# South Australian evaluation of environmental outcomes under the Basin Plan | 2024

*South Australian River Murray Water Resource Plan Area*

SOUTH AUSTRALIA

Government of South Australia
Department for Environment and Water

## Acknowledgment of Country

We acknowledge and respect the Traditional Custodians whose ancestral lands we live and work upon and we pay our respects to their Elders past and present. We acknowledge and respect their deep spiritual connection and the relationship that Aboriginal and Torres Strait Islanders people have to Country.

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

## Acknowledgement of partners

This evaluation report is the result of a collaborative effort involving numerous individuals and staff from South Australian government agencies, universities and organisations. Contributors included the Murray–Darling Basin Authority, the South Australian Research and Development Institute and the University of Adelaide, who provided essential data, information, reports, expert input and reviews throughout all stages of the evaluation. The authors extend their gratitude to all contributors for their valuable support.

This evaluation has relied on a number of monitoring programs for data and information, including The Living Murray (TLM) Initiative, The Riverine Recovery Program, South Australian Floodplain Integrated Infrastructure Program (SARFIIP), the Sustaining Riverland Environments (SRE) Program and the Commonwealth Environmental Water Office's Long-term Intervention Monitoring and Flow Monitoring, Evaluation and Research Programs.

The authors also acknowledge the contributions of past and present staff from the Department for Environment and Water. Special thanks are extended to the following technical experts for their ongoing support, access to data and continued contributions to this evaluation: Chris Bice, Luciana Bucater, Deborah Furst, Suse Gehrig, George Giatas, Matt Gibbs, Rupert Mathwin, Luke Mosley, Jason Nicol, Jody O'Connor, Gareth Oerman, Dan Rogers, Todd Wallace, Michelle Waycott, Qifeng Ye and Brenton Zampatti.

# Contents


# Synopsis

***The South Australian evaluation of environmental outcomes under the Basin Plan: 2024 South Australian River Murray Water Resource Plan Area* is one in a suite of reports submitted every five years by South Australia to meet our obligations under the Basin Plan.**

The South Australian Government remains committed to delivering the Basin Plan in full and ensuring a sustainable, healthy, working river system for future generations. This evaluation consolidates current evidence from the SA River Murray Water Resource Plan (WRP) Area, providing a summary of progress towards key objectives and outcomes. It highlights significant achievements, while also identifying areas where further sustained effort is required.

This evaluation report comes at a critical time in Basin Plan implementation, particularly as we approach the 2026 Basin Plan review, which will determine what is needed to best protect the Basin and its values into the future.

In undertaking this evaluation, we worked closely with technical experts and key stakeholders to address the following questions:

- Was this what we expected to see and have we seen any unanticipated outcomes?
- Why are we seeing these results?
- How has the Basin Plan contributed to what we are seeing?
- What is still to be done and what do we expect to see in the future?

# Key messages

This evaluation demonstrates that:

- Full implementation of the Basin Plan is vital to protect internationally recognised wetlands, including the Coorong, and Lakes Alexandrina and Albert Wetland and to maintain healthy aquatic environments that support irrigation, water supply, recreation and tourism.
- Water for the environment is essential to provide the varied flow regimes needed for ecosystems to thrive and its coordinated delivery, including with upstream watering actions, has contributed to improved outcomes in the SA River Murray.
- Delivery of water for the environment has improved environmental outcomes during low flow conditions, likely preventing similar outcomes to those seen during the Millennium Drought and enhanced outcomes during medium and high (unregulated) flows.
- Whilst many environmental outcomes since adoption of the Basin Plan have generally improved, monitoring has also shown that additional water for the environment is required – particularly during dry years – and is critical for the ongoing recovery and health of aquatic environments in the SA River Murray.
- Operation of South Australia's environmental regulators has expanded water delivery areas across the floodplains, improved connectivity and supported critical habitats for native fish, vegetation and waterbird species.
- High (unregulated) flows have provided system-wide environmental benefits including flushing salt and nutrients, breeding and feeding opportunities for fish and waterbirds and delivered water to wetlands and floodplains.
- The 2022–23 River Murray flood event delivered significant environmental benefits along the SA River Murray. However, improvements such as in tree health and seedling survival across the floodplains and salinity in the Lower Lakes and Coorong may be short-term if not followed-up by regular watering.

This report provides a clear, accessible summary of our evaluation and the environmental outcomes achieved so far and what is still needed. It begins with an overview of the South Australian River Murray WRP Area and its three Priority Environmental Assets (PEA). Detailed findings for key indicators are presented in the form of expected outcome reports, supported by two technical reports: *Channel and Floodplain* and the *Coorong, Lower Lakes and Murray Mouth (CLLMM).*

## Based on this evaluation, to achieve ongoing environmental improvements it is important that Basin Plan implementation:

- recovers and delivers the final 450 GL, critical to improving and maintaining environmental outcomes across South Australia's River Murray and as well as benefits to the connected floodplains in New South Wales and Victoria
- protects water for the environment across the Murray–Darling Basin, ensuring return flows from environmental watering events support downstream environmental outcomes
- addresses current physical and policy constraints to enable more effective delivery of water for the environment, whilst enhancing protection for landholders from higher than normal natural flows
- promotes efficient and effective use of water for the environment through innovative river operations and active management options
- improves monitoring and evaluation efforts to support adaptive management and improved outcomes aligned with the Basin Plan's intended environmental outcomes.

# Snapshot of Environmental responses of the 2022–23 River Murray Flood event

The 2022–23 River Murray flood event delivered unprecedented flow conditions not seen in South Australia for over 60 years. While the impacts on infrastructure and the community were significant, the benefits to the environment were substantial, bolstered by the delivery of approximately 1,227 GL of water for the environment delivered prior and following the flood event.

Many of these benefits are expected to persist, depending on future climate and flow conditions. For instance, new cohorts of native fish are anticipated to enhance populations long-term. However, some benefits, such as floodplain tree condition and water quality conditions in the CLLMM, may be short-lived and will require regular follow up watering to sustain.

The South Australian Government continues to prioritise management of water for environment purposes, even during elevated flow periods. These conditions present crucial opportunities to enhance flow and support the recovery of the River Murray system, both in South Australia and across the Basin.

© SARDI

### River Murray water

Flows peaked at the South Australian border at almost 190,000 ML/day in December 2022, while barrage flows peaked at about 120,000 ML/day at the end of January 2023. This enabled SA's river, floodplain and estuarine environments to be fully reconnected.

### Open Murray Mouth

Increased scouring of the Murray Mouth enhanced marine-estuarine connectivity, flushed excess salt and nutrients and suspended the need to dredge for the first time since August 2017.

### Water quality

End-of-system water quality improved, with the lowest average salinity in Lake Albert since monitoring began in 1968. Salinity levels became fresher and nutrient concentrations decreased in the Coorong.

### Floodplains & wetlands

The inundation of thousands of hectares of stressed floodplain and wetland habitats was crucial for the riverine ecosystem.

### Floodplain vegetation

The condition of long-lived floodplain vegetation improved, including river red gums and black box trees, along with water-dependent understorey vegetation, including various threatened species.

### Riverine productivity

There was an increase in organic matter production and transport from floodplains to the river channel, boosting riverine food webs.

### Fish

Strong recruitment and improved condition of Murray cod and golden perch were observed in the Channel and Floodplain, along with increased abundance and distribution of fish in the Coorong.

### Waterbird breeding

Extensive waterbird breeding activity occurred across many floodplains, including numerous species such as ducks, herons, cormorants, spoonbills, swans and darters.

### Coorong food web

Wide-spread growth of aquatic plants led to increased diversity and distribution of macroinvertebrates and fish, providing essential habitat and food resources.

### Abundant European carp

The inundated floodplain habitat resulted in a significant breeding event of carp, with the highest numbers recorded in the past 20 years following the flood.

### Limited shorebird feeding habitat

Very high water levels in the Coorong significantly reduced mudflat feeding habitat for shorebirds, leading to lower bird population numbers.

### Failed Fairy tern breeding

High water levels inundated threatened Fairy Tern nesting sites in the Coorong, resulting in a failed breeding event.

# South Australian River Murray Water Resource Plan Area

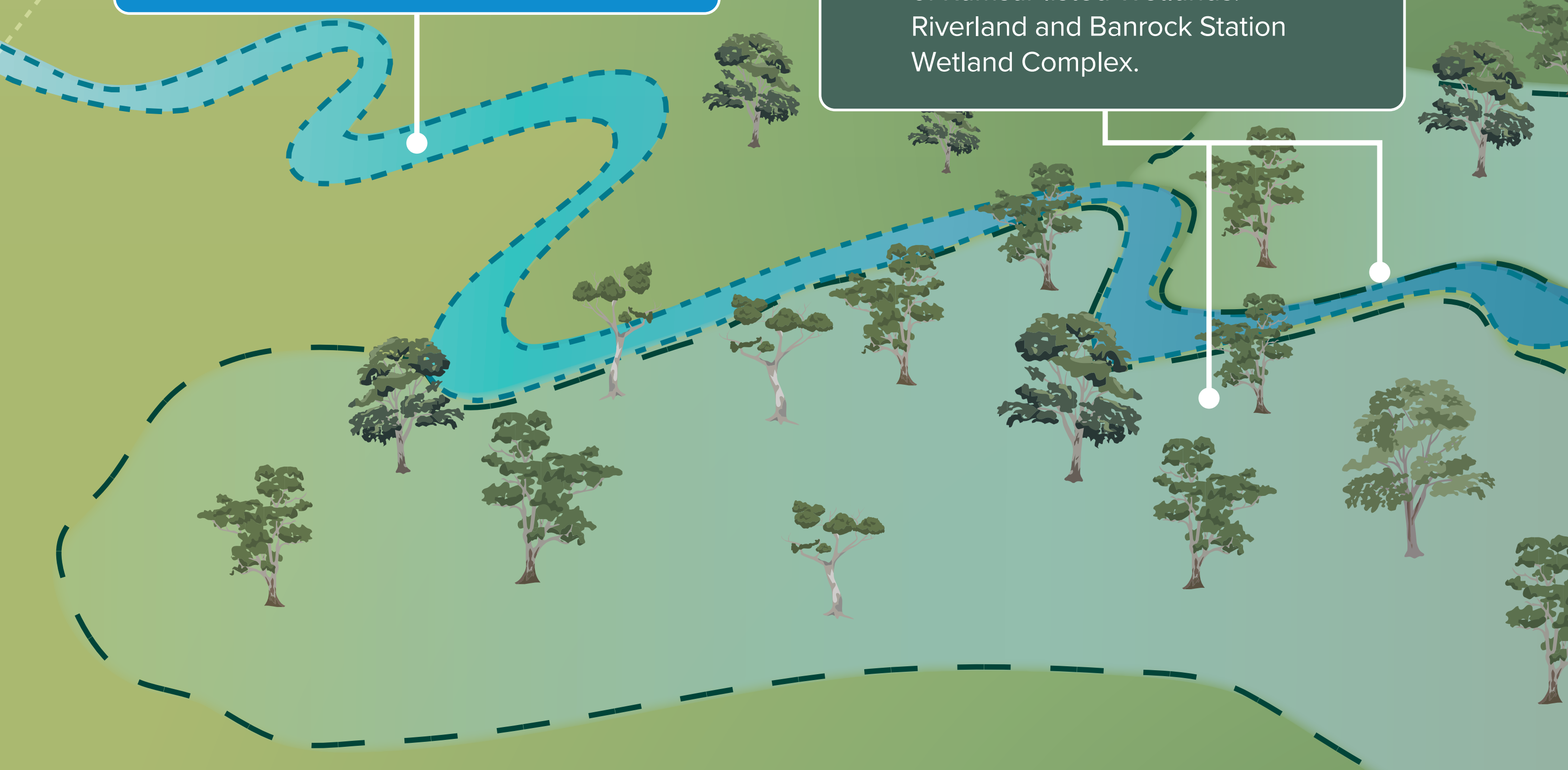
The South Australian (SA) River Murray Water Resource Plan Area (WRPA) includes the River Murray and its floodplain (defined by the 1956 flood extent), from the South Australian, New South Wales and Victorian border (the border) to the Murray Mouth and includes Lakes Alexandrina and Albert. Portions of the Angas and Bremer rivers, Finniss River and Currency Creek that enter Lake Alexandrina are also included.

### *Channel:*

- Stretches from SA border to Wellington, including the area inundated up to 40,000 ML/day.
- Supports a vast array of aquatic habitats and diverse fish, frogs and waterbirds.
- Adjoins two Ramsar-listed Wetlands: Riverland and Banrock Station Wetland Complex.

### *Floodplain:*

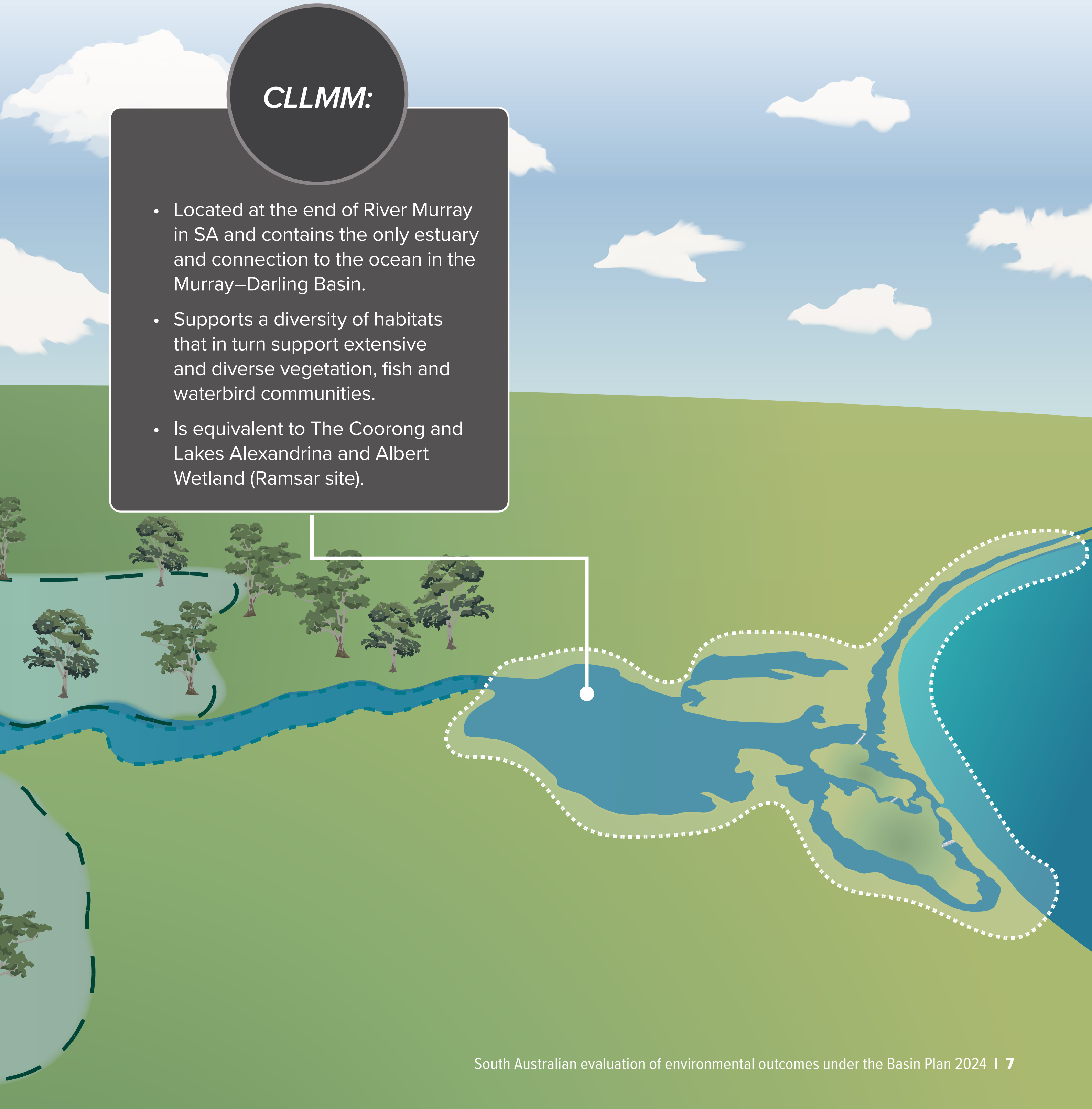
- Stretches length from SA border to Wellington, including the area inundated between 40,000–80,000 ML/day.
- Supports diverse floodplain and wetland habitats that when inundated provide important productivity, habitat and food resources for key species.
- Includes floodplain components of Ramsar-listed Wetlands: Riverland and Banrock Station Wetland Complex.



Our report evaluates environmental outcomes in the three PEAs identified in the South Australian River Murray Long-term Environmental Watering Plan:

- River Murray Channel
- River Murray Floodplain
- Coorong, Lower Lakes and Murray Mouth (CLLMM)

Note: even though the Coorong is included in the Murray Region Water Resource Plan Area, it relies on freshwater flows from the River Murray. To support this connection the River Murray Long-term Environmental Watering Plan includes the Coorong as part of the coordinated management of the CLLMM Priority Environmental Asset in the South Australian River Murray.



# How we evaluated environmental outcomes

This report presents our five-yearly evaluation of progress towards achieving environmental outcomes under the Basin Plan in South Australia. In accordance with Schedule 12 of the Basin Plan, South Australia is required to report on environmental outcomes at the asset scale every five years.

Our approach for the South Australian River Murray is based on expected environmental outcomes for select Long-term Watering Plan (LTWP) targets. These outcomes quantify our expected progress towards these targets following Basin Plan adoption in 2012. They were developed using a best-practice expert elicitation method, informed by Basin Plan hydrological modelling scenarios and best available data and information. Expected outcomes were established for three time points—2019, 2029 and 2042—chosen to align with key Basin Plan implementation activities and reporting.

The achievement of the short-term (2019) expected outcomes was assessed and evaluated in the 2020 South Australian evaluation of environmental outcomes under the Basin Plan. This report summarises our assessment and evaluation of progress, including progress towards intermediate (2029) expected environmental outcomes. Our evaluation of `*is this what we expected to see?' and `what do we expect to see in the future?'* is based on these expected outcomes.

We evaluate environmental outcomes for the three PEAs: the SA River Murray Channel; the River Murray Floodplain; and the Coorong, Lower Lakes and Murray Mouth (CLLMM).



Priority Environmental Asset

# Channel and Floodplain

© SARDI

# Channel and Floodplain ecosystem drivers and pressures

## Drivers

Flow volumes and regime (including the seasonality, frequency, height and duration of flows) supports key biological responses, including seed germination, breeding triggers and provision of food.

Flow velocity and diversity of flow supports water quality, productivity and the transport of nutrients, sediments and biota. It also provides cues for fish movement and breeding.

Rainfall is highly variable and influences the amount of water within the system as well as sustaining local conditions. It is one of the sources of water for floodplain vegetation.

Groundwater level and soil conditions (including soil type, salinity and water content) influence the condition of floodplain vegetation.

## Pressures

Changes in climate and climate extremes have influenced rainfall and temperatures.

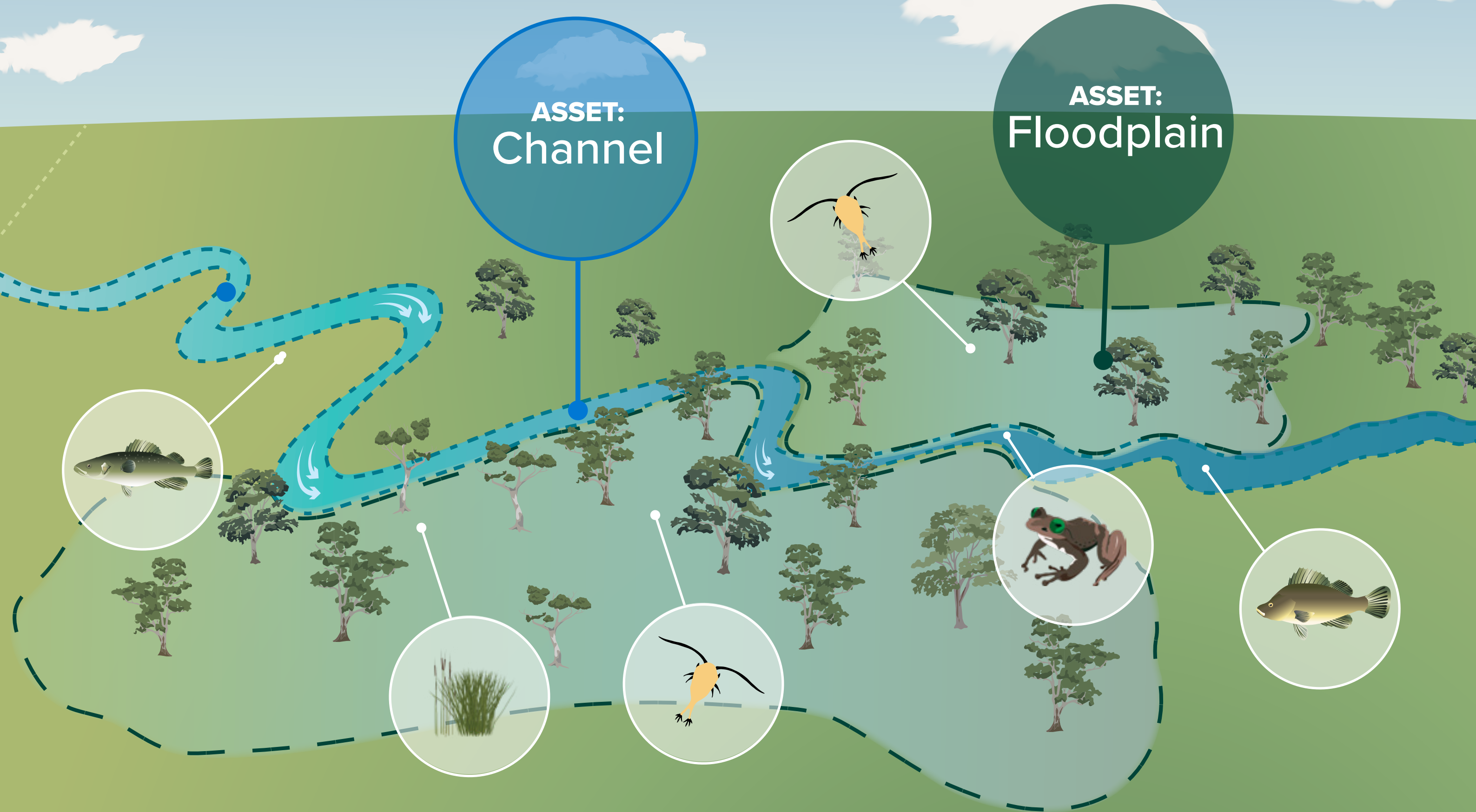
River regulation, including water diversions and barriers have led to reduced flows, reduced levels of surface and groundwater and altered hydrological regimes.

Irrigation and agriculture leading to land clearance, soil disturbance, salinity and elevated groundwater.

Invasive species and problematic natives.

# What have we assessed?

We have evaluated the achievement of environmental outcomes for the Channel and Floodplain using a number of indicators. The achievement of these outcomes aims to maintain or improve the health of vegetation and fish communities, while also maintaining channel flow velocity and floodplain productivity. This assessment also includes case studies detailing the responses of floodplain understorey vegetation communities and frog populations.




**Velocity of flow:** key driver of habitat structure and transport of material and organisms throughout the channel environment.

**Microinvertebrates:** contribute to food webs on the floodplain and in-channel and measure of productivity.

**Understorey vegetation:** provides food and habitat and contributes to nutrient cycling and the protection of floodplain soils from erosion.

**River red gum:** habitat provision and contribution of organic matter to the channel and floodplain ecosystems.

**Black box:** provision of core habitat for biota across the floodplain elevation gradient, extent of flooding, contribution of organic matter to the ecosystem.

**Fish (golden perch and Murray cod):** key recreational, cultural and economic species responsive to flow.

**Frogs:** important part of the floodplain food web and indicator of changes in environmental conditions and habitat quality.

# River Murray Channel and Floodplain key findings

The implementation of the Basin Plan is supporting continued improvement in the environmental condition of the South Australian River Murray Channel and Floodplain. This includes through the delivery of water for the environment, which has:

- supported managed floodplain inundations, improving the condition of river red gum and black box and their capacity to respond to future high (unregulated) flows
- increased densities and diversity of microinvertebrates, critical for channel and floodplain productivity and food webs, particularly in conjunction with managed inundations and overbank flow conditions
- provided spring-summer flows and more localised fast-flowing habitats, that likely facilitate recruitment and improved structure of Murray cod and golden perch populations
- enabled targeted delivery of water, creating conditions for the breeding and recruitment of local frog species in the absence of sufficient natural flows.

For more information on the assessment of outcomes and the evidence that supports the evaluation, see the South Australian River Murray Basin Plan Environmental Outcome Evaluation: River Murray Channel and Floodplain Priority Environmental Asset technical report.

## River Murray Channel and Floodplain key messages

- The delivery of water for the environment, in conjunction with weir pool manipulation and the operation of environmental regulators for managed floodplain inundation, has been essential for improving environmental health and resilience across several floodplains since the Millennium Drought.
- High (unregulated) flows are vital for reaching floodplain areas that cannot be supported through managed inundation. Many indicators are limited to sites with targeted delivery of water for the environment meaning results may not reflect conditions across the broader channel and floodplain assets.
- Full implementation of the Basin Plan, including the recovery and delivery of the 450 GL and addressing current water delivery constraints, is required to achieve more frequent, prolonged and significant overbank flows along the SA River Murray, further enhancing environmental outcomes in these assets.
- Ongoing effort and investment are necessary to continue to improve the health and resilience of the Channel and Floodplain, including the integrated and adaptive management of South Australia's supply measure projects, continued engagement of local communities and First Nations to identify sustainable water management solutions and actions to identify and address key threats such as habitat loss and degradation to the ongoing sustainability of some species.

# Environmental works and measures programs

## South Australian Riverland Floodplains Integrated Infrastructure Program (SARFIIP) outcomes and achievements

SARFIIP was a $155 million program funded by the Australian Government through the Murray–Darling Basin Authority (MDBA) and implemented by the South Australian Government. It was designed to improve the resilience of key Riverland floodplains under reduced frequency of overbank flows and protracted low flow conditions, contributing to delivery of the Basin Plan.

SARFIIP constructed infrastructure and undertook environmental works to enable the inundation of large areas of the Pike and Katarapko floodplains and mechanisms to manage salinity impacts from inundation.

With relatively modest flows to South Australia, infrastructure constructed at the Pike and Katarapko floodplains under SARFIIP has enabled floodplain inundation to occur at a scale only otherwise possible during much higher flow events, to help restore floodplain ecosystem health.

High flows since 2021 have provided opportunities for the full suite of SARFIIP infrastructure to be operated and to monitor the early results from the SARFIIP investment. The 2022-23 River Murray flood event also provided an opportunity to test the infrastructure's ability to withstand flood conditions and was a great foundation for ongoing operations.

### Results so far include:

- significant inundation has enabled carbon, nutrients and invertebrates to be transferred from the inundated floodplains into the main river channel, supporting riverine and estuarine food webs
- fishways incorporated into the new infrastructure and increased flows through the anabranches have supported native fish movement and recruitment
- inundated floodplain vegetation, such as lignum, is responding positively, providing habitat for many native species, including the vulnerable southern bell frog.

The successful commissioning and initial operations period has shown that the SARFIIP infrastructure and related work will provide a long lasting positive legacy and benefits to SA River Murray and associated ecosystems.



## Sustaining Riverland Environments (SRE)

The Sustaining Riverland Environments (SRE) program builds on and seeks to maximise the return on investment to date in Riverland programs such as SARFIIP. With $37.6 million of funding from the Australian Government. SRE has been developed and co-designed by the SA Department for Environment and Water in partnership with local Riverland communities.

SRE will further increase the effectiveness of environmental water use, to improve the condition of the lower River Murray wetland ecosystems and support the Basin Plan. SRE is implementing a full package of works across four main areas:

**Lock 3 reach project:** including infrastructure upgrades at wetlands and floodplains to improve their function and integrate their operations with weir pool manipulations and future high flows and investigation to increase operational flexibility of existing structures.

**Lock 6 reach project:** implementing measures to overcome environmental and economic constraints to weir pool lowering and to enable irrigators to manager lower flow periods in the river during drought.

**Bookmark Creek complex project:** including new fish friendly infrastructure that will increase the flow of water down the creek to reinstate connectivity between Lock 4 and Lock 5 weir pools and create high-value, fast-flowing habitat conditions which benefit large-bodied native fish species.

**Native fish restoration works:** including the installation of fish exclusion screens on pump offtakes at targeted sites to protect native fish and analyse the ecological and economic benefits and installing a range of re-snagging structures along the river to provide habitats and conditions for native fish breeding, feeding, refuge and rest.

## Channel and Floodplain

# Expected outcomes reports

### Trend

The change over time, calculated using all available data for an indicator across the assessment period.

| | | |
|---|---|---|
| ↗ | Trend **Improved** | **Improved:** The indicator has improved over the period of assessment. |
| — | Trend **Stable** | **Stable:** The indicator has neither improved nor declined over the period of assessment. |
| ↙ | Trend **Declined** | **Declined:** The indicator has declined over the period of assessment. |
| NA | Trend **Not Applicable** | **Not Applicable:** Data were not sufficient to determine any trend in the status of the indicator. |

# Summary of outcomes at an asset scale

## The assessment of environmental outcomes presents the trend for each indicator along with an evaluation of the following:

- To what extent have environmental outcomes been achieved?
- If environmental outcomes were not achieved, why not?
- How did the Basin Plan contribute to the achievement of environmental outcomes?
- Have there been any unanticipated environmental outcomes?

For further information please see the technical report for the SA River Murray Channel and Floodplain.

| Theme | Indicator | Trend | Information reliability | Key findings |
|---|---|---|---|---|
| **Flow & Ecosystem Function** | Velocity | Trend Improved | Reliability Good | There has been improvement in the frequency of fast-flowing conditions, but this was largely driven by unregulated, high flows. |
| | Floodplain productivity: Microinvertebrates | NA Trend Not Applicable | Reliability Very good | Microinvertebrate density and richness increased, particularly following high flow conditions. |
| **Vegetation** | River red gum | Trend Improved | Reliability Poor | River red gum condition has increased across the managed areas of Chowilla, Pike and Katarapko floodplains. |
| | Black box | Trend Improved | Reliability Poor | Black box condition has improved particularly in managed floodplain areas. |
| **Fish** | Murray cod | Trend Improved | Reliability Good | Recruitment of Murray cod has continued to improve, with population structure characteristic of a more resilient population. |
| | Golden perch | Trend Improved | Reliability Good | Golden perch recruitment has improved, with young-of-year detected in the population since 2021. |

Expected outcome report: Flow & Ecosystem Function

# Flow Velocity

Trend
**Improved**

Reliability
**Good**

There has been improvement in the frequency of fast-flowing conditions, but this was largely driven by unregulated, high flows.

## What are we trying to achieve:

The Long-term Environmental Watering Plan objective is to *"Provide diverse hydraulic conditions over the range of velocity classes in the lower third of weir pools so that habitat and processes for dispersal of organic and inorganic material between reaches are maintained".*

## Why is flow velocity important?

Velocity describes the speed at which water flows within a river and influences the structure and function of river ecosystems. The velocity of river flow may impact water quality, productivity, habitat condition for a range of species and the transport of nutrients and sediment. Fast-flowing conditions (>0.3 m/sec) are also important for ecological processes such as fish recruitment and the transport of larvae and microinvertebrates within the river.

*Since Basin Plan adoption, fast-flowing conditions lasting for 60 consecutive days in spring-summer have only occurred in 3 of 11 years.*

## What is the trend and current status of flow velocity?

Flows across the South Australian border (QSA) >20,000 ML/day create fast-flowing conditions in the SA River Murray weir pools. Since Basin Plan adoption in 2012, QSA has varied greatly: extreme dry and low flow conditions between 2017–18 and 2019–20, low flow conditions between 2014–15 and 2015–16 and high flow conditions recorded in 2016–17 and 2021–22, the latter being followed by the third largest River Murray flood event recorded in 2022–23 (Figure 1).

It is important that fast-flowing conditions (>0.3 m/s) occur for at least 60 consecutive days between September and March at least every two years. These conditions were assessed in the lower third of weir pools, with the requirement that 95% of the pool achieved the necessary >0.3 m/s fast-flowing conditions.

The occurrence of fast-flowing conditions in the SA River Murray weir pools has improved across the assessment period (between 2014–15 and 2022–23). However, since Basin Plan adoption in 2012, fast-flowing conditions for at least 60 consecutive days in any weir pool has only been recorded in three years; 2016–17, 2021–22 and 2022–23 (Table 1). Additionally, fast-flowing conditions of a duration of at least 60 consecutive days between September and March across all weir pools were only recorded in 2016–17 and 2022–23.

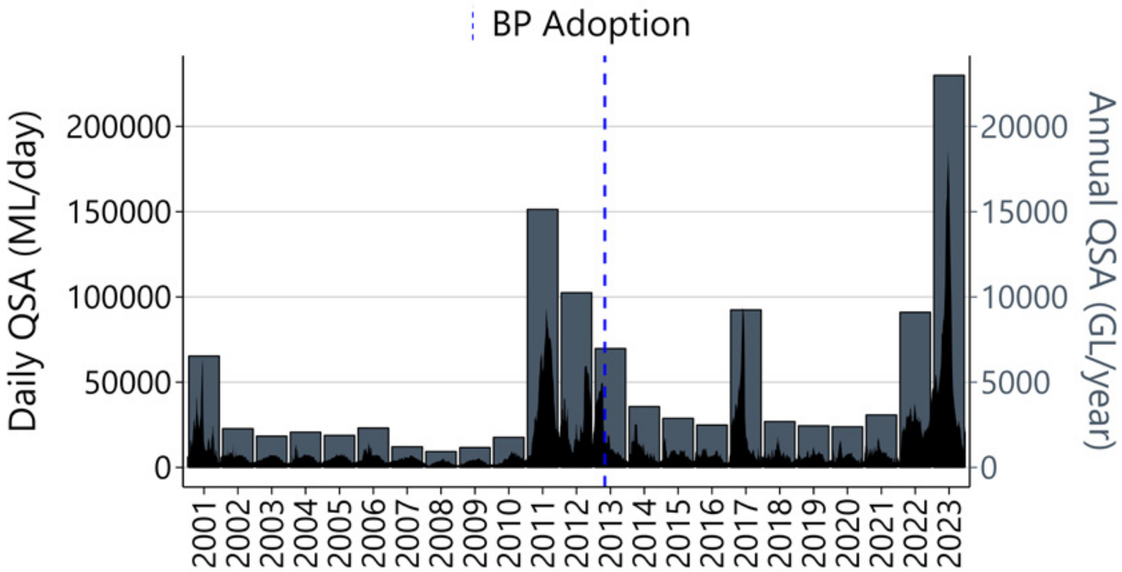




*Figure 1: Flows to South Australia (QSA) between 2000-23. The left axis and black area correspond to daily QSA (ML/day), while the right axis and grey bars correspond to annual QSA (GL/year). Basin Plan adoption is marked by the vertical dashed line. Data Source: DEW.*

| Water year | Weir Pool 1 | Weir Pool 2 | Weir Pool 3 | Weir Pool 4 | Weir Pool 5 |
|---|---|---|---|---|---|
| **2014–15** | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| **2015–16** | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| **2016–17** | 125 (125) | 125 (125) | 99 (93) | 113 (113) | 87 (82) |
| **2017–18** | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| **2018–19** | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| **2019–20** | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| **2020–21** | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| **2021–22** | 105 (65) | 148 (73) | 44 (30) | 16 (13) | 12 (12) |
| **2022–23** | 202 (202) | 179 (115) | 113 (84) | 124 (87) | 141 (92) |

*Table 1. The total number of days in each water year where modelled velocities were >0.3 m/s in at least 95% of the weir pool. The numbers in brackets are the maximum consecutive days observed meeting that velocity requirement, with grey shading indicating the weir pool and water year that met the environmental outcome.*

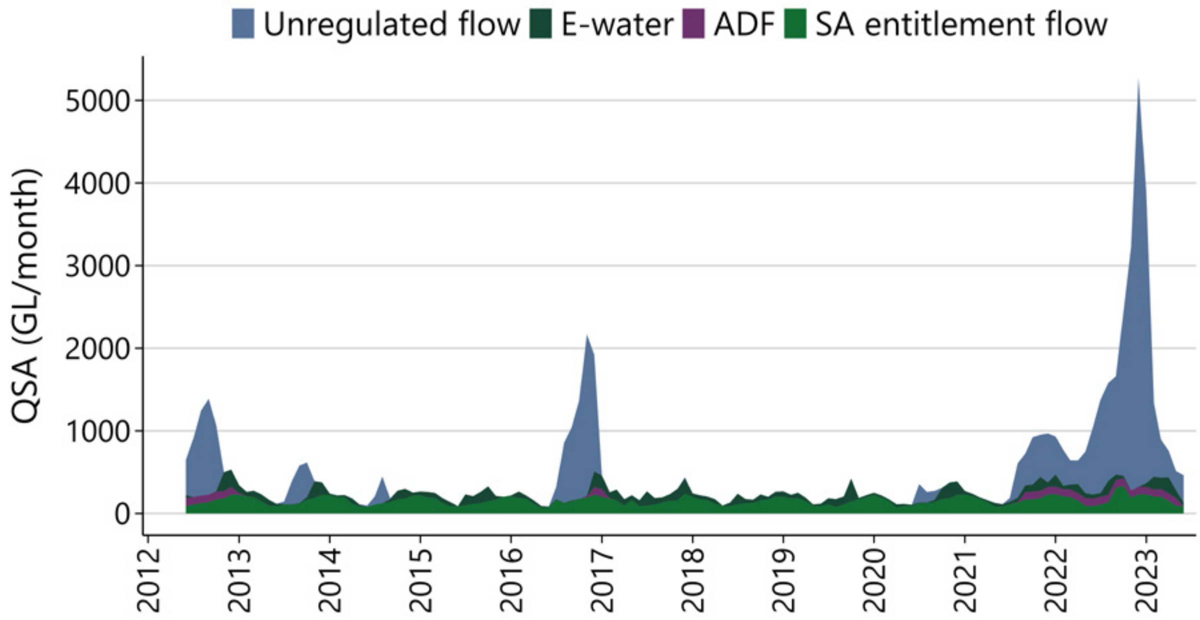



*Figure 2: Contribution of unregulated flow, water for the environment (E-water), additional dilution flow (ADF) and SA Entitlement flow to Flow (GL/month) to the South Australian border (QSA) between June 2012 and June 2023. Data Source: DEW.*

## Is this what we expected to see and have there been any unanticipated outcomes?

Expected velocity conditions were determined from hydrodynamic modelling of the flow regime (including timing and duration of flow). Based on this, we expected to see a range of velocity classes, including fast-flowing conditions, present in the lower third of weir pools for at least 60 days during spring and summer annually. However, since 2019 an increase in fast-flowing conditions with sufficient duration over spring and summer was not achieved outside of years with high (unregulated) flow conditions. However, fast-flowing conditions have been achieved across the SA River Murray weir pools (1–5) approximately 80% of the time since July 2021.

## Why are we seeing these results?

Since 2014–15, velocity outcomes across all weir pools have only been achieved during the high (unregulated) flow events in 2016–17 and 2022–23 (2 of 9 years). The highest number of total and consecutive days of flow velocities >0.3m/s across weir pools was in 2022–23.

High (unregulated) flow conditions were the primary driver for the occurrence, frequency and duration of fast-flowing conditions in the SA River Murray, particularly over the spring-summer months. In the absence of these high flows, the delivery of SA Entitlement, additional dilution flow and water for the environment was insufficient to provide fast-flowing conditions to reflect the timing and duration required to achieve the velocity outcomes (Figure 2).

## What has the Basin Plan contributed?

The Basin Plan is yet to have a significant influence on flow velocities at large scales across the extent of the SA River Murray Channel. South Australia's Entitlement flow is insufficient to achieve fast-flowing conditions within the SA River Murray. To meet the required velocity conditions, high (unregulated) flows and/or an increase in the delivery of water for the environment will be required.

The delivery of water for the environment, along with weir pool management, has supported localised and short periods of fast-flowing conditions in most weir pools across the SA River Murray. Localised increases in the area of fast-flowing conditions were recorded across weir pools between July 2017 and June 2020, which may have contributed to key ecological processes including providing environmental cues for recruitment of native fish, such as golden perch.


## What is still to be done?

Improvement in flow velocities requires restoration of riverine habitats and is only likely to occur with full implementation of the Basin Plan, including the recovery and delivery of the 450 GL of additional water for the environment. Addressing current water delivery constraints will enable the more frequent delivery of flows ≥20,000 ML/day to South Australia.

However, even with current water delivery constraints, flow velocities can still be improved through the coordinated release of environmental water from upstream tributaries and increased discharges from Lake Victoria. Managing weir pools, including weir pool lowering simultaneously across multiple weir pools and in coordination with the delivery of water for the environment, could also further enhance flow velocity diversity. Further investigation of the use of weir pool management to support flow velocities is needed, particularly any potential impacts to sites like Chowilla, which already provide fast-flowing habitats.

High, unregulated flow events remain critical for providing diverse flow velocities, especially fast-flowing conditions, within the River Murray Channel. While unregulated flows are protected as Planned Environmental Water (PEW) in South Australia, further protection of unregulated flows upstream is essential to ensure they are not diminished over time, preserving baseline conditions established under the Basin Plan.

## What do we expect to see in the future?

Through full implementation of the Basin Plan, flow velocity outcomes are expected to improve. Furthermore, addressing current water delivery constraints is expected to enhance the ability to provide fast-flowing conditions during critical periods of spring and summer. Long-term challenges of a changing and variable climate are expected to impact flow velocities in the SA River Murray, which increases the importance of delivering water for the environment.

*Full implementation of the Basin Plan is required, including addressing current water delivery constraints, to achieve velocity outcomes across the SA River Murray Channel.*


# Case Study: Flow and Ecosystem Function

## Floodplain productivity: microinvertebrates

Reliability
**Very good**

NA
Trend
**Not Applicable**

**Microinvertebrate density and richness increased, particularly following high flow conditions.**

### Why are microinvertebrates important?

Microinvertebrates are microscopic aquatic organisms and include rotifers and microcrustaceans such as cladocerans (water fleas), ostracods and copepods. Microinvertebrates are a critical part of the river and floodplain food web, as they consume bacteria, phytoplankton and organic material and provide important food resources for fish, birds, frogs and macroinvertebrates.

Microinvertebrates respond to the timing, duration and frequency of overbank flooding and floodplain inundation, which influences the productivity within the floodplain and channel ecosystems.

### Responses to periodic overbank flows - Lateral connectivity

Overbank flows are essential for lateral connectivity, which enables mobilisation of a diversity of microinvertebrates vital to riverine food webs. Floodplain inundation strongly influences the density, diversity and biomass of microinvertebrates.

Substantial amounts of nutrients, organic matter, phytoplankton and microinvertebrates are transferred from the floodplain into the river during overbank flows. These flows trigger the emergence of microinvertebrates from their egg banks and initiate reproduction within hours of inundation.

Microinvertebrate densities and diversity increased in 2014–15 in response to a managed floodplain inundation event and in 2016–17 in response to high (unregulated) flow conditions (Figure 3 and Figure 4). In 2021–22, a managed floodplain event on the Chowilla floodplain in conjunction with the operation of the Chowilla environmental regulator and raises of Lock 6 (+0.42 m) resulted in a total of 5,500 ha of floodplain and temporary wetlands being inundated. This likely improved localised microinvertebrate diversity and densities, but differences were not found between Locks 4 and 6. Most recently and in response to the magnitude of the 2022–23 River Murray flood event, microinvertebrate densities and diversity in 2022–23 were the highest observed since monitoring began in 2014–15.



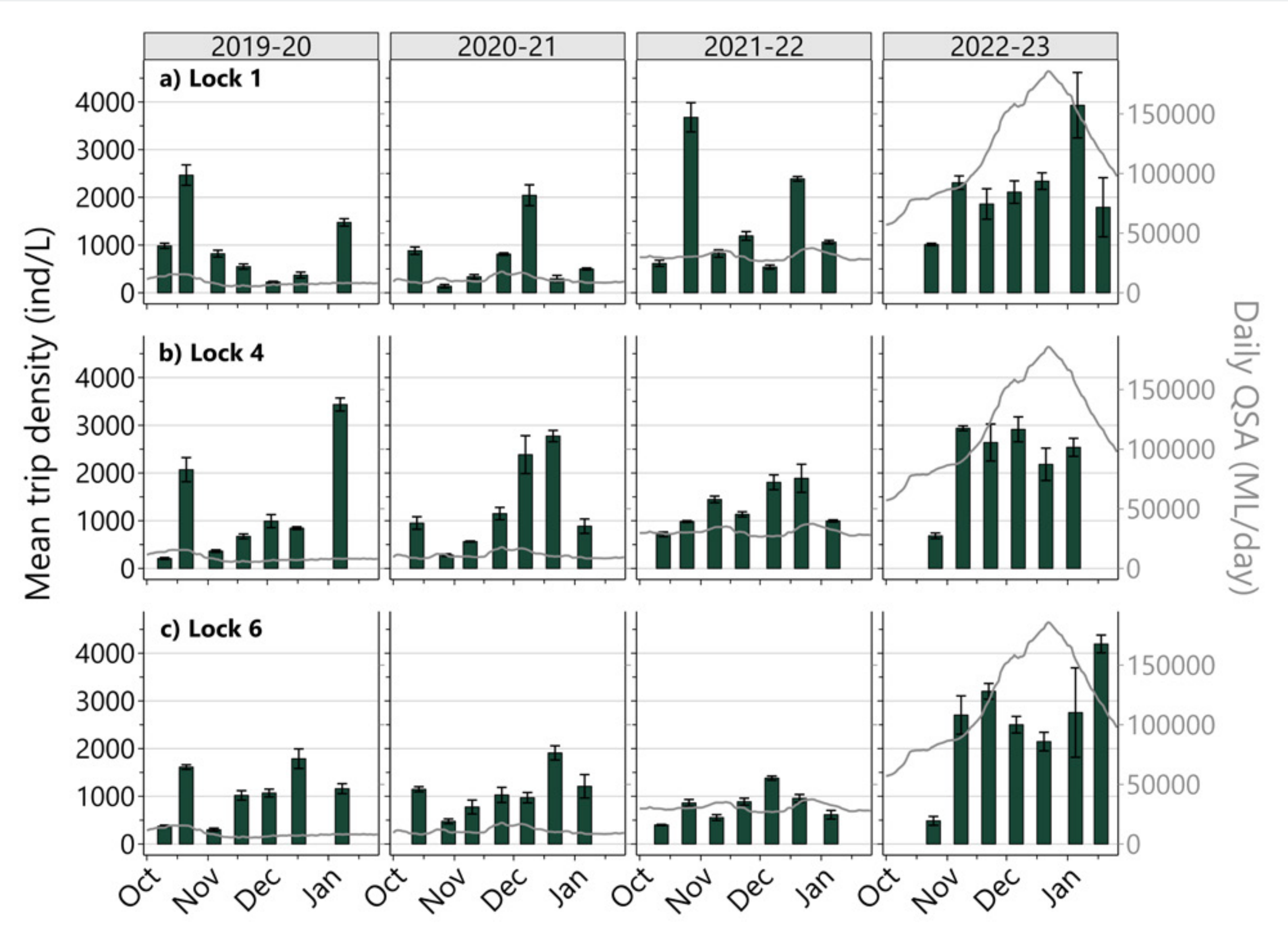



*Figure 3: Mean microinvertebrate densities at Locks 1, 4 and 6 between 2019–20 and 2022–23. The grey line and right-hand axis shows the Flows to South Australia (QSA). Data Source: CEWH.*

## Supporting riverine food webs – Longitudinal connectivity

Longitudinal connectivity is important for the dispersal of a diversity of microinvertebrates and similarities across the sampling Locks (1, 4 and 6) indicates longitudinal connectivity along the SA River Murray.

Longitudinal connectivity is vital for riverine fish species like Murray cod, as Murray cod larvae have been found to consume microinvertebrate (rotifer) species. The abundance of rotifers, such as species of *Trichocerca*, increased in response to flow velocities ranging from 0.15–0.2 m/s, although varied seasonally. Increased *Trichocerca* densities were recorded in 2019–20, 2020–21 and 2021–22 and densities recorded in 2021–22 and 2022–23 coincided with two consecutive years of flow velocities >0.3 m/s across substantial portions of each SA River Murray weir pool (Table 1).

The timing, duration and frequency of riverine flows also influences microinvertebrate communities. Densities and diversity are typically greatest toward the end of spring and early summer (Figure 3 and Figure 4). This period is typically when Flows to South Australia (QSA) are highest, with flows transporting microinvertebrates and boosting productivity and the river food web.

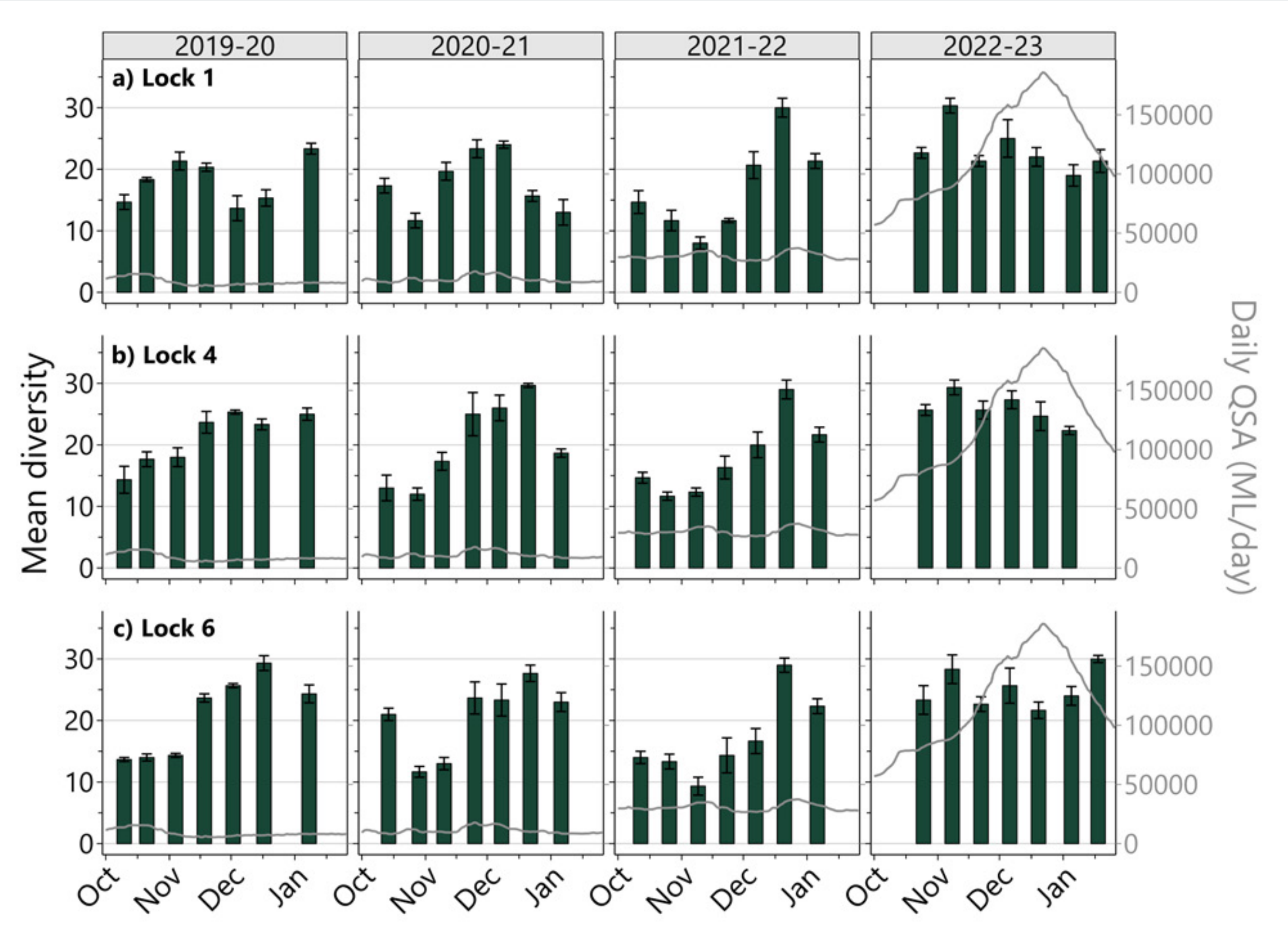
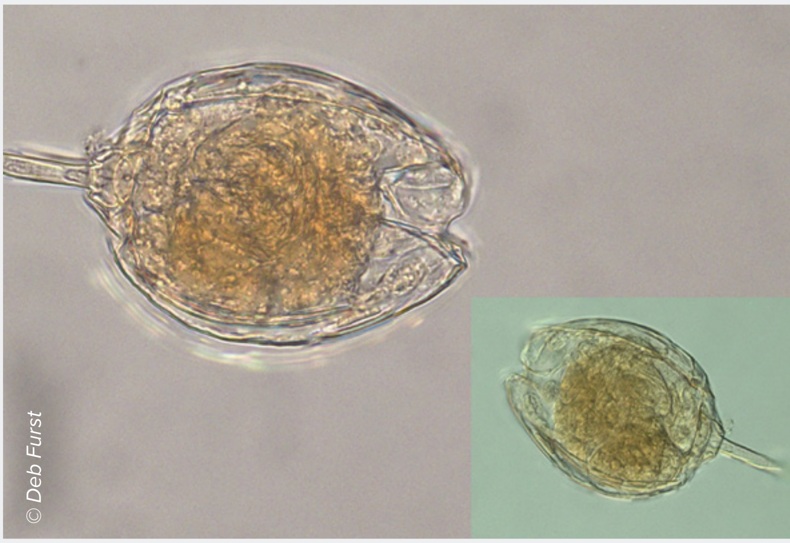



*Figure 4: Mean microinvertebrate diversity (number of species) at Locks 1, 4 and 6 between 2019–20 and 2022–23. The grey line and right-hand axis shows the Flows to South Australia (QSA). Data Source: CEWH.*






## Water for the environment and floodplain management

Measures to enhance microinvertebrate densities and diversity in the SA River Murray include the continued delivery of water for the environment combined with managed floodplain inundations.

The greatest response in microinvertebrate density and diversity was recorded during overbank flooding and high (unregulated) flow conditions. The contribution of the delivery of water for the environment was greatest in the years between these higher flow years (e.g. 2017–18, 2019–20 and 2020–21), with increased microinvertebrate density and diversity occurring below 30,000 ML/day (QSA). Continued delivery of water for the environment will enable spring-flow pulses that are critical for the transport of microinvertebrates, which in turn has a positive effect on the food web.

The continued use of environmental regulators will enable greater expanses of each floodplain to be inundated in future years, particularly during dry years with low flows. Floodplain inundation events in spring and early summer (inundation for at least three weeks), when microinvertebrate density is greatest, support reproduction and growth of microinvertebrates and contribute to an increase in channel and floodplain productivity. It is important to consider floodplain inundations together with within-channel spring flow pulses, which are important for the downstream transport of microinvertebrates.

*Localised increases in microinvertebrate density and diversity are achieved by managed floodplain inundations, supported by water for the environment.*

## Expected outcome report: Vegetation

# River red gum

Trend
**Improved**

Reliability
**Poor**

**River red gum condition has increased across the managed areas of Chowilla, Pike and Katarapko floodplains.**

### What are we trying to achieve?

The Long-term Environmental Watering Plan ecological objective is to *"Maintain viable, functioning river red gum population within the Channel and Floodplain PEA"*.

### Why are river red gum important?

River red gums are long-lived (500–1,000 years), medium-large (up to 42 m high) eucalypts. They are an iconic species due to their ecological, cultural, recreational and economic value. They contribute to the productivity and health of the River Murray system, supporting food webs and providing important habitat for diverse species of birds, reptiles, bats, insects and frogs.

*River red gum condition has improved for both channel and floodplain trees between 2009–10 and 2022–23.*

### What is the trend and current status of river red gum?

The condition of river red gums in the SA River Murray Channel and Floodplain was assessed at Chowilla, Pike and Katarapko using a standardised Tree Condition Index (TCI). A TCI above 10 indicates good health, 4–9 indicates fair condition and may respond to water delivery and below 4 indicates very poor condition, which may have a slow response to watering and require multiple watering events to recover. Data for this assessment is limited to areas with floodplain infrastructure and may not fully represent conditions across the entire SA River Murray Channel and Floodplain.

Towards the end of the Millennium Drought in 2008–09, river red gum condition was very poor. Since then, overall condition has improved. At Channel sites, the percentage of trees with a TCI ≥10 increased from 9% in 2007–08 to 75% in 2022–23 (Figure 5). While tree condition at these sites has varied, a substantial improvement followed the high (unregulated) flows of 2016–17 and has been sustained. At Floodplain sites, the percentage of river red gums with a TCI ≥10 increased from 12% in 2007–08 to 72% in 2022–23 (Figure 6). Tree condition in these areas also varied, with a decline between 2013–14 and 2016–17, followed by a marked recovery in 2017–18 and further improvements in 2022–23.

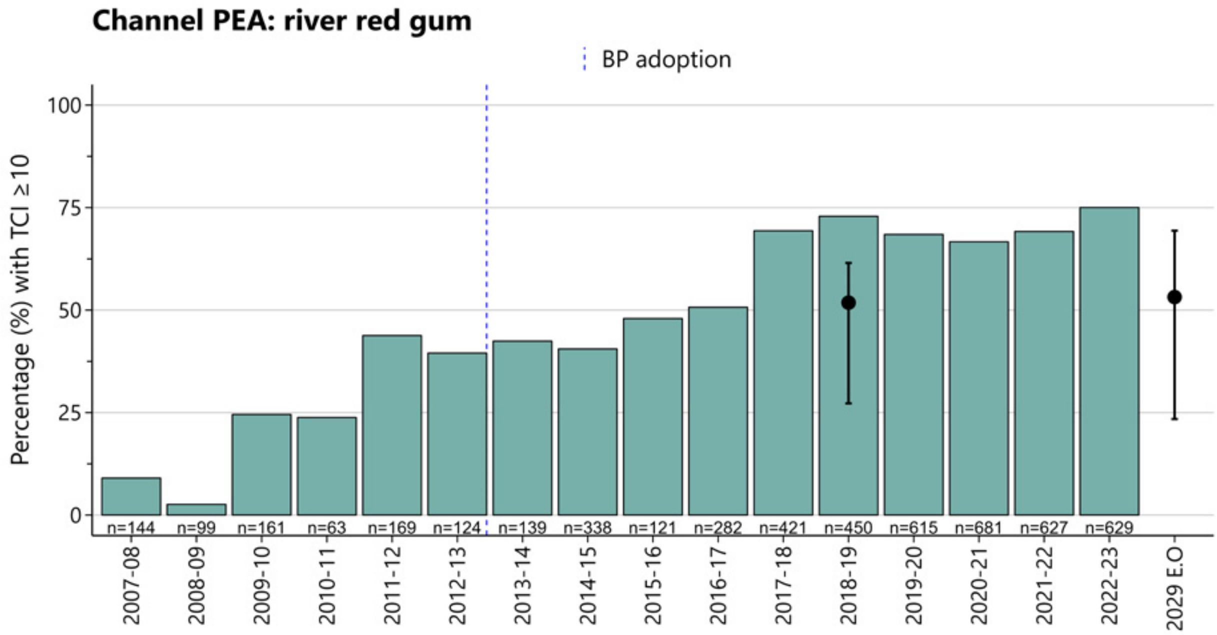




*Figure 5: The percentage (%) of river red gum with a TCI ≥10 in the Channel PEA extent of the Chowilla, Pike and Katarapko floodplains between 2007–08 and 2022–23. Sample size (n) is provided above the x-axis for the corresponding water year. The 2019 and 2029 expected outcomes (±80% confidence interval) are referenced by the black point and associated error bars. Data Source: MDBA and DEW.*

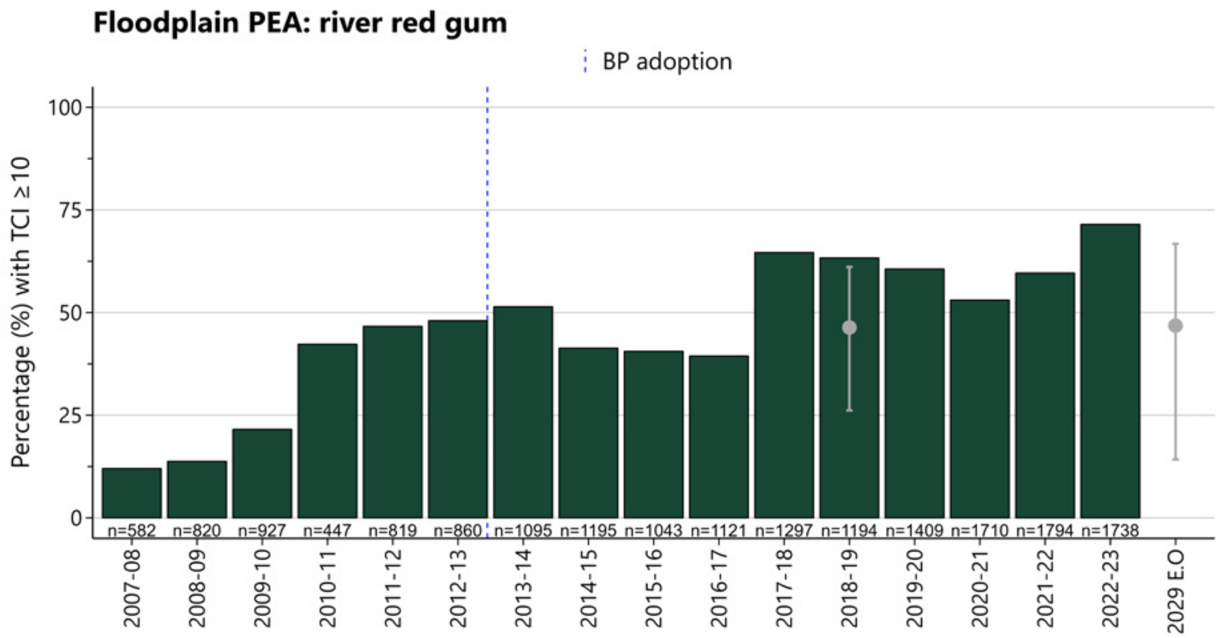



*Figure 6: Percentage (%) of river red gum with TCI ≥10 in the Floodplain PEA extent of the Chowilla, Pike and Katarapko floodplains between 2007–08 and 2022–23. Sample size (n) is provided above the x-axis for the corresponding water year. The 2019 and 2029 expected outcomes (±80% confidence interval) are referenced by the grey point and associated error bars. Data Source: MDBA and DEW.*



## Is this what we expected to see and have there been any unanticipated outcomes?

River red gum condition is influenced by several factors, including frequency of flooding, rainfall, groundwater level, soil moisture and salinity. In 2019, 73% of trees in the Channel had a Tree Condition Index (TCI) of ≥10, compared to the expected 52%. In the Floodplain, 63% exceeded expectations of 46%. Currently, 75% of Channel trees and 72% of Floodplain trees have a TCI of ≥10. This suggests that we are likely on track to meet the 2029 expected environmental outcome for river red gum condition in the Channel (53% of trees) and Floodplain (47% of trees).

However, these results come from areas with targeted water delivery, so the overall condition in the SA River Murray Channel and Floodplain may be lower. Whilst not unanticipated in terms of response, the recent high (unregulated) flow conditions have continued to support overall improvements in river red gum condition in the Channel and across the Floodplain.

## Why are we seeing these results?

River red gum condition has improved at Channel and Floodplain sites within Pike, Katarapko and Chowilla. These improvements were likely influenced by:

- high (unregulated) flow conditions in 2010–11, 2016–17 and 2021–22 and the River Murray flood event in 2022–23, which have led to improvements in tree condition over subsequent years
- the delivery of water for the environment for:
  - elevated within-channel flows that promoted lateral connectivity and generally maintained tree condition during drier years and between floods
  - managed floodplain inundations through environmental regulators at Chowilla (since spring 2014) and Pike and Katarapko (since spring 2020), increasing inundation frequency and extent, improving tree condition and the capacity of trees to respond when high (unregulated) flows are next experienced
  - weir pool raising, provided short-term, localised improvements to tree condition.

## What has the Basin Plan contributed?

The delivery of water for the environment since Basin Plan adoption has helped to improve flow conditions which has increased flows within the channel, increased river water levels and improved hydrological connectivity between habitats. Elevated river water levels provide water to trees through lateral connectivity and has helped maintain tree condition during drier years when river-floodplain connectivity is reduced and between floods when some minor condition declines were observed.

The delivery of water for the environment, together with the operation of environmental regulators, weir pool raising and pumping of water, has increased the area of inundation with more trees receiving water and improved the resilience of trees, including responses of trees to future flooding events.


## What is still to be done?

Delivery of water for the environment is important to improve and support the condition and resilience of tree condition in the SA River Murray Channel and Floodplain. It will help to increase the proportion of trees being watered and their condition, improve the ability of trees to tolerate dry periods and support improved responses of trees to watering when water is available.

Full delivery of the Basin Plan, including the recovery and delivery of the 450 GL of water for the environment and addressing current water delivery constraints is critical, together with the further optimisation of water delivery for improved tree condition. Floodplain environmental regulators have not yet been operated to their fullest extent possible and therefore the delivery of water for the environment may increase inundated areas at these sites in the future.

Further in-channel pulses and weir pool raising, with additional measures such as groundwater management, may also further increase tree condition and resilience. Long-term efforts will need to focus on adaptive management strategies to respond to changing environmental conditions, particularly an increased frequency and duration of drought resulting from the impacts of climate change.

## What do we expect to see in the future?

Through full implementation of the Basin Plan it is expected that the condition of river red gum condition within the Channel and Floodplain will continue to improve and be maintained, noting that the ongoing health will be highly dependent on rainfall and flow conditions, with prolonged dry conditions a major threat to tree condition.

Full implementation of the Basin Plan including addressing current delivery constraints and the increased protection of water for the environment is required to achieve greater frequency, duration and magnitude of overbank flows along the SA River Murray, which would help tree condition. Over the longer-term, climate variability and therefore water availability will continue to increase the importance of water for the environment and the operation of floodplain environmental regulators for river red gum condition in the SA River Murray.

*Water for the environment is critical to improve and maintain the condition of river red gum populations.*

# Expected outcome report: Vegetation

# Black box

Trend
**Improved**

Reliability
**Very good**

Black box condition has improved particularly in managed floodplain areas.

## What are we trying to achieve:

The Long-term Environmental Watering Plan objective is to *"Maintain a viable, functioning black box population within the managed Floodplain PEA"*.

The managed floodplain is the area that is inundated when flows are below 80,000 ML/day flow to SA under normal river operations.

## Why are black box important?

Black box is a long-lived, medium sized (up to 20 m high) and usually single-stemmed tree, commonly distributed over much of the southern Murray–Darling Basin floodplain.

Black box occur on elevated locations across the floodplain and are more drought and salt tolerant than river red gums. They support the productivity of the floodplain, the understorey vegetation community and provide habitat for insects, bats, birds and reptiles. They also play a role in the sequestration and cycling of carbon and nutrients.

*Black box condition has improved, with the highest proportion of trees in good condition following the 2022–23 River Murray flood.*

## What is the trend and current status of black box?

The condition of black box trees in the SA River Murray Floodplain was assessed at Chowilla, Pike and Katarapko using a standardised Tree Condition Index (TCI). A TCI above 10 indicates good health, 4–9 indicates fair condition and potential response to water delivery and below 4 indicates very poor condition, which may respond slowly to watering and require multiple events for recovery. Data for this assessment is limited to areas with floodplain infrastructure and may not fully represent conditions across the entire SA River Murray Floodplain.

The percentage of trees with a TCI score ≥10 improved from 16% in 2007–08 to 68% in 2022–23 but has varied across years (Figure 7). Notable improvements occurred between 2010–11 and 2011–12, coinciding with high rainfall and widespread flooding in 2010–11. Further improvements were recorded between 2012–13 and 2013–14, followed by a decline from 2014–15 to 2016–17. A substantial recovery was recorded from 32% in 2016–17 to 64% in 2017–18. Over the next four water years (2018–19 to 2021–22) the percentage of black box with TCI ≥10 remained above 60%, peaking at 69% in 2022–23.

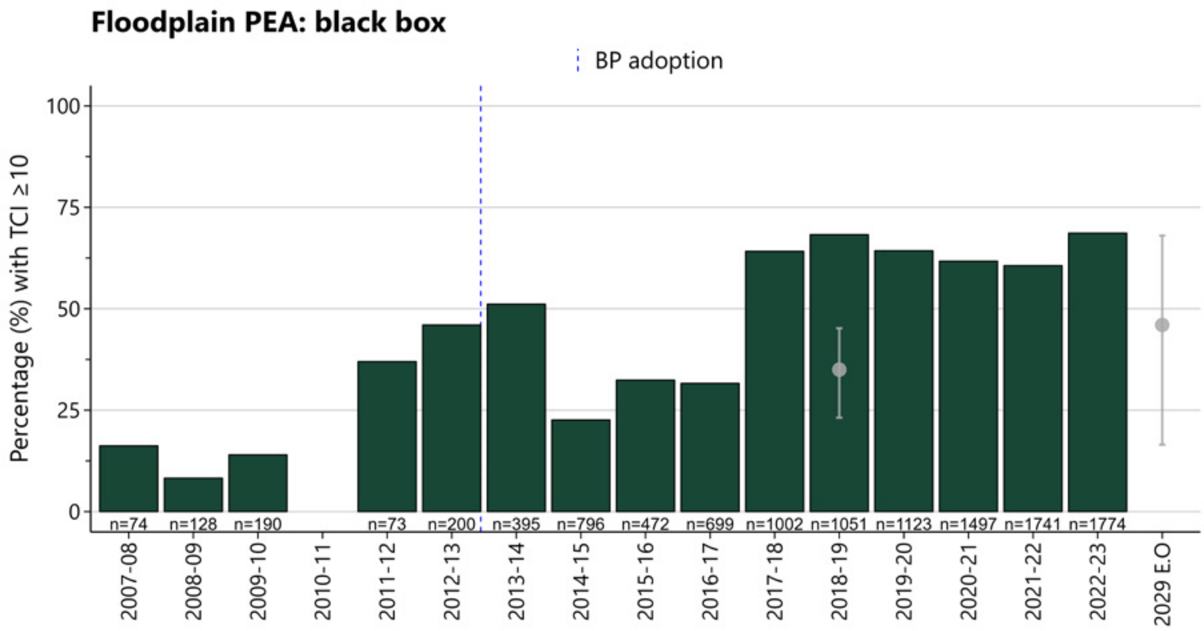




*Figure 7: Percentage of black box with TCI ≥10 in the Floodplain PEA extent of the Chowilla, Pike and Katarapko floodplains between 2007–08 and 2022–23. Sample size (n) is provided above the x- axis for the corresponding water year. The 2019 and 2029 expected outcomes (±80% confidence interval) are referenced by the grey point and associated error bars. Data Source: MDBA and DEW.*


## Is this what we expected to see and have there been any unanticipated outcomes?

Black box condition is influenced by a number of inter-related factors, including the frequency of flooding, rainfall, groundwater level, soil moisture and salinity. In 2019, expected black box condition was exceeded, with 68% of trees at managed floodplain sites with a TCI ≥10 (expected 35%). Currently, there is 69% of black box trees with a TCI ≥10 in managed sites and we are likely on-track to meet the 2029 expected environmental outcome for black box condition at managed sites within the Floodplain (46% of trees with a TCI ≥10).

It should be noted that these data is derived from monitoring undertaken at sites where there has been targeted delivery of water for the environment, thus the results for the entire SA River Murray Channel and Floodplain are largely unknown and may be lower than the observed condition. Whilst not unanticipated in terms of response, the recent high (unregulated) flow conditions have continued to support overall improvements in black box condition in the Floodplain.

## Why are we seeing these results?

The percentage of black box trees at floodplain sites at Pike, Katarapko and Chowilla in good or excellent condition has improved between 2007–08 and 2022–23. Improvements across the Floodplain were likely influenced by:

- high (unregulated) flow conditions in 2010–11 and 2016–17 and the River Murray flood event in 2022–23, which have led to improvements in tree condition in subsequent years
- high rainfall events, particularly in 2010–11, 2016–17 and 2022–23, which provided the primary source of water for black box trees and resulted in improved condition
- the delivery of water for the environment and actions including:
  - managed floodplain inundations through the operation of the Chowilla (since 2014), Pike (since 2020) and Eckerts-Katarapko (since 2020) environmental regulators that delivered water to black box populations that are higher on the elevation gradient
  - weir pool raising and pumping provided short-term, localised improvements to tree condition.

## What has the Basin Plan contributed?

Since Basin Plan adoption, improvements in black box condition have largely been supported by rainfall and high (unregulated) flow events. However, water for the environment, provided by managed floodplain inundations through the operation of environmental regulators have contributed to improvement in the condition of black box. Managed floodplain inundations, along with weir pool raising and pumping, provided minor increases in the area inundated with more trees receiving water. These areas support the maintenance of tree condition, increased resilience of trees and improved future responses to flood events.



## What is still to be done?

Delivery of water for the environment is important to improve the condition and resilience of black box populations, helping to increase the proportion of trees in good condition, improving the ability of trees to tolerate dry periods and supporting improved responses of trees to watering when water is available.

Further optimisation of the delivery of water for the environment along with addressing current water delivery constraints could support improved tree condition. Floodplain environmental regulators have not yet been operated to full inundation and therefore the delivery of water for the environment may increase at these sites in the future.

Further weir pool raising, with additional measures such as groundwater management, would also further increase tree condition and resilience. Long-term efforts will need to focus on adaptive management strategies to respond to changing environmental conditions, particularly an increased frequency and duration of drought resulting from the impacts of climate change.

Although outside of current management influence, periodic high (unregulated) flow events are required more frequently than is currently observed to support the resilience of the population across the entire SA River Murray floodplain. This is particularly important for sites that are outside of the managed floodplains.

## What do we expect to see in the future?

Through implementation of the Basin Plan it is expected that the condition of black box within the SA River Murray floodplain will improve. This improvement will be highly dependent on rainfall and flow conditions, as black box are reliant on high (overbank) flows to maintain or improve their condition.

Full implementation of the Basin Plan including addressing current delivery constraints and continued protection or increased water for the environment is required to achieve greater frequency, duration and magnitude of overbank flows along the SA River Murray which would help improve tree condition. Over the longer-term climate variability and in turn the influence this has on water availability may limit future improvements to black box condition in the SA River Murray.

*Further improvements in black box condition will be highly dependent on rainfall and high (unregulated) flow events.*


# Case study: Floodplain understorey vegetation

The floodplains of the SA River Murray support a diverse community of understorey vegetation (non-woody vegetation). Understorey vegetation communities are important primary producers and support nutrient cycling, provide protection from soil erosion and bank instability and are important habitat and food resources for key waterbirds, terrestrial birds, frogs, reptiles and invertebrates.

Understorey species in the SA River Murray are adapted to regular disturbance through variable flow regimes and species differ in their tolerance to changes in flow regimes. To help define understorey vegetation in the SA River Murray floodplains, they are classified into three functional groups:

1. *Amphibious species* that tolerate or respond to varying water levels (wet and drying phases)
2. *Flood-dependent species* that are not tolerant of extended inundation and will germinate on soils during flood recession, but not in response to rainfall
3. *Terrestrial species* that mostly tolerate low soil moisture but still require high soil moisture at times throughout their lifecycle

The prevalence of these three functional groups on floodplains reflects the recent and historical water regime. A floodplain in healthy condition will respond with a diverse assemblage of understorey vegetation in both dry and wet phases.

To support the ecological restoration of the floodplain environments at Chowilla, Pike and Katarapko, water for the environment is delivered across parts of these floodplains via infrastructure operations. These operations involve operation of environmental regulators to increase the water level upstream and through the anabranch, enabling overbank flows and supporting lateral connectivity within the floodplain. In conjunction with the operation of the floodplain environmental regulators, the River Murray weirs at Lock 6, 5 and 4 can be concurrently raised above normal operating levels to facilitate suitable anabranch flows. Water can also be pumped to discrete wetlands and their immediate floodplains.


© Tom Hunt

## Managed floodplain inundation and water for the environment

Operation of the Chowilla environmental regulator has occurred on six occasions since construction was completed in 2014.

The Pike environmental regulator has been operated on three occasions and at Katarapko on two occasions (excluding the minor operation of Boyties Lagoon regulator in 2022), since construction in 2020.

Water for the environment delivered through floodplain infrastructure has helped to achieve floodplain understorey vegetation targets and is the core option for floodplain management to simulate floodplain inundation and wetting and drying cycles for understorey vegetation.

Prior to the construction of environmental regulators, water for the environment has been delivered to 29 different wetland sites at Chowilla via pumping since 2004. This included large sites such as the Coppermine Complex and Gum Flat wetlands (which are now successfully inundated with the environmental regulator) pumped in 2006 and 2009 after extended periods without water, contributing to understorey vegetation environmental outcomes. Pumped delivery of water for the environment has also been undertaken to a lesser extent at Pike and Katarapko, but continues to be an important option for discrete watering under some conditions.


© SARDI


© SARDI

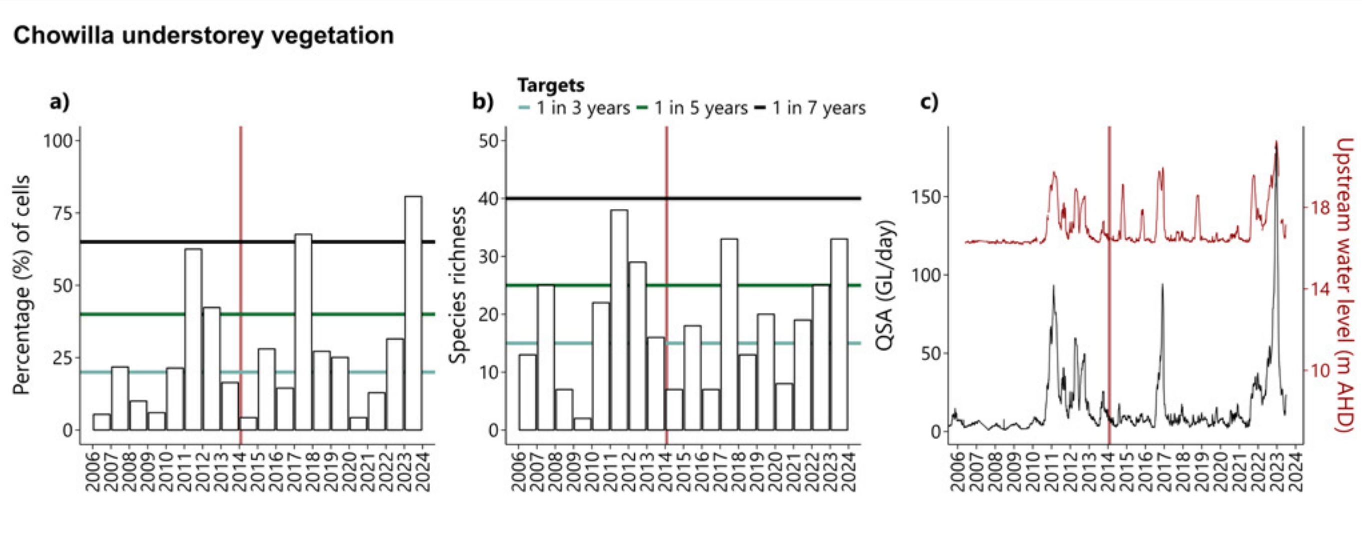



*Figure 8: Chowilla understorey vegetation data. a) the percentage of cells containing flood-dependent or amphibious taxa in sites; b) the number of species of flood-dependent or amphibious taxa in sites; and c) the Flows to South Australia (QSA; black line) and the water level in Chowilla Creek downstream of Monoman Creek (A4261091). The vertical red line is the approximate date of the environmental regulator beginning to operate. Data Source: MDBA and DEW.*

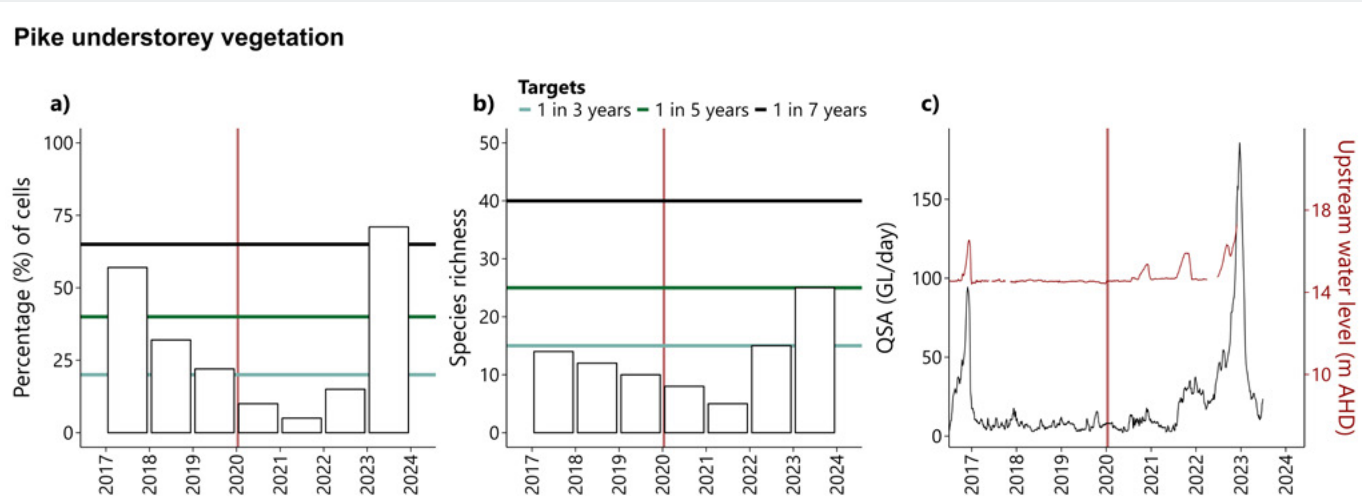



*Figure 9: Pike understorey vegetation data. a) the percentage of cells containing flood-dependent or amphibious taxa in sites; b) the number of species of flood-dependent or amphibious taxa in sites; and c) the Flows to South Australia (QSA; black line) and the water level in Pike River upstream of Col Col (A4261091). The vertical red line is the approximate date of the environmental regulator beginning to operate. Data Source: MDBA and DEW.*

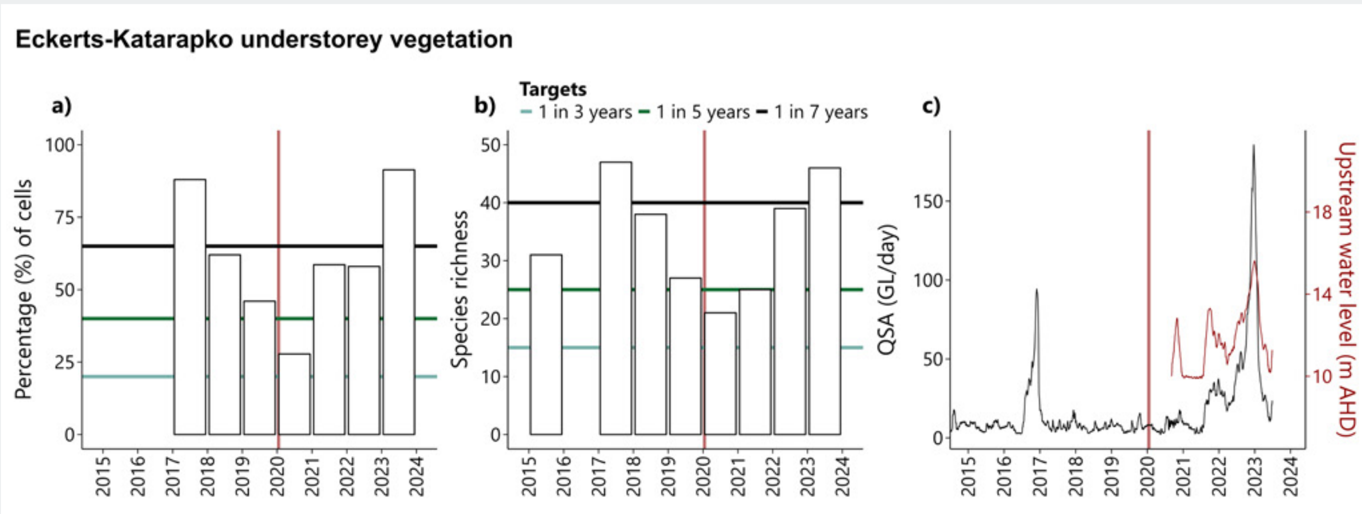



*Figure 10 : Katarapko understorey vegetation data. a) the percentage of cells containing flood-dependent or amphibious taxa in sites; b) the number of species of flood-dependent or amphibious taxa in sites; and c) the Flows to South Australia (QSA; black line) and the water level at The Splash Creek regulator (A4261790). The vertical red line is the approximate date of the environmental regulator beginning to operate. Data Source: MDBA and DEW.*


## Understorey vegetation responses

Annual monitoring from the three managed floodplains (Chowilla, Pike and Katarapko) indicated that understorey vegetation responded positively to increased riverine flows and managed floodplain inundations, including:

- Chowilla vegetation targets were exceeded in years following high (unregulated) flow conditions and the operation of the floodplain environmental regulator, notably in 2011, 2017 and 2023 (Figure 8).
- Pike vegetation targets were exceeded in 2023, following multiple floodplain operations in 2020, 2021 and 2022 and in response to the 2022–23 River Murray flood event (Figure 9).
- Consistently high species richness was observed at Katarapko, with notable improvements in 2022 and 2023 following floodplain operations in 2020 and 2021 and the 2022–23 River Murray flood event (Figure 10).

This case study highlights the importance of floodplain inundation events (both natural flooding and managed inundation) to amphibious and flood-dependent understorey vegetation.

Managed floodplain inundations, through the operation of environmental regulators and water delivery, have contributed to improvements in the understorey vegetation communities at these floodplains. Smaller-scale managed floodplain watering events have helped to maintain soil seed banks and understorey vegetation at locations between periods of larger and natural inundation events, supporting their long-term viability.

The recolonisation and diversity of understorey vegetation on floodplains following extended dry periods will continue to rely on river-floodplain connectivity and flows that enable significant overbank inundation.

Widespread flooding due to the 2022-23 SA River Murray flood also helped enhance the distribution and species richness of understorey vegetation and the achievement of floodplain monitoring targets.

# Expected outcome report: Fish

# Murray cod

Trend
**Improved**

Reliability
**Very good**

**Recruitment of Murray cod has continued to improve, with population structure characteristic of a more resilient population.**

## What are we trying to achieve:

The Long-term Environmental Watering Plan objective is to "*Restore resilient populations of Murray cod*."

The presence of all age classes (recent recruits, sub-adults and adults) represents a healthy population structure, which is required for a resilient population.

## Why are Murray cod important?

Murray cod *(Maccullochella peelii)* is an iconic and nationally threatened native fish species within the Murray–Darling Basin. It is a long-lived (up to 48 years) key predator in the river ecosystem, as well as an important cultural, recreational and economic species, contributing to recreational fishing and tourism. Murray cod are considered an indicator of the overall health of the river environment; changes in their abundance or health can signal broader environmental issues.

Murray cod prefer fast-flowing (flow velocities >0.3 m/s) and structured habitats (e.g. woody debris) and are generally limited in their movements (<10 km) from their home locations in the SA River Murray. In the SA River Murray they spawn annually, but recruitment is variable.

## What is the trend and current status of Murray cod?

Population condition of Murray cod is determined by the age classes (recent recruits, sub-adults and adults) present within the population and the age of Murray cod is determined by length. A healthy and resilient population structure requires all age classes to be present.

From 2002–03 to 2022–23, the annual age structure of Murray cod has improved. Prior to Basin Plan adoption and during the Millennium Drought, recruitment of Murray cod was negligible, with a lack of small fish and all age classes present in only 20% of the years (Figure 11). Since 2012, population condition has improved and all age classes have been detected annually since 2012–13 (Figure 11). The highest proportion of young-of-year (YOY) Murray cod was recorded in 2019–20, at 30% of sampled fish. Since then, there has been a greater proportion of sub-adult fish and a small increase in the proportion of adult fish recorded in 2022–23.

*Murray cod recruitment has improved, reflecting a more resilient population with multiple age classes.*

© SARDI

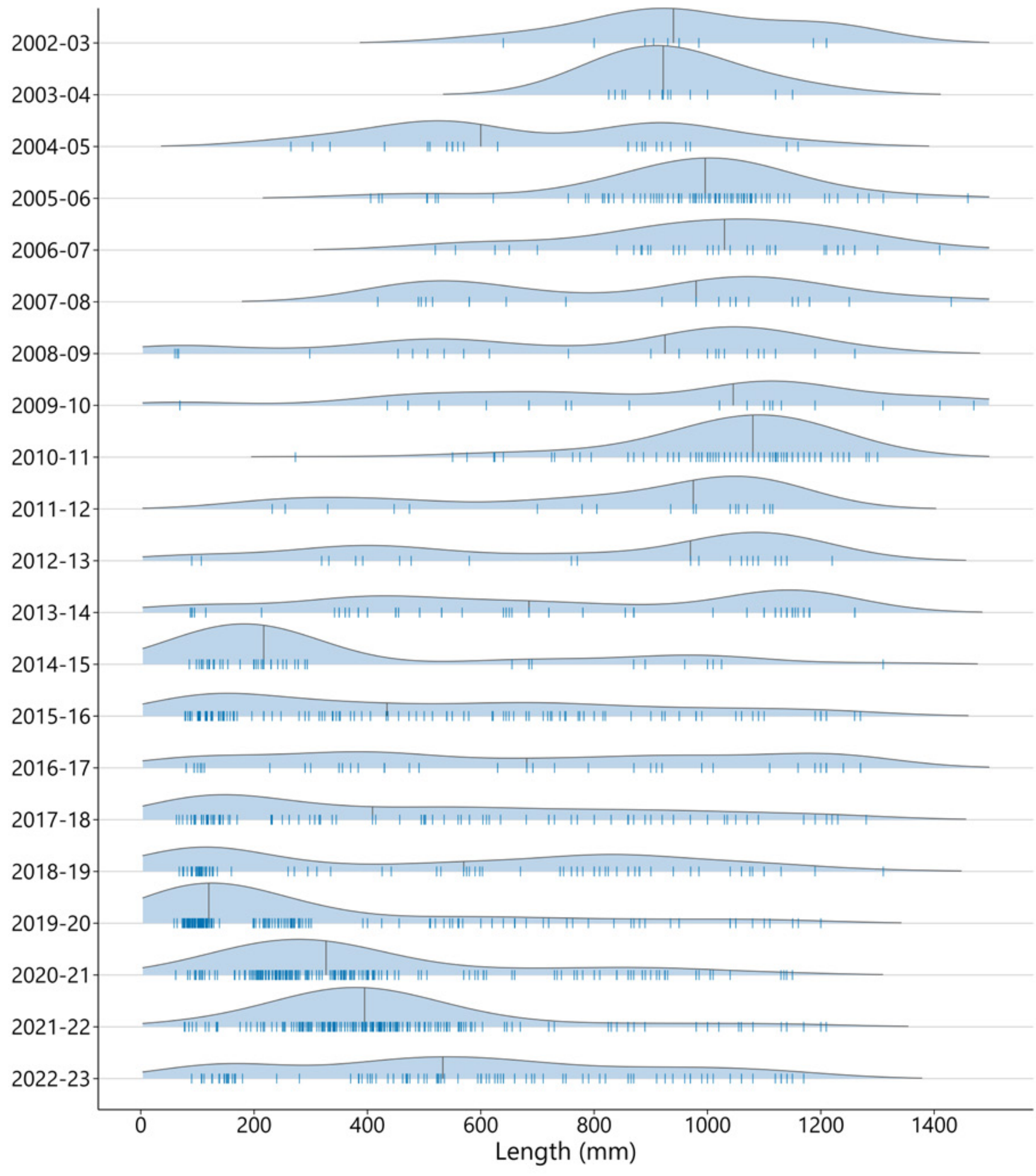



*Figure 11: Murray cod length (mm) sampling between 2002–03 and 2022–23 watering years. Each vertical dash in each water year represents the length of individual fish, while the black line is the median length of sampled Murray cod for that water year. Data Source: SARDI.*



## Is this what we expected to see and have there been any unanticipated outcomes?

In 2019, expected Murray cod recruitment was exceeded, with all age classes recorded in 100% of years since Basin Plan adoption in 2012 (expected 5 of 7; 71% of years). Currently, Murray cod recruitment remains higher than expected, with age classes recorded each year. As a result, we are likely on-track to achieve the 2029 expected outcome for Murray cod recruitment (expected 10 of 17 years; 59%).

Despite higher flow conditions in 2021–22, recruitment was lower than anticipated. The reasons for this are largely unknown, but future monitoring may provide insights as the fish that recruited during that time grow and become more detectable.

## Why are we seeing these results?

Murray cod population condition is dependent on environmental conditions preceding spawning, the number and condition of mature adults, effective dispersal and survival of larvae and the availability of suitable habitats and resources to support all age classes of Murray cod.

Since Basin Plan adoption, improved Murray cod population condition was driven by:

- comparatively wetter climate conditions and associated high (unregulated) flow periods that provided increased areas of fast-flowing conditions, overbank flows and flooding
- increased magnitude and duration of in-channel spring flow pulses supported by the delivery of water for the environment
- complementary habitat restoration actions such as re-snagging to increase structural habitats important for spawning and survival.

Hypoxic blackwater events in 2010–11 and 2016–17 may have prevented strong recruitment and caused some mortality of Murray cod in the SA River Murray. Despite upstream low oxygen water events during the 2022–23 River Murray flood, the flood event provided favourable conditions for Murray cod recruitment in the SA River Murray.

© SARDI


© SARDI

## What has the Basin Plan contributed?

Implementation of the Basin Plan, including delivery of water for the environment, has contributed to improving Murray cod population condition.

Increased in-channel spring flow pulses supported by water for the environment provided conditions to support Murray cod spawning (in spring-summer months), dispersal and recruitment. Water for the environment delivered to prolong the high flow event in 2016–17 may have reduced the overall impacts of low oxygen water and limited Murray cod mortalities in the SA River Murray at that time. Addressing current water delivery constraints will result in increased volumes and magnitudes of flows throughout the SA River Murray, further improving outcomes for the Murray cod population.

## What is still to be done?

Continued delivery of water for the environment to enhance and extend spring flow pulses to support fast-flowing conditions during Murray cod spawning season together with weir pool management (lowering/raising) will increase the magnitude and duration of flow pulses. These flow pulses will improve the dispersal of Murray cod larvae and increase the extent of suitable spawning habitats for adult Murray cod.

Small-scale re-snagging projects are currently being implemented as part of the SRE program to improve the structural habitat extent within the river and support Murray cod populations. Although re-snagging efforts have been relatively small-scale so far, ongoing initiatives will help improve and expand available physical habitat for Murray cod.

Long-term efforts will need to focus on adaptive management strategies to respond to changing environmental conditions, particularly the increased frequency and duration of droughts caused by climate change.

## What do we expect to see in the future?

Implementation of the Basin Plan alone is unlikely to prevent the population of Murray cod declining over time. It will be important that key threats such as habitat loss and degradation, unsuitable flow regimes and reduced connectivity are actively managed to reduce or avoid impacts on Murray cod populations.

Full delivery of the Basin Plan, including the recovery and delivery of the 450 GL for the environment and addressing current water delivery constraints, are also important to ensure the volume, timing and duration of flows create conditions to support Murray cod populations in the SA River Murray.

Over the longer-term, climate variability is likely to be an important driver of Murray cod populations. Water availability and management will continue to be important to contribute to the ongoing health of Murray cod populations.

*Delivery of water for the environment during spring-summer have improved Murray cod populations, facilitating spawning events, egg and larvae dispersal and increasing system productivity.*

# Expected outcome report: Fish

# Golden perch

Trend
**Improved**

Reliability
**Good**

**Golden perch recruitment has improved, with young-of-year fish detected in the population since 2021.**

## What are we trying to achieve:

The Long-term Environmental Watering Plan objective is to *"Restore resilient populations of golden perch."*

The presence of all age classes (recent recruits, sub-adults and adults) represents a good population structure, which is required for a resilient population.

## Why are golden perch important?

Golden perch (*Macquaria ambigua*) are a medium to large-bodied native fish species that is widespread across the Murray–Darling Basin and is found throughout the SA River Murray and Lower Lakes. They are an important commercial, recreational and cultural fish species.

Golden perch are indicators of hydrological connectivity and changes in the flow regime. Populations need suitable river flows (i.e. preference for flowing, deep water habitats with diverse flow velocities) and connectivity to support their key life history requirements, including spawning cues, dispersal of eggs and larvae, refuge and adult body condition.

*Golden Perch population condition have improved, with all age classes including young-of-year detected since 2021.*

## What is the trend and current status of golden perch?

Population condition of golden perch is determined by the age classes (YOY, sub-adults and adults) present within the population. The presence of all age classes represents a healthy population structure, which is required for a resilient population.

From 2005 to 2023, the annual population age structure of golden perch has improved. Prior to Basin Plan adoption and during the Millennium Drought, the golden perch population in the SA River Murray consisted of mainly adult fish, with no YOY and limited recruitment detected (Figure 12). Since Basin Plan adoption in 2012 golden perch population age structure has varied with minimal recruitment and decreased numbers of golden perch between 2015 and 2020, but some recruitment (i.e. the presence of YOY fish) and the presence of all age classes between 2021–2023.



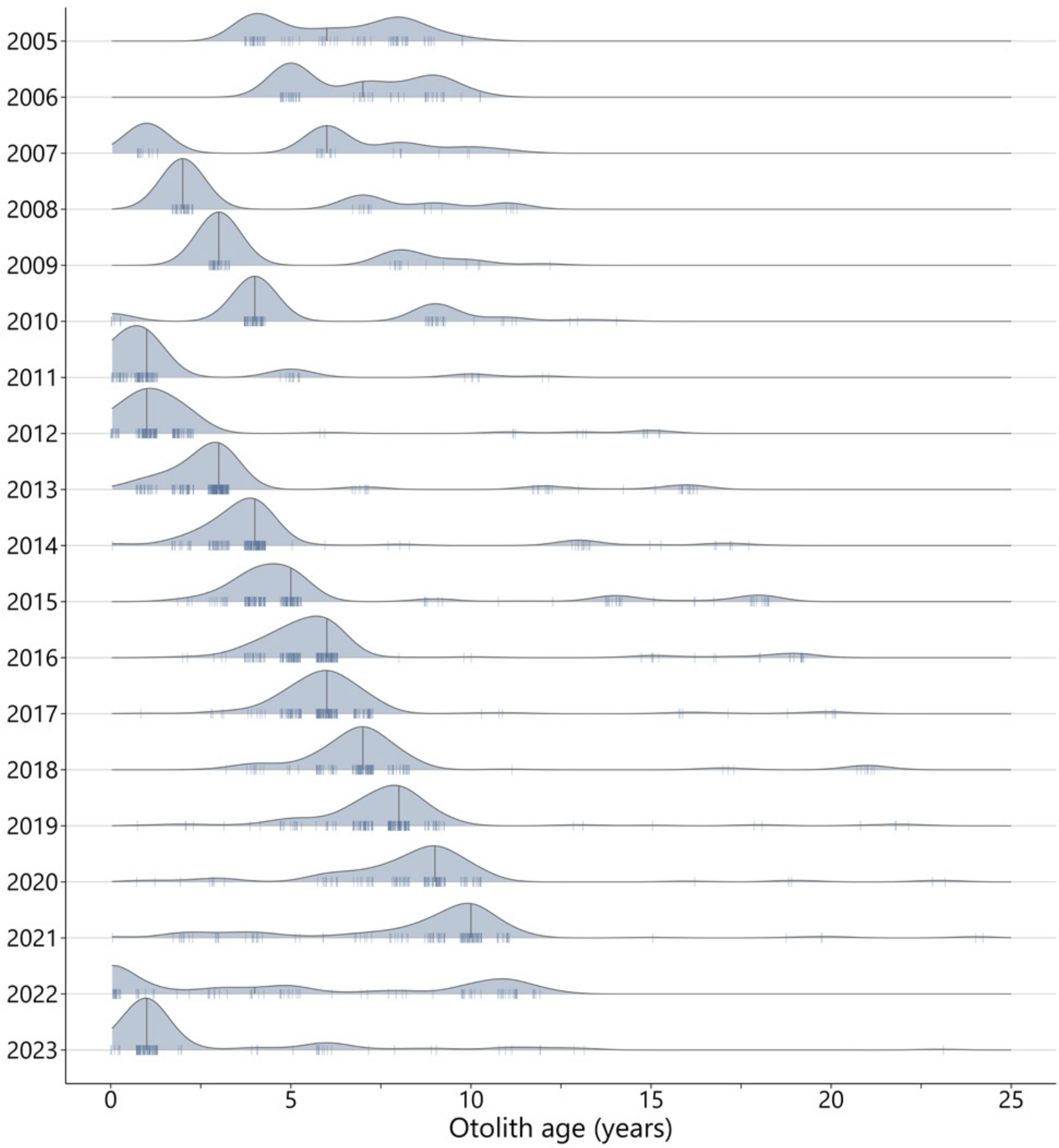



*Figure 12: Golden perch age structure between 2005 and 2023. Each vertical dash represents the age of an individual fish, while the black line is the median age of sample golden perch for that year. Data from the CEWO MER Cat 3 - Targeted YOY has not been included, as this sampling is biased towards fish of a particular age. Data Source: SARDI.*



## Is this what we expected to see and have there been any unanticipated outcomes?

Population age structure and recruitment of golden perch is strongly influenced by flows and system-wide connectivity. In 2019, golden perch population age structure was lower than expected, with only 29% (2 of 7 years) of years containing all age classes (expected 71%; 5 of 7 years). However, in 2019 we also expected the population to feature large recruitment events in 43% (3 of 7) of years, but recruitment was detected in only 14% (1 of 7) of years. Currently, golden perch population age structure and recruitment are both lower than expected and we are not on track to meet the 2029 expected population age structure (expected 11 of 17 years; 65%) or recruitment (expected 8 of 17 years; 47%) for golden perch in the SA River Murray.

## Why are we seeing these results?

Flow and system-wide connectivity are important drivers of golden perch age structure and recruitment. Improved golden perch population condition since Basin Plan adoption has been influenced by:

- comparatively wetter climate conditions and associated high (unregulated) flow conditions that have provided resources to support recruitment and high growth rates in fish
- high in-channel spring-summer flows that provided conditions to likely stimulate spawning, facilitate transport of golden perch eggs and larvae and subsequent recruitment
- spring-summer flow pulses (<18,000 ML/day) have supported low-level recruitment in the population between 2014–2021, which has contributed to overall resilience of the population
- insufficient in-channel flow volumes (i.e. <20,000 ML/day) together with the impacts of the 2016–17 low oxygen water event led to decreased numbers and minimal recruitment between 2014 and 2020
- low oxygen water event in 2016–17 that impacted survival of golden perch eggs and larvae, limiting recruitment.

## What has the Basin Plan contributed?

Implementation of the Basin Plan, including delivery of water for the environment, has contributed to improving golden perch populations, but is still yet to have a significant impact on populations in the SA River Murray. Whilst water for the environment has contributed to spring-summer flow pulses since adoption of the Basin Plan, these have typically been below the in-channel flow volumes (i.e. <20,000 ML/day) required for strong golden perch recruitment. Smaller flows influenced by the management of water for the environment have supported low-level recruitment, contributing to overall resilience, especially following consecutive years with sufficient flows in spring-summer time.




## What is still to be done?

Full implementation of the Basin Plan, including further water recovery and continued delivery of water for the environment, is required to improve flows for fish reproduction and recruitment. Improved water delivery and management to support golden perch populations include:

- providing in-channel flows >20,000 ML/day or overbank flows >40,000 ML/day during spring-summer to promote spawning and recruitment
- addressing current water delivery constraints that have impacted the capacity to deliver higher in-channel flows to the SA River Murray
- in between periodic high-flow events, the continued delivery of smaller volumes of water for the environment to support recruitment and contribute to the overall resilience of the population
- weir pool manipulation, including lowering, which can increase the length of fast-flowing habitat and may further improve recruitment in golden perch.
- maintenance of connectivity at local and regional scales to support spawning and recruitment

The influence of cues such as diversity in flow conditions on spawning of golden perch and the influences of processes occurring in the Lower Lakes (as critical nursery habitats) on the broader population dynamics of golden perch in the SA River Murray remain knowledge gaps that require further investigation.

## What do we expect to see in the future?

It is expected that age structure of golden perch may decline whilst recruitment is expected to be maintained in the future (2029 expected outcome). These outcomes are largely due to expected climate variability and its impact on water availability and management. The reliance on golden perch on higher flows for recruitment make them particularly vulnerable to reductions in the duration and frequency of high (unregulated) flow events and the potential for prolonged dry periods, as the provision of in-channel water for the environment is not enough to support strong recruitment.

Full implementation of the Basin Plan, particularly addressing current water delivery constraints, recovery (450 GL) of water for the environment and coordinated delivery of water for the environment, are needed for improved channel and floodplain connectivity and productivity and to provide conditions that support golden perch recruitment and population condition.

*Improvements to volumes and frequency of water for the environment are needed for further improvements in golden perch populations in the SA River Murray.*

# Case study: Frogs on Chowilla floodplain

## The impact of river regulation on frogs

The inundation of temporary wetlands and floodplains is critical for frog communities in the SA River Murray. The presence and persistence of a diversity of permanent and ephemeral habitats facilitates the dispersal of frog species across the rivers and floodplains. The frequency, timing and duration of river flows, floodplain inundation and rainfall are important for frog populations, triggering breeding and tadpole development (known as metamorphosis).

Seasonal river flows that were once highly variable have been altered by river regulation, creating more stable weir pools and reduced water level changes. The delivery of water for the environment can stimulate conditions in temporary wetlands that are similar to natural wetting and drying phases, leading to positive outcomes for frogs.

## Frog responses to managed inundation and natural flood

Breeding activity was detected for all (eight in total) expected frog species in Chowilla floodplain during the 2021–22 managed inundation event (operation of the floodplain environmental regulator) – a greater diversity than observed in years preceding the operation. Breeding calls for wetland-dependent species (i.e. eastern banjo frog, long-thumbed frog, eastern sign-bearing froglet, Peron's tree frog and southern bell frog) were comparable between the operation event and the 2022–23 River Murray flood event. However, a substantial breeding event was observed for burrowing frogs (the Suddell's and painted burrowing frogs) during the managed inundation event (Figure 13), demonstrating that the delivery of water for the environment elicited opportunistic response in semi-arid frogs.

Tadpole abundances were detected across all surveyed wetlands in Chowilla and were greater at the end of spring, during both events. It was likely that all expected riparian species were successfully breeding. Tadpole abundances of burrowing frogs indicated that a substantial breeding event had occurred during the managed inundation event for these species. Tadpole abundance was similar for both events for most species, including the southern bell frog (Figure 14). The higher volumes of water during the 2022–23 River Murray flood event likely reduced tadpole catches meaning that their regional abundances were likely underestimated during this event.

Successful recruitment of all species (apart from the eastern-sign bearing frog) occurred during both events. Tadpoles of Peron's tree frog and the southern bell frog had slower development during the 2022–23 flood event, but this was likely due to the absence of tadpoles in September 2022. In contrast, these species may have had accelerated development towards the end of the managed inundation event, with receding waters in November coinciding with increasing temperatures, which can accelerate frog development.



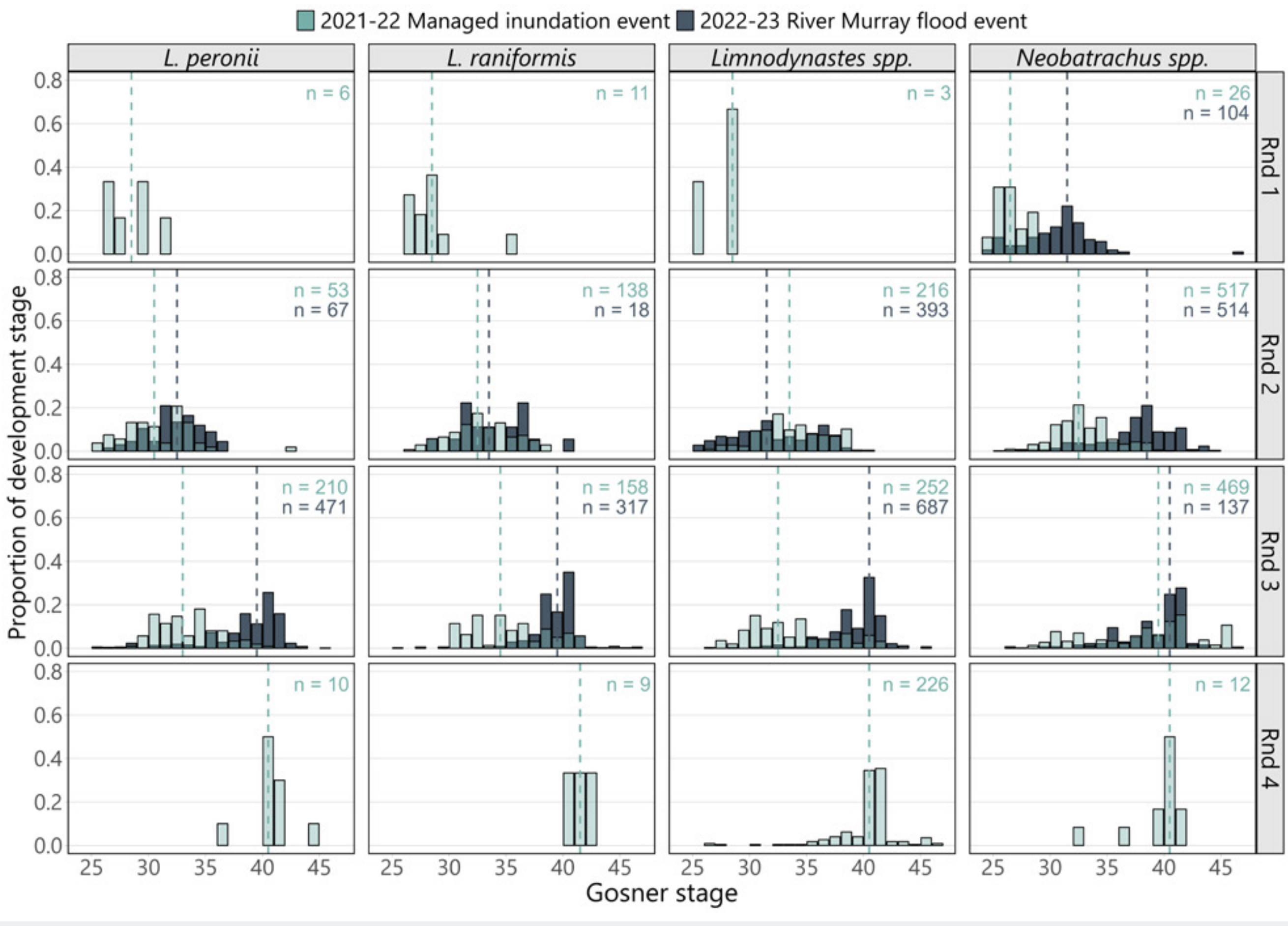



*Figure 13: The proportion of each developmental stage (range: 24–46) for four amphibian taxa sampled in Chowilla wetlands during the environmental regulator event in 2021–22 (pale green) and the flood event in 2022-23 (dark grey). Columns are not stacked – the colour of the column differs when both years overlap. Development stages indicate tadpole progression and growth towards adulthood (stage 46). 'n =' denotes the total number of individuals staged for that species and sampling round, while the dashed line represents the median development stage. The eastern sign-bearing froglet (C. parinsignifera) is not included due to low detection in both years. Note that sampling rounds are not the same dates between both years. Data Source: MDBA and DEW.*


## Importance of water for the environment and natural floods

The Chowilla frogs case study demonstrates that managed inundations can play the same role as natural floods play in supporting amphibian populations. Managed inundations, as seen in the 2021–22 operation of the environmental regulator, effectively create conditions to support breeding and recruitment for local frog species. These outcomes highlight the importance of targeted delivery of water for the environment to improve floodplain frog populations, with managed inundations delivering water in the absence of sufficient natural flows. The 2022–23 River Murray flood event had a broader regional impact, leading to increased recruitment across larger areas of the floodplain, highlighting the greater influence natural flood events can have on floodplain frog populations.

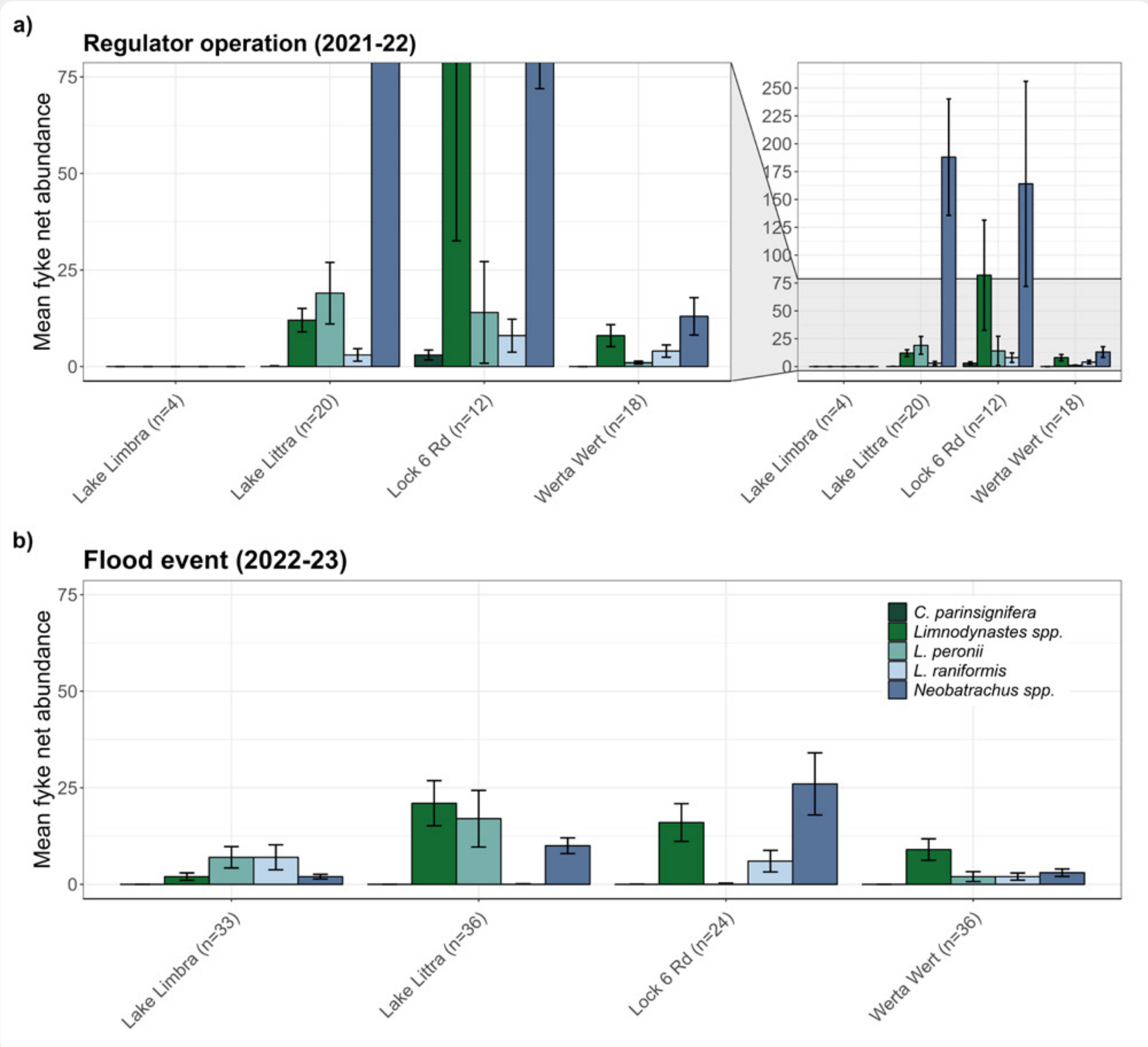
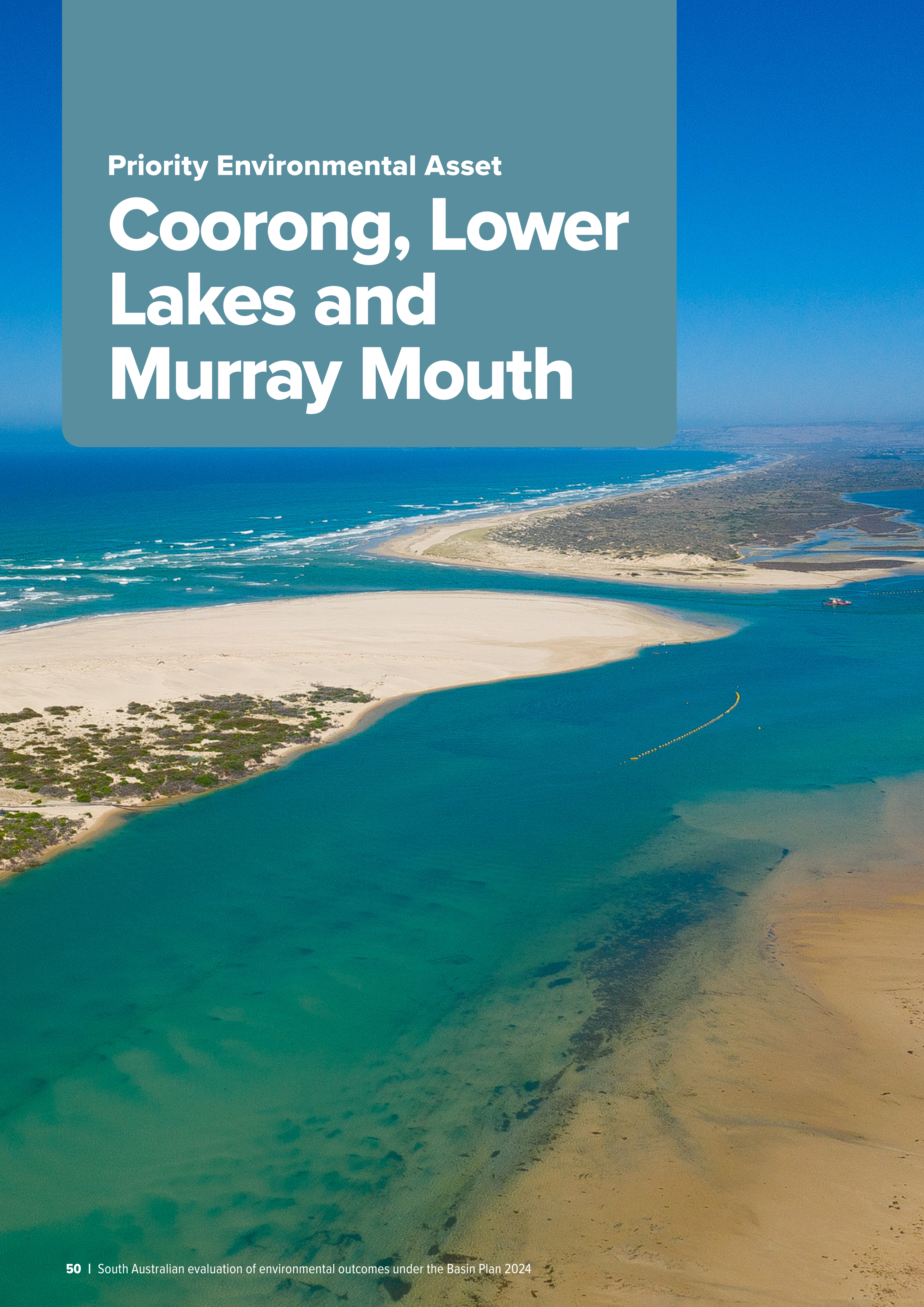



*Figure 14: Mean tadpole abundance per fyke for the five frog taxa that were detected during a) the 2021–22 environmental regulator operation and b) the 2022–23 flood event, on the Chowilla floodplain. "n =" denotes the number of fyke nets sampled in each wetland. Note: Lake Limbra was only surveyed once in September in 2022. Data Source: MDBA and DEW.*

Priority Environmental Asset

# Coorong, Lower Lakes and Murray Mouth



# Coorong, Lower Lakes and Murray Mouth ecosystem drivers and pressures

## Drivers

Inflows from the River Murray provide the primary source of freshwater, which maintains salinity conditions in the Lakes and Coorong, system connectivity and flushes salt and nutrients out to sea.

Salinity is the main driver of the diversity and uniqueness of habitats and species found in the Coorong and Lower Lakes. Conditions range from freshwater, estuarine, marine to hypersaline (in the South Lagoon).

Seasonal changes in lake levels help to support the diversity of vegetation, providing important habitat for key waterbird and fish species.

Water levels in the Coorong influence the habitat conditions for aquatic plants and fish and the availability of food resources for waterbirds.

## Pressures

Changes in climate and climate extremes have influenced rainfall and temperatures, sea level rise and more frequent severe storms.

Increased water diversions and barriers upstream have led to reduced inflows of freshwater and altered hydrological regimes.

Water quality changes through increased salinity, increased nutrients, increased turbidity and exposure of acid sulfate soils.

Invasive species and problematic natives, including blooms of filamentous green algae and phytoplankton.

# What have we assessed?

We assessed progress towards environmental outcomes for the CLLMM using a number of indicators. Broadly, these outcomes aim to maintain or improve the health of vegetation, fish and bird communities, while also maintaining a permanently open Murray Mouth. Additionally, we have included case studies on the Current State of the Coorong and Nutrient dynamics and problematic algal blooms in the southern Coorong.


**Murray Mouth openness:** system driver which indicates connectivity with the ocean and fish movement between freshwater and marine environments. Is also important for discharge of salt and other pollutants to the ocean.

**Ruppia:** extent and condition of habitat and food resources for biota in the Coorong.

**Aquatic and littoral vegetation in Lakes:** Habitat and food source for biota.

**Fish (diadromous fish, black bream, greenback flounder, small-mouthed hardyhead):** Key recreational, cultural and economic species indicative of system connectivity and freshwater inflows and the persistence of estuarine conditions.

**Waterbirds:** highly valued species, indicator of habitat quality and food availability.

**Nutrients:** excess nutrients cause increased algae and phytoplankton growth which interfere with ecosystem functions.

# Coorong, Lower Lakes and Murray Mouth key findings

Implementation of the Basin Plan and the delivery of water for the environment is providing significant benefits and has supported improved environmental conditions in the Coorong, Lower Lakes and Murray Mouth:

- Additional water has helped maintain optimal lake levels and increased barrage flows across the year to improve salinity levels in Lake Alexandrina and Lake Albert.
- Lake level management and seasonal water level cycling has supported aquatic plant recruitment, improving the condition of aquatic and littoral vegetation. This has improved habitat condition and food resources, supporting the abundance, distribution and breeding of waterbird communities across the Lakes.
- Increased freshwater flows through the barrages have maintained and improved the extent of optimal salinity conditions, provided critical pathways for the movement and recruitment of key diadromous fish species and improved black bream and greenback flounder populations in the Murray Estuary and Coorong, as well as small-mouthed hardyhead in the Coorong.
- Maintenance of southern Coorong water levels through spring and summer have improved the abundance and distribution of aquatic plants, including *Ruppia tuberosa*.

Despite these improvements, challenges remain, including:

- The southern Coorong is considered degraded due to prolonged hyper-saline and hyper-eutrophic conditions, risking its ability to support key biota such as waterbirds, fish, plants and invertebrates if additional action is not taken.
- Recovery of waterbird populations, particularly shorebirds, requiring improved quality and availability of local, national and international wetland habitats.
- Improving the recovery and resilience of aquatic plants (including *Ruppia tuberosa*) in the southern Coorong
- Maintaining an open Murray Mouth, without ongoing dredging.

For more information on the assessment of outcomes and the evidence that supports the evaluation, see the South Australian River Murray Basin Plan Environmental Outcome Evaluation: Coorong, Lower Lakes and Murray Mouth (CLLMM) Priority Environmental Asset technical report.

## Coorong, Lower Lakes and Murray Mouth key messages

- Water for the environment and high (unregulated) flows are critical for maintaining the ecological health and function of the Coorong, Lower Lakes and Murray Mouth.
- Implementation of the Basin Plan to date has supported improved connectivity, increased barrage flows and maintained lake levels and salinities within optimal ranges.
- The delivery of water for the environment during recent dry years has likely prevented further disconnections of Lake Alexandrina from the Murray Estuary and Coorong and the resultant ecological outcomes similar to those experienced during the Millennium Drought.
- The 2022–23 River Murray flood event, along with recent high flow conditions, has provided short-term benefits to the Coorong ecosystem but further action is needed to secure its long-term health.

# State of the Coorong

**A key objective of the Basin Plan is to ensure that Ramsar wetlands, such as the Coorong and Lakes Alexandrina and Albert Wetland, maintain their ecological character.**

Recognising the Coorong South Lagoon's declining condition and its significance to the health of the Murray–Darling Basin, the *Healthy Coorong, Healthy Basin* (HCHB) program is working to restore the health of Coorong.

HCHB's Scientific Trials and Investigations project (2019–2022) delivered innovative science that addressed critical knowledge gaps and tested assumptions to determine how to transform the Coorong from its current vulnerable state to a healthier and more resilient ecosystem. This evidence base has been used to develop a shared understanding of the existing and emerging knowledge essential to guide current and future restoration efforts and adaptive management strategies to improve the long-term health of the Coorong.

## Current state

### Variable but low connectivity and inflows

- insufficient inflows and flushing to dilute and export salt and nutrients
- connectivity restricted by the narrow channel at Parnka Point, openness of the River mouth and inflows from the River Murray and south-east
- limited transport and exchange of microinvertebrates and fish that are important for food webs

### Predominantly hyper-saline (>60 g/L)

- below average flow conditions, water does not flush from the South Lagoon because of low inflows and poor connectivity and exchange
- below average salinities in the Coorong in response to the recent River Murray flood event (2022–23)
- evapo-concentration of salt is enhanced by the long residence time of water and lack of connectivity/freshening due to minimal exchange

## Target state

### Variable but adequate connectivity and inflows

- water levels, inflows and water exchange to maintain flushing and connectivity
- only short periods of seasonally restricted connectivity
- microinvertebrates are transported via inflows to support food webs
- fish move freely between lagoons and other connected water bodies

### Variable salinity

- long-term export of salt occurs
- variable salinity including some periods of hyper-salinity (>60 g/L) and a range of lower maximum salinities
- evapo-concentration is balanced with export through water exchange and connectivity

| Current state | Target state |
| --- | --- |
| **Predominantly high nutrient loads**<br>• contains high levels of nitrogen, phosphorus, phytoplankton and filamentous algae, particularly in South Lagoon<br>• increased nutrient-rich and anoxic (low oxygen) sediment conditions, contributing to the formation and prevalence of monosulfidic black oozes<br>• nitrogen and phosphorus have concentrated in surface sediments (50 times higher than water column)<br>• hyper-salinity reinforces eutrophication by impacting plants and macroinvertebrates that cycle nutrients | **Moderate nutrient loads**<br>• sufficient connectivity and water exchange to regulate salinity and nutrient loads<br>• nutrients flux out of sediments<br>• near-absent monosulfidic black ooze sediments<br>• nutrients incorporated into persistent aquatic plants and macroinvertebrates as opposed to high turnover filamentous algae<br>• sediments re-worked and oxygenated by aquatic plants and invertebrates |
| **Food web has low complexity**<br>• algal blooms inhibit growth and reproduction of aquatic plants and do not provide quality food for fish or macroinvertebrates<br>• aquatic plant communities are widespread from Long Point in the north to Salt Creek in the south, with recent biomass improvements in response to improved flow conditions from 2020, but resilience remains low<br>• diverse burrowing macroinvertebrates are present in the North Lagoon but were largely absent in the South Lagoon due to high salinities and poor-quality sediments. The 2022–23 flood event reduced salinity, increasing diversity, abundance and distribution.<br>• salinity was too high for many fish species and hypersaline-tolerant smallmouth hardyhead were dominant in the southern Coorong until the recent flood lowered salinities and improved fish diversity in the South Lagoon<br>• over 50% of monitored waterbird species are reduced in abundance and distribution | **Food web is diverse and resilient**<br>• low density, abundance and coverage of filamentous algae and recovery of aquatic plants<br>• extensive aquatic plants that produce large quantities of seed and turions that provide habitat and food for macroinvertebrates, fish and birds<br>• diverse and abundant macroinvertebrates providing food for fish and waterbirds, oxygenating sediments and filtering water<br>• fish communities are diverse, including yelloweye mullet, congolli and greenback flounder, which support a seasonal fishery<br>• diverse and abundant waterbird populations are supported throughout life stages, including migration and breeding |

## Coorong, Lower Lakes and Murray Mouth

# Expected outcomes reports

### Trend

The change over time, calculated using all available data for an indicator across the assessment period.

| | | |
|---|---|---|
| ↗ | Trend **Improved** | **Improved:** The indicator has improved over the period of assessment. |
| — | Trend **Stable** | **Stable:** The indicator has neither improved nor declined over the period of assessment. |
| ↙ | Trend **Declined** | **Declined:** The indicator has declined over the period of assessment. |
| NA | Trend **Not Applicable** | **Not Applicable:** Data were not sufficient to determine any trend in the status of the indicator. |

# Summary of outcomes at an asset scale

## The assessment of environmental outcomes presents the trend for each indicator along with an evaluation of the following:

- Did we achieve what we expected we would achieve?
- If not, why not?
- How did the Basin Plan contribute to the achievement of environmental outcomes?

For further information please see the technical report for the SA Coorong, Lower Lakes and Murray Mouth.

| Theme | Indicator | Trend | Information reliability | Key findings |
|---|---|---|---|---|
| **Flow & Ecosystem Function** | Murray Mouth openness | ↗ Trend **Improved** | ★★★☆☆ Reliability **Good** | An open Murray Mouth has been possible at times by barrage flows supported by water for the environment but is still heavily reliant on dredging. |
| **Vegetation** | Aquatic and littoral vegetation | ↗ Trend **Improved** | ★★★★☆ Reliability **Very good** | Vegetation condition in the Lakes has continued to improve, largely due to the management of seasonally variable water levels, supported by the delivery of water for the environment. |
| | *Ruppia tuberosa* | ↗ Trend **Improved** | ★★★★☆ Reliability **Very good** | The health of Ruppia has improved, but the community is still not considered resilient and threatened by future perturbations. |
| **Fish** | Black bream and greenback flounder | ↗ Trend **Improved** | ★★★★★ Reliability **Excellent** | Black bream and greenback flounder population condition have improved, reflecting more resilient populations. |
| | Diadromous fish | ↗ Trend **Improved** | ★★★☆☆ Reliability **Good** | Improved connectivity between freshwater, estuarine and marine habitats has supported increased recruitment of diadromous fish. |
| | Small-mouthed hardyhead | ↗ Trend **Improved** | ★★★★☆ Reliability **Very good** | Small-mouthed hardyhead populations have improved, reflecting improved resilience with an increased abundance of juvenile fish. |
| **Birds** | Lakes waterbirds | ↗ Trend **Improved** | ★★★★☆ Reliability **Very good** | Abundances of Lakes waterbirds have improved, but with variability across the different waterbird guilds. |
| | Coorong waterbirds | ↙ Trend **Declined** | ★★★★☆ Reliability **Very good** | The abundance of Coorong waterbirds has continued to decline, particularly for resident and migratory shorebirds. |

Expected outcome report: Flow & Ecosystem Function

# Murray Mouth Openness: annual barrage flow

Trend
**Improved**

Reliability
**Good**

**An open Murray Mouth has been possible at times by barrage flows supported by water for the environment but is still heavily reliant on dredging.**

## What are we trying to achieve?

The Long-term Environmental Watering Plan objective is to *"Maintain a permanent Murray Mouth opening through freshwater outflows with adequate tidal variations to improve water quality and maximise connectivity between the Coorong and the sea."*

## Why is an open Murray Mouth important?

An open Murray Mouth connects the freshwater environments of the River Murray and Lakes to the Murray Estuary, Coorong and the Southern Ocean. The Murray Mouth is the only connection of the River Murray to the ocean. This connection is crucial for flushing excess salts and nutrients, maintaining water quality in the Murray Estuary and Coorong and enabling native fish to move between these environments. The health of the Coorong relies on this exchange, as its water levels and quality (salinity and nutrients) are influenced by the condition of the Murray Mouth. This, in turn, affects the habitat quality and availability for various important plant, fish and waterbird species.

*Dredging to maintain an open Murray Mouth has occurred 67% of the time since Basin Plan adoption.*

## What is the trend and current status of the Murray Mouth?

The openness of the Murray Mouth is assessed using a combination of indicators, including annual flow through the barrages, diurnal tidal ratio (DTR) and dredging actions. The Murray–Darling Basin Authority (MDBA) has calculated that a minimum annual flow of 730–1,090 GL/year is needed to keep the Murray Mouth open. DTR is an indication of the exchange of water between the estuarine and marine environment, ranging from 0.0 (closed) to 1.0 (fully open), with 0.3 typically indicating a functionally open Murray Mouth.

Annual barrage flows have varied greatly from 2000–01 to 2022–23 (Figure 15). During the Millennium Drought, there were nine consecutive years (2001–02 to 2009–10) of zero to low-moderate barrage flows. 'Following the Millennium Drought in 2010 there was widespread flooding and high barrage outflows (12,808 GL) in 2012–13, but flows dropped below <1,000 GL year until high barrage flows were observed again in 2016–17. In the four years that followed, barrage flows remained low-moderate, not exceeding 1,500 GL/year. Moderate flows returned in 2021–22, followed by the 2022–23 River Murray flood event, with significant barrage flows of 16,597 GL.

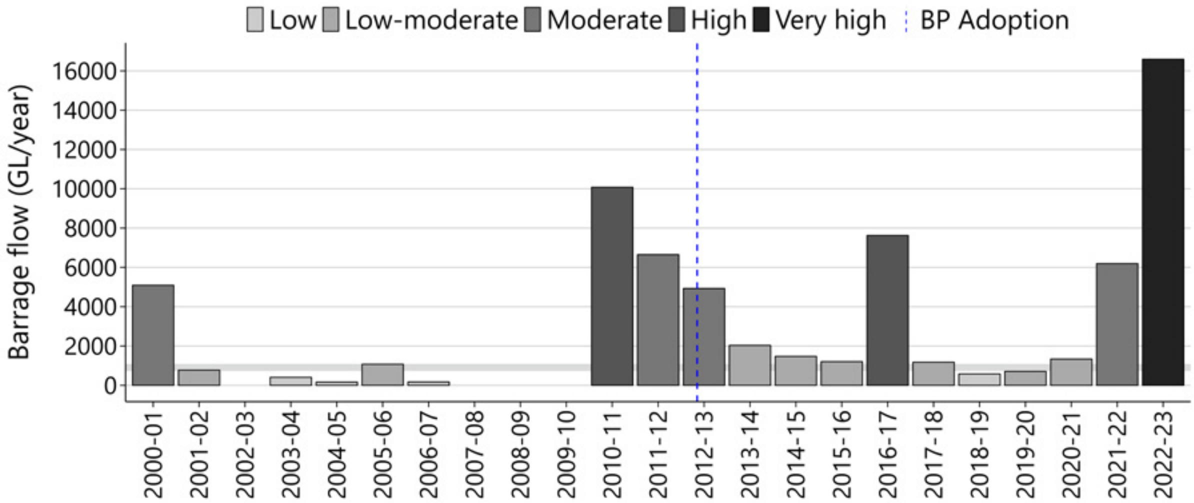



*Figure 15: Barrage flow (GL/year) for each water year from 2000–01 to 2022–23. The grey horizontal shaded area represents the LTWP target range of 730–1,090 GL/year. Shaded columns are the flow categories from the LLCMM Scientific Advisory Group. Data Sources: MDBA MSM-BIGMOD modelled barrage flow data (July 2000 to December 2010) and DEW (A4261002) barrage flow data (January 2011–June 2023).*

Since Basin Plan adoption, there has been a greater frequency of DTR values above 0.3. However, events like the 2022–23 River Murray flood saw DTR values drop after high (unregulated) flows, which reduced the tidal signal and indicated decreased mouth openness (Figure 16). Dredging of the Murray Mouth commenced in 2002 during the Millennium Drought but ceased in 2010–11 with the return of high flows (Figure 16). It resumed in 2014 and has continued almost continuously until June 2023, except during and immediately after high flow conditions in 2016–17 and 2022–23. Since the Basin Plan adoption, dredging to maintain an open Murray Mouth has been needed 67% of the time.

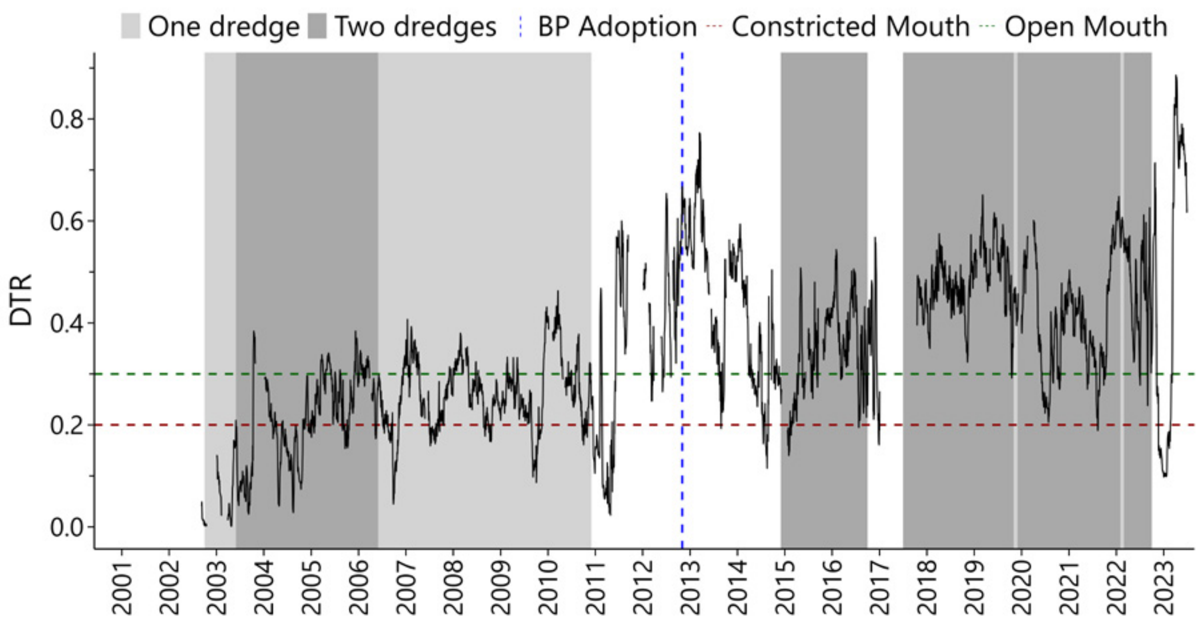



*Figure 16: The Diurnal Tide Ratio (DTR) recorded in the Murray estuary (Goolwa Barrage), between August 2002–03 to June 2022–23. Also shown are periods of dredging operations (shaded rectangles). Data Sources: MDBA MSM-BIGMOD (July 2000 to January 2011), DEW barrage calculator (February 2011 to June 2023) and SA Water (DTR and dredging).*



## Is this what we expected to see and have there been any unanticipated outcomes?

Maintenance of an open Murray Mouth is primarily influenced by climate, as it affects water availability and freshwater inflows to the CLLMM, ensuring sufficient barrage flows to scour the Mouth and limit sand ingression.

Since Basin Plan adoption in 2012, six out of seven years (86%) from 2012 to 2019 exceeded the minimum barrage flow of 730 GL, as expected. By 2023, 9 of 11 years (82%) have had flows >730 GL, with shortfalls in 2018–19 (580 GL) and 2019–20 (707 GL). This indicates we are likely on-track to meet the 2029 expected Murray Mouth openness outcome of, 14 out of 17 years (82%) to exceed 730 GL. However, it is expected that barrage flows alone will remain insufficient to keep the Mouth open without dredging in low to moderate flow conditions.

Dredging was unexpectedly needed during high (unregulated) River Murray flows from July 2021 to October 2022. During the 2022–23 River Murray flood event, dredging ceased as the flood scoured the Mouth, increasing the depth to 11 m and shifting its location. 'However, the extent of the benefit was less than expected due to the sand accumulation prior to the flood peak (i.e. the starting condition of the Mouth) and sand has accumulated faster than expected since the 2023 flood peak.

## Why are we seeing these results?

Since the adoption of the Basin Plan, barrage flows, including water for the environment, have increased the frequency of years meeting the minimum annual flow of 730 GL necessary for an open Murray Mouth. However, despite this improvement, barrage flows alone have been insufficient to maintain an open Murray Mouth outside of high (unregulated) flow conditions.

The ongoing need for dredging to maintain an open Murray Mouth is due to the following:

- reduced rainfall conditions and upstream water extraction have contributed to periods of reduced freshwater inflows and barrage flows
- prolonged periods of barrage flows below approximately 2,000 ML/day have resulted in the significant accumulation of sand within the estuary, that increases the risk of sand deposition and accumulation inside the Murray Mouth
- irregular high flows required to effectively scour the Murray Mouth (60,000–70,000 ML/day), with these flows only recorded in 2016–17, 2021–22 and 2022–23.


## What has the Basin Plan contributed?

Since 2010, continuous connection between Lake Alexandrina and the Coorong has been maintained as a result of the recovery and delivery of water for the environment. Without this, many years over the past decade likely would have seen no flow to the Coorong.

Water for the environment delivered through the Basin Plan has significantly improved barrage flows compared to pre-2010 conditions. In 82% of years, the minimum flow volume of 730 GL required to maintain an open Murray Mouth has been exceeded. However, this minimum annual flow assumes a daily flow of 2,000 ML/day. Since 2012, years where 80% of days exceeded this flow have mostly occurred during high (unregulated) flows. In drier years, water for the environment has been essential to increase daily flows to meet or exceed 2,000 ML/day, ensuring sufficient freshwater flows to sustain ecological connectivity and system resilience.

## What is still to be done?

Current water recovery volumes and physical and operational delivery constraints mean barrage flows alone are unlikely maintain an open Murray Mouth without dredging. Full Basin Plan implementation, including the recovery and delivery of the additional 450 GL of water for the environment and addressing current water delivery constraints, is critical to increase the likelihood of maintaining an open Murray Mouth and achieving the Coorong environmental outcomes. More automated barrage gates could improve the efficiency of targeted water releases.

Maintaining an open Murray Mouth is also reliant on high (unregulated) flows, such as those from flood events. Managing lake levels and barrage flows during these events is crucial for directing flows and ensuring effective scouring to limit constriction.

## What do we expect to see in the future?

In future years, it is unlikely that the percentage of years with annual barrage flows exceeding 730 GL will be maintained without the recovery and delivery of additional water for the environment. However, with full implementation of the Basin Plan, including increased recovery and delivery of water for the environment and addressing current water delivery constraints, we expect an increase in the percentage of days with barrage flows above 2,000 ML/day required to prevent sand ingression.

Despite this, the expected future variability in climate conditions, including the continued decline in the frequency of high (unregulated) flows, means that we expect that barrage flows alone will continue to be inadequate to maintain an open Murray Mouth without the recovery and delivery of additional water for the environment, supported by dredging.

*The recovery and delivery of water for the environment has maintained a continuous connection between Lake Alexandrina and the Coorong since 2010.*

## Expected outcome report: Vegetation

# Aquatic and littoral vegetation

Trend
**Improved**

Reliability
**Very good**

**Vegetation condition in the Lakes has continued to improve, largely due to the management of seasonally variable water levels, supported by the delivery of water for the environment.**

**Aquatic vegetation:** plant species that grow partly or wholly within aquatic environments.

**Littoral vegetation:** plant species that occupies the fringes of waterbodies.

### What are we trying to achieve?

The Long-term Environmental Watering Plan objective is to *"Maintain or improve aquatic and littoral vegetation in the Lower Lakes."*

Healthy aquatic and littoral vegetation communities in the Lakes include high native species richness, diversity and limited cover of invasive and over-abundant native species.

### Why are aquatic and littoral vegetation important?

Lakes aquatic and littoral vegetation is comprised of submergent species that complete their life histories under water, amphibious species that grow both within and out of water, requiring wetting and drying and emergent species that require wet soil or shallow water but also require some plant structures to be above the water line.

Aquatic and littoral vegetation are important for wetland biodiversity and play important roles in primary productivity, nutrient cycling, improvements to water quality, shoreline stabilisation and providing food and habitat for macroinvertebrates, frogs, fish and birds.

*Condition of aquatic and littoral vegetation in the Lakes has improved and is in good condition.*

### What is the trend and current status of Lakes vegetation?

Aquatic and littoral vegetation is assessed using a 'whole of icon site score', derived from individual habitat scores calculated for Lake Alexandrina, Lake Albert, Goolwa Channel and permanent and temporary wetlands around the Lakes. A score of 0.8–1 represents very good condition, 0.6–0.79 indicates good condition, 0.4–0.59 indicates fair condition and below 0.4 indicates poor condition.

Overall, the condition of aquatic and littoral vegetation in the Lakes has improved (Figure 17) and is currently in good condition. Scores were low during the peak of the Millennium Drought (spring 2008 and autumn 2010) but markedly improved with the return of freshwater flows in spring 2010. Scores declined following spring 2011, but from 2012 to 2019 remained relatively stable (0.43 to 0.55). Since spring 2019, scores have continued to improve and are currently approaching 0.7, indicating good condition.

All wetland type habitat scores have increased since spring 2010 (Figure 18), though substantial variability exists among different habitats, particularly in Goolwa Channel and temporary wetlands. Since spring 2019, condition scores have remained stable in Lakes Alexandrina and Albert, while improvements have been observed in the Goolwa Channel and in permanent and temporary wetlands.

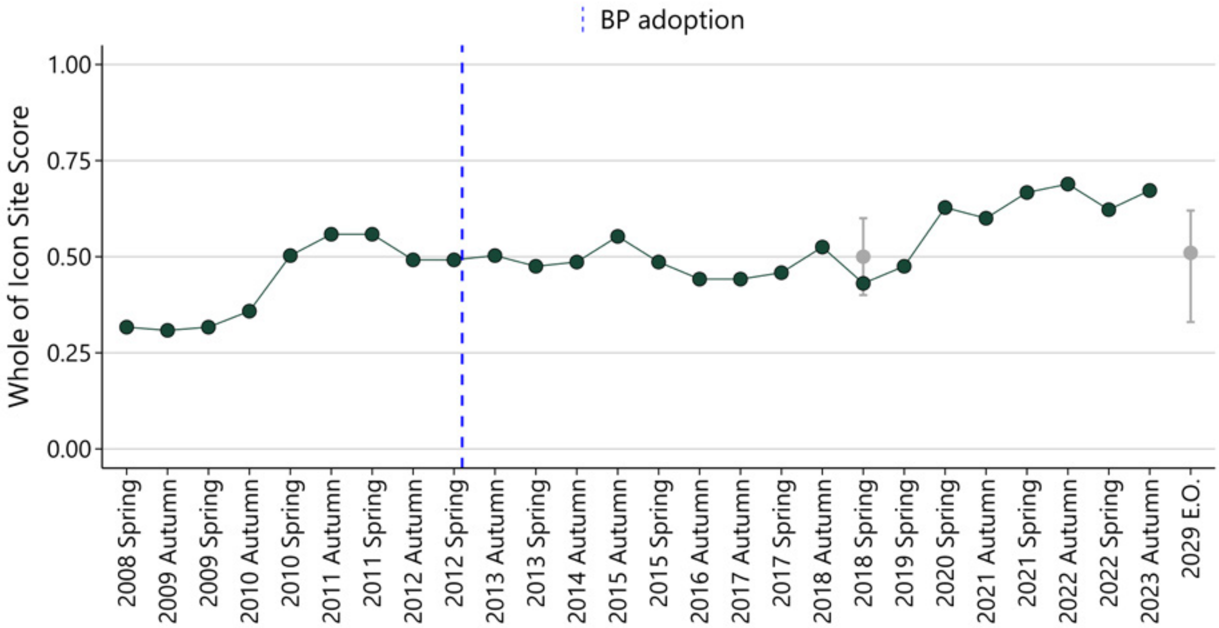



*Figure 17: The whole of icon site score for aquatic and littoral vegetation in the Lakes from spring 2008 to autumn 2023. The grey dots and associated 80% confidence intervals represent the 2019 and 2029 expected outcomes. Data source: SARDI.*

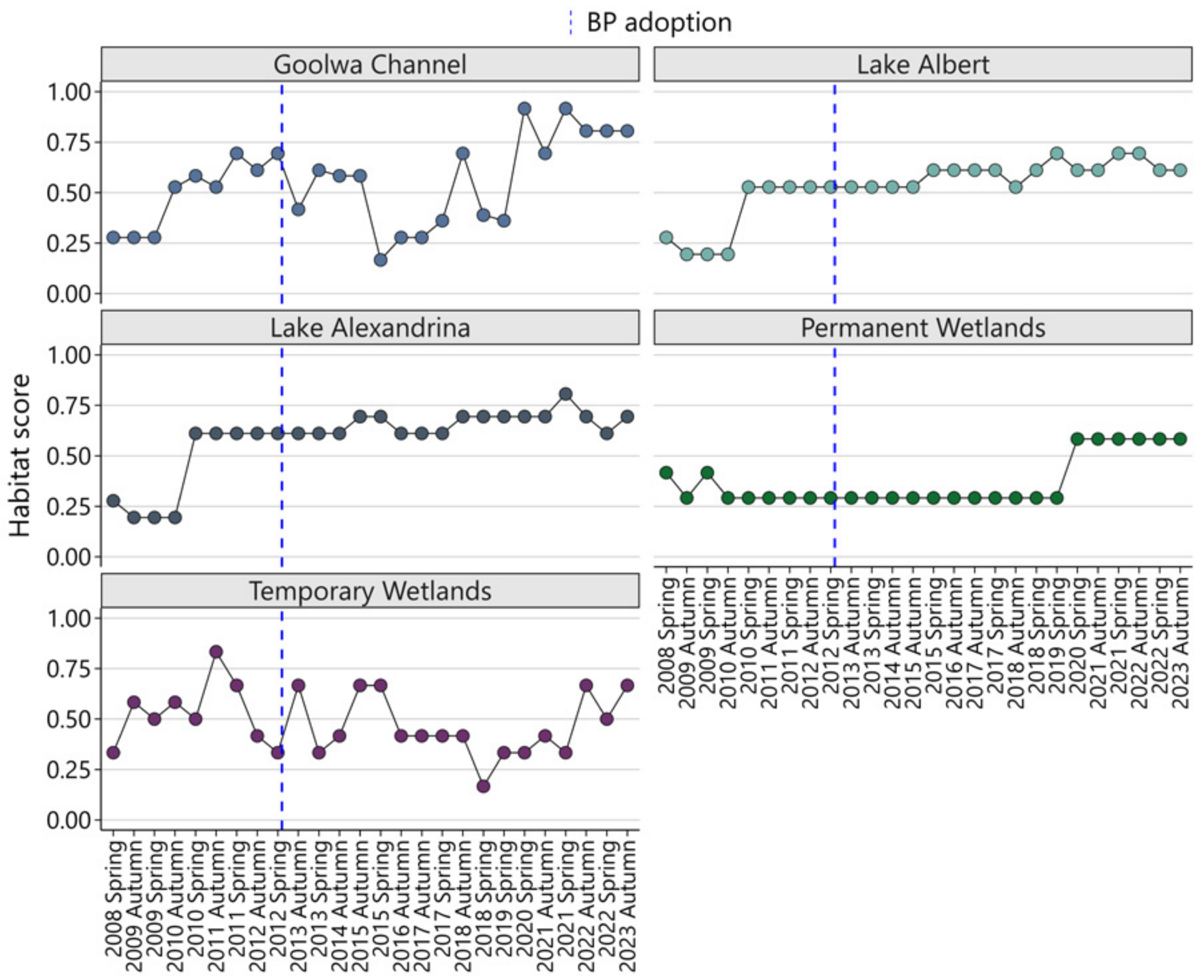



*Figure 18: Habitat scores for each wetland type: Goolwa Channel, Lake Albert, Lake Alexandrina, permanent wetlands and temporary wetlands from spring 2008 to autumn 2023. Habitat scores are averaged to calculate the whole of icon site score. Basin Plan adoption in 2012 is marked by a vertical dashed blue line. Data Source: SARDI.*





## Is this what we expected to see and have there been any unanticipated outcomes?

The water regime, which includes water depth, duration, frequency and timing of wetting and drying, is the primary driver influencing aquatic and littoral vegetation condition in the Lakes. In spring 2019, the whole of icon site condition score was 0.48, slightly lower than the expected outcome of 0.5.

We expected the condition of aquatic and littoral vegetation in the Lakes would be maintained from 2019 onwards. As of autumn 2023, the whole of icon site score was 0.67, with similar scores recorded in all surveys since 2020. These scores were higher than expected, partly due to the unanticipated return of high species richness of native aquatic and littoral plants. The abundance of native species is now comparable to the 2004–05 baseline surveys conducted before the Millennium Drought. This continued improvement in scores indicates we are on track to achieve or exceed the 2029 expected outcome of 0.53 for aquatic and littoral vegetation.

## Why are we seeing these results?

Whole of icon site scores for aquatic and littoral vegetation in the Lakes have improved substantially between spring 2010 and autumn 2023. The greatest improvement initially occurred due to the return of the Lakes to normal operating levels. Further improvements have been supported by:

- seasonal water level cycling between +0.5 m AHD and +0.85 m AHD, which provides water level variability to support growth and reproduction of aquatic and littoral vegetation
- continued maintenance of Lake levels above +0.4 m AHD, which has ensured that habitats are permanently inundated to support aquatic vegetation

Lake levels during the 2022–23 River Murray flood event exceeded 1 m AHD for the first time in over 20 years. This meant that vegetation communities at higher elevations, such as salt marsh that is not inundated at normal Lake operating levels, were inundated and likely had improved growth during this time.

Complementary management actions have also contributed to improvements in aquatic and littoral vegetation condition, including aquatic plant revegetation, wetland management actions to reinstate wetting and drying cycles and restoring flow paths to improve connectivity, along with invasive species management such as the installation of carp screens and removal of dense reeds and exotic weeds.




## What has the Basin Plan contributed?

The implementation of the Basin Plan has contributed to the continued improvement in the aquatic and littoral vegetation in the Lakes through the protection and delivery of water for the environment. Since Basin Plan adoption in 2012, lake levels have been able to be maintained above +0.4 m AHD and the delivery of water for the environment has been imperative for achieving this outcome during years of low River Murray flows and preventing lake levels from approaching sea level, particularly in autumn 2020.

## What is still to be done?

Delivery of water, including water for the environment, will continue to improve the resilience of aquatic and littoral vegetation and help to maintain whole of icon site condition scores through successive years. Addressing current water delivery constraints and the increasing recovery and delivery of water for the environment as part of full implementation of the Basin Plan will enable a more favourable water regime for the aquatic and littoral vegetation, including:

- greater flexibility in timing of water delivery, improving spring and summer flows into the Lakes
- the ability to maintain high water levels (+0.85 m AHD) in spring and into summer for extended durations
- increased confidence for water managers to lower lake water levels in autumn, knowing sufficient volumes will be available to refill the Lakes the following winter or spring.

Additional management actions, such as land management, wetland management (e.g. pumping of water to wetland sites) and direct vegetation management (e.g. weed control), are also likely to be required to improve the condition of Lakes vegetation.

## What do we expect to see in the future?

Our expected outcomes indicate that we anticipate the condition of aquatic and littoral vegetation in the Lakes to be maintained. However, since 2019, the condition of aquatic and littoral vegetation in the Lakes has substantially improved. Further progress is possible if current water management regimes and water quality conditions continue, and we are considered on track towards our 2029 expected outcome.

In the long-term, climate variability is likely to be a crucial factor influencing vegetation condition in the Lakes. Changes in climate could affect water availability and management, potentially limiting future improvements to vegetation condition, particularly without the recovery and delivery of additional water for the environment during dry years.

*The delivery of water under the Basin Plan has enabled the Lakes to operate at normal operating levels and be varied seasonally, resulting in improved condition of aquatic and littoral vegetation.*

# Expected outcome report: Vegetation

# *Ruppia tuberosa*

Trend
**Improved**

Reliability
**Very good**

**The health of Ruppia has improved, but the community is still not considered resilient and is at risk to future disturbances.**

## What are we trying to achieve:

The Long-term Environmental Watering Plan objective is to *"Restore Ruppia tuberosa colonisation and reproduction in the Coorong at a regional and local scale."*

## Why is Ruppia important?

*Ruppia tuberosa* (Ruppia) is part of a community of submerged aquatic plants which occur in the Coorong (the Ruppia community). It plays an important role in the southern Coorong where it is recognised as a key resource to the Coorong ecosystem. Submerged aquatic plants are used for food and shelter and stabilise and oxygenate sediments, which supports the life cycles of animals such as fish and waterbirds, as well as provides habitat for invertebrates and algae.

The current Ruppia community consists of three species of submerged aquatic plants: *Ruppia tuberosa*, *Ruppia megacarpa* and *Althenia cylindrocarpa*. These aquatic plants live their whole life cycle under the water and tolerate a range of salinities. In the past, other species of seagrass have been recorded in parts of the Coorong including *Zostera muelleri* but these are now absent from the system. The species of aquatic plants known to grow in the Coorong over the past 30 years are those that tolerate the very high salinities that occur each year, sometimes more than three times saltier than sea water.

## What is the trend and current status of Ruppia?

Ruppia condition and resilience is assessed using the measures of extent of distribution, area of occupancy and reproductive success. Distribution is assessed by its extent of occurrence (EOO) over its historical extent of 43 km length (Magrath Flat to Tea Tree Crossing). Area of occupation (AOO) is assessed as the proportion of sites occupied by Ruppia, with plants present in both winter and summer (Figure 19). Reproductive success is assessed using the number of seeds within the seed bank at these sites.

The EOO of Ruppia declined across the Coorong during the Millennium Drought, particularly between 2008 to 2010 when it was largely absent. Since the return of freshwater flows in 2010, AOO has improved, reaching 100% in winter since 2014 and around 90% in summer since 2017, except for a slight decline to 78% in 2019 (Figure 19).

The number of Ruppia seeds have varied across sites and years between 2007 to 2023 (Figure 20). Overall, seed numbers have improved and are currently at the highest recorded levels following the 2022–23 River Murray flood event (375±146 $m^2$). Despite improvement, seed counts remain well below the target value (2,000 $m^2$) for a resilient population, indicating the Ruppia community remains at risk to further perturbations.

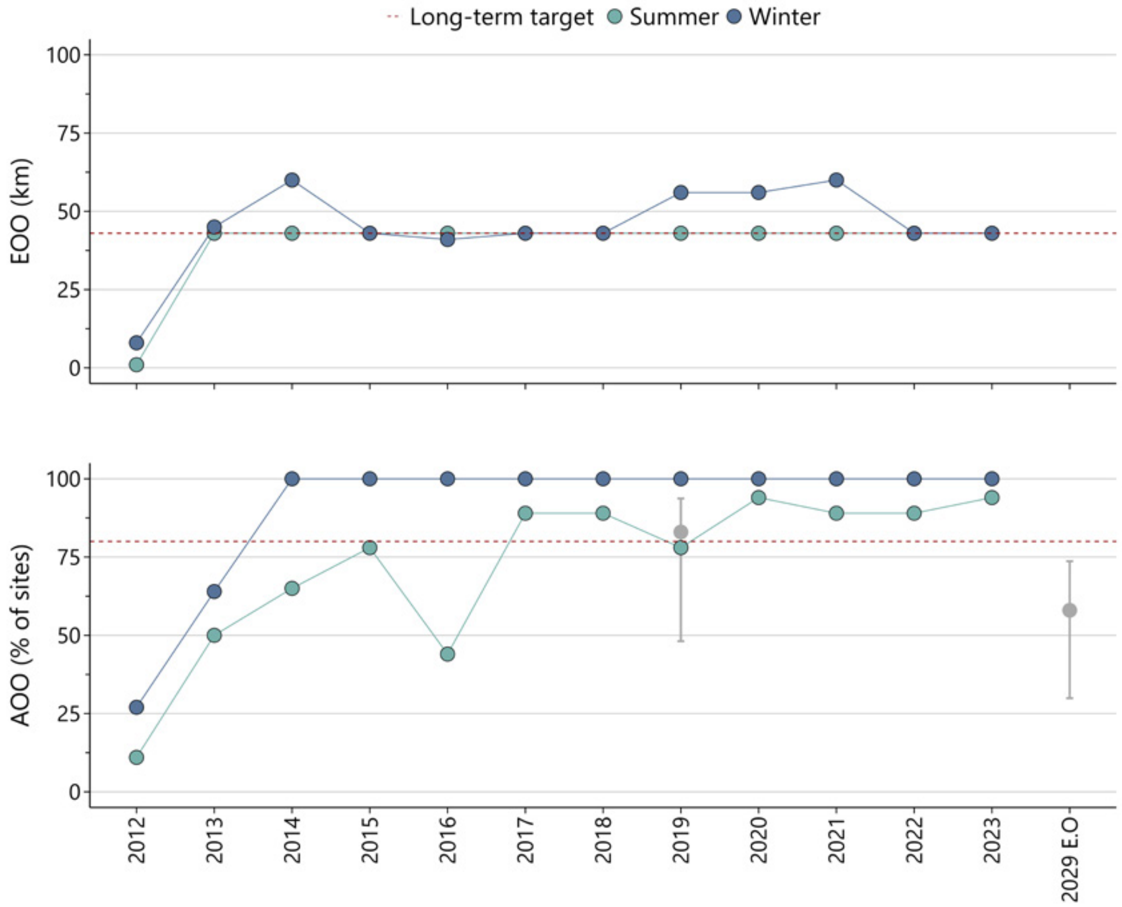



*Figure 19: The extent of occurrence (EOO) and area of occupation (AOO; percentage of sites within the 43 km EOO where live shoots are present) for R. tuberosa during January (summer) and July (winter) monitoring periods from 2012 to 2023. Grey data points at 2019 and 2029 show expected outcomes and error for AOO. Data Source: University of Adelaide, BioR.*

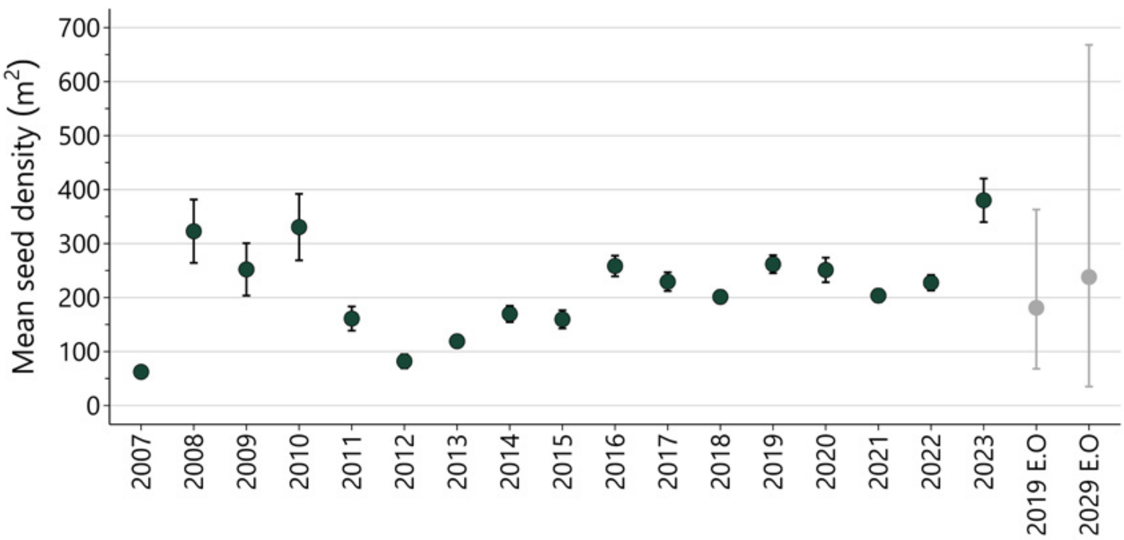



*Figure 20: The estimated mean and standard error for summer seed density (seeds/$m^2$) of R. tuberosa in the Coorong between 2007 and 2023. The expected environmental outcomes for 2019 and 2029 are plotted on the right. The long-term target is 2,000 $m^2$. Data Source: University of Adelaide, BioR.*


## Is this what we expected to see and have there been any unanticipated outcomes?

Adequate water levels in spring and into summer and salinity levels, are key drivers of the Ruppia community's condition in the Coorong.

In 2019, the EOO of Ruppia in summer and winter was ≥43 km, as expected. While Ruppia was expected to be present at 83% of sites in summer and winter, it was only found at 78% of sites in summer but was higher than expected in winter at 100% of sites. The number of Ruppia seeds in 2019 was 278 seeds/m$^2$, slightly higher than the expected 238 seeds/m$^2$.

In 2023, the extent of Ruppia was ≥43 km, as expected. The area occupied by Ruppia was 94% of sites in summer and 100% of sites in winter. This indicated we are likely on-track to achieve the 2029 expected outcome of 58% occupancy in both summer and winter. In 2023, there were 375 seeds/m$^2$. While still low, this was higher than expected and shows progress to meet the expected 238 seeds/m$^2$ by 2029.

Conditions in the Coorong can be highly variable, influenced by factors including inflows, wind, temperature, rainfall and evaporation. High (unregulated) flow conditions between 2021 and 2023 supported 26 months of unregulated flows through the barrages. These unanticipated conditions resulted in lower salinities and high summer water levels, altering the Ruppia community. Species such as *Lamprothamnium papulosum* and other aquatic plants, historically observed in the Coorong, reappeared in the North and South Lagoons.

## Why are we seeing these results?

Improved conditions from increased flows into the Coorong since the Millennium Drought have supported an increase in the distribution and abundance of the Ruppia community. Although there has been some improvement in seed counts, recovery remains slow and limited. The outcomes have been influenced by:

- water levels >0.3 m AHD have been recorded in 2016–17 and continued from 2019–20 to 2022–23, which provide conditions suitable for Ruppia reproduction
- salinity has been maintained at favourable levels for the Ruppia community (e.g. 19–124 g/L for plant growth)
- blooms of filamentous algae and phytoplankton continue to impact the Ruppia community, smothering plants, interrupting flowering and seed production and reducing light for growth
- decline in sediment condition in the southern Coorong, during and post-Millennium Drought, has reduced the optimal growing habitat for the Ruppia community and has been exacerbated by eutrophication
- complementary translocation of Ruppia into the Coorong in 2012 following the Millennium Drought has contributed to improved biomass and some improvement in the resilience of the Ruppia community.



## What has the Basin Plan contributed?

Improvements in the distribution and abundance of Ruppia is primarily due to improved flow conditions and the occurrence of high (unregulated) flows, particularly the 2022–23 River Murray flood event. Since the Basin Plan's adoption, the delivery of water to the Coorong, including water for the environment, has helped maintain higher water levels in spring and into summer while reducing salinities. This delivery of water for the environment also contributed to the export of excess nutrients and salt through increased flushing and connectivity. These favourable conditions have positively influenced the distribution and abundance of Ruppia and contributed to some improvement in its reproduction.

## What is still to be done?

To further improve the health of the Ruppia community in the Coorong and enhance its resilience, the following actions are required:

- maintain favourable water levels between September and January to keep water depths suitable for the survival of Ruppia and ensure salinity is adequate for successful reproduction
- maintain water levels in the Coorong South Lagoon above 0.3 m AHD in spring and into summer to support growth and reproduction of Ruppia
- ensure variable salinity conditions while remaining within the ranges required to support Ruppia reproduction
- strategically deliver water at the tail end of high flow events to extend more favourable conditions in the southern Coorong, supporting Ruppia growth and reproduction.

Full implementation of the Basin Plan, including recovery and delivery of the 450 GL of additional water for the environment and addressing current water delivery constraints, is essential to provide sufficient water volumes to support Ruppia, particularly during early spring and into summer.

While outside of current management influence, more frequent high (unregulated) flow events are crucial for improving the health of the Ruppia community in the southern Coorong. The *Healthy Coorong, Healthy Basin* program is also seeking to implement a range of restoration actions aimed at recovering ecological function and resilience in the Coorong. These include fostering extensive and resilient aquatic plants and removing filamentous algae.

## What do we expect to see in the future?

Continued improvements in Ruppia distribution, abundance and seed counts in the Coorong will be strongly influenced by climate conditions affecting water availability, levels and quality. The current low numbers of seeds and turions (representing sexual and asexual reproduction) indicate the resilience of the Ruppia community is low due to the slow recovery since the Millennium Drought. This low resilience suggests the population is likely more vulnerable to future disturbances to the system, such as further prolonged drought conditions.

# Case study: Nutrient dynamics and algal blooms in the southern Coorong

## Nutrient accumulation

Nutrients enter the Coorong from multiple water sources, including the River Murray and Southern Ocean via the North Lagoon. As with salinity, nutrients generally increase southward with distance from the Murray Mouth. Salt Creek is a minor (<1%) contributor to nutrients in the South Lagoon.

These nutrients are absorbed into the Coorong's ecosystem through interactions between water, sediment, microbes, plants and animals.

Over the past decades, the Coorong has been in a persistently hyper-eutrophic (high nutrients and organic matter/algae) state. Nutrients remain in the South Lagoon due to insufficient 'flushing' to the North Lagoon and ocean via the Murray Mouth. Narrow constrictions and expansive shallow areas between the Coorong North and South Lagoon reduce connectivity and flow, allowing excess nutrients to accumulate in the South Lagoon (Figure 21).

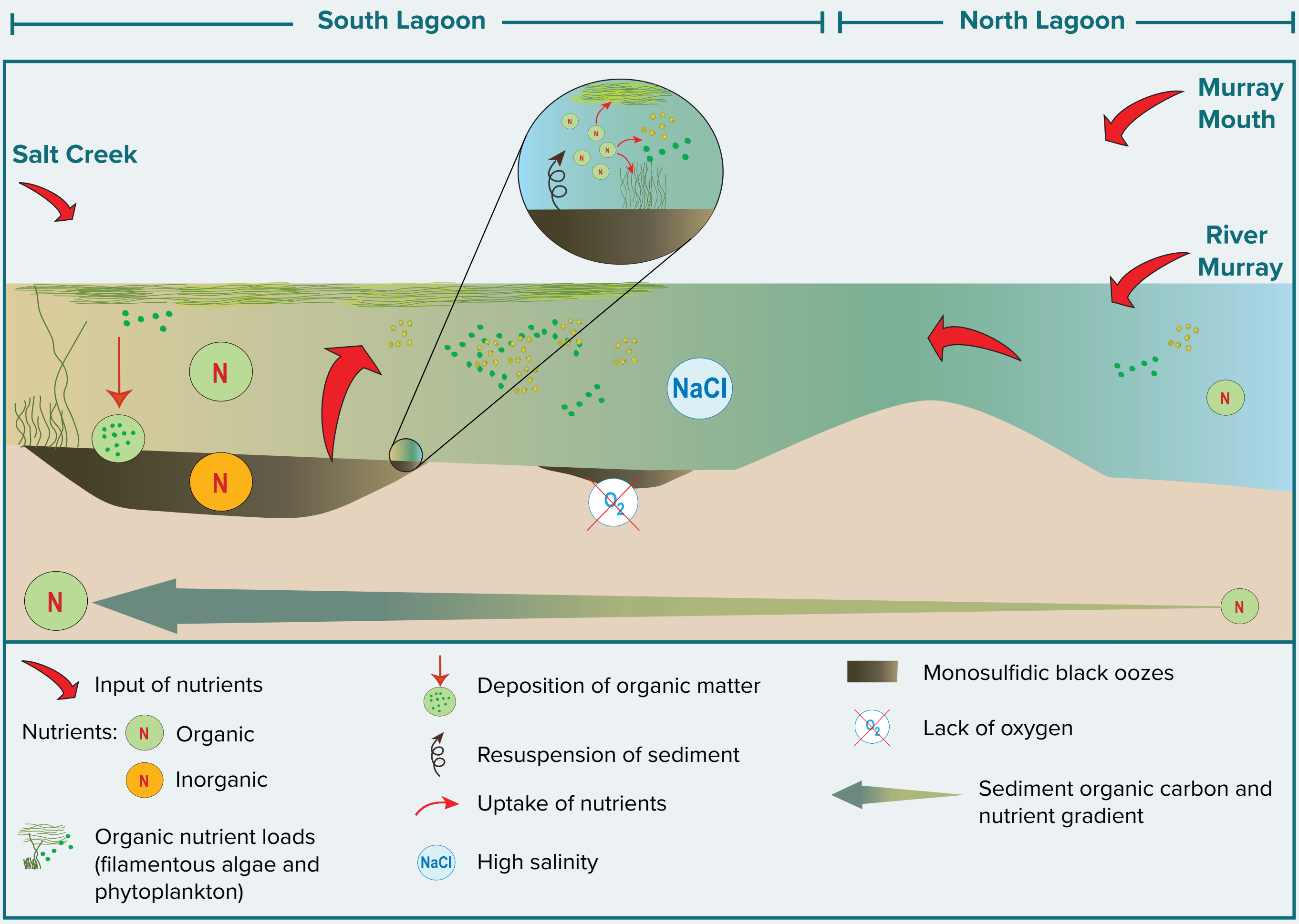



*Figure 21: Nutrient sources and cycling in the southern Coorong. Data Source: DEW.*

## Problems of excess nutrients

Excess nutrients accumulate and promote the growth of phytoplankton and filamentous algae. Filamentous algae blooms form widespread surface mats that interfere with the ability of the aquatic plant community (dominated by *Ruppia tuberosa)* to grow and produce seed and limit waterbird foraging habitat (Figure 22).

Phytoplankton blooms increase the turbidity of the water, reducing the light available to aquatic plants and limiting their distribution to shallow waters. The breakdown of phytoplankton and filamentous algae blooms results in increased nutrient loads in both the water column and sediment. These loads are then decomposed by bacteria to create oxygen-poor, sulfide rich sediments. These sediments dominate the southern Coorong and have created unhealthy nutrient cycling, leading to an accumulation of nitrogen and phosphorus in the water and sediment. The top 5 cm of sediment contains up to 50 times more nutrients compared to the water column.

The accumulation of nutrients in the sediment has also led to the formation and build-up of black, organic and sulfide-rich sediments called 'monosulfidic black oozes (MBOs)'. They have formed over large areas of the southern Coorong under low oxygen sediment conditions and are toxic to macroinvertebrates and aquatic plants. Aquatic plants and macroinvertebrates (e.g. worms and bivalves) can help to oxygenate sediment, but because they cannot inhabit MBOs, the impacts to the nutrient cycle are further fuelled by their absence.

## Current status and what is still to be done

Recent high flow and flood conditions have had a positive effect on the water quality in the Coorong, with increased flows enabling nutrients to be flushed out and salinity reduced. This has supported the aquatic plant community and macroinvertebrates to increase their distribution and abundance, in turn helping to improve nutrient cycling and sediment condition. While these have been short-term improvements, the ongoing export of nutrients is needed and requires increased connectivity and flushing, along with efforts to restore the aquatic plant and macroinvertebrate communities. Full implementation of the Basin Plan, including the recovery and delivery of the additional 450 GL of water for the environment, addressing current water delivery constraints and restoration actions, will contribute to improved nutrient conditions in the Coorong, particularly the southern Coorong.

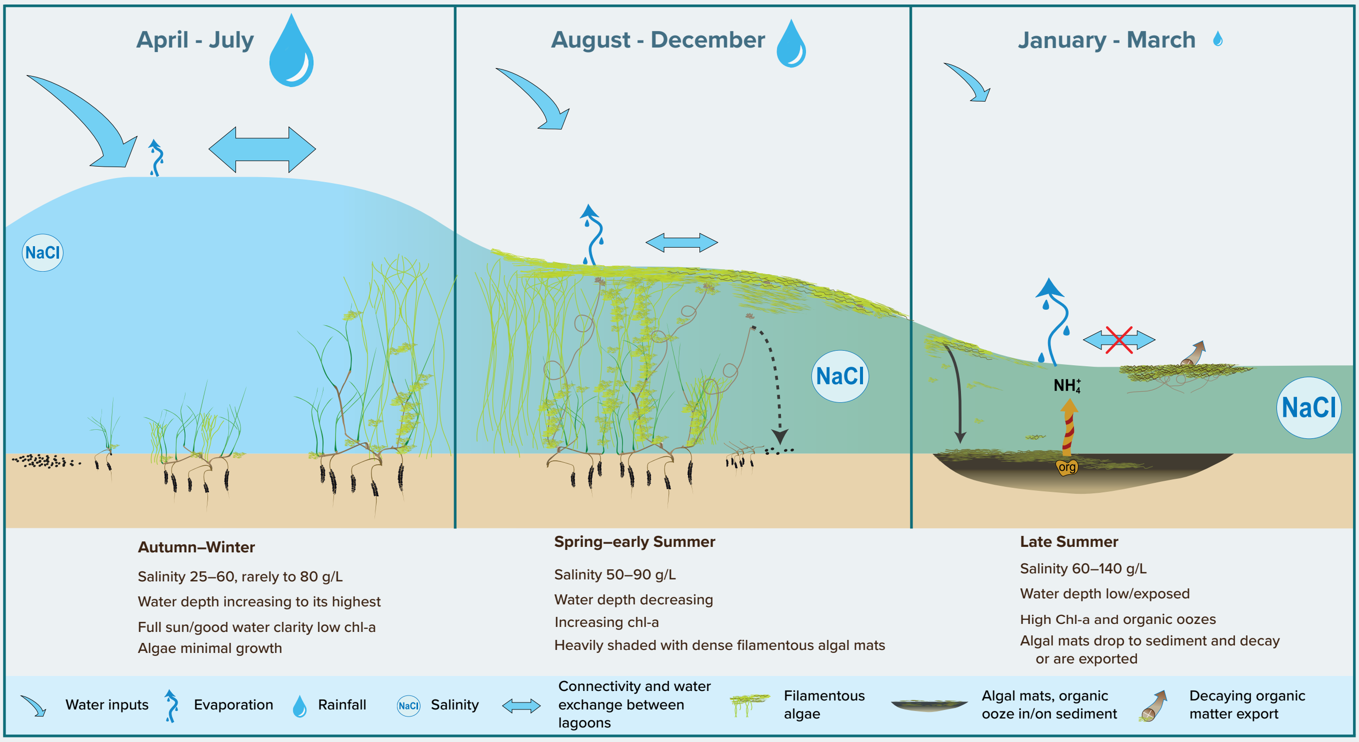



*Figure 22: Typical seasonal water conditions, aquatic plant growth and filamentous algae lifecycle in the southern Coorong. Data Source: DEW.*

## Expected outcome report: Fish

# Black bream and greenback flounder

Trend
**Improved**

Reliability
**Excellent**

**Black bream and greenback flounder population condition have improved, reflecting more resilient populations.**

### What are we trying to achieve:

The Long-term Environmental Watering Plan objective is to *"Maintain a spatio-temporally diverse fish community and resilient populations of key native fish species in the Lower Lakes and Coorong."*

### Why are black bream and greenback flounder important?

Black bream (*Acanthopagrus butcheri*) and greenback flounder (*Rhombolea tapirina*) are two fish species that inhabit estuarine habitats of the Coorong and Murray Estuary and adjacent coastal waters. They are important commercial, recreational and cultural fish species and are food sources for a variety of fish-eating birds, including cormorants and pelicans. The provision of suitable flow and habitat conditions and the availability of key food resources is vital for supporting the overall population condition and recruitment of both species.

### What is the trend and current status of black bream and greenback flounder?

The population condition of black bream and greenback flounder is assessed through an overall population score that combines abundance, distribution, recruitment and age structure. Scores of 1 and 2 indicate very poor and poor condition, a score of 3 indicates moderate condition, while a score of 4 indicates good condition.

In 2010, following the Millennium Drought, both species had poor population conditions. However, since the return of freshwater flows in 2010–11, their overall population conditions have improved, though variability exists between species and over time, influenced by the timing and volume of barrage flows (Figure 23 and Figure 24).

Black bream took longer to recover after the 2010–11 flows. Higher flows in 2016–17 and favourable salt wedge conditions (i.e. an area where freshwater sits above seawater) before spawning improved their condition in 2017–18. However, lower flows in 2018–19 reduced their condition to very poor. Since then, black bream condition has generally improved to moderate levels, reaching good condition in 2021–22 with a strong recruitment event observed.

In contrast, greenback flounder showed rapid recovery after the 2010–11 freshwater flows and increased delivery of water for the environment. Their condition scores declined during drier periods with reduced water availability and barrage flows but have improved from poor in 2019–20 to good condition in 2020–21 and 2021–22 and moderate condition in 2022–23.

*There continues to be improvement in black bream and greenback flounder populations and they are currently in good condition.*

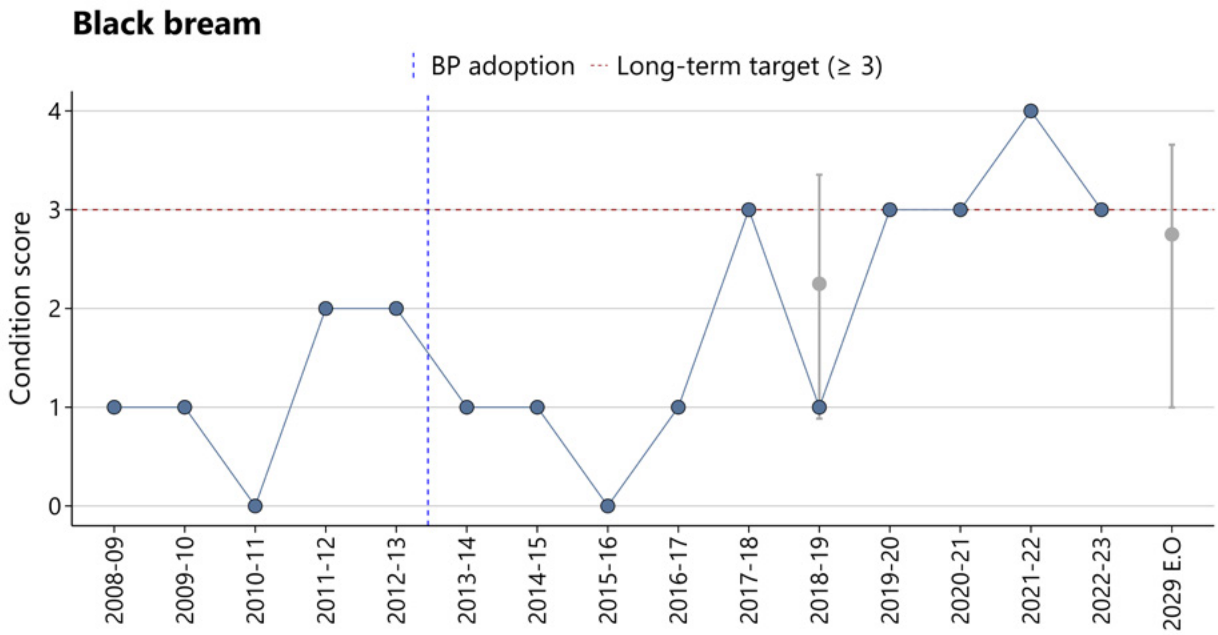




*Figure 23: Black bream population condition assessment scores from 2008–09 to 2022–23, including expected outcomes for 2019 and 2029 (±80% confidence interval) shown in grey. Data Source: SARDI.*

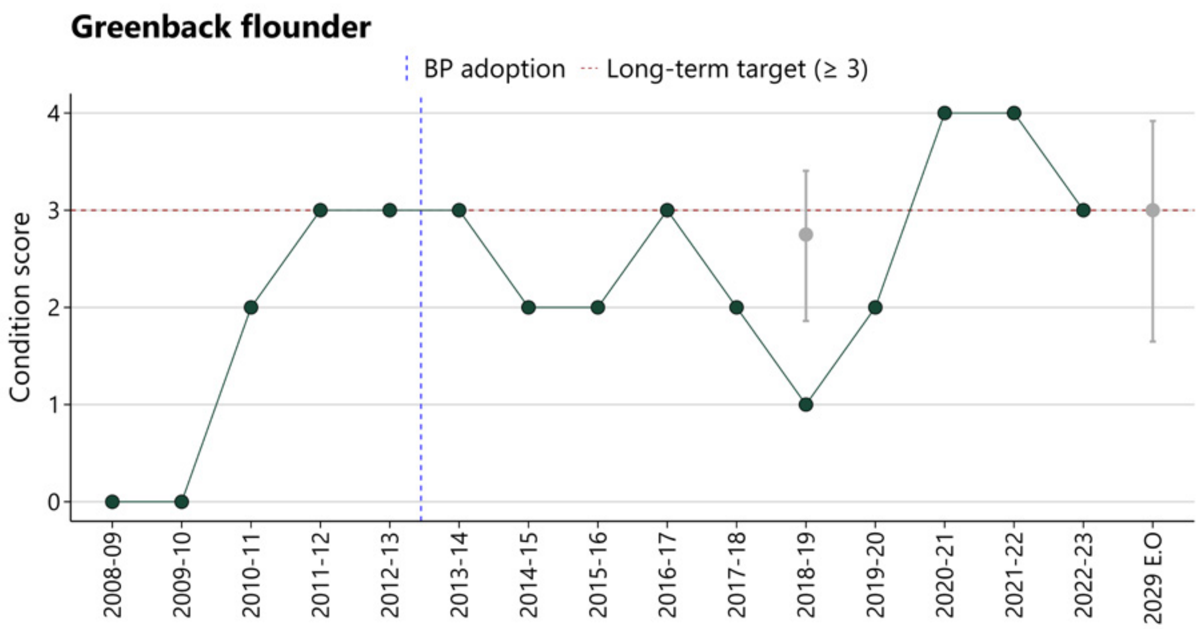



*Figure 24: Greenback flounder population condition assessment scores from 2008–09 to 2022–23, including expected outcomes for 2019 and 2029 (±80% confidence interval) shown in grey. Data Source: SARDI*





## Is this what we expected to see and have there been any unanticipated outcomes?

Black bream and greenback flounder populations are influenced by hydrological conditions, particularly barrage flows and salinity conditions in the Murray Estuary and Coorong. In 2019, we expected a population score of 2.25 for black bream and 2.75 for greenback flounder. However, both species recorded scores of 1, which was lower than we expected.

As of 2022–23, the population condition scores for both species have improved to 3, a significant increase from 2019. These scores have been maintained for the last three years.

A strong recruitment event for black bream in 2021–22 contributed to the highest recorded population condition score (Figure 23). This event was unanticipated, as high-flow years typically result in lower or delayed recruitment. Conversely, while we expected the greenback flounder population to maintain good condition in 2022–23 following high flow conditions, we observed lower than anticipated detection of (YOY) fish, likely due to the seasonally high-water levels in the Coorong.

## Why are we seeing these results?

The improvement in black bream and greenback flounder populations has been supported by the volume and timing of freshwater barrage flows, the delivery of water for the environment, favourable salinity conditions and the maintenance of an open Murray Mouth, primarily through dredging.

Recent high (unregulated) flow conditions have increased barrage flows and reducing salinity in the Coorong. These favourable conditions have increased the extent of suitable habitats and food resources and distribution of both species in the Coorong.

Low to moderate flow conditions before and during the black bream spawning season (e.g. spring-summer in 2017–18 and 2021–22) have created salt wedge habitats that support strong recruitment. Additionally, temporary fishery management measures implemented since 2018–19, including seasonal closures during black bream reproductive period, have helped protect spawning biomass and maximise the survival of new recruits.

Maintaining an open Murray Mouth, primarily through dredging, has also provided opportunities for recruitment in some years.



## What has the Basin Plan contributed?

Implementation of the Basin Plan, particularly the delivery of water for the environment, has enabled actions that significantly improved the population conditions of black bream and greenback flounder in the Murray Estuary and Coorong. Specifically, the management of barrage flows, facilitated by the Basin Plan, has contributed to:

- low to moderate barrage flows (~600–24,000 ML/day), at strategic times and volumes of flow to support the recruitment of both species
- water for the environment, particularly in low-flow years, enabled the establishment of salt wedge habitats, enhancing black bream recruitment and providing cues for larval and juvenile greenback flounder in marine environments to locate nursery habitats in the Murray Estuary and Coorong
- improved system connectivity and increased extents of favourable habitat (e.g. estuarine salinity conditions) to support adult fish from both species.

The delivery of water for the environment has provided cumulative benefits across years and has been critical for maintaining connectivity and increasing the extent of suitable habitats, supporting successful recruitment for both species.

## What is still to be done?

Ongoing actions to support the future conditions of black bream and greenback flounder include:

- increasing the recovery and delivery of water for the environment to enhance barrage flows during drier periods
- continuously optimising of the delivery of water for the environment and barrage flow management to maintain and enhance estuarine habitat conditions that favour the recruitment of both species
- maintaining an open Murray Mouth to ensure system connectivity (e.g. fish passage between estuarine and marine habitats) and favourable salinity conditions
- implementing ongoing fishery management, including measures to protect spawning biomass and maximise the survival of new recruits, to rebuild population abundance and resilience in the Murray Estuary and Coorong.

While outside of current management influence, regular high (unregulated) flow events are essential for maintaining suitable habitat conditions in the Murray Estuary and Coorong, particularly following low-flow years. These events also enhance the productivity of the system, supporting increased numbers and distribution of both species.

## What do we expect to see in the future?

With the full implementation of the Basin Plan, we anticipate continued promotion of connectivity and favourable habitat conditions. Coupled with effective fisheries management, the population conditions of black bream and greenback flounder is expected to be maintained or improved.

Full implementation of the Basin Plan, particularly the recovery and delivery of the 450 GL of additional water for the environment and addressing current water delivery constraints, will ensure that water is able to be delivered to the Murray Estuary and Coorong during critical times (i.e. spring-summer) to support recruitment and resilience of the population condition of both species.

*Delivery of water for the environment is critical to supporting the resilience of these fish species now and into the future.*

Expected outcome report: Fish

# Diadromous fish

Trend
**Improved**

Reliability
**Good**

**Improved connectivity between freshwater, estuarine and marine habitats has supported increased recruitment of diadromous fish.**

## What are we trying to achieve:

The Long-term Environmental Watering Plan objective is to *"Promote the successful migration and recruitment of diadromous fish species in the Lower Lakes and Coorong."*

## Why are diadromous fish important?

The CLLMM is the only site in the Murray–Darling Basin where freshwater, estuarine and marine environments meet. This connectivity is vital for providing habitat and migratory pathways for diadromous fish, influencing their population dynamics. Consequently, diadromous fish recruitment provides a good indication of system connectivity.

This evaluation has assessed two diadromous fish species: congolli (*Pseudaphritis urvillii*) and common galaxias (*Galaxias maculatus*). Each represent distinct movement and life-cycle habitat requirements.

## What is the trend and current status of diadromous fish?

The diadromous fish recruitment index measures the rate of upstream migration for fish less than one year old (YOY). The LTWP sets target values of 44.5 YOY/hour for congolli and 6.1 YOY/hour for common galaxias.

Since the adoption of the Basin Plan in 2012 and the return of freshwater barrage flows after the Millennium Drought in 2010–11, diadromous fish recruitment has improved. Before this, recruitment scores for both species were low (Figure 25) due to barrage closures from late 2006 through to September 2010. Since 2013–14, congolli recruitment index values have generally exceeded the target values, though with significant annual variation. Values peaked at 395.4 in 2014–15, ranging between 177 and 134 from 2015–16 to 2020–21. In recent years, values dropped to 46.4 in 2021–22 and 2.7 in 2022–23.

Common galaxias recruitment index values also exceeded the target values in most years since 2013–14, with considerable annual variation. From 2013–14 to 2015–16, values ranged from 11.6 to 29.4, but fell to 2.2 in 2016–17. This decrease was likely due to peak migration occurring in January, while the index includes October to December. From 2016–17 to 2020–21, recruitment values increased but dropped again during the high (unregulated) flow events in 2021–22 and 2022–23.

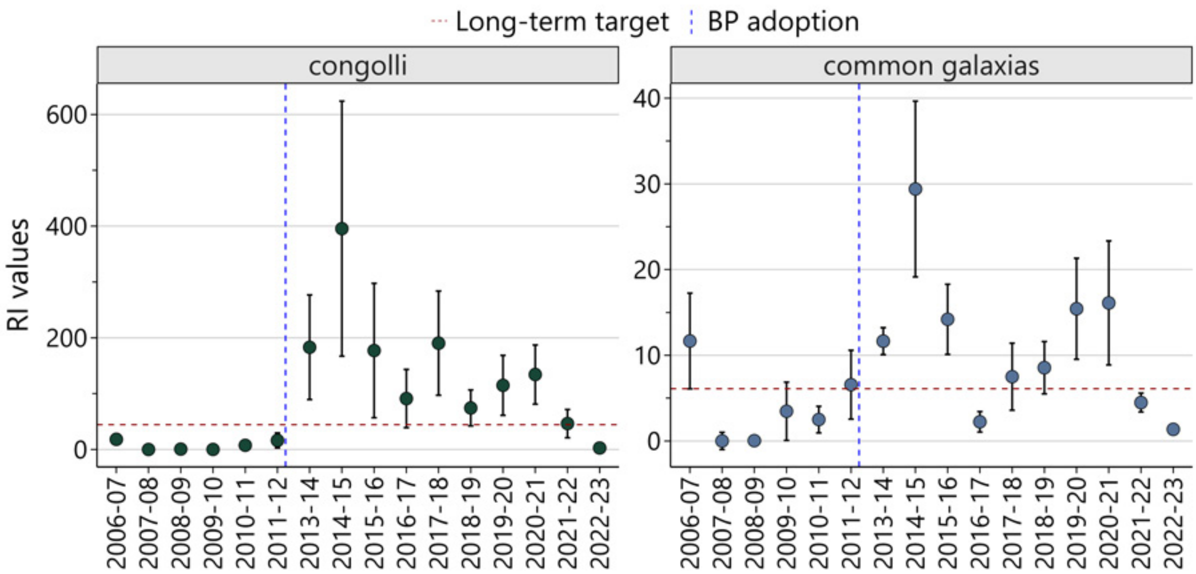




*Figure 25: Annual recruitment index (RI) value, measuring the number of upstream migrating YOY/h congolli and common galaxias from 2006–07 to 2022–23. Basin Plan adoption (2012) is shown as a vertical dashed blue line and the Long-term Watering Plan target is shown as a horizontal dashed red line. NB: no monitoring was conducted in 2012–13. Data Source: SARDI.*

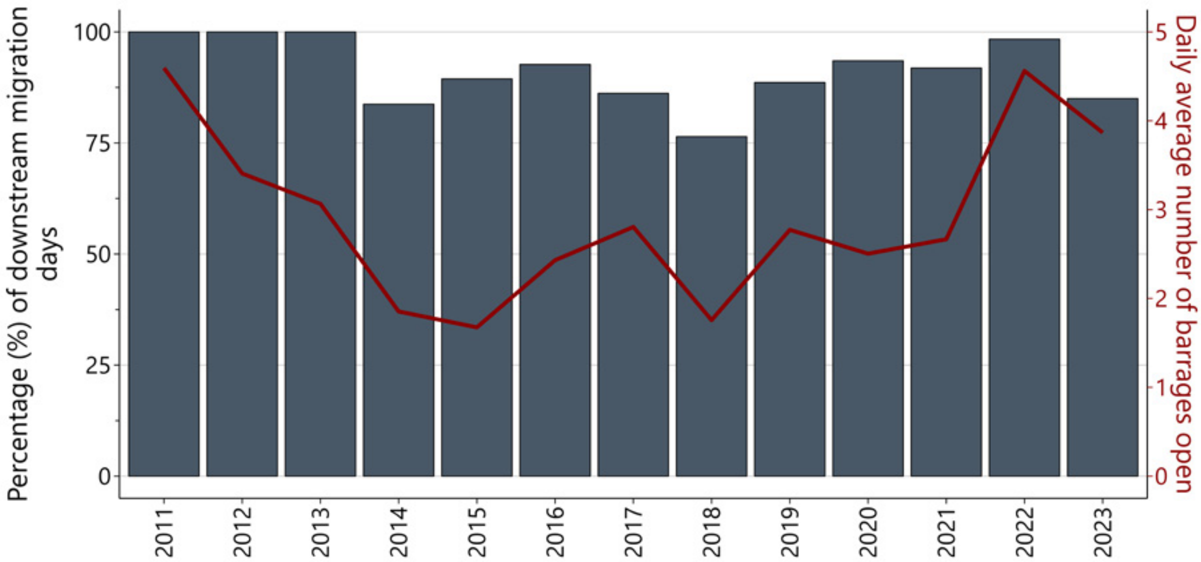



*Figure 26: The proportion of downstream migration days (May to August) per year with at least one gate open on any barrage which have open fishways on any barrage (grey bars) and the daily mean number of networks barrages (barrages) open during those same months (red line). Note: this graph excludes operational fishway data. Data Source: DEW.*





## Is this what we expected to see and have there been any unanticipated outcomes?

Freshwater flows and system connectivity are critical for the movement and recruitment of diadromous fish in the CLLMM.

In 2019, we expected to meet the target recruitment index values in all years (100%) for congolli and 6 of 7 years (86%) for common galaxias, following Basin Plan adoption in 2012. As of 2022–23, congolli met or exceeded target values in 9 of the 10 years and common galaxias in 7 years. This indicates we are likely on-track to achieve the 2029 expected recruitment index values for both species; 15 of 17 years for congolli and 14 of 17 years for common galaxias.

High (unregulated) flow events in 2016–17, 2021–22 and 2022–23 were expected to support strong recruitment. However, recruitment was unexpectedly low in these years, particularly in 2021–22 and 2022–23. This may be due to YOY fish bypassing fishways and moving through open barrage gates, alongside changes in water quality that reduced cues for movement and recruitment. These factors likely contributed to decreased detection rates of young fish.

## Why are we seeing these results?

Improvements in diadromous fish recruitment have been supported by the volume and timing of freshwater barrage flows, salinity conditions and an open Murray Mouth (primarily through dredging).

The Millennium Drought reduced flows and connectivity ceased between 2006 and 2010, leading to negligible recruitment and diminished populations of reproductively mature adults. With the return of freshwater flows in late 2010, connectivity was re-established through barrage gates and fishways.

Since the return of flows and adoption of the Basin Plan, continued delivery of water has allowed barrage gates to remain open in winter and operable fishways in spring-summer, enhancing recruitment. However, the abundance of juveniles was likely limited by low mature adult populations until 2014–15.

From 2014–15 to 2020–21, juvenile congolli and common galaxias abundance correlated with the number of days at least one barrage gate was open in winter to support spawning migrations. In 2021–22 and 2022–23, high (unregulated) flows from the River Murray resulted in increased connectivity between the river and Murray Estuary. However, recruitment did not improve, likely because higher water levels allowed fish to bypass fishway sampling, altered access to sampling sites, or reduced attractant flows for diadromous fish movement. Dredging the Murray Mouth has supported congolli recruitment by enabling females to complete their downstream migration for spawning in the Southern Ocean.

© SARDI

## What has the Basin Plan contributed?

The implementation of the Basin Plan, particularly the recovery and delivery of water for the environment, has enabled actions that have improved diadromous fish recruitment in the Murray Estuary and Coorong. Specifically, the management of barrage flows, facilitated by the Basin Plan, has contributed to:

- improving system connectivity via open barrage gates and fishways throughout the year but particularly in winter
- increasing water volumes reaching the Coorong in spring and summer, supported by fishway operations
- providing winter flow pulses in the SA River Murray that likely facilitated diadromous fish movement and recruitment after low flow periods during winter months (e.g. in 2015, 2017, 2018 and 2019).

## What is still to be done?

Maintaining connectivity between freshwater, marine and estuarine environments within the CLLMM is vital for future diadromous fish movement and recruitment. Continued delivery of freshwater flows through open barrage gates and fishways during critical periods, along with an open Murray Mouth, will support connectivity.

Full implementation of the Basin Plan, particularly the recovery and delivery of the 450 GL of additional water for the environment and addressing current water delivery constraints, will ensure that water is able to be delivered to the Murray Estuary and Coorong during critical times to support diadromous fish movement and recruitment across the system. There is potential to further promote upstream movement of congolli and common galaxias by opening barrage gates when water levels in Lake Alexandrina and the Murray Estuary are similar and the risk of saltwater ingression is low.

## What do we expect to see in the future?

With full implementation of the Basin Plan and continued delivery of water for the environment, we expect the levels of recruitment of congolli and common galaxias to be maintained. Future improvements in diadromous fish recruitment will be influenced by the availability of water during spring and summer, which will be influenced by climate variability over the longer-term.

## Expected outcome report: Fish

# Small-mouthed hardyhead

Trend
**Improved**

Reliability
**Very good**

**Small-mouthed hardyhead populations have improved, reflecting improved resilience with an increased abundance of juvenile fish.**

### What are we trying to achieve:

The Long-term Environmental Watering Plan objective is to *"Maintain a spatiotemporally diverse fish community and resilient populations of key native fish species in the Lower Lakes and Coorong."*

Resilient small-mouthed hardyhead populations are defined as abundant and broadly distributed populations with annual recruitment success.

### Why are small-mouthed hardyhead important?

Small-mouthed hardyhead are a small-bodied native fish species that are a critical part of the Coorong food web. As small-mouthed hardyhead are a salt-tolerant species and can tolerate hypersaline environments, they are particularly abundant in the Coorong South Lagoon. They are an important food source for fish-eating birds (piscivores) and predatory fish. Maintaining or improving small-mouthed hardyhead abundance and distribution is an important part of managing the health of the Coorong.

### What is the trend and current status of small-mouthed hardyhead?

Small-mouthed hardyhead recruitment is assessed by determining the proportion of juvenile to adult fish numbers within the overall population. A value of greater than 60% of juveniles each year represents significant recruitment. The target for this species aims for this to be maintained at a minimum of 75% of monitoring sites.

The percentage of sites with significant recruitment of small-mouthed hardyhead has increased following the end of the Millennium Drought and the return of freshwater flows in 2010–11 (Figure 27). Between 2010–11 and 2019–20, the number of sites meeting the target proportion of juveniles increased to between 88 to 100% during or following years of medium to higher flows. However, during or following lower flow years, there was a reduction in the percentage of sites (e.g. 2014–15 to 2015–16 and 2019–20). Since 2020–21, the percentage of sites with strong recruitment has been steady at around the target percentage of 75%.


© SARDI

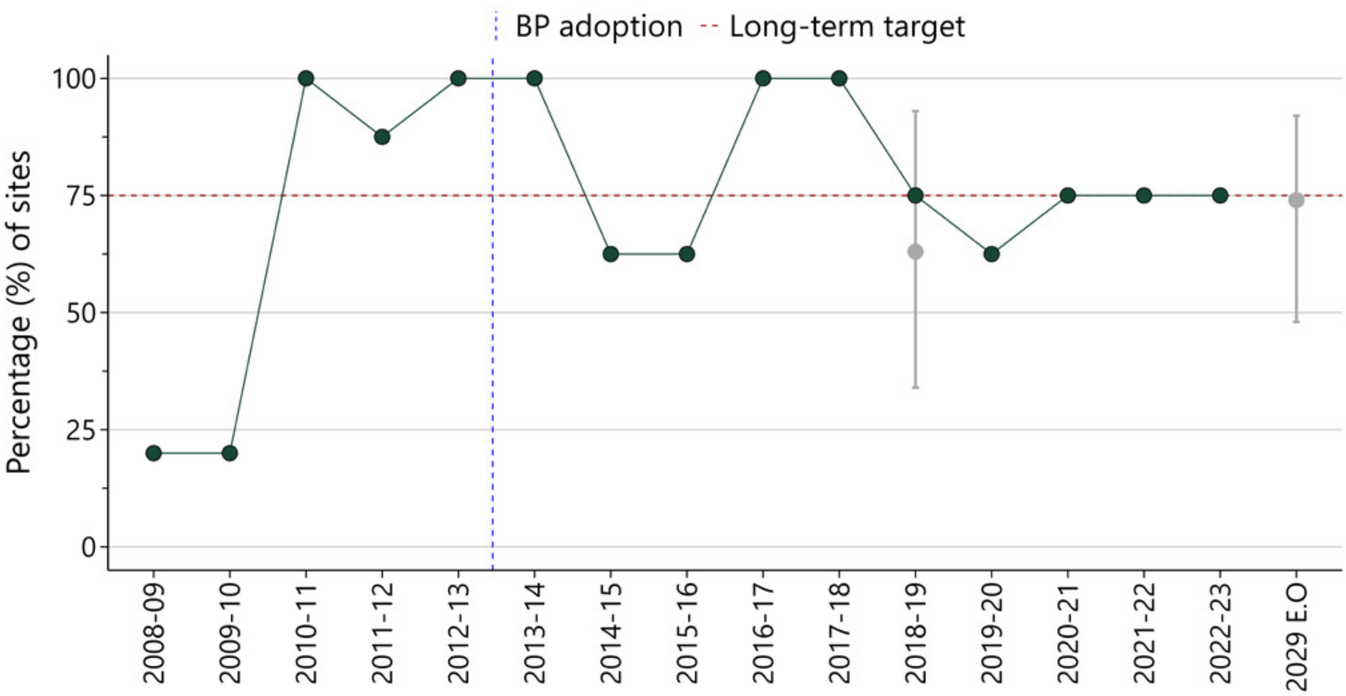



*Figure 27: Percentage of monitoring sites with significant recruitment (>60% juvenile fish) of small-mouthed hardyhead (with expected outcomes for 2019 and 2029 ± 80% confidence limits represented by greyed out points) from 2008–09 to 2022–23. The red-dashed horizontal line represents the target of recruitment at 75% of sites, the blue-dashed vertical line represents adoption of the Basin Plan. Data Source: SARDI.*

© SARDI

## Is this what we expected to see and have there been any unanticipated outcomes?

The condition of small-mouthed hardyhead populations in the Coorong and Murray Estuary is strongly influenced by freshwater flows, which affects salinity, productivity and habitat availability. In 2019, the percentage of sites with strong recruitment was better than expected, at 75% of sites (expected 63%). Currently 75% of sites have strong recruitment and this indicates that we are likely on-track to achieve the 2029 expected percentage of sites with strong small-mouthed hardyhead recruitment (expected 74% of sites).

The lack of significant recruitment (>75% sites) of small-mouthed hardyhead in 2021–22 and 2022–23 was unanticipated. Like previous high (unregulated) flows (e.g. 2010–11 and 2016–17) we would have expected the percentage of sites to be greater, but this could have been caused by reduced catchability of recent recruits and/or the high flows increased fish growth rates and underestimated the abundance of YOY (i.e. those <40 mm total length).

## Why are we seeing these results?

The volume and timing of freshwater barrage flows, including the delivery of water for the environment, favourable salinity conditions and an open Murray Mouth (primarily through dredging) have contributed to improvements in the population of small mouthed hardyhead.

The Millennium Drought reduced flows and connectivity ceased between 2006 and 2010. This led to salinities exceeding the species' preferred range across much of the Coorong, particularly the South Lagoon. The return of freshwater flows in 2010–11 and the delivery of water for the environment have since reduced salinity and boosted productivity, providing favourable conditions for small-mouthed hardyhead. Several high (unregulated) flow events further increased recruitment, distribution and abundances, leading to improved population condition.

Maintaining an open Murray Mouth has been crucial for flushing excess nutrients and salt, ensuring suitable habitat conditions for small-mouthed hardyhead.

## What has the Basin Plan contributed?

Implementation of the Basin Plan, particularly the recovery and delivery of water for the environment, has enabled actions to support small-mouthed hardyhead populations in the Coorong. Specifically, the management of barrage flows through the delivery of water for the environment has contributed to:

- increasing the extent of favourable salinity conditions that support small-mouthed hardyhead
- enhancing barrage flows, particularly in low-flow years, which has been vital for majority of flow volumes and maintaining system connectivity and keeping salinity below 100 g/L (the species' upper threshold) in the South Lagoon
- targeting water delivery (including at Salt Creek) to increase the spatial and temporal extent of favourable salinity conditions, leading to increased habitat availability and a broader distribution of small-mouthed hardyhead in the Coorong.

© SARDI

## What is still to be done?

Ongoing actions to maintain and improve the resilience of small-mouthed hardyhead populations into the future include:

- managing barrage flows and other inflows into the southern Coorong to maintain the extent of suitable habitat conditions
- maintaining an open Murray Mouth to enhance system connectivity, productivity and salinity conditions that support small-mouthed hardyhead recruitment.

Full implementation of the Basin Plan, particularly the recovery and delivery of the 450 GL of additional water for the environment and addressing current water delivery constraints, will ensure that water is able to be delivered to the Murray Estuary and Coorong during critical times to support small-mouthed hardyhead populations.

While outside of current management influence, regular high (unregulated) flow events are essential for maintaining suitable habitat conditions in the Murray Estuary and Coorong, particularly following low-flow years. These events also enhance the productivity of the system, supporting the increased distribution, abundances and recruitment of small-mouthed hardyhead.

## What do we expect to see in the future?

With the full implementation of the Basin Plan, we anticipate benefits to small-mouthed hardyhead populations in the Coorong, in particular through the recovery and delivery of the additional water for the environment. Future improvements in small-mouthed hardyhead will rely on water availability, which is affected by climate variability. Adequate water for the environment and adaptive management of water will be essential for their continued recovery.

*Delivery of water for the environment and high flow conditions have supported small-mouthed hardyhead populations.*

## Expected outcome report: Waterbirds

# Lakes Waterbirds

Trend
**Improved**

Reliability
**Very good**

**Abundances of Lakes waterbirds have improved, but with variability across the different waterbird guilds.**

## What are we trying to achieve?

The Long-term Environmental Watering Plan objective is to *"Maintain or improve waterbird populations in the Coorong and Lower Lakes."*

## Why are Lakes waterbirds important?

The Lakes are part of the Coorong and Lakes Alexandrina and Albert Wetland, a Ramsar wetland of international importance. They support nationally and internationally threatened species and those listed under migratory agreements. The Lakes provide crucial feeding and breeding habitats, particularly during dry years when permanent wetlands serve as refuge.

Waterbirds are highly sensitive to changes in habitat quality and food availability, making them key indicators of ecosystem health. Many species are also culturally and recreationally significant.

## What is the trend and current status of waterbirds?

Waterbirds are grouped into 'guilds' based on diet, feeding behaviour and life history. In the Lakes, ten species of waterbirds from three guilds – generalists, herbivores and piscivores – have been assessed (Figure 28). Their condition is assessed by the proportion of species in each guild that met or exceeded their median abundance target (2013–2015) in two of the last three years. A value of 1 indicates all species in the guild exceeded their target.

Waterbird abundance has varied by guild and year (Figure 28). The overall abundance of generalists and herbivores has improved between 2011 and 2023, while the abundance of piscivores are stable.

Prior to Basin Plan adoption, low freshwater inflows during the Millennium Drought caused water levels in Lake Alexandrina to drop to -1.1 m AHD and salinity rose above 6,000 EC. This resulted in few generalist and herbivore species and no piscivore species, exceeding their abundance targets (Figure 28). From 2013 to 2019, increased freshwater inflows and the delivery of water for the environment improved generalist and herbivore populations. However, piscivores improved between 2013 and 2016 but declined again. Since 2019, fewer generalist and herbivore species have met abundance targets and no piscivore species met their target in 2022 or 2023.

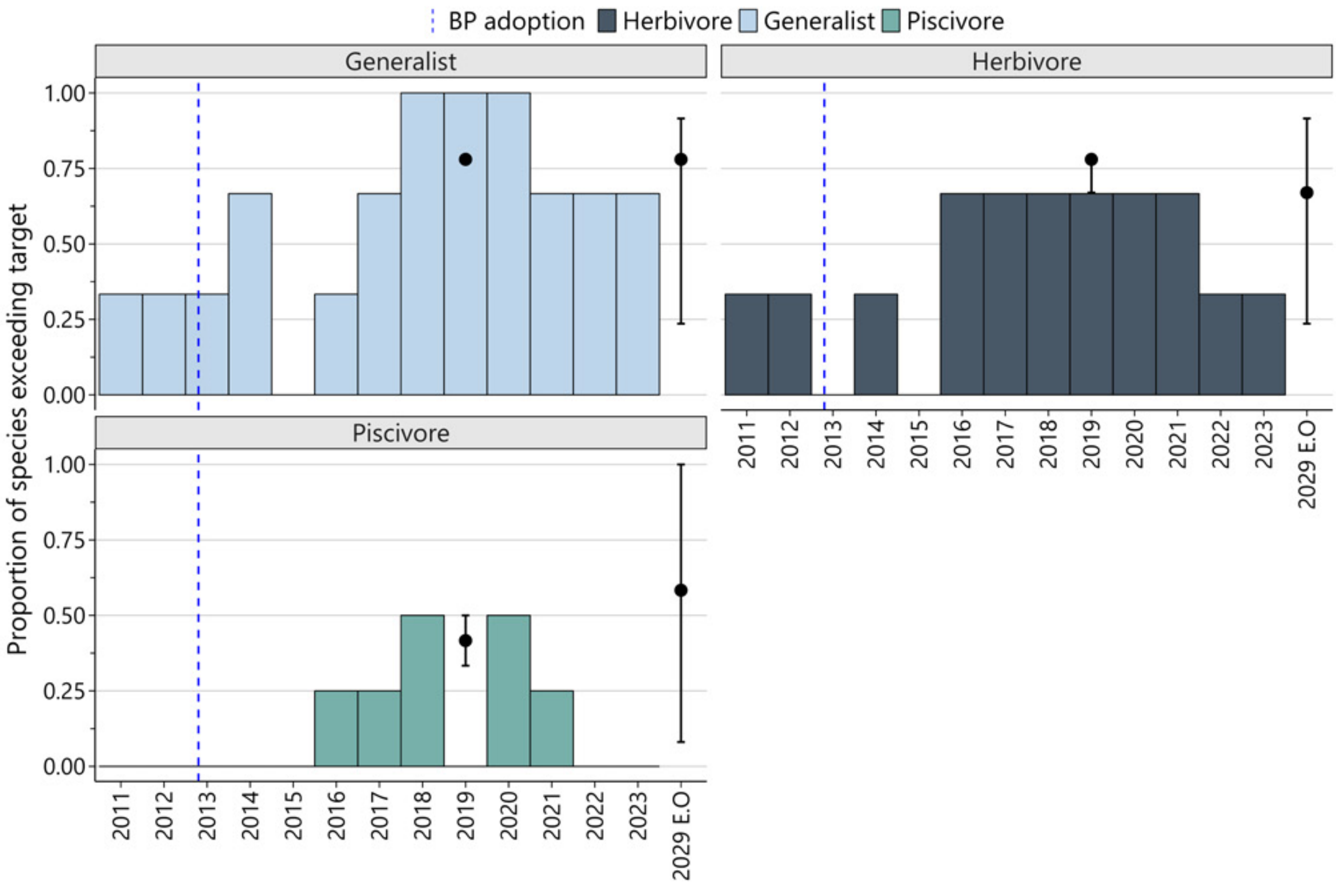




*Figure 28: The proportion of selected Lakes waterbird species within each guild that were at or above their recent (2013–2015) median abundance in two of the last three years, between 2011–2023. Basin Plan adoption (November 2012) is shown by the vertical dashed blue line. The black dots and associated error bar represents the 2019 and 2029 expected outcomes for Lakes waterbird abundance. Zero proportion means zero species have met their median abundance target. Data Source: University of Adelaide.*


## Is this what we expected to see and have there been any unanticipated outcomes?

The availability and quality of waterbird habitat in the Lakes is driven by freshwater inflows, water levels and salinity. In 2019, 100% of generalist species exceeded their abundance target values, higher than the 78% expected. However, herbivores (67%) and piscivores (0%) were below expectations (expected 78% and 48% respectively).

In 2023, 67% of generalist species met their target abundances, slightly below what is expected by 2029, but likely on-track to achieve the 2029 expected percentage. Although only 33% of herbivore species exceeded target abundances, this remains within the expected range for 2029. No piscivore species met target abundances in 2023 and they are considered not on-track to achieve the 2029 expected percentage. This decline in piscivore waterbirds during the high flow conditions of 2022 and 2023 was unexpected, possibly due to changes in prey-sized fish availability and the availability of other wetland habitats in inland Australia due to wetter climate conditions.

## Why are we seeing these results?

During the Millennium Drought, Lake Alexandrina's water levels fell below sea level for nearly three years, disconnecting fringing vegetation from waterlines and limiting food resources for waterbirds. The operation of the Clayton regulator created vital habitat and food resources in the Goolwa Channel, where waterbirds found food unavailable elsewhere in the Lakes.

Since then, waterbird numbers have been shaped by several factors after the drought recovery and with the delivery of water for the environment under the Basin Plan:

- managing seasonally variable lake levels to support aquatic and littoral vegetation, providing habitat and food resources for waterbirds
- keeping lake levels above +0.4 m AHD to maintain permanently inundated habitats for food resources and waterbird breeding
- improving system connectivity and restoring pre-drought salinity levels, improving availability and quality of habitats for waterbirds
- increased wetland availability in inland Australia, likely lowering abundance of several species in the Lakes.

High (unregulated) flows in recent years have made the most significant difference. The 2022–23 River Murray flood event inundated the Lakes, raising levels above +1 m AHD and creating foraging habitats for generalist species.

## What has the Basin Plan contributed?

Planned Environmental Water (PEW) under the Water Allocation Plan for the River Murray Prescribed Watercourse, along with the delivery of water for the environment under the Basin Plan, has maintained improved habitat conditions and supported increases in some waterbird species' abundances in the Lakes.

Without water for the environment being delivered in 2018–19 and 2019–20, including as part of SA's Entitlement, lake levels would likely have dropped close to sea level, disconnecting fringing vegetation from the water line and limiting waterbird breeding. Water for the environment also supported breeding for group nesting species like Cormorants, Ibis and Royal Spoonbill and smaller species that nest in pairs or small colonies, like Purple Swamphen and Black Swan.


## What is still to be done?

Continued delivery of water for the environment is vital in extreme dry years to maintain lake levels and allow seasonal fluctuations, improving foraging habitat and supporting waterbird breeding.

Future efforts should focus on expanding the extent of productive wetland habitat for waterbirds. On-ground works, such as those being undertaken at Tolderol Game Reserve and Teringie Wetland Complex under the Healthy Coorong, Healthy Basin Program, will improve the extent of productive wetland habitat. These initiatives will enhance our ability to deliver water for the environment to key sites, improving habitat quality and availability of complementary waterbird habitats.

Continued regional management of water for the environment, including the operation of infrastructure and pumping to wetlands, will remain essential to maintain water levels and support wetting/drying cycles, further enhancing waterbird habitats.

While outside of current management influence, periodic high (unregulated) flow events will remain important to support key ecosystem processes in the Lakes. These flows are crucial for flushing of salt and maintaining a salinity regime suitable for waterbird habitats.

## What do we expect to see in the future?

Full implementation of the Basin Plan, particularly the recovery and delivery of the 450 GL of additional water for the environment and addressing current water delivery constraints, will ensure that water is able to be delivered to the Lakes, particularly during dry periods.

With water continuing to reach the Lakes, we expect waterbird abundances will likely vary between guilds, depending on the availability and quality of food and habitat. In the longer-term, these abundances are expected to stabilise. However, future climate variability will influence water and habitat availability at both local and Basin scales, leading to fluctuations in species numbers year to year. Future climate variability will likely increase the importance of the Lakes as key refuge habitats for waterbirds within the Basin.

# Expected outcome report: Waterbirds

# Coorong Waterbirds

Trend
**Declined**

Reliability
**Very good**

**The abundance of Coorong waterbirds has continued to decline, particularly for resident and migratory shorebirds.**

## What are we trying to achieve?

The Long-term Environmental Watering Plan objective is to *"Maintain or improve waterbird populations in the Coorong and Lower Lakes."*

## Why are waterbirds important?

The Coorong is part of the Coorong and Lakes Alexandrina and Albert Wetland, a Ramsar wetland of international importance. It supports large numbers of diverse waterbirds, including nationally and internationally threatened species and species listed on international migratory bird agreements. The permanent wetlands of the Coorong provide refuge habitat for waterbirds during summer and during dry years, a drought refuge. Waterbirds are sensitive to changes in environmental conditions as well as the availability and quality of habitat and food resources. They are important indicators of ecosystem health and are culturally and recreationally significant.

## What is the trend and current status of waterbirds?

Waterbirds are grouped into 'guilds' based on their diet, the way they search for food and their life history. In the Coorong, twenty species of waterbirds within five guilds (generalists, herbivores, piscivores, resident shorebirds and migratory shorebirds) have been assessed. The condition of waterbirds in the Coorong is determined by the proportion of species in each guild that have exceeded their long-term median abundance target in 2 of the last 3 years. A value of 1 means that all species within the guild have exceeded their long-term median abundance target.

Since 2002, the abundance of waterbirds in the Coorong has varied greatly between years and the trends in abundance have differed between guilds (Figure 29). Generalists improved following the end of the Millennium Drought and since then, have been at or above pre-drought levels. Herbivores have improved and since 2012 have been consistently higher than pre-2012 levels. The proportion of piscivores exceeding their abundance target was low through the 2000s but has improved and been maintained since 2014; however, the abundances of these birds, on average, have declined between 2000 and 2023. In contrast, resident and migratory shorebirds have declined overall.

© Martin Stokes

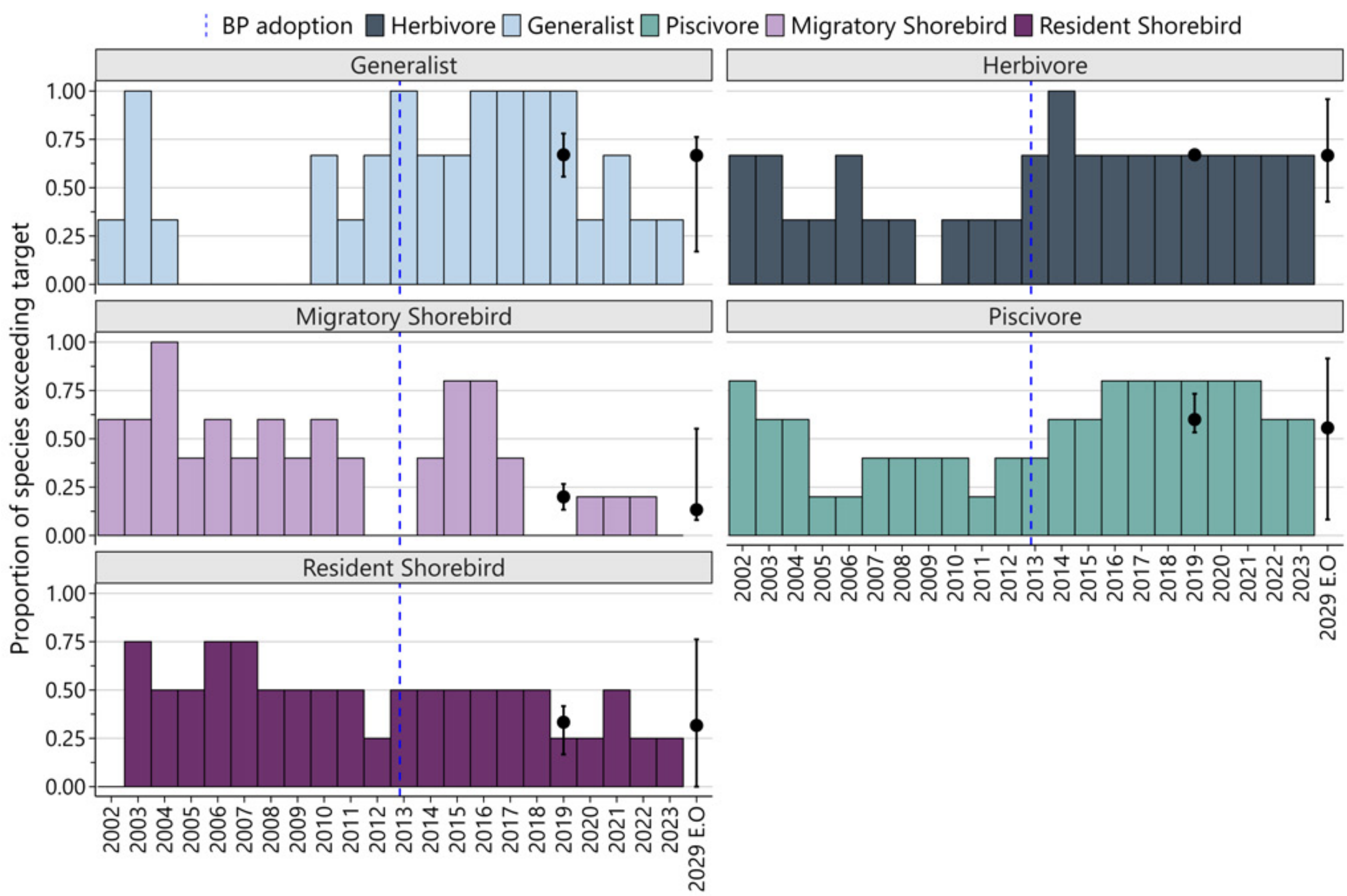



*Figure 29: The proportion of selected species within each Coorong waterbird guild that exceeded their abundance expected outcome in two of the last three years between 2002 and 2023. The black point and error bar represents the 2019 and 2029 expected environmental outcome for Coorong waterbird abundance. Note: only data from 2002 onwards is presented due to insufficient data to assess interval expected outcome in previous years. Data source: University of Adelaide.*

## Is this what we expected to see and have there been any unanticipated outcomes?

Waterbird habitat in the Coorong is influenced by barrage flows, water levels and salinity. In 2019, we expected 67% of generalist species, 67% of herbivore species, 60% of piscivore species, 33% of resident shorebirds and 20% of migratory shorebird species to have exceeded their abundance targets.

In 2019, the proportion of species that met their abundance targets exceeded expectations for generalists at 100% and piscivores at 80%, while herbivores were as expected at 67%. However, resident shorebirds were lower than expected at 25% and migratory shorebirds at 0% did not meet any targets.

By 2023, the proportion of species meeting abundance targets had declined for generalists to 33% and piscivores to 60%, with herbivores stable at 67%. Resident shorebirds remained at 25% and no migratory shorebirds met their target values. While the stability of herbivore species is promising, the consistently low proportions of resident and migratory shorebirds are concerning. With only two guilds meeting their abundance targets (herbivores and piscivores) we are not anticipating achieving the 2029 expected percentages of Coorong waterbirds populations.

The recent decline in piscivores was unanticipated and may be attributed to the highly mobile nature of these waterbirds, the availability of other wetland habitats in inland Australia due to recent wetter than usual climate conditions and changes in Coorong habitat conditions, including availability of prey-sized fish.

While overall declines in Coorong waterbird populations were anticipated, the continued persistence of this trend is of concern, particularly in light of the prolonged impacts of the Millennium Drought, which has significantly affected the ecosystem of the Coorong and the populations of waterbirds. Given the time since the end of the drought, greater recovery should have been observable by this time.

## Why are we seeing these results?

Waterbird abundance in the Coorong has decreased overall, but trends vary between guilds. Factors influencing these trends include:

- suitable water levels, varying between guilds:
  - water levels of approximately +0.3 m AHD in spring and early summer promote Ruppia growth (for herbivores) and prey habitat (for piscivores)
  - mudflats for shorebirds and some generalists require shallow water (4-7 cm) for optimal foraging
  - low water levels that prevent island connections to the mainland help to protect piscivore breeding colonies from predation.
- maintenance of suitable salinity gradients, particularly increasing southward from the Murray Mouth, supports key food resources like aquatic plants and macroinvertebrates
- growth of filamentous algae, a symptom of excessive nutrients levels, reduces food the abundance of aquatic plants and macroinvertebrates, covering shorebird habitats and hindering foraging.

Off-site factors, such as the availability of wetlands at national and international scales and waterbird breeding success these wetlands, also affect Coorong waterbird populations.




## What has the Basin Plan contributed?

Water for the environment and high (unregulated) flows have prevented a return to the extreme salinity levels seen during the Millennium Drought. However, inadequate water levels and quality have limited the recovery of key waterbird habitats and food resources, impacting overall abundance of waterbirds in the Coorong.

## What is still to be done?

To improve abundances of key waterbird species in the Coorong, key actions include:

- ensuring spring-summer water level regimes that provide adequate mudflat habitat and improve the quality and availability of food resources, including Ruppia and macroinvertebrates. Adequate water level regimes also support the protection of important breeding sites, including islands, from terrestrial predators and human disturbance
- increasing flows to flush the system, improving nutrient conditions and limiting the occurrence of filamentous algae, particularly in the South Lagoon, that will support productivity and a healthy, functioning food web for waterbirds
- maintaining an open Murray Mouth, along with periodic high (unregulated) flow events to flush salts and nutrients, which are essential for maintaining suitable water quality conditions.

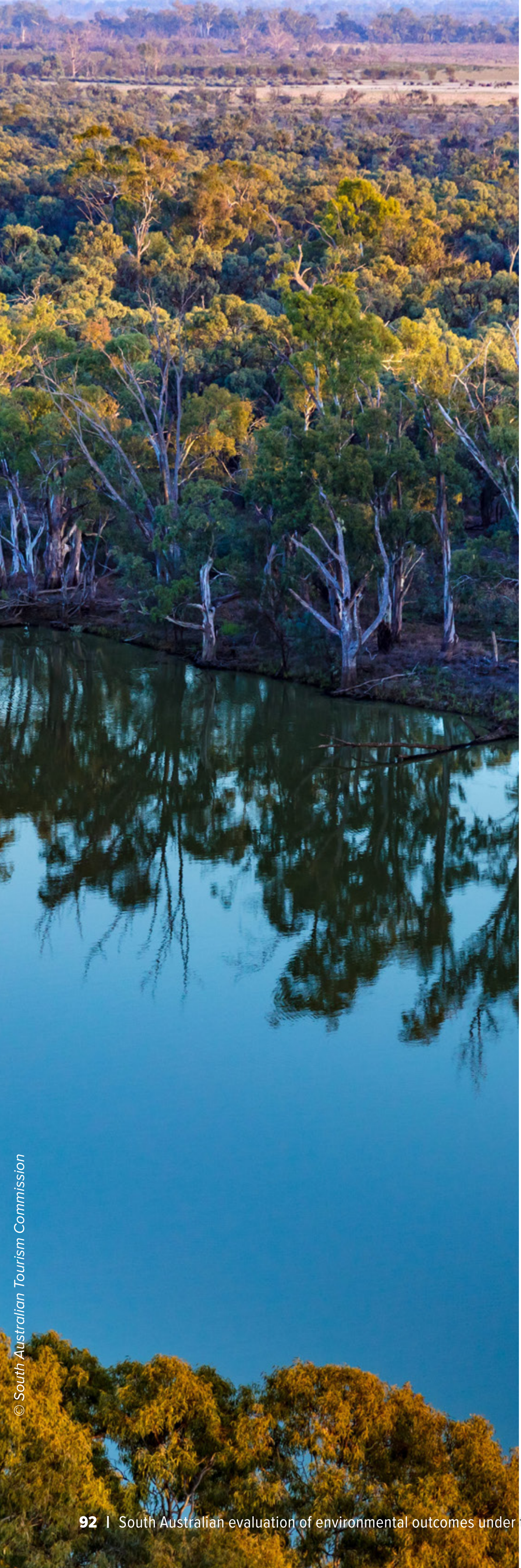
Full implementation of the Basin Plan, including the recovery and delivery of the 450 GL of additional water for the environment and addressing current water delivery constraints, are required to ensure that the volumes and timing of freshwater flows are sufficient to provide improved availability and quality of habitats and food resources for waterbirds.

The *Healthy Coorong, Healthy Basin* program is also exploring options for hydrological and ecological restoration of the Coorong (particularly the South Lagoon) in the long-term, while enhancing short-term waterbird habitat at regional wetlands.

## What do we expect to see in the future?

Full implementation of the Basin Plan will support waterbird species in the Coorong. Abundances are expected to be variable between guilds and be driven by the water regime and quality and availability of habitat and food resources in the Coorong, along with off-site (national and international) changes in the availability of wetland habitats and the breeding success of waterbirds at these wetlands.

In the longer-term, it is expected some species may decline, but climate variability will influence both local and Basin-scale water and habitat availability for waterbirds. This could either help or hinder Coorong waterbird populations, but it will likely increase the Lakes' importance as a refuge for waterbirds within the Basin.




# Abbreviations

| | |
|---|---|
| **AHD** | Australian Height Datum |
| **AOO** | Area of occupation |
| **CEWH** | Commonwealth Environmental Water Holder |
| **CLLMM** | Coorong, Lower Lakes and Murray Mouth |
| **DTR** | Diurnal Tidal Ratio |
| **EOO** | Extent of occurrence |
| **LTWP** | Long-term watering plan |
| **MBO** | Monosulfidic black ooze |
| **MDBA** | Murray–Darling Basin Authority |
| **MER** | Monitoring, Evaluation and Research |
| **PEA** | Priority Environmental Asset |
| **QSA** | Flow at the South Australian border, often expressed as mega litres per day (ML/day). |
| **SRE** | Sustaining Riverland Environments. |
| **SARDI** | South Australian Research and Development Institute |
| **SARFIIP** | South Australian Riverland Floodplains Integrated Infrastructure Program. |
| **TCI** | Tree Condition Index |
| **WRP** | Water Resource Plan |
| **YOY** | Young-of-year |

# Glossary of terms

| | |
|---|---|
| **Additional dilution flows** | A volume of 3,000 ML/day that is released once storage volumes in Hume and Dartmouth Reservoirs and Menindee Lakes exceed specified triggers. |
| **Australian Height Datum** | Australian Height Datum. The vertical height of 0.0 m (sea level) in Australia as defined by taking the mean sea level of 30 tide gauges around the Australian coastline from 1966 to 1968. |
| **Aquatic vegetation** | Plant species that grow partly or wholly within aquatic environments. |
| **Barrage** | In the Coorong, Lower Lakes and Murray Mouth there are five weirs built where the Lakes meet the Murray Estuary. They prevent seawater entering the fresh lakes and river system and help to control water levels in the Lakes and River Murray below Lock 1. |
| **Barrage outflows** | The flows of freshwater released from the Lakes through open barrage gates and fishways. |
| **Biota** | A grouping of animals, plants, fungi and other organisms that all share the same geographical region. |
| **Blackwater** | When floodwaters wash organic material into waterways, where it is consumed by bacteria decreasing dissolved oxygen in the water. |
| **Delivery Constraints** | A river management practice or structure that restricts the volume and timing of water that can be delivered through the river system. |
| **Diadromous (fish)** | Fish that travels between salt water and fresh water as part of its life cycle. |
| **Diurnal Tidal Ratio** | An indication of the exchange of water between the estuarine and marine environment. |
| **Dredging** | The removal of sediments and debris using a machine to deepen a waterway. |
| **Ecosystem** | A group of living organisms that live in and interact with each other in a specific environment. |
| **Egg bank (microinvertebrates)** | The collection of microinvertebrate eggs within sediments of rivers, wetlands and floodplains. |
| **Entitlement flows** | Under the Murray–Darling Basin Agreement 2008 (*Water Act 2007* (Cwlth) Schedule 1), South Australia is entitled to receive up to 1,850 GL/year. |
| **Ephemeral** | Something that lasts for a very short time. |
| **Estuary** | The part of a river in which water levels are affected by tides and where freshwater and saltwater mix. |
| **Expected outcome** | A quantitative measure for the status of an indicator at a time point based upon expert opinion. |


| | |
|---|---|
| **Filamentous algae** | Colonies of microscopic plants that link together to form threads or mesh-like filaments. |
| **Fishway** | A structure that provides fish with passage past an obstruction (i.e. a barrage). |
| **Food web** | All of the food chains within a single ecosystem. |
| **Generalist (waterbird)** | A group of waterbirds that have a wide variety in their diet. |
| **Herbivore (waterbird)** | A group of waterbirds that primarily feed on aquatic plants materials. |
| **High (unregulated) flows** | A river flow that does not result from a controlled release made to service an allocation. |
| **Hydraulic diversity** | A range of water depths, flow velocities and turbulence over a given area. |
| **Hypereutrophic** | A body of water that contains excessive concentrations of nutrients (primarily phosphorus and nitrogen) and organic matter. |
| **Hypersaline** | A waterbody that contains significant concentrations of sodium chloride (salt), with saline levels surpassing that of the ocean water. |
| **Invertebrates** | Cold-blooded animals without a backbone or bony skeleton, such as insects, worms and crabs. |
| **Lake level cycling** | A rapid reduction in water level of the Lakes to flush salt from the Lakes. |
| **Littoral vegetation:** | Plant species that occupies the fringes of waterbodies. |
| **Managed floodplain inundation** | Floodplain inundation events that are attributed to management actions rather than flow related increases in water level. |
| **Microinvertebrates** | A small microscopic animal without a backbone, that resides in water, such as worms, snails, mites and insects. |
| **Migratory shorebird (waterbird)** | A group of waterbirds with long legs and bills relative to their body size, which forage in shallow water habitats and undergo international migrations. |

| | |
|---|---|
| **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. The period from 2007–2010 was particularly extreme with extended periods of no flow through the barrages to the Coorong. |
| **Murray–Darling Basin** | An area of about 1 million $km^2$ in the south east of Australia, it is almost 1,400 km long and about 800 km wide. |
| **Overbank flows** | Flow that rises over the river bank and connects the river to the floodplains and wetlands. |
| **Phytoplankton** | Small plankton algae that is essential to aquatic food webs. |
| **Piscivore (waterbird)** | A group of waterbirds that primarily feed upon fish. |
| **Population age structure** | The distribution of individuals' ages within a population. |
| **Priority Environmental Asset** | An environmental asset that can be managed with environmental water. |
| **Productivity** | The generation of biomass in an ecosystem. |
| **Recruitment** | The process by which young individuals become part of the adult population. |
| **Regulator** | A weir-like structure designed to raise water levels to enable inundation of large areas of the floodplain and wetlands. |
| **Resident shorebird (waterbird)** | A group of waterbirds with long legs and bills relative to their body size, which forage in shallow water habitats and that do not undergo international migrations. |
| **Resilience** | The capacity of an individual, population or ecosystem to persist or adapt to change in their environment. |
| **Re-snagging** | The reintroduction of woody debris to the river. |

| | |
|---|---|
| *Ruppia tuberosa* | An aquatic plant that is the dominant species in the Coorong South Lagoon and an important habitat and food resource for fish and waterbirds. |
| **Salt wedge** | An area where freshwater sits above saltwater. |
| **Seasonal water level cycling** | The fluctuations in the water level of the Lakes for ecological outcomes. |
| **Seed bank** | A natural storage of seed in the soil or under leaf litter that enables the production of plants in future generations. |
| **Spatial** | Relating to or occupying space. |
| **Sub-adult (fish)** | An individual that has passed through the juvenile period but not yet attained typical adult characteristics. |
| **Taxa** | A unit used to biologically classify fungi, plants and animals. |
| **Temporal** | Lasting for a time only. |
| **Tree Condition Index** | A system used to score the condition of floodplain trees based on the extent and density of their crown. |
| **Turbidity** | The cloudiness of water caused by suspended particles. |
| **Velocity (flow)** | The speed of water flow. |
| **Water column algae** | Individual microscopic plants that are present in the water column. |
| **Water for the environment** | Environmental water is 'held' or 'planned' environmental water, defined in the Water Act 2007. Held environmental water is available under a water access right for the purposes of achieving environmental outcomes; planned environmental water is committed to environmental outcomes and cannot be used for any other purpose unless required in emergency circumstances. |
| **Waterbird guilds** | A waterbird species that is grouped based upon similarities in their diet, foraging strategy and life history. |
| **Weir pool** | The body of water stored behind a weir. |
| **Young-of-year (fish)** | The fish of a species younger than one year of age. |

© Accolade Wines

Government of South Australia
Department for Environment and Water