge of Yarluwar-Ruwe emphasises the importance of connectivity and the interdependence of ecological systems. Ngarrindjeri hold complex understandings of the importance of connectivity and mixing of waters at the Meeting of the Waters site for the reproduction of Ngarrindjeri Ngartji, the lands and waters and all living things. For Ngarrindjeri, connectivity is central to the health of Yarluwar-Ruwe (Ngarrindjeri 2019; Wedderburn et al. 2017).

There is a distinction between species whose life histories operate within the spatial scale of the Lakes and are reliant on specific habitats therein (e.g. Murray hardyhead) and those whose life histories operate over greater spatial scales and whose population dynamics within the Lakes are influenced by processes occurring outside of the Ramsar site (e.g. golden perch) (Bice et al. 2018).

Two ecological specialists that complete their life cycles within the Lakes and are reliant on specific littoral and off-channel habitats are the Murray hardyhead and southern pygmy perch. Successful spawning and recruitment of these species are influenced by the water levels in the Lakes, which influences the biotic (e.g. aquatic plants, zooplankton prey, alien fish abundances and interactions) and abiotic (e.g. salinity, connectivity with fringing wetland habitat) components (Wedderburn at al. 2017). As short-lived species, years of poor to no recruitment represents an extreme threat to these populations (Bice et al. 2008).

Golden perch, a common and abundant large-bodied fish in the Lakes, migrate within freshwater habitats, with adult fish undertaking long-distance movements (up to thousands of kilometres) (Bice et al. 2018). Golden perch is one of the few native species in the Murray–Darling Basin that are cued to spawn by elevated flow or flooding, when this coincides with particular temperature thresholds (Mallen-Cooper et al. 2003; Zampatti and Leigh 2013). Eggs and larvae are naturally buoyant and undergo an obligate downstream drifting phase, whilst juveniles have been shown to undertake considerable active downstream migrations in the lower River Murray (Zampatti et al. 2015). Populations in areas such as the Lakes may be influenced by spawning and migration from upstream areas (Bice et al. 2018). Fish stock assessment has indicated different population demographics (i.e. age structure) in the Lakes compared to the lower River Murray (Ferguson and Ye 2012).

Freshwater flows into estuaries (such as the Coorong) create salt wedges (haloclines) which provide favourable spawning and larval nursery habitats for fish species, including black bream (Ye et al. 2019b). The salinity gradient is important as it provides a cue for spawning and locating the spawning ground, a cue for larvae and juveniles to locate suitable habitat and increases food availability for larvae (Ye et al. 2019b). For example, the Murray Estuary provides important salt wedge conditions to support the recruitment of estuarine fish (e.g. black bream) (Ye et al.

2019b) and the Coorong North Lagoon is an important nursery habitat for estuarine fish species (e.g. small-mouthed hardyhead) and marine-estuarine opportunist species (e.g. mulloway, greenback flounder), where freshwater inflows from the River Murray are critical to maintain suitable salinities and the extent of favourable habitat in the Coorong (Ye et al. 2015a).

Estuaries represent critical spawning and recruitment habitats for estuarine fish and essential migratory pathways for diadromous fish (Beck et al. 2001). Diadromous fish require migration between marine, estuarine and freshwaters to complete their life cycles. Population dynamics (i.e. movement and recruitment) are fundamentally driven by connectivity between these environments during critical periods and conditions to support these processes (Bice and Zampatti 2017). The Ramsar site forms the only estuarine habitat in the Murray–Darling Basin, so is the only access point for diadromous fish species within the Basin.

## Threatened species

#### Murray hardyhead

Murray hardyhead (*Craterocephalus fluviatilis*) is critically endangered in South Australia (Hammer et al. 2009) and endangered under the EPBC Act. It is endemic to the Murray–Darling Basin and the Lakes population is genetically diverse and distinct from populations upstream of the Ramsar site – i.e. upstream of Lock 1 (Wedderburn and Hammer 2003). Within the Ramsar site, Murray hardyhead is patchily distributed but can be locally abundant (Wedderburn and Hammer 2003; Wedderburn et al. 2008). It prefers sheltered wetland and lake-edge habitats with abundant submerged and emergent vegetation. The species is considered euryhaline and is highly tolerant of salinities ranging between 5 and 85 ppt (8,656 and 99,852 EC), but does not occur exclusively in saline waters. Core habitat for Murray hardyhead includes Hindmarsh Island, Dunns Lagoon and Waltowa (Bice et al. 2013; Wedderburn and Barnes 2013). Seasonal water level variation in the Lakes contributes to zooplankton emergence (a key food source for this species) and is thought to be key in influencing Murray hardyhead recruitment (Wedderburn et al. 2010). Ngarrindjeri value this Ngartji for its role in the food web (Ngarrindjeri 2019).

#### 4.5.5 Waterbirds

The site was listed as a Wetland of International Importance on the basis that it supported large numbers of waterbirds (O'Connor 2015a; Paton et al. 2018). The Ramsar site provides habitat that supports Australian and international waterbird species during their life histories. For example, Coorong mudflats provide critical foraging habitat for migratory shorebirds in the summer (O'Connor 2015a). The site supports the greatest waterbird diversity and abundance of the 6 Icon sites within the Murray–Darling Basin (Kingsford and Porter 2009) and provides breeding habitat for several colonial-nesting and beach-nesting species (O'Connor et al. 2013). A total of 100,000 to 300,000 waterbirds is typically supported each summer over the Lakes and Coorong, with numbers highest during drought when the system provides a refuge for Australian waterbirds (Paton et al. 2018).

Ngarrindjeri value migratory and non-migratory species because of their importance to the on-going wellbeing of Yarluwar-Ruwe. Wetland birds were once people during the Kaldowinyeri and the process of their transformation into their present forms and their current characteristic behaviours is explained through Creation stories (Ngarrindjeri Nation 2006).

Ngarrindjeri understand that Yarluwar-Ruwe is an important component of a larger living body and provides breeding places and homes for migratory waterbird species. Ngarrindjeri also accept that their responsibility to maintain the health of Ruwe/Ruwar has far reaching consequences, as acknowledged in the Ngarrindjeri Yarluwar-Ruwe Plan:

We know that many of our Ngartjis travel to other countries during certain times of the year and therefore we have a cultural responsibility to care for each other's Ngartji and to care for each other's lands and waters. We have always recognised our responsibilities and connections to other parts of Australia and to distant lands (Ngarrindjeri Nation 2006).

Ngarrindjeri have responsibility to ensure the health of Ngarrindjeri lands and waters extends to the migratory birds that visit Ngarrindjeri Ruwe/Ruwar. Ngarrindjeri have entered an international treaty between indigenous nations (the United League of Indigenous Nations Treaty of August 1, 2007) that has an objective to protect the health of the lands and waters internationally. The Ngarrindjeri Nation Yarluwar-Ruwe Plan (2006) states:

Our Ngarrindjeri Vision for Our Sea Country must remain strong, for the health and survival of our brothers and sisters in distant lands that rely on our Ngartjis – birds, fish and other animals – that are nourished by our Yarluwar-Ruwe and travel over long distances.

# Diversity (species richness)

The Ramsar site supports many species of birds. A total of 307 bird species have been recorded within one kilometre of the Ramsar site (Appendix B), of which 118 species use the wetland habitat (O'Connor et al. 2012), (O'Connor 2015a). The site supports the majority of waterbird species that occur within the Murray–Darling Basin, including a number of species that are not recorded elsewhere within the Murray–Darling Basin (O'Connor 2015a). Species richness and community composition of waterbirds utilising the site varies across the complementary habitats provided by the Lakes and Coorong (Paton et al. 2015b; Paton et al. 2018). The Coorong supports large numbers of shorebirds, particularly red-necked stints, banded stilts, sharp-tailed sandpipers and to a lesser extent red-necked avocets, curlew sandpipers and red-capped plovers (Paton et al. 2015; Paton et al. 2018). A range of other shorebirds are also largely, if not entirely, restricted to the Coorong, including black-winged stilt, common greenshank, oystercatchers, godwits, far eastern curlew, hooded plover and sanderling (Paton et al. 2015d; Paton et al. 2018).

Waterfowl (ducks) and fish-eating (piscivorous) species are prominent in both the Lakes and Coorong (Paton et al. 2015d). In the Coorong grey teal, Australian shelduck, chestnut teal and black swans are the prominent species of waterfowl. Australian shelduck, Pacific black duck, grey teal, Eurasian coot and black swan are the most abundant waterfowl in the Lakes (Paton et al. 2015d; Paton et al. 2018). Other waterfowl including Australasian shoveler, pink-eared ducks and hardheads use both the Lakes and Coorong when present in the site. Freckled ducks mainly use the Lakes (Paton et al. 2015d; Paton et al. 2018).

In the Lakes, great cormorant, pied cormorant, Australian pelican and whiskered tern are the most prominent piscivorous species, while whiskered tern, hoary-headed grebe and Australian pelican are abundant in the Coorong (Paton et al. 2015a; Paton et al. 2018). Five species of cormorant use the Coorong, with great cormorant and little black cormorant the most abundant of these (Paton et al. 2015d; Paton et al. 2018). Other fish-eating species that utilise both the Lakes and Coorong include Caspian tern, great crested grebe, great egret and white-faced heron and fairy tern. Fairy tern are an important fish-eating species, which are restricted to the Coorong (Paton et al. 2015d; Paton et al. 2018).

The Ramsar site supports significant numbers of Royal spoonbills, Australian white ibis, straw-necked ibis and silver gulls (Paton et al. 2015d; Paton et al. 2018). Silver gulls are widespread in both the Coorong and Lakes, while the spoonbills and ibis are more abundant around the margins of the Lakes (Paton et al. 2015d; Paton et al. 2018).

The freshwater swamps and reeds of the Lakes support a suite of largely cryptic birds, including Australasian bittern, Latham's snipe and various rails and water hens (O'Connor et al. 2013). The most conspicuous of these are purple swamphen, little grassbird, Australian reed warbler and golden-headed cisticola, which are also associated with the emergent and fringing vegetation of the freshwater sub-units of the Ramsar site (Paton et al. 2018).

#### **Abundance**

The Ramsar site plays a significant role in supporting waterbirds within the Murray–Darling Basin and in south-eastern Australia. The site provides permanent wetlands that support populations of waterbirds throughout the year, but also support additional species between spring and autumn including migratory shorebirds from the Palaearctic and Australian endemic waterbirds (Paton 2010; Paton et al. 2015d). Waterbird abundances vary greatly between geographic locations (Paton et al. 2009a) and from year to year, reflecting the nature of the different bird species use of the site (Paton et al. 2015d; Paton et al. 2018). Annual counts in January indicate that the Coorong generally supports twice as many waterbirds as the Lakes in summer (Paton et al. 2018).

Waterbird use of the Ramsar site is dependent on the ecological condition of the Coorong and Lakes as well as conditions in other wetlands the birds use at other times of the year (Paton et al. 2018). For example, most species of waterfowl (ducks and swans) do not generally breed in the Coorong or Lakes and move away from the Coorong (and to a lesser extent the Lakes) during winter and spring to breed (Paton et al. 2015d). The numbers of waterfowl that return to the Coorong and Lakes from these breeding areas the following summer will depend on breeding success. The timing of their arrival will be influenced by the conditions in these other wetlands including if and when they start to dry out (Paton et al. 2015d). For these birds, the permanent wetlands of the Ramsar site function as a critical summer refuge and this importance increases in dry years (Paton et al. 2015d; Paton et al. 2018).

# Migratory shorebird species

Within Australia, the Coorong is consistently identified as critical for the diversity and numbers of international migratory shorebirds it supports every summer (Bamford et al. 2008; Kingsford et al. 2012; Paton et al. 2009a; Watkins 1993). The Ramsar site supports 48 wetland-dependent species that are listed as migratory under the EPBC Act and international migratory agreements such as CAMBA, JAMBA, ROKAMBA and CMS (Appendix B) (O'Connor et al. 2012). Thirty-seven species migrate from breeding grounds in north-east Asia and Alaska to non-breeding grounds in Australia, covering a journey of over 10,000 kilometres twice in a single year. This well-established route is known as the East Asian-Australasian Flyway (Figure 4.11).

The life cycle of most international migratory shorebirds involves the following (Bamford et al. 2008):

- Breeding in May to August (Northern Hemisphere)
- Southward migration to the Southern Hemisphere (August to November)
- Feeding and foraging in the Southern Hemisphere (August to April)
- Northward migration to breeding grounds (March to May).

During both northward and southward migration, birds may stop at areas en-route to rest and feed. These stopovers are referred to as staging areas and are important for the birds' survival. In addition, birds on their first southward migration have not yet reached breeding maturity and may remain in Australia over the southern winter period. The Ramsar site supports these migratory shorebirds through the provision of key habitat and food sources to build up reserves prior to the journey back to their breeding grounds in the Northern Hemisphere.



Figure 4.11 East Asian-Australasian Flyway (Bamford et al. 2008).

Of the 37 migratory shorebird species, 7 occur at the site on a regular basis (i.e. recorded 15 or more of the 16 seasons for which counts were made) (O'Connor 2015a). Abundances of the 7 most commonly encountered migratory species in the Coorong are shown in Table 4-4 below. The Ramsar site plays a significant role in regularly supporting 1 % or more of the East Asian-Australasian Flyway population for curlew sandpiper, rednecked stint and sharp-tailed sandpiper (Table 4-5).

Table 4-4 Abundances of the 7 commonly encountered migratory shorebird species in the Coorong (adapted from O'Connor 2015a). Abundance between 1981 and 2000 are derived from Australian Waders Study Group (1981, 1982 and 1987) and Watkins (1993, 2000). Abundances for 2001–14 are sourced from D Paton (University of Adelaide).

Common name	Scientific name	Abundance	Abundance
		1981–2000	2001–14
		Median (range)	Median (range)
Black-tailed godwit	Limosa limosa	140 (105–185)	18 (0–175)
Common greenshank	Tringa nebularia	579 (314–720)	491 (182–714)
Curlew sandpiper	Calidris ferruginea	26,734 (22,512–40,000)	2,088 (50–4,513)
Pacific golden plover	Pluvialis fulva	230 (144–290)	36 (6–124)
Red-necked stint	Calidris ruficollis	54,743 (54,710–63,800)	28,998 (6,605–43,300)
Sanderling	Calidris alba	308 (113–930)	6 (0–515)
Sharp-tailed sandpiper	Calidris acuminata	24,871 (22,898–50,147)	12,702 (178–33,897)

#### **Non-migratory species**

The Ramsar site plays a significant role in regularly supporting 1% or more of the Australian population for 4 non-migratory bird species (Australian pied oystercatcher, chestnut teal, fairy tern and red-capped plover) (Table 4-5).

Table 4-5 Seven species where the site regularly supports 1% or more of the flyway population for migratory species, or the Australian population for non-migratory species (adapted from O'Connor 2015a). 2015 abundances of these species have been sourced from Paton et al. (2016) (annual census data for the Coorong and Lakes) and shown in reference to the 1% flyway population estimate (Hansen 2016) or Australian population estimate (Wetlands International 2013).

Common name	Scientific name	1% flyway or Australian population estimate	2015 abundance
Migratory species (East Asian-Aus	tralasian Flyway)		
Curlew sandpiper	Calidris ferruginea	1,400	3,995
Red-necked stint	Calidris ruficollis	3,200	54,654
Sharp-tailed sandpiper	Calidris acuminata	1,600	14,285
Non-migratory species			
Australian pied oystercatcher	Haematopus longirostris	110	131
Chestnut teal	Anas castanea	1,000	4,056
Fairy tern	Sternula nereis	15	406
Red-capped plover	Charadrius ruficapillus	950	1,459

Populations of other resident species such as banded stilts and red-necked avocets fluctuate greatly in response to off-site conditions. Both will move to the coast from inland locations during periods of dry weather (BirdLife Australia 2015), with peak abundances occurring in dry years (Figure 4.12).

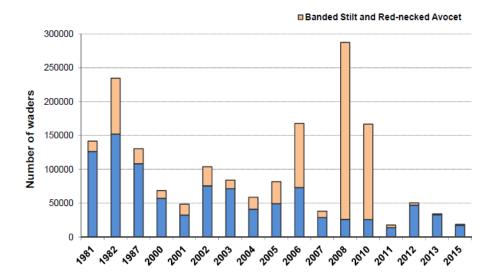


Figure 4.12 Total shorebird species abundance in the Coorong from 1981 to 2015, including banded stilt and rednecked avocet (BirdLife Australia 2015)

#### Foraging, refuge and roosting habitat

Ngarrindjeri have a detailed knowledge of waterbird habitat based on direct experiences, generational knowledge and key Kaldowinyeri stories such as Ngurunderi, Tenetjerar (Fishing Birds story), Wartji Pulyeri (blue wren). The eggs (Ngarthari) of many bird species are important food sources for Ngarrindjeri people, particularly swans, ducks, seagulls and emu. Snipe are also considered good food by Ngarrindjeri, particularly for teaching children to hunt as they are easily caught (Birckhead 2011; Phillips and Muller 2006).

Waterbird species have diverse physical adaptations to feed on a wide variety of food types. Community composition and abundance of species often reflect the availability of food (Ecological Associates 2010). This is a function of prey species abundance and the ability of birds to access food resources, for example, the availability of physical foraging habitat due to water depths (Ecological Associates 2010). The use of habitats by waterbirds can be influenced by the proximity of roost sites, water quality, the availability of preferred habitat and the need for refuge (Ecological Associates 2010).

The Ramsar site provides a diversity of habitat to support waterbird foraging, refuge and roosting. This habitat can be grouped into 4 broad types:

- Deep water (greater than 30 centimetres)
- Shallow water (0–30 centimetres deep) including mudflats
- Areas inundated during tidal flows and with wind seiche
- Supratidal or flood zones.

Within these broad groupings there are a suite of microhabitats that are important for waterbird foraging and roosting (Ecological Associates 2010). These habitats are shown in Table 4-6 and described in further detail below. Further information on the vegetation associated with each of the sub-units are described in section 4.5.3.

Table 4-6 Habitat types and associated microhabitats available to birds within the Ramsar site (modified from Ecological Associates 2010).

	Habitat type			
	Deep water (>0.3 m)	Shallow water (<0.3 m)	Intertidal	Supratidal
Lakes Alexandrina and Albert	Water column and substrate Submergent vegetation	Mudflats and sand flats Emergent reed beds	Lake edge Mudflats and sand flats Rocky substrate Emergent reed beds	Fringing vegetation Saltmarsh Shrubland – lignum
Murray Estuary	Water column and substrate Submergent vegetation	Mudflats and sand flats Submergent vegetation	Mudflats and sand flats Water edge, fringing vegetation	Saltmarsh
Coorong	Water column and substrate Submergent vegetation	Mudflats and sand flats Submergent vegetation Algal beds Emergent reed beds	Mudflats and sand flats Exposed aquatic vegetation Emergent reed and sedge beds Exposed algal beds Rocky substrate Water edge	Saltmarsh Fringing vegetation Mudflats and sand flats
Goolwa Channel and confluences of the tributaries	Water column and substrate Submergent vegetation	Emergent reed beds Submergent vegetation	Emergent reed and sedge beds	Emergent reed and sedge beds River red gum
Fringing Wetlands	Submergent vegetation	Emergent reed beds Submergent vegetation	Emergent reed and sedge beds	Emergent reed and sedge beds Lignum shrubland

A range of waterbirds use deep, open water particularly diving waterbirds (Ecological Associates 2010). Deep diving ducks such as hardhead feed on emergent and submergent plants and insects and fish. Musk ducks feed mainly on insects but will also eat large numbers of freshwater snails and frogs (Ecological Associates 2010). Piscivorous birds may catch fish on the surface (e.g. tern species) or may dive to catch fish and a range of invertebrates (e.g. grebes and cormorants) (Ecological Associates 2010). Grazing waterfowl such as black swan will forage on plant material in deep water (Ecological Associates 2010). While larger birds will use deeper water to forage, they prefer shallower water when food is available, as it is more profitable and uses less energy (Ecological Associates 2010).

The majority of waterbirds in the Ramsar site utilise the margins of the Lakes and lagoons (Paton et al. 2015d). The margins are the areas where water levels are typically less than one metre, coinciding with the productive parts of these wetlands (Paton et al. 2015d). The margins of the Lakes often support reeds and other emergent vegetation that provide resources, as well as cover for waterbirds (e.g. for roosting) (Paton et al. 2015d). These habitats support a suite of largely cryptic birds, which are dependent on the emergent and littoral vegetation (O'Connor et al. 2013). Australasian bittern prefer large areas of homogenous habitat such as large emergent reed beds, while other species such as the Australian spotted crake, purple swamphen and golden-headed cisticola prefer the more heterogeneous structure of the diverse reed beds (O'Connor et al. 2013). Other cryptic species, including Latham's snipe, prefer more sparse cover and samphire habitats. Although the Lakes provide some mudflat habitat, the margins of the Lakes are often steep and have limited habitat suitable for species that wade in shallow water to feed (Paton et al. 2015d).

Intertidal marsh areas that contain both samphire wetlands, saltmarsh habitat and emergent vegetation in the Ramsar site provide important foraging areas for rails, crakes and water hens; and nesting and feeding habitats for a range of waterbirds, including resident and migratory shorebirds (Brandle 2002; Spencer et al. 2009). Samphire low herbland dominated by *Sarcocornia* species and sea heath (*Frankenia pauciflora*) provides key habitat for orange-bellied parrot on the rare occasions it occurs within the Ramsar site. The seeds of black seed samphire (*Sarcocornia quinqueflora*) are an important component of the diet of the orange-bellied parrot (Mondon et al. 2009).

In the Coorong lagoons, if water levels are suitable, there are extensive areas of gently sloping shoreline available for waterbirds to forage in the shallow water (Paton et al. 2015d). The tides, changes in water levels, surface water regime, wind direction and rainfall and evaporation affect patterns of inundation and extent of habitat available to shorebirds. The presence of extensive mudflats covered with shallow water at least during the warmer months of the year makes the Coorong habitat particularly important for shorebirds (migratory and endemic species) (Paton et al. 2015d). The Coorong South Lagoon is considerably more important than the Coorong North Lagoon in terms of mudflat availability, as it contains the majority of all available mudflat (Sharma at al. 2009). The spatial partitioning of available habitat and food resources influences the shorebirds' community distributions in the Ramsar site (see section 4.5.8 of Coorong food web). Shorebirds with long bills are mainly found in the Murray Estuary where larger polychaetes are an abundant food item, whereas shorebirds with medium length bills, such as banded stilt, are common in the Coorong South Lagoon where amphipods and chironomid larvae are abundant (Ditmann et al. 2006). Those shorebirds with short bills occur throughout the Coorong, Murray Mouth and Lake Alexandrina and feed on invertebrates, including amphipods, smaller polychaetes (e.g. capitellids) and insect larvae, which are all found within the top 2-3 centimetres of the sediment (Dittmann et al. 2006).

#### **Breeding**

Waterbirds are Ngarrindjeri Ngartjis and their successful breeding is fundamental to Ngarrindjeri wellbeing and reproduction. Ensuring that waterbirds can breed is a significant Ngarrindjeri cultural responsibility. The 'critical supporting services' provided by the Ramsar wetlands to support waterbird breeding are well understood and highly valued by Ngarrindjeri. The critical processes and elements required to support the breeding of waterbirds are reinforced through Ngarrindjeri Creation stories.

The Murray–Darling Basin is a stronghold in Australia for colonial nesting species, with 470 records of colonial waterbird breeding at 115 wetlands in the Basin from 1899–2008 (Brandis et al. 2009). Of these wetlands, the Coorong and Lakes Alexandrina and Albert Ramsar site is ranked fifth in the total number of breeding events. Bino et al. (2015) identified the Coorong South Lagoon as being 1 of 8 wetlands in the Murray–Darling Basin as critical to supporting waterbird breeding in wet years.

The Ramsar site supports a total of 38 waterbird species that breed within the site (O'Connor 2015a). Species known to breed regularly at the site are shown in Table 4-7 (O'Connor et al. 2012) with their breeding frequency and locations. Additional species that may breed regularly at the site, but are currently data-deficient are included in Appendix B (O'Connor et al. 2012).

Table 4-7 Species that regularly breed within the Ramsar site. Breeding frequency is listed as regular (3 out of 5 years on average) according to expert opinion where adequate records are not available (O'Connor et al. 2012). Annual breeding records are only available for species with annual breeding surveys, or species with obvious breeding behaviour that can be detected during annual population censuses.

Common name (Ngarrindjeri name)	Scientific name	Breeding frequency	Breeding locations
Australian fairy tern (Talamarari)	Sternula nereis	Annual	Coorong South Lagoon islands and Murray Mouth (when limited food available). Breeding success dependent on prey availability (fish) close to predator-free nesting islands
Australian pelican (Ngori)	Pelecanus conspicillatus	Annual	Islands in the Coorong South Lagoon, including Teal, North Pelican, Pelican, Mellor and Seagull islands
Australian pied oystercatcher (Prukal)	Haematopus longirostris	Annual	Younghusband Peninsula beaches, Murray Mouth, Coorong islands
Australian white ibis (Tloperi)	Threskiornis molucca	Annual	Lake Alexandrina and Albert e.g. (Narrung Narrows, Point Sturt, Boggy Lake, Low Point, Currency Creek mouth, Tolderol)
Black swan (Kungari)	Cygnus atratus	Annual	Goolwa Channel, Lakes Alexandrina and Albert
Caspian tern (Tenatjeri)	Hydroprogne caspia	Annual	Coorong South Lagoon islands
Crested tern	Thalasseus bergii	Annual	Coorong South Lagoon islands (e.g. Pelican Island)
Hooded plover (Ngamat)	Thinornis rubricollis	Annual	Ocean beaches, occasionally coastal saline wetlands
Red-capped plover	Charadrius ruficapillus	Annual	Younghusband Peninsula beaches and Murray Mouth
Pied cormorant (Ngalgurindi)	Phalacrocorax varius	Regular	Lakes Alexandrina and Albert
Royal spoonbill (Kraurarli)	Platalea regia	Regular	Lakes Alexandrina and Albert
Silver gull (Throki)	Chroicocephalus novaehollandiae	Regular	Coorong South Lagoon islands
Straw-necked ibis (Tloperi)	Threskiornis spinicollis	Regular	Lakes Alexandrina and Albert

Most of the waterbirds that regularly breed within the Ramsar site are piscivorous species, including the Australian pelican, fairy tern, crested tern, Caspian tern and pied cormorant (O'Connor et al. 2012; Paton et al. 2018). Although crested terns breed in the Coorong South Lagoon and forage to an extent in the Coorong and Lakes, they largely forage in the adjacent marine environment when breeding (Paton et al. 2015d, 2018). Caspian terns and Australian pelican forage substantial distances (probably over 100 kilometres) from their breeding colonies in the Coorong South Lagoon (Paton et al. 2015d; Paton et al. 2018). These species will still breed when conditions in the Coorong South Lagoon do not support available fish prey. Other species, such as fairy tern, vacate breeding

islands in the Coorong South Lagoon and attempt to breed elsewhere within the Ramsar site (i.e. the Murray Mouth) when conditions are unfavourable (Paton et al. 2015d, 2018).

A range of colonial nesting waterbirds breed within the Lakes, including pied cormorant, Australian white ibis, straw-necked ibis and royal spoonbill (Paton et al. 2018). The Ramsar site provides suitable habitat (reed beds) for nesting and some foraging opportunities for Australian white ibis and straw-necked ibis (Paton et al. 2018). Silver gull, another colonial-nesting species, regularly breeds on islands within the Coorong South Lagoon (Paton et al. 2015d, 2018). Silver gulls are adaptable and their breeding may be linked to the breeding of pelicans and terns, as they scavenge food at those sites (Paton et al. 2018). The beaches of the Coorong, Younghusband and Sir Richard Peninsulas are important sites for beach-nesting species, including Australian pied oystercatcher, hooded plover and red-capped plover (O'Connor et al. 2013).

# Waterbird breeding habitat

A diversity of habitat types and food resources found within the Ramsar site support the breeding of a range of waterbirds (as outlined above). The extensive and dense emergent vegetation around the Lakes provides important nesting sites for waterbird breeding. Protected shallow wetland areas provide important habitat and food resources for these breeding species (Phillips and Muller 2006). In the Coorong, the islands are key breeding sites and provide critical habitat when other wetland sites (such as inland salt lakes) are dry and not suitable for nesting (O'Connor et al. 2013). Ngarrindjeri Kaldowinyeri stories feature these breeding areas in relation to the activities of the Ancestral Birds. These stories provide Ngarrindjeri with the knowledge about their Ngartji relationship with birds and Ngarrindjeri wise-use rules for hunting, egg collecting and caring for breeding places.

Breeding habitat for those species that are regularly supported (as above in Table 4-7) by the Ramsar site are outlined below in Table 4-8.

Table 4-8 Waterbird breeding habitat for those species that regularly breed in the Ramsar site (summarised from Ecological Associates 2010).

Common name (Ngarrindjeri name)	Breeding habitat
Australian fairy tern (Talamarari)	Breed in small colonies on islands and beaches inside estuaries and on open sandy beaches. Nests are located above the high-water mark often in clear view of the water and on sites where the substrate is sandy and the vegetation low and sparse. Nests typically consist of a shallow scrape in the sand which may be lined with small shells and vegetation. Colonies occupy areas rather than specific sites and nest sites are often abandoned after 1 year, even if they have been successful.
Australian pelican (Ngori)	Breed colonially on low secluded sandy islands, islets or shores, or among patchy vegetation. Need undisturbed sites with abundant and assured food resources (for 3 months) for successful breeding.
Australian pied oystercatcher (Prukal)	Breed in pairs, with a territory of approximately 200 m defended by both birds. Nest is normally a scrape in the sand, shell grit or shingle just above the high-water mark on beaches, sandbars, margins of estuaries and lagoons. May also breed within or beside saltmarsh, samphire and mudflats.
Australian white ibis (Tloperi)	Breed in fresh, brackish or saline wetlands vegetated with reeds, shrubs or trees in which nests are built. Nest in large colonies, often with the straw-necked Ibis. May have 1 or 2 broods in a year.
Black swan (Kungari)	Breed in simple pairs, solitary on small waters (<2 ha) and on larger waters with a fringe of aquatic plants or with consistent water level during winter-spring. Also breed in larger colonies on larger lakes and swamps with fluctuating water levels and abundant food. Nest mound built in open water, on an island, or in swamp vegetation. Requires minimum water depth of 30–50 cm until cygnets are independent.
Caspian tern (Tenatjeri)	Usually breed usually in colonies on islets of hummocks surrounded by shallow fresh, brackish and saline water. Breed in swamps, streams and flooded saltmarsh.

Common name (Ngarrindjeri name)	Breeding habitat
Crested tern	Breed on islands and banks of sand, shells or rock.
Hooded plover (Ngamat)	Breed on the sandy ocean beaches in narrow strip between the high-water mark and the base of the dunes. Also recorded breeding in the salt lakes of the Coorong.
Red-capped plover	Breed in simple pairs on ground in a diverse range of sites, including brackish or freshwater lagoons, generally near water.
Pied cormorant (Ngalgurindi)	Nest in horizontal branches and forks of trees (live or dead) in or over water. Colonial nester with multiple nests in single trees / shrubs. Requires water to remain until nestlings are independent
Royal spoonbill (Kraurarli)	Nest in colonies over or near water, usually in trees, shrubs or reeds. Freshwater wetlands used for breeding, but birds may nest in brackish or saline habitats.
Straw-necked ibis (Tloperi)	Form large breeding colonies in fresh, brackish or saline wetlands, vegetated with reeds, shrubs or trees in which nests are built. May nest on-ground on islands or wetland margins.
Silver gull (Throki)	Nests on a diverse range of sites from offshore islands to inland wetlands.

## Threatened species

Six nationally and internationally conservation significant species are supported within the Ramsar site (Table 4-9) and are described in further detail below.

Table 4-9 Wetland-dependent bird species that are listed as vulnerable, endangered or critically endangered under national legislation or international frameworks. International (IUCN Red List) and National (EPBC) status is shown as CR (critically endangered), En (endangered), or Vu (vulnerable). IUCN criteria for allocating categories of extinction risk are shown in parentheses.

Common name (Ngarrindjeri name)	Scientific name	International status	National status
Australasian bittern (Talkuri)	Botarus poiciloptilus	En (C1)	En
Australian fairy tern (Talamarari)	Sternula nereis	Vu (C1)	Vu
Curlew sandpiper	Calidris ferruginea	LC	CR
Eastern curlew	Numenius madagascariensis	Vu	CR
Hooded plover (Ngamat)	Thinornis rubricollis	Vu	Vu
Mount Lofty Ranges southern emu-wren (Wirili Pulyeri)	Stipiturus malachurus intermedius	_	En

# Australasian bittern (Talkuri)

The Australasian bittern (*Botaurus poiciloptilus*) (Figure 4.13) is a shy and cryptic wading species of wetland bird, typically solitary in nature, but sometimes occurring in pairs or dispersed aggregations of up to 12 birds. Habitat preferences for Australasian bittern are for permanent, densely vegetated freshwater wetlands (Garnett 1992) and within the Ramsar site this includes homogenous, dense reed beds (O'Connor et al. 2013). This species is believed to breed locally within the Ramsar site, though no nest has ever been found (Eckert 2000). They forage mainly at night in shallow water up to 30 centimetres deep, feeding on frogs, fish and invertebrates as well as occasionally plant material (Marchant and Higgins 1990). The Ramsar site is recognised as a stronghold for this species within South Australia (BirdLife International 2012).



Figure 4.13 Australasian bittern (B. poiciloptilus) (Talkuri) (Ian Montgomery, Birdway).

# Australian fairy tern (Talamarari)

Fairy terns (*Sternula nereis nereis*) were listed as vulnerable in 2011 under the EPBC Act and are listed as vulnerable under the IUCN Red List (IUCN 2012, Table 13-1). They are small piscivorous birds (Figure 4.14) that are generally restricted to shallow coastal wetlands and estuaries (Paton and Rogers 2009). The Coorong population has been considered a traditional stronghold for this species, given the low estimated global population size (Paton and Rogers 2009). During the breeding season, fairy terns are central-place foragers. Their foraging locations are restricted by the location of their nest site, as they must return to the nest between foraging trips (Paton and Rogers 2009). Fairy terns return to their breeding colonies with single prey items (i.e. small-bodied fish) and, so unlike other piscivorous species, they cannot increase the number of items they return with (Paton and Rogers 2009). Within the Ramsar site, fairy terns require a reliable source of suitable-sized fish in close proximity to nesting sites (Paton and Rogers 2009).



Figure 4.14 Fairy tern (S. nereis nereis) with small fish (© Marcel Hoog Antik 2015).

#### **Curlew sandpiper**

The curlew sandpiper (*Calidris ferruginea*) was listed as critically endangered under the EPBC Act in 2015 and is predominantly found in coastal sites in Australia with inland sightings believed to be vagrants passing through during migration. This species breeds in Siberia and migrates to Australia for the non-breeding period, arriving in Australia between August and November and departing between March and mid-April. Many young non-breeding birds remain in Australia during the winter (Emison t al. 1987). Curlew sandpipers typically occur in littoral and estuarine habitats and are predominantly found in the Murray Estuary and Coorong within the Ramsar site. They forage on invertebrates, including worms, molluscs, crustaceans and insects, as well as seeds (e.g. *Ruppia* seeds). They typically forage in water, near the shore on bare wet mud at the edge of wetlands and often forage in mixed flocks, including with red-necked stint.

#### **Eastern curlew**

The eastern curlew (*Numenius madagascariensis*) was listed as critically endangered under the EPBC Act in 2015 and is listed as vulnerable in the IUCN Red List (Table 4-9). This species is Australia's largest shorebird and undertakes annual migration flights to Russia and north-eastern China to breed, returning to Australia in August. The eastern curlew feeds on crabs and molluscs on intertidal mudflats and is predominantly found in the Murray Estuary and Coorong within the Ramsar site. The eastern curlew is highly sensitive to human disturbance (Lane 1987), making it highly vulnerable to development and human recreation at beaches, shorelines and estuaries.

#### **Hooded plover (Ngamat)**

The hooded plover (*Thinornis rubricollis*) (Figure 4.15) is listed as vulnerable under the EPBC Act and on the IUCN Red List (Table 13-5). It occurs on ocean beaches (typically above the high-water mark) and at coastal lakes across Australia (Buick and Paton 1989; Weston and Elgar 2005). The adults forage across the beaches on insects, sandhoppers (e.g. amphipods), small bivalves and soldier crabs. Nests are shallow scrapes in the sand or fine gravel and may be encircled with pebbles, seaweed and other beach debris (BirdLife Australia 2015). Within the Ramsar site, hooded plovers nest on the ocean beach above the high tide mark and close to the base of the frontal dunes (Buick and Paton 1989), between August and March (O'Connor et al. 2013). A major threat to this species within the Ramsar site is off-road vehicles on the ocean beaches which can cause the loss of nests and reduce reproductive success (Buick and Paton 1989).



Figure 4.15 Hooded plover (T. rubricollis) (Ngamat) (Ian Montgomery, Birdway).

## Mount Lofty Ranges southern emu-wren (Wirili Pulyeri)

The Mount Lofty Ranges southern emu-wren (*Stipiturus malachurus intermedius*) (Figure 4.16) is listed as endangered under the EPBC Act and on the IUCN Red List (Table 13-5). Within the Ramsar site it is found in the Currency Creek and Finniss River catchments of the EMLR tributaries. This species utilises 2 broad habitat types, including swamp and dry heath (including sedgeland and shrubland) and is found within the critically endangered Swamps of the Fleurieu Peninsula ecological community. Approximately 250 hectares of known habitat for this species is within the Ramsar site (Phillips and Muller 2006), although the birds occur sparsely throughout this area.



Figure 4.16 Mount Lofty Ranges southern emu-wren (*S. malachurus intermedius*) (Photograph: Marcus Pickett in Phillips and Muller 2006).

#### 4.5.6 Wetland habitat

The Coorong and Lakes Alexandrina and Albert Wetland consists of a mosaic of 23 Ramsar wetland types, including intertidal mud, sand or salt flats, coastal brackish/saline lagoons, permanent freshwater lakes, permanent freshwater marshes/pools, shrub dominated wetlands and water storage areas. 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. The total area of wetland is 115,940 hectares. The balance of the land (29,046 hectares) within the Ramsar site is terrestrial habitat, which is not classified under the Ramsar Convention. Chapter 2 of this document outlines the extent of the 23 wetland types located within the site. More detailed information on the wetland types is available in Phillips and Muller (2006).

Habitats around the edge of the Lakes are influenced by and respond to water regulation procedures at the barrages. There is a cyclical change in levels from about +0.85 metres AHD in late spring to a low of +0.4 metres AHD in autumn and lower in drought years. This slight rise and fall in lake water levels results in seasonal variation of habitats. Wind has an important influence on lake levels (Gibbs et al. 2018). Wind can push water higher up one side of the Lakes or the other and along the river. This results in daily and weekly localised variations in lake levels of nearly a metre during periods of prolonged, strong winds (Seaman 2003). Most of the Lakes habitat is representative of permanent freshwater lakes (Ramsar type O) with the lakeshores dominated by shrub dominated wetlands (W), permanent freshwater marshes/pools (Tp), freshwater, tree dominated wetlands (Xf), seasonal/intermittent saline/brackish/alkaline marshes/pools (Ss) and lakes and flats (R).

The dominant habitat of the Murray Estuary and Coorong is representative of coastal brackish/saline lagoons (J) surrounded by intertidal mud, sand or salt flats (G), estuarine waters (F), sand shingle and pebble shores (E), rocky marine shores (D) and intertidal marshes (H). The Coorong experiences seasonal changes in water level by as much as a metre in the Coorong South Lagoon from late spring highs to late autumn lows. As water levels start to fall in early summer, extensive tidal mud flats are exposed along the southern shores of the Coorong. On the peninsula side, there are freshwater soaks, which provide further variety of habitat types. Wind and tide also cause short-term variations in water levels locally. Storm and tide events can force seawater back through open barrage gates into Lake Alexandrina and across causeways on Ewe and Tauwitchere islands into the Lake. The seaward side of the coastal dune barrier is a high energy coast with a continuous sand beach (Seaman 2003).

Habitat mapping across the entire site was undertaken in 2003 (Seaman 2003).

# 4.5.7 Threatened ecological communities and species

In addition to the threatened fish and waterbird species identified in 4.5.4 Fish and 4.5.5 Waterbirds, 2 threatened ecological communities, the Swamps of the Fleurieu Peninsula and the Subtropical and temperate coastal saltmarsh and one threatened species the Southern bell frog (*L. raniformis*) are found within the site.

#### Swamps of the Fleurieu Peninsula

The Swamps of the Fleurieu Peninsula ecological community (Figure 4.17) were listed as critically endangered under the EPBC Act in 2003. They occur sparsely throughout the Fleurieu Peninsula, with only a component of the community (estimated approximately 262.5 hectares) found within the Currency Creek and Finniss River areas located in the Ramsar site. Typically the community is described as localised wetlands occurring in high rainfall areas, which support dense vegetation and occur adjacent to waterlogged soils around low-lying creeks and flats (TSSC 2003). This community is dependent on surface water runoff and groundwater, particularly the continued and gradual flow of springs and sedimentary aquifers and is associated with the freshwater submergent and emergent vegetation communities. This ecological community also supports the nationally endangered Mount Lofty Ranges southern emu-wren (*S. malachurus intermedius*). These wetlands/nurseries are an important part of Ngarrindjeri Yarluwar-Ruwe and highlight the importance of connectivity through ground water and springs. They are part of the Meeting of the Waters site and are markers of the health of Ngarrindjeri Ruwe/Ruwar (Ngarrindjeri 2019).



Figure 4.17 Part of the Swamps of the Fleurieu Peninsula ecological community that overlaps with the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site. (Photograph: Marcus Pickett in (Phillips and Muller 2006).

# Subtropical and temperate coastal saltmarsh

The Subtropical and temperate coastal saltmarsh ecological community was listed as vulnerable under the EPBC Act in 2013 and includes the assemblage of plants, animals and micro-organisms associated with saltmarsh in coastal regions of sub-tropical and temperate Australia. The community that exists in southern Australia has high floristic biodiversity (about 75% of saltmarsh species) and occurs in large areas behind the open coastline of sheltered waters (Fairweather 2011b; TSSC 2013).

Samphire communities are generally restricted to areas above +0.2 metres AHD in the Coorong (Nicol 2016). The saltmarsh habitats are only periodically inundated by the highest tides, they grow in sediments or soils that are often waterlogged and extremely saline (with salt concentrations often well above seawater, due to evaporation (Fairweather 2011a)

The percentage cover of the temperate coastal saltmarsh ecological community on the lagoon edges of the Murray Estuary and Coorong is stable at 480 hectares (DEW 2018a) with the majority protected within Coorong National Park. The community is often dominated by *S. australis* and *S. quinqueflora* in the lower zone, with Tecticornia species in the mid zone and a diverse array of species in the higher, brackish zone including, *Puccinellia stricta*, *Wilsonia sp*, *Disphyma crassifolium*, *Atriplex sp* and *Triglochin striata*. The range of infaunal and epifaunal invertebrates is unknown (Fairweather 2011a).

Detailed mapping of the saltmarsh communities in the Murray Estuary and Coorong was completed in 2006 and the associated data used to determine the conservation status of these habitats and list those in need of protection. The mapping provides the type and size of the habitats present and can be accessed through DEW Nature Maps. An understanding of the faunal assemblages in the community across the Ramsar site is a knowledge gap for the site. For Ngarrindjeri, these areas also have importance as Ruwe health indicators that use salinity as a marker (Ngarrindjeri 2019).



Figure 4.18 Samphire saltmarsh (Photograph: Jason Nicol).

# Southern bell frog

The southern bell frog (*Litoria raniformis*) (Figure 4.19) is listed as vulnerable under the EPBC Act, endangered on the IUCN Red List and in South Australia under the NPW Act. It is a large ground-dwelling frog, reaching 60-104 millimetres in length in females and 55-65 millimetres in males (Anstis 2013; Mason and Turner 2018). The skin varies from dull olive-brown to bright emerald green, mottled with irregular brown to tan blotches within or without a cream or pale green vertebral stripe. The skin surface contains numerous dark brown to gold raised warts which can be arranged in longitudinal rows. A distinguishing feature of southern bell frog compared to other frogs in the CLLMM region is the bright turquoise colouring of the skin on the inside of the back legs and groin (Robinson 1993; Stratman 2007; Anstis 2013).

Individuals are most active in spring and summer when they may be seen basking in the sun. In winter they can be found in groups beneath thick beds of reeds on the edges of wetlands (Stratman 2007). Generally feeding at night, southern bell frog eat small water bugs, beetles, termites and insect larvae. They can also be cannibalistic, eating other frogs including individuals of their own species (Bannerman 2005). They are opportunistic predators, sitting and waiting to ambush whatever prey comes within reach (Schultz 2007).



Figure 4.19 Southern bell frog (L. raniformis) (from Mason 2014).

The southern bell frog is known to occupy a range of natural and artificial habitats including permanent and ephemeral wetlands, streams, riverine floodplains, farm dams, flooded paddocks, marshes, garden ponds, quarries and irrigation channels (Stratman 2007). The habitat preference of southern bell frog in Lake Alexandrina, Lake Albert and tributaries regions of the Ramsar site has generally consisted of lignum (*D. florulenta*) shrublands (Figure 4.20), low sedgelands, inundated grasses and dense floating aquatic plants such as filamentous algae (Mason 2014).



Figure 4.20 Lignum shrublands at Pelican Lagoon from where adult southern bell frog was observed calling, February 2011 (Mason and Hillyard 2011).

Breeding can occur from spring to autumn and preferred breeding habitats are associated with seasonally flooded wetlands containing complex aquatic vegetation communities (Wassens et al. 2008). Water levels play an important role in the provision of suitable habitat, with southern bell frog being highly responsive to flooding or rising water levels (Mason and Durbridge 2015). The inundation of suitable habitat is one of the known cues for calling (Mason and Hillyard 2011), with preferences for temporary wetlands or wetlands with significantly fluctuating water levels (Schultz 2007).

The main threats to this species include degradation and fragmentation of habitat (Bannerman 2005); introduction of alien predatory and competitive fish; infection by chytridiomycosis disease (more commonly referred to as chytrid fungus); accumulation of chemicals in aquatic habitats; disturbance to the riparian zone through grazing and removal of woody debris; and altered water regimes that impact the seasonality of flooding and hydrological connectivity affecting movement and limiting triggers for breeding (Bannerman 2005; Stratman 2007; Clemann and Gillespie 2010). As tadpoles, the species is sensitive to high fish densities and habitat disturbance (Pyke 2002), in particular competition/predation from Eastern gambusia (*Gambusia holbrookii*) and common carp (*C. carpio*) (Gonzalez et al. 2011).

# 4.5.8 Coorong food web

Estuaries are among the most productive ecosystems because they produce and receive nutrients and organic matter from a variety of sources – terrestrial, freshwater, estuarine and/or marine (Schelske and Odum 1962). Food webs describe how energy flows through the ecosystem and represent tools that aid in understanding of ecosystem function and how biota can respond to change (Odum 1971). Critical to Estuary management is maintaining species or taxonomic groups that are fundamental to maintaining food web structure or function (keystone species), as their removal may impact the stability of the food web (Paine 1969; Mills et al. 1993).

The Coorong supports a range of biota of conservation, economic and cultural significance (Phillips and Muller 2006). These biota do not occur as random assemblages but as interdependent functional groups that interact through complex food webs. The focus of this critical CPS is on the Coorong, as food webs for the Lakes have limited empirical data (Giatas et al. 2018).

#### Components of the food web

A generalised food web model for the Coorong depicts the different trophic levels across 4 main groups, including primary producers, primary consumers, secondary consumers and higher order consumers (Figure 4.21) (Giatas et al. 2018).

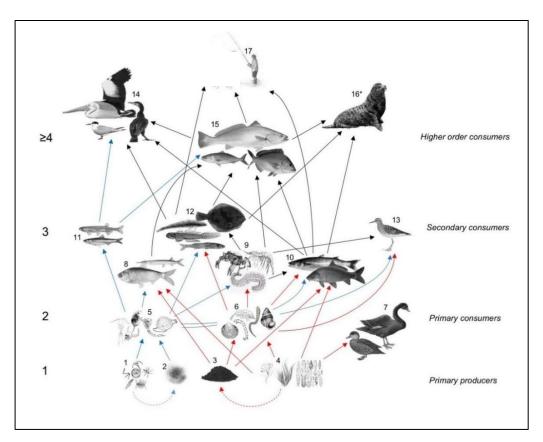


Figure 4.21 Conceptual food web of the Coorong using feeding functional guilds (Giatas et al. 2018). Red trophic links represent those supported by benthic production (benthic algae/plants), while blue trophic links represent those supported by pelagic production (phytoplankton). Primary producers and organic material are:

- (1) phytoplankton
- (2) suspended particulate organic matter
- (3) benthic detritus
- (4) benthic macrophytes, micro- and macro-algae

# Feeding guilds are

- (5) suspension-feeding micro- and macroinvertebrates
- (6) deposit-feeding and herbivorous macroinvertebrates
- (7) herbivorous waterfowl

- (8) omnivorous fishes (part 1)
- (9) carnivorous invertebrates
- (10) omnivorous fishes (part 2)
- (11) zooplanktivorous fishes
- (12) zoobenthivorous fishes
- (13) zoobenthivorous shorebirds
- (14) piscivorous birds
- (15) piscivorous fishes
- (16) piscivorous mammals
- (17) humans

# **Primary producers**

Energy is photosynthetically produced through pelagic production via phytoplankton and benthic production via benthic macrophytes, macro- and microalgae (Figure 4.21). The relative contribution of some primary producers (e.g. benthic microalgae) to the overall production in the Coorong is poorly understood (Giatas et al. 2018). Macroalgae (e.g. filamentous *Ulva*) are widespread (Geddes 2005; Geddes and Tanner 2007) and possibly an important source of benthic production, with a large proportion likely converted to detritus (Figure 4.21). Macrophytes (such as *R. tuberosa* and associated macrophyte *Althenia cylindrocarpa*) are an important food source and provide structure for epiphytes (algae that grow on other plants), habitat for invertebrates and a direct food source for grazers (shoots) and birds (seeds and turions) (Paton 1986; Paton 2010).

#### **Primary consumers**

Micro- and macroinvertebrates are the dominant primary consumers in the Coorong (Figure 4.21) (Dittmann et al. 2018). These include: 1) suspension feeders, e.g. many pelagic microcrustaceans (copepods and cladocerans etc), the sessile tubeworm (*Ficopomatus enigmaticus*) and bivalve *Arthritica helmsi*; 2) deposit feeders, e.g. the polychaete *Capitella capitate*; and 3) herbivorous macroinvertebrates, e.g. amphipods and chironomid larvae (Giatas et al. 2018).

The primary consumer trophic group also comprises herbivorous waterfowl (e.g. black swan and grey teal) (Figure 4.21). Whilst specialist detritivorous fishes occur in the Coorong in low abundance (e.g. goldspot mullet), herbivorous fishes are absent, which is common in dynamic environments such as temperate estuaries (Bice et al. 2018). The major trophic pathway for suspension feeders is considered to be through the pelagic pathway, while energy for deposit feeders, grazers/browsers and herbivorous waterfowl is provided through the benthic pathway (Figure 4.21). As the Coorong is shallow and prone to sediment resuspension, benthic primary production may also support suspension feeders (Giatas et al. 2018).

Omnivores as shown in Figure 4.21 include omnivorous scavenging invertebrates (e.g. the crab *Paragrapsus gaimardii* and polychaete *Simplisetia aequisetis*) and omnivorous fishes. In the Coorong, omnivorous fishes are divided into 2 parts – species whose animal prey are dominated by 1) pelagic microcrustaceans (e.g. bony herring); and 2) benthic macroinvertebrates (e.g. yelloweye mullet and invasive common carp) (Giatas et al. 2018).

#### **Secondary consumers**

Polychaetes (*Nephtys australiensis* and *Phyllodoce novaehollandiae*), zooplanktivorous fishes (e.g. sandy sprat), zoobenthivorous fishes and shorebirds represent the secondary consumer trophic group (Figure 4.21). Benthic invertebrates such as amphipods, polychaetes and insect larvae form important components of the diet of shorebirds (Paton 2010) and many zoobenthivorous fishes (e.g. greenback flounder, small-mouthed hardyhead and Tamar goby) (Earl 2014; Hossain et al. 2017). Prey use in shorebirds is determined by leg length and beak length, where benthic invertebrates burrow into the sediments – for example, in the Murray Estuary and Coorong North Lagoon (Paton 2010; Keuning 2011). Thus, the longer-legged and longer-beaked shorebirds (e.g. blacktailed godwit and eastern curlew) can usually access mudflats covered with deeper water and probe deeper into the sediments than the shorter-legged and shorter-beaked species (e.g. red-necked stint and sharp-tailed sandpiper) (Paton 2010; Keuning 2011).

Zooplanktivorous fishes generally rely on pelagic production to support zooplankton biomass, while many zoobenthivorous species obtain their food resources (e.g. benthic macroinvertebrates) via benthic production (Figure 4.21). However, benthic primary production may also support pelagic zooplankton and zooplanktivorous fishes due to sediment resuspension in shallow habitats (Giatas et al. 2018).

# **Higher-order consumers**

The majority of higher-order consumers in the Coorong are piscivores that feed on zooplanktivorous, zoobenthivorous or omnivorous fishes (Figure 4.21). Large predatory or omnivorous benthic invertebrates and other piscivorous fishes may be consumed by higher-order consumers (Giatis and Ye 2015).

Mulloway (*A. japonicas*) is the largest piscivorous fish in the Coorong. It along with piscivorous birds (e.g. Australian pelican, cormorants and terns) is capable of feeding on a variety of fishes (Giatas et al. 2018). In the Coorong South Lagoon, small-mouthed hardyhead is an essential prey item for piscivorous birds (e.g. fairy tern) as this is the dominant fish species in the region. Long-nosed fur seals (which were largely undocumented in the Coorong prior to 2007) and humans (i.e. fishers) are considered to be the apex predators in the Coorong (Figure 4.21). Mulloway, yelloweye mullet, black bream and greenback flounder are the most commercially harvested fishes (Ferguson et al. 2018).

#### Influence of salinity gradient on food web structure in the Coorong

The Coorong, as an inverse Estuary, has an extensive and persistent salinity gradient, typically spanning from brackish in the Murray Estuary to hypersaline in the Coorong South Lagoon (Gibbs et al. 2018). The salinities in the Coorong are influenced by freshwater inflows and seasonality (e.g. winds, tides and evaporation) (Gibbs et al. 2018). Under higher freshwater inflows, a broader range of biota can inhabit otherwise hypersaline areas, allowing more complex food chains to operate. Longer and more complex food chains that are present in the Coorong North Lagoon can temporarily operate in parts of the Coorong South Lagoon under higher freshwater inflows before receding when flows stop and hypersalinity returns (Deegan et al. 2010).

As the Coorong is shallow, relatively small variations in water level result in large areas of sediments being either flooded or exposed at daily to seasonal timescales (Gibbs et al. 2018). These 2 features combine to produce a complex mosaic of habitats, food webs and overall species diversity across the Coorong (Phillips and Muller 2006). As salinities increase from marine (approximately 40 ppt/ 55,658 EC), there is a general decline in the diversity of species, feeding guilds and food chain length, driven by species salinity preferences and tolerances (Deegan et al. 2010; Giatas et al. 2018).

# Key components of the Coorong food web

Maintaining the species or taxonomic groups that play fundamental roles in the food web structure is critical to the Coorong (Giatis et al. 2018). The keystone species of the Coorong South Lagoon food web are described in further detail below and include the following:

- Ruppia tuberosa keystone primary producer in the hypersaline food webs of the Coorong
- Benthic macroinvertebrates primary or occasionally secondary consumers are a keystone prey species for fishes and shorebirds
- Small-mouthed hardyhead secondary consumer are the critical prey species for piscivorous fishes and birds.

# Ruppia tuberosa – primary producer

The submergent halophyte *R. tuberosa* is a key element in the Coorong food web, particularly in the Coorong South Lagoon (Figure 4.22). Core populations of *R. tuberosa* exist in water that is typically 0.3 – 0.9 metres deep during winter and spring within the Coorong South Lagoon. Peak performance at the intermediate depths within this range (Paton et al. 2015a). These populations provide food resources for higher-order consumers (Figure 4.21), including waterbirds such as black swans, which forage on the shoots and turions and migratory shorebirds which forage on turions and seeds and spawning sites for fish such as small-mouthed hardyhead (Rogers and Paton 2009).

*R. tuberosa* is typically covered in water from late autumn through spring and into summer, before drying out in late summer and autumn (Figure 4.22). When dry, the plants occur on the surface of the substrate as seeds and turions, with the turions. The turions sprout and seeds germinate with rising water levels in late autumn and winter (Paton and Bailey 2012a). Low water levels, leading to extended exposure of the plants prior to setting of seeds or turions, have significant impacts on reproductive success. A series of years with inadequate water levels in the Coorong South Lagoon, in particular, will have critical flow-on effects to the food web of the Coorong (Paton and Bailey 2012a).

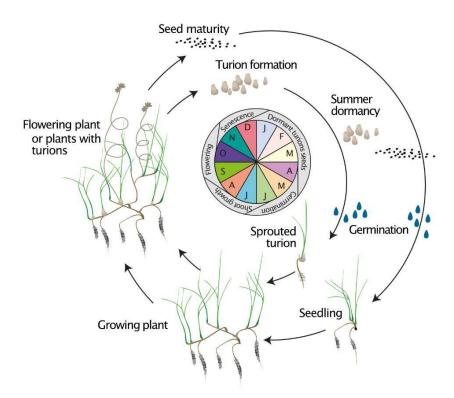


Figure 4.22 Illustration of the *R. tuberosa* life cycle showing annual growth from both seeds and turions (from Waycott et al. 2020).

In the Coorong *R. tuberosa* is restricted to water that is no more than approximately 0.9 metres deep as water turbidity restricts light penetration at greater depths (Paton et al. 2015a). Although seeds and turions sprout in shallow water, those that are growing in water less than around 0.3 metres in depth rarely survive to reproduce (Paton et al. 2015a). This is because daily wind-induced changes in water levels can approach 0.3 metres in the Coorong South Lagoon. When this occurs, these plants are exposed to desiccation (Paton et al. 2015a).

Each life stage of *R. tuberosa* has salinity sensitivities (Figure 4.23) with germination from seed and sprouting from turions requiring the lowest salinity (Collier et al. 2017). Maximum seed germination rate occurs at 10 – 40 ppt (16,623-55,658 EC) but previous exposure to extreme salinities (105 – 180 ppt/ 116,508-169,689 EC) can increase germination rate (Collier et al 2017). A period of extreme salinity during the dormant summer phase may increase seed germination (Collier et al. 2017). While optimal salinities for seed germination are less than 60 ppt (76,736 EC) and turion sprouting is less than 70 ppt (86,342 EC), suboptimal tolerances are higher. Seeds also able to germinate less than 85 ppt (99,852 EC) and turions less than 120 ppt (128,175 EC) (Collier et al 2017).

While salinity, turbidity, water regime and wind and wave action influence distribution (Ganf 2000), seasonal water level, the presence of filamentous green algae and grazing pressure by waterfowl can influence reproduction of *R. tuberosa* and the services it provides (Paton et al. 2015a).

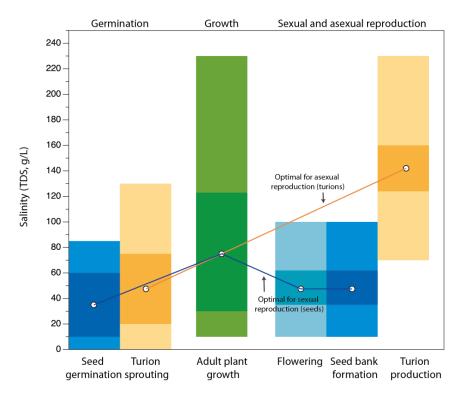


Figure 4.23 Summary of optimal salinity for different stages of the *R. tuberosa* life cycle (from Collier et al. 2017). This is separated into optimal conditions for sexual reproduction (flowers and seed germination in blue), or by turion formation (in orange). Darker shades indicate the optimal salinity while lighter shades indicate sub-optimal conditions. Unsuitable conditions are not indicated on this figure.

# Benthic macroinvertebrates - primary consumers

Benthic macroinvertebrates play an important role as primary or occasionally secondary consumers in the Coorong food web (Figure 4.21). They are key to trophic interactions, as they represent various feeding modes (e.g. deposit feeder, suspension feeder, grazer, and predator) and constitute one of the most important food sources for fish and shorebirds (Giatas et al. 2018). Benthic macroinvertebrates include bristleworms, molluscs, crustaceans and larval life stages of insects which are greater than 0.5 mm. They live either in the sediments, or on the sediment surface (Dittmann et al. 2017).

Benthic macroinvertebrate communities inhabit different sections of the Coorong in accordance with the presiding salinity gradient and physical habitat (Dittmann et al. 2018). Diversity, abundance and biomass are highest in the Murray Estuary, then decrease southward into the Coorong South Lagoon. Over 60 species of macroinvertebrates have been recorded in the Murray Estuary and Coorong. The 5 most abundant Coorong taxa recorded are amphipods, polychaetes, bivalves and chironomid larvae (a complete species list can be found in Appendix C).

Amphipods, which characterise the Coorong assemblage during high inflows, are important in the diet of benthic feeding fish (e.g. Earl 2014; Hossain et al. 2017), whilst polychaetes and bivalves, characterised by moderate to low inflows, are important in the diets of shorebirds (Ditmann et al. 2015; Keuning 2011). Under drought (low flow) conditions, small-bodied organisms are typical and abundance, biomass and diversity is generally low (Dittmann et al. 2017). Major disturbances such as extended periods of drought and rapid changes in salinity regime can impact Coorong macroinvertebrate communities.

Sediment composition and grain size can influence macroinvertebrate assemblages, with higher proportions of coarse grains associated with lower numbers of invertebrates (MDBA 2006). Notable changes to the abundances of macroinvertebrates have flow-on effects to higher trophic levels, where abundant and harvestable prey for fish and shorebirds can support a functioning and resilient ecosystem (Dittmann et al. 2018).

# Small-mouthed hardyhead - secondary consumer

Small-bodied fish with high salinity tolerance such as the small-mouthed hardyhead (*A. microstoma*) are critical prey for higher-order consumers in the Coorong. Within the Murray–Darling Basin, the small-mouthed hardyhead is restricted to the Ramsar site (Molsher et al. 1994; Wedderburn and Hammer 2003; Lester et al. 2011b) and is highly abundant in the Coorong (Ye et al. 2017). The species is regarded as one of the most salt-tolerant fish in the world (Mosher et al. 1994) and has been recorded in salinities up to 130 ppt (135,620 EC) in the Coorong (Geddes 1987; Noell et al. 2009; Lester et al. 2011b).

Small-mouthed hardyhead exhibits a protracted spawning period from September to December each year (Molsher et al. 1994; Ye et al. 2014) and can complete its life cycle in a range of salinities from brackish to hypermarine (Ye et al. 2014). In the Coorong, this species is commonly abundant in both the Coorong North and Coorong South lagoons (Rogers and Paton 2008; Ye at al. 2014). Recruitment, relative abundance and spatial distribution of small-mouthed hardyhead are dependent on freshwater flows to the Coorong and maintaining salinities below 100 ppt (112,471 EC) in the Coorong South Lagoon (Ye et al. 2014). Increases in abundance, particularly in the Coorong South Lagoon, may relate to the re-establishment of *R. tuberosa*, increasing habitat quality and availability (Frahn et al. 2012; Paton and Bailey 2012a). The distribution and abundance of small-bodied fish in the Coorong, including small-mouthed hardyhead, are fundamental to the Coorong food webs, which represents a key prey item for the fairy tern (Paton 2010).

# 4.6 Non-critical components, processes and services

The non-critical CPS are those considered important for supporting the ecological character of the site, but are not considered critical. A brief summary of each non-critical CPS is presented in Table 4-10. Further details for each non-critical CPS is presented below.

For Ngarrindjeri critical and non-critical components, processes and services are all connected and part of the living body of the Ngarrindjeri Yarluwar-Ruwe. This perspective is supported by the Creation stories of the Kaldowinyeri. Ngarrindjeri have a cultural responsibility to care for Ruwe/Ruwar, and if this responsibility is not exercised then Ngarrindjeri wellbeing is severely compromised.

Table 4-10 Summary of non-critical components, processes and services (CPS).

Non-critical CPS and subcomponents	Description	Туре
Climate	<ul> <li>Typically, a Mediterranean climate with mild, wet winters and hot dry summers.</li> <li>Average annual rainfall is 468 millimetres and is winterdominated with the majority of the rain falling from April to October.</li> </ul>	Component, process, regulating service
	<ul> <li>Rainfall variability is high with the lowest annual rainfall of 241 millimetres and the highest annual rainfall of 696 millimetres.</li> </ul>	
Geomorphic setting	<ul> <li>Lakes Alexandrina and Albert and the Coorong Lagoon are Holocene estuarine features, occupying tectonically subsiding Quaternary inter-dune areas.</li> <li>Sir Richard Peninsula and Younghusband Peninsula separate the Estuary from the sea.</li> </ul>	Component
	<ul> <li>Complex and dynamic area of interaction between inputs of freshwater with the coastal and marine influences of tides, waves, currents and winds.</li> </ul>	

Non-critical CPS and subcomponents	Description	Туре
<ul> <li>Soils</li> <li>Acid sulfate soils</li> <li>Acid sulfate soils</li> <li>The soils of the lake beds contain sulfidic material exposed to air and oxidised, can be activated to put that could affect soil and water pH.</li> <li>The Coorong is dominated by yellow-grey calcard and mudflats.</li> </ul>		Component, process
Sedimentation	<ul> <li>Lake Alexandrina acts as both a sink for sediment brought in by the River Murray and a source of sediments.</li> <li>Sediment resuspension is an important process in Lake Alexandrina at all lake water levels.</li> </ul>	
Water quality	<ul> <li>Turbidity is closely coupled with the volume of inflows, nutrients, rates of sedimentation, sediment resuspension and production of phytoplankton.</li> <li>High turbidity in the Lakes and Coorong is a primary factor in restricting submergent and emergent aquatic plant growth to the Lake and Lagoon margins.</li> <li>Biogeochemical processes store, release, transform and transport the nutrients, which in turn drive patterns of primary productivity underpinning the food webs.</li> <li>The waters of the Lakes and Coorong are alkaline, with pH values in the range of 7.5 to 10.0.</li> </ul>	Component, process
Algae and phytoplankton	<ul> <li>Inflows strongly influence phytoplankton communities within the Lakes.</li> <li>Mixed communities of phytoplankton species occur in the Lakes and the Coorong, with the dominant species dependent on the underlying conditions at the time.</li> </ul>	Component
Invertebrates  • Macrobenthic invertebrates  • Zooplankton	<ul> <li>Invertebrates are a fundamental part of the food webs that exist across the site.</li> <li>Distinct adult and juvenile benthic assemblages were identified for the Murray Mouth, Coorong North Lagoon and Coorong South Lagoon areas.</li> <li>The composition of zooplankton assemblages is influenced by the habitat.</li> </ul>	Component
Biodiversity Flora Flora Fish Vaterbirds Reptiles Frogs Mammals  Frogs Mammals  Frogs Fro		Component, process and cultural service

# PUBLIC

Non-critical CPS and subcomponents	Description	Туре
Benefits		
Water supply	<ul> <li>The site supports supply of critical human water needs to Adelaide and surrounding areas</li> <li>The site supports mix of predominantly irrigated and dryland agriculture.</li> <li>The site supports manufacturing industries centred on wine, machinery and equipment; boat building and maintenance; and recreation and tourism activities.</li> </ul>	Provisioning regulating, supporting and cultural service
Aquatic foods	<ul> <li>The site supports a commercial fishery and significant recreational fishery driven by Pipi (Goolwa cockle), golden perch, mulloway and yelloweye mullet.</li> <li>Freshwater and saltwater fishing is an integral part of Ngarrindjeri cultural and economic wellbeing.</li> </ul>	Provisioning and cultural service
Natural hazard reduction	<ul> <li>Operation of the barrages allows for the management of floods.</li> <li>The peninsulas provide coastal shoreline stabilisation and storm protection.</li> <li>Ngarrindjeri view some flood events to be a beneficial part of Ngarrindjeri Ruwe-Ruwar.</li> </ul>	Regulating service
Pollution control	<ul> <li>The site plays a role in slowing flow, trapping and assimilating sediments, nutrients and other contaminants and buffering the amount of contaminant transfer that may occur during flow events.</li> </ul>	Regulating service
Special ecological, physical or geomorphic features	<ul> <li>The site provides critical drought refuge for waterbirds.</li> <li>The laws and traditions associated with these features guide Ngarrindjeri wise-use of Country.</li> </ul>	Supporting and cultural service
Primary ecosystem production and nutrient cycling	<ul> <li>Nutrient cycles underpin food webs within the system.</li> <li>For Ngarrindjeri nutrient cycling is understood as a key element of the Meeting of the Waters, the patterns of flow and flushing that give life to Ngarrindjeri Ruwe/Ruwar</li> </ul>	Supporting and cultural service
Healthy Ngarrindjeri Ruwe/Ruwar	<ul> <li>The Coorong and Lakes Alexandrina and Albert Wetland is a significant 'Sacred Site' – the Meeting of the Waters, and has been registered under the <i>Aboriginal Heritage Act 1988 (SA)</i>.</li> <li>Its spiritual and cultural significance is essential to the wellbeing and productivity of the Ngarrindjeri nation.</li> </ul>	Cultural service
Spiritual and inspirational	<ul> <li>Spiritual and inspirational 'services or benefits' are inseparable from the fundamental character of Ngarrindjeri Yarluwar-Ruwe.</li> <li>When the Ramsar site is unhealthy, negative spiritual and inspirational consequences are experienced.</li> </ul>	Cultural service
Science and education	<ul> <li>The site is important for improving understanding of large terminal lacustrine and estuarine systems.</li> <li>Yarluwar-Ruwe is intrinsically experienced as a source of Ngarrindjeri knowledge, education and research.</li> </ul>	Cultural service
Aesthetic amenity	<ul> <li>Includes unique waterscapes such as the Murray Mouth.</li> <li>For Ngarrindjeri, the Ramsar site was created in the Kaldowinyeri and has unique inherent 'beauty' purely through being part of Ngarrindjeri Yarluwar-Ruwe.</li> <li>Ngarrindjeri aesthetic understandings rely on spiritual feelings and specific cultural interpretations that provide meaning to what non-Indigenous values might interpret in other ways.</li> </ul>	Cultural service

Non-critical CPS and subcomponents	Description	Туре
Recreation	<ul> <li>Significant visitation for water activities, camping and experiencing nature.</li> <li>For Ngarrindjeri, being able to engage in recreational activities in the Ramsar site is essential to healthy Ruwe/Ruwar. What might be termed 'recreation' often combines cultural responsibility, teaching and Caring for Country.</li> </ul>	Cultural service
Tourism	<ul> <li>The tourism industry is a significant contributor to the Murraylands regional economy. <sup>3</sup></li> <li>Ngarrindjeri can only conduct Ngarrindjeri tourism on Ngarrindjeri Yarluwar-Ruwe and therefore they consider this crucial.</li> </ul>	Cultural service

#### 4.6.1 Climate

Climate across the Murray–Darling Basin plays an important role in influencing the hydrology and water quality that support the CPS at the Ramsar site.

Ngarrindjeri consider that there are 4 seasons each year, each associated with specific Creation ancestors. For example, Waiyungari is associated with Luwadang (spring); a time of growth and reproduction and therefore renewal and the provision of 'benefits' to Yarluwar-Ruwe. Similarly, for Ngarrindjeri seasonal shifts are a time of change that signal shifts in the spiritual 'flows' connected with Creation ancestors (Ngarrindjeri 2019).

The climate in the vicinity of the Ramsar site is typically Mediterranean with mild, wet winters and hot, dry summers. Average annual rainfall is 468 millimetres and is winter-dominated with the majority of the rain falling from April to October. Similar to other coastal areas of South Australia, variability is high with the lowest annual rainfall of 241 millimetres and the highest annual rainfall of 696 millimetres (BOM 2020).

Mean annual Class A pan evaporation has been estimated as 1,660 millimetres. Using a pan factor of 0.69 to convert pan evaporation to lake evaporation shows that on average, rainfall exceeds lake evaporation only during the 3 months of winter (DEWNR 2014b).

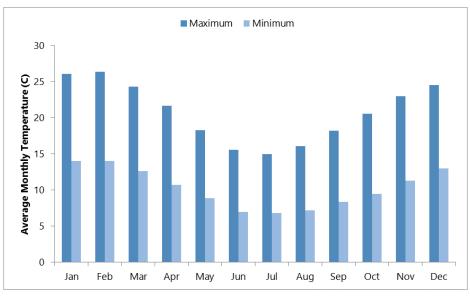


Figure 4.24 Maximum and minimum monthly temperature (degrees Celsius) at Meningie (1966–2015) (Bureau of Meteorology).

<sup>&</sup>lt;sup>3</sup> Tourism Research Australia (TRA) region that incorporates River Murray community below Lock 1. See TRA for boundary.

The mean daily maximum temperature at Meningie for the winter months is around 15° Celsius and rises to around 26° Celsius during the summer months. Daily summer temperatures can be as low as 12° Celsius and as high as 46° Celsius. The range of temperatures encountered during winter months is 8° to 26° Celsius. Frosts can be expected during cold nights (DEWNR 2014b).

The winds in the region generally reflect the migration of anticyclones and cold fronts across the southeast of the continent (Barnett 1993). In the summer and autumn months, south-westerlies, southerlies and south-easterlies are more frequent, whereas in winter the winds are more north-westerlies and northerlies (Barnett 1993).

#### 4.6.2 Geomorphic setting

Whilst a significant element contributing to meeting Ramsar Criterion 1, the geomorphic setting is not considered a critical component, as it is not considered likely to change in non-geological timeframes. However, Ngarrindjeri understandings of the geomorphological setting of the region are somewhat different. To Ngarrindjeri, Creation ancestors formed the landscape we see today and populated it. Creation stories such as those of Ngurunderi (see Chapter 3) and Thukabi (described below) emphasise the ways in which various Creation activities formed the geomorphology of the lower river, Lower Lakes, Coorong and adjacent coastal areas. Given this, geomorphological features are active components of Yarluwar-Ruwe, because they have spiritual as well as physical presence in the landscape (Ngarrindjeri 2019).

Ngurunderi the Creation ancestor travelled throughout Ngarrindjeri Country creating landforms, waterways and life. Another Creation ancestor, a man called Jekejeri, played an important role in the Kaldowinyeri and is linked to the Ngurunderi's Creation journey and landforms near Goolwa. The story of Jekejeri explains both the creation of a specific sandy beach and also the spiritual importance of that site. It should be noted that this version of the story is not complete, as Ngarrindjeri consider some details to be unsuitable for a wider audience (Ngarrindjeri 2019).

A long time ago at Goolwa our Spirit Ancestor, as he moved around our lands and waters, he gave teachings to our Ancestors, he gave meanings to the lands and waters and all its existence.

Before Ngurunderi came to Goolwa a man named Jekajeri cleansed the area and prepared a sandy beach for his arrival, upon Ngurunderi's arrival he said thankyou ...you have done a good job. Ngurunderi set up camp and carried out special spiritual teachings to the Nation.

Since that time Ngarrindjeri people have lived here and travelled here for gatherings because of its spiritual importance to women, men and our spiritual existence. (Tom Trevorrow's Speech Amelia Park Goolwa 10<sup>th</sup> October) (Trevorrow 2002)

Geomorphically the Lower Lakes and Coorong area is naturally very dynamic. A major impact of river regulation has been to reduce that dynamism. The region is not only affected by river flows. It is also affected by aeolian processes, tidal oscillations, storm surges, wave action on lake and ocean shores, wind induced lake level changes and variations in local sea level changes and long-term land subsidence. Human influences impact on many of these processes (Bourman et al. 2018).

The current Lower Lakes and Coorong are Holocene estuarine features, formed 7,000 years BP (before present) following the post-glacial marine transgression and development of the modern coastal barriers of Sir Richard Peninsula and Younghusband Peninsula. Subsequently, the barriers have migrated landward. The last interglacial shoreline parallels the modern shoreline several kilometres inland and most of the barrage system has been built on this substrate.

The northern half of Hindmarsh Island formed during the last interglacial period (125,000 BP) when longshore transport was dominantly from the southeast, effectively pushing the course of the River Murray westward, partly explaining the large bend in the River Murray at Goolwa (Ngarrindjeri for elbow). These processes are superimposed upon a tectonically subsiding landscape in the Lakes area with gentle uplift in the Coorong South Lagoon (Bourman et al. 2018).

The spatial extent of the Estuary has been constrained by the construction of barrages separating Lake Alexandrina from the Murray Estuary. Geomorphologically, the Murray Estuary is a complex and dynamic area of interaction between large inputs of freshwater with the coastal and marine influences of tides, waves, currents and winds together influencing development of beaches, dunes, coastal barriers and back-barrier lagoons and lakes. Aeolian processes are of significance, with occasionally 5,000 tonnes of sand being moved around the modern shoreline under strong wind conditions (Bourman 1986 in Bourman et al. 2018). In the Coorong, sand is blown directly from barrier dune systems into lagoons clogging channels. The position of the Murray Mouth is extremely dynamic migrating over 1.6 kilometres since the 1830s. Movements of 14 metres in 12 hours have been observed (Bourman in Jensen et al. 2000; Bourman 2000).

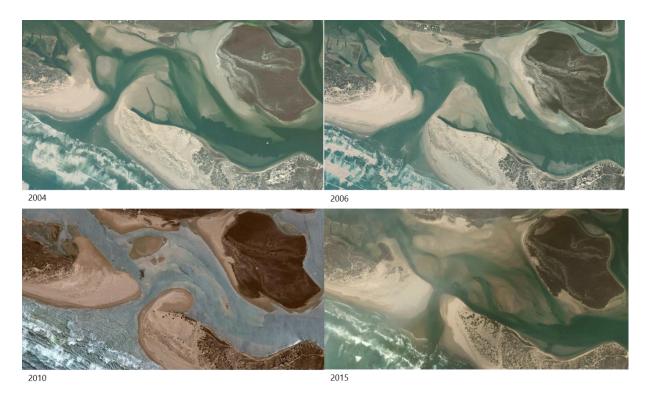


Figure 4.25 Series of Google Earth images of Murray Mouth region illustrating the dynamic nature of channel.

The Murray Mouth area is a part of the Meeting of the Waters, a place where the mixing of the waters is spiritually very important to the Ngarrindjeri (Hemming et al. 2002). The following statements by Ngarrindjeri Rupelli (traditional leader), George Trevorrow illustrates the importance of the area:

That's what we're talking about when we call it the meeting of the waters. Those waters, once they start mixing that is the spiritual waters of this area and of the Ngarrindjeri. This is where the major connections happen. This is the breeding place for all the ngatji and everything that goes with the mixing of the water underneath the water, so it's very, very important to us spiritually, because those things, as I said, they are closer than a friend to you. They are nearly almost part of you. They speak to you, you speak to them and this is the place where they all come to (Trevorrow in Bell 2014).

The Meeting of the Waters is fundamental to the Ngarrindjeri world where all things are connected, whether they are living, from the past and/or for future generations. The Meeting of the Waters makes manifest core concepts of Ngarrindjeri culture that bind land, body, spirit and story in an integrated, inter-functional world. Creation stories such as Thukabi, Ngurunderi and the Mantjinggar are associated with the Murray Mouth area that informs the Ngarrindjeri people's understanding of its significance (Ngarrindjeri Nation 2006 and Bell 1998, 2008 and 2014).

The principles that flow from this cultural system are based upon respect for story, country, the old people, Elders and family. The pursuit of these principles is contingent upon maintaining a relationship with country. The violation of these respect principles is manifest through the destruction of Ngarrindjeri Yarluwar-Ruwe (a concept that embodies the connectedness and inter-functionality of their culture) and their effect upon the behaviours and survival of Ngatji (the animals, birds and fish). According to these principles and contingent beliefs the 'environment' cannot be compartmentalised: The land is Ngarrindjeri and Ngarrindjeri are the land. All things are connected and interconnected. Ngarrindjeri philosophy is based on maintaining the integrity of the relationship between place and person. It is the responsibility of the living to maintain this continuity. The past is not and cannot be separated from the here and now or the future. To break connections between person and place is to violate Ngarrindjeri culture (Meeting of the Waters, Registered Aboriginal Heritage site, Ngarrindjeri).

#### 4.6.3 Soils

Soils of and surrounding the Lakes (including Hindmarsh Island, which is dissected with seasonal streams) are described as poorly drained, black, self-mulching cracking clays. The Coorong is dominated by yellow-grey calcareous sands and mudflats (Brandle 2002).

Ngarrindjeri have detailed knowledge of changing soil types and their importance in predicting the vegetation, animals, fish and other living things associated with various locations within Ngarrindjeri Ruwe/Ruwar. Various soil types are also associated with Ngarrindjeri Lakalinyeri (clan groups) and the dialects associated with different parts of Country (Ngarrindjeri 2019).

# Acid sulfate soils

The soils in much of the Ramsar site contain sulfidic materials which, if exposed to air and oxidised, can be activated to produce acid that could affect both soil and water pH. If left undisturbed and covered with water, sulfidic material poses little or no threat to human health or the Lakes environment. Data on inland acid sulfate soils (ASS) was limited prior to the Millennium Drought, which triggered a significant amount of research into the presence and activation of soils in the Ramsar site. Lakes Alexandrina and Albert and parts of the EMLR tributaries sub-units were found to have high levels of potential ASS (i.e. sulfidic and sulfuric material (Fitzpatrick et al. 2008b; Fitzpatrick et al. 2010). During 2009, sulfuric soil subtypes were mapped (Figure 4.26) and identified as follows (Fitzpatrick et al. 2010):

- Sulfuric soils (hydrosols) occurring in Currency Creek and Finniss River, adjacent to the barrages and near Loveday Bay and along the north eastern shores of both lakes
- Sulfuric (unsaturated) soils predominantly in Currency Creek and Finniss River, near the barrages along the north western and north eastern shores of Lake Alexandrina and north eastern shores of Lake Albert
- Sulfuric subaqueous soil, a new soil subtype identified in Loveday Bay
- Hypersulfidic and hyposulfidic subaqueous soil subtypes (overlying water 0.0 to 2.5 metres) are the most dominant soil subtypes in the area
- Hypersulfidic (approximately 90%) and hyposulfidic (approximately 10%) deep water soils are localised
  and only occur where deep channels were identified by bathymetry such as in the Goolwa Channel near
  the Murray Mouth
- Hypersulfidic and hyposulfidic hydrosols (sandy) (i.e. saturated within 50 centimetres below soil surface), occurring along the exposed margins of Lake Alexandrina and associated with sand bars that are at the water level.

This work showed that drops in water level in the Lower Lakes below 0.0 metres AHD will begin to expose acid sulfate soils, creating the potential for pH to decline below Australian and New Zealand guideline levels (ANZECC and ARMCANZ 2000). This has implications for the maintenance of the ecological character of the lakes and individual wetlands, as a suite of aquatic flora and fauna could be put at risk as pH falls below 6.5.

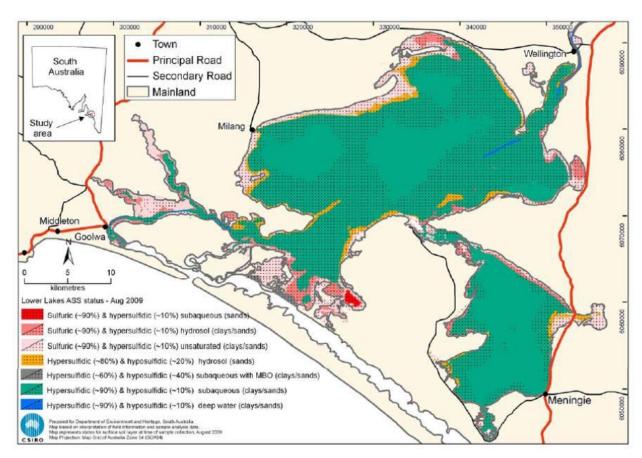


Figure 4.26 Soil classification map of the distribution of acid sulfate soil subtypes (Fitzpatrick et al. 2010). Map legend shows: i) acid sulfate soil materials with sulfuric (pH less than 4), hypersulfidic (pH less than 4 after incubation), hyposulfidic (pH greater than 4 after incubation) and monosulfidic (MBO) materials; ii) depth of water with deep water (overlying water greater than 2.5 metres), subaqueous (overlying water 0 to 2.5 metres), hydrosols (saturated to a depth of 50 centimetres below the mineral soil surface) and unsaturated (unsaturated to a depth of 50 centimetres below the mineral soil surface); iii) soil texture with sands, loams and clays.

Fitzpatrick et al. (2010) also mapped ASS classes, which integrated soil characteristics with soil depth, water depth or water saturation of the soil using bathymetry, identification of monosulfidic material and knowledge about the location of calcrete and granite rock outcrops. The maps were generated for upper and lower subsoil layers and provide a generalised overview of the ASS variation that was identified in the 2009 research (Figure 4.27) (Fitzpatrick et al. 2010).

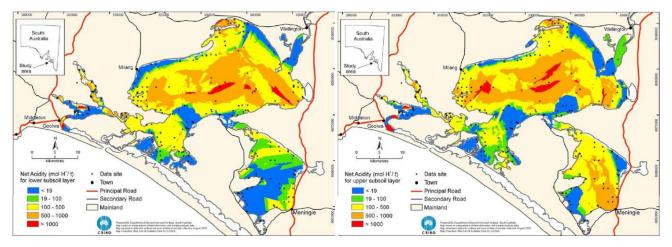


Figure 4.27 Lower (left) subsoil layer (30 to 50 centimetres) and upper (right) subsoil layer (10 to 30 centimetres) map showing net acidity in 2009 (Fitzpatrick et al. 2010).

#### 4.6.4 Sedimentation

Lake Alexandrina acts as both a sink for sediment brought in by the River Murray and a source of sediments (via lakeshore erosion and transfer of River Murray water) to the Southern Ocean, Murray Mouth Estuary and the Coorong.

Sediment mixing was considered a significant factor in redistributing sediments within the system (Barnett 1993). Since construction of the barrages, the most obvious changes to sedimentation rates have occurred on either side of the Goolwa barrage at the Murray Mouth, where estuarine shelly sand is overlain by a surface layer of lacustrine mud. Despite the sediment trapping properties of upstream dams and weirs, the rate of sedimentation within the Ramsar site has increased. Barnett (1993) reported 20 centimetres of sediment deposited over the previous 50 years. Increased sedimentation rates in Lake Albert have also been recorded since European settlement (Bourman et al. 2018).

Sediment resuspension is an important process in Lake Alexandrina at all water levels (Skinner 2011). Skinner (2011) showed that wind speeds of 7.7 metres per second can resuspend sediments when lake water levels are high; while wind speeds of 2.4 metres per second can resuspend sediments when water levels are low. This means that the proportion of time in which resuspension occurs is much higher at low water levels compared with high water levels (Skinner 2011). Evidence of this was seen in the increased turbidity within Lake Alexandrina with increasing drawdown during the Millennium Drought.

# 4.6.5 Water quality

#### **Turbidity**

Turbidity is a measure of the cloudiness or haziness in water caused by suspended solids such as sediments and algae. Turbidity in the Lakes is closely coupled with the volume of inflows, nutrients, rates of sedimentation, sediment resuspension and production of phytoplankton. The major source of sediment is the inflows of the River Murray, with tributaries draining the EMLR and lakeshore erosion being relatively minor contributors that can become more important during periods of low flow. The turbidity of incoming River Murray flows can also vary, with water originating from the Darling typically more turbid than water sourced from the southern-connected basin. Turbidity in Lake Alexandrina at Milang is often higher than the inflows (Figure 4.30), reflecting the production of phytoplankton and resuspension of shallow sediments by wind. High turbidity in the Lakes and Coorong is a primary factor in restricting submerged and emergent aquatic plant growth to the lake and lagoon margins, with reduced light penetration preventing plants from establishing and growing in deeper water.

Productivity in the eutrophic lakes may be light limited by high turbidity (Geddes 1984), but in reality it is very difficult to separate the combined effects of light, nutrients and flow in structure of plankton assemblages (Oliver et al. 2013; Oliver et al. 2014). For example, filamentous algae *Planctonema lauterbornii* may be favoured in periods of high turbidity, low light availability and high nitrogen and phosphorus availability, whilst cyanobacteria regularly bloom in the Lakes in periods with low flows, low nutrients and low turbidity (Aldridge et al. 2010).

In the Coorong, *R. tuberosa* generally doesn't grow deeper than 0.9 metres because of light limitation. High turbidity levels favour algal and biofilm growth over submerged aquatic plant growth, adversely affecting submerged plant growth in the Lakes (Phillips and Muller 2006). Increasing turbidity has also been noted by Ngarrindjeri Elders, who consider it to be an indicator of poor water quality. Modern stories relate how water has changed from clear to cloudy within living memory, reducing the effectiveness of some techniques used for gathering traditional foods.

When there is little or no flow over the barrages, turbidity decreases in the Coorong and Murray Estuary due to flocculation and lack of new inputs. Generally turbidity in the Coorong is low (e.g. less than 30 nephelometric turbidity units) (Phillips and Muller 2006). In contrast, Aldridge and Brookes (2011) recorded a pulse of turbid water as flood waters flushed though the Coorong from the Lakes and out to sea at the end of the Millennium Drought (Aldridge and Brookes 2011). This elevated turbidity in the Coorong North Lagoon from approximately 30 nephelometric turbidity units to over 200 nephelometric turbidity units at the start of January 2011 and took 4 months to clear (Figure 4.28).

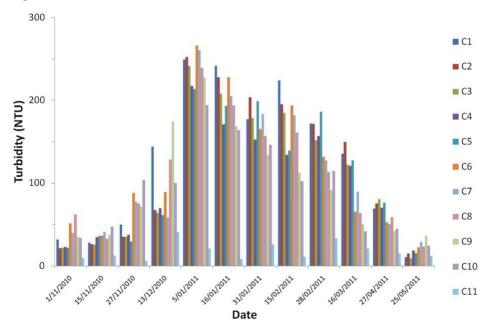


Figure 4.28 Changes in turbidity in the Coorong North Lagoon and Murray Mouth, November 2010–May 2011 (Aldridge and Brookes 2011). C1 – Goolwa Barrage Downstream; C2 – Half Way; C3 – Sugar's Beach; C4 – Southern Ocean; C5 – Murray Mouth; C6 – Hunter's Creek; C7 – Mundoo Channel; C8 – Boundary Creek; C9 – Ewe Island; C10 – Tauwitchere; C11 – Mark Point (see Aldridge and Brookes 2011 for localities).

#### **Nutrients**

Inflows from the Murray–Darling Basin carry suspended sediment, nutrients and organic matter into Lake Alexandrina and then Lake Albert. Biogeochemical processes in the freshwater lakes store, release, transform and transport the nutrients, which drive patterns of primary productivity underpinning the lake food webs. These processes determine the water quality of the managed outflows through the barrages into the Murray Estuary and Coorong lagoons (Phillips and Muller 2006; Aldridge et al. 2010).

The Lakes are classified as eutrophic due to high nitrogen and phosphorus concentration (Geddes 1984), although most of the nutrient load arriving in the Lakes is associated with turbid inflows and is largely in particulate form that is not readily bioavailable. Particulates settle in the low velocity environment of the Lakes, with lake sediments generally a sink for inorganic nitrogen (nitrate and nitrite), phosphorus and silica (Figure 4.29; Cook et al. 2008).

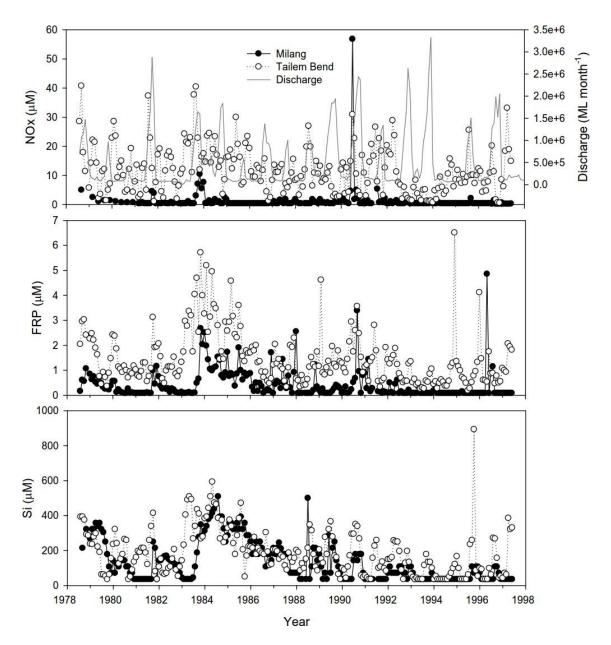


Figure 4.29 Average monthly NOx (nitrate+nitrite; top), Filterable Reactive Phosphorus (FRP; middle) and Silicon (Si; bottom) in Lake Alexandrina at Milang and upstream at Tailem Bend. River discharge is shown in the top panel in megalitres per month (Cook et al. 2008).

In contrast, the Lakes are a net exporter of organic nitrogen (total Kjeldahl nitrogen) to the Coorong. Lake concentrations of total Kjeldahl nitrogen are consistently higher than inflows (Figure 4.30) despite an estimated 80% of the inflowing nitrogen being buried in the sediments (Cook et al. 2008). The high levels of organic nitrogen in the Lakes are attributed to uptake of inorganic forms by algae and nitrogen gas fixation by cyanobacteria (Cook et al. 2008); however, resuspension of sediments and liberation of ammonia during periods of stratification also appear important in maintaining high nutrient levels during periods of low inflows (Aldridge et al. 2010).

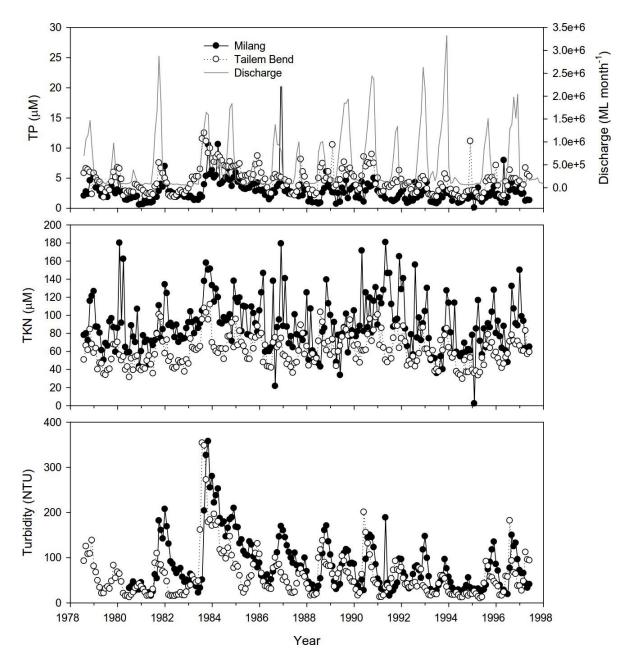


Figure 4.30 Average monthly total phosphorus (TP; top), Total Kjeldahl Nitrogen (TKN; middle) and turbidity (NTU; (bottom) in Lake Alexandrina at Milang and upstream at Tailem Bend. River discharge is shown in the top panel in megalitres per month (Cook et al. 2008).

Barrage operation and the quality of water leaving Lake Alexandrina, along with water entering from the Southern Ocean through the Murray Estuary, determine water quality in the Coorong. During periods of high flows through the barrages, the Murray Estuary exports material and nutrients through the Murray Mouth to the sea. In periods of low flow, it is common for material to be imported into the Coorong from the sea as water is drawn from the ocean to replace evaporative losses (Grigg et al. 2009). The Coorong South Lagoon typically acts as a sink for nutrients, even in high flow years. Evaporation from the shallow basins in the south draw water and suspended material from the Coorong North Lagoon. This pattern of reverse flows transporting dissolved and particulate nutrients southward creates a nutrient gradient in the Coorong that mirrors the pattern of salinity increasing from the Murray Mouth to the Coorong South Lagoon (Brooks et al. 2009b).

The waters of the Coorong are generally considered to be nitrogen limited and the Lakes moderate the supply of nutrients from the River Murray to the Coorong, transforming inorganic nitrogen to bio-available organic forms (Ford 2007; Brookes et al. 2009b). The resulting growth of phytoplankton rapidly removes nutrients from

the water column and the concentration of bio-available forms such as ammonia, nitrate and phosphate in the Coorong are extremely low. For example dissolved inorganic is nitrogen less than 4 micro molar and dissolved inorganic phosphorus less than one micro molar (Ford 2007; Fernandes and Tanner 2009). Despite this, the Coorong is characterised by high phytoplankton biomass in the water column, particularly in the Coorong South Lagoon where chlorophyll-a concentrations exceed 100 micrograms per litre (Thomas and Lang 2003 cited in Fernandes and Tanner 2009). High primary productivity within a low nutrient environment suggest a tight coupling between nutrient mineralisation and biomass uptake, or nutrient limitation leading to very low rates of primary productivity despite high phytoplankton standing stocks (Fernandes and Tanner 2009). The fact that primary production in the Coorong remained high during the Millennium Drought, despite low nutrient inputs from the River Murray, suggests high levels of retention and nutrient recycling from sediment pools in the Coorong (Deegan et al. 2010).

Detailed nutrient flux and budget information can be found in Cook et al. (2008) for the Lakes and Brookes et al. (2009b) for the Murray Estuary and Coorong.

# pН

The waters of the Lakes and Coorong are alkaline, with pH values in the range from 7.5–10.0. Values greater than pH 8.0 are considered normal, while pH values up to 9.5 have been recorded (Figure 4.31) (Cook et al. 2008), reflecting re-aeration and/or metabolism of dissolved  $CO_2$  (e.g. by autotrophs) and buffering by the carbonate rich lake bed sediments.

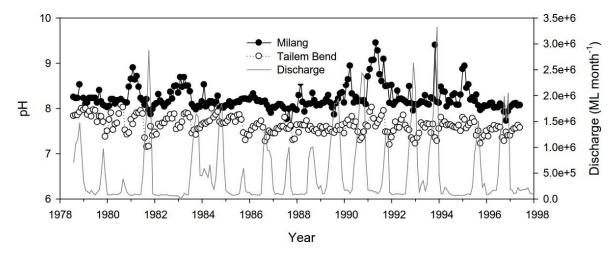


Figure 4.31 Average monthly pH in Lake Alexandrina at Milang and upstream at Tailem Bend with river discharge in megalitres per month (Cook et al. 2008).

#### 4.6.6 Algae and phytoplankton

Algae and phytoplankton are a fundamental part of the food webs that exist across the Ramsar site, and contributors to ecosystem biodiversity.

Aldridge et al. (2010) reviewed general patterns of phytoplankton population structure in response to changing flows and found that although mixed communities of phytoplankton species occur in the Lakes, particular groups are more likely to be dominant under certain conditions. For example, the filamentous green alga *P. lauterbornii* can become dominant during periods of high flow, high turbidity, low light availability and high nutrient availability. Conversely, cyanobacterial blooms of *Nodularia spumigena, Anabaena* species and *Aphanizomenon* species are associated with extended periods of low flow, low turbidity, low turbulence and high light availability. During the Millennium Drought (2006) the first recorded bloom of the cyanobacteria *Cylindrospermopsis* raciborskii occurred in the Lakes (Cook et al. 2008). Although the data available for these analyses were limited, it demonstrates a strong influence of river flows on the types of phytoplankton that are dominate within the Lakes.

Transport of freshwater phytoplankton species from the Lakes can also influence Coorong phytoplankton community structure. Even after a small release of Lake Alexandrina water into the Coorong in 2004 (approximately 30–40 gigalitres over 15 days), abundant numbers of freshwater phytoplankton (*Aphanocapsa*, *Monoraphidium*, *Crucigenia*, *Planktonema*, *Oocystis* and *Planktolyngyba*) were found in the northern part of the lagoon (Geddes 2005) but decreased with distance from the barrage outflows. During periods of low or no flow over the barrages, the phytoplankton of the Coorong are dominated by estuarine and marine species of diatoms and flagellates (Geddes and Butler 1984; Geddes 1987).

Ngarrindjeri Elders report a significant increase in algal growths of various kinds in recent decades. It is considered to be an indicator of poor water quality and an indicator of damage to the Yarluwar-Ruwe (Ngarrindjeri 2019).

#### 4.6.7 Invertebrates

Like algae and phytoplankton, invertebrates are also a fundamental part of the food webs that exist across the Ramsar site. The dynamic nature of the habitats across space and time in the Ramsar site is reflected by a diverse invertebrate fauna (Keith et al. 2013).

Aquatic invertebrates are well known to the Ngarrindjeri, who value them for their place in the food chain. Invertebrates of many kinds are especially valuable during breeding periods as food for Ngartjis and therefore their abundance and diversity is considered to be a marker of health for the Yarluwar-Ruwe (Ngarrindjeri 2019).

#### **Macroinvertebrates**

Benthic macroinvertebrates play an important role as mainly primary or occasionally secondary consumers in the Coorong food web. Refer to section 4.5.8 for a description of the benthic macroinvertebrates.

# Zooplankton

The zooplankton composition varies across the site. Zooplankton are an integral part of the food webs that exist across the Ramsar site. The structure and dynamics of habitats influence the composition of zooplankton assemblages. At a coarser scale, the movement and mixing that result from the hydrodynamics of the Lakes, lagoons and river mouth also shape physical conditions that influence zooplankton assemblages.

A significant attribute of the Ramsar site is the transition of zooplankton along the increasing salinity gradient during barrage releases. Barrage flows carry with them zooplankton that can osmoregulate at salinities up to concentrations of 4–5 ppt (Shiel and Tan 2013). Freshwater plumes displace estuarine assemblages through passive displacement, prompting active dispersal or causing death of the halotolerant zooplankton species. Marine water intrusions and reduction of barrage flows drive these species changes in the opposite direction (Shiel and Tan 2013).

Zooplankton are food sources for organisms such as macroinvertebrates and fish. Studies such as those by Bice (2010) and Ye et al. (2010) have emphasised the importance of zooplankton in providing food for the early development of fish larvae. More than half of the lower River Murray, Lower Lakes and Coorong fish species listed by Bice (2010) spawn in spring and summer. Fish larval predation of zooplankton is strongly seasonal and fish larval growth rates are such that individuals remain at the size that targets food of zooplankton dimensions only briefly.

#### 4.6.8 Biodiversity

Due to the high diversity of wetland types present, the Ramsar site is highly significant in terms of the biodiversity value in the region. This biodiversity is central to the health of Ngarrindjeri Yarluwar-Ruwe and Ngarrindjeri see the maintenance of biodiversity as part of their cultural responsibility (Ngarrindjeri 2019).

Biodiversity is inherently part of the concept of Ruwe/Ruwar and because of this Ngarrindjeri understand that the Ramsar site is a crucial part of the overall living body that makes up the Murray–Darling system. This is knowledge passed down through Creation stories such as Ngurunderi and Pondi. Heritage listing of the Meeting of the Waters site recognises the site's unique importance which is underpinned by the biodiversity that it supports (Ngarrindjeri 2019).

# Flora

The Coorong and Lakes Alexandrina and Lake Albert Wetlands Ramsar site supports a diverse range of plant species, including 2 regionally endemic wetland-dependent flora species (the sandhill greenhood orchid (*Pterostylis arenicola*) and silver daisy-bush (*Olearia pannosa*) and several vegetation species and communities of biodiversity significance (Eichler et al. 2011). These include diverse reed beds of common reed (*P. australis*) and *Typha* spp, river red gum (*E. camaldulensis*), freshwater herblands (e.g. *Triglochin* spp.), cutting grass (*G. filum*) sedgeland, swamp paperbark (*M. halmaturorum*) woodland, lignum (*D. florulenta*) shrubland and samphire chenopod shrubland (e.g. *Tecticornia pergranulata*, *S. australis*, *S. quinqueflora* and *Juncus kraussi*) (DEWNR 2013).

#### Fish

The Ramsar site regularly supports around 30 fish species (Higham et al. 2002) including the small-mouthed hardyhead (A. microstoma), lagoon goby (T. lasti) and Tamar goby (A. tamarensis). The site supports 3 fish species protected under the Fisheries Management Act 2007 in South Australia: freshwater catfish (T. tandanus), southern purple-spotted gudgeon (M. adspersa) and southern pygmy perch (N. australis) (Bice et al. 2009). Other species of conservation significance in South Australia include flat-headed gudgeon (P. grandiceps), dwarf flat-headed gudgeon (P. macrostomus), unspecked hardyhead (C. stercusmuscarum fulvus), congolli (P. urvillii), pouched lamprey (G. australis), short-headed lamprey (M. mordax), mountain galaxias (G. olidus), estuary perch (M. colonorum) and short-finned eel (A. australis) (Bice et al. 2009, Lintermans 2009). The site is the only access point to the Murray–Darling Basin for diadromous fish species.

# Waterbirds

The Ramsar site supports high waterbird species richness, with 307 bird species recorded within 1 kilometre of the Ramsar site, 118 of which utilise wetland habitat (O'Connor et al. 2012). The site contains the majority of waterbird species that occur within the Murray–Darling Basin and supports the highest waterbird species richness and abundance of any of The Living Murray Icon sites, with 92% of the roughly 250,000 waterbirds counted across all 6 icon sites and 44 of the 46 waterbird species surveyed (O'Connor et al. 2012). Ten bird species that are of state or regional conservation significance occur in the site (O'Connor et al. 2012): little tern (*S. albifrons*), white-bellied sea eagle (*H. leucogaster*), banded stilt (*C. leucocephalus*), Eastern curlew (*N. madagascariensis*), Freckled duck (*S. naevosa*), Lewin's rail (*L. pectoralis*), Australasian shoveler (*A. rhynchotis*), blue-billed duck (*O. australis*) and sooty oystercatcher (*H. fuliginosus*).

# Reptiles

Biological surveys focused on the Coorong and Murray Mouth region and Hindmarsh Island in 1982, 2001 and 2002 (Brandle 2002). Fifteen species of reptile were recorded. (Table 4-11).

Table 4-11 Reptile species recorded in the South East Coast Survey 1982 and Murray Mouth Reserves Survey 2002 (Brandle 2002).

Common Name	Species name	Total Observations 1982, 2002
Common long-necked tortoise	Chelodina longicollis	1
Painted dragon	Ctenophorus pictus	2
Eastern bearded dragon	Pogona barbata	1
Marbled gecko	Christinus marmoratus	2
Eastern spotted ctenotus	Ctenotus orientalis	5
Eastern striped skink	Ctenotus robustus	1
Four-toed earless skink	Hemiergis peronii	4
Southern four-toed slider	Lerista dorsalis	3
Dwarf skink	Menetia greyii	4
Common snake-eye	Morethia boulengeri	1
Mallee snake-eye	Morethia obscura	4
Southern grass skink	Pseudemoia entrecasteauxii	4
Black tiger snake	Notechis cf	1
Eastern tiger snake	Notechis scutatus	2
Eastern brown snake	Pseudonaja textilis	3

Six species of reptiles have recently been recognised as important biodiversity assets within the site, of which 3 are found in wetland habitats (Table 4-12) (Eichler et al. 2011).

Table 4-12 Conservation status of 6 reptiles that are biodiversity targets at the site (Eichler et al. 2011).

Common name	Scientific name	Water dependent	SA	Adelaide Mount Lofty Ranges
Common long-necked tortoise	Chelodina longicolia	Υ		
Olive snake-lizard	Delma inornata	N		Vulnerable
Macquarie short-necked tortoise	Emydura macquarii	Y	Vulnerable	
Yellow-bellied water skink	Eulamprus heatwolei	Υ	Rare	
Five-lined earless dragon	Tympanocryptis lineata	N		Vulnerable
Heath goanna	Varanus rosenbergi	N	Vulnerable	

# **Frogs**

Frogs form part of the food webs within the Ramsar site, providing services throughout all stages of their aquatic and terrestrial life cycles. These services include limiting algae growth, consuming insects and acting as prey for many water-dependent and terrestrial species (Robinson 2000; Baldwin et al. 2005; Hocking and Babbitt 2014). Frogs are considered major contributors to ecosystem functions, such as decomposition and nutrient cycling and to ecosystem structure through aquatic bioturbation (interactions between sediment particles and the water column) and soil burrowing (Hocking and Babbitt 2014). Key frog species in the Ramsar site are described in Mason and Turner (2018) and summarised below.

Eight frog species have been recorded in the Ramsar site since 2009 (Mason and Durbridge 2015):

- Common froglet (Crinia signifera)
- Eastern banjo frog (Limnodynastes dumerilii)
- Long-thumbed frog (Limnodynastes fletcheri)
- Spotted grass frog (Limnodynastes tasmaniensis)
- Brown tree frog (*Litoria ewingi*)
- Peron's tree frog (Litoria peronii)
- Painted frog (Neobatrachus pictus)
- Southern bell frog (*L. raniformis*).

Of the 8 species regularly recorded in the CLLMM, 2 of these are considered true burrowing frogs (*L. dumerilii* and *N. pictus*) and 6 are generally considered to be above-ground dwellers (Mason and Durbridge 2015) that shelter within deep organic matter or under forms of structure. Species found within the Ramsar site occupy water bodies with a range of hydrological characteristics, including permanent wetlands, inundated ephemeral and temporary wetlands and creeks and highly modified environments such as irrigation channels (Gonzalez et al. 2011). Although most species are associated with a range of water regimes, they are highly dependent on inundated vegetation and/or habitat, such as snags or fallen timber, which are important for shelter and for the anchoring of eggs (Gonzalez et al. 2011). Table 4-13, adapted from Mason and Turner (2018) and Bice et al. (2014), outlines the habitat and breeding requirements of the common species found in the Ramsar site.

Table 4-13 Occurrence, habitat and breeding requirements of frogs within the Ramsar site (Mason and Turner 2018). Southern bell frog have not been described in the below, for a more detailed description of southern bell frog refer to section 4.5.7.

Species	Occurrence and requirements
Common froglet	The common froglet is the most widespread and abundant species recorded in the site since 2009.
	Preferred habitat:
	There is a positive association of adults with vegetation along the River Murray in SA (Healy et al. 1997).
	Occurs among dense aquatic vegetation at the water's edge (Tyler 1994).
	Breeding cues:
	<ul> <li>Cooler temperatures are preferred and breeding generally occurs through autumn, winter and spring, but could occur at any time of the year depending on the availability of habitat and temperature (Anstis 2002).</li> </ul>
	• Described as frequent breeders with eggs laid throughout the year (Anstis 2013).

Species	Occurrence and requirements
Eastern banjo frog	The Eastern banjo frog is common and abundant in the Ramsar site.
	<ul> <li>Preferred habitat:</li> <li>Lives in small holes beneath damp wood or stones; aestivates in a sealed burrow during summer (Tyler 1977).</li> </ul>
	<ul> <li>Breeding cues:</li> <li>Calling is most intense after heavy rains and mass spawning can occur on the same 1 or 2 nights (Anstis 2002).</li> <li>Breeding is most likely to occur in spring and summer but species can be active at any time of the year (Tyler 1977). Spawning is typically communal, with large numbers of individuals breeding simultaneously at a site, usually on warm, wet nights (Ulkrin 1980).</li> </ul>
Long-thumbed frog	<ul> <li>Preferred habitat:</li> <li>This is an aquatic species that is found in water or sheltering in moist places (Amey and Grigg 1995).</li> <li>Only occurs among dense aquatic vegetation at the water's edge along the River</li> </ul>
	<ul> <li>Murray (Tyler 1994).</li> <li>Shelters during the day under large rocks, logs and other debris and in cracks and ground crevices, including yabby burrows (Barker et al. 1995; Cogger 2000).</li> </ul>
	<ul> <li>Breeding cues:</li> <li>Most likely to breed in spring and summer, but can also be active during warmer late-winter weather and into autumn (Anstis 2013).</li> </ul>
Spotted grass frog	<ul> <li>The spotted grass frog is common and abundant in the Ramsar site.</li> <li>Preferred habitat:         <ul> <li>The species is found under stones and debris on the beds of dry creeks, pools and dams during summer (Tyler 1977).</li> <li>Occurs in a range of microhabitat types, but frequently in beds of <i>Cyperus</i> spp. and <i>Paspalum distichum</i> (Healey et al. 1997); however, other studies have found occupancy of sites by adults to be unrelated to any of the measured habitat or water quality variables (Wassens and Maher 2011).</li> <li>The spotted grass frog has limited capacity to burrow. Adults congregate around permanent water during droughts and distribution is restricted to areas with some permanent water (Wassens 2011).</li> </ul> </li> </ul>
	Breeding is opportunistic and may occur at any time of year, with males calling through spring to autumn and mild winter weather, especially after rain (Wassens 2011), but it usually peaks in summer and autumn (Anstis 2013).
Brown tree frog	The brown tree frog is a common species in the Ramsar site utilising the dense reed beds of bulrush ( <i>T. domingensis</i> ) and common reed ( <i>P. australis</i> ) that are common to Lakes Alexandrina and Albert.
	<ul> <li>Preferred habitat:</li> <li>The species is a habitat generalist, documented from a range of habitat types, such as wet and dry sclerophyll forest, farmland, heathland, semi-arid areas, alpine regions and suburban gardens (Anstis 2002).</li> </ul>
	<ul> <li>Breeding cues:</li> <li>The brown tree frog does not have a distinct breeding season; calls and breeds at any time of the year (Anstis 2013).</li> </ul>

Species	Occurrence and requirements
Peron's tree frog	Peron's tree frog is sparsely distributed in the Ramsar site.
	Preferred habitat:
	The species is able to utilise vertical landscape (e.g. floodplain trees) with distribution closely linked to the availability of standing timber, in particular river red gum forests (Wassens 2011).
	Greater vegetation diversity is a predictor of presence (Lane et al. 2007).
	Breeding cues:
	Although calling and spawning are restricted to spring and summer, tadpoles may
	linger within water bodies until April (Wassens 2011).

#### **Mammals**

Based on biological surveys the most commonly surveyed mammal was the introduced house mouse (*Mus musculus*) (Brandle 2002). Water rats and swamp rats were far less common. Swamp rat are a cryptic species listed as rare in South Australia but evidence suggests numbers have increased since the break of drought in 2010 (Eichler et al. 2011). The presence of the water rat and swamp rat at 4 wetland edge localities in the Ramsar site was confirmed with evidence from motion-sensor cameras deployed during April and May 2014 (Mason 2014).

Long-nosed seals (Arctocephalus forsteri), previously New Zealand fur seals, are transient visitors to the site.

# 4.6.9 Water supply

Lock 1 down to (and including) the Lower Lakes is one connected weir pool, approximately 274 kilometres long. It supplies critical human water needs water along the length of the weirpool to Adelaide and surrounding areas and the upper south-east. This weir pool also supports a mix of irrigated and dryland agriculture, manufacturing industries centred on wine, machinery and equipment; boat building and maintenance; and recreation and tourism activities.

# 4.6.10 Aquatic foods

The Lakes and Coorong Fishery is a small scale, multi-species fishery largely driven by 4 species: pipi (Goolwa cockle) (*P. deltoides*), golden perch (*M. ambigua*), mulloway (*A. japonicas*) and yelloweye mullet (*A. forsteri*). Other species that make a significant contribution include bony bream (*N. erebi*) and carp (*C. carpio*). In 2014–15, there were 36 licence holders with a catch of 1598 tonnes and a catch value of \$7.7 million (EconSearch 2017).

Recreational fishing accounts for a significant proportion of the total catch of a number of Lakes and Coorong Fishery species and includes high value species such as mulloway, yelloweye mullet, golden perch and pipi (PIRSA 2017).

Aboriginal communities have a long-established history of fishing in what are now called South Australian waters. Each community has its own distinct fishing activities and cultural practices. Ngarrindjeri have a long-established history of fishing and gathering aquatic plants in these waters. Aquatic foods also have medicinal, ceremonial and other cultural uses for Ngarrindjeri (Ngarrindjeri 2019).

As a fundamental element of the Ngarrindjeri people's cultural economy, freshwater and saltwater fishing is still an integral part of Ngarrindjeri cultural and economic wellbeing. Ngarrindjeri have a close spiritual, kinship relationship with fish as Ngarrindjeri Ngartjis and through Creation stories. The long-term importance of fishing for food, medicine and other uses to Ngarrindjeri is demonstrated by the presence of otoliths from fish such as mulloway (mullowi), Murray cod (pondi), matfish (pomeri), black bream (tjiri) and yelloweye mullet (kunmari) in the Old People's places (middens) throughout Ngarrindjeri Yarluwar-Ruwe (Ngarrindjeri 2019).

#### 4.6.11 Natural hazard reduction

Operation of the barrages allows a flood to pass without raising water levels in the lower river, mitigating the effects of floods on local upstream communities. Paperbark, reed beds, grassland and samphire communities stabilise lakeshores and prevent erosion. The peninsulas of the Ramsar site provide coastal shoreline stabilisation and storm protection by reducing impacts of wind and wave action and currents (DEH 2010).

Ngarrindjeri view some flood events to be a beneficial part of Ngarrindjeri Ruwe-Ruwar (Ngarrindjeri 2019).

#### 4.6.12 Pollution control

The Murray Mouth is the only site where water contaminants such as silt, salt and nutrients can be discharged from the Murray–Darling Basin to the ocean. Through-flow depends on coordinated barrage releases and dredging in times of low flow, to maintain an open Murray Mouth to the Southern Ocean (DEH 2010). The Lakes play a role in slowing flow, trapping and assimilating sediments, nutrients and other contaminants and 'buffering' the amount of contaminant transfer that may occur during flow events. This service is heavily influenced by the hydrological regime.

# 4.6.13 Special ecological or geomorphic features

The Ramsar site traditionally provided a drought refuge for approximately 80% of aquatic birds in the Murray-Darling Basin (Brookes 2011). The site also supports life stages, most notably spawning and nursery grounds for fish.

The presence of the Murray Mouth and the physical nature of the Coorong and Estuary make this a special feature in the Murray–Darling Basin and in South Australia.

These special features were created in the Kaldowinyeri by Ngarrindjeri Creation ancestors such as Ngurunderi, Pondi, Thukabi and Muntjingga. The laws and traditions associated with these features guide Ngarrindjeri wise-use of Country (Ngarrindjeri 2019).

# 4.6.14 Primary ecosystem production and nutrient cycling

Primary production is the amount of carbon and energy that enters ecosystems. It provides the energy that drives all biotic processes, including the trophic webs that sustain animal populations and the activity of decomposer organisms that recycle the nutrients required to support primary production. Nutrient cycles allow the transformation of matter to different specific forms that different organisms can use. Important nutrients, including carbon, oxygen, hydrogen, phosphorus and nitrogen, are required to be recycled for the existence of organisms. Nutrient cycles involve not only living organisms, but non-living components as well. These processes support the food webs.

For Ngarrindjeri, nutrient cycling is understood as a key element of the Meeting of the Waters, the patterns of flow and flushing that give life to Ngarrindjeri Ruwe/Ruwar (Ngarrindjeri 2019).

# 4.6.15 Healthy Ngarrindjeri Ruwe/Ruwar

For Ngarrindjeri, 'components, processes and services' are all part of the living body of the Ngarrindjeri Yarluwar-Ruwe and this perspective is supported by the Creation stories of the Kaldowinyeri. In addition, Ngarrindjeri have a cultural responsibility to care for Yarluwar-Ruwe and if this responsibility is not exercised then Ngarrindjeri wellbeing is severely compromised (Ngarrindjeri 2019).

The Coorong and Lakes Alexandrina and Albert Wetland is a significant 'Sacred Site' – the Meeting of the Waters - and has registered sites under the *Aboriginal Heritage Act 1988 (SA)*. Its spiritual and cultural significance is essential to the wellbeing and productivity of the Ngarrindjeri nation. Ngarrindjeri consider healthy Ngarrindjeri Yarluwar-Ruwe a crucial service (Ngarrindjeri 2019).

# 4.6.16 Spriritual and inspirational

Spiritual and inspirational 'services or benefits' are inseparable from the fundamental character of Ngarrindjeri Yarluwar-Ruwe. Ngarrindjeri are a part of Ngarrindjeri Yarluwar-Ruwe through their Miwi (spirit), their connections to Ngartji and through the activities and teachings of the Creation ancestors. The Meeting of the Waters is a primary focus for these connections and links them to healthy reproduction (Ngarrindjeri 2019). As stated in the *Ngarrindjeri Yarluwar-Ruwe Plan* (2006):

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.

Ngarrindjeri spiritual and inspirational services rely on a healthy Ramsar site. When the Ramsar site is unhealthy, negative spiritual and inspirational consequences are experienced (Ngarrindjeri 2019).

#### 4.6.17 Science and education

The site is a well-studied and important educational and research site and is particularly important in understanding large terminal lacustrine and estuarine systems.

Yarluwar-Ruwe is intrinsically experienced as a source of Ngarrindjeri knowledge, education and research (Ngarrindjeri 2019).

Ngarrindjeri rely on healthy lands and waters to enable them to continue to educate their community about Ngarrindjeri philosophy, tradition, spirituality, history and law. Aspects of this education are also being provided to the non-Indigenous community, including for the purpose of incorporating indigenous knowledge into site management. This cannot be done without Ngarrindjeri Yarluwar-Ruwe (Ngarrindjeri 2019).

# 4.6.18 Aesthetic amenity

The Ramsar site is of national significance and occupies a unique place in the Australian psyche through Colin Thiele's book *Storm Boy* and people are attracted to the area's diversity of scenery and topography (DEH 2010). There are also less tangible values associated with the area's natural beauty. People speak of its spiritual value and the sense of freedom and renewal they experience when spending time there (DEH 2010).

People living in the area have a strong affinity with the site's aesthetics while, perhaps most importantly in the case of its Ramsar listing, others derive 'existence value' from the icon site – that is, they gain satisfaction purely from the continued existence of the site'. (MDBC 2006)

The concept of 'aesthetics' is of Western origin and does not match Ngarrindjeri concepts of aesthetic amenity. For Ngarrindjeri, the Ramsar site was created in the Kaldowinyeri and has unique inherent 'beauty' purely through being part of Ngarrindjeri Yarluwar-Ruwe. Ngarrindjeri aesthetic understandings rely on spiritual feelings and specific cultural interpretations that provide meaning to what non-Indigenous values might interpret in other ways (Ngarrindjeri 2019).

#### 4.6.19 Recreation

The Lakes and Coorong are important recreational areas for activities such as sightseeing, boating, fishing and bird watching (Stone et al. 2016). They are an important recreation resource for Adelaide and the local region (Dyack et al. 2007). There is a high degree of place attachment within the site with repeat visits common (Dyack et al. 2007).

For Ngarrindjeri, being able to engage in recreational activities in the Ramsar site is essential to healthy Ruwe/Ruwar. What might be termed 'recreation' often combines cultural responsibility, teaching and Caring for Country. This service can be a negative service if the health and character of Ngarrindjeri Yarluwar-Ruwe is negatively impacted by recreation activities (Ngarrindjeri 2019).

# 4.6.20 Tourism

In 2014–15, the tourism industry contributed an estimated \$167 million to the Murraylands regional economy, or 12.8% of the gross regional product. The industry employs about 700 people directly and 900 indirectly (Strathearn 2017).

Ngarrindjeri have a cultural responsibility to welcome visitors to Ruwe/Ruwar and to teach others about their values, culture and traditions. To enable these responsibilities to be successfully carried out, the Ramsar site needs to be healthy. Ngarrindjeri can only conduct Ngarrindjeri tourism on Ngarrindjeri Yarluwar-Ruwe and therefore they consider this crucial (Ngarrindjeri 2019).

# 5 Ecological character conceptual models

# 5.1 Landscape models

The 6 conceptual models below show the relationships between the components, processes, benefits and services of the wetland that most strongly determine the ecological character of the site. The relative position of the subunit models within the Ramsar site is shown in Figure 5.1 and includes the following:

- Lake Alexandrina. This model represents the area of inflows from the River Murray, the northern area of Lake Alexandrina, some of the EMLR tributaries and the fringing wetland system. The sub-unit also includes major islands on the freshwater side of the barrages, but these are not illustrated in the model (Figure 5.2).
- Lake Albert. This model represents the area of Lake Albert which connects to Lake Alexandrina at the Narrung Narrows, the main body of the lake and the fringing wetland systems (Figure 5.3).
- **EMLR tributaries**. This model captures the Finniss, Angas and Bremer Rivers and Currency Creek and the Goolwa Channel. Only part of the sub-unit is represented in the model in Figure 5.4.
- **Murray Estuary**. This model represents the Murray Mouth and Murray Estuary which extends from the Goolwa Barrage to Pelican Point, including the Goolwa, Coorong and Mundoo Channels and part of Younghusband Peninsula (Figure 5.5).
- **Coorong North Lagoon**. This model represents the Coorong North Lagoon which extends from Pelican Point to Parnka Point and also captures the inland side of the Younghusband Peninsula as well as the beach component of the sub-unit (Figure 5.6).
- **Coorong South Lagoon.** This model represents the area around the entrance of Salt Creek into the Coorong South Lagoon, the ephemeral wetlands at the southern end of the lagoon and the freshwater springs on the inland side of the Younghusband Peninsula, as well as the beach area of the sub-unit (Figure 5.7).

Coorong and Lakes Wetland Management Units

# Legend WETLAND Coorong North Lagoon Coorong South Lagoon Eastern Mount Lofty Ranges Tributaries Lake Albert Lake Alexandrina Murray Mouth and Estuary MILANG Peninsula and Beach ADELAIDE



Figure 5.1 Location of the sub-units within the Ramsar site.

#### 5.1.1 Lake Alexandrina

#### **Summary of critical CPS in Lake Alexandrina**

The model represents the critical CPS within Lake Alexandrina as well as the some of the non-critical CPS and key threats. Critical components and processes include:

- hydrological regime (River Murray flows and barrage operations that drive lake levels)
- salinity
- freshwater vegetation
- fish diversity
- waterbird abundances and diversity.

#### Critical services include:

- provision of habitat for foraging, refuge, roosting and breeding
- provision of habitat for threatened wetland species.

River Murray inflows and lake levels are the primary driver of salinity, extent and condition of freshwater vegetation, 13 wetland types (including 2 man-made), hydrological connectivity and diversity of habitat to support a diversity of waterbird and fish species.

Seasonally variable lake levels are critically important to the health of fringing wetlands and the provision of quality habitat for waterbird feeding and breeding and habitat for other biota including threatened species (e.g. small-bodied threatened fish species).

At typical regulated lake levels (i.e. ranging between +0.5m AHD and +0.85m AHD), the Lakes and Coorong are connected, as is a variety of wetland habitat which support a diverse assemblage of freshwater, diadromous and euryhaline estuarine fish species, including species of conservation significance with specialist habitat requirements. At low lake levels, salinity is elevated and connectivity with fringing vegetated wetlands between the Lower Lakes and Coorong is reduced. This diminishes the abundance of fish species with specialist habitat requirements and leads to dominance of freshwater and euryhaline species with generalist habitat requirements. Abundance of diadromous species is reduced in response to limited connectivity between freshwater and estuarine/marine environments.

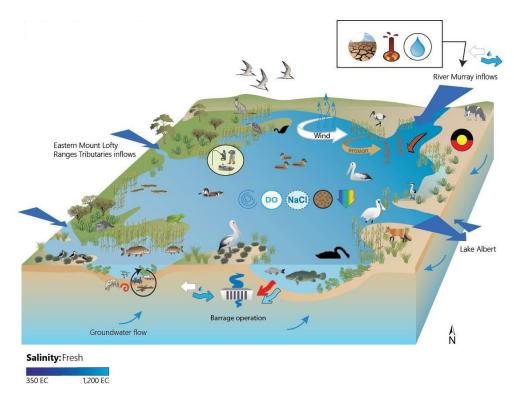


Figure 5.2 Conceptual model representing northern area of Lake Alexandrina. Not to scale and not all features included; the model is representative only. Refer to Table 5-1 for a key to the models figures.

Table 5-1 Key to symbols used in conceptual model for Lake Alexandrina (Figure 5.2).

	River Murray flows enter the Ramsar site at the northern end of Lake Alexandrina. Flows move southward through Lake Alexandrina with a portion funnelled through the Narrows and into Lake Albert. There is some exchange from Lake Albert and minor flows from the EMLR tributaries. Water in Lake Alexandrina leaves through 5 barrages.
	Groundwater flow into Lake Alexandrina is minor.
	Hydrology is altered by water resource management (upstream of Lake Alexandrina) and barrage operations (downstream). Lake levels are maintained within a relatively small operating range. Barrage operations influence freshwater, salt and nutrient fluxes into the Murray Estuary and Coorong.
	Inflows transport nutrients and sediments from surrounding and upstream catchments, with sediment deposition occurring in the lake.
A Constant of	Wind influences lake levels by producing a seiche (a standing wave oscillating in a body of water) which influences evaporation rates and erosion of lake shorelines, contributing to sediment resuspension.
( DO NaC) ( V	Lake waters are mixed via wind and wave action, with high dissolved oxygen. Salinity is low, turbidity high and light penetration limited.
	Primary production is high and aquatic plant dominated, with significant stands of submergent and emergent freshwater macrophytes throughout the littoral zone. The different macrophyte communities are important in providing fish habitat and nursery areas, food resources for herbivorous waterbirds, habitat for cryptic waterbird species and nesting resources for waterbirds. Areas of saltmarsh and shrubland occur in fringing wetlands and along areas of the lake shoreline, providing additional habitat diversity. The diversity of habitat in Lake Alexandrina support critical life stages for fish, frogs and waterbirds, contributing to Ramsar criterion 4.
	Secondary production is via detrital food webs, with decomposition of organic material facilitated by invertebrates which support higher trophic levels including fish and waterbirds. High productivity supports biodiversity, with a high diversity in vegetation communities, fish and waterbirds which contributes to meeting Ramsar criterion 3.
	Threatened species supported in Lake Alexandrina (that contribute to meeting Ramsar criterion 2), include the Australasian bittern ( <i>B. poiciloptilus</i> ), Murray hardyhead ( <i>C. fluviatilis</i> ) and Southern bell frog ( <i>L. raniformis</i> ). Murray cod ( <i>Maccullochella peelii</i> ) and silver perch ( <i>Bidyanus bidyanus</i> ) were once widespread and played an important role in the lake, but are now infrequently encountered.
The same of the sa	Waterbirds from a range of guilds are present with waterfowl and piscivores being dominant in Lake Alexandrina. Large numbers are often recorded, contributing to meeting Ramsar criterion 5. Lakes Alexandrina and Albert support 13 species of cryptic waterbirds. Large breeding events have occurred for some species, including strawnecked ibis ( <i>T. spinicollis</i> ), Australian white ibis ( <i>T. molucca</i> ) and pied cormorant ( <i>P. varius</i> ).
	Fish assemblages in Lake Alexandrina are characterised by high abundance with a diverse mix of freshwater and diadromous species and euryhaline estuarine species such as small-mouthed hardyhead ( <i>A.microstoma</i> )). High native fish species diversity, diadromous life cycle traits and a range of spawning strategies contribute to the Ramsar site's high biodisparity.
j	Climatic conditions and climate change including drought and increasing temperatures in the upper catchment, combined with water resource management influence freshwater inflows into Lake Alexandrina.
	Invasive species affect the ecological values of the Ramsar site and include exotic fish species, feral cats, rabbits, foxes and weeds. Some native species can be problematic when overabundant.
	Lake Alexandrina provides water for stock and agriculture, has significant commercial and recreational values and is part of Ngarrindjeri Yarluwar-Ruwe.

#### 5.1.2 Lake Albert

#### **Summary of critical CPS in Lake Albert**

The model represents the critical CPS within Lake Albert as well as the some of the non-critical CPS and key threats. Critical components and processes include:

- hydrological regime (lake levels and flows)
- salinity
- freshwater vegetation
- fish diversity
- waterbird abundance and diversity.

#### Critical services include:

- ecological connectivity with Lake Alexandrina
- provision of habitat for foraging, refuge, roosting and breeding
- provision of habitat for threatened wetland species.

Lake Albert is a terminal lake with no outflows and operates as a sink for salinity. Inflow from Lake Alexandrina and lake levels are the primary drivers of the lake's salinity, extent and condition of its predominantly freshwater vegetation, 7 wetland types (including 1 man-made) and resulting diversity of habitat to support a diversity of waterbird and fish species.

Seasonally variable lake water levels are critically important to the health of fringing wetlands and the provision of quality habitat for waterbird feeding and breeding and habitat for other biota including threatened species (e.g. small-bodied threatened fish species).

The narrows which connect Lake Albert with Lake Alexandrina are important nesting and breeding grounds for waterbirds.

Fish Assemblages are generally characterised by a diverse range of predominantly freshwater species and some diadromous species.

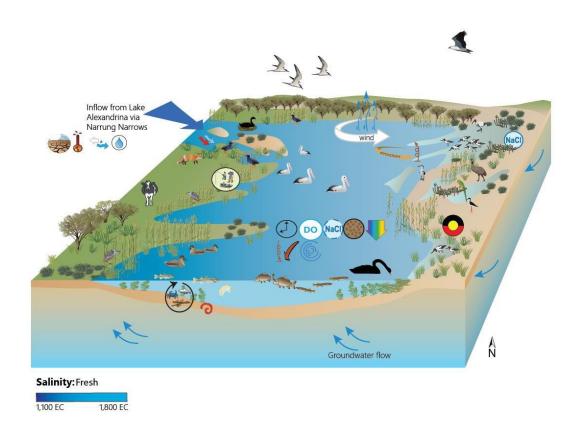


Figure 5.3 Conceptual model for Lake Albert. Not to scale and not all features included; the model is representative only. Refer to Table 5-2 for a key to the models figures.

Table 5-2 Key to symbols used in conceptual model for Lake Albert (Figure 5.3).

	Single flow path for surface water is via Narrung Narrows. Additional freshwater inputs are from local runoff and rainfall onto the surface of the lake.
	Groundwater flows into Lake Albert are more significant than in Lake Alexandrina, with more discharge zones in Lake Albert.
	Water resource management affecting Lake Alexandrina dictate the hydrological regime in Lake Albert and strongly influence freshwater, salt and nutrient fluxes in Lake Albert.
	Inflows transport nutrients and sediments from the surrounding landscape, with sediment deposition occurring in the lake.
wid of	Wind influences lake levels by producing a seiche (a standing wave oscillating in a body of water) which influences evaporation rates and erosion of lake shorelines, contributing to sediment resuspension. Being smaller than Lake Alexandrina evaporation rates have a greater influence on the salinity regime.
(NaCl) © DO	Lake waters are mixed via wind and wave action, with high dissolved oxygen. Salinity is moderate to high (within fresh range) with the lake operating as a sink for salt. Turbidity is high and light penetration limited, similar to that in Lake Alexandrina. Water residence time is high.
	Primary production is high and aquatic plant dominated, with significant stands of submergent and emergent freshwater vegetation throughout the littoral zone. Vegetation composition is affected by salinity levels. The different vegetation communities are important, providing fish habitat and nursery areas, food resources for herbivorous waterbirds, habitat for cryptic waterbird species and nesting resources for waterbirds. Large areas of semi-permanent saline saltmarsh (Ramsar wetland type Ss) occur in the north-eastern corner of Lake Albert and the northern shoreline is dominated by shrubland (Ramsar wetland type W). There are several smaller islands, mud and sandbars which provide roosting habitat for many birds. Significant waterbird breeding areas occur in the vicinity of the Narrung Narrows, contributing to meeting Ramsar criterion 4.
	Secondary production is via detrital food webs, similar to Lake Alexandrina, but with some difference in species composition. High productivity supports high biodiversity values which contribute to meeting Ramsar criterion 3.
	Threatened species supported in Lake Albert and that contribute to meeting Ramsar criterion 2 include the Australasian bittern ( <i>B. poiciloptilus</i> ) and potentially Murray hardyhead ( <i>C. fluviatilis</i> ).
	Waterbird composition is similar to Lake Alexandrina being notable for supporting cryptic waterbirds, but also more shorebirds such as red-necked avocets ( <i>R. novaehollandiae</i> ) in the saltmarshes.
	Fish assemblages are similar to Lake Alexandrina with potentially fewer large bodied native species.
j	Climatic conditions and climate change including drought and increasing temperatures in the upper catchment, combined with water resource management significantly influence freshwater inflows into Lake Alexandrina and then Lake Albert.
	Invasive species affect the ecological values of the Ramsar site and include exotic fish species, feral cats, rabbits, foxes and weeds. Some native species can be problematic when overabundant.
	Lake Albert provides water for stock and agriculture, has significant recreational values and is part of Ngarrindjeri Yarluwar-Ruwe.

## 5.1.3 Eastern Mount Lofty Ranges tributaries

## Summary of the critical CPS in the EMLR tributaries

The model represents the critical CPS within the EMLR tributaries and some of the non-critical CPS and key threats. Five tributaries: Currency Creek, Tookayerta Creek, Finniss River, Angas River and Bremer River flow into Lake Alexandrina. Critical components and processes include:

- hydrological regime (tributary inflows and lake levels)
- salinity
- freshwater vegetation
- fish diversity
- waterbird abundance and diversity.

#### Critical services include:

- ecological connectivity with Lake Alexandrina
- provision of habitat for foraging, refuge, roosting and breeding
- provision of habitat for threatened wetland species and communities.

The tributaries are fed by regional (Mt Lofty Ranges) rainfall and unconfined aquifers. These, along with lake levels in the lower reaches, are the primary drivers of the tributaries salinity, extent and condition of a diverse array of freshwater vegetation, 9 wetland types (including two man-made) and diversity of habitat to support waterbird and fish species. The freshwater habitats of the tributaries provide refugia, particularly in drought years, for many fish and other freshwater-dependent biotas.

The tributaries have the greatest aquatic plant diversity and abundance in the Ramsar site, with structurally diverse and dense wetland habitats. Habitats range from woodlands including the only stand of red gums in the Ramsar site, to diverse reed beds, peat bog-freshwater marshes and extensive submerged aquatic plant communities. These habitats support fish spawning and breeding. The tributaries contain the critically endangered Swamps of the Fleurieu Peninsula ecological community, which important for a variety of fauna, including the endangered Mount Lofty Ranges southern emu-wren.

Fish assemblages in the tributaries are very similar to Lake Alexandrina, except for some large bodied native species.

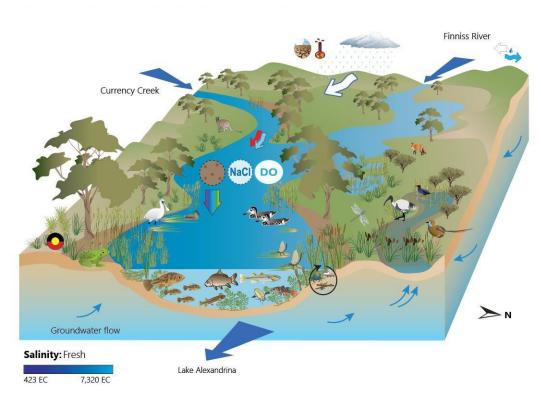


Figure 5.4 Conceptual model representing the Eastern Mount Lofty tributaries near the connection of the Finniss River and Currency Creek to the southern section of Lake Alexandrina near Goolwa. Not to scale and not all features included; the model is representative only. Refer to Table 5-3 for a key to the models figures.

Table 5-3 Key to symbols used in conceptual model for the Eastern Mount Lofty Ranges tributaries (Figure 5.4).

	Major surface inflows from 5 creeks and rivers feed freshwater into Lake Alexandrina. Local run off from rainfall contributes to instream flows. Inflows transport nutrients, sediments and organic material from the surrounding catchment.
	Groundwater discharge is important in maintaining surface water in the marsh habitats and is likely to also discharge into the creeks and rivers.
DO (NaCl)	Water quality is generally good, with high dissolved oxygen, low salinity and low turbidity and high light penetration.
	Primary production is high and aquatic plant dominated, with significant and diverse stands of submergent and emergent freshwater macrophytes.
	Secondary production is via detrital food webs, with decomposition of organic material facilitated by invertebrates which support higher trophic levels including fish and waterbirds. Invertebrate composition is different to the other freshwater sub-units due to flowing water habitats. High productivity supports biodiversity values with a high diversity of vegetation communities, fish and waterbirds, all of which contribute to meeting Ramsar criterion 3.
	Threatened species supported in the tributaries sub-unit that contribute to meeting Ramsar criterion 2 include Murray hardyhead ( <i>C. fluviatilis</i> ), southern bell frog ( <i>L. raniformis</i> ), Australasian bittern ( <i>B. poiciloptilus</i> ) and Mount Lofty Ranges southern emu-wren ( <i>S. malachurus intermedius</i> ). This sub-unit also supports part of the endangered ecological community Swamps of the Fleurieu Peninsula.
A Comment	Waterbirds including waterfowl, piscivores, cryptic birds and large waders are found in the tributaries, but do not occur in the large numbers often seen in the Lakes.
	Fish assemblages in the tributaries are characterised by high abundances, with a diverse mix of freshwater and diadromous species. Estuarine euryhaline species, such as small-mouthed hardyhead ( <i>A. microstoma</i> ), can also found in the downstream reaches. High native fish species diversity, diadromous life cycle traits and a range of spawning strategies contribute to the Ramsar site's high biodisparity.
	The physical habitat supported in the tributaries includes a suite of wetland types not found elsewhere in the Ramsar site. Stands of river red gum and the endangered ecological community, Swamps of the Fleurieu Peninsula occur only in this sub-unit. The tributaries also supports large stands of <i>Gahnia filum</i> and instream vegetation associations are the most diverse amongst the freshwater sub-units in the Ramsar site. These habitats are critical in supporting several species of small bodied native fish, contributing to Ramsar listing criterion 4.
	Climatic conditions and climate change including drought and increasing temperatures in the upper catchment, combined with water resource management will influence freshwater inflows from the tributaries.
	Invasive species affect the ecological values of the Ramsar site and include exotic fish species, feral cats, rabbits, foxes and weeds. Some native species can be problematic when overabundant.
	The tributaries provide water for stock and agriculture, have significant recreational values and form part of Ngarrindjeri Yarluwar-Ruwe.

## 5.1.4 Murray Estuary

#### **Summary of critical CPS in the Murray Estuary**

The model represents the critical CPS within the Estuary and Murray Mouth and some of the non-critical CPS and key threats. Critical components and processes include:

- hydrological regime (barrage flows and Murray Mouth openness)
- salinity
- vegetation
- fish diversity
- waterbird abundance and diversity.

#### Critical services include:

- maintenance and regulation of hydrological regimes
- ecological connectivity between marine, estuarine and freshwater environment
- provision of habitat for foraging, refuge, roosting and breeding
- provision of habitat for threatened wetland species and communities.

Barrage flows scour the Murray Mouth channel, maintaining physical and biological connectivity with the ocean. This is the only estuary in the Murray-Darling Basin and the only natural exit for catchment water, mobilised sediments and salts. Water levels in the Murray Estuary naturally vary with tides, winds and inflows from Lake Alexandrina via the barrages. These factors are the primary drivers of salinity, the extent and condition of freshwater and saltwater vegetation, 8 wetland types and diversity of habitat for waterbirds and fish.

Salinity ranges from seawater to brackish to fresh depending on the level of barrage flows.

A variety of habitats are present in the Murray Estuary, ranging from freshwater marshes to intertidal forested wetlands. The area provides important foraging grounds for many shorebird species. The Estuary supports a distinctive and diverse community of waterbirds characterised by species that are typically associated with freshwater and estuarine aquatic ecosystems.

The Estuary is an important transitional area for many species of fish that rely on estuarine conditions to complete their lifecycles. During times of high flows, fish assemblages are generally characterised by overall high abundance and a diverse mix of freshwater, diadromous, estuarine and marine estuarine opportunist species. During low flows species richness is reduced and there is an increased prevalence of marine estuarine opportunist species.

The Murray Estuary provides a salt wedge and range of salinity habitats critical to estuarine dependent fish species.

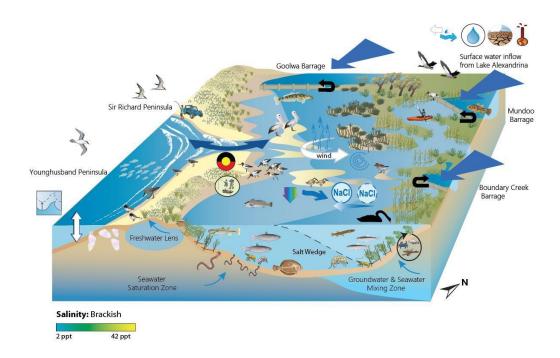


Figure 5.5 Conceptual model representing the Murray Estuary. Not to scale and not all features included; the model is representative only. Refer to Table 5-4 for a key to the models figures.

Table 5-4 Key to symbols used in conceptual model for the Murray Estuary (Figure 5.5).

	Major freshwater inflows from Lake Alexandrina, largely controlled via the barrages, maintain scouring of the Murray Mouth Channel. Tidal exchange brings seawater into the Estuary leading to the creation of a salt wedge.
	Groundwater interactions and flow are complex including the seawater saturation zone, surface aquifers associated with the dunes and mixing zones of groundwater and seawater.
wind ©	Wind action and turbulence in the Murray Mouth channel where tidal exchange occurs maintains mixing of the surface waters, with evaporation increased by wind.
(NaCl) (NaCl)	Water quality is influenced by tidal regime and inflows from Lake Alexandrina. Dissolved oxygen is high, turbidity low, with high light penetration. Salinity gradient occurs from the Estuary along the Coorong. The mixing of freshwater and seawater produces brackish-estuarine water.
	Primary production is driven by aquatic plants, seagrasses and fringing emergent and submergent vegetation. In the saline areas seagrasses provide critical habitat and food resources for a variety of species (fish and waterbirds). Samphire and saltmarsh areas are considered important foraging and nesting habitats for a range of waterbirds as well as refuge areas for small native fish. These habitats contribute to meeting Ramsar listing criterion 4.
	Secondary production is detrital based and reliant on a simplified food web compared to the freshwater units. Invertebrate composition is substantially different, with polychaetes, crustacea, molluscs (e.g. pipis) and chironomids playing important roles in the food web.
	Species of conservation significance in this sub-unit include hooded plover ( <i>T. rubricollis</i> ), Australian fairy tern ( <i>S. nereis nereis</i> ), eastern curlew ( <i>N. madagascariensis</i> ) and curlew sandpiper ( <i>C. ferruginea</i> ). The Murray Estuary and Goolwa Channel provide important foraging habitat for the curlews and the beach above high tide is the primary habitat for the hooded plovers. This sub-unit also supports the endangered ecological community, Subtropical and Temperate Coastal Saltmarsh community.
	Fish assemblages are highly abundant with a diverse mix of diadromous, estuarine and marine – estuarine opportunist species. The existence of a salt wedge and a range of habitats with differing salinities is critical to estuarine dependent fish species. Many species utilise the Estuary as nursery habitat.
	The Murray Mouth and Murray Estuary supports a species rich community of waterbirds comprised of species typically associated with freshwater and estuarine environments, such as black-winged Stilt ( <i>H. himantopus</i> ) and Australian white ibis ( <i>Threskiornis moluccus</i> ). Beaches of the Sir Richard and Younghusband peninsulas are important for beach-nesting birds (e.g. hooded plover, red-capped plovers and oystercatchers) over summer.
	Climatic conditions and climate change including drought and increasing temperatures, combined with water resource management, significantly influence freshwater inflows through the barrages. Sea level rise is also a threat to the character of the site.
	Invasive species affect the ecological values of the sub-unit and include feral cats, rabbits, foxes and weeds. Some native species can be problematic in periods when there is an overabundance of native herbivores. The Australian tube worm ( <i>F. enigmaticus</i> ) impacts on the physical environment of estuarine areas by building hard reefs that replace soft sediments.
	The Murray Estuary supports significant commercial and recreational fisheries, including the collection of pipis. Recreational use of this sub-unit is high, particularly through beach access. Some recreational activities are threats to the beach dwelling shorebirds (through disturbance of nesting sites).
AL STORE CO.	Connectivity between marine, estuarine and freshwater environments is fundamental to allow fish movement and recruitment. Passage through the Murray Mouth and the barrages is essential for supporting sustainable populations of these fish populations and biodisparity, contributing to Ramsar criterion 7.
	For Ngarrindjeri, Yarluwar-Ruwe requires connectivity, flow and mixing to occur between all living things and the lands and waters and the spirit world. Places within this sub-unit have particular significance for the Ngarrindjeri, but are seen as part of the whole Yarluwar-Ruwe.

## 5.1.5 Coorong North Lagoon

#### Summary of critical CPS in the Coorong North Lagoon

The model represents the critical CPS within the Coorong North Lagoon and some of the non-critical CPS and key threats. Critical components and processes include:

- hydrological regime (barrage flows and Murray mouth openness)
- salinity
- vegetation
- fish diversity
- waterbird diversity and abundance.

#### Critical services include:

- maintenance and regulation of hydrological regimes
- ecological connectivity between the Murray Estuary and Coorong South Lagoon
- provision of habitat for foraging, refuge, roosting and breeding
- provision of habitat for threatened wetland species.

Water levels in the Coorong North Lagoon naturally vary with tides, winds and inflows from Lake Alexandrina via the barrages. Barrage flows and conditions in the Murray Estuary are the primary drivers of salinity, the extent and condition of freshwater and saltwater vegetation, 6 wetland types and diversity of habitat to support waterbird and fish species.

Salinity ranges from fresh to brackish during high flow times to salinities higher than seawater during low flow periods.

The Coorong North Lagoon provides important habitats including mudflats for shorebirds including migratory birds.

Spatial distinctions in fish assemblage structure between the Murray Estuary, Coorong North Lagoon and Coorong South Lagoon are driven by the persistent salinity gradient, from marine at the Murray Estuary to hypersaline within the Coorong South Lagoon. Decreasing species richness relates to increasing salinity. The Coorong North Lagoon provides important nursery habitat for a number of species and is an important breeding and recruitment site for small-mouthed hardyhead as a keystone species to the food web associated with the Coorong.

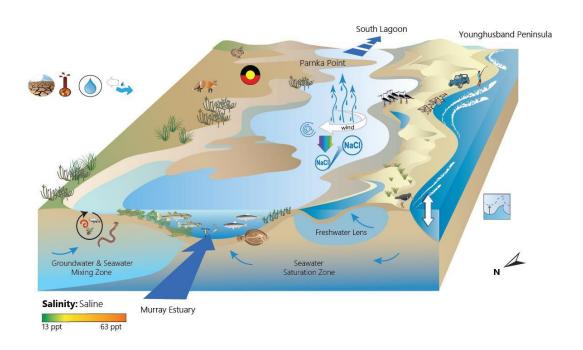


Figure 5.6 Conceptual model representing the Coorong North Lagoon. Not to scale and not all features included; the model is representative only. Refer to Table 5-5 for a key to the models figures.

Table 5-5 Key to symbols used in conceptual model for the Coorong North Lagoon (Figure 5.6).



Water level variation in the Coorong North Lagoon is a key determinant of habitat suitability and availability, as well as an important driver of water exchange and salinity. Local conditions (winds and tides) strongly influence hydrological interaction with freshwater inflows over the barrages. The lagoons are hydrologically connected, with variable flow predominantly from the Coorong North Lagoon into the Coorong South Lagoon, but occasionally from the South to the North as well.



Groundwater interactions and flows are complex, including the seawater saturation zone, surface aquifers associated with the dunes and mixing zones of groundwater and seawater. Wind action and tidal exchange maintains mixing of the surface waters, with evaporation increased by wind.



Salinity is controlled by freshwater inflows and tidal exchange from the Murray Estuary, evaporation and inflows of hypersaline water from the Coorong South Lagoon. A significant salinity gradient exists in the Coorong, with lower salinity in the northwest and higher salinity towards the Coorong South Lagoon. Dissolved oxygen is high, turbidity low, with high light penetration. Nutrient fluxes can contribute to abundant algal growth.



Primary production is driven by aquatic plants including seagrasses and fringing emergent and submergent vegetation. *R. tuberosa* is the dominant submerged aquatic plant in the Coorong North Lagoon. The seagrasses *Lepilaena cylindrocarpa* and *Zostera muelleri* are occasionally encountered in the Coorong North Lagoon and do not play a major role in supporting key species.



Secondary production is detrital based and reliant on a simplified food web compared to the freshwater sub-units. Invertebrate composition is substantially different, with polychaetes, crustaceans and chironomids playing important roles in the food web.



Species of conservation significance in this sub-unit are the same as the Murray Estuary and includes hooded plover (*T. rubricollis*), Australian fairy tern (*S. nereis nereis*), Eastern curlew (*N. madagascariensis*) and curlew sandpiper (*C. ferruginea*). The endangered ecological saltmarsh community also occurs in this sub-



Fish assemblages are diverse and similar to the Murray Estuary, with the Coorong North Lagoon providing nursery habitat for a number of species.



The Coorong is iconic for the abundant waterbirds it supports, notably including migratory species. Species richness is high and composition different to that of the Murray Estuary and the Coorong South Lagoon. Variation in inundation results in the exposure of mudflats and intertidal marshes along the shoreline, providing important habitat for many waterbirds. The beach area of this sub-unit supports large numbers of migratory shorebirds and beach-nesting birds – e.g. hooded plover (*T. rubricollis*), red-capped plover (*C. ruficapillus*) and oystercatchers (*Haematopodidae* spp.) over summer.



Climatic conditions and climate change impacts are the same as occurs across the other saline sub-units.



Invasive species and problematic native species affecting this sub-unit are the same as for the Murray Estuary sub-unit, although the impact of the Australian tubeworm (*F. enigmaticus*) is less extensive in the Coorong North Lagoon.



Recreational use is considerable with beach access, fishing and collection of pipis common activities. Some recreational activities are threats to the beach-dwelling shorebirds (through disturbance of nesting sites).



Places within this sub-unit have particular significance for the Ngarrindjeri, but are seen as part of the whole Yarluwar-Ruwe.

## 5.1.6 Coorong South Lagoon

#### **Summary of critical CPS in the Coorong South Lagoon**

The model represents the critical CPS of the Coorong South Lagoon and some of the non-critical CPS and key threats. Critical components and processes include:

- hydrological regime (barrage flows and Upper South East Drainage Network)
- salinity
- vegetation
- fish diversity
- waterbird diversity and abundance.

#### Critical services include:

- ecological connectivity with the Coorong North Lagoon
- critical food webs
- provision of habitat for foraging, refuge, roosting and breeding
- provision of habitat for threatened wetland species and communities.

Water levels in the Coorong South Lagoon are driven by natural drainage, wind and inflows from the Coorong North Lagoon. Barrage flows and to a lesser extent, flows from the Upper South East Drainage Network are the primary drivers of salinity, the extent and condition of freshwater and saltwater vegetation, 6 wetland types, provision of habitat for waterbirds and fish, and maintenance of the Coorong food web.

Salinities range from seawater during high Murray River and South East Drainage Network flow periods, to hypersaline during low flow periods. The median salinity is twice that of seawater. Freshwater inflows are highly beneficial to the food web structure of the Coorong South Lagoon, leading to a reduction in salinities and an expansion of suitable habitat. Under optimal salinity and nutrient conditions, the Coorong South Lagoon supports a wide diversity of organisms across numerous trophic levels including a diverse range of waterbirds. The Coorong South Lagoon contains some 61% of available mudflat in the whole Ramsar site, which are crucial foraging grounds for many waterbirds, particularly migratory shorebirds.

The key elements of the Coorong Food web are R. tuberosa, small-mouthed hardyhead and benthic macroinvertebrates.

Fish diversity in the Coorong South Lagoon is low and the salt tolerant small-mouthed hardyhead, which is the dominant fish species, plays an important role in the food web.

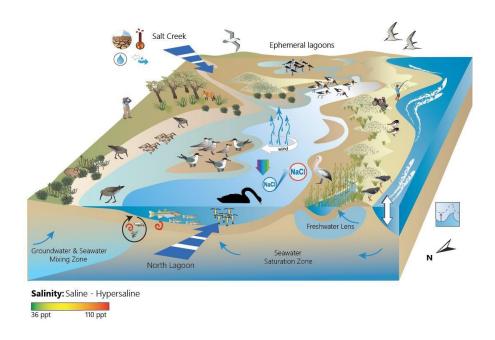
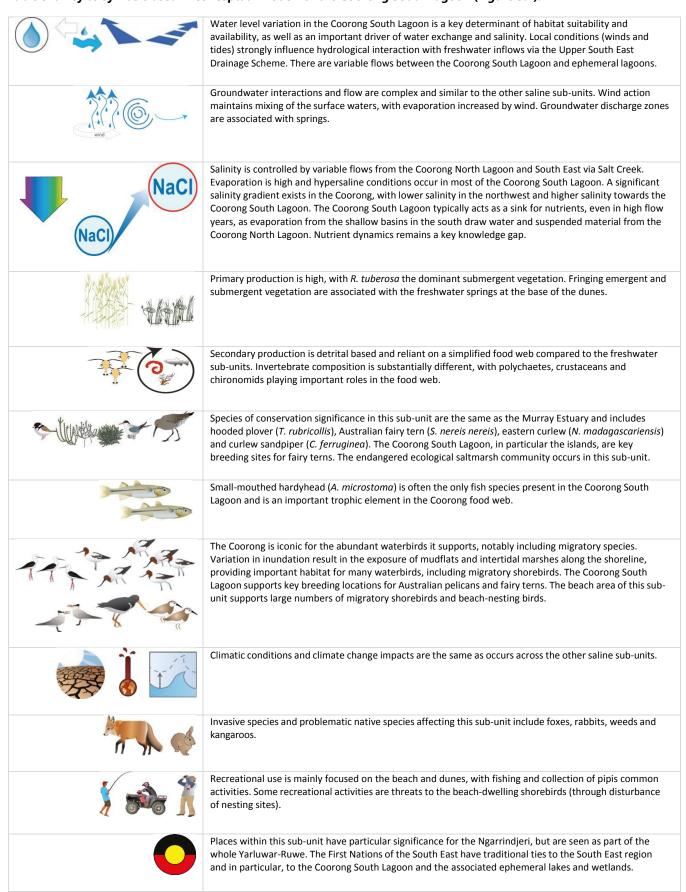


Figure 5.7 Conceptual model representing the Coorong South Lagoon. Not to scale and not all features included; the model is representative only. Refer to Table 5-6 for a key to the models figures.

Table 5-6 Key to symbols used in conceptual model for the Coorong South Lagoon (Figure 5.7).



# 6 Limits of acceptable change

# 6.1 Process for setting limits of acceptable change

Limits of acceptable change (LAC) are defined as the variation that is considered acceptable for a measure or parameter of a particular component or process of the ecological character of the wetland (Phillips 2006). The inference is that if the particular measure or parameter moves outside the limits of acceptable change this may indicate a change in ecological character that could lead to a reduction or loss of the values (criteria) for which the site was listed.

LAC and the natural variability in the measures or parameters on which the LAC are set are impossible to separate. (Phillips 2006) suggested that LAC should be beyond the levels of natural variability (Figure 6.1). In reality however, patterns of natural variability are rarely fully understood and even with long-time series data it can be difficult to resolve whether shifts in patterns of variability are natural cycles occurring over longer time scales than the data available, natural shifts between different stable states, or change in response to some external pressure. Defining LAC is therefore rarely a purely statistical procedure and commonly LAC are determined by consensus of experts informed by available data sets and current statistical interpretation.

LAC are thresholds, set at the point at which a potential change in a critical CPS has occurred, which may represent a change in ecological character. If a LAC is exceeded, this may require an investigation to determine whether there has been a change in ecological character within the meaning of the Ramsar Convention.

The following points are important to note:

- LAC are a tool by which ecological change can be measured. However, ECDs are not management plans and LAC are not the management regime for the Ramsar site.
- Exceeding LAC does not necessarily indicate that there has been a change in ecological character within the meaning of the Ramsar Convention. However, exceeding LAC may require investigation to determine whether there has been a change in ecological character.
- While the best available information has been used to prepare this ECD and define LAC for the site, a
  comprehensive understanding of site character may not be possible as only limited information and data is
  available for these purposes. The LAC may not accurately represent the variability of the critical components,
  processes, benefits or services under the management regime and natural conditions that prevailed at the
  time the site was listed as a Ramsar wetland.
- LAC should be updated as new information becomes available to ensure they more accurately reflect the natural variability of critical CPS of the Ramsar wetland.

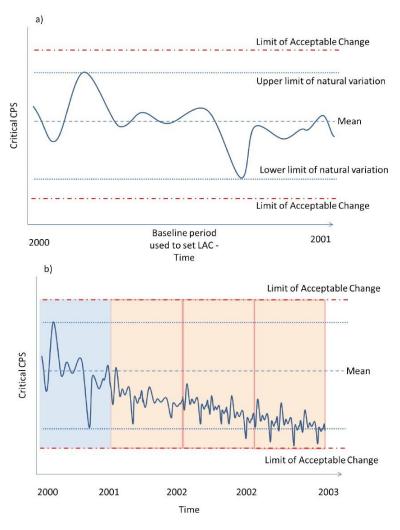


Figure 6.1 Issue of setting LAC only on upper and lower limit of natural variability. a) represents upper and lower limit of natural variation and b) shows a changed temporal pattern as well as a declining trend, which would not be detected as it would not trigger the LAC. (Butcher and Cottingham 2016).

# 6.2 Ngarrindjeri perspectives on limits of acceptable change

At the centre of Ngarrindjeri knowledge and identity is an understanding of the interconnectedness of all things, the Ngarrindjeri concept of Ruwe/Ruwar (country/body/spirit). From a Ngarrindjeri perspective, the lands and waters of the Coorong and Lakes Alexandrina and Albert Wetland are part of the Ngarrindjeri living body. Maintaining connectivity between all parts of the living body is crucial for the health and wellbeing of the Ramsar site and Ngarrindjeri people. Changes to the character of Ngarrindjeri Yarluwar-Ruwe therefore have direct effects on Ngarrindjeri wellbeing (Ngarrindjeri 2019).

From this perspective, Ngarrindjeri support the overall need to define Limits of Acceptable Change (LAC) because it is crucial that there is an improvement and not a worsening of the current health of Ngarrindjeri lands and waters. Therefore, effective LAC for Ngarrindjeri require an appropriate alignment with Ngarrindjeri concepts of flow, interconnectivity and reproduction, as well as the principles of wise-use that are at the centre of Ngarrindjeri law (Ngarrindjeri 2019).

Long-term Ngarrindjeri knowledge of the character of the site provides significant insight into 'natural' variation. Ngarrindjeri knowledge regarding long-term variability is embedded in Creation stories and information relating to Yarluwar-Ruwe that stretches back to before the last Ice Age. The Ngarrindjeri view is that the landscape was not 'natural' in the non-indigenous sense, but instead is the product of the Kaldowinyeri and the Creation ancestors and the activities of Ngarrindjeri. From this perspective, any 'natural' variation within the Ramsar site is an embodiment of Ruwe/Ruwar and therefore also cultural in nature (Ngarrindjeri 2019).

Ngarrindjeri have developed formal positions relating to the condition/health of the Ramsar site and in relation to LAC that take into account the cultural consequences of changes to 'ecological character' (Birckhead 2011; Hemming et al. 2002; Ngarrindjeri Nation 2006; Ngarrindjeri Ramsar Working Group 1998). Whilst qualitative in nature, this information is useful for establishing historical baselines for many determinants of the ecological character (Ngarrindjeri 2019).

Whilst some Ngarrindjeri long-term knowledge is being used in this ECD to define LAC and changes over time to the ecological character of the Ramsar site, more work is required to recognise the interconnected nature of Ngarrindjeri concepts of Ruwe-Ruwar (Ngarrindjeri 2019).

# 6.3 Limits of acceptable change for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site

Limits of acceptable change (LAC) have been set for the Ramsar site according to the available national guidance. Where possible, site specific information has been used to statistically develop and refine LAC. In the absence of sufficient site-specific data, LAC are based on recognised standards, expert opinion or information in the scientific literature that is relevant to the site. In all these cases, the source of the information upon which the LAC has been determined is documented.

Advice (2016) from DoEE and DAWR specified the use of consistent terminology in describing LAC, which includes the following:

- Direct LAC LAC is directly and easily measurable, with an expectation that change is detectable.
- **Indirect LAC** A direct LAC is not easily measurable; however, an indirect LAC can indicate a change. An indirect LAC generally uses a surrogate to measure change in a particular CPS.
- **Double LAC** needs 2 LAC to be exceeded to indicate a potential change in character.

The LAC presented in this ECD have been developed from baselines as of 2015 and are representative of conditions post the Millennium Drought. Data from the time of listing may still be relevant for setting some LAC, indicating that changes over the drought period were transitory. The majority of the critical CPS have not had a permanent change and as such the data available at listing or best available nearest to listing has been included in the development of 2015 LAC.

The critical CPS, their subcomponents and attributes measured to assess against the LAC are summarised in Table 4-1. A description and justification for each LAC for the Ramsar site follows (Table 6-1).

Table 6-1 Summary of critical CPS, subcomponents, attributes measured, LAC, LAC type and confidence level.

Critical CPS and subcomponent	Attribute measured	LAC	LAC Type	Confidence level
Hydrology				
Inflows	Lake Alexandrina water level	Lake Alexandrina water levels fall below – 0.25m AHD for 8 consecutive months.	Indirect	Medium
Lake Alexandrina water level	Lake Alexandrina water level	Lake Alexandrina water levels fall below – 0.25m AHD for 8 consecutive months.	Direct	High
Salinity				
Lake Alexandrina salinity	Electrical conductivity in Lake Alexandrina	Lake Alexandrina average annual salinity levels greater than 1,500 EC for 2 consecutive years.	Direct	High
Murray Estuary and Coorong salinity	Salinity as ppt in the Murray Estuary, Coorong North and Coorong South lagoons	Murray Estuary (Goolwa Channel, Murray Mouth to Pelican Point) average monthly salinity greater than 40 ppt (55,658 EC) for more than 18 consecutive months.  OR	Direct	High
		<u>Coorong North Lagoon</u> average monthly salinity level greater than 70 ppt (86,342 EC) for more than 18 consecutive months.  OR		
		<u>Coorong South Lagoon</u> average monthly salinity level greater than 100 ppt (112,471 EC) for more than 18 consecutive months.		
Vegetation				
Submergent freshwater vegetation	Lake Alexandrina water level and salinity	Average daily Lake Alexandrina water levels less than +0.2 m AHD or salinity greater than 2,000 EC for 2 consecutive years.	Indirect	Medium
Emergent freshwater vegetation	Lake Alexandrina water level	Average daily Lake Alexandrina water levels less than +0.2 m AHD for greater than 2 consecutive years.	Indirect	Medium
Submergent halophytes	Cover of Ruppia tuberosa	Less than 5% cover of <i>R. tuberosa</i> recorded at greater than 50% of Direct H all winter monitored sites for 2 or more consecutive years. See also Coorong food web LAC.		High
Emergent halophytes	Lake Alexandrina water level	Average daily water levels in Lake Alexandrina less than +0.2 m AHD for 2 or more consecutive years.	Indirect	Medium

Fish				
Diversity (species richness and biodisparity)	Species richness	Lake Alexandrina and Albert and EMLR tributaries: Loss of any of the common freshwater species for 2 consecutive years which include targeted surveys.  OR  Coorong: Loss of any of the common estuarine and marine-estuarine opportunist species for 5 consecutive years which include targeted surveys. Refer to Table 6-2 for the species list.	Direct	High
	Number of fish families (biodisparity)	Less than 13 of the 17 fish families (in targeted surveys) recorded in any 3 consecutive years. Refer to Table 6-3 for the families list	Direct	High
Movement and recruitment	Young of year for congolli ( <i>Pseudaphritis urvillii</i> ) and common galaxias ( <i>Galaxias</i> <i>maculatus</i> )	Young of year for congolli not recorded in the site for more than 5 consecutive years (in targeted surveys)  OR  Young of year for common galaxias not recorded in the site for more than 3 consecutive years (in targeted surveys)	Direct	High
Threatened species  • Murray hardyhead	Presence/absence of Murray hardyhead ( <i>Craterocephalus</i> <i>fluviatilis</i> )	Absence of Murray hardyhead in any 3 out of 5 targeted surveys within a 3-year period.	Direct	High
Waterbirds				
Diversity (species richness)	Abundances of selected waterbird species	<u>Lakes Alexandrina and Albert</u> : Less than 17 of 20 selected waterbird species have counts above their 10th percentile abundance for 2 consecutive years. Refer to Table 6-4 for the target species	Direct	Medium
		Murray Estuary/Goolwa Channel: Less than 18 of 21 selected waterbird species have counts above their 10th percentile abundance for 2 consecutive years. Refer to Table 6-5 for the target species	Direct	High
		Coorong North Lagoon: Less than 19 of 23 selected waterbird species have counts below their 10th percentile abundance for 2 consecutive years. Refer to Table 6-6 for the target species	Direct	High
		Coorong South Lagoon: Less than 18 of 21 selected waterbird species have counts above their 10th percentile abundance for 2 consecutive years. Refer to Table 6-7 for the target species	Direct	High
Abundance	Abundance across Ramsar site	Fewer than 190,122 waterbirds counted over the Ramsar site in the annual census over 2 consecutive years.	Direct	High

Abundance	Presence/absence of priority migratory shorebird species	Counts for any 3 of the 7 pr (University of Adelaide, D Pa Common greenshank, curled necked stint and sharp-tailed species in the Coorong durit 10 <sup>th</sup> percentile abundance ( Black-tailed godwit: Black-tailed godwit: Bla	aton) are at the follow w sandpiper, Pacific g ed sandpiper: Counts ng an annual census 2000–2015) for 2 con ailed Godwit are not con in the Coorong.	ving levels: olden plover, red- of these priority are below their secutive years. letected for 4	Direct	High
	Percent of 1% East Asian Australasian Flyway population for selected species	The 10 <sup>th</sup> percentile percentages 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 2000–2015 are not met for 2 consecutive years.		Direct	Medium	
		Species	10th percentile (2000–2015)	Median (2000–2015)		
		Curlew sandpiper Red-necked stint	504 15,675	2,250 26,267		
	Percent of 1% Australian population for selected species	Sharp-tailed sandpiper  The 10th percentile percent of Australian pied oystercate and red-capped plover prescensuses from 2000-15 are	cher, chestnut teal, Ausent in the Coorong d	ıstralian fairy tern uring annual	Direct	Medium
		<b>Species</b> Australian pied oystercatch	10th percentil (2000–2015)	Median (2000–2015) 14 158		
		Chestnut teal	4,3			
		Fairy tern		26 336		
		Red-capped plover	4	56 1,235		

Breeding	Number of breeding events of annual and regular breeding species	Annual breeding species: No successful breeding events in any 3 consecutive years for the following species and attributable to onsite changes, assessed for each species. A successful breeding event occurs when greater than 5 % of recorded nests fledge young. Shorebird species are underlined in the list below:  • Australian pelican (Pelecanus conspicillatus)  • Black swan (Cygnus atratus)  • Caspian tern (Hydroprogne caspia)  • Crested tern (Thalasseus bergii)  • Australian fairy tern (Sternula nereis nereis)  • Hooded plover (Thinornis rubricollis)  • Australian white ibis (Threskiornis molucca)  • Australian pied oyster catcher (Haematopus longirostris)  • Red-capped plover (Thinornis rubricollis)  • Straw-necked ibis (Threskiornis spinicollis)  Regular breeding species: No successful breeding events in any 4 consecutive years for the following species and attributable to onsite changes. A successful breeding event occurs when greater than 5 % of recorded nests fledge young.  • Pied cormorant (Phalacrocorax varius)  • Royal spoonbill (Platalea regia)  • Silver gull (Chroicocephalus novaehollandiae)	Direct	Low
Threatened species				
<ul> <li>Australasian bittern (Botaurus poicilopilus)</li> </ul>	Absence in targeted surveys	Absence of Australasian bittern at greater than 20% of sites that contain suitable habitat in 3 out of any 5 targeted surveys.	Direct	High
<ul> <li>Australian fairy tern (Sternula nereis nereis)</li> </ul>	Abundance	Abundance of Australian fairy tern less than 226 in the January census for 2 consecutive years.	Direct	High
• Curlew sandpiper (Calidris ferruginea)	Abundance	Abundance of curlew sandpiper less than 508 in the January census for 2 consecutive years.	Direct	Medium
Eastern curlew (Numenius madagascariensis)	Abundance	Abundance of eastern curlew less than 2 in the January census for 2 consecutive years.	Direct	Medium

Hooded plover     (Thinornis rubricollis)	Absence in targeted surveys	Absence of hooded plover in any 3 out of 5 targeted surveys assessed over a rolling 10-year period.	Direct	High
<ul> <li>Mount Lofty Ranges southern emu-wren (Stipiturus malachurus intermedius)</li> </ul>	Absence in targeted surveys	Absence of Mount Lofty Ranges southern emu-wren from all known core population locations in any 1 out of 5 targeted surveys assessed over a rolling 10-year period.		Medium
Habitat				
Wetland habitat	Condition	Decline in condition at greater than 60% of the sites assessed over any 10-year period.	Direct	High
Threatened ecological communities and species				
Swamps of the Fleurieu Peninsula	Extent or condition of threatened community	Insufficient data to develop a baseline. To be defined in future.	-	-
Subtropical and temperate coastal saltmarsh	Extent of threatened community	Murray Estuary and Coorong: Reduction of greater than 10% in percentage cover over any 10-year period.	Direct	Low
Southern bell frog	Lake Alexandrina water level and salinity	See LAC for freshwater submergent and emergent vegetation and the Lake Alexandrina salinity LAC.	Indirect	Low
Coorong food web				
<i>Ruppia tuberosa</i> – primary producer	Cover of <i>R. tuberosa</i> and percent viable seeds in sediment cores	Less than 5% cover of <i>R. tuberosa</i> recorded at greater than 50% of all winter monitored sites.  AND  Viable seeds of <i>R. tuberosa</i> in less than 20% of sediment cores at two-thirds of sampling locations across the Coorong South Lagoon for 4 consecutive seasons.	Double Direct	High
Benthic macroinvertebrates – primary consumers	Salinity as ppt in the Murray Estuary, Coorong North and Coorong South lagoons	See LAC for salinity for the Murray Estuary and the Coorong North and Coorong South lagoons.	Indirect	Medium
Small-mouthed hardyhead – secondary consumer	Salinity in the Coorong South Lagoon	See LAC for salinity in the Coorong South Lagoon.	Indirect	Medium

## 6.3.1 Hydrology

## 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.

#### Lake Alexandrina water level

Lake levels are required to be maintained at certain levels to ensure hydrological connectivity between Lake Alexandrina and Lake Albert, and Lake Alexandrina and the EMLR tributaries, and to prevent broad-scale lake acidification of Lake Alexandrina and Lake Albert.

Attribute measured	Lake Alexandrina water level
Baseline	2015 baseline set using all available data up to 2015, in particular outputs from the Acid Sulfate Soil Research Program. The research details can be found at <a href="https://www.environment.sa.gov.au/topics/river-murray/improving-river-health/coorong-lower-lakes-and-murray-mouth/monitoring-CLLMM-health/research-projects/Acid Sulfate Soils Research Program reports.">https://www.environment.sa.gov.au/topics/river-murray/improving-river-health/coorong-lower-lakes-and-murray-mouth/monitoring-CLLMM-health/research-projects/Acid Sulfate Soils Research Program reports.</a>
LAC	<b>Direct LAC</b> : Lake Alexandrina water levels fall below -0.25 metres AHD for 8 consecutive months.
	Lake level based on the average water level at 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 0metres AHD), substitute stations may be established to ensure water level in a nearby location is recorded.
Justification	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. The LAC is set at a point where sustained low lake levels could be expected to trigger broadscale lake acidification of Lake Albert and would be expected to have an impact on connectivity between Lake Alexandrina and Lake Albert.
Confidence rating	High

## Supporting evidence for LAC

Water levels in Lake Alexandrina have a direct impact on water levels in Lake Albert and there is an extensive and considerable acid sulfate soil hazard in Lake Alexandrina and Lake Albert. The LAC is set at the recommended upper level of the lowest water management level for Lake Albert (-0.25m AHD) with regard to acid sulfate soils. The Acid Sulfate Soil Program Research Cluster recommended water management levels of no lower than -1.5 metres and -0.5 metres  $\pm$  0.25 metres AHD for Lake Alexandrina and Albert respectively (MDBA 2014a). The risk of broad-scale lake acidification is reduced if water levels are stabilised at or above -1.5 metres AHD in Lake Alexandrina and -0.5 metres AHD in Lake Albert. The risk profile substantially increases past these water levels and/or with prolonged time near these levels (DENR 2010).

Acidity begins entering the water body at lake levels of 0.0 metres AHD when both lake beds become exposed and increases as lake levels reduce. Currency Creek, Finniss River and the Goolwa Channel are likely to express acidity at -0.2 metres AHD (MDBA 2014a). Acidification can occur rapidly with seiching being a prime contributor to acid release. Despite inundation since the drought, studies undertaken in 2013 indicate that there are some sites around the Lakes that are expected to re-acidify rapidly once dry again, impacting upon surface waters (Baker et al. 2013). Lake levels of -0.25 metres AHD allow for seasonal oscillations in water level and take into account some of the inertia and build-up of acidity over time in the system (MDBA 2014a).

Wind and wave action in the Lakes is such that there will be times when Lake Alexandrina and Lake Albert become disconnected at -0.25 metres AHD. The Lakes formally disconnect at -0.3 metres AHD but interconnection is restricted from 0.0 metres AHD. The return period for the threshold of -0.25 metres ADH of 8 months has been set to incorporate knowledge of forecast winter flows that could be expected to raise the level of the lake above -0.25 metres AHD during periods of below average flows.

## 6.3.2 Salinity

## Lake Alexandrina salinity

Salinity in Lake Alexandrina is primarily controlled by inflows from the River Murray and outflows through the barrages (Heneker 2010). Once salinities reach an average of 1,000 EC for Lake Alexandrina, they approach known tolerances for some of the more salt-sensitive biota in the CLLMM region (Lester et al. 2011a).

Attribute measured	Electrical conductivity in Lake Alexandrina
Baseline	2015 baseline has been established using the observed data set and the modelling of Heneker (2010) and Lester et al. (2011a; 2011b).
LAC	<b>Direct LAC:</b> Lake Alexandrina average annual salinity levels greater than 1,500 EC for 2 consecutive years.
	Lake salinity is based on the monthly 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 0.0 metres AHD), substitute stations may be established to ensure water level in a nearby location is recorded.
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). The LAC is set at 1,500 EC, a point where freshwater biota would be significantly adversely affected by sustained salinities in Lake Alexandrina (Lester et al. 2011a).
Confidence rating	High

## **Supporting evidence for LAC**

Salinity in Lake Alexandrina directly influences a number of biota and ecological processes. Hart et al. (1991) found that a salinity of 1 g/L (which is approximately 1,500 EC) was the point at which

Australian freshwater biota would be significantly adversely affected, with sub-lethal impacts due to salinity increasingly common and Nielsen et al. (2003) found the same threshold for aquatic plants (Lester et al. 2011a). Monitoring in the Lakes has shown that most of the vegetation species have a higher salinity tolerance than reported for other parts of Australia (Bailey et al. 2002; Gehrig et al. 2011 in Nicol 2016) but lower salinity resulted in vegetation that was in better condition and more diverse (Frahn et al. 2014 in Nicol 2016). Accordingly Nicol (2016) suggested a LAC for vegetation of an average salinity of 2,000 EC and a management trigger of 1,500 EC.

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. Heneker (2010) considered the observed and modelled relationship between Lake Alexandrina and Lake Albert salinity for the period of normal connection and interchange (January 1975 to March 2007) when water levels in both lakes were between +0.25 and + 0.85 metres AHD). The modelled data lies within the envelope created by the majority of the observed data, indicating a good relationship between salinity in the 2 lakes above water levels of 0.0 metres AHD.

Salinities above 2,000 EC in Lake Albert were shown to occur when salinities in Lake Alexandrina were greater than 1,000 EC (Heneker 2010). Average outflows of 2,000 and 1,000 gigalitres per annum have been shown to maintain maxima of 1,000 and 1,500 EC in Lake Alexandrina, respectively (Heneker 2010, Lester et al. 2011b). While connected Lake Alexandrina acts as a refuge for aquatic fauna and a propagule source for aquatic flora if salinities in Lake Albert exceed the requirements of resident biota.

Submergent freshwater plants were completely lost from the site between 2007 and 2009 (Nicol 2016). Salinities in Lake Alexandrina increased from 1,500 to 3,000 EC between April and November 2007 and salinities in Lake Albert were around 2,500 EC (Heneker 2010) as water levels fell from +0.25 metres AHD to 0.0 metres AHD. The LAC is set at 1,500 EC, a point where freshwater biota would be significantly adversely affected by sustained salinities in Lake Alexandrina and flows over the barrages would not prevent extreme conditions in the Coorong. The time period for the threshold level to be exceeded is 2 years.

## Murray Estuary and Coorong

Salinity in in the Murray Estuary and the Coorong North and Coorong South lagoons directly influence a number of biota and ecological processes. Given the salinity gradient supports differing ecological communities, the LAC will vary depending on individual site locations.

Attribute measured	Salinity as ppt in the Murray Estuary, Coorong North and Coorong South lagoons
Baseline	2015 baseline set using modelled daily salinity data from 1963 to 2012 at 11 sites from the Murray Mouth to the Coorong South Lagoon (data supplied by I. Webster, CSIRO).
LAC	<b>Direct LAC:</b> Murray Estuary (Goolwa Channel, Murray Mouth to Pelican Point) average monthly salinity greater than 40 ppt (55,658 EC) for more than 18 consecutive months.
	OR Coorong North Lagoon average monthly salinity level greater than 70 ppt (86,342 EC) for more than 18 consecutive months.
	OR Coorong South Lagoon average monthly salinity level greater than 100 ppt (112,471 EC) for more than 18 consecutive months.

Justification	The LAC for the Murray Estuary is set at 40 ppt (55,658 EC) as salinity above the level of seawater (36 ppt/ 51,070 EC) will significantly affect the estuarine plankton and macroinvertebrate species in the Murray Mouth and there is no refuge for biota should salinities exceed this level. The LAC for the Coorong North Lagoon is set at 70 ppt (86,342 EC), above the maximum level of salinity that polychaete worms (the most salinity tolerant of the Coorong North Lagoon biota) will tolerate (70 ppt/ 86,342 EC). The LAC for the Coorong South Lagoon is set at 100 ppt (112,471 EC), the level that mobile species in the Coorong South Lagoon biota would have evacuated the Coorong South Lagoon.
Confidence rating	High

## **Supporting evidence for 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 (55,658 EC), 10% above the salinity level of sea water (36 ppt/51,070 EC). 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 (*A. butcheri*) and tamar goby (*A. tamarensis*) (60.1 ppt), greenback flounder (*R. tapirina*) and yelloweye mullet (*A. forsteri*) (74.1 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.

## 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 (128,175 EC) 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 and Bailey 2012a, Ye et al. 2020).

## 6.3.3 Vegetation

All LAC for vegetation were determined by reviewing existing data, conceptual models and expert opinion (Nicol 2016). Only limited data is available prior to 2008.

#### Submergent freshwater vegetation

Distribution and abundance of submergent freshwater vegetation in Lakes Alexandrina and Albert are strongly influenced by water level and salinity (Nicol 2016). The 2 primary drivers of the submergent vegetation community are delivery of flows from the River Murray and barrage operations affecting water levels and salinity throughout the site (Nicol 2016). Knowledge of salinity effects on freshwater submergent plant communities in the Lakes is limited; however, elevated salinities (i.e. greater than 2,000 EC) do not support diverse freshwater submergent plant communities within Lakes Alexandrina and Albert and tend to promote the occurrence of monospecific communities. 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. *P. pectinatus* in the Goolwa Channel).

Attribute measured	Lake Alexandrina water level and salinity
Baseline	2015 baseline set using all available data up to 2015, in particular survey data from 2004-16 (various studies – see Nicol 2016). Salinity levels to be <2,000 EC and lake levels +0.8 to +0.4 metres AHD with +0.2 metres AHD minimum (Nicol 2016).
LAC	Indirect LAC: Average daily Lake Alexandrina water levels less than +0.2 metres AHD or salinity greater than 2,000 EC for greater than 2 consecutive years.
Justification	Freshwater submergent plants in the Lakes generally do not colonise areas below sea level, except in Goolwa Channel where plants often grow in areas as low as -0.5 metres AHD (Frahn et al. 2014; Nicol 2016). Therefore, water levels in the Lakes need to be maintained at a minimum of +0.2 metres AHD and preferably 0.4 metres AHD and above to support these communities. Levels below +0.2 metres AHD for any length of time will cause the loss of this community. Salinities above 2,000 EC lead to reduced diversity (Frahn et al. 2014).
Confidence rating	Medium

#### **Emergent freshwater vegetation**

Emergent plants tend to occupy elevations between +0.9 metres AHD and to sea level (Nicol 2016). Water requirements for plants growing at higher elevations and the requirement for high soil moisture in the root zone when growing out of water, mean it is preferable that water levels be maintained at a minimum of +0.2 metres AHD, but preferably +0.4 metres AHD and above for hydrological connection (Nicol 2016). The primary driver of the emergent vegetation community is freshwater inflows from the River Murray and barrage operations affecting water level below Lock 1 (Nicol 2016).

Attribute measured	Lake Alexandrina water level
Baseline	2015 baseline set using all available data up to 2015, in particular survey data from 2004-16 (various studies – see Nicol 2016). Lake levels +0.8 metres to +0.4 metres AHD with +0.2 metres AHD minimum (Nicol 2016).
LAC	Indirect LAC: Average daily water levels in Lake Alexandrina less than +0.2 metres AHD for 2 consecutive years, isolating and causing decline in freshwater emergent vegetation.
Justification	The LAC for emergent freshwater vegetation is based on expert opinion and partial accounts of Ngarrindjeri knowledge. If average daily Lake Alexandrina water levels are less than 0.2 metres 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 and an increase in terrestrial species (predominately 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.
Confidence rating	Medium

#### Submergent halophytes

*R. tuberosa* is now the only submerged aquatic plant that can tolerate the current conditions (salinity and water level variation) in the Coorong South Lagoon and if it is lost there are no other plants that can provide similar ecological services (Paton et al. 2015a). Sites with 5% cover are likely to provide less than 5% of the services that a vigorous population would have provided and the chances of sites with 5% cover recovering to a good condition (e.g. a modest 30% cover) over the following year is limited. This will particularly be the case if the propagule bank is low and the ecological conditions needed for recovery and successful reproduction (e.g. sufficient magnitude and timing of flows, water level and salinity) are difficult to provide (Paton et al. 2015a). The ability to recover through interventions (e.g. translocations) is limited because only small sections (up to a kilometre) can be treated at a time and, even when translocations are undertaken, they still require several years for *Ruppia* populations to reach modest levels of cover (Paton et al. 2015a).

Attribute measured	Cover of Ruppia tuberosa
Baseline	2015 baseline set on data collected 2009–15 (Paton et al. 2015a).
LAC	<b>Direct LAC</b> : Less than 5% cover of <i>R. tuberosa</i> recorded at greater than 50% of all winter monitored sites for 2 or more consecutive years.  See also LAC for Coorong food web.
Justification	Ruppia tuberosa is the most important submergent halophyte in the Coorong, hence the LAC for submergent halophytes is assessed directly via R. tuberosa cover and distribution in the Coorong. LAC assessed by method described in Rogers and Paton (2009). The term "cover" 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 not to exceed the LAC, R. tuberosa must meet the conditions regarding cover for at least one water depth where the plant is sampled.
	The distribution and abundance of <i>R. tuberosa</i> in the Coorong has been highly variable since 2000 (Paton et al. 2015a). The LAC of less than 5% cover of <i>R. tuberosa</i> 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. (Paton et al. 2015a). The LAC for <i>R. tuberosa</i> as a submergent halophyte focuses on coverage, whereas the LAC for the Coorong food web (i.e. the services and resources provided by <i>R. tuberosa</i> ) focuses on life cycle (i.e. viability of seed bank and potential to reproduce).
Confidence rating	High

#### **Emergent halophytes**

Emergent halophytes, also known as samphire and saltmarsh vegetation, are widespread throughout the Ramsar site in areas where there is moderate to high salinity (Seaman 2003). They are generally restricted to areas above +0.8 metres AHD in the Lakes and +0.2 metres AHD in the Coorong (Nicol 2016). Under normal operating regimes (Lake Alexandrina between +0.4 to +0.80 metres AHD), these levels would coincide with a short period of shallow inundation on an annual basis.

If water levels fall below +0.4 metres AHD in the Lakes or below +0.1 metres 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 metres 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. Lake levels, however, have been subject to major fluctuations such as those experienced during the Millennium Drought. An indirect Lake Alexandrina water level LAC has therefore been set at the minimum possible level of +0.2 metres AHD (Nicol 2016).

Attribute measured	Lake Alexandrina water level
Baseline	2015 baseline set using published literature on ecology of samphire and saltmarsh vegetation.
LAC	Indirect LAC: Average daily water levels in Lake Alexandrina less than +0.2 metres AHD for 2 or more consecutive years.
Justification	Water levels below +0.4 metres AHD (minimum +0.2 metres AHD) in the Lakes will result in saltmarsh and samphire vegetation becoming disconnected from open water habitats leading to a decline in recruitment and condition (Nicol 2016). LAC set on expert opinion.
Confidence rating	Medium

#### 6.3.4 Fish

## Diversity (species richness and biodisparity)

There is a lack of underlying knowledge of the variability in fish species richness at the time of listing. The majority of data on fish diversity and abundance are from 2006–15, with data predominantly captured during the drought and post drought years. The number of species considered in the whole of site and number of families within the biodisparity LAC are based on empirical data and expert opinion. The species included within the LAC have been adapted from the species list identified in Bice et al. (2018) to include those species (and families) that are critical to the trophic dynamics and/ or are characteristic of the site and would be expected to be present on a semi-regular to regular basis.

Attribute measured	Species richness
Baseline	2015 baseline set on species occurrences in greater than 80% of years from 2006–15 within the site using current monitoring techniques.
LAC	Direct LAC:  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 surveys.  OR  Coorong: Loss of any of the common estuarine and marine-estuarine opportunist species for 5 consecutive years which include targeted surveys.  See Table 6-2 for the relevant species list.
Justification	The LAC is set for the freshwater and saline areas, along with a combined overall species richness that will account for variability between the sub-units of the Ramsar site. The timeframes for LAC are related to the life-history of common species (e.g. short-lived freshwater species) and consider the dynamic nature of the Estuary.
Confidence rating	High

Table 6-2 List of species to be assessed as part of the fish diversity (species richness) 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)	Pseudaphritis 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	
Sandy sprat	Hyperlophus vittatus	
Small-mouthed 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	

Attribute measured	Number of fish families (biodisparity)
Baseline	2015 baseline set using number of families sampled in greater than 80% of years from 2006–15 using current monitoring techniques.
LAC	<b>Direct LAC:</b> Less than 13 of the 17 fish families (in targeted surveys) recorded in any 3 consecutive years  See Table 6-3 for the relevant families list
Justification	The LAC is based on a 20% decline in number of families present at the site, excluding those families that are alien or marine stragglers. Family richness is measured as a cumulative total over 3 years to allow for inter-annual variation
Confidence rating	High

Table 6-3 List of families to be assessed as part of the fish diversity (biodisparity) LAC.

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

#### Movement and recruitment

While fish movement and recruitment can be highly variable within the Ramsar site, the drivers of these critical processes include surface water regime, salinity and for some species the presence of suitable habitat (e.g. submergent vegetation, salt wedge conditions). Most studies of fish populations at the Ramsar site, however, have focused on the response of species richness, abundance and community structure in each sub-unit in response to environmental drivers (drought, floods). The assessment of the extent of fish recruitment has focused more on diadromous species such as congolli and common galaxias, threatened species such as the southern pygmy perch (e.g. Bice et al. 2013; Bice et al. 2018) and key estuarine (e.g. black bream, small-mouthed hardyhead) and marine-estuarine opportunist species (e.g. greenback flounder) (Ye et al. 2012; Ye et al. 2017).

Diadromous fish have been identified as the most suitable indicator for this LAC given the importance of hydrological connection and requirements for their population condition. Data is available for several other diadromous fish species (lamprey, golden perch and black bream) that occur in the Ramsar site, but this LAC uses congolli and common galaxias as the focus species due to the increased data availability (e.g. fishway monitoring for these species have been conducted in every year from 2006–07 with the exception of 2012–13) and expert opinion on the general overlap in indication of movement and presence of available habitat conditions (i.e. freshwater-estuarine-marine habitats).

Attribute measured	Young of year for congollis ( <i>Pseudophritis urvillii</i> ) and common galaxias ( <i>Galaxias maculatus</i> )
Baseline	2015 baseline set on ecological and reproductive requirements of common galaxias and congolli and data collected during 2006–15.
LAC	Direct LAC: Young of year for congolli not recorded in the site for more than 5 consecutive years (in targeted surveys).  OR  Young of year for common galaxias not recorded in the site for more than 3 consecutive years (in targeted surveys).
Justification	Estimates of the lifespan of these species have been used to set the LAC. Female congolli are assumed to take 4 to 6 years to mature (Hortle 1978). Common galaxias generally live for 1-2 years (Lintermans 2007).
Confidence rating	High

## Threatened species

Murray hardyhead are a nationally threatened freshwater fish, which depend on specific littoral vegetation and wetland habitats in the Lakes within the Ramsar site (Bice et al. 2018). This species has been recorded within the Ramsar site on a regular basis prior to the Millennium Drought (Bice et al. 2013; Wedderburn and Barnes 2014). Targeted monitoring of these species has been undertaken throughout and beyond the Millennium Drought (Wedderburn and Barnes 2014). This data has been used in addition to expert opinion in developing the LAC for these species.

Attribute measured	Presence/absence of Murray hardyhead ( <i>Craterocephalus fluviatilis</i> ) in targeted surveys
Baseline	2015 baseline set on ecological and reproductive requirements of Murray hardyhead and expert opinion.
LAC	<b>Direct LAC:</b> Absence of Murray hardyhead in any 3 out of 5 targeted surveys within a 3-year period.
Justification	The LAC for Murray hardyhead is based on expert opinion that the site continues to support Murray hardyhead. Within a 3-year period, this includes a minimum of 2 seasonal targeted surveys per year. Murray hardyhead lives for one year only, so annual recruitment is essential to achieve a self-sustaining population (Wedderburn et al. 2017).
Confidence rating	High

#### 6.3.5 Waterbirds

## Diversity (species richness)

The LACs were set using the 10<sup>th</sup> percentile abundance of selected waterbird species during annual censuses recorded over the site from 2009-15 (DEW 2021).

Species lists are described in O'Connor (2015b) and further refined by Robinson (2017). Species specific differences mean that there is a need for minimum abundance values for each species within each of the diversity LAC (split by sub region), below which the species is considered functionally absent.

The triggers are set at the lower 80% confidence limit of compliant species (i.e. those with abundances at or above their  $10^{th}$  percentile), which has a probability of being exceeded of 0.1. Selected species that have a  $10^{th}$  percentile abundance of 0 were not included in this assessment as they are not expected to be present on an annual basis. The LAC was set to be exceeded if the trigger was exceeded for 2 consecutive years. The probability of an event that exceeds the LAC is 0.01 (0.1×0.1).

A temporal aspect is included as it is possible that conditions elsewhere may be substantially better for 1 or 2 years when compared with the Ramsar site, so the expected waterbird numbers may not be present. A sustained decline in diversity is also expected to be reflected in other critical CPS, such as surface water regimes, salinity, Coorong food webs and provision of habitat.

## **Lakes Alexandrina and Albert**

Data used in the Lakes Alexandrina and Albert includes data for the Goolwa Channel.

Attribute measured	Abundances of selected waterbird species
Baseline	2015 baseline set using median abundances of selected waterbird species using January census data from 2009–15 (University of Adelaide, D Paton). The medians and 10 <sup>th</sup> percentiles for the abundance of the 20 selected waterbird species during annual censuses over Lakes Alexandrina and Albert from 2009-15 are shown in Table 6-4.
LAC	<b>Direct LAC:</b> Less than 17 of 20 selected waterbird species have counts above their 10 <sup>th</sup> percentile abundance for 2 consecutive years.
Justification	Selected species identified by O'Connor (2015) and DEW (2021). The LAC is based on an abundance compliance approach, where each species has the same likelihood of achieving its 10 <sup>th</sup> percentile abundance. All of the selected waterbird species for the Ramsar site had a 10 <sup>th</sup> percentile abundance greater than 0 and therefore all 20 selected species were used to calculate the lower 80% confidence limit for the number of compliant species in a given year. The lower 80% confidence limit of the expected number of selected species to be above their 10 <sup>th</sup> percentile abundance in a given census was 16.28 (DEW 2021). Therefore, the trigger was set at less than 17 selected waterbird species have counts above their 10 <sup>th</sup> percentile abundance during the annual census. The LAC was set to be exceeded if the trigger was exceeded for 2 consecutive years. The probability of an event that exceeds the LAC is 0.01 (DEW 2021).
Confidence rating	Medium, due to the limited data (2009-15).

Table 6-4 The 10<sup>th</sup> percentile and median abundance of selected waterbird species counted over the Lakes from 2009-15 during annual summer waterbird census. Data source: University of Adelaide (Assoc. Prof. David Paton).

Species	10 <sup>th</sup> percentile (2009-15)	Median (2009-15)
Australasian shoveler (Kalpari)	7	17
Australian pelican (Ngori)	2,877	4,460
Australian shelduck (Pitjangoili, Purnar, Tarankinyi)	11,952	14,296
Australian white ibis	349	611
Black swan (Kungari)	1,159	1,799
Cape barren goose (Lawari)	939	1,303
<b>Eurasian coot</b>	167	3,165
Great cormorant	3,831	9,375
Great crested grebe	19	108
Greater crested tern	311	335
Grey teal	932	5,780

Species	10 <sup>th</sup> percentile (2009-15)	Median (2009-15)
Hardhead (Pungkari, Waranggaiperi)	2	44
Little black cormorant	290	907
Little pied cormorant (Teilakawari, Tereiwari)	67	96
Masked lapwing	394	553
Pacific black duck (Nakari, Pebulaipuri, Teintar)	1,485	4,408
Pied cormorant (Ngalgurindi)	1,198	3,955
Silver gull (Throkarri)	1,558	2,819
Straw-necked ibis (Tloperi)	206	532
Whiskered tern	2,154	3,744

# **Murray Estuary**

The Murray Estuary is between the Goolwa Barrage and Pelican Point.

Attribute measured	Abundances of selected waterbird species
Baseline	2015 baseline set using median abundances of selected waterbird species using January census data from 2000–15 (University of Adelaide, D Paton). The medians and 10 <sup>th</sup> percentiles for the abundance of 24 selected waterbird species during annual censuses over the Murray Estuary from 2009-15 are shown in Table 6-5.
LAC	<b>Direct LAC:</b> Less than 18 of 21 selected waterbird species have counts above their 10 <sup>th</sup> percentile abundance for 2 consecutive years.
Justification	Selected species identified by O'Connor (2015) and DEW (2021). The LAC is based on an abundance compliance approach, where each species has the same likelihood of achieving its 10 <sup>th</sup> percentile abundance. Black-tailed godwit, red-necked avocet and sanderling had 10 <sup>th</sup> percentile abundances of 0 in the Murray estuary and were not included in the 21 selected species used to calculate the lower 80% confidence limit for the number of compliant species in a given year. The lower 80% confidence limit of the expected number of selected species to be above their 10 <sup>th</sup> percentile abundance in a given census was 17.14 (DEW 2021). Therefore, the trigger was set at less than 18 selected waterbird species have counts above their 10 <sup>th</sup> percentile abundance during the annual census. The LAC was set to be exceeded if the trigger was exceeded for 2 consecutive years. The probability of an event that exceeds the LAC is 0.01 (DEW 2021).
Confidence rating	High

Table 6-5 The 10<sup>th</sup> percentile and median abundance of selected waterbird species counted over the Murray Estuary from 2000–2015 during annual summer waterbird censuses. Data source: University of Adelaide (Assoc. Prof. David Paton). \*Species with 10<sup>th</sup> percentiles of 0 were omitted from compliance calculations.

Species	10 <sup>th</sup> percentile (2000-15)	Median (2000-15)
Australian pelican (Ngori)	236	577
Black-tailed godwit*	0	21
Black-winged stilt (Nyilkanyi)	52	157
Black swan (Kungari)	215	820
Caspian tern (Tenatjeri)	48	209
Common greenshank (Terilteril)	113	194
Curlew sandpiper	24	877
Eastern curlew	2	12
Greater crested tern	183	330
Grey teal	528	1,682
Hoary-headed grebe	1	30
Little black cormorant	19	116
Little pied cormorant (Teilakawari, Tereiwari)	19	138
Masked lapwing	53	97
Pacific black duck (Nakari, Pebulaipuri, Teintar)	34	173
Pacific golden plover	3	18
Pied oystercatcher (Prukal)	34	52
Red-capped plover	12	94
Red-necked avocet (Nitinyi)*	0	206
Red-necked stint	719	4,234
Sanderling*	0	1
Sharp-tailed sandpiper	740	4,289
Silver gull (Throkarri)	985	1,612
Whiskered tern	338	865

# **Coorong North Lagoon**

The Coorong North Lagoon sub-unit is defined as the northern lagoon area from Pelican Point to near Parnka Point.

Attribute measured	Abundances of selected waterbird species
Baseline	2015 baseline set using median abundances of selected waterbird species using January census data from 2000–15 (University of Adelaide, D Paton). The medians and 10 <sup>th</sup> percentiles for the abundance of 24 selected waterbird species during annual censuses over the Murray Estuary from 2009-15 are shown in Table 6-6.
LAC	<b>Direct LAC:</b> Less than 19 of 23 selected waterbird species have counts below their 10 <sup>th</sup> percentile abundance for 2 consecutive years.
Justification	Selected species identified by O'Connor (2015) and DEW (2021). The LAC is based on an abundance compliance approach, where each species has the same likelihood of achieving its 10 <sup>th</sup> percentile abundance. Pacific golden plover had a 10 <sup>th</sup> percentile abundance of 0 in the Coorong North Lagoon and were not included in the 23 selected species used to calculate the lower 80% confidence limit for the number of compliant species in a given year. The lower 80% confidence limit of the expected number of selected species to be above their 10 <sup>th</sup> percentile abundance in a given census was 18.85 (DEW 2021). Therefore, the trigger was set at less than 19 selected waterbird species have counts above their 10 <sup>th</sup> percentile abundance during the annual census. The LAC was set to be exceeded if the trigger was exceeded for 2 consecutive years. The probability of an event that exceeds the LAC is 0.01 (DEW 2021).
Confidence rating	High

Table 6-6 The 10<sup>th</sup> percentile and median and abundance of selected waterbird species in the Coorong North Lagoon. Data source: University of Adelaide (Assoc. Prof. David Paton). \*Species with 10<sup>th</sup> percentiles of 0 were omitted from compliance calculations.

Species	10 <sup>th</sup> percentile (2000-15)	Median (2000-15)
Australian pelican (Ngori)	916	1,413
Australian shelduck (Pitjangoili, Purnar, Tarankinyi)	905	4,342
Black swan (Kungari)	171	483
Black-winged stilt	37	122
Cape Barren goose (Lawari)	3	26
Caspian tern (Tenatjeri)	109	295
Common greenshank (Terilteril)	83	186
Curlew sandpiper	178	752
Great cormorant	92	544
Greater crested tern	139	303
Grey teal	1,448	6,499

Species	10 <sup>th</sup> percentile (2000-15)	Median (2000-15)
Hoary-headed grebe	266	1,410
Little black cormorant	169	861
Little pied cormorant (Teilakawari, Tereiwari)	21	116
Masked lapwing	141	213
Pacific golden plover*	0	7
Pied cormorant (Ngalgurindi)	84	211
Pied oystercatcher (Prukal)	23	53
Red-capped plover	185	458
Red-necked avocet (Nitinyi)	77	646
Red-necked stint	7,009	12,448
Sharp-tailed sandpiper	2,806	5,622
Silver gull (Throkarri)	2,204	3,179
Whiskered tern	1,236	3,439

# **Coorong South Lagoon**

The Coorong South Lagoon sub-unit is defined as the southern lagoon area south of Parnka Point to 42 Mile Crossing. Counts from Salt Creek are excluded as its brackish waters provide habitat for species that are not characteristic of the Coorong South Lagoon.

Attribute measured	Abundances of selected waterbird species
Baseline	2015 baseline set using median abundances of selected waterbird species using January census data from 2000–15 (University of Adelaide, D Paton). The medians and 10 <sup>th</sup> percentiles for the abundance of 23 selected waterbird species during annual censuses over the Murray Estuary from 2009-15 are shown in Table 6-7.
LAC	<b>Direct LAC:</b> Less than 18 of 21 selected waterbird species have counts above their 10 <sup>th</sup> percentile abundance for 2 consecutive years.
Justification	Selected species identified by O'Connor (2015) and DEW (2021). The LAC is based on an abundance compliance approach, where each species has the same likelihood of achieving its 10 <sup>th</sup> percentile abundance. Great crested grebe and little black cormorant had a 10 <sup>th</sup> percentile abundance of 0 in the Coorong South Lagoon and were not included in the 21 selected species used to calculate the lower 80% confidence limit for the number of compliant species in a given year. The lower 80% confidence limit of the expected number of selected species to be above their 10 <sup>th</sup> percentile abundance in a given census was 17.14 (DEW 2021). Therefore, the trigger was set at less than 18 selected waterbird species have counts above their 10 <sup>th</sup> percentile abundance during the annual census. The LAC was set to be exceeded if the trigger was exceeded for 2 consecutive years. The probability of an event that exceeds the LAC is 0.01 (DEW 2021).
Confidence rating	High

Table 6-7 The 10<sup>th</sup> percentile and median and abundance of selected waterbird species in the Coorong South Lagoon. Data source: University of Adelaide (Assoc. Prof. David Paton). \*Species with 10<sup>th</sup> percentiles of 0 were omitted from compliance calculations.

Species	10 <sup>th</sup> percentile (2000-15)	Median (2000-15)
Australian fairy tern (Talamarari)	6	128
Australian pelican (Ngori)	354	1,600
Australian shelduck (Pitjangoili, Purnar, Tarankinyi)	1,473	3,205
Banded stilt	848	8,179
Black swan (Kungari)	7	148
Caspian tern (Tenatjeri)	7	62
Chestnut teal (Ngarraki)	334	2,757
Common greenshank (Terilteril)	13	39
Curlew sandpiper	7	44
Great crested grebe*	0	13
Greater crested tern	1,409	2,989
Grey teal	941	4,267
Hoary headed grebe	63	2,263
Little black cormorant*	0	26
Masked lapwing	115	177
Pied oystercatcher (Prukal)	17	48
Red-capped plover	198	529
Red-necked avocet (Nitinyi)	69	945
Red-necked stint	2,089	6,781
Sharp-tailed sandpiper	301	2,304
Silver gull (Throkarri)	1,193	1,960
Whiskered tern	118	1,058
White-faced heron	10	23

#### **Abundance**

# **Total abundance across Ramsar site**

Attribute measured	Abundance across Ramsar site
Baseline	2015 baseline set using median annual abundance present in the January census data for the Lakes and Coorong from 2009–15 (University of Adelaide, D Paton).
LAC	<b>Direct LAC:</b> Annual waterbird counts in the January census are less than 190,122 for 2 consecutive years.
Justification	The median total abundance of waterbirds recorded over the Ramsar site (Lakes and Coorong) from 2009–15 was 282,212 (University of Adelaide, D Paton). The 10 <sup>th</sup> percentile abundance of waterbirds recorded over the Ramsar site was 190,122 individuals from 2009–2015, and therefore, the trigger was set at fewer than 190,122 waterbirds counted over the Ramsar site in the annual census over 2 consecutive years (DEW 2021). Robinson (2017) showed that abundances are independent between years, seldom decreasing for more than 2 years in succession (Robinson 2017). A temporal aspect is included as it is possible that conditions elsewhere may be substantially better for 1 or 2 years when compared with the Ramsar site, so the expected waterbird numbers may not be present.
Confidence rating	High

# **Priority migratory shorebird species**

Only the Coorong (including the Murray Estuary) data set was used for the priority migratory shorebird species as comparatively few species use the Lakes.

Attribute measured	Presence/absence of priority migratory shorebird species
Baseline	2015 baseline set using January census data from 2000–15 (University of Adelaide, D Paton).
LAC	<b>Direct LAC:</b> Counts for any 4 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 10 <sup>th</sup> percentile abundance (2000– 2015) 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	The LAC is based on the 7 commonly encountered shorebird species that are listed as part of migratory agreements (JAMBA, ROKAMBA, CAMBA and CMS) and identified as priority species by O'Connor (2015a). The triggers were set for each priority species at their 10 <sup>th</sup> percentile abundance from 2000-15. The LAC was set to be exceeded if the trigger was exceeded for 2 consecutive years. The

	probability of an event that exceeds the LAC is 0.01 (DEW 2021). However if a priority species had a 10 <sup>th</sup> percentile abundance of 0, then the trigger was based upon the number of consecutive annual censuses in the Coorong that the species was not detected. Note that an exceedance of this LAC may not represent a local impact on abundances but may reflect off-site factors.
Confidence rating	High

# Migratory shorebird abundance

The Coorong (including the Murray Estuary) data set was used for the East Asian Australasian (EAA) flyway species.

Attribute measured	Percent of 1% East Asia species	n Australasian fl	yway populatio	on for selected
Baseline	2015 baseline set using the median percentage of the total flyway populations of curlew sandpipers, red-necked stints and sharp-tailed sandpipers present in the Coorong during annual January census data from 2000–15 (University of Adelaide, D Paton).			
LAC	<b>Direct LAC:</b> The 10 <sup>th</sup> per any 2 of curlew sandpip in the Coorong annual cyears.	er, red-necked stir	s or sharp-taile	ed sandpipers present
	Species	10 <sup>th</sup> percentile (2000–2015)	Median (2000–2015)	EAA Flyway population
	Curlew sandpiper	504	2,250	90,000
	Red-necked stint	15,675	26,267	475,000
	Sharp-tailed sandpiper	4,819	13,175	85,000
Justification	Selected East Asian Aust (2015) with counts in the flyway population. Curley sandpipers are the prom flyway populations were of each flyway species are to derive the flyway populations were of each flyway species are to derive the flyway populations and sharp-tailed saccensuses from 2000-15 wiff the trigger was exceed that exceeds the LAC is 0 may not represent a local	Ramsar site that w sandpipers, red inent migratory specification by Hand the total flyway ulation present in lyway populations andpipers present vas used as the treed for 2 consecut 0.01 (DEW 2021).	regularly exceed -necked stints a pecies at the situsen et al. (2016) population of a the Coorong. To a for curlew sand in the Coorong igger. The LAC wive years. The poor that an exception is the coorong is given that an exception is the coorong	d 1% of their total EAA and sharp-tailed e. The most recent ). Annual census counts each species were used he 10 <sup>th</sup> percentile lpipers, red-necked g during annual was set to be exceeded robability of an event
Confidence rating	Medium			

#### Non-migratory waterbird species abundance

The Coorong (including the Murray Estuary) data set was used for Australian resident species.

Attribute measured	Percent of 1% Australian pop	oulation for selec	ted species	
Baseline	2015 baseline set using mediar pied oystercatcher, chestnut te present in the Coorong during (University of Adelaide, D Pato	eal, Australian fairy the annual Janua	y tern and red-	capped plover
LAC	<b>Direct LAC:</b> The 10 <sup>th</sup> percentile Australian pied oystercatcher, plover present in the Coorong consecutive years.	chestnut teal, Aus annual censuses	tralian fairy ter from 2000-15 a	and red-capped a e not met for 2
	Species	10 <sup>th</sup> percentile (2000–2015)	Median (2000–2015)	Australian population
	Australian pied oystercatcher	114	158	11,000
	Chestnut teal	4,330	7,220	100,000
	Australian fairy tern	226	336	1,500
	Red-capped plover	456	1,235	95,000
Justification	Selected non-migratory species population present at the site apopulations were estimated by counts of each species and the derive the population present populations of Australian pied and red-capped plover present 2000-15 was used as the trigger was exceeded for 2 consecutive the LAC is 0.01 (DEW 2021). No represent a local impact on ab	es identified by O'  Wetlands Internate total population in the Coorong. To oystercatcher, che t in the Coorong of the LAC was see years. The probote that an exceed	Connor (2015). ational (2013). A of each species he 10 <sup>th</sup> percent estnut teal, Ausduring annual cet to be exceed ability of an evolution of this LA	Annual census s were used to tile of the total stralian fairy tern censuses from led if the trigger ent that exceeds AC may not
Confidence rating	Medium			

#### **Breeding**

The Ramsar site supports breeding of up to 27 waterbird species. The number of species recorded breeding in any single year is highly variable and is not well documented (O'Connor 2015a). Many of the records are for single breeding events only or are historic records. O'Connor et al. (2013) noted that there are many gaps in the data, with location, timing and focal species of waterbird breeding surveys being inconsistently recorded since they began in 1911. Multiple year records are only available for 13 species, with species assigned as regularly breeding at the site based on expert opinion (O'Connor et al. 2012), or as annual breeding species where annual records exist. These 13 species have been used as the baseline for this LAC.

Attribute measured	Number of breeding events of annual and regular breeding species	
Baseline	2015 baseline set using species which have annual or regular breeding records as defined by O'Connor (2015a).	
LAC	Annual breeding species	
	<b>Direct LAC:</b> Annual breeding species: No successful breeding events in any 3 consecutive years for the following species and attributable to on-site changes, assessed for each species. Shorebird species are <u>underlined</u> in the list below:	
	Australian pelican (Pelecanus conspicillatus)	
	Black swan ( <i>Cygnus atratus</i> )	
	Caspian tern ( <i>Hydroprogne caspia</i> )	
	Crested tern ( <i>Thalasseus bergii</i> )	
	Australian fairy tern (Sternula nereis nereis)	
	Hooded plover (Thinornis rubricollis)	
	Australian white ibis ( <i>Threskiornis molucca</i> )	
	<u>Australian pied oystercatcher</u> (Haematopus longirostris)	
	Red-capped plover (Thinornis rubricollis)	
	Straw-necked ibis (Threskiornis spinicollis)	
	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 ( <i>Phalacrocorax varius</i> )	
	Royal spoonbill ( <i>Platalea regia</i> )	
	Silver gull (Chroicephalus novaehollandiae)	
Justification	The confidence rating for annual and regular breeding species is given as low, as it requires additional breeding surveys to confirm the regularity of species breeding at the site and there is a lack of baseline and current data. A successful breeding event should be defined by a measure of fledgling success, however this measure is currently a knowledge gap. An interim measure of successful breeding event is one in which greater than 5% of recorded nests fledge some young. This interim value is very low and should be refined to reflect the lower ranges of expected breeding success for individual species as more information becomes available (O'Connor 2015a).	
Confidence rating	Low	
	-	

#### Threatened species

# Australasian bittern (Talkuri)

The Australasian bittern has recently been recorded from 7 locations by O'Connor et al. (2013): Finniss River, 'Jacobs', Clayton Bay, Loveday Bay, Pomanda Point, Narrung Narrows and Tolderol. It is expected that the species moves around and utilises suitable habitat within the Ramsar site (i.e. preference of relatively homogenous and dense reed habitats) and is likely to be present at locations beyond those surveyed as reported by O'Connor et al. (2013) and O'Connor (2015b). Numbers are low, with typically only 1–2 birds being observed at sites (sightings and calls).

Attribute measured	Absence in targeted surveys
Baseline	Data on Australasian bittern ( <i>Botaurus poiciloptilus</i> ) are not suitable to provide quantitative measures of abundance on which to set a baseline other than presence/absence. Survey data (including sites and sampling methods) from 2012–14 (O'Connor 2015b).
LAC	<b>Direct LAC:</b> 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 2015b). The species has been recorded at several sites around the Lakes and it is likely that the LAC would be met in future.
Confidence rating	High

#### Australian fairy tern

The Coorong (including Murray Estuary) data set is used for the Australian fairy tern as abundance and distribution can vary depending on the ambient conditions.

Attribute measured	Abundance
Baseline	2015 baseline set using median abundances of Australian fairy tern ( <i>Sternula nereis nereis</i> ) using January census data from 2000–15 (University of Adelaide, D Paton).
LAC	<b>Direct LAC:</b> Abundance of Australian fairy tern less than 226 in the January census for 2 consecutive years.
Justification	Annual counts and the total flyway population were used to derive the median and the 10 <sup>th</sup> percentile abundance of the population of fairy tern present in the Coorong. 10 <sup>th</sup> percentile values have a probability of 0.1 of not being met on an annual basis. The LAC was set to be exceeded if this trigger was exceeded for 2 consecutive years, an event with a probability of 0.01 (DEW 2021).
Confidence rating	High

# **Curlew sandpiper**

Only the Coorong (including Murray Estuary) data set was used for curlew sandpiper as few curlew sandpiper use the Lakes.

Attribute measured	Abundance
Baseline	2015 baseline set using median abundances of curlew sandpiper ( <i>Calidris ferruginea</i> ) using January census data from 2000–15 (University of Adelaide, D Paton).
LAC	<b>Direct LAC:</b> Abundance of curlew sandpiper less than 508 in the January census for 2 consecutive years.
Justification	Curlew sandpiper has a median abundance of greater than or equal to 1 from the annual censuses from 2000-15. The most recent flyway populations were estimated by Hansen et al. (2016). Annual counts and the total flyway population were used to derive the median and the 10 <sup>th</sup> percentile abundance of the population of curlew sandpipers present in the Coorong. Tenth percentile values have a probability of 0.1 of not being met on an annual basis. The LAC was set to be exceeded if this trigger was exceeded for 2 consecutive years, an event with a probability of 0.01 (DEW 2021). Note that an exceedance of this LAC may not represent a local impact on abundances but may reflect off-site factors.
Confidence rating	Medium

# **Eastern curlew**

Only the Coorong (including the Murray Estuary) data set was used for the eastern curlew.

Attribute measured	Abundance
Baseline	2015 baseline set using median abundances of eastern curlew ( <i>Numenius madagascariensis</i> ) using January census data from 2000–15 (University of Adelaide, D Paton).
LAC	<b>Direct LAC:</b> Abundance of eastern curlew less than 2 in the January census for 2 consecutive years.
Justification	Eastern curlew has a median abundance of greater than or equal to 1 from the annual censuses from 2000-15. The most recent flyway populations were estimated by Hansen et al. (2016). Annual counts and the total flyway population were used to derive the median and the 10 <sup>th</sup> percentile abundance of the population of Eastern curlew present in the Coorong. Tenth percentile values have a probability of 0.1 of not being met on an annual basis. The LAC was set to be exceeded if this trigger was exceeded for 2 consecutive years, an event with a probability of 0.01 (DEW 2021). Note that an exceedance of this LAC may not represent a local impact on abundances but may reflect off-site factors.
Confidence rating	Medium

#### **Hooded plover (Ngamat)**

Data collected by the Australian Wader Study Group over 16 seasons (1981, 1982, 1987, 2000–08, 2010–12) provides a mean count of 10±7. This data set is not representative of the total numbers which may be supported by the site, as it does not include beach assessments.

Attribute measured	Absence in targeted surveys
Baseline	Data on Hooded Plover ( <i>Thinornis rubricollis</i> ) are not suitable to provide quantitative measures of abundance on which to set a baseline other than presence/absence.
LAC	<b>Direct LAC:</b> Absence of hooded plover in any 3 out of 5 targeted surveys assessed over a rolling 10 year period.
Justification	As the abundance numbers are low for this species, the absence of the species is set as the basis for this LAC. Based on expert opinion.
Confidence rating	High

#### Mount Lofty Ranges southern emu-wren (Wirili Pulyeri)

The estimated maximum total southern emu-wren population between 1993 and 2013 was estimated to be 85 to 170 mature individuals (Pickett 2013). As the numbers are low for this species, the absence of the species is set as the basis for this LAC.

Attribute measured	Absence in targeted surveys
Baseline	Data on the Mount Lofty Ranges southern emu-wren ( <i>Stipiturus malachurus intermedius</i> ) is not suitable to provide quantitative measures of abundance on which to set a baseline other than presence/absence.
LAC	<b>Direct LAC:</b> Absence of Mount Lofty Ranges southern emu-wren from all known core population locations in any 1 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, with the LAC based on expert opinion.
Confidence rating	Medium

#### 6.3.6 Wetland habitat

Habitat mapping across the entire site was undertaken in 2003 (Seaman 2003) and defines the baseline from which changes in ecological character of the site are to be assessed. Habitat assessments during and after the Millennium Drought (Thiessen 2010, Billows 2014, Dickson et al. 2015) illustrated that the extent of wetland habitat at the site is highly dependent on River Murray inflows to the site and that it is not practical to identify a specific LAC for wetland extent. Wetland extent is therefore considered as part of habitat condition LAC.

The habitat condition LAC has been developed based on Seaman (2003), where habitat condition was assessed using a qualitative measure that rated wetland habitat from completely degraded to degraded, good, very good and excellent. Degradation of wetland type according to the habitat condition represents major and long-term alterations in ecosystem function, ecological processes and

ecological character. In contrast, intervention management (e.g. the construction of regulators that control water flows and destocking) has the potential to maintain or improve habitat condition.

As a result, habitat condition assessment considers certain ecological values, including hydraulic and habitat connectivity (and the interplay between); cover and abundance of native and introduced species; integrity of vegetation associations and the structure and health and vigour of the vegetation. Full descriptions of these categories are provided by Seaman (2003). The 2003 assessment and subsequent samplings provide a basis to determine change in ecological health of the physical habitat at the site.

Attribute measured	Condition
Baseline	2015 baseline uses best available data, namely Seaman (2003) which assessed habitat condition at 774 sites.
LAC	<b>Direct LAC</b> : Decline in condition at greater than 60% of the sites assessed over any 10 year period.
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, identified in Seaman (2003). The LAC is set at a point above the number of sites assessed as having declined in habitat condition in Lakes Alexandrina and Albert during the assessment undertaken in 2010 (Thiessen 2010) during the Millennium Drought.
Confidence rating	High

# 6.3.7 Threatened ecological communities and species

#### **Swamps of the Fleurieu Peninsula**

No detailed mapping of this community has occurred and so the approximate extent of 262 hectares developed by Phillips and Muller (2006) is the only available data. A LAC based on a decline in extent was considered, however insufficient baseline data was available relevant to 2015. Expert opinion assumes that a moderate change in extent, sustained over several years, would potentially represent a change in character.

Attribute measured	Extent or condition of threatened community
Baseline	<b>Direct LAC</b> : Insufficient data to develop a baseline and LAC. Last available data on extent is from 2006, with an estimate of 262 ha (Phillips and Muller 2006).
LAC	Insufficient data to develop a baseline and LAC.
Justification	Wetlands of this type are naturally variable in extent in response to surface water and groundwater input and local climatic conditions. Mapping of extent over time at 5 or more key swamps within the Ramsar site will be considered as opposed to total area.
Confidence rating	-

#### Subtropical and temperate coastal saltmarsh

Detailed mapping of the saltmarsh communities in the Murray Estuary and Coorong was completed in 2006.

Attribute measured	Extent of threatened community
Baseline	Murray Estuary and Coorong baseline is 480 ha (DEW 2018a).
LAC	<b>Direct LAC:</b> Reduction of greater than 10% in percentage cover over any 10 year period.
Justification	The extent of the community is for the Murray Estuary and Coorong sub-units only.
Confidence rating	Low

#### Southern bell frog

Population size for southern bell frog within the Ramsar site is variable and low in recent years (Mason 2014). The probability of detection of southern bell frog in the Ramsar site increases with increased cover of emergent and submergent vegetation (Wassens et al. 2008) and with increased water level in late spring and summer (Mason and Durbridge 2015; Mason and Turner 2018). As a result, the LAC for freshwater submergent and emergent vegetation (which in turn are assessed indirectly via Lake Alexandrina water level and salinity) are used to indirectly assess the presence of southern bell frog within the Ramsar site.

Attribute measured	Lake Alexandrina water level and salinity
Baseline	As per baseline for freshwater submergent and emergent vegetation and Lake Alexandrina salinity LAC.
LAC	<b>Indirect LAC:</b> No direct LAC has been developed and instead the southern bell frog will be assessed indirectly through the LAC for freshwater submergent and emergent vegetation and Lake Alexandrina salinity LAC.
Justification	No direct LAC has been developed for the southern bell frog, it will be assessed indirectly through the freshwater submergent and emergent vegetation and Lake Alexandrina salinity LAC based on habitat preferences and responses of southern bell frog in the Ramsar site.
Confidence rating	Low

#### 6.3.8 Coorong food web

Direct Coorong food web LAC were developed for *Ruppia tuberosa* by reviewing existing data and expert opinion (Paton et al. 2015). No direct LAC have been developed for small-mouthed hardyhead or benthic macroinvertebrates. These LAC will be assessed through the Coorong salinity LAC, as representative of suitable habitat conditions for these components of the Coorong food web.

#### Ruppia tuberosa - primary producer

For *R. tuberosa*, the quality and quantity of the services and resources that the plant provides is likely to be related to the distribution and abundance of the plant; as the level of cover diminishes, the level

of resources and services provided diminishes proportionately (Paton et al. 2015a). Sites with 5% cover are likely to provide less than 5% cover of the services that a vigorous population would have provided and the chances of sites with 5% cover recovering to a good condition (e.g. a modest 30% cover) over the following year is limited. This will particularly be the case if the propagule bank is low and the ecological conditions needed for recovery and successful reproduction (e.g. sufficient magnitude and timing of flows, water level and salinity) are difficult to provide (Paton et al. 2015a). The ability to recover through interventions (e.g. translocations) is limited because only small sections (up to a kilometre) can be treated at a time and, even when translocations are undertaken, they still require several years for *Ruppia* populations to reach modest levels of cover (Paton et al. 2015a).

The LAC for seed density has been set at less than 20% of sediment cores at two-thirds of sampling locations should have viable seeds, for 4 consecutive seasons. To maintain the critical service of the Coorong food web, absence of *R. tuberosa* in the Coorong South Lagoon should be avoided (Paton et al. 2015a).

Attribute measured	Cover of Ruppia tuberosa and percent viable seeds in sediment cores
Baseline	2015 baseline set on data collected 2009–15 (Paton et al. 2015a).
LAC	<b>Direct LAC:</b> Less than 5% cover of <i>R. tuberosa</i> recorded at greater than 50% of all winter monitored sites for 2 or more consecutive years.  AND <b>Direct LAC:</b> Viable seeds of <i>R. tuberosa</i> in less than 20% of sediment cores at two-thirds of sampling locations across the Coorong South Lagoon for 4 consecutive seasons.
Justification	LAC assessed by the methods described in Rogers and Paton (2009). The LAC for <i>R. tuberosa</i> is a double LAC and requires 2 LAC to be exceeded to indicate a potential change in character. The first part is a LAC for <i>R. tuberosa</i> cover and the second LAC relates to retaining a viable seed bank. Both of these were developed by expert opinion and data analysis.
Confidence rating	High

# Benthic macroinvertebrates – primary consumers

Benthic macroinvertebrates are affected by environmental conditions, with the macroinvertebrate community in the Coorong driven by salinity (Dittmann et al. 2015). Major disturbances such as extended periods of drought and rapid changes in salinity regime can impact Coorong macroinvertebrate communities. The surface water salinity LAC for the Murray Estuary, Coorong North Lagoon and Coorong South Lagoon is used to indirectly assess the Coorong macroinvertebrate assemblage.

Attribute measured	Salinity as ppt in the Murray Estuary, Coorong North and Coorong South lagoons
Baseline	2015 baseline set using modelled daily salinity data from 1963 to 2012 at 11 sites from the Murray Mouth to the Coorong South Lagoon (data supplied by I. Webster, CSIRO).
LAC	<b>Indirect LAC:</b> No direct LAC has been developed and instead the critical service will be assessed indirectly through the LAC for salinity for the Murray Estuary and the Coorong North and Coorong South lagoons.

Justification	Salinity plays a significant role in determining macroinvertebrate abundance and composition across the Coorong (Deegan et al. 2010; Brookes et al. 2009a; Dittmann et al. 2015). The salinity LAC for the North Lagoon exceeds the tolerance of all polychaete species in the Coorong (with the exception of <i>Capitella capitata</i> that can occur in low densities in salinities up to 90 ppt (104,149 EC)). The salinity LAC for the South Lagoon is set at >100 ppt (112,471 EDC), which was recorded at the height of the Millennium Drought (2007-2010) and was associated with the extirpation of salt-tolerant chironomids ( <i>Tanytarsus barbitarsis</i> ) (Paton and Bailey 2012). Therefore, the LAC for this aspect of the food web is salinity as measured across the Murray Estuary and the Coorong North and Coorong South lagoons.
Confidence rating	Medium

# Small-mouthed hardyhead – secondary consumer

Small-mouthed hardyhead is the most abundant fish species in the Coorong South Lagoon where it plays a significant role in the Coorong food web. It tolerates a wide salinity range, but peak abundances are recorded in salinities between 60 to 100 ppt (76,736 to 112,471 EC) (Ye et al. 2011). As a solely estuarine species, small-mouthed hardyhead are highly responsive to freshwater flows to the Coorong, showing rapid increases in abundance, recruitment and distribution following high flows and reduced salinity (Ye et al. 2017). As a result, no direct LAC for small-mouthed hardyhead has been set and will be assessed through Coorong Salinity LAC.

Attribute measured	Salinity in the Coorong South Lagoon	
Baseline	2015 baseline set using modelled daily salinity data from 1963 to 2012 for the Coorong South Lagoon (data supplied by I. Webster, CSIRO).	
LAC	<b>Indirect LAC:</b> No direct LAC has been developed, instead the critical service will be assessed indirectly through the salinity LAC for the Coorong South Lagoon.	
Justification	The LAC for this species is based on salinity tolerances, 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 the species distribution in the Coorong. Such salinities were recorded in the South Lagoon during the height of the Millennium Drought (2007-2010) and were associated with the extirpation of small-mouthed hardyhead (Paton and Bailey 2012).	
Confidence rating	Medium	

# 7 Threats to ecological character

#### 7.1 Identification of threats

The major threats identified for the Ramsar site are as follows:

- Water diversions upstream leading to reduced inflows and altered hydrological regimes
- 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, nutrients and exposure of acid sulfate soils
- Invasive species and problematic natives
- Recreational activities.

A detailed risk assessment is beyond the scope of this ECD, however an indication of the impacts of threats to ecological character, likelihood and timing of threats has been summarised in accordance with the DEWHA (2008) framework at Table 7-1 and further details regarding each threat is provided after the summary table.

# 7.2 Ngarrindjeri perspectives on threats

Because a healthy Yarluwar-Ruwe relies on the interconnectivity between land, waters, spirit and all living things (Ruwe/Ruwar), the potential threats to the health of ecological character outlined below can also be understood as a threat to the health and wellbeing of the Ngarrindjeri nation. Conversely, threats to the well-being of Ngarrindjeri – especially in terms of governance and the ability to speak as and care for country – can also be seen as threats to Yarluwar-Ruwe. These threats are not rhetorical or metaphorical, but rather are practical and material in nature and reflect the intrinsically interconnected benefits expressed by Ruwe-Ruwar.

# 7.3 Threats

Table 7-1 Summary of threats to The Coorong and Lakes Alexandrina and Albert Wetland Ramsar site.

Threat	Impact	Likelihood	Timing
Water diversions upstream leading to:	Altered hydrological regimes (timing, magnitude and frequency of flows)	Certain	Immediate
• reduced inflows	Decreases in water levels and increased salinity in the Lakes and Coorong		
<ul> <li>altered hydrological regimes (timing,</li> </ul>	Changes to habitat availability from changes in wetland area and frequency of flooding		
magnitude and frequency of flows)	Limited ecological and hydrological connectivity between fresh (Lakes) and saline (Murray Estuary) components		
	Decreased water quality from increasing turbidity due to increased erosion of lake shorelines and acidity from exposure of acid sulfate soils		
	Impacts on flora and fauna breeding events and vegetation distribution		

# PUBLIC

Threat	Impact	Likelihood	Timing
Climate change leading to:	Altered hydrological regimes (timing, magnitude and frequency of flows)	High	Immediate to long- term
<ul> <li>changed rainfall, increased temperatures and evaporation</li> <li>sea level rise</li> </ul>	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		
• more frequent and severe storms	Increased probability of Murray Mouth closure due to increased sedimentation from marine sources from more frequent storms		
	Increased erosion and habitat destruction leading to reduced waterbird nesting		
Water quality changes through:	Loss of key species, habitats and ecosystem processes	High	Immediate
- in averaged colinity	Food web changes		
<ul><li>increased salinity</li><li>increased turbidity</li></ul>	Loss of flora and fauna through the toxic effects of decreased pH and release of heavy metals		
<ul><li>nutrients</li><li>exposure of acid sulfate soils</li></ul>	Reduced recruitment through sub-lethal impacts on survival of critical life history stages (i.e. fish eggs)		
	Behavioural changes, decreased growth and increased disease		
Invasive species and	Predation on native species	Certain	Immediate
problematic natives	Displacement of native species		to medium
	Increased vegetation grazing pressure		term
	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		
Recreational activities	Disturbance of nesting sites and compaction of sediments by 4WD activity on beaches	Certain	Immediate to
	Reduced abundance of fish species targeted by recreational fishing		medium term
	Shoreline erosion from boating activity and wave wash		

#### 7.3.1 Water diversions upstream

#### Reduced inflows

The Coorong and Lakes Alexandrina and Albert Wetland is part of a managed system that relies almost exclusively on flows from the Murray–Darling Basin. Consumptive water use and regulation has reduced the average annual stream flow to the Ramsar site by approximately 61% to 4,700 gigalitres such that the river ceases to flow to the sea 40% of the time, compared to 1% of the time at a time before water resource development (CSIRO 2008).

If 4,700 gigalitres flowed over the barrages every year, the Coorong and Lakes Alexandrina and Albert wetland would likely be in good condition. However, average flows do not occur every year. Consecutive years of below-average flows are a cause for concern. The reduced flows alter the hydrological regimes (timing, magnitude and frequency of flows), result in decreased water levels and increased salinity in the Lakes and Coorong and changes in habitat availability through decreased wetland area and frequency of flooding.

Freshwater inflow from Lake Alexandrina into the Coorong is essential for food web function and resilience. It increases zooplankton abundance, which supports zooplanktivorous fishes and higher order predators. A freshwater plume is required to provide the riverine signatures that stimulate the upstream (return) migrations of those fish species with life history stages that take place in the marine environment (Ye 2016).

Since they were completed in the 1940s, the barrages have affected ecological connectivity, particularly fish migration between the Lakes and the waters of the Estuary and Coorong. From 2002, eleven fishways were constructed at Goolwa barrage (3 vertical slot fishways), Hunters Creek (vertical slot fishway), Mundoo barrage (dual vertical slot fishway), Boundary Creek barrage (vertical slot fishway), Ewe Island barrage (dual vertical slot fishway) and Tauwitchere barrage (rock ramp fishway, 2 vertical slot fishways and a trapezoidal fishway). These allow diadromous and catadromous fish to migrate between saline and freshwater environments to breed. Monitoring evidence shows that adult and juvenile diadromous and estuarine fish are using the fishways to migrate between the Coorong and the Lakes and into the Goolwa Channel (Jennings 2008; Zampatti BP 2012). The fishways allow obligate freshwater species that inadvertently get washed into the Murray Estuary to return to the freshwaters of the Lakes (Jennings 2008).

Fishway operation is dependent on sufficient downstream flow and lake levels to provide connectivity. Vertical slot fishways on the Goolwa barrage have the largest operating range and can pass flows to 0m AHD. The rock ramp and trapezoidal fishways at Tauwitchere barrage have the smallest operating range and become ineffective at lake levels around +0.5 to +0.6 metres AHD. The Salt Creek outlet at the southern end of the Coorong has also affected ecological connectivity, particularly for native fish that require passage between the hypermarine Coorong South Lagoon and the brackish drainage network in the south-east. Restoration works established fishways at the northern end of Morella Basin and the Salt Creek outlet to mitigate this issue.

Protracted disconnection of the Estuary and freshwater habitats by closure of the fishways due to reduced inflows is a significant threat to the site.

Many species require changes in flow to trigger breeding events and flows for dispersal of reproductive structures (seeds, propagules larvae, eggs, gametes and cells). Reduced flows reduce the hydrological and ecological connectivity between the Lakes and Murray Estuary and the frequency of no water passing over the barrages results in increased sand pumping to maintain an open Murray Mouth.

Freshwater flows down the Murray–Darling system are seen by the Ngarrindjeri as the life blood of the living body of the River Murray, Lower Lakes and Coorong. Sufficient water flows into the water dependent systems is crucial to bringing life to Yarluwar-Ruwe and the wellbeing of Ngarrindjeri. The Ngarrindjeri have observed the draining of wetlands along the rivers and in the south-east and the disconnection of the living body of the River Murray, Lower Lakes and Coorong. This has been carried out through the installation of locks, levee banks and barrages and water over-allocation from river and Lakes, which have collectively contributed to reduced flows. This prevents the mixing of salt and freshwater, crucial to connectivity, flow, reproduction and the sustenance of the life of the waterways, lands, birds, fish and people within Yarluwar-Ruwe (Ngarrindjeri Nation 2006).

Ngarrindjeri have observed firsthand the culturally damaging consequence of these interventions through Ngartji such as kungari (black swan) which is breeding less frequently and without seasonal predictability. Ngarrindjeri believe this change is due to the impacts of reduced water flows to support habitat and trigger breeding. Important Ngarrindjeri cultural and social activities associated with kungari are therefore impacted (Birckhead 2011).

Water regulation has led to profound changes to mullowi (mulloway) habitat, leading to a reduction in abundance and size of the fish. Reduced flows through the Murray Mouth also hinder or prevent mullowi and other key fish species from entering the Coorong for breeding during summer months. Barrages impede the movement of mullowi and other fish into the Lakes. Long-term alteration of water flows has led to habitat change within the Lakes and river for pondi (Murray cod) and a dramatic decline in the numbers of this culturally significant fish (Ngarrindjeri 2019).

### 7.3.2 Climate change

#### Rainfall and temperature

Climate science predicts that south-eastern Australia, which includes the southern Murray–Darling Basin, is likely to become drier and hotter in the future. Climate change may have significant implications for stream-flow in the Murray–Darling Basin, particularly at the end of the system.

In the near future (2030), in the Murray–Darling Basin, natural rainfall variability is projected to predominate over trends due to greenhouse gas emissions. Late in the century (2090) cool season (April to October) rainfall is projected to decline under both an intermediate (RCP4.5) and high (RCP8.5) emission scenario. In the warm season (November to March), there is little change predicted with increases and decreases of rainfall projected by different models. The magnitude of projected changes for late in the century (2090) span approximately -40 to +5% in winter and -15 to +25% in summer for a high emissions case (RCP8.5) (CSIRO 2016).

There is very high confidence in continued substantial increases in projected mean, maximum and minimum temperatures in line with the current understanding of the effect of further increases in greenhouse gas concentrations.

For the near future (2030), the annually averaged warming across all emission scenarios is projected to increase by around 0.6 to 1.3 ° Celsius compared to the climate of 1986 to 2005. By late in the century (2090), under a high emission scenario (RCP8.5) the projected range of warming is 2.7 to 4.5 ° Celsius. Under an intermediate scenario (RCP4.5) the projected warming is 1.3 to 2.4 ° Celsius. (CSIRO 2016).

Regional rainfall and temperature projections for the South Australian part of the Murray–Darling Basin are similar to the wider Murray–Darling Basin. Drier and hotter conditions in the local area will increase evaporation, leading to lower water levels and increased salinity, which can affect habitat availability and condition for plants and animals at the Ramsar site.

In the absence of changes to extractions, decreased rainfall and higher temperatures are expected to lead to decreased catchment run-off and decreased inflows into Lake Alexandrina. Flow at the barrages are expected to decrease, increasing the maximum number of days without flow to the Coorong. This, with increased evaporation rates, will lead to increased Coorong salinity (Ryan 2018). Although not an immediate threat, future planning for the area must consider a range of possible futures and a gradual or staged transition over the longer term.

#### Sea level rise

Current predictions based on the Intergovernmental Panel for Climate Change are for a sea level rise of at least 0.3 metres by 2050 and 1.0 metre by 2100 (DEH 2010). There has been conjecture that the Sir Richard and Younghusband peninsulas could be breached. However, modelling undertaken for the full range of sea level scenarios for +1.5 metres sea level rise to 2109 indicates that the dune barrier will not be breached (Coastal Studies 2009). Over the next 50 to 100 years, elevated Murray Estuary levels and more frequent extreme storm surge events (Ryan 2018) could temporarily swamp mudflats and fringing wetlands, in particular across the low-lying barrage islands, increasing salinity in the Lakes and impacting on nesting and feeding waterbirds and wetland biota.

Sea level rise is not seen as an immediate threat due to the geomorphology of the region, but may lead to a transition of the Lakes from a freshwater environment by the end of the 21<sup>st</sup> century. A gradual or staged transition is required over the longer time.

Kaldowinyeri stories provide information about the flooding of Ngarrindjeri lands and changes to rivers and coast lines in the distant past. Today, Ngarrindjeri recognise the impacts of global warming on their lands and waters and all living things. In recent years they have observed changes in the local environment that indicate climate change is a reality. Shifts in long-established cultural indicators such as changes in the breeding behaviour of birds and the fruiting and flowering patterns of certain Ngarrindjeri foods indicate that climate is changing. These changes are highly significant, because natural processes such as these are key cultural markers of seasonal activity.

Ngarrindjeri have witnessed coastal camping places and middens being washed away by rising sea levels. Losing such places is not only a loss of Ngarrindjeri cultural heritage, but it is also the loss of an irreplaceable record of Ngarrindjeri adaptation to past climatic conditions (Ngarrindjeri Nation 2006).

#### 7.3.3 Water quality

#### Salinity

Salinity has a strong influence on aquatic ecosystems with the salinity of a water body determining the organisms that can inhabit it. All aquatic organisms can tolerate a range of salinity but will not persist at salinities outside that range. Therefore salinity is a fundamental determinant of species composition and health.

The impacts of increased salinity were particularly noted around the Lakes during the later parts of the Millennium Drought (2007–2010) when the abundance of salinity tolerant Australian tubeworm (*F. enigmaticus*) in the Goolwa Channel increased (Dittmann 2009). Submerged macrophytes disappeared and fringing vegetation was disconnected from the Lakes when water levels fell below sea level and salinity increased (Nicol et al. 2016). Submerged macrophyte coverage in the Lakes increased once water levels returned to normal after the drought (2010 onwards) and fringing vegetation was reconnected (Nicol at al. 2016a). However, recovery was not universal across the Ramsar site. Increasing salinity led to increasing rates of flocculation of fine sediments and increased deposition of calciferous materials.

In the case of the Coorong, during low inflows, high salinities in the Coorong North and Coorong South lagoons can constrict habitat availability and affect food-web structure (Deegan et al. 2010). For example, diversity and abundances of macroinvertebrates and fishes are highest in the Murray Estuary region where salinities are marine (approximately 30–45 ppt), but decline when progressing into the Coorong North and Coorong South lagoons. Correspondingly, food chain length also decreased along this gradient (Giatas and Ye 2016).

Pollution of the river, Lakes and Coorong from increased salinity and siltation has led to a decline in a number of Ngarrindjeri Ngartjis such as pondi (Murray cod) and mullowi (mulloway), as well as yabbies and many mrayi (birds). Important plant species used for Ngarrindjeri cultural weaving have declined around the Lakes and changes in harvesting patterns and distribution patterns present challenges to contemporary Ngarrindjeri weavers. Siltation seriously impacts swan weeds, which are important spawning sites, nurseries and food for Ngarrindjeri Ngartji such as mami (fish) and mrayi (bird) species.

Many of the freshwater soaks along the Coorong and in the Lower Murray have become saline as a consequence of land degradation and decreased inflow. This is one of the many indicators Ngarrindjeri use to monitor the long-term degradation of Yarluwar-Ruwe. These soaks used to support the water requirements of both the aquatic and terrestrial animals of the Coorong as well as providing the Ngarrindjeri people with drinking water.

#### **Turbidity**

The growth of aquatic plants and algae and the ability of aquatic fauna to detect food items is greatly influenced by turbidity. Highly turbid conditions reduce light penetration which limits the growth of aquatic plants and the hunting success of sight feeding fish and birds. Increased nutrient levels from suspended solids favour algal growth over plant growth, further limiting light penetration and visibility.

Lake Alexandrina acts as both a sink for sediment bought in by the River Murray (Bourman and Barnett 1995) and a source of sediments (via lakeshore erosion and transfer of River Murray water) to the Southern Ocean, Murray Estuary and Coorong. Lake Albert acts primarily as a sediment sink for the Basin given its lack of through-flow and long water residence time (Bourman et al. 2018). Turbidity in the EMLR tributaries is generally low although erosion heads in the upper catchment can be significant episodic sources of sediments (Phillips and Muller 2006).

Turbidity is variable and changes according to the source of flow. For example, the water from the Darling River is more turbid while water from the River Murray is less turbid. (Geddes 1988). Wind induced mixing and wave action leads to the resuspension of settled particles in the exposed shallow Lakes, increasing their turbidity (EPA 2016). Erosion of lakeshores is the other major source of turbidity. The Poltalloch soil association of the Lakes comprises a heavy clay topsoil, underlain by white sand. This soil association is highly susceptible to erosion when water levels are below the clay horizon (Bourman et al. 2018), which is typically above +0.55 metres AHD around the lake margin. These clays erode more rapidly than the soils covering them, so as the clay erodes, it undermines the banks of the Lakes causing slumping and collapse of topsoil into the Lakes. Static lake levels, bare lake edges and uncontrolled grazing promote lakeshore erosion (Randall 2006).

Barrage flows are the major source of sediment (and thus organic carbon and nutrients) to the Coorong and Murray Estuary. Turbidity in the Coorong increases in response to increased barrage flows (EPA 2016) (Aldridge et al. 2018). Turbidity is high in the Coorong South Lagoon because of the high concentrations of organic material due to eutrophication (Brookes et al. 2018). Sediments may also be remaining suspended more in the water column because the density of macrophytes is low (Brookes et al. 2018).

#### **Nutrients**

The drought-breaking rains of spring 2010 flushed the Murray Mouth and Coorong North Lagoon, reducing salinities, eliminating stratification, and increasing the supply of phosphorus and nitrogen. This in turn stimulated an increase in the abundance, diversity and productivity of phytoplankton (Aldridge and Brookes 2011). Water column nutrients elevated during the Millennium Drought seem to be recovering to pre-drought levels (Brookes et al. 2018). The elevated levels may have contributed to the cause of excessive growth of phytoplankton and filamentous algae (Brookes et al. 2018).

Algae now dominate the primary productivity of the Coorong South Lagoon. When water levels recede, the algae form a dense mat that excludes foraging shorebirds and creates low-oxygen conditions in sediments and killing invertebrates (Brookes et al. 2018). The presence of algae increases the risk that the sediments become anoxic, exacerbating the nutrient problem and increasing the risk of build-up of sulfides which are toxic at high concentrations (Brookes et al. 2018).

Whilst water monitoring suggests nutrient levels in the water column are recovering to pre-drought levels, there is limited understanding of the role of sediments in providing additional sources of nutrients (Brookes et al. 2018). Knowledge regarding the combined effects of salinity, water level and nutrients on the interactions between *R. tuberosa* and filamentous algae is limited (Brookes et al. 2018).

#### Exposure of acid sulfate soils

Acid sulfate soils are naturally occurring soils rich in metal sulfides. They are commonly formed by bacterial action in waterlogged conditions with low oxygen and high organic matter concentrations. Between 2009 and 2010 when water levels in the Lower Lakes were at their lowest, up to 20,000 hectares of acid sulfate soils were exposed in the Lakes and the EMLR tributaries. The receding shoreline meant that the soils were exposed to the air reacting with oxygen to form sulfuric acid and release heavy metals from the soil. When the soils were re-wet through rainfall or increased river flow, the acid and metals mobilised causing detrimental effects to the environment and the ecosystem (DEH 2010).

In August 2009, at Loveday Bay in Lake Alexandrina the water became so acidic (pH level less than 3) that mussel shells were completely or partially dissolved along the shoreline and sampling of the acidified waters revealed a complete absence of invertebrates (DEH 2010). A pH level of less than 5 is considered lethal to most fish at the site, with sub-lethal effects (pH between 5.0 and 6.5) including altered behaviour, decreased feeding, lowered reproductive success and skin disease (Bice 2010). Acidification has also been shown to reduce the condition and survival of waterbirds (Rattner et al. 1987) and eliminate sensitive macroinvertebrate groups (especially crustaceans and molluscs) (Sommer and Horwitz 2001).

The hazard of further impacts remains largely unmitigated by re-inundation of the soils and localised acidification may still occur at water levels up to 0 metres AHD. For example, localised rewetting in 2009 after prolonged soil exposure during the Millennium Drought created acidic pools with pH below 3 that were later diluted by extensive rewatering of the system (DEH 2010). A significant acid load remains in the soil profile and localised metal release and deoxygenation risks have been identified (Fitzpatrick et al. 2008b; MDBA 2011b).

Acid sulfate soils also have impacts on Ngarrindjeri old people places such as middens, camping places and burial grounds (DEH 2010).

#### 7.3.4 Invasive species and problematic native species

#### Weeds

Invasive weeds have negative impacts on native vegetation. Three weeds were identified as posing a significant threat to the Lakes, and 6 weeds were identified for the Coorong in the Habitat Management Plan for the CLLMM region (DENR 2011). Priority weed species in the Lakes included Athel pine (*Tamarix aphylla*), boneseed (*Chrysanthemoides monilifera*) and prickly pear (*Opuntia* spp.). Priority weed species in the Coorong included boneseed, coastal tea-tree (*Leptospermum laevigatum*), dolichos pea (*Dipogon lignosus*), Aleppo pine (*Pinus halepensis*), Athel pine and spiny rush (*Juncus acutus*).

Other weed species in the region include African boxthorn (*Lycium ferocissimum*), pyp grass (*Ehrharta villosa*), bridal creeper (*Asparagus asparagoides*) and perrenial veldt grass (*Ehrharta calycina*) (DENR 2011).

#### Algal blooms

Since the Millennium Drought, the health and extent of aquatic plant communities have decreased in the Coorong, mainly due to inadequate water flows, water levels, poor water and sediment quality, and the resulting impacts of blooms of algae and other microbiota (DEW 2019). The presence of filamentous algae is preventing aquatic plants from completing their life-cycle and interfering with the ability of waterbirds to feed on both plants and invertebrates in mudflats (Brookes et al. 2018).

#### Rabbits, foxes, cats, goats and red deer

Feral rabbits, foxes, cats, goats and red deer occur throughout the Ramsar site except for some of the islands. Rabbits are widespread through the coastal and inland areas of the Ramsar site where they decrease cover of native species in saltmarshes and their digging increases wind and water erosion. Foxes and cats contribute to the mortality of many waterbirds during feeding, roosting and especially during primary moult, when the birds are flightless. Predation on juvenile waterbirds by foxes and cats when water levels around nest sites fall is of concern, although cats are likely to be restricted to the drier edges of wetlands (Scott 1997). At locations where foxes can reach nest colonies, fox predation has been implicated in the failure of Australian fairy tern breeding (Paton and Rogers 2009). Fox predation on freshwater turtles and their nests can sometimes result in the loss of over 9% of nests adjacent to wetlands (Goodwin and Hopkins, 2005). Goats and red deer are known to damage sensitive wetland vegetation. These pests are managed at the site level if they are found in high biodiversity value assets or if they pose a threat in sites where significant revegetation or restoration is occurring (DENR 2011).

#### Alien fish

Alien fish species recorded in the Ramsar site include European carp (*C. carpio*), eastern gambusia (*G. holbrooki*), brown trout (*Salmo trutta*), tench (*Tinca tinca*), goldfish (*C. auratus*) and redfin perch (*P. fluviatilis*). Of these species European carp and Eastern gambusia are the most abundant (Bice 2010).

European carp are now the most abundant, large-bodied fish species in the region having first been recorded in South Australia in 1975. They are common in Lakes Alexandrina and Albert, the EMLR tributaries and on occasion can enter the Murray Estuary. Since the Millennium Drought there have been significant increases in the catch of European carp from the Lakes and Coorong Fishery (Ferguson et al. 2010). This recent success may be because carp are generalists that can perform well in degraded habitats and successful recruitment is not dependent on strong water flows (Ye et al.

2008). The spread of European carp and its impact on the Lakes habitat has come at the expense of native fish species and aquatic vegetation. Carp have significant impacts on native aquatic plants both through direct grazing and through uprooting plants while feeding, leading to a reduction in plant density and biomass. Sediment disturbance during feeding leads to increased turbidity and poor water quality. On average approximately 600 tonnes per year of European carp is taken from the Lakes and Coorong fishery (EconSearch 2012 cited in Colloff et al. 2015).

Eastern gambusia compete with native species for food and resources (Wedderburn et al. 2016). They can behave aggressively towards other species by chasing and fin nipping, which can lead to secondary bacterial or fungal infections and potentially death of other fish. Eastern gambusia are known to prey upon the eggs and juveniles of other fish species. The high reproductive rate and extended breeding season of Eastern gambusia, along with broad feeding habits can enable this species to overwhelm suitable habitats with juveniles and deplete food supplies. Field-based studies and controlled aquaria experiments indicate that Eastern gambusia are likely to have contributed to the decline in distribution and/or abundance of olive perchlet (*Ambassis agassizii*), southern pygmy perch (*N. australis*), Murray–Darling rainbowfish (*Melanotaenia fluviatilis*) and purple-spotted gudgeon (*M. adspersa*) (Bice et al. 2018; Wedderburn at al. 2016). Whilst reports exist, much of the data is based on correlative field data. Eastern gambusia have also been linked to the decline of frog species, through the predation of tadpoles and adult frogs. They are considered a threat to the southern bell frog (*L. raniformis*), which is listed as vulnerable under the EPBC Act and the South Australian NP&W Act 1972 (Schultz 2005).

Redfin perch are carnivorous and compete with native species for food and resources. Adult redfin perch are almost entirely piscivorous, yet juveniles target invertebrates and small fish (Wedderburn et al. 2016). They are known to hunt fish either solitarily (by ambushing or stalking their prey) or in organised groups. In groups, they herd shoals of small fish until encircled or pinned against the bank; a few of the redfin then chase into the shoal while the majority hold position and prey on fleeing fish. Schools of redfin perch also use a similar method known as beating, where they flush out insects and small fish from weed beds or other shelter into open water. Redfin perch lay several hundred thousand eggs in a gelatinous ribbon amongst aquatic vegetation, submerged logs or other sheltered areas. The egg mass is unpalatable to most other fish and is hence generally protected from predation (NSW Department of Primary Industries 2020).

Exotic species, such as European carp, foxes, cats and wild dogs, and destructive farming practices such as dairy farming, irrigation, land clearing and cattle and sheep grazing, have all had significant impacts on the Ngarrindjeri Yarluwar-Ruwe. The impact of some of these practices, on Ngartjis in particular, has caused significant distress. The introduction and spread of European carp has caused competition and habitat change for pondi (Murray cod) and contributed to a decline in their numbers. Introduced pest species include dogs, cats and foxes, that are kungari (black swan) predators. Grazing cattle trample lake edges and damage or destroy kungari nests, or eat the reeds required by kungari for successful nesting and breeding. Trampling also causes an increase in the silt entering the Coorong lagoons, which kills off the swan weed and fills in deep fish holes (Yu 2014). In some cases, cattle and rabbits also compete with kungari for food resources (Ngarrindjeri 2019).

#### Australian tubeworm

The Australian tubeworm (*F. enigmaticus*) is a fast-growing, aggressive native species that alters the ecosystem physically, chemically and biologically. This species builds extensive reefs (of tubes) that alter sediment dynamics and hydrology and create islands of hard substrate in areas normally dominated by soft sediments (Dittmann 2009). The bulky reefs impede the movement of water, allowing sediment to build up around them.

Seepage of estuarine water through the barrages allowed larval dispersal into Lake Alexandrina in the early stages of the Millennium Drought. With a wide salinity tolerance, preference for sheltered waters with weak currents, the ability to cope with eutrophication and low dissolved oxygen concentrations, the Australian tubeworm found ideal living conditions in the Goolwa Channel (Dittmann 2009). In 2008, colonial growth of tubeworms became an issue of concern for freshwater turtles (Figure 7.1) and bivalves, infrastructure and boats in the Goolwa Channel.



Figure 7.1 Australian tubeworm encrustation on a live long-necked turtle (photo: Chris Jackson, Clayton, 2008).

#### Long-nosed fur seal

Long-nosed fur seals (*A. forsteri*) are native to Australia and New Zealand. The number of long-nosed fur seals in the Murray Mouth, Estuary and Coorong North Lagoon fluctuates throughout the year. Numbers peak over winter months and then decline in the lead-up to the breeding season in December, as animals spend more time in outer shelf and oceanic waters up to 1000 kilometres off the coast. The long-nosed fur seal was likely an occasional visitor to the Murray Mouth and Coorong but reports of fur seals appearing in the Coorong began in about 2007.

Fishers and the Traditional Owners of the Lower Murray, Lakes and Coorong and surrounding areas, the Ngarrindjeri, have both been impacted by the arrival of seals in the Coorong. In response, DEW and other stakeholders have been monitoring seal numbers in the Coorong since 2015, as well as evaluating various non-lethal management methods to reduce seal impacts on fisheries. To date, monitoring and investigations have not demonstrated impacts to the ecological character of the Coorong and Lakes Alexandrina and Albert Wetland.

Predation by seals on waterbirds and interference with nests and breeding behaviors has been raised as a concern by Ngarrindjeri. An increased in seal numbers is perceived to threaten important Ngartji such as the ngori (Australian pelican) and kungari (black swan) (Ngarrindjeri 2019).

#### 7.3.5 Recreational activities

The Ramsar site includes areas that are popular for recreational activities such as sightseeing, bird watching, camping, walking, fishing, swimming, canoeing, sailing, water-skiing, picnicking and four-wheel driving. The South Australian Tourism Commission estimated the annual number of visitors to the Coorong National Park in 2008 at about 138,000 (DEH 2010).

Although recreation and visitor use are an ecosystem service of the Ramsar site, there are aspects to recreational activities that can also act as a threat to ecological character and some recreational activities can present a serious potential threat to the health of the Ngarrindjeri Yarluwar-Ruwe. The main visitor impacts are from fishing and boating (including jet skis) and off-road driving on beaches which can disturb waterbirds (DEH 2000). Lost or discarded materials such as nets and fishing line can maim or kill waterbirds and mammals, many of which are Ngarrindjeri Ngartjis.

Off-road vehicles are a significant threat to hooded plover breeding success along the beaches of the Younghusband Peninsula. Buick and Paton (1989) reported the preferred nesting area of hooded plover was within 6 metres of the base of the fore dune, often where vehicle track density was the highest. Four-wheel driving and tourist operators have also done considerable damage to Ngarrindjeri old people places (middens and burial places).

Off-road vehicles can impact intertidal zones and can be of more concern than disturbance associated with localised commercial harvesting of species (Brown and McLachlan, 2002; Brown et al. 2008 cited in Fairweather 2011a). Off-road vehicles, particularly in areas with high activity, may compact sediments which in turn impact bivalves such as donax, paphies or katelysia (Schlacher et al. 2008; Sheppard et al. 2009 cited in Fairweather 2011b).

# 8 Current ecological character and change since listing

# 8.1 Ramsar definition

Under the Ramsar Convention, change in ecological character is 'the human-induced adverse alteration of any ecosystem component, process and/or ecosystem benefit/service' (Ramsar Convention 2005a, Resolution IX.1 Annex A). Changes to the ecological character of the wetland may be positive or negative. However, notifications to the Ramsar Convention Secretariat are limited to 'human-induced adverse alteration' (DEWHA 2009). Change in character should be established against the ecological character at a given point in time, usually at the time of designation as a Ramsar site. This 2015 ECD is different, as it describes the ecological character of the site following an Article 3.2 notification of change in ecological character and subsequent recovery actions.

# 8.2 2006 Change in ecological character

In 2006, the Australian Government advised the Ramsar Convention Secretariat (in accordance with Article 3.2 of the Ramsar Convention) of a change in the ecological character of the Ramsar site. This was a result of the findings of the 2006 ECD for the site. Detailed quantitative data describing the 1985 listing condition was not available at that time. However, the 2006 ECD concluded that the site had been declining for at least 20 to 30 years prior to Ramsar listing with the rate of decline exacerbated by the Millennium Drought. It noted that nearly half of the 53 key functions and values of the site were 'of alarm' and a further third 'of serious concern'4. Despite these concerns, the site continued to meet 8 of the 9 Ramsar criteria for listing at that time (Phillips and Muller 2006).

#### 8.3 Current character

The site appears to be recovering following the Article 3.2 notification and subsequent recovery actions funded under the CLLMM Recovery Project and through the provision of Commonwealth and State environmental water. Expert opinion and recent data indicate the system is still in recovery, with improvements evident in a range of conditions and/or indicators in recent, post drought years (see Bucater et al. 2015; Nicol 2015; Oliver et al. 2015; Paton et al. 2015).

The following assessments for the critical CPS and LAC use the best available data. Some of the critical CPS that have been identified in this ECD may not yet have reached a state of equilibrium following impacts from the Millennium Drought. Further refinement of baselines and LAC will be required once additional data is collected.

<sup>&</sup>lt;sup>4</sup> The 2006 ECD was prepared before the development of the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEWHA 2008) and described 'primary determinants of ecological character' rather than critical components, processes and services, which makes it difficult to compare the 2006 ECD with this 2015 ECD.

#### 8.3.1 Hydrology

Hydrological aspects such as inflows from the Eastern Mount Lofty Ranges tributaries, inflows from the south-east via Salt Creek and rainfall and evaporation have not changed since the time of Ramsar listing. As such the descriptions contained in section 4.5.1 reflect current conditions. Inflows from the River Murray dominate the hydrological regime of the Ramsar site. Reductions in River Murray inflows have had a significant effect on the water levels and salinity of Lakes Alexandrina and Albert, barrage flows, Murray Mouth openness and therefore the tidal signal, water levels and salinity of the Coorong.

Historically, River Murray inflows, as variable as they were under natural conditions, kept the Murray Mouth of the river open at all times, even during drought periods (Phillips and Muller 2006). The water level in the Lakes varied depending on inflow from the Murray River, lake evaporation and barrage operation. Barrage outflows were managed to provide an annual cycle of between +0.4 and +0.75 metres AHD that resulted in the barrages being closed at 0.45 metres AHD and barrage flows above the annual cycle being passed through to the Murray Estuary and Coorong (Phillips and Muller 2006).

In 1981 the Murray Mouth closed for the first time and had to be cleared by dredging. The dredged channels kept the Murray Mouth open, reinstating the tidal signal and providing oxygenated seawater to the Coorong. The Murray Mouth was then kept open by River Murray flows until the early 2000s. During that time there were 7 periods when the barrages were closed continuously for more than 200 days. The lowest level Lake Alexandrina dropped to during that time was 0.31 metres AHD.

From 2001 barrage flows were very low. Between 2007 and 2010 there were no barrage outflows and the river ceased to discharge to the ocean (EPA 2013). Dredging recommenced in October 2002 to keep the Mouth channel open. The lowest water levels (–1.05metres AHD in Lake Alexandrina, – 0.55metres AHD in Lake Albert) during the drought were reached in April 2009 (EPA 2013).

Dredging continued until the end of the Millennium Drought in 2010 when high inflows rapidly occurred and Lake levels returned to normal operating levels. In 2011–12 there was widespread flooding and high barrage outflows (12,808 gigalitres), after which low barrage flows (less than 1,000 gigalitres/year) continued and dredging recommenced in 2015.

#### Lake Alexandrina water level LAC

Time series of monthly averages for the period from 1974 to 2015 indicate that since designation (1985), the water levels for Lake Alexandrina were managed to provide an annual cycle of between +0.4 and +0.75 metres AHD until 2007-2010. The lowest water levels (–1.05metres AHD in Lake Alexandrina and -0.55 metres AHD in Lake Albert) during the drought were reached in April 2009 (EPA 2013). When high inflows rapidly occurred in 2010 Lake levels increased and have since been managed to provide an annual cycle of between +0.4 and +0.85 metres AHD.

In 2015, water levels across the site had returned to levels prior to the Millennium Drought and at the time of Ramsar listing as illustrated by water levels in Lake Alexandrina (Figure 8.1).

The LAC for Lake Alexandrina (less than -0.25 metres AHD) was only exceeded by continuous low water levels during the Millennium Drought between January 2008 and June 2010. Lake Alexandrina operating levels were reviewed as part of the development of the Barrage Operating Strategy (DEW 2019) and have been managed since the Millennium Drought to provide an annual cycle in lake levels ranging from +0.5 to +0.85 metres AHD.

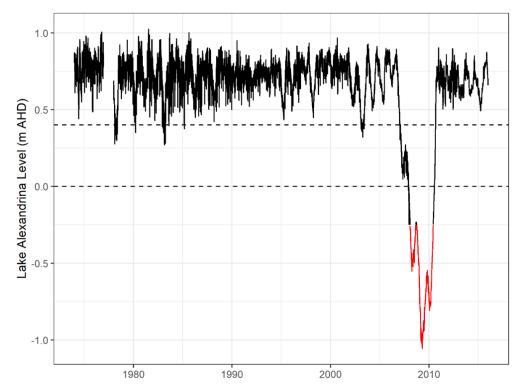


Figure 8.1 Time series of daily averaged water levels in Lake Alexandrina (1974–2015). The red line indicates when the LAC (-0.25m AHD) was exceeded, with the management triggers of 0 and +0.4m AHD shown as dashed lines.

#### 8.3.2 Salinity

Salinity has been influenced and impacted by reduced inflows from upstream water resource development and droughts, particularly during the Millennium Drought.

For the period to the end of March 2007, salinities in Lake Alexandrina up to around 1,000 EC corresponded to salinities in Lake Albert within a band from 1,000 to 2,000 EC. When salinities were greater than 1,000 EC in Lake Alexandrina, salinities in Lake Albert increased. Between April and November 2007 water levels fell from 0.25 to 0.0 metres AHD and the connection between the Lakes became shallower and reduced interchange between the Lakes likely occurred. Despite salinities in Lake Alexandrina increasing from 1,500 to 3,000 EC, salinities in Lake Albert remained generally constant around 2,500 EC.

Salinity in Lake Alexandrina returned to pre-Millennium Drought levels in November 2010. Lake Albert salinity had not returned to pre-Millennium Drought levels in late 2015. Lake Albert salinity returned to pre-Millennium Drought levels in late 2017 following a period of lake level cycling, artificially raising and lowering its level over time to encourage more water to circulate leading to a reduction in salinity. Both Lakes have remained within natural variation since 2015.

For the Coorong, the absence of continuous water quality monitoring prior to 1998 means that longer-term changes are much more difficult to establish (Aldridge et al. 2018). The earliest comprehensive water quality surveys in the Coorong appear to be those of Geddes and Butler (1984) which document water quality in the Coorong North and Coorong South lagoons during a low-flow period in 1982 to 1983. In the Coorong South Lagoon, salinities increased to 90-100 ppt (104,149- 112,471 EC) and in the Coorong North Lagoon, salinities were 20-80 ppt (31,019-95,457 EC) during this low-flow period.

More continuous post 1998 water quality results show generally higher salinity levels during the 2002 to 2010 low flow period (compared to Geddes and Butler 1984 results), particularly in the Coorong South Lagoon (Aldridge et al. 2018). Reduced inflows during the drought resulted in salinities rising dramatically in the Coorong. Salinities reached greater than 4 times that of sea water at the southern end of the Coorong. Post-2011 improvements in salinity have occurred following higher River Murray inflows and barrage and Salt Creek outflows (Mosley et al. 2017). In 2015, salinity in the Murray Estuary and the Coorong returned to pre-Millennium Drought levels.

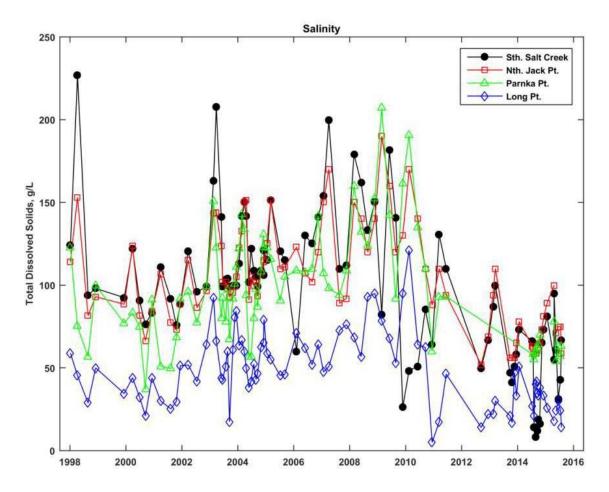


Figure 8.2 Salinity along the Coorong from 1998 to 2016 from Mosley et al. (2017). N.B. This graph shows data to June 2016 to show that the cyclical pattern is being maintained.

# Lake Alexandrina salinity LAC

Statistical analyses of the time series data indicate that prior to the Millennium Drought, overall salinity in Lake Alexandrina was increasing at a slow rate of approximately 8  $\mu$ S cm<sup>-1</sup> (0.08 EC) per year (Aldridge et al. 2018). Similar analyses for Lake Albert were restricted by a lack of data, but it appears that salinity has not changed significantly (Aldridge et al. 2018).

Lake Alexandrina salinity data for the period 1974 to 2015 showed annual and seasonal variability, but that salinity generally remained below 1,500 EC between 1974 and 1999 (Figure 4.6). For this period salinity exceeded the LAC threshold of 1,500 EC only 1% of the time, occurring in 1981 and 1983, with exceedance events having a maximum duration of 5 to 10 days and average recurrence interval of 3 to 20 years (Oliver et al. 2015). While there were no salinity measurements taken for Lake Alexandrina between mid-1999 and mid-2002, salinity modelling suggests that salinity remained below 1,000 EC during this period (Heneker 2010).

From 2002 onwards, lake salinity increased substantially as catchment inflows declined substantially. Between April and November 2007 water levels fell from 0.25 to 0.0 metres AHD and the connection between the Lakes became shallower and reduced interchange between the Lakes likely occurred. This resulted in a prolonged period in Lake Alexandrina between late June 2007 and early November 2010 when salinity continuously exceeded 1,500 EC. Despite salinities in Lake Alexandrina increasing from 1,500 to 3,000 EC, salinities in Lake Albert remained generally constant around 2,500 EC.

As the salinity LAC for Lake Alexandrina is exceeded only after 2 consecutive years above 1,500 EC, the LAC was not exceeded until July 2009 and salinity returned to pre-drought levels in November 2010.

# Murray Estuary salinity LAC

Examination of salinity for the Murray Estuary from 1998 to 2015 indicates that there has been no continuous period of 18 months or longer where average monthly salinity has exceeded 40 ppt (55,658 EC) (Figure 4.8). While there were periods during the Millennium Drought when annual salinity exceeded 40 ppt (55,658 EC) (2002–04, 2007–09), variability in monthly averages meant that were months in each year when salinity was below 40 ppt (55,658 EC). This means that the salinity LAC for the Murray Estuary was not exceeded, despite monthly averages being above 40 ppt (55,658 EC) for approximately 53% of months between 2002 and 2010, inclusive. Since the breaking of the Millennium Drought, and in 2015, salinity in the Murray Estuary had returned to a similar pattern to that recorded prior to 2002.

# Coorong North Lagoon salinity LAC

Prior to the Millennium Drought the highest readings in the Coorong North Lagoon were 65 ppt (81,605 EC) in March 1982, a period preceded by the Murray Mouth closure in 1981 and a long period of barrage closure. During the Millennium Drought salinity levels at Long Point in the central Coorong North Lagoon reached over 100 ppt (112,471 EC) during 2007.

Similar to the Murray Estuary, there was no time when average monthly salinity in the Coorong North Lagoon of the Coorong remained above the LAC of 75 ppt (90,957 EC) for 18 consecutive months or longer (Figure 4.8). Salinity approached 75 ppt (90,957 EC) in 2008 and 2009, when the annual average salinity was 74.8 ppt and 74.4 ppt (90,774 EC and 90,409 EC), respectively and average monthly salinity exceeded 75 ppt (90,957 EC) in 50% of months. Variation of monthly average salinity in any 1 year meant that the LAC was not exceeded, as there was no period of 18 consecutive months or longer where salinity was above 75 ppt (90,957 EC).

Since the breaking of the Millennium Drought, and in 2015, salinity in the Coorong North Lagoon has returned to a similar pattern to that at the time of listing.

### Coorong South Lagoon salinity LAC

At the time of listing as a Wetland of International Importance in 1985, the typical salinity range in the Coorong South Lagoon was between 90,000 EC (50 ppt) and 230,000 EC (127 ppt) (Geddes 1987). Coorong South Lagoon salinities of less than seawater (35 ppt / 49,900 EC) have not been recorded since the River Murray floods of 1974–75 (Webster 2005).

During the Millennium Drought, salinities peaked at over 200 ppt (182,133 EC). Salinity levels greater than 150 ppt (149,824 EC) (extremely hypersaline) were consistently recorded during summers between 2005 and 2010 (Figure 4.8). The LAC was exceeded from 2005 until salinities began to drop with the return of higher flows in 2011. Salinities would have been even higher had a dredging program not been commenced in 2002.

#### 8.3.3 Vegetation

The main datasets used to document the changes since listing and inform the development of and assess the Vegetation LAC and are described in Table 13-8 of Appendix D.

#### Submergent freshwater vegetation

Over 90% of the Lakes is open water habitat with no vegetation (Nicol 2016). The earliest quantitative aquatic and littoral vegetation data collected from the Lakes was a snapshot of the aquatic vegetation of Hindmarsh Island in February 1989 (Renfrey et al. 1989). Transects on the northern shoreline of the Island showed zonation of the plant community, with submergent species at intermediate elevations and the low elevations containing only submerged taxa (Renfrey et al. 1989). Very little information was collected between 1989 and 2004. There was a one-off survey of Murray Mouth Reserves in March 2002 (Brandle 2002) and habitat mapping (Seaman 2003). These studies indicated that in areas where the water depth exceeded 1 metre, plants were generally absent (Seaman 2003). The areas with the greatest abundances of submerged and amphibious species were wetlands and sheltered areas along the western shoreline of Lake Alexandrina, the northern shoreline of Hindmarsh Island, Goolwa Channel and the lower Finniss River and lower Currency Creek (Brandle 2002; Seaman 2003). Species that have been historically recorded in the Lakes, included long-fruit water mat (*L. cylindrocarpa*), Australian water mat (*Lepilaena australis*), amphibious water-milfoil (*Myriophyllum simulans*) and threadleaf crowfoot (*R. trichophyllus*). These species have not been recorded post-drought (Nicol 2016).

In spring 2004 and again in 2005, vegetation surveys were undertaken in selected wetlands (SKM 2005; Nicol et al. 2006). Data from these surveys showed that the wetland plant communities were similar to the broad-scale habitats mapped by Seaman in 2003. These surveys provided more detailed site-scale information; for example, extensive beds of ribbon weed were present at Milang shores, Dunns Lagoon and Clayton Bay and in the Channels on Hindmarsh Island (SKM 2005) and milfoil was abundant near the Hindmarsh Island bridge, in Clayton Bay, Dunns Lagoon (SKM 2005) and Hunters Creek (Nicol et al. 2006).

From 2007 to 2010 the water level in the Lakes fell to unprecedented low levels (Figure 8.3) (Nicol et al. 2018). Drying of these habitats resulted in the complete loss of submergent species (Gehrig et al. 2011). Submergent species recruited in Goolwa Channel during this time due to engineering interventions undertaken to mitigate acid sulfate soils. The submergent vegetation was dominated by dense beds of sago pondweed (Gehrig et al. 2011). Dense monocultures of this species occupied 1,491 hectares of Goolwa Channel, with sparse sago pondweed (*P.pectinatus*) submerged herblands occupying a further 100 hectares and mixed sago pondweed/ milfoil submerged herblands occupying 572 hectares (Gehrig et al. 2011). The combined area of the above submergent plant communities covered 53% of the area of Goolwa Channel (Gehrig et al. 2011). A viable seed bank was present in Dunns and Shadow lagoons and Goolwa Channel, allowing recolonisation with appropriate hydrological conditions (Nicol 2016). Viable seed banks of submergent taxa were probably present throughout wetlands and fringing habitats in the Lower Lakes, but assessments were only undertaken in Dunns and Shadows lagoons (Nicol et al. 2018).

Increased inflows into the Lakes in late 2010 resulted in reconnection throughout the Lakes and reinstatement of historical water levels. The inflow of fresh turbid water into Goolwa Channel resulted in the extirpation of much of the submergent vegetation that recruited after the Clayton regulator was constructed, however this was slowly replaced with more diverse submergent vegetation consisting of sago pondweed, milfoil, hornwort, curly pondweed and ribbon weed (Nicol et al. 2018).

It was not until spring 2011 that a significant cover of native submergent species was reported. There was an increasing trend after spring 2011 that peaked in autumn 2015 after which there was a decrease in spring 2015. It was not possible to determine whether the community present was comparable to the community prior to 2007 because direct quantitative comparisons between the condition monitoring data and the small amount of data collected prior to 2007 could not be made (Nicol 2016). However, for sites where data did exist (Teringie, Narrung, Clayton Bay, Dunns Lagoon, Milang, Loveday Bay, Point Sturt and Hunters Creek) the diversity and abundance of submergent species was higher prior to 2007 compared to the recent surveys (SKM 2005; Nicol et al. 2006 as reported in Nicol 2016).

#### Submergent freshwater vegetation LAC

River Murray flows over Lock 1 have been sufficient to maintain water levels between +0.4 metres AHD and +1.0 metres AHD in the lake since spring 2010 and reduce surface water EC in Lake Alexandrina and Goolwa Channel to below 1,000 EC and Lake Albert below 2,000 EC (Nicol et al. 2018). The reinstatement of water levels and favourable salinity conditions in Lakes Alexandrina and Albert have resulted in improvement in vegetation condition, including increased abundance in submergent species in Lake Alexandrina (submergent species are uncommon in Lake Albert) and wetland habitats (Nicol et al. 2018).



Figure 8.3 Water levels in Goolwa Channel (upstream of Goolwa barrage – grey line), Lake Alexandrina (Milang – orange line) and Lake Albert (Meningie – blue line) from January 2005 to December 2015 (Data accessed through DEW surface water archive, Waterconnect), showing the water level LAC (+0.2 m AHD; yellow line) for submergent and emergent freshwater vegetation and emergent halophytes. Surface water stations A4260630, A4260524, A4261034 used.

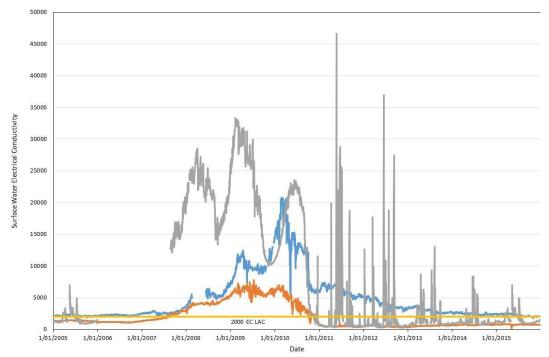


Figure 8.4 Surface water electrical conductivity in Goolwa Channel (upstream of Goolwa barrage – grey line), Lake Alexandrina (Milang – orange line) and Lake Albert (Meningie – blue line) from January 2005 to December 2015 (DEW 2016), showing the salinity LAC (2,000 EC – yellow line) for submergent freshwater vegetation. Surface water stations A4260630, A4260524 and A4261122 used.

Based on the information above and that reviewed in Nicol (2016) the LAC for freshwater submergent vegetation was exceeded during the Millennium Drought (i.e. water levels greater than +0.2 metres AHD and salinity greater than 2,000 EC in Lake Alexandrina for greater than 12 months between 2007 and 2010 (Figure 8.3 and Figure 8.4).

#### **Emergent freshwater vegetation**

Early quantitative surveys by (Renfrey et al. 1989) showed zonation of the plant community on the northern shorelines of Hindmarsh Island, with tangled lignum (*D. florulenta*) and common reed (*P. australis*) the dominant species at high elevations and intermediate elevations dominated by cumbungi (*T.domingensis*) and river clubrush (*S. tabernaemontani*) (along with freshwater submergent species) (Renfrey et al. 1989). Habitat mapping undertaken by Seaman in 2003 identified that the shores of Lakes Alexandrina and Albert were dominated by common reed and cumbungi, with limited areas of diverse reed beds on sheltered shorelines.

Surveys in selected wetlands in spring 2004 (SKM 2005) and spring 2005 (Nicol et al. 2006) showed that the wetland plant communities were similar to the broad-scale habitats mapped by Seaman in 2003. These surveys identified that wetlands along the eastern shoreline of Lake Alexandrina and around the edges of Lake Albert (Poltalloch, Narrung, Teringie and Waltowa) were typically fringed by samphire and saltmarsh plants (*Sarcocornia spp., S. australis, Juncus krausii, Tecticornia spp.*), with limited common reed and cumbungi stands in areas adjacent to the Lakes (SKM 2005).

The low water levels between 2007 and spring 2010 (Figure 8.3) resulted in the drying of fringing habitats (wetlands and shorelines) (Nicol et al. 2018). During this time, the extensive common reed stands and tangled lignum that were present around the edges of the Lakes prior to 2007 were still present and in some areas expanded their distribution down the elevation gradient to colonise areas of the dry lake bed (Marsland and Nicol 2009 cited in Nicol et al. 2018). Cumbungi and river clubrush stands showed reduced extent and appeared to be in poor condition (Nicol et al. 2018). Stands of

freshwater emergent species persisted during this time, but were not inundated and were disconnected from the Lakes (Marsland and Nicol 2009 cited in Nicol et al. 2018).

The construction of the Narrung Bund enabled water levels to be raised in Lake Albert (Figure 8.3), but there was insufficient water to inundate the fringing habitats (Nicol et al. 2018). In contrast, the Clayton regulator enabled water levels in the Goolwa Channel to be raised sufficiently to inundate fringing habitats (Nicol et al. 2018). The increased salinity in Goolwa Channel was expected to result in significant mortality of fringing vegetation, but this did not occur and there was a noticeable improvement in the condition of the fringing vegetation during this period (Gehrig et al. 2011; Nicol 2016).

Increased inflows from the River Murray to the Lakes in spring 2010 resulted in reconnection of fringing vegetation throughout the Lakes and the reinstatement of historical water levels (Figure 8.3) (Nicol et al. 2018). Reinstatement of water levels in Lakes Alexandrina and Albert has resulted in an improvement in vegetation condition.

As of 2015, emergent and amphibious species have increased in abundance on the shorelines of both Lakes and in fringing wetlands (Nicol et al. 2018). Lakes shorelines are dominated by emergent species, primarily cumbungi and common reed (Frahn et al. 2014; Nicol et al. 2014). Diverse reed beds are present along the western shorelines of the main lakes, throughout Goolwa Channel, including the lower reaches of the Finniss River and Currency Creek (Frahn et al. 2014), (Nicol et al. 2014), in shoreline wetlands (Frahn et al. 2014) and areas where river club rush has been planted (Nicol 2015).

# Emergent freshwater vegetation LAC

Based on the information above and that reviewed in Nicol (2016) the LAC for freshwater emergent vegetation was exceeded during the Millennium Drought – i.e. water levels greater than +0.2 metres AHD for greater than 2 years between 2008 and 2010 (Figure 8.3) but not exceeded since.

#### Submergent halophytes

The composition of the submerged aquatic plants was more diverse in the Coorong at the time of Ramsar nomination than is currently the case (Paton et al. 2015). In the early 1980s, *R. megacarpa*, *L. cylindrocarpa* and *Z. muelleri* were reported from the Coorong North Lagoon (Geddes and Butler 1984, Geddes 1987), while *R. tuberosa* and *Lamprothamnium papulosum* were in the Coorong South Lagoon (Geddes 1987). Of these, only *R. tuberosa* remains. A combination of changes in salinity and water levels are likely to have caused these changes in distribution and abundance, with the plant populations likely to have been in a state of change even at the time of nomination as a wetland of international importance (Paton et al. 2015a).

During the Millennium Drought, salinities in winter exceeded 100 ppt (112,471 EC) throughout most of the Coorong South Lagoon from 2003 to 2006 and exceeded 120 ppt (128,175 EC) from 2007-2010. These high salinities were likely to have contributed to the loss of *R. tuberosa* from the Coorong South Lagoon in the 2000s. During this time *R. tuberosa* gradually established mid-way along the Coorong North Lagoon in the vicinity of Noonameena. Plants first appeared in this area in winter 2005 and slowly established over the next 5 years. By 2009 and 2010, *R. tuberosa* was spread over a 25 kilometre stretch of the Coorong North Lagoon, from Magrath Flat to Long Point, with populations at Noonameena and Rob's Point approaching 90% cover in these years (Paton and Bailey 2012a; Paton et al. 2015).

When extensive River Murray flows returned to the Murray Mouth in late 2010, the salinities in the middle sections of the Coorong North Lagoon quickly dropped and the *R. tuberosa* beds that had established were swamped during summer by filamentous green algae (*Enteromorpha* spp.). This effectively eliminated *R. tuberosa* from the middle sections of the Coorong North Lagoon and, few, if

any, plants were detected at sites within this region by winter 2011 or subsequently (e.g. Paton and Bailey 2012a; Paton et al. 2015).

Recovery of *R. tuberosa* in the Coorong South Lagoon has remained slow due to the depauperate seed bank, but an increase in abundance and extent was observed between 2012 and 2014, then a decrease in 2015 (Paton et al. 2017). Five years on, the species has not recovered to any extent except at the northernmost sites in the Coorong South Lagoon (Paton et al. 2015a).

#### Submergent halophytes LAC

Since regular annual surveys began in 1999, significant changes have occurred in the distribution and abundance of *R. tuberosa* (Rogers and Paton 2009). There are striking patterns to the changes in the distribution and abundance of *R. tuberosa* in the Coorong since 1999 (Paton et al. 2016).

There was a significant decline and then loss of *R. tuberosa* from the 4 long-term monitoring sites spread along the Coorong South Lagoon, such that no *R. tuberosa* was detected growing in July at any of these sites from 2008 to 2010 (Figure 8.5 and Figure 8.6) (Paton et al. 2016).

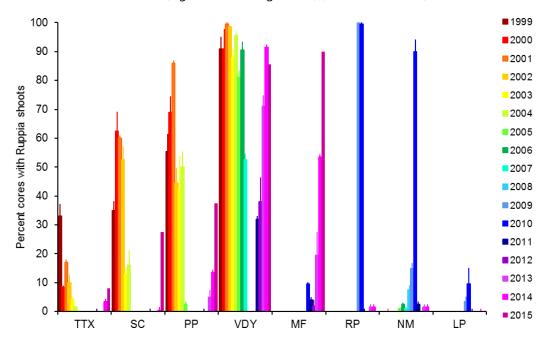


Figure 8.5 The percentage of 200 cores (75-mm diameter x 40-mm deep) that contained *R. tuberosa* shoots at each of the 8 sites along the Coorong North and Coorong South lagoons, during July from 1999 to 2015 (from Paton et al. 2016). Sites are arranged from the southernmost site (TTX) in the Coorong South Lagoon to the northernmost site (LP) in the Coorong North Lagoon. The dashed line at 5% cores represents the LAC threshold (i.e. 50% of sites fall below 5% cover) (Paton et al. 2015a).

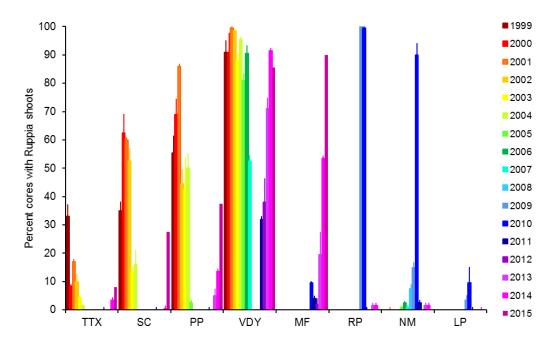


Figure 8.6 Mean number of *R. tuberosa* shoots counted in 200 cores taken in July from 8 sites spread along the Coorong from 1999 to 2015 (from Paton et al. 2016). Sites are arranged from the southernmost site (TTX) in the Coorong South Lagoon to the northernmost site (LP) in the Coorong North Lagoon, with the 4 sites on the left in the Coorong South Lagoon and the 4 on the right in the Coorong North Lagoon. Data show mean number of shoots per core + s.e. Shoots per core can be converted to shoots per m<sup>2</sup> by multiplying by 226. Purple and pink colours are used to highlight more recent years.

From July 2005 on, there was a gradual colonisation of sites in the middle of the Coorong North Lagoon, so that, in July 2009 and July 2010, extensive *R. tuberosa* beds (greater than 90% cores with plants and greater than 10 shoots/core) had established along the Coorong North Lagoon (Figure 8.5 and Figure 8.6) (Paton et al. 2016). By 2009 and 2010, *R. tuberosa* had spread over a 25 kilometre stretch of the Coorong North Lagoon, from Magrath Flat (where it existed prior to the drought) to Long Point, with populations at Noonameena and Rob's Point approaching 90% cover in these years (Paton et al. 2015). These populations were outside of the historic distribution of *R. tuberosa* within the Coorong (Paton et al. 2016).

By July 2011, following the return of inflows from the River Murray in spring 2010, there was a reduction in the cover of *R. tuberosa* in the Coorong North Lagoon, with *R. tuberosa* all but eliminated except for a few plants at Magrath Flat and Noonameena – i.e. less than 5% cores with plants and less than 0.3 shoots/ core (Figure 8.5 and Figure 8.6) (Paton et al. 2016). While *R. tuberosa* was lost from the Coorong North Lagoon, some (present in 32% cores) re-appeared at Villa dei Yumpa, the northernmost monitoring site in the Coorong South Lagoon in July 2011 (Paton et al. 2016).

Despite suitable salinities throughout the Coorong South Lagoon between 2011 and 2015 (Figure 8.7), *R. tuberosa* has recovered slowly but steadily during this period (Paton et al. 2016). By winter 2013, 2 sites had at least 30% of cores having shoots (Figure 8.7) and this increased to 3 sites in winter 2014 and then 6 sites in winter 2015 (Figure 8.7).

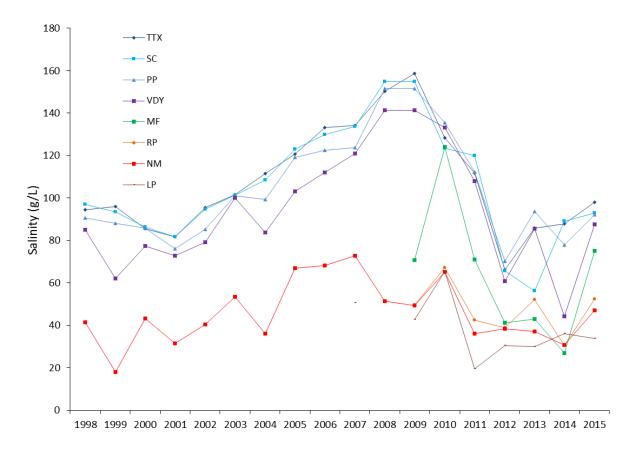


Figure 8.7 Winter salinities at monitoring sites for *R. tuberosa* in the Coorong in July from 1998 to 2015 (Paton et al. 2016). Sites TTX (Tea Tree Crossing), SC (Salt Creek), PP (Policeman's Point) and VDY (Villa dei Yumpa) were spread along the Coorong South Lagoon, while MF (Magrath Flat), RP (Rob's Point), NM (Noonameena) and LP (Long Point) were spread along the Coorong North Lagoon. Coorong South Lagoon sites are shown in navy through to purple colours and those in the Coorong North Lagoon in green to red colours. TTX is the southernmost site and LP the northernmost site amongst the 8 sites. MF, RP and LP were only sampled annually in July from 2009 onwards.

In general, the percent cover of *R. tuberosa* showed a marked increase in July 2015 compared to recent years, including 2 sites (Villa dei Yumpa and Magrath Flat) that exceeded 80% cover (Figure 8.7) (Paton et al. 2016). Whilst there have been recent increases in the percent cover of shoots, most sites in the Coorong South Lagoon are still well below the cover of *R. tuberosa* that was recorded when monitoring commenced in the late 1990s (Paton et al. 2016).

Based on the information above and that reviewed in Paton et al. (2016) the LAC for submergent halophytes (*R. tuberosa* cover) was exceeded between 2008 and 2011.

# **Emergent halophytes**

Emergent halophytes, also known as samphire and saltmarsh vegetation, are widespread throughout the Ramsar site in areas where there is moderate to high salinity (Seaman 2003). They are generally restricted to areas above +0.8 metres AHD along the eastern shore of Lake Alexandrina, adjacent to the barrages and around Lake Albert and +0.2 metres AHD in the Coorong (Nicol 2016). Under normal operating regimes (Lake Alexandrina between +0.4 to +0.80 metres AHD), these levels would coincide with a short period of shallow inundation on an annual basis.

Wetlands along the eastern shoreline of Lake Alexandrina and around the edges of Lake Albert (Poltalloch, Narrung, Teringie and Waltowa) were typically fringed by samphire and saltmarsh plants (detailed surveys in spring 2004 and 2005 reported in Nicol 2016). The inundated areas of these

wetlands were dominated by submergent halophytes such as fox tail stonewort (*Lamprothamnium macropogon*), water mat (*L. cylindrocarpa*), *R. tuberosa* and widgeon grass (*R.polycarpa*) (Nicol 2016).

During the Millennium Drought, water levels in Lake Alexandrina fell below +0.4 metres AHD and the existing samphire and saltmarsh communities became disconnected from open water habitats resulting in a decline in recruitment and poor condition of existing plants. When water levels increased rapidly to +0.8 metres AHD in late 2010 the communities were reconnected.

The change in the distribution and abundance of samphire and saltmarsh species was not well documented during the period of low water levels between 2007 and 2010. The assessment of habitat condition in Lakes Alexandrina and Albert in 2010 recorded both colonisation of samphire and saltmarsh communities by introduced grasses, and colonisation of exposed open water habitats such as mudflats by samphire and saltmarsh species (Thiessen 2010, Billows 2014).

The emergent halophyte vegetation found on the lagoon edges of the Murray Estuary and Coorong is part of the endangered Subtropical and Temperate Coastal Saltmarsh ecological community. The majority of this community has been protected within Coorong National Park since 1966.

Baseline mapping and classification for the Ramsar site was carried out in 2002-03 and 94% of the sites were classified as being in good or better condition (Seaman 2003). In 2015, repeat field habitat condition of 50% of the original baseline mapping assessments within the Coorong found that 34 sites (36%) have improved in condition, 40 sites (42%) have not changed in condition and 21 sites (22%) have declined in condition since 2003 (Dickson et al. 2015).

## **Emergent halophytes LAC**

If water levels fall below +0.4 metres AHD in the Lakes or below +0.1 metres 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 metres 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.

Lake levels, however, have been subject to major fluctuations such as those experienced during the Millennium Drought. An indirect Lake Alexandrina water level LAC has therefore been set at the minimum possible level of +0.2 metres AHD (Nicol 2016). Based on Figure 8.3 average daily water levels in Lake Alexandrina were less than +0.2 metres AHD for greater than 2 consecutive years between 2008 and 2010 and the LAC for emergent halophyte vegetation was exceeded at that time.

## 8.3.4 Fish

There is a lack of underlying knowledge of the variability in fish species richness at the time of listing. The majority of data on fish diversity and abundance are from 2006 to 2015 with data captured during the drought and post drought years. The main datasets used to assess the Fish LAC and document the changes since listing are described in Table 13-9 in Appendix D.

## Diversity (species richness and biodisparity) LAC

### **Species richness: Lakes Alexandrina and Albert**

Nine of the 10 common freshwater species identified (Table 13-3) were found to be present in every year between 2006 and 2015. The only exception was unspecked hardyhead which was not detected in 2008–09. Whilst species richness did not vary greatly from 2006 to 2015, changes in the individual species' abundance and assemblage structure were observed. For example, as the Millennium Drought progressed through 2006–07, reduced river flows led to water level recession in the Lakes, fragmentation of remnant water bodies, increasing salinity, loss of connectivity and causing freshwater

aquatic vegetation to be replaced with salt-tolerant species or bare sediment (Nicol et al. 2016a; Bice et al. 2018). This resulted in a corresponding decline in the abundance of threatened freshwater and diadromous fish species (i.e. Congolli and common galaxias) and an increasing dominance of generalist freshwater (e.g. Australian smelt) and estuarine species (e.g. lagoon goby) (Wedderburn et al. 2012). During the drought freshwater exotic fish species (primarily carp) comprised more than 50% of commercial fishery catches in Lake Alexandrina (Ferguson and Ye 2016).

The return of higher river flow and water levels (greater than +0.5 metres AHD) in the Lakes in late 2010 resulted in a range of responses from the fish populations (Bice et al. 2018). Abundances of small-bodied estuarine species and generalist native fish species decreased in the Lakes due to reduced salinity and improved connectivity between the Lakes and Coorong (Ye et al. 2016, Bice et al. 2018). The abundances of diadromous fish species (i.e. congolli and common galaxias) increased due to the re-established connectivity between the marine, estuarine and freshwater habitats within the Ramsar site (Ye et al. 2016). Overall, the increases in flow and lake water levels following 2010 facilitated improvement (e.g. increased abundances) to the fish assemblages, but the assemblage structure has not returned to that of the pre-drought period in 2015 (Ye et al. 2016).

## **Species richness: Murray Estuary and Coorong**

All 18 of the common estuarine and marine-estuarine opportunist species were recorded annually between 2006–07 and 2014–15 except for the smooth toadfish, which was not detected in 2010–11 (Ye et al. 2011). The presence of the common species, remained relatively constant, but changes to species abundance during this period were recorded (Ye et al. 2015b).

During the Millennium Drought there was a general decrease in fish species richness and abundance in the Murray Estuary and Coorong (Ye et al. 2016). The lack of freshwater inflows resulted in elevated salinity throughout the system with hypersaline conditions (greater than 100 ppt / 112,471 EC) persistent in the Coorong South Lagoon for much of this period (Ye et al. 2016). Increased salinities and the decreased salinity gradient reduced the area of suitable habitat and restricted the range of many species (Ye et al. 2016). For example, the estuarine resident small-mouthed hardyhead, one of the most salt-tolerant species, was not present in the Coorong South Lagoon during the latter stage of the drought period (Ye et al. 2011). Meanwhile the distributions of several commercially important estuarine (e.g. black bream) and marine-estuarine opportunist species (e.g. greenback flounder) were largely restricted to within the Murray Estuary (Ye et al. 2017). The drought ultimately led to significant changes in the fish assemblage structure in the Murray Estuary and Coorong, which was characterised by reduced abundances of freshwater, estuarine and diadromous species and an increased dominance by some marine-estuarine opportunist species (e.g. yelloweye mullet) and marine stragglers (Ye et al. 2016).

Following the return of freshwater inflows in 2010, salinities were reduced throughout the Murray Estuary and Coorong, which led to an overall increase in fish abundance and species diversity (Ye et al. 2015b). Reduced salinities resulted in southward range extensions for many species, including solely estuarine species (e.g. Tamar River goby and black bream), marine estuarine opportunist species (e.g. sandy sprat and greenback flounder) and diadromous species (e.g. congolli), with some of these species recorded in the Coorong South Lagoon for the first time since 2001 (Ye et al. 2015b). The return of freshwater inflows resulted in enhanced recruitment and abundances of a number of estuarine and marine estuarine opportunist species, particularly small-bodied fish in the Coorong North Lagoon (Ye et al. 2015b).

Overall, increased freshwater inflow to the Murray Estuary and Coorong facilitated enhanced recruitment, abundance and distribution of estuarine, diadromous and marine estuarine opportunist species, but with reduced inflows between 2013 and 2015, the estuarine fish assemblage is transitioning towards that characteristic of drought/low flow years (Ye et al. 2016).

## **Biodisparity**

The number of families recorded annually ranged between 15 and 17 from 2006–07 to 2014–15. The greatest number of families was recorded in 2006–07 and 2011–12 and the least was recorded in 2007–08 (Figure 8.8). Between 2006–07 and 2014–15 the LAC threshold of 13 families present within the Ramsar site was never exceeded, however there were changes in the presence of families across the subunits. Pouched lamprey, while exhibiting low frequencies of occurrence, were present in 2006–07 but absent through 2007 to 2010 (Bice et al. 2015). Only one family of fish (represented by small-mouthed hardyhead) was present in the Coorong South Lagoon between 2006–07 and 2010–11, except for 2009–10, when a second family (represented by the Western blue spot goby) was also recorded.

Overall, the number of families recorded in the Murray Estuary and Coorong North and Coorong South lagoons were lowest in 2007–08 and greatest in 2011–14, reflecting the variability in freshwater inflows and barrage outflows and subsequent salinity changes in the Murray Estuary and Coorong over this period. Salinity throughout much of the Coorong between 2011 and 2014 was substantially reduced relative to 2007 to 2010, promoting the co-occurrence of representatives from estuarine and marine families with freshwater families (Bice and Zampatti 2015; Ye et al. 2016).

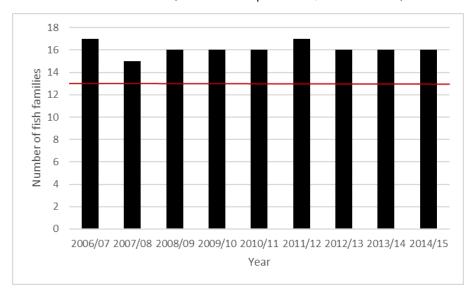


Figure 8.8 Number of families sampled from the list of 17 nominated families between 2006–07 and 2014–15. Red line represents the LAC threshold of 13 families.

## Movement and recruitment LAC

In response to declining freshwater inflows and water levels in the Lakes during the Millennium Drought, the barrages (including fishways) were shut in March 2007, disconnecting the Lakes from the Coorong until September 2010 (Bice et al. 2018). Following the closure of the barrages, the abundance of diadromous fish species declined and records suggested, for example, that reproductively mature fish (i.e. of female congolli) were attempting to undertake migrations but were obstructed by the closed barrages, resulting in the failure to reach spawning grounds (Bice and Zampatti 2015). This period may have resulted in a depleted population of reproductively mature adult fish due to the lack of connectivity and reduced recruitment (Bice and Zampatti 2015).

In contrast, the period between 2010 and 2015 was characterised by continuous freshwater discharge and connectivity (Bice et al. 2018). From September 2010, freshwater discharge and connectivity allowed adults to undertake migrations through the barrages, resulting in a gradual increasing trend in abundances of diadromous fish species between 2010–11 and 2014–15 (Bice and Zampatti 2015). Peak abundances of Congolli and Common galaxias were recorded in 2014–15 and likely reflects the

cumulative benefit of multiple consecutive years of enhanced connectivity, despite freshwater discharges decreasing between 2011–12 and 2014–15 (Bice and Zampatti 2015). Specific changes in the movement and recruitment of congolli and common galaxias in reference to the LAC are described below.

## Congolli recruitment (Young-of-year)

Young-of-year (YOY) congolli have been sampled from sites at the barrages since 2006-07, except for 2012-13 when no fishway monitoring was conducted. Average abundance of YOY from all monitoring stations fluctuated in response to changes in connectivity between the Lakes and Coorong (Bice and Zampatti 2015). Following the disconnection of the Lakes and the Coorong, abundance of upstream migrating YOY congolli declined from 18 fish per hour in 2006–07 to less than 0.8 fish per hour in 2007–08, 2008–09 and 2009–10. Abundances of congolli increased significantly in spring/summer 2010–11 and continued to increase in subsequent years. Peak abundance (approx. 400 fish per hour) was recorded in 2014–15 (Figure 8.9).

## Common galaxias recruitment (Young-of-year)

The abundance of YOY common galaxias declined from approximately 12 fish per hour in 2006–07 to less than 0.05 fish per hour during sampling in 2007–08 and 2008–09. Following reconnection, abundances of YOY common galaxias continued to increase annually, peaking at approximately 30 fish per hour in 2014–15 (Figure 8.9).

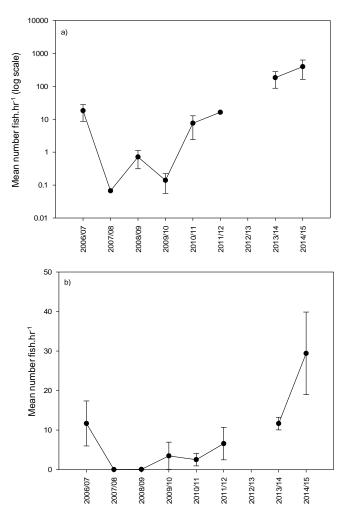


Figure 8.9 Mean relative abundance (fish per hour) of a) YOY congolli and b) YOY common galaxias sampled from sites at the barrages annually from 2006–07 to 2014–15 (developed using data from Bice and Zampatti 2015).

Increases in the abundance of YOY for congolli and common galaxias, particularly the successful recruitment detected in 2014–15 were likely the result of a combination of 2 factors: (1) high levels of hydrological connectivity between freshwater and marine habitats and subsequent favourable conditions for migration, spawning and survival of larvae and juveniles under brackish conditions; and (2) enhanced spawning output as a result of the high abundance of reproductively mature males (Bice and Zampatti 2015). These trends highlight the importance of freshwater inflows and the maintenance of connectivity between the Lakes, Coorong and the Southern Ocean on an annual basis and the influence of consecutive favourable years on the population dynamics of these diadromous fish species (Bice et al. 2018).

## Threatened species LAC

A survey undertaken by Wedderburn and Hammer in 2003 represents the baseline information in assessing condition of the threatened fish species (i.e. Murray hardyhead) within the Ramsar site (Wedderburn 2017). At that time relatively little was known of the distribution and habitat requirements of Murray hardyhead. Abundance data suggested suitable environmental conditions on Hindmarsh Island supported a core population, with ephemeral sites maintained by distant dependent colonisation (Wedderburn and Hammer 2003).

As the Millennium Drought progressed through 2007 to 2010, reduced river flows led to water level recession in the Lakes, desiccating fringing littoral vegetation and off-channel habitats, critical to Murray hardyhead (Bice et al. 2018). There was a corresponding decline in the abundance of this threatened fish species (Bice et al. 2018, Figure 8.10). In light of these substantial changes to the habitats and character of freshwater fish assemblages, several management actions (e.g. environmental watering, fish capture and captive maintenance/ breeding) were implemented to support the survival of these species (Hammer et al. 2013; Bice et al. 2018).

The salt-tolerant Murray hardyhead persisted through the drought and showed signs of population recovery in the south-western region of Lake Alexandrina (Bice et al. 2018). Following the return of stable water levels greater than +0.5metres AHD in late 2010 and favourable habitat within the Lakes (in spring 2011), approximately 7,500 Murray hardyhead were reintroduced into Lake Alexandrina from 2011 to 2013 (Bice et al. 2014). There is evidence of self-sustaining populations of Murray hardyhead following return of freshwater inflows and reintroductions (Wedderburn and Barnes 2014).

Specific changes in the abundances and recruitment of Murray hardyhead in reference to the LAC are described below.

# Murray hardyhead

Murray hardyhead has had a long-term presence in the Lakes, with several collections made from the Finniss River arm in the 1980s (Wedderburn and Hammer 2003). Lloyd and Walker (1986) recorded species at the mouth of the Angas River. Regular surveys as part of pygmy perch and environmental flows monitoring failed to detect this species in these locations in the years preceding the 2003 survey (Wedderburn and Hammer 2003). The 2003 survey found Murray hardyhead to be more widespread in the Lakes than previously recognised (Wedderburn and Hammer 2003). It had disappeared from several sites where it had been previously known but was found at 10 sites in broad proximity to Hindmarsh Island (Wedderburn and Hammer 2003). The abundance of Murray hardyhead recorded in 2005 was the largest catch recorded in the region and followed a period of medium to high lake water levels (Bice et al. 2008).

Murray hardyhead abundance in the Lakes declined substantially in the period 2007 to 2010, in response to declining freshwater inputs, increasing salinity and loss of aquatic vegetation and littoral habitat (Bice et al. 2013; Bice et al. 2018). Relatively low numbers of Murray hardyhead were recorded in October 2007 and February 2008 (Wedderburn and Barnes 2013). The subsequent increase in relative abundances in 2008–09 is likely a reflection of the concentration of the species in off-channel

sites during the drought (i.e. easier to catch), which was followed by a substantial decline as sites dried over 2009–10 (Figure 8.10) (Wedderburn and Barnes 2013). In November 2009, relatively low numbers of Murray hardyhead were captured at lake edges, natural channels and modified channels (connected and isolated sites) and a relatively high number in a drainage channel on Mundoo Island (Wedderburn and Hillyard 2010). In March 2010, a relatively low number of Murray hardyhead was recorded at a newly selected site adjacent the Hindmarsh Island Bridge, which was inundated only because of the Clayton regulator and moderate numbers were captured from channels at Dog Lake and Boggy Creek (Wedderburn and Hillyard 2010).

Abundance did not increase substantially following increased freshwater inputs to the Lakes in 2010–11, in part due to the mobility of the species. This may have been due to dispersal of relatively small numbers of fish, making detection of individuals difficult (Bice et al. 2011). The species was undetected in 2011–12 in the Living Murray Icon Site threatened fish condition monitoring, but 13 individuals were captured as part of the CLLMM Recovery Project's Critical Fish Habitat (CFH) Project (Bice et al. 2012). In the 2 surveys conducted in 2012 the numbers of Murray hardyhead recorded were relatively low, but substantial increases in abundances were recorded in 2013 (n = 65, Figure 8.10) (Bice et al. 2013). The majority (n = 56) of the Murray hardyhead recorded in the 2013 survey were not re-introduced fish, suggesting they were part of the wild population (Bice et al. 2013).

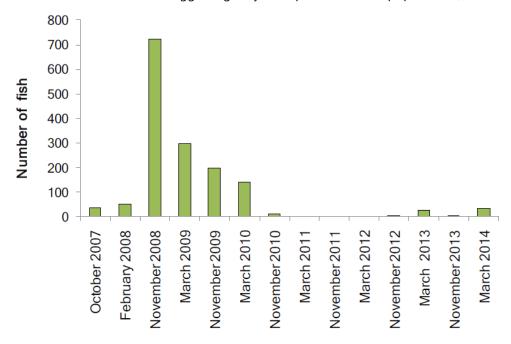


Figure 8.10 Murray hardyhead recorded in The Living Murray (TLM) threatened fish condition monitoring in the Lakes (Critical Fish Habitat – reintroductions data excluded) (Wedderburn and Barnes 2014).

The 2012–13 threatened fish condition monitoring detected Murray hardyhead within the Finniss River and Goolwa Channel area, in addition to a few individual fish at one of the re-introduction sites on Mundoo Island (Wedderburn and Barnes 2013). The 2012–13 monitoring identified a single cohort of adult fish in spring 2012 and 2 distinct cohorts in autumn 2013, indicating Murray hardyhead recruitment in the Lakes at this time (Wedderburn and Barnes 2013). A single cohort of adult fish was detected in spring 2013 and a distinct cohort of young-of-year fish was also apparent in autumn 2014, confirming recruitment of Murray hardyhead in the Lakes at this time (Wedderburn and Barnes 2014). In autumn 2015, Murray hardyhead were captured at 7 of the 24 sites, with a total abundance of 56 fish (Wedderburn and Barnes 2016).

Murray hardyhead appears to have been more resilient to the drought than other threatened fish, possibly due to its higher salinity tolerance (Ye et al. 2016). Environmental water delivery during the drought is likely to have facilitated the species persistence in low abundances in specific refuge areas in Lake Alexandrina (Ye et al. 2016). This may have contributed to their initial population recovery post-drought, in addition to reintroduction efforts (Bice et al. 2012). Increased freshwater inflows, higher lake water levels and improved connectivity are likely to have facilitated the dispersal of Murray hardyhead throughout this region in the Ramsar site (Ye et al. 2016).

Based on the presence of Murray hardyhead (Figure 8.10) the LAC was exceeded between March 2011 and March 2012, as Murray hardyhead were absent from 3 targeted surveys (i.e. March and November 2011 and March 2012).

#### 8.3.5 Waterbirds

The Ramsar site supports significant numbers of waterbird species across each of the 4 main sub regions (Lakes, Murray Estuary, Coorong North Lagoon and Coorong South Lagoon). Although most species that were present at time of listing still use the site today, many do so with reduced frequencies and in much lower abundances (BirdLife Australia 2015; Paton 2010; Paton et al. 2009a).

Numerous studies show that waterbird numbers have declined within Australia and globally over the past 20 years, possibly longer (Rogers and Paton 2008; Wainwright and Christie 2008; Kingsford and Porter 2009; Paton and Rogers 2009; Paton 2010; Thiessen 2011; O'Connor et al. 2012). O'Connor (2015a) noted that despite the extensive monitoring of waterbird populations in the Ramsar site since the early 2000s, the information base required for the assessment of ecological character change remains limited by:

- a lack of adequate baseline data around time of Ramsar listing
- limited continuous and spatially adequate datasets to assess changes over consecutive years.

The main datasets used to assess the waterbird LAC and document the changes since listing are described in Table 8.3 in Appendix D (noting breeding records and data are separate to this, see Appendix B for breeding records).

## Diversity (species richness) LAC

## **Lakes Alexandrina and Albert**

During the 2000s (particularly the mid to late 2000s) the Ramsar site experienced substantial perturbations, with unprecedented low lake water levels (dropping well below sea level) and the disconnection of fringing aquatic vegetation from the water (Paton et al. 2015a). Extensive areas of mudflats were exposed for the first time, which changed the waterbird community using the Lakes substantially (Paton and Bailey 2011a; (Paton and Bailey 2012b; Paton and Bailey 2013). Reed-dependent waterbirds were largely absent and species that were common in the early 2000s dropped to very low numbers or were absent during this time (e.g. eurasian coot, great crested grebe, little pied cormorant and pink-eared duck) (O'Connor 2015a, Paton et al. 2015a). Conversely during this time, a range of shorebirds (e.g. sandpipers, plovers and stilts) utilised the exposed mudflats of the Lakes, particularly those that abutted the Coorong (Paton et al. 2015a).

With the re-instatement of freshwater inflows in late 2010, waterbird species utilising the Ramsar site changed, due to the large volume of inflows and rapid filling of the site (Paton et al. 2015a). Many shorebirds and other species that typically forage while wading in shallow water (e.g. egrets, herons and spoonbills) were excluded from their usual feeding niches due to the high water levels which limited their accessibility (Paton et al. 2015a). From 2011, the re-establishment of typical lake water levels and submergent and emergent vegetation around the margins of the Lakes, saw the return of

waterbird communities that were assumed (expected) to have existed prior to the Millennium Drought (Paton et al. 2015, Paton et al. 2018).

In 2015, the waterbird diversity in the Lakes were characterised by large numbers (greater than 1,000 birds in the highest count between December and March) of silver gulls; piscivorous species such as the great cormorant, Australian pelican and whiskered tern; and waterfowl including chestnut teal, grey teal and Pacific black duck (O'Connor 2015a, Paton et al. 2015).

The Lakes waterbird community did not meet the target of 17 of the 20 selected waterbird species having counts above their 10<sup>th</sup> percentile abundance in 2009 and 2011. As the years were not consecutive the LAC for Lakes Alexandrina and Albert waterbird diversity was not exceeded between 2009 and 2015 (Figure 8.11).

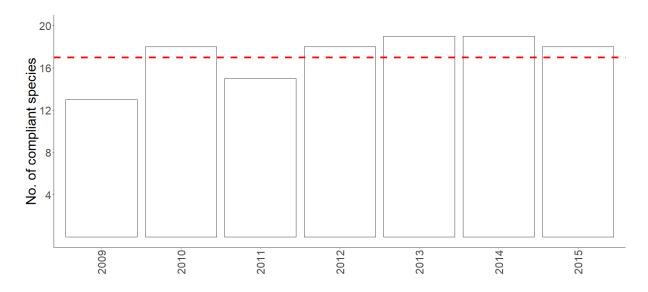


Figure 8.11 Number of target species that met their 10<sup>th</sup> percentile abundances for the Lakes Alexandrina and Albert waterbird diversity LAC between 2009 and 2015. The red line denotes the LAC for the number of compliant species (17).

# **Murray Estuary**

The Murray Estuary supports waterbirds across a broad range of guilds, including high shorebird species diversity (O'Connor 2015a). This sub-unit is characterised by more marine conditions, supporting species such as sanderling, Eastern curlew and black-tailed godwit. These species are far less common in other parts of the Ramsar site (O'Connor 2015a). The Murray Estuary sub-unit generally supports the greatest diversity of waterbird species (Paton et al. 2015c).

High barrage flows over 2010-11 to 2011-12 limited the availability of mudflat in the Murray Estuary. The target of 18 of the 21 selected waterbird species having counts above their 10<sup>th</sup> percentile abundance were not met in 2010, 2011 and 2012. The target has been met in every other year. As a result the LAC for Murray Estuary waterbird diversity was only exceeded in 2011 and 2012 (Figure 8.12).

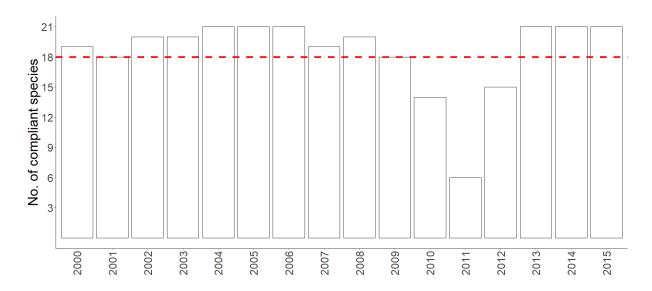


Figure 8.12 Number of target species that met their 10<sup>th</sup> percentile abundances for the Murray Estuary/Goolwa Channel waterbird diversity LAC between 2009 and 2015. The red line denotes the LAC for the number of compliant species (18).

## **Coorong North Lagoon**

For the Coorong (and the Murray Estuary), there were no substantial River Murray flows over the barrages for almost 8 years between 2002 and 2010 (Paton et al. 2015b). This disrupted seasonal water levels and the salinity regime of the Coorong. Changes to flows and salinity, and the distribution and abundance of key food resources, affected the distribution and abundance of waterbirds in the Coorong (Paton et al. 2015b).

The target of 19 of the 23 selected waterbird species having counts above their 10<sup>th</sup> percentile abundance was not met in 2008, 2010 and 2011. The target has been met in every other year since. The trigger was only exceeded for 2 consecutive years in 2011. The LAC for Coorong North Lagoon waterbird diversity was only exceeded in 2011 (Figure 8.13).

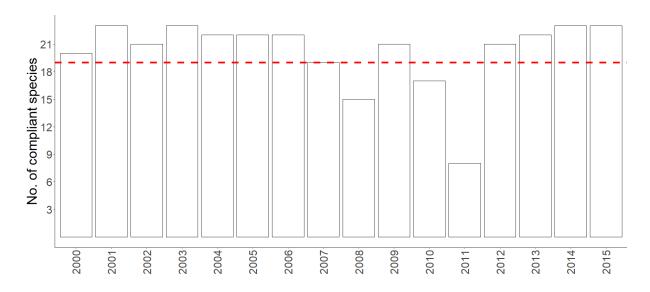


Figure 8.13 Number of target species that met their 10<sup>th</sup> percentile abundance for the Coorong North Lagoon waterbird diversity LAC between 2000 and 2015. The red line denotes the LAC for the number of compliant species (19).

## **Coorong South Lagoon**

During the Millennium Drought the lack of freshwater inflows severely disrupted the seasonal patterns in water levels and resulted in the accumulation of excessive amounts of salt in the Coorong South Lagoon (Paton et al. 2015b; 2018). This led to changes in the distribution and abundance of key aquatic food resources (e.g. plants, invertebrates and fish) used by waterbirds (Paton et al. 2018). These changes in turn affected the distribution and abundances of waterbirds, with many piscivorous (e.g. fairy tern) and herbivorous (e.g. black swan) bird species no longer using the Coorong South Lagoon (Paton 2010). During this time banded stilt took advantage of the abundance of brine shrimps. Some other species switched their normal food source to feed on brine shrimp (e.g. hoary-headed grebe, chestnut teal, whiskered tern) (Paton et al. 2015b).

The return of freshwater inflows in spring 2010 diluted the high salinities in the Coorong South Lagoon (Paton et al. 2018). This supported the quick re-colonisation of chironomids (a key food resource in the Coorong South Lagoon), but there was a lag-effect on the abundance and distribution of small-mouthed hardyhead in the Coorong South Lagoon and limited recovery of *R. tuberosa* during this time (Paton et al. 2015b). As at 2015, species are still present but the abundances for some species (e.g. common greenshank) are lower than they were in January 2010, at the end of the Millennium Drought (Paton et al. 2015). Abundances of other species, particularly waterfowl, remain low in the Coorong South Lagoon, despite extensively using this area in the past (Paton et al. 2015b).

The target of 18 of the 21 selected waterbird species having counts above their 10<sup>th</sup> percentile abundance was not met in 2008, 2009, 2010 and 2011. The target has been met in every other year since. As a result the LAC for Coorong South Lagoon waterbird diversity was only exceeded from 2009 to 2011 (Figure 8.14). The likely cause of this change in the Coorong South Lagoon was the degradation of waterbird habitat (O'Connor 2015a).

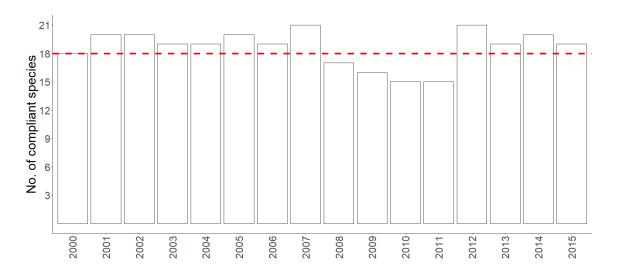


Figure 8.14 Number of target species that met their 10<sup>th</sup> percentile abundance for the Coorong South Lagoon waterbird diversity LAC between 2000 and 2015. The red line denotes the LAC for the number of compliant species (18).

#### **Abundance**

### **Total abundance across the Ramsar site LAC**

The Ramsar site has consistently supported more than 90,000 waterbirds since data collection began. The Coorong generally supports twice as many birds as the Lakes in summer, with the average number of birds supported in the Coorong (in January) greater than 167,000 between 2000 and 2015 compared to an average of 79,000 birds in the Lakes between 2009 and 2015 (Paton et al. 2015c). During the Millennium Drought the Ramsar site was an important waterbird refuge and supported over 400,000 waterbirds at times (Paton et al. 2015c).

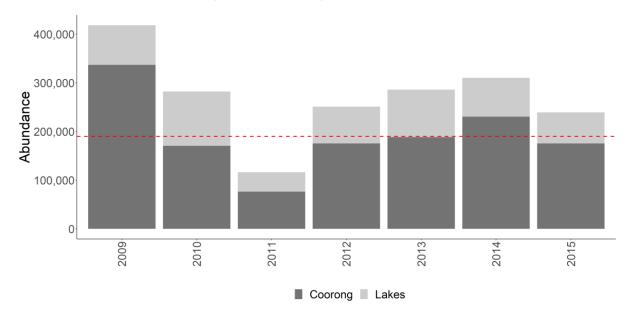


Figure 8.15 Total abundance of waterbirds in the Ramsar site between 2009 and 2014. The red line denotes the LAC threshold for annual total abundance (190,122).

In January 2015 over 175,000 waterbirds (59 species) were counted in the Coorong, with grey teal, hoary-headed grebe, red-necked stint and sharp-tailed sandpiper present in abundances that exceeded 10,000 individuals (Paton et al. 2016). These 4 species accounted for more than 5% of the birds counted and collectively over 50% of the total birds counted (Paton et al. 2016). Four other species were present in abundances that approached or exceeded 5,000 individuals, including Australian shelduck, whiskered tern, silver gull and red-necked avocet (Paton et al. 2016). At this time, the Coorong North Lagoon had over 102,000 waterbirds present, compared with over 35,000 in the Murray Estuary and nearly 37,000 in the Coorong South Lagoon (Paton et al. 2016).

Overall, most waterbird species occur at much lower abundances now than they did 30 to 40 years ago (Paton et al. 2009a, Paton 2010). The abundance of waterbirds using the Ramsar site varies from one year to the next. These variations can be substantial (Paton et al. 2015c). An extreme example is the banded stilt. In January 2009 there were in excess of 210,000 banded stilts using the Coorong, but between 2013 and 2015, fewer than 2,000 have been present in any year (Paton et al. 2015c). The factors influencing the abundances of various waterbirds using the Coorong and Lakes in any one year are poorly understood, but factors outside the site as well as factors within the wetlands themselves are likely to be influential (Paton et al. 2015c).

High barrage flows over 2010-11 to 2011-12 limited the availability of mudflat through significant increases in water level and dampening of the tidal signal in the Coorong, reducing the extent of foraging habitat for migratory shorebirds (Paton and Bailey 2012b). High barrage flows are characteristic of the dynamic hydrology of the Coorong (Gibbs at al. 2018) and help prime the system for beneficial ecological condition (Lester et al. 2011). Accordingly, single year reductions in waterbird

abundance that overlap with high flow years should be considered to be within natural variation. Based on the information above and the assessment shown in Figure 8.15 above, the LAC threshold of 190,122 has not been exceeded between 2009 and 2015.

# Presence/absence of priority migratory shorebird species LAC

Within Australia, the Coorong is consistently identified as a critical wetland site in terms of the diversity and numbers of international migratory shorebirds that it supports every summer (Bamford et al. 2008; Kingsford et al. 2012; Paton et al. 2009b; Watkins 1993). Seven migratory shorebird species (black-tailed godwit, common greenshank, curlew sandpiper, pacific golden plover, red-necked stint, sanderling and sharp-tailed sandpiper) occur at the site on a regular basis (i.e. recorded 15 or more of the 16 seasons for which counts were made) (O'Connor 2015a).

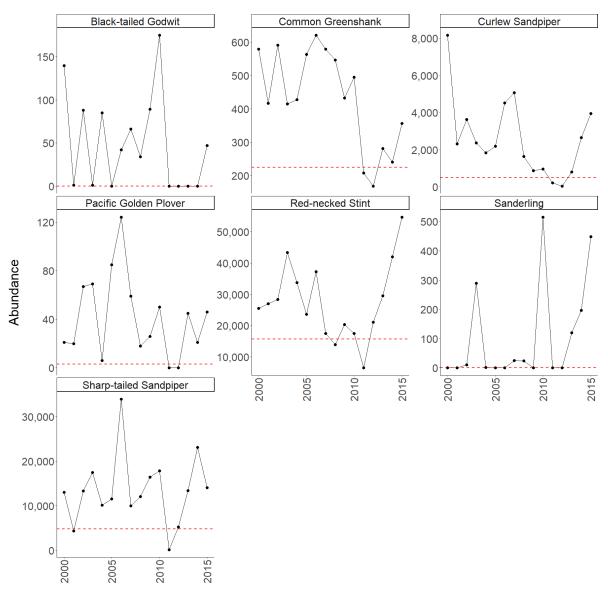


Figure 8.16 Annual abundances of priority species in the Coorong from 2000-2015 with respect to their 10<sup>th</sup> percentile abundance (red dashed line) based on a 2000-15 baseline.

All 7 priority migratory shorebird species have experienced population declines in the Coorong since time of listing. Black-tailed Godwit were not detected for 4 consecutive censuses (2011-14). Counts for common greenshank, curlew sandpiper and pacific golden plover were below their 10<sup>th</sup> percentile abundance for 2 consecutive years in 2011-12 but have since recovered. Counts for red-necked stint

(2008, 2011) and sharp-tailed sandpiper (2001, 2011) were below their 10<sup>th</sup> percentile abundance in 2 non-consecutive years and sanderling have been detected every year.

Based on the LAC assessment above the priority migratory species LAC was exceeded during 2011-12 when barrage flows were well above the mean annual end of system discharge post regulation. High barrage flows dampen the tidal signal which can reduce the extent of mudflat available for shorebird foraging.

## Percent of 1% of East Asian Australasian Flyway population for selected species LAC

Waterbird counts show that the Ramsar site regularly supports 1% of the individuals in a population of the 3 target species of migratory shorebirds in the East Asian Australasian Flyway (curlew sandpiper, red-necked stint and sharp-tailed sandpiper (Figure 8.17). The target species are those that are regularly (3 out of 5 years on average) present in numbers that exceed the most recent 1% flyway population estimates (using population estimates from Hansen et al. 2016 and abundance numbers from University of Adelaide, D Paton 2000–15).

The 3 target species all had higher abundances in the 1980s and 1990s (O'Connor 2015a). O'Connor (2015a) notes that although the current understanding is that that local waterbird counts are impacted by local environmental conditions, there is still an ongoing need to understand these changes within the context of broader waterbird habitat availability nationally and globally. For example, curlew sandpiper numbers have continued to decline in recent years, reaching a low of just 49 individuals in 2012 (i.e. failed to meet baseline flyway contribution) (Figure 8.17). This species may be affected by ecological conditions at other sites along the East-Asian Australasian flyway (Bamford et al. 2008; Aman et al. 2010), in addition to responses to local changes in condition.

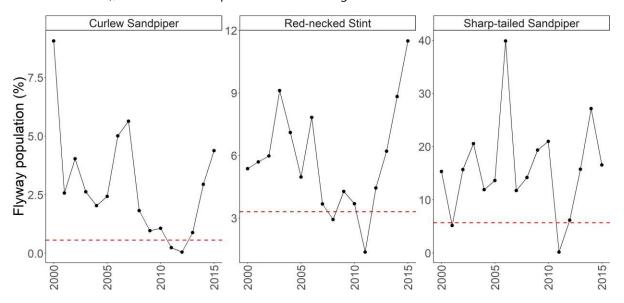


Figure 8.17 Abundances of the 3 target species of the 1% flyway population LAC. Red lines represents the 10<sup>th</sup> percentile abundance for each target flyway species: Curlew sandpiper (0.56%), Red-necked stint (3.30%) and Sharp-tailed sandpiper (5.67%).

The target of the 10<sup>th</sup> percentile percentage of the flyway population of curlew sandpiper was not met in 2011 and 2012. The census years were consecutive and the LAC threshold was exceeded. The target for red-necked stint was not met in 2008 and 2011 and the target for sharp-tailed sandpiper was not met in 2001 and 2011. The census years were not consecutive and the LAC thresholds were not exceeded. Based on the assessment above (Figure 8.17) the migratory shorebird abundance LAC has been met in all years as only curlew sandpiper failed to meet its 10<sup>th</sup> percentile abundance in 2011-12.

## Percent of 1% Australian population for selected species LAC

The Ramsar site also plays a significant role in regularly supporting 1% or more of the Australian population for 4 non-migratory bird species (Australian pied oystercatcher, chestnut teal, Australian fairy tern and red-capped plover). The target species are those that are regularly (3 out of 5 years on average) present in numbers that exceed the most recent 1% Australian population estimates (using population estimates from Wetlands International 2013 and abundance numbers from University of Adelaide, D Paton 2000–15).

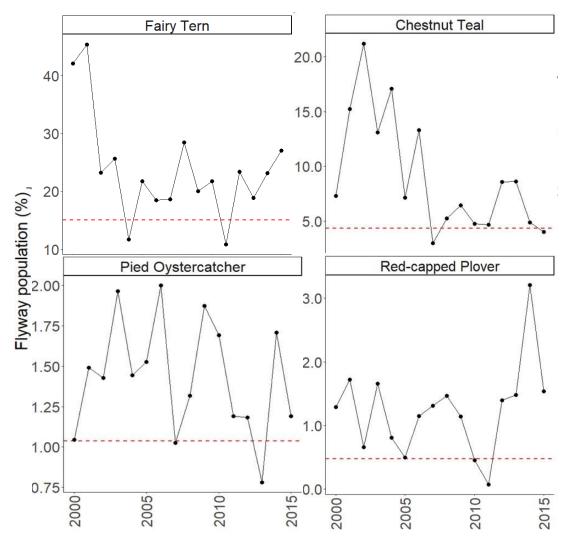


Figure 8.18 Abundances of the 4 target species of the 1% Australian population LAC. Red lines represent the 10<sup>th</sup> percentile abundance for each target flyway species: Australian fairy tern (15.1%), chestnut teal (4.30%), Australian pied oystercatcher (1.04%) and red-capped plover (0.48%).

Figure 8.18 above presents the January census data of the abundances of Australian fairy tern, chestnut teal, Australian pied oystercatcher and red-capped plover in the Coorong (including the Murray Estuary) between 2000 and 2015, which forms the basis of the assessment of the LAC.

The target of the 10<sup>th</sup> percentile percentage of the total population of Australian fairy tern was not met in 2004 and 2011. Likewise the target for chestnut teal was not met in 2007 and 2015 and the target for Australian pied oystercatcher was not met in 2007 and 2013. The census years were not consecutive and the LAC thresholds were not exceeded. The 10<sup>th</sup> percentile percentage of the total population target for red-capped plover was not met in 2010 and 2011 and as the years were consecutive the LAC threshold was exceeded. However as the LAC threshold was not exceeded for another species the LAC is not exceeded.

# **Breeding**

# **Number of breeding events LAC**

Waterbird breeding records for the entire Ramsar site are limited, particularly at the time of listing, and more recent data is also sporadic and only regularly collected for a few species (Table 8-1) (O'Connor 2015a). This lack of data makes it difficult to assess change in this critical process (O'Connor 2015a).

Table 8-1 Breeding records for species that breed annually or regularly in the Coorong and Lower Lakes (O'Connor 2015a).

Scientific name	Common name	Years recorded breeding since 1985	LAC status		
Annual breeding species					
Pelecanus	Australian	No data 1985–2002, 2007, 2008	Data deficient		
conspicillatus	pelican	No breeding (little to no breeding)2003–2005 <sup>8</sup>	LAC exceeded 2003–05		
		Breeding records: 2006, 2009–14 <sup>1,2</sup>			
Cygnus atratus	Black swan	No data 1985–2010, 2014	Data deficient		
		Breeding records: 2011–13 <sup>1,5</sup>	LAC not exceeded 2011–14		
Hydroprogene	Caspian tern	No data: 1985–96, 1998–2006	Data deficient		
caspia		Breeding records: 1997, 2007–14 <sup>1,3</sup>	LAC not exceeded 2007–14		
Thalasseus	Crested tern	No data: 1985–96	Data deficient		
bergii		Breeding records: 1997–2014 <sup>1</sup>	LAC not exceeded 1997– 2014		
Threskiornis	Australian	No data: 1985–2011, 2014	Data deficient		
molucca	white ibis	Breeding records: 2012–13 <sup>5</sup>			
Threskiornis	Straw-necked	No data: 1985–99, 2001–10, 2013–14	Data deficient		
spinicollis	ibis	Breeding records: 2000 <sup>6</sup> , 2012–13 <sup>5</sup>			
Sternula nereis	Australian	No data: 1987–96, 2001–03, 2008	Data deficient: fledging		
	fairy tern	No successful breeding: 2004–058,	success limited		
		Breeding records: (successful attempts): 1985–1986, 1997–2000 <sup>9, 10</sup> , 2006, 2007, 2009 <sup>10</sup> 2010–14 <sup>1,2</sup>			
Haematopus	Australian	No data: 1985–2007, 2011, 2013	Data deficient: success of		
longirostris	pied oystercatcher	Breeding records: 2008 <sup>7</sup> , 2009 <sup>1</sup> , 2010, 2012 <sup>7</sup> , 2014 <sup>1</sup>	breeding attempts unknown		
Thinornis	Hooded	No data:	Data deficient		
rubricollis plover		Breeding records: 2008, 2010, 2012 <sup>7</sup> , 2014 <sup>7</sup>	LAC not exceeded 2008-14		
Charadrius	Red-capped	No data:	Data deficient: success of		
ruficapillus plover		Breeding records: 2003 <sup>1</sup> , 2008, 2010, 2012 <sup>7</sup> , 2014 <sup>7</sup>	breeding attempts unknown		

Scientific name	Common name	Years recorded breeding since 1985	LAC status
Regular breedin	g species		
Phalacrocorax varius	Pied cormorant	No data: 1985–2010, 2014  Breeding records: 2011–13 <sup>1,5</sup>	Data deficient  LAC not exceeded 2012-13
Platalea regia	Royal spoonbill	No data: 1985–2012, 2014  Breeding records: 2013 <sup>5</sup>	Data deficient
Chroicephalus novaehollandiae	Silver gull	No data: 1985–2012, 2014  Breeding records: 2013 <sup>5</sup>	Data deficient

Data sources: 1: University of Adelaide annual census data (D Paton), 2: DENR pelican monitoring, 3: 1997 Fairy Tern survey (A Partridge), 4: DENR fairy tern surveys, 5: DEWNR colonial-nesting waterbird aerial surveys, 6: Eckert (2000), 7: Birdlife Beach-nesting Birds surveys, 8: Paton (2005), 9: Paton (2003), 10: Paton (2013).

Based on the breeding records available for the annual breeding species, the Australian pelican failed to have a successful breeding event between 2003 and 2005 (Table 8-1) (O' Connor 2015a). This species is iconic to the Ramsar site and believed to be an annual breeder, with large colonies characteristic of the system. Pelicans typically nest on the islands of the Coorong South Lagoon, but the high salinities and reduced numbers of small fish prey during this period are believed to have led to the failed breeding (Paton 2005). In the mid-later stages of the Millennium Drought, species including crested tern and Caspian tern still bred, despite the Coorong South Lagoon supporting no fish (Paton et al. 2015c).

Fairy terns experienced low and intermittent nesting success during the Millennium Drought and vacated their breeding islands in the Coorong South Lagoon to attempt to breed near the Murray Mouth. They had limited success due to human disturbance and fox predation (Paton et al. 2015c). Fairy tern numbers and breeding success have improved since, but the population is only 26% of the size of the Coorong South Lagoon population at the time of Ramsar listing (O'Connor 2015a).

During the late 2000s, pied cormorants did not breed due to the exceptionally low water levels in the Lakes and the disconnection of the reeds from the water line (Paton et al. 2015b).

Following the drought, significant breeding events occurred for a number of species including strawnecked ibis (greater than 1,600 nests), Australian white ibis (greater than 600 nests) and pied cormorant (greater than 900 nests) in the Lakes and Australian pelican (greater than 2,000 nests) and greater crested tern (greater than 4,000 nests) on islands in the Coorong South Lagoon (O'Connor et al. 2013).

Overall waterbird breeding continues at the Ramsar site but there have been noticeable declines in some species. Further targeted surveys are required to make a full assessment against the LAC, as there is insufficient data to assess many of the target species. There is evidence for 3 years or more of unsuccessful breeding events for Australian pelicans (2003–05), which indicates that the LAC for annual breeding species may have been triggered (O'Connor 2015a).

## Threatened species

## Australasian bittern (Talkuri) LAC

Australasian bittern (*Botarus poiciloptilus*) has been recorded from 7 locations around the freshwater components of the Ramsar site (Figure 8.19). O'Connor et al. (2013) reported 20 records from localities within the Ramsar site and noted that the site is a stronghold for this endangered species within South Australia, which has a bittern population estimated at 26 to 116 individuals (BirdLife International 2012). Given the cryptic nature of this species, coupled with a low survey effort until recently, it is likely that the utilisation of the site by this species may be greater than already documented.

Data on the Australasian bittern is limited to relatively recent surveys of cryptic species (O' Connor 2015b) and currently is insufficient to assess against the LAC. The species has been recorded at several sites around the Lakes and it is likely that the LAC would be met in future.



Figure 8.19 Location of 2012 cryptic waterbird surveys sites from O'Connor et al. (2013). (Reedy Island shown in yellow was only surveyed on one occasion). Australasian bittern were recorded from Finniss River, 'Jacobs', Clayton Bay, Loveday Bay, Pomanda Point, Narrung Narrows and Tolderol.

## Australian fairy tern (Talamarari) LAC

At the time the Ramsar site was listed, the Coorong supported a fairy tern (*Sternula nereis nereis*) population of approximately 1,500 individuals, with 1,330 being recorded for the Coorong South Lagoon alone in January 1985 (Paton 2010). From 1974 to 2006, the entire fairy tern population underwent a 24% decline and this rate of decline was expected to continue for the next 3 generations (i.e. 33 years) (TSSC 2011). There have been significant declines of the population of fairy tern in the Coorong (Paton et al. 2009a), with greater than 600 birds recorded in 2000–01 compared to 283, 347 and 406 birds recorded in 2013, 2014 and 2015 respectively (Figure 8.20).

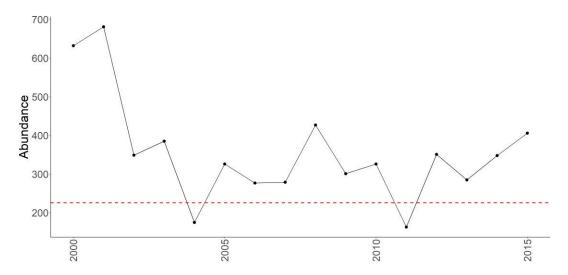


Figure 8.20 Total count of fairy terns in January in the Coorong from 2000–15 (Data from the January census, D Paton). Red line represents the 10<sup>th</sup> percentile abundance of fairy tern (226).

Within the Ramsar site, fairy tern abundance and distribution can vary. Paton and Bailey (2014) noted that during the years 2000 to 2003, fairy terns were using both the Coorong North and Coorong South lagoons, but between 2007 and 2011 they used the Coorong North Lagoon and Murray Estuary to a much greater extent than the Coorong South Lagoon, consistent with the limited food availability (i.e. small-bodied fish) in the Coorong South Lagoon.

The numbers of fairy terns since 2012 have been relatively stable (Figure 8.20) (O'Connor at al. 2013; Paton and Bailey 2014b). As a result of shifting ecological conditions following the Millennium Drought, fairy tern have shown a decline in the use of the Coorong North Lagoon and a return to the Coorong South Lagoon (O'Connor and Rogers 2014). In 2015 the birds were more widely dispersed compared to the previous 2 years. This may be due to fewer birds tied to breeding islands (Paton et al. 2015d).

In January 2015, a total of 406 fairy terns (above the median baseline abundance of 337 fairy terns) were recorded in the Coorong and were largely present across the northern half of the Coorong South Lagoon and the southern half of the Coorong North Lagoon (Figure 8.21) (Paton et al. 2015d). At this time no fairy terns were recorded in the Murray Estuary, consistent with recordings in the previous 2 years (Paton et al. 2015d).

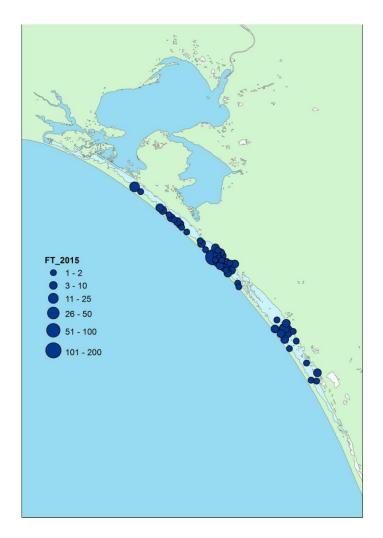


Figure 8.21 Map showing abundance and distribution of fairy terns during the 2015 census of the Coorong. The larger the dot, the more birds detected, as specifically indicated by the key on the map, which represents the numbers of fairy terns.

Counts of fairy terns have only been below their 10<sup>th</sup> percentile abundance (226) during annual censuses in 2004 and 2011. As the events were not consecutive, the fairy tern abundance LAC was not exceeded over the 11-year assessment period (i.e. 2005–15).

## **Curlew sandpiper LAC**

Since the 1980s there has been a substantial decline in the numbers of curlew sandpiper (*Calidris ferruginea*) at the site, which reflects the decline of this species across the flyway (Figure 8.22). The loss of coastal habitat in China, particularly in the Yellow Sea region, has been a significant issue for this species that has contributed to the global decline in numbers of this species that use the East Asian-Australian Flyway (Szabo at al. 2016). Twenty-eight percent of tidal flats that existed in the 1980s have disappeared by the late 2000s (1.2% annually) and up to 65% of tidal flats in the Yellow Sea region have been lost over the past 5 decades (Murray et al. 2014; Murray et al. 2015). The rate of decline in Curlew sandpiper may have slowed in the past 5 years as a result of several consecutive years of breeding success (BirdLife Australia 2015).

While declines in migratory shorebird numbers of the East Asian–Australasian Flyway are largely being driven by factors outside of Australia (Clemens et al. 2016), curlew sandpiper are declining at a faster rate in the Coorong compared to other wetlands in South-Eastern Australia (Clemens et al. 2016; Gosbell and Grear 2005).

Figure 8.22 below presents the January census data of the abundances of curlew sandpiper in the Coorong (including the Murray Estuary) between 2000 and 2015, which forms the basis of the assessment of the LAC. Based on this information the LAC was exceeded in 2012, with abundances below the threshold (i.e. 508) in both 2011 and 2012 (Figure 8.22). However at 2015, the LAC is currently not exceeded as abundances of curlew sandpiper in 2014 and 2015 have been higher than the abundance threshold required to exceed the LAC.

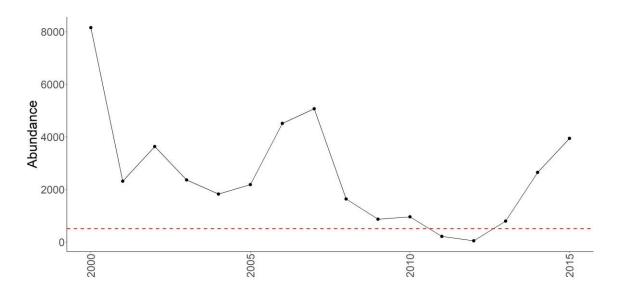


Figure 8.22 Total count of curlew sandpiper in January in the Coorong from 2000–15 (Data from the January census, D Paton). Red line represents the 10<sup>th</sup> percentile abundance of curlew sandpiper (508).

## **Eastern curlew LAC**

Eastern curlew (*Numenius madagascariensis*) is a regular visitor to the Ramsar site. There is variation in the number of individuals recorded but no year when eastern curlew have not been recorded. The LAC has not been triggered for this species since 2001.

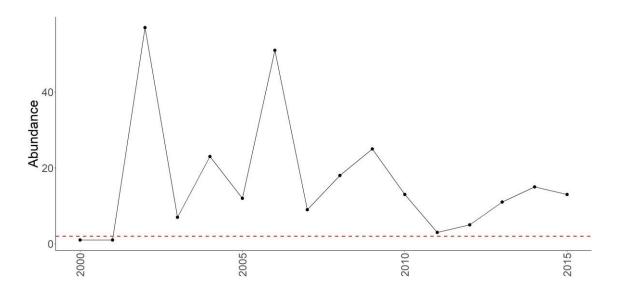


Figure 8.23 Total count of eastern curlew in January in the Coorong from 2000–15 (Data from the January census, D Paton). Red line represents the 10<sup>th</sup> percentile abundance of eastern curlew (2).

## **Hooded plover (Ngamat) LAC**

Between 2010 and 2014 the results from the biennial hooded plover (*Thinornis rubricollis*) counts indicated a decline of 8% in the density of birds per kilometre searched in the Coorong (Driessen and Maguire 2015), with a 52% decrease in numbers between 2010 and 2012 (Mead et al. 2012). Disturbance of the beach area by vehicles is one suggested reason for the decrease in density and numbers of the birds (Driessen and Maguire 2015). In January 2014 and 2015, only 5 and 6 hooded plovers were observed in the Coorong South Lagoon, respectively (Figure 8.24). Despite this decline, the LAC for hooded plover is not exceeded.

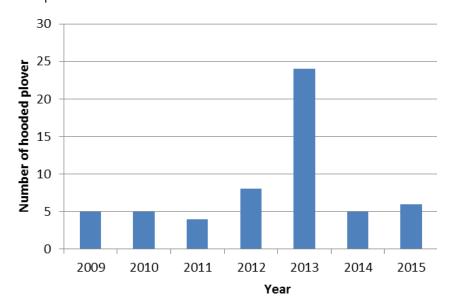


Figure 8.24 Abundance of hooded plovers in January in the Coorong from 2009–15 (adapted from Paton and Paton 2016).

## Mount Lofty Ranges southern emu-wren (Wirili Pulyeri) LAC

No estimates of population sizes were made prior to the early 1990s, but it is generally accepted that there has been a severe decline in numbers during the past century (Littely and Cutten 1994). Populations in the Ramsar site are based on 1993 to 2006 status, reported by the Mount Lofty Ranges southern emu-wren and Fleurieu Peninsula Swamps Recovery team (2007). They estimate that the Finniss River group consist of possibly 50 pairs and that the site is arguably the second-most important Mount Lofty Ranges southern emu-wren (*Stipiturus malachurus intermedius*) local population overall, and probably the most viable and genetically diverse population.

Data from observations between 1993 and 2013 are shown below in Figure 8.25, indicating 3 areas for the species within the Ramsar site (although monitoring sites 22 and 23 are arguably in a single patch and represent functionally the same population). The estimated maximum total Mount Lofty Ranges southern emu-wren population between 1993 and 2013 varied from 85 to 170 mature individuals in 1993 to a population size in 2013 of 60 to 120 mature individuals (M Pickett, personal communication, 2013).

Between 1993 and 2010 there was widespread decline in the Mount Lofty Ranges southern emu-wren population across its entire distribution within the swamps of the Fleurieu Peninsula. A total of 19 populations became extinct and by 2010 birds were recorded in only 16 out of 54 previously recorded sites (Conservation SA 2013). Despite this decline, in 2012 the populations located in the lower Finniss swamps (within the Ramsar site) were relatively abundant and had a high number of nesting pairs. There have been no recorded instances when targeted surveys have failed to record any individuals within these core known populations, therefore the LAC is unlikely to have been exceeded.

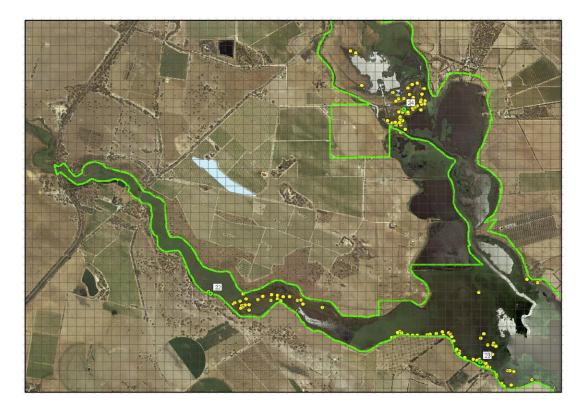


Figure 8.25 Distribution of the Mount Lofty Ranges southern emu-wren within the Ramsar site (yellow dots = MLRSEW observations 1993–2013, green spots = MLRSEW nominal site, green line = Ramsar boundary. Data supplied Marcus Pickett, Conservation Council SA, personal communication, December 2013).

## 8.3.6 Wetland habitat

The baseline mapping and classification was carried out in 2002–03 (Seaman, Coorong and Lower Lakes habitat-mapping program, 2003), approximately 18 years after the listing in 1985. At that time, 70% of the 587 sites assessed in Lake Alexandrina, Lake Albert, Currency Creek, Finniss River, Hindmarsh Island and Goolwa Channel were assessed as being in good or better condition. In the Coorong between the Murray Mouth and the southern Coorong National Park boundary near Kingston, 94% of habitats were assessed as being in good or better condition.

## **Lakes Alexandrina and Lake Albert**

In 2010, a stratified repeated measures study design was used to compare the 2010 condition of 162 sites in the Lower Lakes, Currency Creek, Finniss River, Hindmarsh Island and Goolwa Channel, which equated to 20% of the sites assessed in 2003 (Thiessen, Habitat Condition of Ramsar Wetland Types in Lake Alexandrina, Lake Albert, Goolwa Channel and associated tributaries, 2010). The selection of wetlands included an over-representation of sites determined in 2003 to be in excellent or very good condition as the greatest change would be anticipated in these sites during a period of drought. (Thiessen 2010). Of the sites assessed in the survey, 54% were found to have declined in condition, 41% had no change in condition and 5% improved condition (Table 8.4). Declines were mainly due to changes in the water regime with only 37 of the 85 wetlands assessed and deemed to be permanent wetlands in the 2003 survey maintaining their permanent status in 2010 (Thiessen 2010).

Table 8-2 Characteristics of 162 wetland sites assessed in 2010 (Thiessen, Habitat Condition of Ramsar Wetland Types in Lake Alexandrina, Lake Albert, Goolwa Channel and associated tributaries, 2010) by order of their 2003 (Seaman, Coorong and Lower Lakes habitat-mapping program, 2003) classification, detailing the number of sites per condition classification that improved, remained stable and declined.

Habitat condition in 2003	Sites assessed 2010	Description of change in habitat condition according to 2010 survey results		
		Improved No Change		Decline
Excellent	35		8	27
Very good	55		15	40
Good	41	2	21	18
Degraded	28	5	22	1
Completely degraded	3	2	1	
Total Number (%)	162	9 (5%)	67 (41%)	86 (53%)

In 2014, after the return of River Murray inflows to the site, the 152 sites from the 2010 assessment were assessed again revealing broad improvement in habitat conditions consistent with the restoration of pre-drought water regimes (Billows C 2014). The study identified an almost equal reversal in habitat condition with 60% of wetlands improving in habitat condition, 35% classified as stable and 5% showing a decrease in condition compared to 2010 (Billows 2014). An assessment of longer-term changes in habitat condition showed that 45% of the 152 wetlands assessed for all 3 assessment periods either returned to their original 2003 condition or maintained a constant condition throughout the drought to the 2014 survey, whilst 27% of wetlands made a net improvement.

# **Murray Estuary and Coorong**

In 2015, repeat field habitat condition assessments for 95 (50%) of the 187 sites from the Murray Mouth to the southern Coorong National Park boundary near Kingston were undertaken (Dickson et al. 2015). The study found that 34 (36%) have improved in condition, 40 (42%) have not changed in condition and 21 (22%) have declined in condition since 2003. Table 8-3 details the proportion and direction of change for each habitat condition class.

Table 8-3 Distribution of change in habitat condition from 2003 to 2015 from the Murray Mouth to the southern Coorong National Park boundary.

Habitat condition score	No. of sites with habitat Distribution of change in habitat condition from 2003 to 2015			
	condition score in 2003	Improved (%)	No change (%)	Declined (%)
Pristine	17	0 (0%)	9 (52.9%)	8 (47.1%)
Excellent	49	17 (34.7%)	22 (44.9%)	10 (20.4%)
Very good	20	10 (50.0 %)	7 (35.0%)	3 (15.0%)
Good	6	5 (83.3 %)	1 (16.7%)	0
Degraded	3	2 (66.7 %)	1 (33.3%)	0

Wetland condition has not declined in 60% of the sites over any 10 year period and the LAC has not been exceeded.

## 8.3.7 Threatened ecological communities and species

## **Swamps of the Fleurieu Peninsula LAC**

Within the boundary of the swamps of the Fleurieu Peninsula threatened ecological community (both within and outside of the Ramsar site), significant restoration work has occurred to enhance habitat condition. This included revegetation with local native emergent freshwater species, weed control, stock-proof fencing and the installation of alternative watering points for stock. Data on restoration efforts estimated that up until December 2014, approximately 344 hectares of swamps were revegetated and general restoration works occurred across 890 hectares (Stubbs 2020). While it is likely that the condition of the swamps of the Fleurieu Peninsula has improved as a result of these restoration efforts, there is currently no quantitative assessment.

# Subtropical and temperate coastal saltmarsh LAC

The majority of this community is found on the lagoon edges of the Murray Estuary and Coorong and is protected within the Coorong National Park. Baseline mapping and classification for the Ramsar site was carried out in 2002–03 and 94% of the sites assessed were classified as being in good or better condition (Seaman 2003). In 2015, repeat field habitat condition assessments found that 34 (36%) sites have improved in condition, 40 (42%) have not changed in condition and 21 (22%) have declined in condition since 2003 (Dickson et al. 2015).

## Southern bell frog LAC

The main datasets used to assess the southern bell frog (*Litoria raniformis*) LAC and document the changes since listing are described in Table 13-11 in Appendix D.

Based on records from various surveys (such as Mason and Hillyard 2011; Mason 2013; Mason 2014; Mason and Durbridge 2015; Mason 2018) the southern bell frog has been recorded at a total of 17 individual sites within the Ramsar site (Figure 8.26). Some records pre-dated 1980 (Figure 8.26).

Frog census data collected in September 2000 resulted in the identification of southern bell frog at the Wellington Ferry and Langhorne Creek. Frog surveys were carried out as part of the River Murray Baseline Survey during 2004 and 2005. Southern bell frog was only recorded at 2 out of 13 wetlands surveyed (SKM 2004; Simpson et al. 2006). Several males were heard calling in March 2004 at Tolderol Game Reserve and in November 2005 at Pelican Lagoon (Figure 8.26). The landholders of Mundoo Island also provided photographs of an adult southern bell frog recorded on the island in 2005.

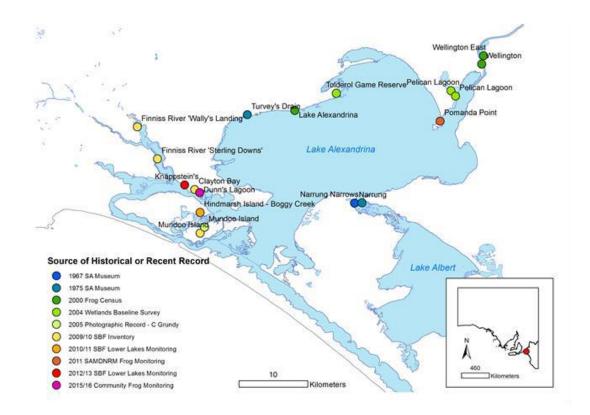


Figure 8.26 Known distribution of southern bell frog in the region displaying earliest record of occupancy (from Mason and Durbridge 2015).

Individuals were detected at a small number of sites in the Lakes during 2009 (Figure 8.26) (Mason 2013). Southern bell frog were recorded at 3 locations during the 2009 inventory (Figure 8.27). The largest population (10 to 50 individuals) was recorded at Clayton Bay. Smaller populations were detected in the Finniss River at 'Wally's Landing/ Watchalunga' (2 to 9 individuals) and Mundoo Island (1 individual). Clayton Bay and Wally's Landing were located within inundated wetlands and shorelines following the implementation of the Goolwa Water Level Management Area (i.e. management response to exposure of acid sulfate soils encompassing the Goolwa Channel between the barrage and Clayton Bay and the lower reaches of the Finniss River and Currency Creek) (Mason and Turner 2018).

Frog monitoring conducted in the region in 2010 detected southern bell frog at 6 locations in moderate to low abundances. Pelican Lagoon (sites 1 and 2), Finniss 'Watchalunga/ Wally's Landing', Finniss 'Sterling Downs', Clayton Bay 'Red Top Bay' and Mundoo Island. Southern bell frog had been found at or near 3 of these sites in the past (Figure 8.27). A photograph of an adult discovered in a pump shed at Turvey's Drain was provided by landholders, north-east of Milang Township in 2010. No formal southern bell frog monitoring was conducted in 2011, however opportunistic survey events yielded moderate abundances at Nalpa Station 'Pomanda Point Causeway', approximately 4.5 kilometres south of Pelican Lagoon where they were recorded the previous year.

In 2012–13, Southern bell frog were detected at 2 locations: Pomanda Point causeway in moderate abundances and 1 individual near Clayton Bay (Goolwa Channel) (Figure 8.27) (Mason and Durbridge 2015). In 2013–14, southern bell frog were detected in low numbers (i.e. 3 to 5 individuals) at Wellington East Wetland, and 1 individual again at Clayton Bay (Figure 8.27) (Mason and Durbridge 2015). Community surveys of 78 sites on 3 occasions between 2013 and 2014 failed to record the species (Mason and Durbridge 2015). Out of the 84 sites surveyed in 2014–15, only 1 site was found to be occupied by southern bell frog, a site which was previously occupied in 2013, 2012 and in close vicinity to a site occupied in 2009 suggesting the species has persisted in this area for over 6 years

(Mason and Durbridge 2015). The observation of only 1 individual frog displaying breeding behaviour (calling) on 2 occasions suggests the species is present in extremely low abundance in the site (Mason and Durbridge 2015). The continued recovery of wetland habitats within the fringes of Lake Alexandrina, Lake Albert and the tributaries of Currency Creek and Finniss River since the return of water levels in 2010 have resulted in increased habitat complexity and amount of available habitat, and it was anticipated that these habitats would be conducive for southern bell frog breeding events (Mason and Durbridge 2015).

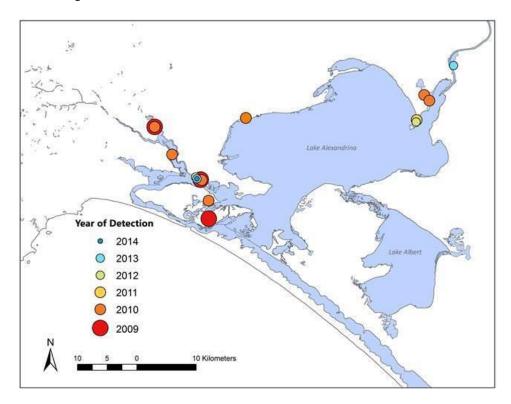


Figure 8.27 Sites occupied by southern bell frog between September 2009 and March 2015 (from Mason and Durbridge 2015).

The decline in water levels that occurred throughout the duration of the survey period resulted in the drying of fringing areas above 0.5-0.6metres AHD, including some areas previously occupied by southern bell frog (Mason and Durbridge 2015). However, the expansion and diversification of submerged and emergent plant communities in the region provided areas of similar vegetative structure to that of previously occupied sites. The response by southern bell frog to water level management during past years (2009–13) and the knowledge of the species readiness to favour newly inundated areas (Pyke 2002; Wassens, 2011) suggests that water levels were the primary driver in southern bell frog occupancy in 2014–15. Calling activity may also have occurred in the 2 months directly prior to the survey period when higher lake levels prevailed. The highest abundances of southern bell frog across all survey events between 2009 and 2014 have been within recently inundated areas suggesting greater variation in water levels will promote an increase in breeding behaviour (calling) (Mason and Durbridge 2015).

While a direct LAC for southern bell frog has not been established, the very low numbers and limited sites (i.e. only one site in 2014–15) where the southern bell frog has been recorded indicates a significant change in the persistence of this species in the Ramsar site. Direct assessments of the freshwater submergent and emergent vegetation and Lake Alexandrina salinity LAC are described in sections 8.3.3 and 8.3.2, respectively.

## 8.3.8 Coorong food web

The main datasets used to inform the development and assessment of the Coorong Food Web LAC and document the changes since listing are described in Table 13-12 in Appendix D. Assessment of the Coorong Food Web LAC (for small-mouthed hardyhead and benthic invertebrate components) occurs indirectly via the LAC for Coorong salinity.

# Ruppia tuberosa - primary producer

The submergent halophyte *R. tuberosa* is a key element of the Coorong food web, particularly in the Coorong South Lagoon. The quality and quantity of the services and resources that the plant provides is likely to be related to the distribution and abundance of the plant. As the level of cover diminishes, the level of resources and services diminishes proportionately (Paton et al. 2015a). The chances of sites with low levels of cover recovering to good condition over the following years if the seedbank is low is limited.

*R. tuberosa* will be assessed indirectly through the LAC for submergent halophytes (less than 5% cover of *R. tuberosa* recorded at greater than 50% of all winter monitored sites) and viable seeds of *R. tuberosa* in less than 20% of sediment cores at two-thirds of sampling locations across the Coorong South Lagoon for 4 consecutive seasons.

The following text describes the LAC assessment and changes in the *R. tuberosa* seed bank (percentage of viable seeds). Please refer to section 8.3.3 (vegetation – submergent halophytes) for the LAC assessment and changes in *R. tuberosa* cover and distribution.

Prior to the Millennium Drought, the population of *R. tuberosa* at Villa dei Yumpa in the northern part of the Coorong South Lagoon had a seed bank of a little over 3,000 seeds per metre square, and this population re-established each winter until 2008 (Paton et al. 2015b). This level of seed abundance is much lower than what was once recorded in the Coorong South Lagoon, where sites had greater than 20,000 seeds per metre square (Paton et al. 2015c). Seed abundances in the initial 3 years of monitoring (1998–2000) in the Coorong were about 10-fold higher compared to 2015 abundances (Table 8-4) (Paton et al. 2015b). Other populations in the Coorong South Lagoon with much lower accumulated seed banks disappeared in 2005 and 2006 (Paton et al. 2015b). This loss was also reflected in the simplified food web present in the southern Coorong North and Coorong South lagoons during the Millennium Drought, where algae and brine shrimp were dominant (Kim et al. 2013).

Table 8-4 Abundances of seeds detected in core samples along transects at each of the thirteen monitoring sites for July 1998-2000, July 2011–13, July 2014 and July 2015. The data for all years except July 2015 show the mean number of seeds based on 50 cores from each site in each year. Data for July 2015 are means ± s.e. for 50 core samples. The 1998–2000 data and the 2011–13 data are based on 150 cores, 50 in each of the 3 years (from Paton et al. 2015a; see Paton et al. 2015c for detailed site locations).

Site	July 1998–2000	July 2011-13	July 2014	July 2015
	Seeds per core	Seeds per core	Seeds per core	Seeds per core
Coorong South Lagoon				
ттх	1.57	0.38	0.40	0.60±0.17
sc	2.34	0.16	0.68	0.60±0.07
PP	3.88	0.75	2.08	0.46±0.15
VDY	14.06	2.21	2.46	1.12±0.26
S06W	-	1.91	0.74	1.70±0.28
S21E	-	0.21	0.28	0.08±0.04
PS	-	0.36	0.26	0.30±0.17
S39W	-	0.01	0.0	0.02±0.02
Coorong North Lagoon				
MF	-	0.68	1.02	1.20±0.28
RP	-	0.95	0.04	0.0
NM	0.0	0.06	0	0.06±0.03
LP	-	0.11	0	0.0

Since the re-establishment of suitable salinities in the Coorong South Lagoon, the recovery of populations of *R. tuberosa* has been slow because of the absence of an effective seedbank (Figure 8.28 and Figure 8.29) (Paton et al. 2015a). In previous years (2010–12), over 600 seeds from the Coorong South Lagoon were examined and none contained internal contents (Paton and Bailey 2013). The reported abundances of seeds in recent years will likely over-estimate the functional seed abundance (Paton et al. 2015a). The low viability of seeds in the Coorong South Lagoon reflects the absence of any recent substantial seed production (Paton et al. 2015a).

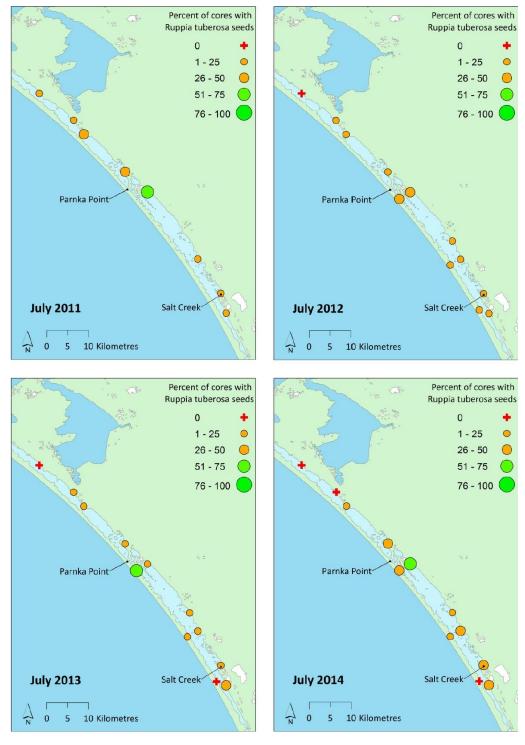


Figure 8.28 Percent of 50 cores with *R. tuberosa* seeds at monitoring sites in the Coorong South Lagoon in July for 2011–14 (Paton et al. 2015a). Sites with less than 20% (i.e. the LAC threshold) of cores with seeds are within the smaller orange circle.

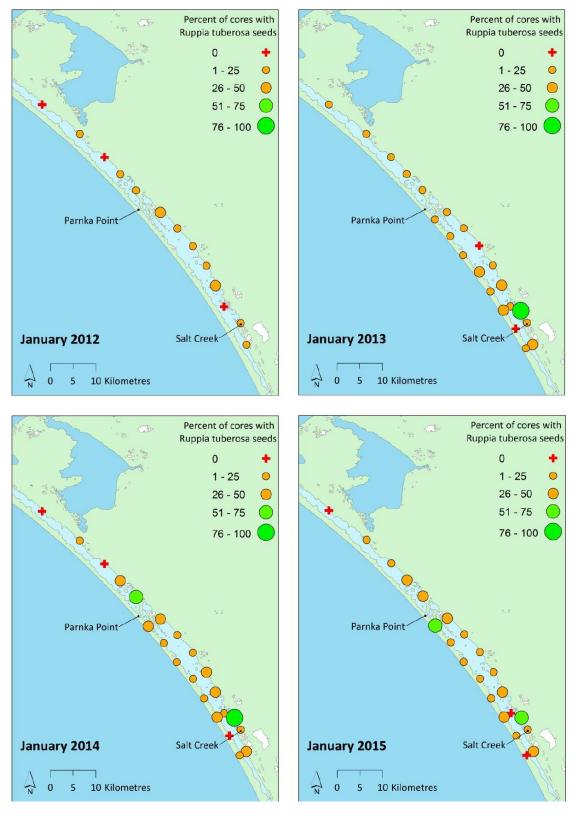


Figure 8.29 Percent of 50 cores with *R. tuberosa* seeds at monitoring sites in the Coorong South Lagoon in January for 2012–15 (Paton et al. 2015a). Sites with less than 20% (i.e. the LAC threshold) of cores with seeds are within the smaller orange circle.

By 2015, seed density had recovered to some extent particularly at the northernmost sites in the Coorong South Lagoon. However there has been no increase in the seed banks at any of the sites, which is indicative of on-going limited reproduction (Paton et al. 2015). None of the translocated populations have been able to increase their seed banks (Table 8-5) and so *R. tuberosa* continues to be vulnerable as it lacks the resilience that comes with a substantial seed bank (Paton et al. 2015a). As a result the LAC for *R. tuberosa* in the Coorong food web remains exceeded.

Table 8-5 Mean ± s.e. for *R. tuberosa* seeds per core at sites that received surface sediment containing seeds from Lake Cantara in autumn 2013 (WW, PP), in both autumn 2013 and 2014 (PPsup) and in autumn 2014 (FCPBN, FCPS, JP, SGI). WW = Woods Well, PP = Policeman Point, PPsup = sites at Policeman's Point with a second translocation, FCPN = Fat Cattle Point North, FCPS = Fat Cattle Point South, JP = Jack Point and SGI = Seagull Island (Paton et al. 2015a).

Site	July 2013	October 2013	July 2014	February 2015	July 2015
ww	0.78±0.16	1.65±0.11	0.54±0.13	0.42±0.09	0.49±0.10
PP	2.54±0.23	3.45±0.49	1.40±0.17	2.21±0.42	1.41±0.20
PPsup	-	-	4.40±0.60	4.67±0.66	2.39±0.35
FCPN	-	-	1.26±0.14	0.64±0.19	1.41±0.43
FCPS	-	-	1.58±0.44	2.53±0.57	0.63±0.12
JP	-	-	0.39±0.16	0.75±0.08	0.35±0.11
SGI	-	-	1.54±0.18	0.90±0.24	2.39±0.56

## Benthic macroinvertebrates – primary consumers

The below text describes changes related to Coorong benthic macroinvertebrates. For the direct assessment of the LAC refer to section 8.3.2 (Coorong salinity).

Dittmann et al. (2015) examined changes to Coorong benthic macroinvertebrate diversity, abundance, biomass, distribution and community composition during 2004–13. Water delivery to the Coorong during this period consisted of a relatively small release in 2005–06, drought conditions with 4 years of no flow, a large flow event in late 2010, and then moderate flows from 2011–13.

The period of no barrage flows (2007–10) corresponded with decreased taxonomic richness, abundance and biomass of benthic macroinvertebrates, and is attributed to extreme hypersaline conditions and reduced water levels in the Coorong South Lagoon (Dittmann et al. 2015). Extreme salinities (greater than 120 ppt (128,175 EC) in the Coorong South Lagoon and southern section of the Coorong North Lagoon severely altered the structure of the Coorong food web, which was characterised by low species diversity, high densities of phytoplankton and ostracods, and the Australian brine shrimp *Artemia* species (Giatis et al. 2018). The reduction in macroinvertebrate diversity led to a shift in bird assemblage in the Coorong South Lagoon to a community dominated by the banded stilt (*C. leucocephalus*), which feeds predominantly on brine shrimp.

Following the end of the Millennium Drought in spring 2010, recovery in Coorong macroinvertebrate populations took longer than was previously recorded from a short period of reduced flows. While macroinvertebrate abundance increased quickly after flows were restored and salinity reduced, the benthic community was initially composed of only small bodied organisms (Dittmann et al. 2015). Biomass increased after several years once larger organisms became more abundant. Individual densities and distribution dropped during the drought for almost all macroinvertebrate taxa, but recovery after the flood were taxon-specific, and occurred at different temporal rates. In recent times,

there has been a slow increase in abundance of species that were rare after the Millennium Drought and flood (Dittmann et al. 2015), such as the micro-bivalve (A. helmsi).

By 2015, macroinvertebrate communities were slowly shifting back to pre-drought conditions in the Murray Estuary, but communities in the Coorong North Lagoon were less diverse and abundant than in recent years and in the Coorong South Lagoon were in very low abundances or completely absent (Dittmann and Baring 2015). Warmer, low-flow conditions in early summer 2015 led to the growth of dense mats of green filamentous algae in the Coorong (Dittmann and Baring 2015), which was observed to smother mudflats and undertake decay, and likely impeded benthic invertebrate growth and reproduction. The invertebrate community of the Coorong South Lagoon remains depauperate, despite improvements in the Murray Estuary and Coorong North Lagoon (Dittmann at al. 2015).

## Small-mouthed hardyhead - secondary consumer

Changes related to the Coorong small-mouthed hardyhead (*Antherinosoma microstoma*) population are described below. For the direct assessment of the LAC refer to Coorong salinity in section 8.3.2.

Ye et al. (2012) reported on small-mouthed hardyhead abundance, distribution, size classes and recruitment in the Coorong between 2008 and 2012. Data indicated that, despite being tolerant of high salinities, abundances and distribution of small-mouthed hardyhead decreased in the Coorong South Lagoon during the drought. The decrease in abundance and distribution during this period was attributed to a lack of freshwater inflows, increasing salinity and a reduction in *R. tuberosa* (key habitat) in the Coorong South Lagoon (Ye et al. 2012). Despite the tolerance of small-mouthed hardyhead to high salinities, the extreme salinities experienced in the Coorong South Lagoon from 2002 to 2009 restricted the species' distribution. Wedderburn et al. (2016) stated the absence of the fish from over 50% of its range when salinities exceeded 120 ppt (128,175 EC) was due to salinities exceeding the osmoregulatory ability of the fish.

Significant inflows from the barrages during 2010 and 2011 reduced salinity in the Coorong South Lagoon to less than 100 ppt (112,471 EC). This corresponded with an increase in abundance of small-mouthed hardyhead and a return to its former range (Ye et al. 2012, Wedderburn et al. 2016). This shifting distribution of small-bodied fish, the primary prey for fairy tern, saw a similar shift in the distribution of fairy tern (see section 8.3.5 Waterbirds – threatened species) (Paton and Bailey 2014).

# 9 Knowledge gaps

During the development of this ECD a number of knowledge gaps were identified and are outlined below in Table 9.1. The key knowledge gaps that are required to fully describe the ecological character of the site are lightly shaded.

Table 9-1 Summary of key knowledge gaps and recommended actions for the Coorong and Lakes Alexandrina and Albert Wetland Ramsar site.

CPS/threat	Knowledge gap	Recommended action
Critical CPS		
Vegetation – threatened ecological	Extent of the Swamps of the Fleurieu Peninsula	Verify the extent of the Swamps of the Fleurieu Peninsula within the Ramsar site via aerial mapping and ground truthing.
communities	Detailed mapping of the saltmarsh community around the Lakes and an understanding of the faunal assemblages of the temperate coastal saltmarsh ecological community.	Undertake detailed mapping and ground truthing of the saltmarsh community around the Lakes.  Targeted research to determine faunal assemblages of the temperate coastal saltmarsh ecological community.
Fish – diversity and biodisparity	The status of large-bodied native freshwater fish in Lakes Alexandrina and Albert (Ye et al. 2016).	Confirm whether fisheries data is sufficient to inform species richness and biodisparity assessment, otherwise a specific targeted large-bodied lakes fish monitoring program is needed
Fish – movement and recruitment	Movement patterns of large-bodied freshwater fish between Lake Alexandrina, Albert and the Lower River Murray in response to the flow regime (e.g. Ye et al. 2016).	Targeted research to determine the mechanisms involved in fish assemblage and recruitment responses and how they are linked to flow regimes (e.g. magnitude, timing and duration).
	Knowledge of critical habitat requirements and food resources that contribute to recruitment success of estuarine species within the Murray Estuary and Coorong (Watt 2013; Ye et al. 2016).	Confirmation of critical habitat requirements and food resources that contribute to recruitment success for key estuarine fish species
Waterbirds – diversity and	Population dynamics, spatial distribution and movement of waterbirds across the	Targeted survey of waterbird distributions at appropriate spatial and temporal scales.
abundance	site.	Targeted research to identify where and when waterbirds move within the site.
	Population dynamics, breeding and spatial distribution of cryptic species in the Lakes (O'Conner 2015).	Annual targeted surveys of cryptic species.

CPS/threat	Knowledge gap	Recommended action			
Critical CPS					
Waterbirds – breeding and threatened species	Assessment of whether any of the species identified as potential regular breeders should be included breeding assessments	Breeding monitoring of species identified as potential regular breeders from O'Connor et al. (2012): Australasian bittern (Botarus poiciloptilus), Australian reed warbler (Acrocephalus australis), dusky moorhen (Gallinula tenebrosa), Eastern great egret (Ardea modesta), Goldenheaded cisticola (Cisticola exilis), grey teal (Anas gracilis), musk duck (Biziura lobata), nankeen night heron (Nycticorax caledonicus), purple swamphen (Porphyrio porphyria), sooty oystercatcher (Haematopus fuliginosus), Mount Lofty Ranges Southern emu-wren (Stipiturus malachurus intermedius).			
Coorong food web	Quantified relationships between hydrological regimes and associated environmental and habitat changes to food availability and accessibility for key biota, including fish and waterbirds in the Coorong.  Habitat quality and utilisation by waterbirds within the Coorong.	Targeted research to identify primary food sources and importance to key fish and waterbird species and the influence of environmental factors on these food sources.  Targeted research to develop methods to effectively measure habitat quality for key waterbird species and determine the critical habitat features required to support			
		waterbird populations.			
Important non-crit					
Groundwater	Groundwater interactions with the Lakes Alexandrina and Albert and the Coorong. Groundwater inputs are likely to be more significant in the Coorong than in Lake Alexandrina, particularly in supporting freshwater habitat in the Coorong South Lagoon.	Establish groundwater interaction with surface water in Coorong South Lagoon in terms of mediating salinity levels.			
Important non-critical CPS/Threats					
Water quality - nutrients	The relative importance of external and internal nutrient sources and sinks, the fate of nutrients entering the system and the role of nutrient cycling in the Coorong.	Targeted research to identify the loads and concentrations of nutrients entering the Coorong, the influence of these nutrients on ecological processes and function and pathways for nutrient cycling.			
	The nature and rate of nutrient uptake and transfer of nutrients through the ecosystem.				
	The nature and role of processes (e.g. wind-driven resuspension and breakdown of organic detritus) in influencing the nutrient dynamics in the Coorong.				



Figure 9.1 Fish Monitoring

## 10 Monitoring

As a signatory to the Ramsar Convention, Australia is obliged to maintain the ecological character of its Wetlands of International Importance. While there is no explicit requirement for monitoring the site, long-term monitoring data has been integral to developing LAC for critical CPS and assessing change in condition over time.

A description of the monitoring and assessments required to determine whether LAC have been exceeded for each critical CPS is provided in Table 10.1. The majority of the monitoring programs described are existing, long-term monitoring programs undertaken by DEW, including monitoring to track ecological condition of the site and ecological responses to the delivery of water for the environment over time (DEWNR 2017) and surface water data collected at telemetered stations across the Ramsar site. Data requirements to assess progress against resource condition targets and management triggers are outlined in the Ramsar Management Plan (under development).

Ngarrindjeri see research and monitoring of their Ruwe/Ruwar as an ongoing process. The following statement characterises their approach (Ngarrindjeri 2019):

Ngarrindjeri science is how we read our land and our waters; how we take notice to the behaviours of our birds and animals. We take notice to our plants that grow in particular areas and then they die, that's what tells us that there is a problem within our waterways. We take notice of the pelican and his behaviour with different weather patterns; that's our science. (Tom Trevorrow – NRA and Change Media, 'Flow' 2013)

Ramsar Resolution VII.8 calls on Contracting Parties to encourage active and informed participation and assumption of responsibility by local communities and Indigenous people in the management of Ramsar-listed sites and the implementation of the wise use principles. Ramsar Resolution VII.8 also encourages contracting parties, technical experts and indigenous communities to work together in the planning and management of wetlands to ensure that the best available science and local knowledge are taken into consideration in decision making (Ramsar 1999; Ramsar 2002; Ramsar 2005). Recognition of these needs will enable the further development and potential application of the Yannarumi Assessment process and the Ngarrindjeri approach to Caring as Country, alongside the monitoring needs for the Ramsar site (as outlined below). This approach ensures the interconnectivity of lands/ waters/ spirit (Ruwe/Ruwar) is maintained in the development of monitoring programs/models (Ngarrindjeri 2019).

Table 10-1 Summary of monitoring and assessment requirements to inform Limits of Acceptable Change for Critical CPS.

Critical CPS	Sub-component	Data Requirements/Assessment	Locations	Frequency	Priority
Hydrology	Inflows (indirect via Lake Alexandrina water levels)	Monthly average daily water level (m AHD) at telemetered surface water monitoring stations in Lake Alexandrina	See Lake Alexandrina monitoring stations (below)	Continuous	Medium
	Lake Alexandrina water level	Monthly average daily water level (m AHD) at telemetered surface water monitoring stations in Lake Alexandrina	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 0m AHD), substitute stations may be established to ensure water level in a nearby location is recorded.	Continuous	High
Salinity	Lake Alexandrina salinity	Annual average daily salinity (EC) at telemetered surface water monitoring stations in Lake Alexandrina	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 0m AHD), substitute stations may be established to ensure water level in a nearby location is recorded.	Continuous	High
	Murray Estuary and Coorong salinity	Monthly average daily salinity (EC converted to ppt) at telemetered surface water monitoring stations in the Murray Estuary and Coorong	Murray Estuary: A4261036 (Beacon 12 Goolwa Channel) A4261039 (Barker Knoll), A4261128 (Mundoo Channel), A4261043 (Beacon 1, Ewe Island Shacks). Coorong North Lagoon: A4261134 (Beacon 19 Pelican Point), A4261135 (Long Point), A4260572 (Robs Point). South	Continuous	High

Critical CPS	Sub-component	Data Requirements/Assessment	Locations	Frequency	Priority
			Lagoon: A4260633 (Parnka Point), A4261209 (near Cattle Island), A4261165 (NW Snipe Island).		
Vegetation	Submergent freshwater vegetation (indirect via Lake Alexandrina water levels and salinity)	Average daily water level (m AHD) and salinity (EC) at telemetered surface water monitoring stations in Lake Alexandrina	See Lake Alexandrina surface water level monitoring stations (above)	Continuous	Medium
	Emergent freshwater vegetation (indirect via Lake Alexandrina water levels)	Average daily water level (m AHD) at telemetered surface water monitoring stations in Lake Alexandrina	See Lake Alexandrina surface water level monitoring stations (above)	Continuous	Medium
	Submergent halophytes	Annual Coorong <i>Ruppia tuberosa</i> monitoring (using % cover data), as per Paton et al. (2017a)	Sediment cores sampled at 13 sites; including 4 sites in the Coorong North Lagoon, 8 sites in the Coorong South Lagoon (including 3 on the western side) and 1 site at Lake Cantara	July each year	High
	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	Medium
Fish	Diversity (species richness and biodisparity)	Fish species and families present, using data from the Lakes (Wedderburn 2017); Coorong (Ye et al. 2017a, 2017b); barrage fishways (Bice and Zampatti 2017) and Lakes and Coorong Fishery data	Entire Ramsar site	Annual	High
	Movement and recruitment	Presence of upstream migrating YOY Congolli and common galaxias, as per methods described in Bice and Zampatti (2017)	Vertical slot fishways at Tauwitchere and Goolwa Barrages and Hunters Creek, fyke netting	Annual (October – January)	High

Critical CPS	Sub-component	Data Requirements/Assessment	Locations	Frequency	Priority
			adjacent to Tauwitchere rock ramp and Goolwa barrage.		
	Threatened species (Murray hardyhead)	Presence of Murray hardyhead 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)	High
Waterbirds	Diversity (species and richness)	Annual waterbird abundance assessed against abundance thresholds, per target species, per region. Waterbird census methods as per Paton et al. (2017b).	Abundance of target waterbird species assessed in Lake Alexandrina and Albert, Murray Estuary, Coorong North and South lagoons	Annual (January)	High
	Abundance	Total annual waterbird abundance, as per Paton et al. (2017b)	Entire Ramsar site	Annual (January)	High
	Presence/absence of target migratory shorebird species	Presence of 7 target migratory species in the Ramsar site during the waterbird census (Paton et al. 2017b)	Murray Estuary and Coorong	Annual (January)	High
	Flyway population 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. 2017b)	Murray Estuary and Coorong	Annual (January)	High
	Breeding	Assessment of breeding success for 10 annual breeding species and 3 regular breeding species. Breeding occurrence assessed via waterbird census (Paton et al. 2017b) and annual aerial survey (Kingsford and Porter 2009)	Entire Ramsar site	Annual (January census and November aerial survey)	Medium

Critical CPS	Sub-component	Data Requirements/Assessment	Locations	Frequency	Priority
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	Medium
	Australian fairy tern	Adult population abundance in annual census, as per methods described in Paton et al. (2017b) and fledging success as a measure of juveniles within the population, as per methods described in Paton and Paton (2016)	Murray Estuary, Coorong North Lagoon and Coorong South Lagoon	Annual (January)	High
	Curlew sandpiper	Presence or absence in annual census, as per methods described in Paton et al. (2017b)	Murray Estuary, Coorong North Lagoon and Coorong South Lagoon	Annual (January)	High
	Eastern curlew	Presence or absence in annual census, as per methods described in Paton et al. (2017b)	Murray Estuary and Coorong North Lagoon	Annual (January)	High
	Threatened species – hooded plover	Presence or absence in targeted bi-annual surveys by Birdlife Australia	Coorong ocean beach	Bi-annual	High
	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	High
Wetland habitat	Condition	Habitat condition assessed at sites as per methods described in Seaman (2003)	Entire Ramsar site	Once every 10 years	Medium
Threatened ecological communities and species	Swamps of the Fleurieu Peninsula	Extent of threatened ecological community – number of hectares confirmed via aerial photography and ground-truthing.  Condition assessment methodology required.	Eastern Mount Lofty Ranges tributaries	At least once every 10 years	Medium

Critical CPS	Sub-component	Data Requirements/Assessment	Locations	Frequency	Priority
	Subtropical and Temperate Coastal Saltmarsh	Extent of threatened ecological community – number of hectares of threatened ecological community confirmed via aerial photography and ground-truthing.	Lake Alexandrina, Lake Albert and Murray Estuary and Coorong	At least once every 10 years	Low
	Southern bell frog (indirect via Lake Alexandrina water levels and salinity)	Average daily water level (m AHD) and salinity (EC) at telemetered surface water monitoring stations in Lake Alexandrina	See Lake Alexandrina surface water level monitoring stations (above)	Continuous	Medium
Coorong food web	Ruppia tuberosa – primary producer (includes cascade submergent halophyte LAC)	The presence of viable <i>Ruppia tuberosa</i> seeds in Coorong South Lagoon sites, as per methods described in Paton et al. (2017a)  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)	High
	Benthic macroinvertebrate – primary consumers (indirect via Coorong salinity)	Monthly average daily salinity (EC converted to ppt) at telemetered surface water monitoring stations in the Coorong	See Coorong monitoring stations (above) for Murray Estuary, Coorong North and South Lagoon sites	Continuous	Medium
	Small-mouthed hardyhead - secondary consumer (indirect via Coorong salinity)	Monthly average daily salinity (EC converted to ppt) at telemetered surface water monitoring stations in the Coorong	See Coorong monitoring stations (above) for Coorong North and South Lagoon sites	Continuous	Medium

# 11 Communication and education messages

During the development of this ECD 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 environmental, cultural, social and economic value and is of local, regional, national and international significance.
- 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.
- 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 Coorong South Lagoon back to health.
- The purpose of this ECD is to document baseline conditions for the Ramsar site as at 2015. These are the conditions that the site will be managed for in the future through the implementation of the Ramsar Management Plan currently under development.
- The ECD incorporates the extensive knowledge gathered through the CLLMM Recovery Project since 2009 and monitoring associated with the delivery of water for the environment since 2007.
- 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.

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

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## 13 Appendices

#### A. Fish

#### Fish species recorded at the Ramsar site

A total of 104 species have been recorded in the site (Table 13-1, Bice et al. 2018) and includes 6 species of conservation significance (Table 13-1, Bice et al. 2018). These species are described using a guild approach (Elliott et al. 2007) which aggregates fishes based on similarities in their biology and ecology and groups fishes into 4 life history categories, defined primarily by the environment in which spawning occurs: a) freshwater, b) diadromous, c) estuarine and d) marine (Elliott et al. 2007, Potter et al. 2015, Bice et al. 2018).

Table 13-1 List of fish species that have been recorded in the Ramsar site and their guild classification. Species were designated to guilds by means of an expert workshop following the 'Estuarine Use Functional Guild' approach proposed by Potter et al. (2015). Table adapted from Bice et al. (2018).

Common name	Scientific name	Family	Guild
Freshwater category			
Murray hardyhead <sup>E, P</sup> (Terukurar)	Craterocephalus fluviatilis	Atherinidae	Freshwater straggler
Unspecked hardyhead	Craterocephalus fulvus	Atherinidae	Freshwater straggler
Oriental weatherloach@^	Misgurnis anguillicaudatus	Cobitidae	Freshwater straggler
Goldfish <sup>@</sup>	Carassius auratus	Cyprinidae	Freshwater straggler
Common carp <sup>@, C</sup>	Cyprinus carpio	Cyprinidae	Freshwater straggler
Tench@^	Tinca	Cyprinidae	Freshwater straggler
Carp gudgeon complex	Hypseleotris spp.	Eleotridae	Freshwater straggler
Dwarf flat-headed gudgeon	Philypnodon macrostomus	Eleotridae	Freshwater straggler
Mountain galaxias	Galaxias olidus complex	Galaxiidae	Freshwater straggler
Murray rainbowfish	Melanotaenia fluviatilis	Melaenotaenidae	Freshwater straggler
River blackfish	Gadopsis marmoratus	Percichthyidae	Freshwater straggler
Murray cod <sup>E, P</sup> (Pondi)	Maccullochella peelii	Percichthyidae	Freshwater straggler
Golden perch <sup>C</sup> (Pilalki)	Macquaria ambigua	Percichthyidae	Freshwater straggler
Southern pygmy perch <sup>p</sup>	Nannoperca australis	Percichthyidae	Freshwater straggler
Yarra pygmy perch <sup>E, P</sup>	Nannoperca obscura	Percichthyidae	Freshwater straggler
Redfin perch <sup>@, C</sup>	Perca fluviatilis	Percidae	Freshwater straggler
Freshwater catfish <sup>P</sup>	Tandanus	Plotosidae	Freshwater straggler
Eastern Gambusia <sup>®</sup>	Gambusia holbrooki	Poecilidae	Freshwater straggler
Rainbow trout <sup>®</sup>	Oncorhynchus mykiss	Salmonidae	Freshwater straggler
Brown trout <sup>®</sup>	Salmo trutta	Salmonidae	Freshwater straggler
Silver perch <sup>E, P</sup>	Bidyanus	Terapontidae	Freshwater straggler

Common name	Scientific name	Family	Guild
Freshwater category			
Spangled perch <sup>^</sup>	Leiopotherapon unicolor	Terapontidae	Freshwater straggler
Bony herring <sup>C</sup>	Nematalosa erebi	Clupeidae	Freshwater est. opportunist
Flat-headed gudgeon	Philypnodon grandiceps	Eleotridae	Freshwater est. opportunist
Australian smelt	Retropinna semoni	Retropinnidae	Freshwater est. opportunist
Diadromous category			<u>'</u>
Pouched lamprey	Geotria australis	Geotriidae	Anadromous
Short-headed lamprey	Mordacia mordax	Mordaciidae	Anadromous
Short-finned eel	Anguilla australis	Anguillidae	Catadromous
Congolli	Pseudaphritis urvillii	Bovichtidae	Catadromous
Common galaxias (Pulangi)	Galaxias maculatus	Galaxiidae	Semi-catadromous
Estuary perch <sup>^</sup>	Macquaria colonorum	Percichthyidae	Semi-catadromous
Australian bass^	Macquaria novemaculeata	Percichthyidae	Semi-catadromous
Estuarine category			
Small-mouthed hardyhead	Atherinosoma microstoma	Atherinidae	Solely estuarine
Tamar River goby	Afurcagobius tamarensis	Gobiidae	Solely estuarine
Western bluespot goby	Pseudogobius olorum	Gobiidae	Solely estuarine
Lagoon goby	Tasmanogobius lasti	Gobiidae	Solely estuarine
Black bream <sup>C</sup> (Tjiri)	Acanthopagrus butcheri	Sparidae	Solely estuarine
Western river garfish	Hyporhamphus regularis	Hemiramphidae	Solely estuarine
Bridled goby	Arenigobius bifrenatus	Gobiidae	Estuarine & marine
Estuary catfish <sup>^</sup>	Cnidoglanis macrostomus	Plotosidae	Estuarine & marine
Soldierfish	Gymnapistes marmoratus	Tetrarogidae	Estuarine & marine
Marine category		'	<u>'</u>
Australian herring <sup>C</sup>	Arripis georgianus	Arripidae	Marine est. opportunist
Western Australian salmon <sup>C</sup>	Arripis truttaceus	Arripidae	Marine est. opportunist
Sandy sprat	Hyperlophus vittatus	Clupeidae	Marine est. opportunist
Australian anchovy	Engraulis australis	Engraulidae	Marine est. opportunist
Yelloweye mullet <sup>C</sup> (Kunmari)	Aldrichetta forsteri	Mugilidae	Marine est. opportunist
Goldspot mullet	Liza argentea	Mugilidae	Marine est. opportunist
Sea mullet	Mugil cephalus	Mugilidae	Marine est. opportunist

Common name	Scientific name	Family	Guild
Marine category			
Blue-spotted flathead	Platycephalus speculator	Platycephalidae	Marine est. opportunist
Longsnout flounder	Ammotretis rostratus	Pleuronectidae	Marine est. opportunist
Greenback flounder <sup>C</sup>	Rhombosolea tapirina	Pleuronectidae	Marine est. opportunist
Tailor <sup>^</sup>	Pomatomus saltatrix	Pomatomidae	Marine est. opportunist
Mulloway <sup>C</sup> (Mullowi)	Argyrosomus japonicus	Sciaenidae	Marine est. opportunist
Yellowfin whiting	Sillago schomburgkii	Sillaginidae	Marine est. opportunist
Prickly toadfish	Contusus brevicaudus	Tetraodontidae	Marine est. opportunist
Smooth toadfish	Tetractenos glaber	Tetraodontidae	Marine est. opportunist
Cowfish <sup>^</sup>	Aracana ornata	Aracanidae	Marine straggler
Tasmanian blenny <sup>^</sup>	Parablennius tasmanianus	Bleniidae	Marine straggler
Silver trevally <sup>^</sup>	Pseudocaranx georgianus	Carangidae	Marine straggler
Bronze whaler shark	Carcharhinus brachyurus	Carcharhinidae	Marine straggler
Magpie perch <sup>^</sup>	Cheilodactylus nigripes	Cheilodactylidae	Marine straggler
Silver spot <sup>^</sup>	Threpterius maculosus	Chironemidae	Marine straggler
Southern crested weedfish <sup>^</sup>	Cristiceps australis	Clinidae	Marine straggler
Ogilby's weedfish <sup>^</sup>	Heteroclinus heptaeolus	Clinidae	Marine straggler
Australian pilchard	Sardinops sagax	Clupeidae	Marine straggler
Blue sprat	Spratelloides robustus	Clupeidae	Marine straggler
Old wife <sup>^</sup>	Enoplosus armatus	Enoplosidae	Marine straggler
Southern Longfin Goby	Favonigobius lateralis	Gobiidae	Marine straggler
Southern garfish	Hyporhamphus melanochir	Hemiramphidae	Marine straggler
Broadnose shark <sup>^</sup>	Notorynchus cepedianus	Hexanchidae	Marine straggler
Zebra fish	Girella zebra	Kyphosidae	Marine straggler
Sea sweep	Scorpis aequipinnis	Kyphosidae	Marine straggler
Blue groper <sup>^</sup>	Achoerodus gouldii	Labridae	Marine straggler
Little weed whiting <sup>^</sup>	Neoodax balteatus	Labridae	Marine straggler
Longray weed whiting <sup>^</sup>	Siphonognathus radiatus	Labridae	Marine straggler
Flathead sandfish	Lesueurina platycephala	Leptoscopidae	Marine straggler
Bridled leatherjacket	Acanthaluteres spilomelanurus	Monacanthidae	Marine straggler
Southern pygmy leatherjacket <sup>^</sup>	Brachaluteres jacksonianus	Monacanthidae	Marine straggler
Gunn's leatherjacket <sup>^</sup>	Eubalichthys gunnii	Monacanthidae	Marine straggler

Common name	Scientific name	Family	Guild
Marine category			
Six-spined leatherjacket	Meuschenia freycineti	Monacanthidae	Marine straggler
Velvet leatherjacket <sup>^</sup>	Meuschenia scaber	Monacanthidae	Marine straggler
Rough leatherjacket <sup>^</sup>	Scobinichthys granulatus	Monacanthidae	Marine straggler
Red mullet	Upeneichthys vlamingii	Mullidae	Marine straggler
Southern eagle ray <sup>^</sup>	Myliobatus tenuicaudatus	Myliobatidae	Marine straggler
Rock ling <sup>^</sup>	Genypterus tigerinus	Ophidiidae	Marine straggler
Common saw shark <sup>^</sup>	Pristiophorus cirratus	Pristiophoridae	Marine straggler
Southern saw shark <sup>^</sup>	Pristiophorus nudipinnis	Pristiophoridae	Marine straggler
Red gurnard perch <sup>^</sup>	Helicolenus percoides	Scorpaenidae	Marine straggler
Black-spotted gurnard perch	Neosebastes nigropunctatus	Scorpaenidae	Marine straggler
Common gurnard perch	Neosebastes scorpaenoides	Scorpaenidae	Marine straggler
King George whiting	Sillaginodes punctatus	Sillaginidae	Marine straggler
Snapper <sup>^</sup>	Chrysophrys auratus	Sparidae	Marine straggler
Smooth hammerhead <sup>^</sup>	Sphyrna zygaena	Sphyrnidae	Marine straggler
Big belly seahorse <sup>^</sup>	Hippocampus abdominalis	Syngnathidae	Marine straggler
Rhino pipefish <sup>^</sup>	Histiogamphelus cristatus	Syngnathidae	Marine straggler
Tucker's pipefish <sup>^</sup>	Mitotichthys tuckeri	Syngnathidae	Marine straggler
Common seadragon <sup>^</sup>	Phyllopteryx taeniolatus	Syngnathidae	Marine straggler
Pug-nosed pipefish	Pugnaso curtirostris	Syngnathidae	Marine straggler
Spotted pipefish <sup>^</sup>	Stigmatophora argus	Syngnathidae	Marine straggler
Western striped grunter <sup>^</sup>	Pelates octolineatus	Terapontidae	Marine straggler
Richardson's toadfish	Tetractenos hamiltoni	Tetraodontidae	Marine straggler
School shark	Galeorhinus galeus	Triakidae	Marine straggler
Gummy shark	Mustelus antarcticus	Triakidae	Marine straggler
Red gurnard <sup>^</sup>	Chelidonichthys kumu	Triglidae	Marine straggler

<sup>&</sup>lt;sup>®</sup>denotes alien species, <sup>E</sup> denotes species listed under the *Environment Protection and Biodiversity Conservation Act 1999*, <sup>P</sup> denotes species protected in South Australia under the *Fisheries Management Act 2007*, <sup>C</sup> denotes species of commercial importance within the site, <sup>^</sup>denotes species with few records from the Lower Lakes and Coorong.

#### Fish species of conservation concern

Table 13-2 List of fish species of conservation concern found in the Ramsar site (from Bice et al. 2018) and their relevant National and State conservation status. National listings relate to the federal *Environment Protection and Biodiversity Conservation Act* (1999). State listings include *protection* from take under the Fisheries Management Act (2007) and interim listings under the *Action Plan for South Australian Freshwater Fishes* (Hammer et al. 2009).

Common name Scientific name		South Australian listing		National listing
		Fisheries Management Act 2007	Action Plan for South Australian Freshwater Fishes 2009	EPBC Act 1999
Murray cod (Pondi)	Maccullochella peelii	Protected	Endangered	vulnerable
Silver perch	Bidyanus	Protected	Endangered	critically endangered
Freshwater catfish (Pomeri)	Tandanus	Protected	Endangered	-
Southern pygmy perch	Nannoperca australis	Protected	Endangered	-
Murray hardyhead	Craterocephalus fluviatilis	Protected	Critically Endangered	endangered

#### Fish species to be assessed as part of the fish diversity (species richness) LAC

Table 13-3 List of common freshwater, estuarine and estuarine-marine opportunist species to be assessed as part of the fish diversity (species richness) LAC.

Common name (Ngarrindjeri name)	Scientific name			
Common freshwater species	Common freshwater species			
Australian smelt	Retropinna semoni			
Bony herring (Thukeri)	Nematalosa erebi			
Carp gudgeon complex	Hypseleotris spp.			
Common galaxias (Pulangi)	Galaxias maculatus			
Congolli (Kungguldhi)	Pseudaphritis 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	ustralian herring Arripis georgianus			
Common estuarine and marine migrant species				

Common name (Ngarrindjeri name)	Scientific name
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
Sandy sprat	Hyperlophus vittatus
Small-mouthed 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

#### Fish species to be assessed as part of the fish diversity (biodisparity) LAC

#### Table 13-4 List of families to be assessed as part of the fish diversity (biodisparity) LAC.

Fish Families
Arripidae
Atherinidae
Bovichtidae
Clupeidae
Eleotridae
Galaxiidae
Geotriidae
Gobiidae
Hemiramphidae
Mugilidae

Fish Families
Percichthyidae
Pleuronectidae
Retropinnidae
Sciaenidae
Sparidae
Tetraodontidae
Tetrarogidae

## B. Waterbirds

Species list of wetland birds recorded at the Ramsar site

Table 13-5 Wetland bird species list for The Coorong and Lakes Alexandrina and Albert Wetland Ramsar site

EPBC Act listing: J = JAMBA; C= CAMBA; R = ROKAMBA, CMS = Convention on the Conservation of Migratory Species of Wild Animals; CE = critically endangered internationally, Vu = vulnerable, En = endangered. Breeding: Limited = sparse records of breeding, usually with low counts but possible breeding still occurs irregularly at the site; Regular = less than annual; Annual = breeding occurs annually with strong data record. Conservation status as of April 2017 – note this means some species do not contribute to criterion 2 in the 2015 assessment. Migratory status based on Department of the Environment (2017). SPRAT EPBC Migratory Lists in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: http://www.environment.gov.au/sprat. Accessed 2017-03-21 T15:33:56 . Note this lists all species recorded at the site including vagrants. Species list compiled from (Phillips and Muller 2006), (Ecological Associates 2010), (O'Connor et al. 2012), (O'Connor 2015a) and higher taxonomic groupings after (Christidis and Boles, 2008).

Common Name (by family)	Scientific Name	Breeding	EPBC/IUCN/ International treaty	
Accipitriformes – Accipitridae				
Eastern osprey	Pandion cristatus (haliaetus)			
Swamp harrier	Circus approximans			
White-bellied sea eagle	Haliaeetus leucogaster			
Anseriformes – Anatidae				
Australasian Shoveler (Kalpari)	Anas rhynchotis	Limited		
Australian Shelduck (Pitjangoli, Purnar, Tarankinyi)	Tadorna tadornoides	Limited		
Australian Wood Duck	Chenonetta jubata	Limited		
Black Swan (Kungari)	Cygnus atratus	Annual		
Blue-billed Duck (Pulki-nyeri)	Oxyura australis	Limited		
Cape Barren Goose (Lawari)	Cereopsis novaehollandiae			
Chestnut Teal (Ngarraki)	Anas castanea	Regular		
Freckled Duck	Stictonetta naevosa			
Grey Teal	Anas gracilis	Limited		
Hardhead (Pungkari, Waranggaiperi)	Aythya australis	Limited		
Musk Duck(M:nanawuli, F:rtilmeri)	Biziura lobata	Limited		
Mallard (introduced)	Anas platyrhynchos			
Pacific Black Duck	Anas superciliosa	Regular		
Pink-eared Duck (Witjuwandi, Wiwuldi)	Malacorhynchus membranaceus	Limited		

Common Name (by family)	Scientific Name	Breeding	EPBC/IUCN/ International treaty		
Charadiiformes - Charadriidae	Charadiiformes - Charadriidae				
Black-fronted Dotterel	Elseyornis melanops				
Banded Lapwing	Vanellus tricolor				
Charadiiformes - Haematopodidae		<u>'</u>			
Australian Pied Oystercatcher (Prukal)	Haematopus longirostris	Regular			
Sooty Oystercatcher	Haematopus fuliginosus	Limited			
Charadiiformes - Laridae					
Arctic Tern	Sterna paradisaea		CMS		
Australian Fairy Tern (Talamarari)	Sternula nereis	Annual	Vu (EPBC)		
Caspian Tern (Tenatjeri)	Sterna caspia	Regular	J		
Common Tern	Sterna hirundo		C, J, R		
Crested Tern	Thalasseus bergii	Annual	J		
Gull-billed Tern	Gelochelidon nilotica		С		
Kelp Gull	Larus dominicanus				
Little Tern	Sternula albifrons		CMS, C, J, R		
Pacific Gull	Larus pacificus				
Silver Gull (Throkarri)	Chroicocephalus novaehollandiae	Regular			
Sooty Tern	Onychoprion caspia				
Whiskered Tern	Chlidonias hybrida				
White-winged Black Tern	Chlidonias leucopterus		C, J, R		
Charadiiformes – Recurvirostridae		<u>'</u>			
Banded Stilt	Cladorhynchus leucocephalus				
Black-winged Stilt (Nyilkanyi)	Himantopus	Limited	CMS		
Red-necked Avocet (Nitinyi)	Recurvirostra novaehollandiae				
Double-banded Plover	Charadrius bicinctus		CMS		
Greater Sand Plover	Charadrius leschenaultii		CMS, C, J, R		
Grey Plover	Pluvialis squatarola		CMS, C, J, R		
Hooded Plover (Ngamat)	Thinornis rubricollis	Annual	Vu (EPBC)		
Inland Dotterel	Charadrius australis				

Common Name (by family)	by family) Scientific Name Breeding		g EPBC/IUCN/ International treaty		
Charadiiformes – Recurvirostridae	Charadiiformes – Recurvirostridae				
Lesser Sand Plover	Charadrius mongolus		CMS, C, J, R		
Masked Lapwing	Vanellus miles				
Oriental Plover	Charadrius veredus		CMS, C, J, R		
Pacific Golden Plover	Pluvialis fulva		CMS, C, J, R		
Red-capped Plover	Charadrius ruficapillus	Regular			
Red-kneed Dotterel	Erythrogonys cinctus	Limited			
Charadiiformes – Rostralulidae					
Australian Painted-snipe	Rostratula australis	Limited	En (EPBC), En (IUCN)		
Charadiiformes – Scolopacidae	'				
Bar-tailed Godwit	Limosa lapponica		CMS, C, J, R		
Black-tailed Godwit	Limosa		CMS, C, J, R		
Broad-billed Sandpiper	Limicola falcinellus		CMS, C, J, R		
Common Greenshank (Terilteril)	Tringa nebularia		CMS, C, J, R		
Common Redshank	Tringa totanus		CMS, C, J, R		
Common Sandpiper	Actitis hypoleucos		CMS, C, J, R		
Curlew Sandpiper	Calidris ferruginea		CE (EPBC), NT (IUCN), CMS, C, J, R		
Eastern Curlew	Numernius madagascariensis		CE (EPBC), En (IUCN), CMS, C, J, R		
Great Knot	Calidris tenuirostris		CE (EPBC), NT (IUCN), CMS, C, J, R		
Grey Phalarope	Phalaropus fulicarius				
Grey-tailed Tattler	Tringa brevipes		CMS, C, J, R		
Latham's Snipe	Gallinago hardwickii		CMS, J, R		
Little Curlew	Numernius minutus		CMS, C, J, R		
Little Stint	Calidris minuta				
Lesser Yellowlegs	Tringa flavipes				
Long-toed Stint	Calidris subminuta		CMS, C, J, R		
Lewin's Rail	Lewina (Rallus) pectoralis				
Marsh Sandpiper	Tringa stagnatilis		CMS, C, J, R		

Common Name (by family)	Scientific Name	Breeding	EPBC/IUCN/ International treaty
Charadiiformes – Scolopacidae			
Pectoral Sandpiper	Calidris melanotos		CMS, J, R
Red Knot	Calidis canutus		En (EPBC), En (IUCN), CMS, C, J, R
Red-necked Phalarope	Phalaropus lobatus		CMS, C, J, R
Red-necked Stint	Calidris ruficollis		CMS, C, J, R
Ruddy Turnstone	Arenaria interpres		CMS, C, J, R
Ruff	Philomachus pugnax		CMS, C, J, R
Sanderling	Calidris alba		CMS, C, J, R
Sharp-tailed Sandpiper	Calidris acuminata		CMS, C, J, R
Terek Sandpiper	Xenus cinereus		CMS, C, J, R
Whimbrel	Numeius phaeopus		CMS, C, J, R
Wood sandpiper	Tringa glareola		CMS, C, J, R
Charadiiformes – Stercorariidae			'
Arctic Jaeger (Artic Skua)	Stercorarius parasilticus		C, J, R
Brown Skua	Stercorarius antarticus (Catharacta skua)		
Ciconiiformes – Pelecanidae		'	
Australian Pelican (Ngori)	Pelecanus conspicillatus	Annual	
Ciconiiformes – Ardeidae		'	
Australasian Bittern (Talkuri)	Botaurus poiciloptilus	Regular	CE (IUCN), En (EPBC)
Australian Little Bittern	Ixobrychus dubius		
Cattle Egret	Ardea ibis		
Eastern Great Egret	Ardea modesta	Limited	
Intermediate Egret	Ardea intermedia		
Little Egret	Egretta garzetta		
Nankeen Night-heron	Nycticorax caledonicus		
White-faced Heron	Egretta novaehollandiae		
White-fronted Tern	Sterna striata		
White-necked Heron	Ardea pacifica		

Common Name (by family)	Scientific Name	Breeding	EPBC/IUCN/ International treaty		
Ciconiiformes - Threskiornithidae					
Australian White Ibis	Threskiornis molucca	Regular			
Glossy Ibis	Plegadis falcinellus	Limited	CMS		
Royal Spoonbill (Kraurarli)	Platalea regia	Regular			
Straw-necked Ibis (Tloperi)	Threskiornis spinicollis	Regular			
Yellow-billed Spoonbill	Platalea flavipes	Limited			
Coraciiformes - Alcedinidae					
Azure Kingfisher	Alcedo azurea				
Coraciiformes - Halcyonidae			'		
Red-backed Kingfisher	Todiramphus prrhopygia				
Sacred kingfisher	Todiramphus sanctus				
Gruiformes - Rallidae					
Australian Spotted Crake	Porzana fluminea	Limited			
Ballion's Crake	Porzana pusilla				
Black-tailed Native-hen	Tribonyx ventralis				
Buff-banded Rail	Gallirallus philippensis				
Dusky Moorhen (Leiwulgi, Keili)	Gallinula tenebrosa	Limited			
Eurasian Coot	Fulica atra				
Purple Swamphen	Porphyrio porphyrio	Limited			
Spotless Crake	Porzana tabuensis				
Passeriformes - Acrocephalidae					
Australian Reed Warbler (Calamorous Reed-warbler)	Acrocephalus australis				
Great (Oriental) Reed Warbler	Acrocephalus orientalis		С		
Passeriformes - Cisticolidae					
Golden-headed Cisticola	Cisticola exilis	Limited			
Passeriformes - Maluridae	Passeriformes - Maluridae				
MLR Southern Emu-wren (Wirili Pulyeri)	Stipiturus malachurus intermedius	Limited	En (EBPC)		
Passeriformes - Megaluridae					
Little Grassbird	Megalaus gramineus				

Common Name (by family)	Scientific Name	Breeding	EPBC/IUCN/ International treaty	
Phalacrocoraciformes - Anhingidae				
Australasian Darter	Anhinga novaehollandiae			
Phalacrocoraciformes - Phalacrocor	acidae			
Black-faced Cormorant	Phalacrocorax fuscescens			
Great Cormorant	Phalacrocorax carbo	Limited		
Little Black Cormorant	Phalacrocorax sulcirostris	Limited		
Little Pied Cormorant (Teilakawari, Tereiwari)	Microcarbo melanoleucos	Limited		
Pied Cormorant (Ngalgurindi)	Phalacrocorax varius	Regular		
Phalacrocoraciformes - Sulidae				
Australasian Gannet	Morus serrator			
Podicipediformes - Podicipedidae				
Australasian Grebe	Tachybaptus novaehollandiae			
Great Crested Grebe	Podiceps cristatus			
Hoary-headed Grebe	Poliocephalus poliocephalus			
Procellariformes - Diomededidae				
Black-browed Albatross	Diomedea melanophris		Vu(EPBC), CMS	
Grey-headed Albatross	Diomedea chrysostoma		En (EPBC), CMS	
Shy Albatross	Diomedea cauta		Vu (EPBC), CMS	
Wandering Albatross	Diomedea exulans		Vu (EPBC), CMS	
Yellow-nosed Albatross	Diomedea chlororhynchos			
Procellariformes – Procellariidae				
Antarctic Petrel	Thalassoica antarctica			
Antarctic Prion	Pachyptila desolata			
Blue Petrel	Halobaena caerulea		Vu (EPBC)	
Broad-billed Prion	Pachyptila vittata			
Common Diving-petrel	Pelecanoides urinatrix			
Fairy Prion	Pachyptila turtur			
Fleshy-footed Shearwater	Ardenna (Puffinus) carneipes		J	
Fluttering Shearwater	Puffinus gavia			

Common Name (by family)	Scientific Name	Breeding	EPBC/IUCN/ International treaty		
Kergueien Petrel	Lugensa brevirostris				
Mottled Petrel	Pterodroma inexpectata				
Short-tailed Shearwater	Ardenna tenuirostris		C ,J, R		
Slender-billed Prion	Pachyptila belcheri				
Soft-plumaged Petrel	Pterodroma mollis		Vu (EPBC)		
Southern Fulmar	Fulmarus glacialoides				
Southern Giant-petrel	Macronectes giganteus		En (EPBC), CMS		
White-headed Petrel	Pterodroma lessonii				
Psittaciformes - Psittacidae					
Orange-bellied parrot (Prolin, Mangkeri, Tartituwi)	Neopherma chrysogaster		CE (EPBC)		
Spheniciformes -	Spheniciformes -				
Fiordland Penguin	Eudyptes pachyrhynchus				
Little Penguin	Eudyptula minor				
Rockhoper Penguin	Eudyptes chrysocome				

## Waterbird breeding data

Table 13-6 Waterbird species known to breed in The Coorong and Lakes Alexandrina and Albert Wetland

Data from (Paton et al. 2009a) cited in (Ecological Associates 2010), (O'Connor et al. 2012). Limited data = sparse records but possible breeding still occurs irregularly at the site; Regular = breeding records for 3 of every 5 years; Annual = solid annual record of breeding events.

Common name	Scientific name	Breeding records	Known habitat/Notes
Australasian Shoveler (Kalpari)	Anas rhynchotis	Limited data; Prior to 1980s	
Australian Painted- snipe	Rostratula australis	Limited data; Single record Tuckers Swamp 1980	Not considered likely to be breeding at the site post listing.
Australian Pelican (Ngori)	Pelecanus conspicillatus	Annual; Active nests with eggs and chicks recorded in 2006, 2009, 2010, 2011, 2012, 2013 <sup>1,2,6</sup>	Historic breeding: unspecified Coorong islands in 1929, 1932, 1935, 1937, 1962–1963 (Chapman 1963 cited in O'Connor et al. 2012) and Pelican Island in 1986. Teal, North Pelican, Pelican, Mellor and Seagull islands (South Lagoon).
Australian Pied Oystercatcher (Prukal)	Haematopus longirostris	Regular; Juveniles in 1997 <sup>4,5</sup> . Nests in 2002 <sup>4</sup> and 2011 (per	Younghusband Peninsula beaches, Murray Mouth <sup>5</sup> , North and South Coorong islands (Paton 2010)

Common name	Scientific name	Breeding records	Known habitat/Notes
		obs. D. Rogers cited in O'Connor et al. 2012).	
Australian Shelduck (Pitjangoli, Purnar, Tarankinyi)	Tadorna tadornoides	Limited data	
Australian Spotted Crake	Porzana fluminea	Limited data	
Australian White Ibis (Tloperi)	Threskiornis molucca	Regular: Nests in 2011 <sup>3</sup> ; breeds annually at Snake Island (Eckert 2000).	Lake Alexandrina and Albert (Narrung Narrows, Point Sturt, Boggy Lake, Low Point, Currency Creek mouth, Tolderol (O'Connor et al. 2012, O'Connor and Rogers 2014).
Australian Wood Duck (Na:ri)	Chenonetta jubata	Limited data	
Black Swan (Kungari)	Cygnus atratus	Annual; Cygnets recorded 2010–2014 <sup>3,7</sup>	Historic breeding records: 1910s to 1930s (White 1918, Paton 2010 cited in O'Connor et al. 2012). Breeding recorded in Goolwa Channel, Lakes Alexandrina and Albert.
Black-winged Stilt (Nyilkanyi)	Himantopus himantopus	Limited data	
Blue-billed Duck (Pulki-nyeri)	Oxyura australis	Limited data	
Caspian Tern (Tenatjeri)	Hydroprogne (Sterna) caspia	Regular; Regular breeding activity (Paton 2010). Nests and chicks in 1997; juveniles recorded in 2009 <sup>3,4</sup>	South Lagoon islands.
Chestnut Teal (Ngarraki)	Anas castanea	Regular; 2011: 6 juveniles in census <sup>3</sup> . Regular breeding in the Finniss estuary (Eckert 2000).	Lakes Alexandrina and Albert.
Crested Tern	Thalasseus bergii	Annual; greater than 1,000 pairs per year (Paton 2010). Greater than 900 nests with eggs in 1997, fledged young recorded in 2009 <sup>4,5</sup> , 700–3,350 birds on nests (Nov–Dec 2012) and (Oct–Dec 2013) 285–1,750 birds on nests	South Lagoon islands (e.g. Pelican Island).
Dusky Moorhen (Leiwulgi, Keili)	Gallinula tenebrosa	Limited data; 2011: 3 juveniles in census at Lake Alexandrina <sup>3</sup>	Lakes Alexandrina and Albert
Eastern Great Egret	Ardea modesta (alba)	None, however the species uses the site during its breeding season (O'Connor et al. 2013), note Paton (2009b) states common pre 1970s	Lakes Alexandrina and Albert

Common name	Scientific name	Breeding records	Known habitat/Notes
Australian Fairy Tern (Talamarari)	Sternula nereis nereis	Annual; Nesting activity recorded 1997, 1999, 2008 and 2009–2012 <sup>1,4,5</sup> . Greater than 50 active nests in 2012 <sup>5</sup> .	South Lagoon islands and Murray Mouth. Annual breeding surveys. Breeding success dependent on prey availability (hardyhead fish) close to predator-free nesting islands.
Glossy Ibis	Plegadis falcinellus	Limited data	
Golden-headed Cisticola	Cisticola exilis	Limited data; Nests in 1980 <sup>7</sup> and 1931 (Sutton 1931 cited in O'Connor et al. 2012)	Freshwater reed beds, Lignum swamps.
Great Cormorants	Phalacrocorax carbo	Limited data	
Grey Teal	Anas gracilis	Limited data; 2011: 8 juveniles in census at Lake Alexandrina <sup>2</sup>	Lakes Alexandrina and Albert
Hardhead (Pungkari, Waranggaiperi)	Aythya australis	Limited data	
Hooded Plover (Ngamat)	Thinornis rubricollis	Annual; Nesting activity recorded annually 2002-12 <sup>4</sup>	Ocean beaches, occasionally coastal saline wetlands. Annual surveys undertaken to establish breeding activity.
Little Black Cormorant	Phalacrocorax sulcirostris	Limited data	
Little Pied Cormorant (Teilakawari, Tereiwari)	Microcarbo melanoleucos	Limited data	
Musk Duck (M;nanawuli F;rtilmeri, Peldi)	Biziura lobata	Limited data; Breeding at Tolderol Game reserve in 1989 (Eckert 2000).	Shallow, sheltered wetlands.
Pacific Black Duck (Nakari, Pebulaipuri, Teintar)	Anas superciliosa	Regular; Juveniles recorded in Lake Alexandrina 2011 <sup>3</sup>	Lakes Alexandrina and Albert.
Pied Cormorant (Ngalgurindi)	Phalacrocorax varius	Regular; 2007: breeding at Lake Albert Kingsford and Potter 2008, Porter 2008 and 2011: 420 large nestlings at Lake Alexandrina <sup>3</sup> . Regular breeding at Lake Alexandrina (Eckert 2000).	Lakes Alexandrina and Albert. Historic records: South Lagoon islands, 1930s (Sutton 1933 cited in O'Connor et al. 2012) and Snake Island, 1980 <sup>2</sup>
Pink-eared Duck (Witjuwandi, Wiwuldi)	Malacorhynchus membranaceus	Limited data	
Purple Swamphen	Porphyrio	Limited data; 2011: 3juveniles in census at Lake Alexandrina <sup>2</sup>	Lakes Alexandrina and Albert

Common name	Scientific name	Breeding records	Known habitat/Notes
Red-capped Plover	Charadrius ruficapillus	Regular; Regular breeding (Paton 2010). Nests in 2011 (pers obs. D. Rogers cited in O'Connor et al. 2012).	Younghusband Peninsula beaches and Murray Mouth. Historic record: nest with eggs in 1931 (Sutton 1931 cited in O'Connor et al. 2012)
Red-kneed Dotterel	Erythrogonys cinctus	Limited data	
Royal Spoonbill (Kraurarli)	Platalea regia	Regular; More common pre 1970s. Nests in 2011 <sup>3</sup> . Regular breeding at Snake Island (Eckert 2000).	Lakes Alexandrina and Albert. Historic breeding records near Snake Island 1978 <sup>2</sup>
Silver Gull (Throki)	Chroicocephalus novaehollandiae	Regular breeding activity (Paton 2010)	South Lagoon islands. Historic breeding records (Sutton 1931 cited in O'Connor et al. 2012). Muldungawa Salt Lakes (O'Connor and Rogers 2014).
Sooty Oystercatcher	Haematopus fuliginosus	Limited data; 2011: 2 juveniles counted in survey <sup>3</sup>	Younghusband Peninsula beaches and Murray Mouth
Mount Lofty Ranges Southern Emu-wren (Wirili Pulyeri)	Stipiturus malachurus intermedius	Limited data; 1982 (near Finniss River) <sup>1</sup> No recent breeding records from the 3 known populations around Currency Creek/ Finniss River. However, the persistence of these populations since 1993 implies that breeding has occurred (pers. comm. M. Pickett)	Dense swamps around Currency Creek and Finniss River
Straw-necked Ibis (Tloperi)	Threskiornis spinicollis	Regular; 2007: breeding at Lake Albert (Kingsford and Porter 2008). 2011: 160 nestlings at Lake Alexandrina <sup>3</sup> . Regular breeding at Snake Island (Eckert 2000).	Lakes Alexandrina and Albert. Historic breeding records near Snake Island 1978 <sup>2</sup>
Yellow spoonbill	Platalea flavipes	Limited data; More common pre 1970s	

<sup>&</sup>lt;sup>1</sup> Data sourced from South Australian Department for Environment and Natural Resources Biological Database of SA. Record set number DENR BDBSA 120123-1, 2 Australian Pelican Survey <sup>3</sup> David Paton CLLMM census, 2011, <sup>4</sup> Beach-nesting Birds Project (Birds Australia), <sup>5</sup> Fairy Tern Survey, 6 O'Connor and Rogers colonial survey 2014, <sup>7</sup> Coorong Nature Tours surveys 2013, 2014, 8 O'Connor et al. (2013).

## C. Macroinvertebrates

Table 13-7 Macroinvertebrate species in the Coorong. Data from (Ditmann et al. 2017)

Phyla/Cla	ss/Order	Family/Genus/Species
Annelida	Oligochaeta	
	Polychaeta	Capitella spp.
		Simplisetia aequisetis
		Australonereis ehlersi
		Boccardiella limnicola
		Ficopomatus enigmaticus
Crustacea	Amphipoda	
	Isopoda	
	Ostracoda	
	Mysidacea	
	Brachyura	Hymenosomatidae
		Helograpsus haswellianus
Mollusca	Bivalvia	Arthritica helmsi
		Soletellina ydroalba
		Spisula trigonella
	Gastropoda	Hydrobiidae sp
		Salinator fragilis
Hexapoda	Diptera	Chironomidae
		Diptera
		Culicidae
		Dolichopodidae
		Ceratopogonidae
		Scyomyzidae
		Stratiomyidae
	Coleoptera	Ptilodactylidae

## D. Datasets used

Table 13-8 Summary of datasets used to assess the Vegetation LAC for the Coorong and Lakes Alexandrina and Albert Wetland.

Dataset	Years	Subunits and sites	Data recorded	Reference
Aquatic Flora assessment of Hindmarsh Island	1989	Lake Alexandrina	Presence/ absence	(Renfrey, Rea, & Ganf, 1989)
River Murray Wetlands Baseline Survey	2004 & 2005	Lake Alexandrina, Lake Albert	Cover/ abundance of each taxon  Map of dominant plant communities	(SKM 2005) (Nicol, Weedon, & Doonan, 2006)
Aquatic and Littoral Vegetation Condition Monitoring	2008-15	Lake Alexandrina, Lake Albert	Cover/ abundance of each taxon	(Frahn et al. 2014)
Dunns Lagoon and Shadows Lagoon & Goolwa Channel seed bank assessments	2009 & 2010	Lake Alexandrina	Seed bank assessment	(Nicol & Ward, 2010a) (Nicol & Ward, 2010b)
Aquatic and littoral vegetation monitoring of Goolwa Channel, the lower Finniss River and Lower Currency Creek	2009-11	Lake Alexandrina	Cover/ abundance of each taxon  Spatial distribution of dominant plant communities at time of survey	(Gehrig, Nicol, & Marsland, 2011)
Schoenoplectus planting monitoring	2013-15	Lake Alexandrina, Lake Albert	Cover/ abundance of each taxon	(Nicol JM, 2015)
Emergent vegetation mapping in Lakes Alexandrina and Albert	2014	Lake Alexandrina, Lake Albert	Map of distribution and percentage cover of large emergent species at time of survey	(Nicol, Gehrig, & Strawbridge, 2014)
Annual spring / summer Ruppia tuberosa monitoring in the Coorong	1984-2014	Coorong North and South Lagoon	Presence per site Shoots per core Flower head density Presence of seed and turions	(Paton and Bailey 2012a)
Annual winter <i>Ruppia tuberosa</i> monitoring in the Coorong	1998-2014	Coorong North and South Lagoon	Presence per site  Shoots per core  Presence of seed and turions	(Paton, Bailey, & Paton, 2015)

Dataset	Years	Subunits and sites	Data recorded	Reference
Ecological observations from small barrage outflows	2003 and 2004	Murray estuary and Coorong North Lagoon	Distribution and abundance of <i>Ruppia</i> spp. (observations)	(Geddes, 2005a) (Geddes, 2005b)
Impact of barrage releases on the population dynamics of <i>Ruppia megacarpa</i> in the Murray estuary and North Lagoon of the Coorong. Progress Report 06/07.	2006	Murray estuary and Coorong North Lagoon	Shoots per core Presence of seed and turions	(Nicol 2007a)

Table 13-9 Summary of the datasets used to assess the Fish LAC and document changes since listing. Datasets used are those where sampling was undertaken annually for at least 5 years and was undertaken in a consistent, standardised and quantifiable manner.

Dataset	Years	Subunits and sites	Data recorded	Reference
Diadromous fish condition monitoring (SARDI)	2006-07 to 2014-15*	Murray barrages:  Tauwitchere – 3 sites  Goolwa – 2 sites  Hunters Creek	Abundance Fish length	(Bice and Zampatti, 2015) Bice and Zampatti (2017)
Lower Lakes threatened fish condition monitoring (University of Adelaide)	2004 to 2015	Lakes Alexandrina: 17 sites Lake Albert: 3 sites	Abundance Fish length	Wedderburn (2017) Wedderburn and Barnes (2016)
Coorong fish condition monitoring (TLM)  Coorong fish intervention monitoring (SARDI) (CLLMM Recovery Program)	2008-09 to 2014-15 2010-11 to 2014-15	13 sites in the Murray estuary, North Lagoon and South Lagoon of the Coorong	Abundance Fish length/ age	Ye et al. (2017) Ye et al. (2015a)  Ye et al. (2015b) Ye et al. (2012)
Lakes and Coorong Commercial Fishery	1984-85 to 2014-15	Lakes and Coorong	Catch and effort	SARDI Fisheries Statistics

<sup>\*</sup>No data was collected in 2012-13

Table 13-10 Summary of the datasets used to assess the Waterbird LAC and document changes since listing (noting breeding records data in Appendix B). The University of Adelaide (D. Paton) dataset includes a total census count of all waterbirds in the Coorong South Lagoon in 1985, a total census of waterbirds in the entire Coorong from 2000-08 and a total census of waterbirds in the entire Coorong, Lower Lakes and Murray Mouth from 2009 onwards. The Coorong Nature Tours (D & M Dadd) dataset includes point count data of all waterbird species in the Coorong, Lower Lakes and Murray Mouth from 2001 onwards. The Australian Wader Study Group (AWSG) dataset includes a total census of all wader species in the entire Coorong and Murray Mouth area in 1981, 1982, 1987, 2000–08 and 2010–13. This dataset also included the 'Watkins 1993' data, which represents the highest count of wader species taken from Royal Australian Ornithological Union Coorong wader surveys between 1980 and 1993 (Watkins 1993).

Dataset	Years	Subunits and sites	Data recorded	Reference
University of Adelaide (D. Paton)	1985, 2000-15	Coorong Murray estuary	Number of individuals for each waterbird species	Rogers and Paton (2009)
		(1 km sections: land shoreline, sea shoreline, lagoon centre)		Paton et al. (2015d)
				(Paton, Paton, & Bailey, Birds, 2017)
University of Adelaide	2009-15	Lake edges and open water	Number of	Paton et al. (2015)
(D. Paton)		(1 km x 1 km grid cells)	individuals for each waterbird species	Paton et al. (2017)
Coorong Nature	2001-14	Lake edges (up to 35 sites/ yr)	Number of	(Thiessen 2011)
Tours (D and M Dadd)		East coast Coorong	individuals for each	O'Connor and
		(up to 21 sites/ yr)	waterbird species	Rogers (2014)
		Murray estuary		
		(up to 18 sites/ yr)		
		(1.5 km arc for 30 mins/ site)		
Australian Wader	1981-82,	East/ west coast Coorong	Number of	(Jaensch & Barter
Study Group	1987,	Murray estuary	individuals for	1988)
	2000-08, 2010-13	(26 sections of either coast, sections are ~5-12 km long)	wader species only	(Wainright & Christie 2008)

Table 13-11 Summary of datasets used to assess the Southern bell frog LAC for the Coorong and Lakes Alexandrina and Albert Wetland.

Dataset	Years	Subunits and sites	Data recorded	Reference
Frog census	2000	Lakes and tributaries*	Number of frogs (sound recordings)	(Walker & Goonan, 2000)
River Murray Wetlands Baseline Survey	2004-05	Individual wetland sites within the SA Murray-Darling Basin	Adult abundance	(SKM 2004), (Simpson, Holt, Champion, Horan, & Shirley, 2006)
SBF Inventory	2009	Lakes and tributaries	Adult abundance (call recognition and visual assessment) and evidence of recruitment (tadpoles) at targeted sites	(Mason 2010)

Dataset	Years	Subunits and sites	Data recorded	Reference
SBF Monitoring	2010-11- 2016-17	Lakes and tributaries	Adult abundance (call recognition, sound recording and visual assessment)  Evidence of recruitment (tadpoles) at targeted sites (excluding 2014-15)	Mason and Hillyard (2011), (Mason 2013), Mason (2014), Mason and Durbridge (2015) (Mason, 2018)

<sup>\*</sup>Note this is a South Australian South-East and River Murray survey that included the Lakes and tributaries sub-units of the Ramsar site.

Table 13-12 Summary of datasets used to assess the Coorong food web LAC for the Coorong and Lakes Alexandrina and Albert Wetland.

Dataset	Years	Subunits and sites	Data recorded	Reference
Annual spring / summer Ruppia tuberosa monitoring in the Coorong	1984- 2014	Coorong North and South Lagoon	Presence per site Shoots per core Flower head density Presence of seed and turions	Paton et al. (2016), Paton et al. (2017), Rogers & Paton (2009)
Annual winter Ruppia tuberosa monitoring in the Coorong	1998- 2014	Coorong North and South Lagoon	Presence per site Shoots per core Presence of seed and turions	Paton et al. (2015b), Paton et al. (2017), Rogers & Paton (2009)
Annual Coorong benthic invertebrate condition monitoring	2005- 2014	Coorong North and South Lagoons, Murray Estuary	Benthic macroinvertebrate abundance, diversity and biomass per core	Dittmann et al. (2014a), Dittmann (2017)
Salinity (cascade LAC assessment for macroinvertebrates)	to 2015	Murray estuary, Coorong North and South Lagoon salinity	Salinity (EC converted to ppt)	Refer to section 8.3.1 surface water regime
Annual Coorong fish condition monitoring (small- mouthed hardyhead)	2008- 2014	Coorong North and South Lagoons	Presence per site, abundance, length	Ye et al. (2012), Ye et al. (2017)
Salinity (cascade LAC assessment for small-mouthed hardyhead)	to 2015	Coorong North and South Lagoon salinity	Salinity (EC converted to ppt)	Refer to section 8.3.1 surface water regime



*(f}j*}

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